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Assessing the Impact of Housing Characteristics and Multimodal Accessibility on Social Vulnerability in the City of Detroit

H.J. Koo[1*], V. Demetracopoulou[2] and M. Atilola[1]

[1] Dept of Civil & Environmental Engineering, Wayne State University, Detroit, MI, USA
[2] Dept. of Civil & Environmental Engineering, Rutgers University, Piscataway, NJ, USA

ABSTRACT: Equitable access to transit infrastructure and affordable housing is essential for health, education, and employment opportunities in metropolitan areas. However, many US cities prioritize car-centric mobility that often overlooks the combined impact of housing characteristics and multimodal accessibility on vulnerable populations. While existing studies examined transit and social vulnerability using mobility data, few explore the interaction of housing characteristics and their multimodal accessibility within the context of social vulnerability. Therefore, this study explores these relationships in Detroit to provide a better understanding of their impact on vulnerable communities. The authors collected data on 2,510 houses in Detroit, including price per square foot, year built, and their multimodal accessibility metrics such as walk, bike, and transit scores. Social vulnerability (SV) was measured using the Social Vulnerability Index (SVI). Through the data analysis, the authors identified (1) correlations between housing characteristics, multimodal accessibility, and SV, (2) the impacts of housing characteristics and multimodal accessibility on SV, and (3) variations of these variables across Detroit's seven districts. Findings indicate that SV negatively correlates with house price, walk score, and transit score but positively correlates with house age and bike score. Regression analysis results show that house price and walk score predict SV, while house age and transit score are not significant predictors. This study provides valuable insights into the relationships between housing characteristics, multimodal accessibility, and SV across Detroit, and offers data-driven guidance for transit planning and housing construction rehabilitation decisions promoting equity and resilience.

1. INTRODUCTION

Social vulnerability (SV) refers to the demographic and socioeconomic factors, such as poverty, lack of access to transportation, and crowded housing, that increase a community's susceptibility to hazards and other community-level stressors (CDC, 2024). Measuring SV is critical for public health officials, cities, and local governments to respond more efficiently to emergencies and health inequities. Beyond public health, SV has also been examined to inform decisions in various areas such as construction maintenance and rehabilitation (Cutter et al., 2013), infrastructure systems interdependencies (Coleman et al., 2020), and public transit planning (Lubitow et al., 2017).

Transportation and mobility are critical to SV, as they directly influence access to health, employment, and educational opportunities (Preis, 2024). While cars remain the primary mode of transportation in most US cities, reducing car dependency and promoting walking, biking, or public transit can provide economic, social, and environmental benefits (Rissel et al., 2012; Smart & Klein, 2015). Likewise, housing characteristics are a key determinant of SV, as they affect environmental conditions (Anyanwu & Beyer,

2024), health outcomes (Wang et al., 2018), and social stability. Understanding the intersection of transportation and housing is crucial for addressing SV and promoting equitable urban development. Previous studies have examined SV in relation to mobility and housing characteristics separately, yet limited research examines the combined impact of these three elements — SV, multimodal accessibility, and housing characteristics. This gap highlights the need for a more integrated approach.

To respond to this gap, this study aims to investigate the relationship between housing characteristics, multimodal accessibility, and SV in the City of Detroit. Detroit was selected as the study area due to its declining population, increased vulnerabilities, and aging infrastructure, highlighting the need to understand relationships to inform decision-making. This study has three main objectives: (1) identifying the relationships among housing characteristics, multimodal accessibility, and SV; (2) investigating the impacts of housing characteristics and multimodal accessibility on SV; and (3) analyzing the variation of these elements across Detroit's seven districts.

For the purpose of this study, SV was measured using the Social Vulnerability Index (SVI) (CDC, 2024), and housing characteristics included price per square foot (sq.ft) and house age. Given that multimodal accessibility has been used widely to measure mobility access in literature (Bereitschaft, 2023), this study captured accessibility as three primary transportation modes — walking, biking, and use of public transit — at each housing location.

