CIAMTIS

U.S. DOT Region 3 University Transportation Center

Long-term Transportation Management Strategies in the context of Low-density Development at the Urban Fringe

September 2, 2024

Prepared by:
Y. Yoon and M. I. Rahman
West Virginia University

r3utc.psu.edu

PennState College of Engineering | LARSON TRANSPORTATION INSTITUTE

DISCLAIMER

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CIAM-COR-R70		

4. Title and Subtitle	5. Report Date
Long-term Transportation Management Strategies in the context of Low-density Development at the Urban Fringe	September 2, 2024
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Yoojung Yoon, https://orcid.org/0000-0002-9160-8956, M Imtiaz Rahman	

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
West Virginia University 1306 Evansdale Drive Morgantown, WV 26506-6103	**11. Contract or Grant No.** [Enter contract number here]

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation Research and Innovative Technology Administration 3rd Fl, East Bldg E33-461 1200 New Jersey Ave, SE Washington, DC 20590	Draft Final Report 7/25/2022 – 1/24/2023
	14. Sponsoring Agency Code

15. Supplementary Notes

Work funded through the Pennsylvania State University via the University Transportation Center Grant Agreement, Grant No.

16. Abstract

Urban sprawl, marked by the extensive growth of low-density development at the edges of cities, has been heavily shaped by factors like population growth, rising incomes, and the expansion of highways since the Federal-Aid Highway Act of 1956. This growth has altered transportation patterns, particularly leading to a decline in public transportation usage as more people move to suburban areas. Managing sustainable urban growth presents challenges due to the diverse functions of urban areas and the uncertainties associated with urban expansion. This research introduces a scenario-based approach (SBA) combined with the decision-making trial and evaluation laboratory (DEMATEL) method to develop transportation management strategies that address the primary drivers of urban sprawl. The study identified 46 political, economic, social, technological, environmental, and legal (PESTEL) factors, which were further refined through expert surveys and fuzzy DEMATEL analysis to pinpoint the key influential factors and their cause-effect relationships. The results highlight ten critical factors, such as Government Budget and Land Use Planning, essential for creating scenarios and strategies for sustainable urban growth. Using the scenario planning method in a Delphi survey, the research developed long-term transportation management strategies by evaluating extreme scenarios of critical uncertainty factors. The scenarios developed in this research offer crucial insights for government transportation agencies, enabling informed decision-making to support sustainable urban growth. They help agencies proactively manage risks, optimize resource allocation, and engage the public in discussions about urban futures. Additionally, the scenarios foster interagency collaboration, facilitating a coordinated approach to complex urban challenges.

17. Key Words	18. Distribution Statement
Urban growth, DEMATEL, scenario-based planning, transportation management, transportation scenarios	No restrictions. This document is available from the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	35	

Table of Contents

List of Figures

List of Tables

CHAPTER 1

Introduction

BACKGROUND

The Federal-Aid Highway Act of 1956 has been largely credited with allowing the mass growth of low-density development (a more descriptive definition of urban sprawl) at the urban fringe (Ezike et al., 2020). In recent decades, the integration of interrelated and complex circumstances such as population growth, rising incomes, extensive highway construction, higher availability of private car ownership, and decreasing commuting costs have made relocation to low-density development more accessible than ever (Karakayaci, 2016). In the process of rapid urban expansion, most megacities are experiencing changes in transportation patterns, including the dramatic growth of trip distance and motorized travel. For example, urban public transportation use decreased by 56% from 1960 to 2019 (Burrows et al., 2021). Such a decrease is partly due to the relocation of urban dwellers to suburban areas. Government agencies currently employ growth management, in which transportation planning is an integral part, to effectively control urban growth sustainably in the long run (O'Toole, 2016).

In general, growth management is a series of strategies to manage urban growth rationally in already-developed urban areas and undeveloped suburban areas (O'Toole, 2016). However, government agencies face difficulties in developing optimal strategies for sustainable urban growth due to the complexity resulting from the functional diversity of urban areas for ecology, social aspirations, and balancing economic and environmental benefits and costs (Perveen et al., 2017; Shkaruba et al., 2017). Also, the uncertainty in urban growth makes establishing well-informed decisions in long-term urban transportation management even more complex. Thus, developing several alternative scenarios to predict future urban growth has been proficiently done to apprehend the complexity and uncertainty in growth management. In recent years, a scenario-based approach (SBA) has demonstrated its usefulness and efficiency in developing optimal management strategies for urban transformation scenarios. The current SBA approaches to urban transportation management strategies have yet to simultaneously incorporate:

- All essential factors, particularly economic, social, and technological factors, that affect urban growth
- Cause-effect relationships among the factors to develop informed management scenarios for urban transformation systems

OBJECTIVES

This project aims to develop informed management strategies for urban transportation systems, incorporating exhaustive, essential factors affecting urban transformation scenarios due to low-density development at the urban fringe. This project will apply a standardized SBA that will be developmentally applied by integrating a decision-making trial and evaluation laboratory (DEMATEL). The standardized SBA is a multidisciplinary and top-down approach for this project to forecast important and uncertain factors related to transportation management strategies for sustainable urban growth under different future urban transformation scenarios. DEMATEL is used to analyze the cause-effect relationships among factors and accounts for the inherent fuzziness of survey results to improve the reliability of project results (e.g., scenarios and strategies for each scenario). The specific objectives of the proposed project are:

- Develop a list of factors that influence the uncertainty of optima transportation management strategies related to urban growth.
- Create urban transformation scenarios, assessing the performance impacts and uncertainty degrees of the factors.
- Determine the optimal transportation management strategies for each scenario.

