Walkability, Safety, and Housing Values in Shrinking Cities: Spatial Hedonic Study in Buffalo, Pittsburgh, and Detroit

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Abstract: The growing market demand for pedestrian and transit-oriented communities can be capitalized into higher housing values and can generate much-needed revenue for shrinking cities. Few studies, however, have examined sufficiently walkability and its economic outcomes, especially for shrinking cities. Using geographically weighted regression (GWR) models, this study examines the impact of neighborhood walkability, measured by Walk Score and an accessibility–walkability index constructed for shrinking cities on property values of single-family and duplex homes in three rust belt shrinking cities—Buffalo (New York), Pittsburgh, and Detroit. The results suggest that, controlling for spatial autocorrelation effects, GWR models perform more robustly than the traditional ordinary least-squares models. The findings showed that the impact of walkability on single and two-family housing sales in these three cities is significant. Our findings highlight the economic premium of safe and pedestrian-oriented communities in the housing market of shrinking cities and provide validated and empirical evidence for policy implications and approaches that help promote more walkable communities for the redevelopment of shrinking cities. **DOI:** 10.1061/(ASCE)UP.1943-5444.0000595. *© 2020 American Society of Civil Engineers.*

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Introduction

Many cities and communities target to build walkable neighborhoods that are often characterized by good connectivity and accessibility, such as well-connected streets and sidewalks and mixed land uses. These features have been linked with higher levels of physical activity and greater health benefits (Frank et al. 2006; Sallis and Glanz 2006; Owen et al. 2007; Yin 2013). However, the economic premium of walkability has not been studied sufficiently in the literature (Koschinsky and Talen 2015; Li et al. 2015; Bereitschaft 2019). Few studies have examined the association of walkability with economic outcomes, such as housing values, especially for shrinking cities (Pivo and Fisher 2011; Li et al. 2015). This study examines the impact of neighborhood walkability, measured by Walk Score and an accessibility–walkability index (AWI) developed for shrinking cities on property values by analyzing single-family and duplex home sale transactions in three rust belt shrinking cities.

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Shrinking cities are cities that are experiencing acute population loss. Previous studies have suggested that the development in shrinking cities occurs in a different context than in cities and regions experiencing continuous growth (Silverman et al. 2013). It is important for shrinking cities to consider a neighborhood transformation approach that can combine investments in urban revitalization and physical redevelopment with enhanced walkability and improved services and transit. There is a growing market demand for houses in pedestrian and transit-oriented communities, which can be capitalized into higher housing sale prices and can generate much-needed revenue for the revitalization in shrinking cities (Myers and Gearin 2001; Pivo and Fisher 2011; Li et al. 2015). A study of the walkability impacts on residential property values can help shrinking cities and governments with severe fiscal constraints reap the maximum benefit from walkability premiums for revitalization and smart shrinkage (Hollander and Németh 2011; Hollander 2011; Rhodes and Russo 2013).

The determinants of urban land values and housing values have been studied using the hedonic price approach for over a century, focusing primarily on the roles of accessibility and transportation (Haig 1927; Alonso 1964; Pivo and Fisher 2011). However, few studies have incorporated walkability premiums into hedonic housing price models that control for spatial autocorrelation effects until recently.

This study aims to assess the economic benefits of neighborhood walkability and safety in rust belt cities employing a spatial hedonic price modeling framework, building on the works of Pivo and Fisher (2011), Rauterkus and Miller (2011), and Li et al. (2015). Controlling for spatial autocorrelation effects, the spatial hedonic modeling approach can help to effectively explain the economic and spatial impact of the built environment, especially walkability and neighborhood safety, on the housing market. The following sections include literature review on walkability premium in the housing market, geographically weighted regression (GWR) and hedonic price models, and revitalization of shrinking cities, followed by method, findings, and conclusion.

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Literature Review

Walkability Premium in the Housing Market

Existing studies demonstrated that certain built environment features facilitate walking and impact physical activity and health (Rodríguez and Mojica 2009; Lee and Moudon 2006). Safe and well-serviced neighborhoods imbued with built environment qualities that make walking a positive experience are good for people's health (Speck 2013, Talen and Koschinsky 2013). Walkable neighborhoods can offer substantial economic benefits (Leinberger 2007). Studies on housing prices in New Urbanist development, a development type closely associated with walkability, found that most projects were able to price units above market rates (Tu and Eppli 1999, 2001; Song and Knaap 2003). A survey of residents in Boston and Atlanta suggested that there seems to be a mismatch between the desire for pedestrian-friendly neighborhoods and the choices available to consumers (Levine et al. 2002).

Until recently, the economic impact of walkable neighborhoods was not well presented in hedonic pricing models because of inadequate techniques and availability of data (Gilderbloom et al. 2015). Few studies to date have used the hedonic pricing method to capture walkability impacts on property values (Li et al. 2015). Litman (2003) argued the impacts of walkability be measured using increased land use efficiency, healthcare cost savings, and increased economic development by examining the value of walkability (Litman 2003).