The findings contribute to the body of construction management knowledge by supporting decision-making and risk assessment processes, particularly within urban context of major cities. Understanding the relationships between housing characteristics, multimodal accessibility, and SV will support strategic planning and execution of adaptive reuse, sustainable construction, and equitable urban development. It also provides valuable guidance for construction practitioners to improve resource allocation and prioritize projects and optimize infrastructure investment. Ultimately, the results will supports aligning construction and rehabilitation efforts with broader social and mobility needs.

2. LITERATURE REVIEW

The interplay between mobility, transportation infrastructure, and housing conditions is crucial in shaping social vulnerability (SV). Previous research has explored the relationships between these factors across various contexts. Broadly, these studies can be classified into two categories: (1) the relationship between SV and mobility or transportation infrastructure, and (2) the relationship between SV and housing characteristics.

The first category includes studies such as Bereitschaft (2023) which evaluates equitable access to walkable and transit-accessible neighborhoods for SV populations in major U.S. metropolitan areas through equity mapping analysis. The study finds that while some cities achieve equitable access, others show significant disparities, with high-SV populations often facing challenges like increased crime, poor school quality, and limited transit options.

Similarly, Chan et al. (2023) study investigates transport equity in Hong Kong by analyzing multimodal public transport route choices and categorizing them as trade-offs or redundant based on fare and travel time. This study revealed spatial disparities, with the New Territories providing more diverse options. While limited by its focus on time-money trade-offs and transit-oriented contexts, the findings offer practical insights into improving transport equity and addressing user needs.

France-Mensah et al. (2019) developed four optimization models based on equity theories to evaluate highway network equity in Texas, using metrics like Gini coefficients and Theil's indices. Findings show that certain equity distribution policies, such as egalitarianism and socialism, are more effective in reducing inequity, with higher budgets accelerating progress toward equity goals. However, limitations of this study include the exclusion of other infrastructure assets, parameter uncertainty, and long-term planning.

Bereitschaft (2017) also examines spatial and statistical relationships between SV and neighborhood walkability in Charlotte, NC; Pittsburgh, PA; and Portland, OR, using Walk Score® as a walkability proxy. Results highlight significant variability, with Charlotte showing the most inequitable access for high-SV neighborhoods, while Portland and Pittsburgh demonstrate more equitable access with distinct spatial patterns. While these studies provide visibility on the relationship between equity and multimodal mobility, there is a gap in addressing housing criteria at the same level.

The second category examines the relationship between social vulnerability (SV) and housing characteristics. For example, Hollar et al. (2022) conducted a cross-sectional analysis using census tract-level Social Vulnerability Index (SVI) data from the CDC/ATSDR, parcel data from the Florida Department of Revenue, and building code violation data from the City of Miami Building Department, focusing on 95 census tracts. The results revealed a strong correlation between higher SVI scores and increased 40-year recertification violations, with a 21-fold increase in the odds of high violation rates. Logistic regression and choropleth mapping further highlighted a significant spatial overlap between high SVI scores and tracts with frequent violations, emphasizing the connection between SV and deteriorating housing conditions.

Another study by Anyanwu and Beyer (2024) examines the intersection of housing disparities and environmental inequities, particularly in low-income and minoritized communities, where poor housing conditions negatively affect health outcomes such as chronic diseases and mental health. The study proposes a conceptual model and advocates for public health interventions, including equitable housing code enforcement, affordability measures, and green space investments to promote health equity.

Existing literature has explored SV in relation to either mobility and transportation infrastructure (Chan et al., 2023; France-Mensah et al., 2019; Bereitschaft, 2017, 2023) or housing characteristics (Hollar et al., 2022; Anyanwu & Beyer, 2024). However, the interaction between these factors and their combined influence on SV remains underexplored. This study conducts a novel analysis that incorporates walk, bike, and transit scores, similar to the approach of Bereitschaft (2017, 2023) and assesses SV using SVI, as in Hollar et al. (2022). It also introduces new variables such as house price and age, which have not been considered in the existing literature. A comprehensive approach integrating housing conditions, multimodal accessibility, and SV is crucial for informed decision-making in building rehabilitation, infrastructure planning, and resource optimization within urban development.