DATA AND DATA STRUCTURES

The raw data for this project include responses from the expert, DEMATEL, and Delphi surveys, stored in Excel and PDF formats. Additionally, the processed data, generated using statistical tools, are also available in Excel and PDF formats. Both the raw and processed data can be provided upon request from the Principal Investigator (PI).

CHAPTER 2

Methodology

INTRODUCTION

This section explains the details of the methodology, which consists of four tasks: identifying influential factors, conducting an expert survey, determining key influential factors by evaluating survey results, and developing transportation management strategies through urban transportation scenario planning.

TRANSPORTATION MANAGEMENT STRATEGY DEVELOPMENT

Influential Factors

This task focused on identifying factors potentially influencing the optimization of transportation management strategies related to urban growth through a survey. Thus, a comprehensive discovery search of relevant publications (e.g., technical reports, journal articles, and government websites) was conducted first to collect a broad range of factors through a PESTEL analysis. PESTEL, which stands for political, economic, social, technological, environmental, and legal categories, is a research organization tool to produce a comprehensive list of PESTEL factors. The literature review identified a total of 46 PESTEL factors, finalized through eliminating any instances of duplication. This involved identifying factors that were either identical or had similar connotations. Table 1 shows the list of these PESTEL factors.

Table 1. PESTEL Factors

Category	Factor
Political	Political Stability; Influence of Local Action Committees; Political Perception of New Construction; Lobbying; Predominant Political Party; Voter Participation Rate
Economic	Average Income; Housing Supply; Unemployment; Transit Price; Government Budget; Urbanization; Government Subsidies for Public Transit; Home Ownership Rates; Loan Availability for Single-Family Houses; Inflation Rate; Housing Price Stability
Social	Single-Family Home Preference; Demand for Increased Privacy; Demand for Increased Mobility; Perception of Public Transit Use; Perception of Land Use Policies; Perception of Green Technology; Shift to Working at Home
Technological	Traffic Congestion; Rail Transit Development; Renewable Energy Resources; Technology Life Cycle; Access to Electric Vehicles; Automated Vehicles; Expansion of the Highway System
Environment	Emission Rates; Climate Change; Natural Disasters in Newly Developed Areas; Air Pollution; Water Pollution; Natural Resource Availability; Greenspace Availability
Legal	Land Use Planning; Building Permits; Government Regulations; Tax Policies Discrimination Laws; Employment Laws; Health and Safety Laws; EPA* Regulations

*EPA: the United States Environmental Protection Agency

Expert Survey

The expert survey was designed to assess the importance of the PESTEL factors that significantly affect the application of transportation management strategies, resulting in key influential factors. Developing a pool of experts considered relevant expertise in urban growth and transportation management as well as geographical diversity to ensure the reliability and representativeness of survey results. Identifying experts used the Internet search for state Departments of Transportation (DOTs) and academic institutions in the United States (U.S.). The search identified a total of 187 experts in two categories: internal for hands-on experience from professionals and external for theoretical knowledge from academic researchers. Figure 1 shows the specialty areas of these experts. The online survey questionnaire consisted of seven questions using a 5-point Likert scale, ranging from 0 to 4 (see Appendix A). The online survey received 15 responses from an internal group and 17 responses from an external group, representing 25.9% and 13.2% of invited internal and external experts, respectively. The locations of these responses were geographically distributed over the nation, as shown in Figure 2.