A recent study regressing property value on correlates of the walkable neighborhood found that development density, land use mix, public open space, and *pedestrian infrastructure* contributed to higher property values (Sohn et al. 2012). Another study claimed that a one-point increase in Walk Score translated to a $3,000 increase in property value (Cortright 2009). Sohn et al. (2012) found that pedestrian infrastructure and land use mix contributed to the increases in rental property values. Pivo and Fisher (2011) quantified the incremental increase in walkability associated with up to a 9% increase in commercial property value.

Walkability is one of the important emerging topics in the growing dialogue concerning neighborhood sustainability from various aspects including public health, neighborhood decline, crime, and environmental justice (Gilderbloom et al. 2015; Talen and Koschinsky 2013; Gilderbloom 2014; Habibian and Hosseinzadeh 2018). Great design in the form of a walkable neighborhood not only fuels economic growth, but it also supports market forces that increase property values and tax revenues for local governments. Although a few studies explored the economic benefits of walkable neighborhoods to some degree, the measurement of walkability is still under debate, and the impact of walkability on property values has only been studied and advanced in recent years.

In summary, there is a substantial amount of research on hedonic housing prices, but the selection of explanatory variables varies based on the specific context and research purpose. In recent years, walkability and neighborhood safety have gained increasing credence as critical explanatory factors. With the advancement of methodology and data availability, our study contributes to the current discussion of the premium of walkability and neighborhood safety in the housing market.

Controlling for Spatial Autocorrelation—Application of GWR

The hedonic price model (HPM) framework helps to disassociate the individual prices from the total price when evaluating housing values. Using data on housing sale prices along with characteristics of the houses and the environments, HPM estimates the marginal implicit price of each characteristic (Rosen 1974).

According to Anselin (2013), research results may be subject to biases and inconsistent estimation caused by spatial autocorrelation effects (SAEs) (Anselin 2013). SAE can happen in a hedonic price model when one house's value is influenced by values or certain characteristics of neighboring properties. Some omitted variables in a hedonic model, both property-specific variables and variables related to neighboring properties, can be spatially correlated and cause SAE in the error terms (Case 1991).

Despite the significant amount of research on neighborhood and environment impacts on property sales, few studies have developed spatial regression models, such as GWR models, to effectively control for SAE. Hedonic pricing models have been used to study the effects of various prowalking environmental factors on property values with some recent hedonic pricing models used spatial regressions (Ferreira et al. 2010), such as the Cliff-Ord spatial regression model (Li et al. 2015), to control for spatial autocorrelation. It is noteworthy that GWR is part of a growing trend focusing on local analysis to control SAE, as opposed to traditional global analysis (Fotheringham et al. 2003a). Bereitschaft (2019) suggested to use GWR that considers local variations to conduct analysis on housing affordability and walkability.

To control for SAE, this study applied the GWR approach and developed local GWR models to better calibrate the impact of the social and built environment, specifically walkability and neighborhood safety, on residential property values.

Revitalization of Shrinking Cities—New Perspective

Deindustrialization and out-migration are some of the common reasons that make cities shrink. In the United States, this problem is most commonly associated with rust belt cities, such as Detroit, Buffalo (New York), and Pittsburgh. In the 1950s and 1960s, affordable single-family homes became available to white middle- and working-class Americans in the suburbs. Older housing filtered down to black workers migrating to central cities for jobs in manufacturing. These migration patterns and segregation fueled by racism accelerated white flight in the ensuing decades. In the wake of these changes, vacant housing and deterioration became more pronounced in urban centers. The decline of increasingly segregated core cities became more entrenched as local governments became fiscally constrained and they fell behind on the maintenance of infrastructure, other services, and the provision of public safety (Schett 2011).

Increasingly, policy makers have focused on enhancing the attractiveness of neighborhoods and promoting a sense of community as a strategy to reverse decades of decline and facilitate the revitalization of shrinking cities. Creating walkable neighborhoods has been a part of this strategy. It is worthwhile to note that few studies have focused on the premium of built environment externalities, such as walkability, in the housing market among shrinking cities.

Current research depicts a growing market demand for pedestrian-oriented development and houses (Levine and Garb 2002). Nevertheless, the leverage of the walkable neighborhood and safe communities for revitalizing shrinking cities needs to be studied empirically with more cases. This paper aims to enrich the field, studying the association between walkability, neighborhood safety, and property values in shrinking cities while controlling for spatial autocorrelation effects, in order to provide validated and empirical evidence for policy implications and approaches that help promote more walkable communities for the redevelopment of shrinking cities.