3. RESEARCH METHODOLOGY

To bridge the gap in the literature, this study addressed the following research question: "*What is the impact of housing characteristics and multimodal accessibility on SV in urban environments such as the city of Detroit?"*. To answer this question, this study pursued three key objectives: (1) examining correlations among housing characteristics, multimodal accessibility variables, and SV, (2) identifying predictive variables by determining which housing characteristics and multimodal accessibility factors influence SV, and (3) assessing variations by examining whether significant differences exist in housing characteristics and multimodal accessibility across Detroit's seven districts. Figure 1 illustrates an overview of the research methodology.

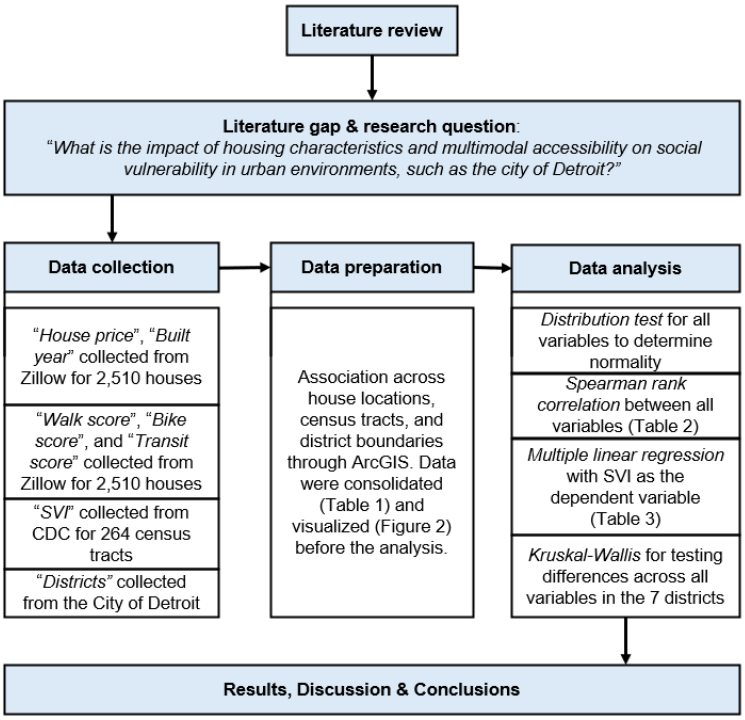

Figure 1: Overview of research methodology.

After completing the literature review and identifying the research gap, the authors collected the necessary data to address the research question. Data for 2,510 houses in Detroit, Michigan, were obtained from Zillow, a widely used online real estate marketplace that provides property listings and housing characteristics, and has been used in similar studies (e.g., Bereitschaft, 2023). The dataset includes house price (in dollars per square foot), built year, walk score, bike score, and transit score. To better represent how old a house is, the built year was converted into house age, by subtracting the built year from 2024. To measure SV across Detroit, this study used SVI developed by the CDC. The SVI is the most widely used metric for assessing SV in the U.S., and is based on 15 social variables, categorized into four themes: socioeconomic status, household characteristics, racial and ethnic minority status, and housing type and transportation. SVI values range from 0 to 1, with values closer to 1 indicating greater social vulnerability relative to other census tracts nationwide (Ibrahim et al., 2021). The use of CDC SVI scores is a standard practice in SV research (e.g., Lardier Jr. et al., 2023). Table 1 presents an excerpt of the dataset used for analysis.

Each housing location was georeferenced to its corresponding census tract, as the CDC SVI data is organized at the census tract level. The Detroit metro area comprises 297 census tracts (U.S. Census Bureau, n.d.), with the 2,510 collected house units spanning 264 census tracts. To examine spatial differences across neighborhoods, the boundaries of Detroit's seven districts were obtained from the City of Detroit Interactive District Map (City of Detroit, n.d.). To facilitate spatial analysis and visualization, the dataset was mapped using ArcGIS before conducting further data analysis. Figures 2 and 3 provide examples of these visualizations, showing the distribution of house prices and walk scores across Detroit's seven districts.