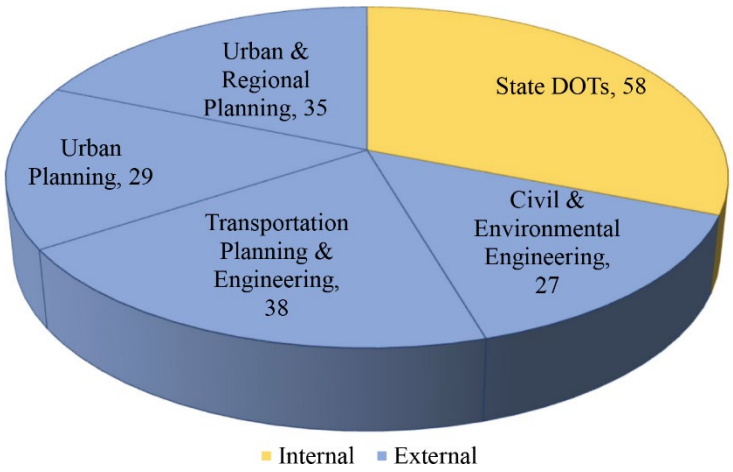

Figure 1. Internal and External Experts identified for Survey

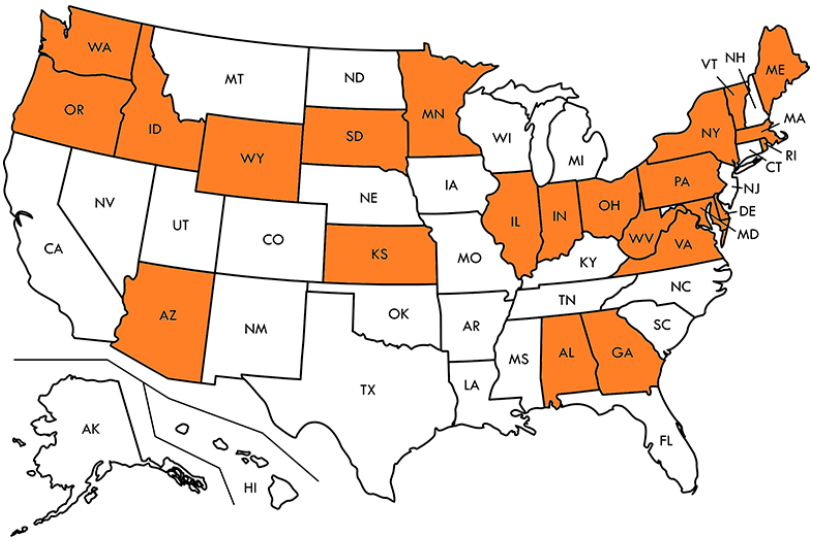

Figure 2. Geographical Locations of Responses

Key Influential Factors and Cause-Effect Relationships

This task determined key influential factors and evaluated the cause-effect relationships. The key influential factors are those that significantly affect transportation management strategies for sustainable urban growth. To identify the key influential factors, the expert survey responses were analyzed using the relative importance index (RII) to rank them and the Mann-Whitney U test to evaluate statistical differences between the highest-ranked factor and the others. The significance level for the Mann-Whitney U test was 0.01, indicating that the p-values of factors greater than 0.01 were considered key influential.

The cause-effect relationships represent the complex interconnections between the key influential factors shaping transportation management strategies in the context of urban growth. The decision-making trial and evaluation laboratory (DEMATEL) integrated with fuzzy set theory was a tool used to determine these relationships. The fuzzy DEMATEL analysis required an online survey in which a total of 164 experts from diverse academic and professional disciplines were identified, as shown in Figure 3. The DEMATEL survey focused on the key influential factors, asking respondents to assess the effect of each factor on the others in a pairwise comparison. The ratings for each question were based on a five-point Likert scale: 0 – no effect, 1 – low effect, 2 – medium effect, 3 – high effect, and 4 – very high effect. Appendix B provides the DEMATEL survey questionnaire.

The DEMATEL survey finally collected 27 responses, consisting of 12 internal and 15 external experts, who represented 18.8% and 15.0% of the invitations. The respondents were geographically distributed across 14 states, including Arizona, California, Delaware, Illinois, Louisiana, Maryland, Montana, New York, North Carolina, Ohio, Pennsylvania, Texas, Washington, and West Virginia.

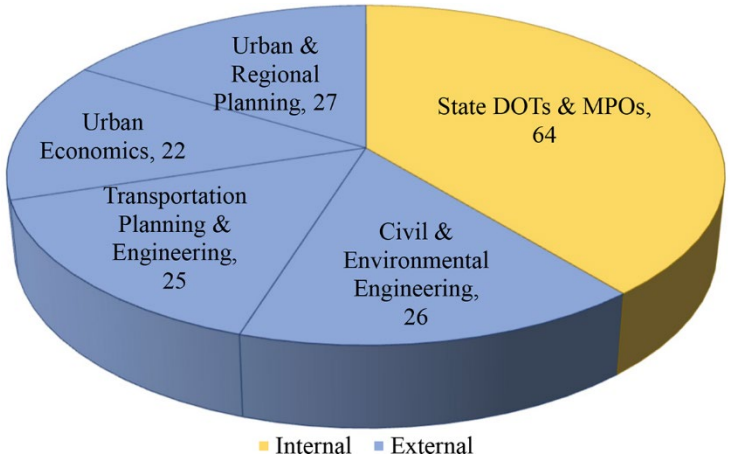

Figure 3. Internal and External Experts identified for the DEMATEL Survey

Based on the DEMATEL survey responses, the fuzzy DEMATEL analysis took the steps as follows:

- Constructing $m \times m$ direct relation matrices for every survey respondent, with m representing the total number of key influential factors
- Calculating a fuzzy average direct relation matrix, calculating the arithmetic means of all direct relation matrices
- Conducting a defuzzification to control imprecise or uncertain human judgments
- Normalizing the average direct relation matrix
- Attaining the total relation matrix
- Calculating the sum of rows (D) and columns (R), where the D and R values of a key influential factor represent its ability to influence and its susceptibility to being influenced by other factors

- Producing a cause-effect diagram with D+R as the *x*-axis and D-R as the *y*-axis

The values of D+R and D-R were computed for the key influential factors and then plotted on the cause-effect diagram. The cause-effect diagram was divided into four quadrants based on the mean values of D+R and D-R. In the cause-effect diagram, the D+R axis represents the degree of prominence for the importance of key influential factors. Higher D+R values indicate that a key influential factor is more significant. On the other hand, the D-R axis represents the relation among the key influential factors. Factors with positive D-R values are classified as causal factors, while those with negative D-R values are considered effect factors. Factors in Quadrant I indicate are identified as strong causal factors, serving as the primary drivers of urban sprawl. In Quadrant II, factors show low prominence but maintain a high level of interaction with others, considering them weak causal factors. Factors in Quadrant III exhibit both low prominence and limited relationships, making them weak effect factors. The factors in Quadrant IV are identified as strong effect factors and core problems that must be managed through the driving causal factors.

Strategies through Scenario Planning

Scenario planning is a method of thinking through to develop possible future states – in this case, transportation management strategies – based on different scenarios (Schoemaker, 1995). The SBA typically applies the two most critical uncertainty (CU) factors (Wulf et al., 2010). Scenarios were then developed considering the extreme conditions of these CU factors. These scenarios, along with causal factors, were presented to experts in the Delphi survey to develop long-term strategies for each scenario, including the items: decisions and actions by stakeholders, opportunities/positive aspects, and challenges/negative aspects. Two rounds of the Delphi survey were conducted to gather the experts' inputs and reach a consensus on the conclusions. A total of nine experts, consisting of four internal experts and five external experts, participated in the Delphi survey. Table 2 shows the demographic details of the Delphi survey participants.