The walkable neighborhood has been shown to be associated with trust and social engagement (Leyden 2003) as well as sociability (Brown and Cropper 2001), which is vital for the revitalization of shrinking cities struggled with poverty, segregation, and alarming health conditions. Researchers have argued that beyond environmental and health benefits, the walkable neighborhood facilitates "the generation and maintenance of social capital," an important determinant of "quality of life" (Rogers et al. 2011). Social benefits might involve resident interaction and neighboring, in turn leading to social connection and a sense of community or collective efficacy. Researchers have found higher rates of social interaction, "substantially greater sense of community," and stronger place attachment in walkable neighborhoods (Kim and Kaplan 2004). A well-designed public space, a key component of the walkable neighborhood, has been shown to encourage social interaction, especially in mixed-income areas (Chaskin and Joseph 2013). Neighborhoods designed to be *safe and social*, incorporating frequent destinations associated with walkability, have been shown to improve both social capital and feelings of safety (Wood et al. 2008).

Defining and measuring sustainable urban forms has advanced significantly over the past two decades (Breheny 1992; Clemente et al. 2005; Farr 2011; Frey 2003; Miles and Song 2009; Wheeler 2013). Talen (2011) summarized sustainable urban forms as places with: walkable and connected streets, compact building forms, well-designed public spaces, diverse land uses, and mixed housing types (Talen 2011). There are predictions that demand for walkable, mixed-use neighborhoods is likely to grow in the coming decades (Leinberger 2010; Levine et al. 2005). In recognition of the importance of neighborhood retrofitting in shrinking cities, housing policy has become increasingly oriented toward ensuring that residents live in *sustainable* neighborhoods—not only low in poverty and low in crime, but walkable, transit-served, and accessible to a wide variety of services and facilities. Federal initiatives have specifically called for affordable housing in the context of sustainable communities, achieved by increasing opportunities to access amenities by foot or public transit, decreasing vehicle miles traveled and other transportation and energy costs, promoting *natural* forms of community surveillance (*eyes on the street*), encouraging compact mixed income and mixed land uses, and fostering a sense of place and social connectedness.

This article contributes to the literature by incorporating walkability and neighborhood safety in spatial hedonic pricing models, particularly considering housing price determinants in shrinking cities. While a significant literature supports the need for compact, mixed-use, pedestrian-oriented cities (Ewing et al. 2003; Frey 2003; Jenks and Dempsey 2005), few are prepared to dictate the specific housing challenges that shrinking cities encounter, including the continuous increase of vacant and dilapidated houses, as well as the lack of enough financial support from local governments to update them. The prerequisite to *cure* the aforementioned challenges also need more attention through a thorough understanding of the socioeconomic premium of walkability and neighborhood safety.

Method

We identified three shrinking cities as our case study areas and collected relevant data from a variety of sources. Two types of models were built using data collected including the traditional OLS model and the GWR model to examine walkability and its economic outcomes (Fig. 1).

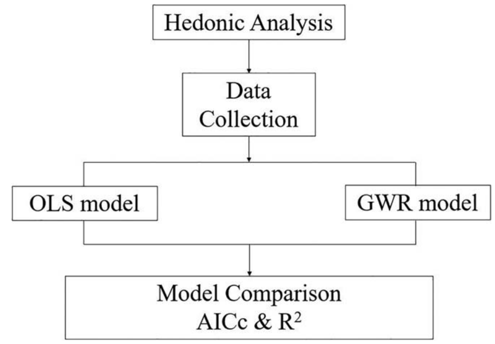

Fig. 1. Flowchart.

Case Study Area and Data Collection

Buffalo, Pittsburgh, and Detroit, are on the list of the top 10 metropolitan areas in the US with the fastest declining population between 1980 and 2010. The first two are also among Walk Score's top 10 picks for affordable and walkable American cities. They are selected as the study areas because they represent an important case study of the walkability and housing prices in shrinking cities.

As the second largest city in New York State, Buffalo is located in the rust belt along with other shrinking cities. We collected the property sales data of Buffalo from City of Buffalo's database of property sales and transactions, as well as other widely used sources of property sale records, such as Property Shark. The property sales data include sales price, number of full bathrooms, overall condition, square feet of living area, building style, and so forth. The housing records were geocoded in ArcGIS 10 using the address information of the properties. We obtained data related to neighborhood safety from Buffalo's Open Data Portal. The crime incidents data included crime type, date/time, and address. We further divided the crime data into property crime (burglary, larceny-theft, and vehicle theft) and violent crime (including homicide, rape, armed robbery, and aggravated assault). Other social demographic data including population density per square mile, percentage of the population unemployed, percentage of college and graduate degree holders, percentage of whites, percentage of African Americans, per capita income, and vehicles availability by housing units are from the US Census Bureau, the American Community Survey 2012–2016 5-year estimates, at the block group level.