Table 1. Excerption of Dataset

#	House price ($ per sq.ft)	House age (year)	Walk score (0-100)	Transit score (0-100)	Bike score (0-100)	Social vulnerability index (0-1)
1	7	82	48	40	42	.9522
2	8	96	51	41	44	.9727
3	69	71	44	48	39	.9443
…						
2,510	30	73	77	54	50	.8592

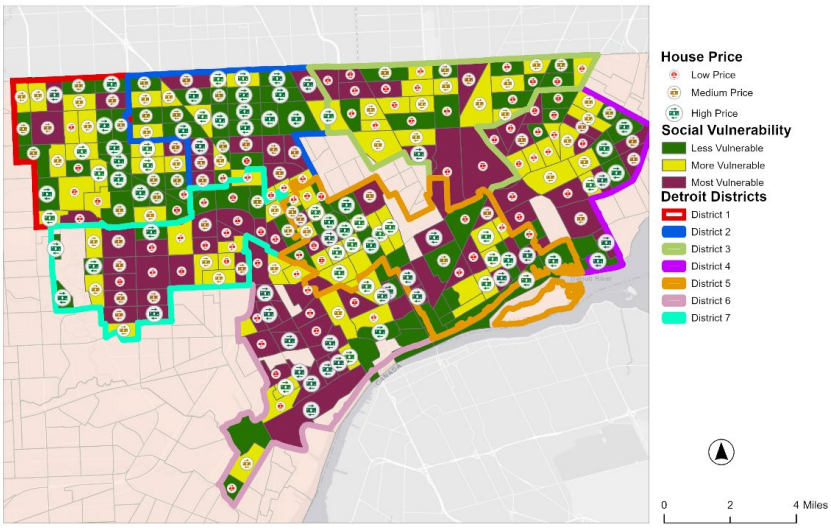

Figure 2: Visualization of *house price* and *SV* in Detroit's seven districts across 264 census tracts.

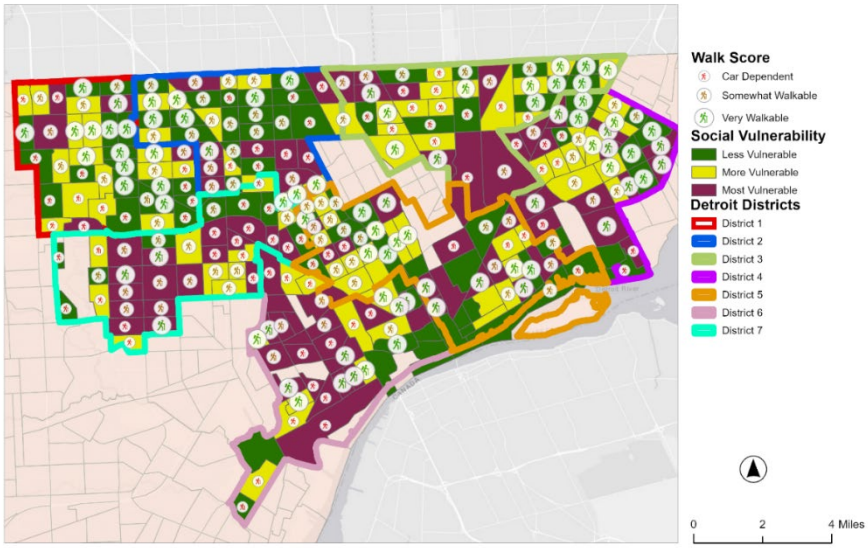

Figure 3: Visualization of *walk score* and *SV* in Detroit's seven districts across 264 census tracts.

To conduct the statistical analysis, the authors first performed distribution tests, which indicated that the data were not normally distributed. The Shapiro-Wilk test further confirmed the significant deviations from normality ($p<0.001$). Given this non-normality, a non-parametric regression method was applied. Specifically, bootstrapping was employed to account for non-normality and mitigate the effects of outliers (Efron & Tibshirani, 1993; Davison & Hinkley, 1997). For the regression analysis, SV was selected as the dependent variable to emphasize the importance of construction and infrastructure interventions in addressing disparities. Variables such as house price and transit score are modifiable through targeted actions — for instance, renovations or adding bus stops in disadvantaged neighborhoods. As these independent variables change, the methodology employed in this study can be replicated to evaluate their impact on SV, which can offer a framework to guide equitable infrastructure planning and decision-making.