Table 2. Expert Expertises for Delphi Survey

Expertise	Number of Experts	Group
Design/Planning Engineer	1	Internal (DOT)
Senior Planner	1	Internal (DOT)
Regional Transportation Manager	1	Internal (MPO*)
Planning Director	1	Internal (MPO)
Urban & Regional Planning	2	External
Urban Economics	1	External
Transportation Planning & Engineering	1	External
Civil & Environmental Engineering	1	External

*MPO: Metropolitan Planning Organization

CHAPTER 3

Findings

EXPERT SURVEY RESULTS

The expert survey response results were summarized as score frequencies in Tables 3 through 8. The influential factors that received higher scores from more responses are considered more important in affecting transportation planning for sustainable urban growth. Examples of these factors include Political Stability, Government Budget, Urbanization, Government Subsidies for Public Transit, Demand for Increased Mobility, Traffic Congestion, Climate Change, Land Use Planning, Government Regulations, and EPA Regulations.

Table 3. Expert Survey Responses on Political Factors

Factor	Score Frequency					
	4	3	2	1	0	No Response
Political Stability	9	10	7	6	0	0
Influence of Local Action Committees	4	15	11	2	0	0
Political Perception of New Construction	4	11	12	4	0	1
Lobbying	6	9	10	6	0	1
Predominant Political Party	2	2	15	9	2	2
Voter Participation Rates	0	8	8	9	5	2

Table 4. Expert Survey Responses on Economic Factors

Factor	Score Frequency					
	4	3	2	1	0	No Response
Average Income	4	9	11	6	0	2
Housing Supply	3	15	10	2	1	1
Unemployment	1	7	12	11	0	1
Transit Price	7	9	9	6	1	0
Government Budget	19	7	5	1	0	0
Urbanization	9	9	10	4	0	0
Government Subsidies for Public Transit	9	9	8	5	1	0
Home Ownership Rates	1	6	14	8	0	3
Loan Availability for Single Family Houses	0	8	7	13	1	3
Inflation Rate	1	8	13	7	2	1
Housing Price Stability	2	8	12	6	2	2

Table 5. Expert Survey Responses on Social Factors

Factor	Score Frequency					
	4	3	2	1	0	No Response
Single Family Home Preference	4	10	13	5	0	0
Demand for Increased Privacy	1	8	11	11	0	1
Demand for Increased Mobility	10	15	5	1	1	0
Perception of Public Transit Use	9	15	6	2	0	0
Perception of Land Use Policies	5	14	7	4	2	0
Perception of Green Technology	1	11	12	5	2	1
Shift to Working at Home	5	14	9	3	0	1

Table 6. Expert Survey Responses on Technological Factors

Factor	Score Frequency					
	4	3	2	1	0	No Response
Traffic Congestion	17	7	7	1	0	0
Rail Transit Development	5	10	11	4	0	2
Renewable Energy Resources	6	7	8	6	4	1
Technology Life Cycle	0	15	10	2	2	3
Access to Electric Vehicles	3	9	12	6	0	2
Automated Vehicles	1	6	12	9	0	4
Expansion of the Highway System	8	7	12	4	1	0

Table 7. Expert Survey Responses on Environment Factors

Factor	Score Frequency					
	4	3	2	1	0	No Response
Emission Rates	5	10	11	3	1	2
Climate Change	11	8	8	1	2	2
Natural Disasters in Newly Developed Areas	2	13	6	7	1	3
Air Pollution	5	15	5	5	1	1
Water Pollution	2	10	11	6	2	1
Natural Resource Availability	3	12	7	8	1	1
Greenspace Availability	4	10	11	5	0	2

Table 8. Expert Survey Responses on Legal Factors

Factor	Score Frequency					
	4	3	2	1	0	No Response
Land Use Planning	14	14	4	0	0	0
Building Permits	3	10	16	3	0	0
Government Regulations	13	13	2	4	0	0
Tax Policies	3	14	13	1	0	1
Discrimination Laws	4	7	14	4	2	1
Employment Laws	1	4	13	10	2	2
Health and Safety Laws	0	5	17	6	2	2
EPA Regulations	9	11	5	5	0	2

KEY INFLUENTIAL FACTORS AND CAUSE-EFFECT RELATIONSHIPS

Table 9 presents the top 15 influential factors and the *p*-values from the Mann-Whitney U test, conducted at a significance level of 0.01. Factors with *p*-values below 0.01 significantly differ from the top-ranked factor, Government Budget. These factors can, therefore, be excluded from the evaluation of cause-effect relationships. Consequently, ten key influential factors were determined, ranging from Government Budget to Political Stability.

Table 9. The Influential Factors at Top 15 and Mann-Whitney U Test Results

Factor	RII	Mann-Whitney U Test
Government Budget	0.844	-
Land Use Planning	0.828	0.50926
Traffic Congestion	0.813	0.61708
Government Regulations	0.773	0.24604
Demand for Increased Mobility	0.75	0.09102
Perception of Public Transit Use	0.742	0.05238
Climate Change	0.708	0.07186
EPA Regulations	0.700	0.03156
Urbanization	0.680	0.01242
Political Stability	0.672	0.01242
Shift to Working at Home	0.669	0.00288
Influence of Local Action Committees	0.664	0.00128
Government Subsidies for Public Transit	0.656	0.0096
Tax Policies	0.653	0.00062
Air Pollution	0.645	0.00244

The fuzzy DEMATEL analysis created the total relation matrix of ten influential factors, assessing the expert inputs from the DEMATEL survey. Table 10 presents the average direct relation values and the sum of rows (D) and columns (R) calculated for the key influential factors.