We collected the property sales data of Pittsburgh from the local database, Allegheny County property sale transactions. Data on the number of bathrooms, overall conditions, and square feet of the living area were collected from Zillow.com and other online sources. The housing records were geocoded in ArcGIS 10 using the address information of the properties. Crime information was extracted from Pittsburgh Police Arrest Data from Data.gov. Neighborhood sociodemographic characteristics were collected from the US Census Bureau and Social Explorer.

We collected the property sales data of Detroit from Detroit Open Data Portal. The housing records were geocoded in ArcGIS 10 using the address information of the properties. We obtained data related to neighborhood safety from Police Records and Reports Information, and the City of Detroit's official website (City of Detroit 2018). Neighborhood characteristics data were collected from the US Census Bureau and Social Explorer.

The externality of walkability and neighborhood safety in Buffalo on the prices of 11,848 single and two-family homes from 2012 to 2015 was estimated (Fig. 2). We analyzed no more than

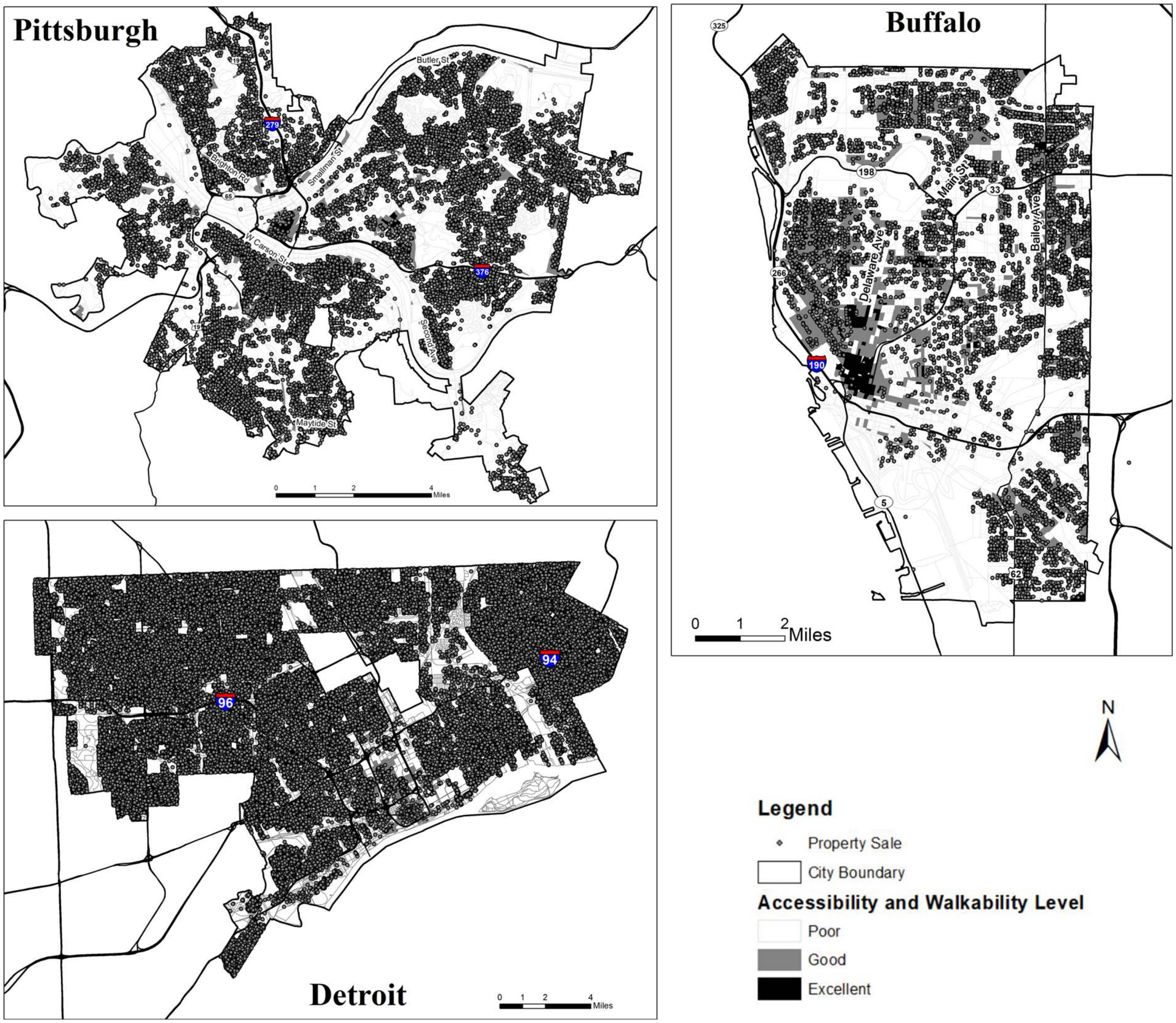

Fig. 2. Property sales of Buffalo, Pittsburgh, and Detroit, 2012–2015.