4. RESULTS & DISCUSSION

Table 2 presents the results of Spearman's correlation tests between all variables. The results indicate significant correlations among most variables at the 0.01 significance level, except for the relationships between 1) house age and house price; 2) house age and walk score; 3) house age and bike score; 4) house price and transit score; 5) house price and bike score.

Table 2. Correlation Table – Spearman's test

	1	2	3	4	5	6
1_SV score	1.0					
2_House age	.120**	1.0				
3_House price	-.206**	-0.027	1.0			
4_Walk score	-.109**	0.036	.142**	1.0		
5_Transit score	-.122**	.180**	0.032	0.332**	1.0	
6_Bike score	.087**	.211	0.23	0.413**	0.116**	1.0

**Correlation is significant at the 0.01 level (2-tailed)

This results provide multiple insights into the relationship among SV, housing characteristics, and multi-modal accessibility in the City of Detroit. These findings suggest that house age and house price are not significantly associated with bike score, indicating that older or higher-priced homes do not necessarily correlate with increased bike accessibility. In addition, the strongest positive correlation was found between bike and walk scores, which was expected as walkable neighborhoods often support bike-friendly infrastructure and well-connected routes for short bike rides.

On the other hand, all variables show significant correlations with SV. Specifically, house price, walk score, and transit score are negatively related to SV. This finding indicates that socially vulnerable populations tend to reside in lower-priced housing located in neighborhoods with limited walkability and transit access, which reflect their economic status. This is because socially vulnerable populations have historically been concentrated in areas affected by disinvestment and infrastructure neglect (Bullard, 2007). These conditions contribute to limited access to essential services, transportation, and economic opportunities, which reinforces socioeconomic and spatial disparities (Jargowsky, 1997). In Detroit, car dependency is an exaggerated challenge for vulnerable populations, as public transit options remain limited. Conversely, house age and bike score are positively correlated with SV, indicating that areas with older housing and higher bike accessibility tend to have higher social vulnerability scores.

Table 3 presents the results of the regression analysis, which identified three significant predictors of SV. House price ($B = -0.001$, $p < 0.001$) and walk score ($B = -0.001$, $p < 0.001$) were negatively associated with SV, suggesting that higher property values and better walkability are linked to lower social vulnerability. This finding implies that areas with higher home values and greater walkability tend to have better socioeconomic conditions, improved infrastructure, and greater access to resources, ultimately reducing vulnerability. Conversely, bike score ($B = 0.003$, $p < 0.001$) was positively associated with SV, indicating that higher bike scores correlated with increased social vulnerability. This result may suggest that areas

with greater bike accessibility are more likely to be in historically underinvested neighborhoods, where biking is a necessity rather than a choice due to limited access to other transportation options. These regression findings align with the correlation results while providing additional insights into the predictive relationships between variables and SV.

Table 3. Multiple Linear Regression Results Predicting SV

Predictor	B	Standard Error (SE)	t-value	p-value
(constant)	0.816	0.032	25.212	<0.001**
House price	-0.001	0.000	-11.731	< 0.001**
House age	< 0.001	0.007	0.347	0.729
Walk score	- 0.001	0.000	-5.231	< 0.001**
Transit score	- 0.001	0.001	-1.391	1.164
Bike score	0.003	0.000	8.215	< 0.001**

The finding that house price, but not house age, is a significant predictor of SV is a novel contribution to existing literature. This means that the market value of a home has a stronger relationship with the level of SV, rather than the age of the home itself. Although older houses are common in major U.S. cities like Detroit, their age alone does not necessarily correlate with higher vulnerability. Instead, factors such as location, surrounding neighborhood conditions, and the extent of renovation, repair, and rehabilitation efforts can significantly influence property values (Accordino & Johnson 2000). This finding has practical implications for both public and private stakeholders. This suggests that targeted investment in rehabilitation efforts on older homes could be the way to enhance neighborhood resilience and stability (Mallach, 2006). Moreover, it provides data-driven evidence on distinct impacts of house price and house age on SV that have not been explicitly addressed in prior literature.