Table 10. Total Relation Matrix, showing the Sum of Columns and Rows

Factor / Factor	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	Sum of Rows (*D*)
F1	0.48	0.60	0.59	0.58	0.49	0.46	0.56	0.51	0.53	0.46	5.28
F2	0.62	0.55	0.67	0.61	0.56	0.52	0.61	0.54	0.61	0.46	5.75
F3	0.62	0.66	0.54	0.59	0.57	0.52	0.62	0.54	0.58	0.45	5.70
F4	0.62	0.66	0.62	0.51	0.52	0.48	0.61	0.57	0.57	0.47	5.62
F5	0.54	0.57	0.58	0.52	0.40	0.46	0.52	0.46	0.52	0.39	4.96
F6	0.51	0.54	0.54	0.50	0.49	0.36	0.50	0.44	0.49	0.38	4.75
F7	0.52	0.54	0.52	0.53	0.45	0.44	0.44	0.51	0.48	0.42	4.84
F8	0.50	0.52	0.50	0.52	0.42	0.41	0.52	0.38	0.45	0.38	4.61
F9	0.67	0.71	0.71	0.64	0.61	0.56	0.66	0.58	0.53	0.50	6.16
F10	0.50	0.51	0.48	0.49	0.41	0.38	0.47	0.44	0.44	0.31	4.44
Sum of Columns (*R*)	5.60	5.87	5.75	5.48	4.93	4.60	5.51	4.96	5.21	4.21	

F1: Government Budget; F2: Land Use Planning; F3: Traffic Congestion; F4: Government Regulations; F5: Demand for Increased Mobility; F6: Perception of Public Transit Use; F7: Climate Change; F8: EPA Regulations; F9: Urbanization; F10: Political Stability

Figure 4 is a cause-effect diagram that organizes the ten influential factors into four quadrants. Urbanization and Government Regulations are identified as the prominent causal factors driving the establishment of transportation management strategies for urban growth in relation to other factors. The subsequent causal factors include Demand for Increased Mobility, Perception of Public Transit Use, and Political Stability in Quadrant II. Land Use Planning, Traffic Congestion, and Government Budget are the prominent effect factors in Quadrant IV. These factors are also recognized as core problems that cannot be resolved directly. Lastly, Climate Change and EPA Regulations are indicated as weak effect factors with limited interaction with causal factors due to their high degree of independence.

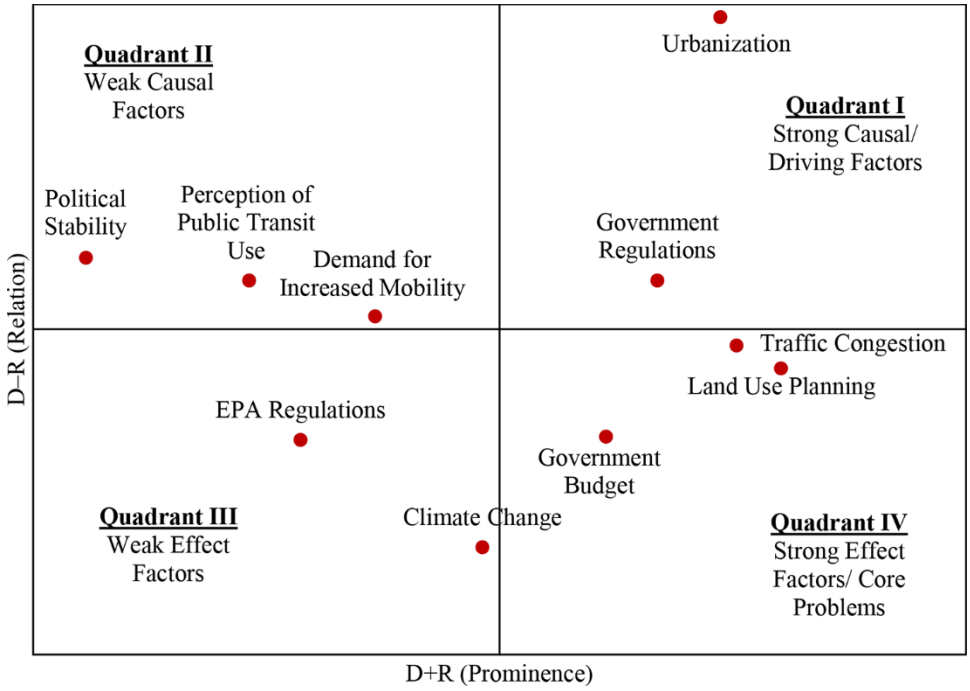

Figure 4. Cause-effect Diagram

SCENARIOS AND TRANSPORTATION MANAGEMENT STRATEGIES

The four scenarios were created in accordance with the extreme conditions of the CU factors, Land Use Planning, and Traffic Congestion:

- Scenario 1: very strict land use planning and severe traffic congestion
- Scenario 2: very strict land use planning and minimal traffic congestion
- Scenario 3: very relaxed land use planning and severe traffic congestion
- Scenario 4: very relaxed land use planning and minimal traffic congestion

Upon the completion of the Delphi survey, the long-term strategies, along with other items, were developed for each scenario as follows:

Scenario 1: very strict land use planning and severe traffic congestion

Decisions and actions by stakeholders:

- Segregated land use planning and stringent zoning laws
- Euclidean zoning in suburban areas
- Increased reliance on cars
- Poor focus on public transit