4 years of data to reduce the risk of compromising the assumption of market equilibrium, which is a prerequisite for hedonic analysis (Maclennan 1977). The original sales data included 14,249 property records. Following Li et al. (2015), we excluded 266 property records with the sale price higher than \$510,000 (the 99 percentile of the sample) or lower than \$2,000 (the 1 percentile of the sample). Furthermore, 68 additional records were excluded due to missing or mistyped values in structural variables. Another 2,067 records were excluded after spatial joining property sale data, walkability data, crime data, and neighborhood social demographic data due to missing values. The final dataset included 11,848 housing transaction records. By excluding data that might be biased, incorrect, or missing information to focus on data that better represent the real market value, our final data used for the regression models is more accurate and less biased.

The original property sales data in Pittsburgh included 76,174 single-family and duplex property records and detailed geographic information about the properties such as neighborhood, council district, zip code, and block group of each property. We excluded 19,057 property records with the sale price higher than \$1,040,525 (the 99 percentile of the sample) or lower than \$1 (the 1 percentile of the sample). In addition, we excluded 31,440 additional records due to missing or mistyped values after spatial joining property sale data, walkability data, crime data, and neighborhood social demographic data. The final sample included 25,677 housing transaction records from 2012 to 2015.

The original property sale data for Detroit included 137,466 single-family property records from 2012 to 2015. We excluded 49,412 property records with the sale price higher than \$650,000 (the 99 percentile of the sample) or lower than \$1 (the 1 percentile of the sample). Furthermore, 11,014 additional records were excluded due to missing or mistyped values in structural variables. The final sample included 77,040 housing transaction records.

Walk Scores, developed by a private company called Walk Score, have been used by researchers as a proxy of neighborhood walkability in recent years. Walk Score provides publicly accessible numerical walkability scores for every street in the United States. We downloaded Walk Scores from Walk Score's website using an application program interface (API) for every census block in the study areas. Following Yin (2013) and Yin et al.

(2015), we constructed an accessibility–walkability index (AWI) that incorporating walkability and accessibility to anchor institutions and transit for shrinking cities. This AWI is based on the variables and destinations that reflect the 5Ds—density, design, diversity, destination accessibility, and access to transit, in addition to access to anchor institutions, as suggested by the literature.

Building Hedonic Price Models

Global Ordinary Least-Squares (OLS) Model

The global OLS models were developed using property sale price as the dependent variable Y. The independent variables X_i comprise three structural characteristics and eight neighborhood variables at the census block group level, following Sirmans et al. (2005). The structural characteristics included the number of full bathrooms, the assessor's defined overall house condition, and square feet of living area. The eight neighborhood variables included population density, percentage of the population unemployed, percentage of college and graduate degree holders, percentage of the population in poverty, percentage of whites, percentage of African Americans, per capita income, and vehicles availability by housing units. The variables that capture the externality include the walkability, measured by walk score and AWI, as well as neighborhood safety, measured by the number of violent crimes and the number of property crimes.

We developed the spatial hedonic pricing framework to estimate premiums of walkability and neighborhood safety in the housing market of the three shrinking cities [Eq. (1)]

$$Y(\text{Sale price}) = f(X_{\text{Structural}}, X_{\text{Neighborhood}}, X_{\text{Externality}}, \varepsilon_i) \quad (1)$$

or

$$\begin{aligned}\text{Sale price} = {} & \text{Full\_Bath} + \text{Overall\_Condition} \\ & + \text{Squarefeet of living area(Structural)} \\ & + \text{Pop\_Dens} + \text{Perc\_Unemp} + \text{Perc\_Grad} \\ & + \text{Perc\_Poverty} + \text{Perc\_White} \\ & + \text{Perc\_Black(Neighborhood)} + \text{Walk\_Score} \\ & + \text{Num\_Violent crimes} \\ & + \text{Num\_Property crimes(Externality)} + \varepsilon_i\text{(Error)}\end{aligned}$$

where x_{ij} include vectors of structural and neighborhood characteristics for i, as well as a vector of walkability and safety related externality for i; α_j = fixed coefficient of the globally fixed terms; β_j = jth locally varying coefficient of the locally varying terms; (u_i, v_i) = spatial location of property i; and ε_i = error term.

The candidate variables were tested for multicollinearity for all predictors, and the OLS model was found to be robust. We excluded some structural variables, the number of violent crimes per block group, as well as some sociodemographic variables due to severe multicollinearity. The errors were found to be randomly scattered with no systematic patterns, which indicates homoscedasticity.

Local GWR Model

The GWR models were used to control for the spatial autocorrelation effects. GWR explores spatial nonstationarity and provides statistics that can be mapped to visualize the spatial patterns of the relationships between the dependent and independent variables (Brunsdon et al. 1996). Along with the global OLS model outlined previously, a semiparametric local GWR model was developed as shown in the following equation:

$$Y_i = \sum_{j=1}^{m} \alpha_j\, x_{ij} + \sum_{j=m}^{n} \beta_j(u_i,\ v_i) x_{ij} + \varepsilon_i \quad (2)$$

where Y_i = sale price of property i; and x_{ij} = independent variable. Eq. (2) has two parts; the first half is the global model, the second half is the local model, and the last element is the error term. In this way, the model allows some parameters to vary over space, but others to stay consistent.