The authors conducted an additional statistical analysis to examine differences in these variables across Detroit's seven districts, as designated by the city. To assess these differences, the Kruskal-Wallis test was applied to six variables: social vulnerability (SV), house price, house age, walk score, transit score, and bike score. The results indicated that all variables significantly differed across districts ($p<0.001$), emphasizing the spatial disparities in housing conditions, transportation accessibility, and social vulnerability across Detroit's neighborhoods. A closer examination of the results revealed notable differences in specific variables. House prices varied significantly across districts, with some areas exhibiting substantially higher median prices than others, reflecting economic disparities throughout the city (Figure 2). Similarly, walk scores (Figure 3) and transit scores showed considerable variation, indicating differences in accessibility to public transportation and pedestrian-friendly infrastructure. The SVI also displayed significant disparities, with certain districts experiencing higher levels of social vulnerability, potentially due to socioeconomic and infrastructural inequalities, as shown in Figures 2 and 3.

From a construction and management perspective, these findings highlight the importance of incorporating SV metrics into infrastructure and rehabilitation planning, as this can improve accessibility, reduce transportation barriers, and better address the financial constraints of vulnerable populations. Incorporating SV into early-stage planning of projects will support decision-making by informing cost estimation, investment prioritization, and resource allocation. For instance, understanding the relationship between house age, house price, and SV can guide public agencies in identifying technically feasible rehabilitation projects that align with community needs. Overall, this approach supports more equitable and sustainable construction management practices.

The primary limitation of this study is that all data on SV, housing, and mobility pertain solely to the City of Detroit. As such, the findings may not be directly generalizable to other cities and areas without considering contextual similarities and differences with Detroit. For instance, while house price, but not house age, was a significant predictor of SV in Detroit, this may also hold in other major U.S. cities. However, future research

could apply a similar methodology to assess whether these relationships persist across diverse geographic and socioeconomic conditions.

5. CONCLUSION

Access to affordable housing and reliable multimodal transportation is critical for equitable urban development, particularly for socially vulnerable (SV) communities. In many cities, including Detroit, disparities in housing conditions, transportation accessibility, and socioeconomic status contribute to uneven living conditions that can exacerbate social vulnerability. While previous research has explored these factors, these studies have often treated them independently rather than as an integrated system.

To address this gap, this study examined the relationships between housing characteristics, multimodal accessibility, and social vulnerability (SV) in the city of Detroit. By analyzing 2,510 housing units across seven districts of the city, the findings reveal that house price and walk score were negatively associated with SV, suggesting that higher property values and better pedestrian infrastructure contribute to lower social vulnerability. Conversely, bike score was positively associated with SV, implying that greater bike accessibility may be linked to historically underinvested neighborhoods. House age and transit score were not significant predictors, indicating that older housing stock and public transit access alone do not necessarily correlate with increased vulnerability. Additionally, the Kruskal-Wallis test confirmed significant disparities in house price, house age, walk score, bike score, transit access, and SV across Detroit's seven districts.

This study provides critical insights for construction management by emphasizing the importance of strategic rehabilitation, sustainable infrastructure investments, and equitable development practices to reduce social vulnerability. Targeted rehabilitation efforts can extend the lifespan of existing structures, improve housing conditions, and enhance neighborhood stability, particularly in historically underinvested areas. This findings offer guidance on prioritizing rehabilitation projects based on cost-effectiveness and technical feasibility, while supporting efficient resource allocation and strategic planning. Ultimately, aligning rehabilitation strategies with equitable development principles ensures that revitalization efforts support vulnerable populations without contributing to displacement.

Future research could expand this analysis by incorporating longitudinal data to examine how changes in housing markets, infrastructure investments, and socioeconomic policies affect social vulnerability over time. Expanding this analysis to other metropolitan areas could provide comparative insights and refine predictive models for urban inequality.

This research advances the body of literature by integrating the relationships between housing characteristics, multimodal accessibility, and SV. Practically, these findings provide valuable insights for policymakers, urban planners, and construction managers, informing strategic housing rehabilitation, infrastructure investments, and sustainable development. By identifying spatial disparities in SV, this study identified the need for targeted interventions that enhance mobility access, improve housing conditions, and foster a more equitable community.

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