- Affordable housing shortage and preference for suburban living
- Policy reform hindered by political instability

Opportunities/positive aspects:
- Mixed-use, decentralized development, and increased transportation supported by regulatory framework
- Potential for shorter trips and alternative modes to reduce emission impacts
- Enhanced community understanding of planning, development processes, and finance
- Separation of residential and commercial areas facilitates transportation alternatives
- Urban growth and congestion increase demand for amenities, putting pressure on officials for transit relief

Challenges/negative aspects:
- Need for exceptions in planning process
- Increased preference for personal cars
- Development policies face public resistance
- Affordable housing
- Focus on symptomatic solutions like increasing road capacity
- Sectors like tourism and economic development severely affected

Proposed long-term strategies:
- Integrating Sustainable Transportation Options and Multimodal Systems
- Encouraging Mixed-Use Development
- Collaborating with Urban Planning Experts
- Improving Greenspaces and Neighborhood Character
- Implementing Pricing Mechanisms
- Improving Quality of Life Indicators
- Enhancing Political Stability

Scenario 2: very strict land use planning and minimal traffic congestion

Decisions and actions by stakeholders:
- Regulations cut car trips, fostering higher density and mixed land use
- Policies drive density along transportation corridors
- Regulations limit suburban growth
- Improved urban connectivity, micromobility and public transit systems
- Flexible work options introduced
- Higher parking fees discourage car use
- Reduced demand for mobility
- Political stability supports strict policies

Opportunities/positive aspects:
- Reduced traffic cuts environmental degradation
- Public transit focus shifts cities to zero-emission centers
- Implement form-based codes for mixed-use zoning
- Lower congestion enhances commuter experiences and quality of life

Challenges/negative aspects:
- Stakeholders resist high regulation levels
- Collaboration with urban planners to avoid design mistakes

- Reduced traffic leads to higher speeds and increased accidents
- Not everyone prefers urban living
- Gerrymandering in dysfunctional governments diminishes hope for positive change

Proposed long-term strategies:
- Maintaining and Upgrading Sustainable Methods of Transportation
- Incentivizing Improvement or Redevelopment
- Providing Affordable Housing and Promoting Increased Density
- Employing Robust Incident Management Program
- Implementing Scalable Transportation Demand Management Program

Scenario 3: very relaxed land use planning and severe traffic congestion

Decisions and actions by stakeholders:
- Road construction prioritized for mobility
- Lack of alternative transportation promotion
- Weak transportation supply (infrastructure, modes)
- Public preference for cars due to unreliable transit
- Resistance leads to sprawl and traffic issues
- Regulations have minimal impact, the laissez-faire approach prevails
- Undesirable policies affect urban design
- Rural areas transformed into distribution centers, sparking development
- Moderately stable political system with limited transparency
- Residents unaware of significant developments until after they occur

Opportunities/positive aspects:
- Declining quality of life acts as a catalyst for positive change

Challenges/negative aspects:
- Regulatory inertia is a challenge
- Public resistance to change
- Inefficient transit routing causes a shift to private cars
- Inadequate infrastructure and micro-mobility safety
- Uncoordinated land use increases motorized trips, straining transportation networks
- Land use planning faces challenges due to competing priorities and resource constraints
- Traffic management, congestion costs, and potential environmental impacts
- High congestion may discourage business development
- Socioeconomic inequality rises due to limited transportation options
- Unresponsive political system

Proposed long-term strategies:
- Promoting Mixed Use Development and Restrictive Parking
- Enhancing Sustainable Multimodal Transportation System
- Implementing TDM Strategies and Awareness Campaigns for Public Transit
- Optimizing Key Transportation Networks
- Strengthening Regulatory Standards for DOT Projects
- Promoting Government Transparency

Scenario 4: very relaxed land use planning and minimal traffic congestion

Decisions and actions by stakeholders:

- Highly influenced by favorable market conditions and luck
- Moderate mobility demand due to robust TDM programs
- Improved transit perception through promotions and infrastructure investments
- Stable government emphasizes regional collaboration
- Urban population stable or decreasing due to limited economic activity
- Lenient land use regulations enable higher density and suburban development
- Strict regulations limit free parking to reduce private car trips

Opportunities/positive aspects:
- Pro-growth environment
- Community goal identification
- Consistency with public demands
- Environmental benefits
- Untapped natural resources
- Innovative urban development

Challenges/negative aspects:
- Resistance to new regulations
- Resource constraints
- Adverse social and economic effects
- Risk of urban sprawl
- Potential for congestion
- Property value uncertainty
- Limited public services

Proposed long-term strategies:
- Optimizing Existing Transportation Systems
- Maintaining Mixed-Use and Sustainable Transit
- Ensuring Collaborative City Development Plans
- Planning for Increased Residency and Employment
- Focusing on Low-Cost Safety Improvements

CHAPTER 4

Conclusions and Recommendations

CONCLUSIONS

This research developed four plausible scenarios and transportation management strategies for U.S. cities facing urban growth over the next 20 years. These scenarios were built on an in-depth analysis of critical causal and effect factors, identified and ranked using discovery search, expert and DEMATEL surveys, and fuzzy DEMATEL analysis. Land Use Planning and Traffic Congestion were the critical uncertainty factors used to shape the four scenarios, which were then validated using a Delphi survey.