A semiparametric GWR model was chosen because the predictor variables had spatially varying characteristics at the local level and fixed characteristics at the neighborhood level. Nakaya et al. (2009) recommended that such a mixed model may reduce complexities and enhance the model's prediction performance. Crespo and Grêt-Regamey (2013) provide details on the use of a similar mixed-GWR method for a study conducted in Zurich.

The GWR4 software package was adopted as the core computational module for modeling the geographically varying relationships between the house prices as the dependent variable and the structural, neighborhood, and externality characteristics as independent variables (Fotheringham et al. 2003b). This model was employed to extract the locally varying nature of price contributory variables. A Gaussian model with adaptive spatial kernels using a bisquare function was used. For the selection of bandwidth, an automated golden section search method was employed to determine the optimal size for the bandwidth.

There are several prerequisites for the validity of our spatial hedonic model, according to Rosen (1974), including market equilibrium, perfect competition, perfect information for both buyers and sellers, and continuum of products. No severe market fluctuation was found during the study period from 2012 to 2015. Therefore, market equilibrium, according to Maclennan (1977) and Wallace and Meese (1997), could be assumed. Perfect competition is not necessary to ensure the validity of the model in our study, which was supported by the findings of Bajari and Benkard (2005). The assumption of a continuum of products could be satisfied due to the large sample size. Finally, perfect information for both buyers and sellers could be assumed because information related to property is accessible from the internet, the realtors, and home inspections.

To verify the existence of spatial autocorrelation in our dataset, we performed Moran's I test and obtained highly significant Moran's I statistics, indicating the existence of spatial autocorrelation. Therefore, instead of OLS, we employed the GWR spatial hedonic model as the optimal modeling approach to mitigate the risk of spatial autocorrelation and omitted neighborhood variables.

Findings

Table 1 shows that on average, Detroit has the highest rate of both property and violent crimes compared with the other two cities, while Pittsburgh has the lowest crime rate. Buffalo has the highest Walk Score and accessibility–walkability index on average. The sociodemographics suggest that racial composition and the percentage of the population unemployed varied significantly among the three cities. Detroit has the highest percentage of African Americans, while Pittsburgh has the highest percentage of whites. In addition, Pittsburgh has the highest percentage of college and graduate degree holders, the lowest unemployment rate, and the highest per capita income compared with the other two cities. Detroit has the lowest population density, the highest percentage of the population in poverty, and the lowest percent of household with no car.

Economic Premium of Walkability and Safety

Table 2 reports the results of the spatial hedonic model based on Walk Score, and Table 3 reports the results based on the accessibility–walkability index (AWI). Both the models based on Walk Score and AWI generate similar results for externality and neighborhood characteristics. The effects of walkability, neighborhood safety, and sociodemographic characteristics on property values are significant and, in general, have expected signs. The meaning of a coefficient for a normalized variable (e.g., 0.015 for the normalized walk score in Buffalo) is the elasticity of sale price with respect to the variable. Normalized Walk Score and AWI were both positively associated with the sale price of the three cities. It is noteworthy that, AWI proved to be more significantly associated with the sale price in the case of Pittsburgh since it has a lower value of standard error, suggesting its superiority compared with Walk Score.

Interestingly, the rate of property crimes was negatively associated with sale prices in Buffalo but positively associated with sale prices in Pittsburgh and Detroit. This may be due to regional characteristics, nevertheless, we do not have a satisfactory explanation for the varying signs on the neighborhood safety variable. As expected, the population density was significantly associated with the sales price in all three cities and a higher population density predicted increased sale price. The findings suggested that a higher

Table 1. Summary statistics

Variable definition and unit	Buffalo ($n = 11{,}848$) Mean	SD	Min.	Max.	Pittsburgh ($n = 25{,}677$) Mean	SD	Min.	Max.	Detroit ($n = 77{,}040$) Mean	SD	Min.	Max.
Home sale price, \$1,000	69.35	80.70	2.00	510.00	114.38	149.13	0.00	1029.41	26.07	58.02	0.00	650.00
Structural characteristics												
Overall condition	2.90	0.46	1.00	5.00	2.46	0.46	0.96	3.91	2.80	0.42	0.75	4.35
Externality												
Walk Score, 0–100	62.95	14.20	0.00	96.00	57.04	21.98	0.00	99.00	52.92	12.74	0.00	98.00
Accessibility–walkability index (AWI)	1.55	1.90	−4.61	17.90	1.22	2.91	−12.05	55.59	−0.01	1.28	−8.21	16.17
Number of violent crimes, within block group	66.80	46.42	2.00	857.00	61.20	58.89	0.00	424.00	68.53	31.49	11.00	217.00
Number of property crimes, within block group	168.70	111.10	23.00	2235.00	40.13	45.05	1.00	310.00	191.36	115.29	28.00	1367.00
Neighborhood characteristics												
Population, person/block group, 1,000	10.02	5.18	0.60	28.35	8.38	5.55	0.01	38.86	6.67	3.44	0.30	22.50
Percentage of whites, 0–100	46.67	34.56	0.00	100.00	64.81	29.30	0.00	100.00	9.85	16.67	0.00	85.18
Percentage of African Americans, 0–100	39.30	36.58	0.00	100.00	27.33	29.41	0.00	100.00	85.05	23.61	0.00	100.00
Percentage of college and graduate degree holders, 0–100	20.69	17.27	0.00	81.60	35.03	22.23	0.00	100.00	11.88	10.85	0.00	80.15
Percentage of unemployed population, 0–100	10.95	9.11	0.00	60.93	9.64	8.67	0.00	55.17	25.45	12.76	0.00	77.02
Per capita income, \$1,000	20.38	9.89	4.15	81.21	28.85	15.43	0.00	123.66	15.01	6.19	4.71	78.36
Percentage of population in poverty, 0–100	54.20	20.13	3.85	100.00	43.10	19.05	0.00	92.30	63.86	16.64	1.34	100.00
Percent of household with no car, 0–100	28.43	15.35	0.00	70.46	24.76	16.50	0.00	86.52	22.96	13.97	0.00	87.80

Table 2. Estimation coefficients for the local GWR model (measured with Walk Score)

Variable names	Buffalo Coefficients	Pittsburgh Coefficients	Detroit Coefficients
Constant term	4.57082**	4.514864*	3.723616*
Externality			
Normalized Walk Score	0.015028**	0.014283*	0.012721**
Normalized number of property crimes per block group	−0.031825**	0.012389*	0.117788*
Neighborhood characteristics (normalized)			
Population per block group, 1,000	0.020492**	0.073295**	0.068452**
Percentage of unemployed population, 0–100	−0.030477**	NA	NA
Percentage of African Americans, 0–100	−0.191586**	−0.244268*	NA
Percent of households with no car, 0–100	NA	NA	NA
Number of observations	11,848	25,677	77,040
Adjusted R^2	0.510871 (compared to 0.288544 for the OLS counterpart model)	0.271734 (compared to 0.177535 for the OLS counterpart model)	0.163813 (compared to 0.038908 for the OLS counterpart model)
Akaike information criterion (AIC)	7,711.756102 (compared to 12,087.452605 for the OLS counterpart model)	60,172.011795 (compared to 63,188.294928 for the OLS counterpart model)	192,633.063891 (compared to 203,070.794402 for the OLS counterpart model)

Note: *significance level of 0.10; **significance level of 0.05; and ***significance level of 0.01.

Table 3. Estimation coefficients for the local GWR model (measured with AWI)

Variable names	Buffalo Coefficients	Pittsburgh Coefficients	Detroit Coefficients
Constant term	4.600896**	4.551158*	3.737336**
Externality			
Normalized AWI	0.001221**	0.015702**	0.010211**
Normalized number of property crimes per block group	−0.018573**	0.0263*	0.124564*
Neighborhood characteristics (normalized)			
Population per block group, 1,000	0.026973**	0.066492**	0.080995**
Percentage of unemployed population, 0–100	NA	NA	−0.06356**
Percentage of African Americans, 0–100	−0.166381**	−0.258793*	NA
Percent of households with no car, 0–100	−0.054611**	NA	NA
Number of observations	11,848	25,677	77,040
Adjusted R^2	0.512143 (compared to 0.305197 for the OLS counterpart model)	0.271783 (compared to 0.175714 for the OLS counterpart model)	0.169445 (compared to 0.051794 for the OLS counterpart model)
Akaike information criterion (AIC)	7,680.156955 (compared to 11,806.833517 for the OLS counterpart model)	60,169.687383 (compared to 63,245.070145 for the OLS counterpart model)	192,189.563897 (compared to 202,031.85304 for the OLS counterpart model)

Note: *significance level of 0.10; **significance level of 0.05; and ***significance level of 0.01.

unemployment rate, percent of African Americans, and percent of household with no car lead to the lower housing sale prices. These findings confirmed what is suggested from the literature review (Pivo and Fisher 2011; Rauterkus and Miller 2011; Li et al. 2015; Koschinsky and Talen 2015; Gilderbloom et al. 2015). These sociodemographic variables are generally considered as negative neighborhood amenities, which significantly impair property values.