The scenarios presented in this research have important implications for government transportation agencies involved in long-term transportation management planning for urban areas:

1. They provide a comprehensive understanding of potential urban futures, enabling agencies to make informed decisions that promote sustainable urban growth.
2. By highlighting the challenges and opportunities associated with each scenario, agencies can proactively reduce risks and better prepare for uncertainties in urban growth.
3. These long-term strategies are intended to optimize resource allocation, allowing agencies to prioritize interventions most relevant to envisioned scenarios. Furthermore, the scenarios provide a useful framework for public engagement, encouraging discussions about desired urban futures.
4. The comprehensive nature of these scenarios encourages interagency collaboration, allowing transportation agencies to work more effectively with other sectors to address complex urban challenges coherently and coordinatedly.

RECOMMENDATIONS

This research suggests promising avenues for further investigation. Future research could include additional factors such as environmental considerations, technological advancements, or demographic shifts to make the scenarios and strategies more comprehensive. Expanding the research in this manner would provide a broader view of the complexities of urban transportation planning. In the context of sustainable urban growth, equity—ensuring fair access to resources, opportunities, and amenities for all community members—has become increasingly important. As the demand for equitable urban development grows, it is crucial to integrate equity considerations into long-term transportation management strategies. Lastly, the 20-year projection timeframe used in this research should be revisited and updated at regular, shorter intervals. This approach would address the challenges of accurately predicting urban developments over such an extended period, allowing the scenarios and strategies to remain relevant and responsive to unforeseen events, technological advancements, and socioeconomic shifts that may impact urban dynamics.

References

Burrows, M., Burd, C., & McKenzie, B. (2021). Commuting by public transportation in the United States: 2019. American Community Survey Reports, 802.

Ezike, R., Tatian, P., & Velasco, G. (2020). Defining "Communities of Concern" in Transportation Planning. Washington, DC. Urban Institute.

Karakayaci, Z. (2016). The Concept of Urban Sprawl and its Causes. Journal of International Social Research, 9(45), 815–815.

O'Toole, R. (2016, October 18). The New Feudalism: Why States Must Repeal Growth-Management Laws. Cato Policy Analysis No. 802.

Perveen, S., Kamruzzaman, Md., & Yigitcanlar, T. (2017). Developing Policy Scenarios for Sustainable Urban Growth Management: A Delphi Approach. Sustainability, 9(10), 1787.

Schoemaker, P. J. H. (1995). Scenario Planning: A Tool for Strategic Thinking. MIT Sloan Management Review, 25–40.

Shkaruba, A., Kireyeu, V., & Likhacheva, O. (2017). Rural–urban peripheries under socioeconomic transitions: Changing planning contexts, lasting legacies, and growing pressure. Landscape and Urban Planning, 165, 244–255.

Wulf, T., Meißner, P., & Stubner, S. (2010). A scenario-based approach to strategic planning: Integrating planning and process perspective of strategy. HHL Leipzig Graduate School of Management.

Appendix A: Survey Questionnaire

Please fill out the information below.

Name	
Job Title	
Department	
Organization	

About the Survey

This survey aims to determine the implications various factors will have on the best decision for transportation planning strategies to promote sustainable urban growth. These factors are categorized into the six groups: Political, Economic, Social, Technological, Environmental, and Legal. This project is being conducted by Dr. Yoojung Yoon and Graduate Research Assistant, M Imtiaz Rahman in the department of Civil and Environmental Engineering at West Virginia University. This survey will take approximately 5 minutes to complete. All inputs will be confidential and be only used for research purpose.

Below is a list of all **political** factors identified that could influence best practice transportation planning for sustainable urban growth. Please rank the importance of each factor.

Not at all important 0	Slightly important 1	Moderately important 2	Very important 3	Extremely important 4

Political Stability

Influence of Local Action Committees

Political Perception of New Construction

Lobbying

Predominant Political Party

Voter Participation Rates

Below is a list of all **economic** factors identified that could influence best practice transportation planning for sustainable urban growth. Please rank the importance of each factor.

Not at all important 0	Slightly important 1	Moderately important 2	Very important 3	Extremely important 4

Average Income

Housing Supply

Unemployment

Transit price

Government budget

Urbanization

Government Subsidies for Public Transit

Home Ownership Rates

Loan Availability for Single Family Houses

Inflation rate

Housing Price Stability

Below is a list of all **social** factors identified that could influence best practice transportation planning for sustainable urban growth. Please rank the importance of each factor.

Not at all important 0	Slightly important 1	Moderately important 2	Very important 3	Extremely important 4

Single Family Home Preference

Demand for Increased Privacy

Demand for Increased Mobility

Perception of Public Transit Use

Perception of Land Use Policies

Perception of Green Technology

Shift to Working at Home

Below is a list of all **technological** factors identified that could influence best practice transportation planning for sustainable urban growth. Please rank the importance of each factor.

Not at all important 0	Slightly important 1	Moderately important 2	Very important 3	Extremely important 4

Traffic Congestion

Rail Transit Development

Renewable Energy Resources

Technology Life Cycle

Access to Electric Vehicles

Automated Vehicles

Expansion of the Highway System

Below is a list of all **environmental** factors identified that could influence best practice transportation planning for sustainable urban growth. Please rank the importance of each factor.

Not at all important 0	Slightly important 1	Moderately important 2	Very important 3	Extremely important 4

Emission Rates

Climate Change

Natural Disasters in Newly Developed Areas

Air Pollution

Water Pollution

Natural Resource Availability

Greenspace Availability

Below is a list of all **legal** factors identified that could influence best practice transportation planning for sustainable urban growth. Please rank the importance of each factor.

Not at all important 0	Slightly important 1	Moderately important 2	Very important 3	Extremely important 4

Land Use Planning

Building Permits

Government Regulations

Tax Policies

Discrimination Laws

Employment Laws

Health and Safety Laws

EPA Regulations

If you believe any relevant factors for transportation planning related to urban growth were not included in this survey, please list them in the text boxes below with their level of importance.