The model results suggested that the impact of walkability on single and two-family housing sales in the three cities measured by both Walk Score and AWI is significant, demonstrating the economic premium of walkability and safety in the housing marketplace of the three cities. AWI is more significantly positively related to property values than Walk Score. A plausible explanation would be AWI incorporates comprehensive aspects of environment features closely related to shrinking cities. The major difference between the Walk Score and AWI is that AWI considered and included the unique characteristics related to shrinking cities, such as number of occupied housing and number of anchor institutions. Underpinned by the ideology of New Urbanism, houses within convenient walking distance of stores, restaurants, and other amenities sell at a premium. The advantages of using AWI to access the economic premium of walkability on housing sale price is proved by the GWR model results in our study. The impact of the Walk Score on property sale price in our model results is less significant compared with AWI, suggesting that it is necessary to assess the economic benefits of walkability with more sophisticate measures such as AWI in shrinking cities.

Global Ordinary Least-Squares (OLS) Model versus the Local GWR Model

While R^2 is a measure of explanatory power, we do not expect models to include all relevant predictors, especially in social or behavioral sciences. Previous studies on walkability and housing price generated a range of R^2 values for the US cities that are similar or different from the selected for this study (Bereitschaft 2019), because property and neighborhood characteristics are different in different cities. As suggested by the literature, we compared the results from the global OLS model and the local GWR model built for the same cities using AICc and R^2.

Akaike information criterion (AIC) provides an objective means for model selection and has been used to compare spatial regression models and their OLS counterparts, with lower AIC indicating superiority of a model (Li et al. 2015; Burnham and Anderson 2002). AICc is "a second-order AIC, necessary for small samples" (Burnham and Anderson 2002; Glossary) and is reported to have better small-sample behavior.

As shown in Tables 2 and 3, for all three study areas, adjusted R^2 of the spatial hedonic models are much higher than their OLS counterparts while AICc of the spatial hedonic models are lower than their OLS counterparts, indicating higher robustness of this spatial regression approach over OLS in our study areas.

The decrease of the AICc value and the improvement of the adjusted R^2 in the local GWR model highlighted the significance of incorporating the spatial autocorrelation effect in the hedonic model on the impact of walkability measured by both Walk Score and AWI. The GWR ANOVA shows that the model improved with lower residual values. The GWR model provided locally varying estimated coefficients of predictors.

Conclusion and Discussion

This study builds hedonic pricing models while controlling for the spatial autocorrelation effect to examine the economic benefits of walkability and neighborhood safety, measured by Walk Score and AWI, and the number of violent crime and property crime per block group. The analysis focuses on three shrinking cities—Buffalo, Pittsburgh, and Detroit.

Previous studies on walkability and housing prices generated a range of AICc and R^2 values across the US cities (Bereitschaft 2019; Li et al. 2015). While comparing these values across cities are not recommended, recent studies compared GWR and OLS models

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using AIC and R^2. Our results of the local GWR models are more pronounced than those of the traditional global OLS models reflected in the lower AICc and higher adjusted R^2 values. This suggests that the local GWR models perform more robustly when assessing the impact of walkability, neighborhood safety, and sociodemographic factors on property sales prices in the three shrinking cities.

It is important to develop and initiate suitable urban redevelopment and shrinkage strategies in order to create sustainable development in cities that struggled with poverty, segregation, and acute health conditions. This study demonstrates the advantages imbued in the housing market in safe and pedestrian-oriented communities in shrinking cities and provide evidence-based guidance for developers and planners to considerably improve the safety of inner city neighborhoods. The findings show the benefits of paying more attention to the economic and social benefits of safe and walkable neighborhood by fostering sustainable physical environments, social connections, and a sense of community. The incentives of property values, as well as its association with walkability and built environment features, have been studied most recently, and this study further enriches the field with a focus on shrinking cities. Our research provides evidence-based foundations for neighborhood transformation approaches that can combine investments in urban revitalization and physical environment improvement with enhanced walkability, safety, and service.

Our results also suggested the advantages of using AWI over Walk Score. The major difference between Walk Score and AWI is that AWI considers and includes unique characteristics related to shrinking cities. This study makes further efforts in supporting houses within convenient walking distance to stores, restaurants, and other amenities sell at a premium. Population density is positively associated with property sales price in our study. The higher unemployment rate, percent of households with no car, and the percentage of African Americans are associated with lower property sales prices.

The local GWR models in this paper account for a series of variables related to the housing structure, neighborhood environment, and externality. Yet, they provide little information about other physical characteristics such as pedestrian infrastructure. These characteristics may be regarded as important features by local residents or professionals and thus should be included in the models for future research. In addition, the generalizability of our study remains untested. Future studies may involve more shrinking cities in the United States and overseas and may include other types of properties, such as the office or commercial properties. Furthermore, including some *nonshrinking* cities or booming suburban cities to compare their results with shrinking cities may bring more insights.

Data Availability Statement

Some or all data, models, or code generated or used during the study are available from the corresponding author by request (list items): property sales and crime data of Pittsburgh and Detroit.

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