Not at all important 0	Slightly important 1	Moderately important 2	Very important 3	Extremely important 4

Factor 1 [ ]

Factor 2 [ ]

Factor 3 [ ]

Factor 4 [ ]

Factor 5 [ ]

Factor 6 [ ]

Factor 7 [ ]

Factor 8 [ ]

Thank you for completing the survey. Your input is very valuable to this research.

Submit

Appendix B: DEMATEL Survey

Please fill out the information below.

Name	
Job Title	
Department	
Organization	

About the Survey

This survey is a follow-up to our initial survey, which was conducted to identify factors significantly affecting transportation management strategies for sustainable urban growth. The current survey aims to assess the interdependencies among the top 10 influential factors over each other. These interdependencies will be analyzed for cause-effect relationships using the fuzzy DEMATEL (Decision-Making Trial and Evaluation Laboratory) tool.

Dr. Yoojung Yoon and Graduate Research Assistant M Imtiaz Rahman from the Department of Civil and Environmental Engineering at West Virginia University are leading this project. Completing the survey should take approximately 5 minutes. Please note that all responses will remain confidential and be used solely for research purposes.

An example is given below to illustrate the factors and scale values:

The factors pertain to the city level and are designed to capture the respondent's perception of their respective city.

For example, you will be asked to rank the effect of "Urbanization" on "Traffic Congestion". Here, if you think Urbanization has a strong effect on the outcome of Traffic Congestion for your city, then you would select the scale value **3 (i.e., Strong Effect).**

Similarly, you will also be asked to rank the effect of "Traffic Congestion" on "Urbanization". In this case, if you think Traffic Congestion has a slight effect on the outcome of Urbanization for your city, then you would select the scale value **1 (i.e., Slight Effect).**

Please rank the effect of **Government Budget** on the following nine factors.

No Effect	Slight Effect	Moderate Effect	Strong Effect	Very Strong Effect
0	1	2	3	4

Land Use Planning

Traffic Congestion

Government Regulations

Demand for Increased Mobility

Perception of Public Transit Use

Climate Change

EPA Regulations

Urbanization

Political Stability

Please rank the effect of **Land Use Planning** on the following nine factors.

No Effect	Slight Effect	Moderate Effect	Strong Effect	Very Strong Effect
0	1	2	3	4

Government Budget

Traffic Congestion

Government Regulations

Demand for Increased Mobility

Perception of Public Transit Use

Climate Change

EPA Regulations

Urbanization

Political Stability

Please rank the effect of **Traffic Congestion** on the following nine factors.

No Effect	Slight Effect	Moderate Effect	Strong Effect	Very Strong Effect
0	1	2	3	4

Government Budget

Land Use Planning

Government Regulations

Demand for Increased Mobility

Perception of Public Transit Use

Climate Change

EPA Regulations

Urbanization

Political Stability

Please rank the effect of **Government Regulations** on the following nine factors.

No Effect	Slight Effect	Moderate Effect	Strong Effect	Very Strong Effect
0	1	2	3	4

Government Budget

Land Use Planning

Traffic Congestion

Demand for Increased Mobility

Perception of Public Transit Use

Climate Change

EPA Regulations

Urbanization

Political Stability

Please rank the effect of **Demand for Increased Mobility** on the following nine factors.

No Effect	Slight Effect	Moderate Effect	Strong Effect	Very Strong Effect
0	1	2	3	4

Government Budget

Land Use Planning

Traffic Congestion

Government Regulations

Perception of Public Transit Use

Climate Change

EPA Regulations

Urbanization

Political Stability

Please rank the effect of **Perception of Public Transit Use** on the following nine factors.

No Effect	Slight Effect	Moderate Effect	Strong Effect	Very Strong Effect
0	1	2	3	4

Government Budget

Land Use Planning

Traffic Congestion

Government Regulations

Demand for Increased Mobility

Climate Change

EPA Regulations

Urbanization

Political Stability

Please rank the effect of **Climate Change** on the following nine factors.

No Effect	Slight Effect	Moderate Effect	Strong Effect	Very Strong Effect
0	1	2	3	4

Government Budget

Land Use Planning

Traffic Congestion

Government Regulations

Demand for Increased Mobility

Perception of Public Transit

EPA Regulations

Urbanization

Political Stability

Please rank the effect of **Environmental Protection Agency (EPA) Regulations** on the following nine factors.

No Effect	Slight Effect	Moderate Effect	Strong Effect	Very Strong Effect
0	1	2	3	4

Government Budget

Land Use Planning

Traffic Congestion

Government Regulations

Demand for Increased Mobility

Perception of Public Transit

Climate Change

Urbanization

Political Stability

Please rank the effect of **Urbanization** on the following nine factors.

No Effect	Slight Effect	Moderate Effect	Strong Effect	Very Strong Effect
0	1	2	3	4

Government Budget

Land Use Planning

Traffic Congestion

Government Regulations

Demand for Increased Mobility

Perception of Public Transit

Climate Change

EPA Regulations

Political Stability

Please rank the effect of **Political Stability** on the following nine factors.

No Effect	Low Effect	Moderate Effect	Strong Effect	Very Strong Effect
0	1	2	3	4

Government Budget

Land Use Planning

Traffic Congestion

Government Regulations

Demand for Increased Mobility

Perception of Public Transit

Climate Change

EPA Regulations

Urbanization

Thank you for completing the survey. Your input is very valuable to this research.

Submit