Evaluating Community Building Effectiveness of Transportation Investments: Knowledge Transfer Webinar Series

Webinar III: Multi Criteria Decision Analysis

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Outline

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- Objectives
- Methodology
- Analysis and Results
- Summary

Introduction

- Transportation infrastructure investments are designed to enhance the movement of people and goods
  - Impact land use, urban residential location decisions and activity patterns, economic growth, and overall quality of life.
- Transportation infrastructure projects
  - Build connections across regions
  - Catalyst for developing, shaping, guiding, and strengthening community life
- With emerging transportation infrastructure (such as connected vehicles and infrastructure, driverless cars, electric cars) and analytics (social media and big data approaches, machine learning methods) is likely to play a major role in building true Smart Cities.

Project Objectives

- The proposed research effort is geared towards examining the role of transportation infrastructure investments in community building measures.
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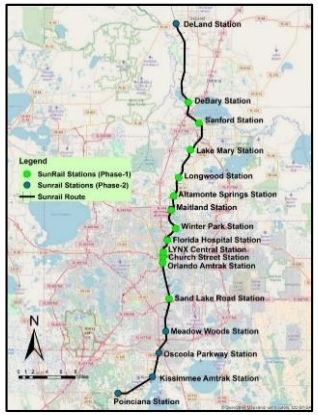
  - **Objective 1: Identify Data Sources -** *Identify* publicly accessible databases for identifying indicators of community development achieved through transportation projects.
  - **Objective 2: Develop Custom Queries for Social Media -** The research will develop custom queries for extracting social media data reflecting the influence of several current and proposed transportation infrastructure investments on community building.
  - **Objective 3: Assess Projects –** Quantify the impact of transportation infrastructural changes using traditional and big data oriented analytical approaches

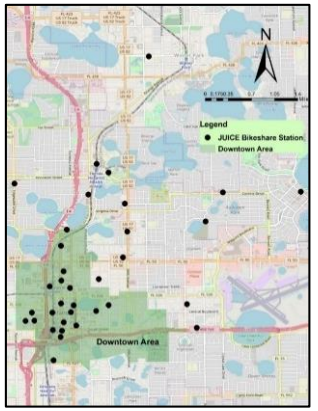
Projects for Evaluation

- We selected the following 3 projects for evaluating community building impacts and developing the Measures of Effectiveness (MOE):
  1. SunRail commuter rail extension
  2. I-4 expansion
  3. JUICE Orlando Bikeshare



SunRail

I-4 Expansion



JUICE Bikeshare

Projects for Evaluation

- For our project, we divided Sunrail stations into 3 categories:
  - Phase-1 stations (Outside Downtown) - 9 stations
  - Phase-1 stations (Core Downtown) - 3 stations including LYNX Central, Church Street and Orlando Amtrak stations
  - Phase-2 stations
- The construction area of I-4 Expansion is divided into 4 stretches:
  - Attractions area (5.7 miles)
  - Downtown Orlando area (4.2 miles)
  - Ivanhoe area (4.9 miles) and
  - Altamonte area (6.4 miles)
- For our analysis, the bikeshare stations were divided into two segments:
  - Stations located within Downtown area
  - Stations located outside of downtown area

Multi Criteria Decision Analysis Objectives

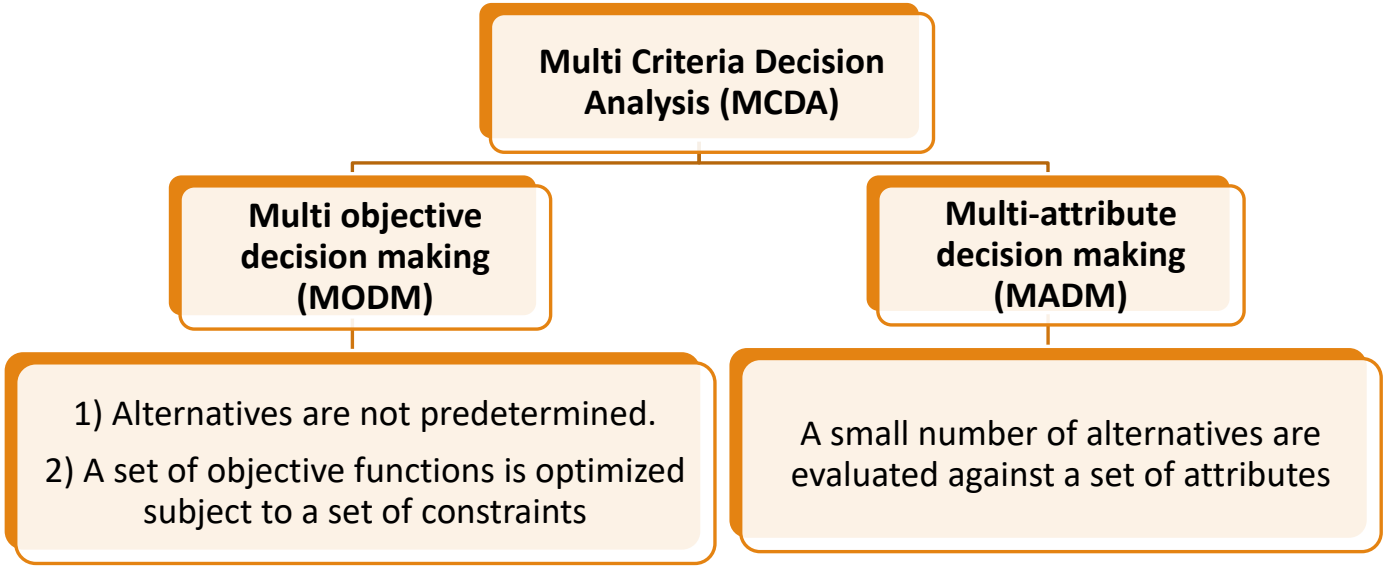
- To identify the community benefits to the Central Florida region
- Explore the literature on Multi Criteria Decision Approaches approaches to find appropriate methods for our research
- To develop and implement a framework to compare the changes in MOEs across scenarios
- To provide a net positive, neutral or negative rating of a project for the three projects

Measures of Effectiveness (MOE)

- **Measure 1: Property value change**
  - Disaggregate parcel level data layers will be employed to compute the change in property value
- **Measure 2: Changes to job accessibility**
  - Census bureau data will be used to examine how the number of employment has varied
- **Measure 3: Commuting time change**
  - American Community Survey data will be used to measure changes to commute travel times
- **Measure 4: Land use type change**
  - Disaggregate parcel level data layers will be employed to identify the land use change from vacant to residential, industrial and commercial
- **Measure 5: Changes to travel patterns for zero car households**
  - Census bureau data will be used to measure job accessibility around MOE

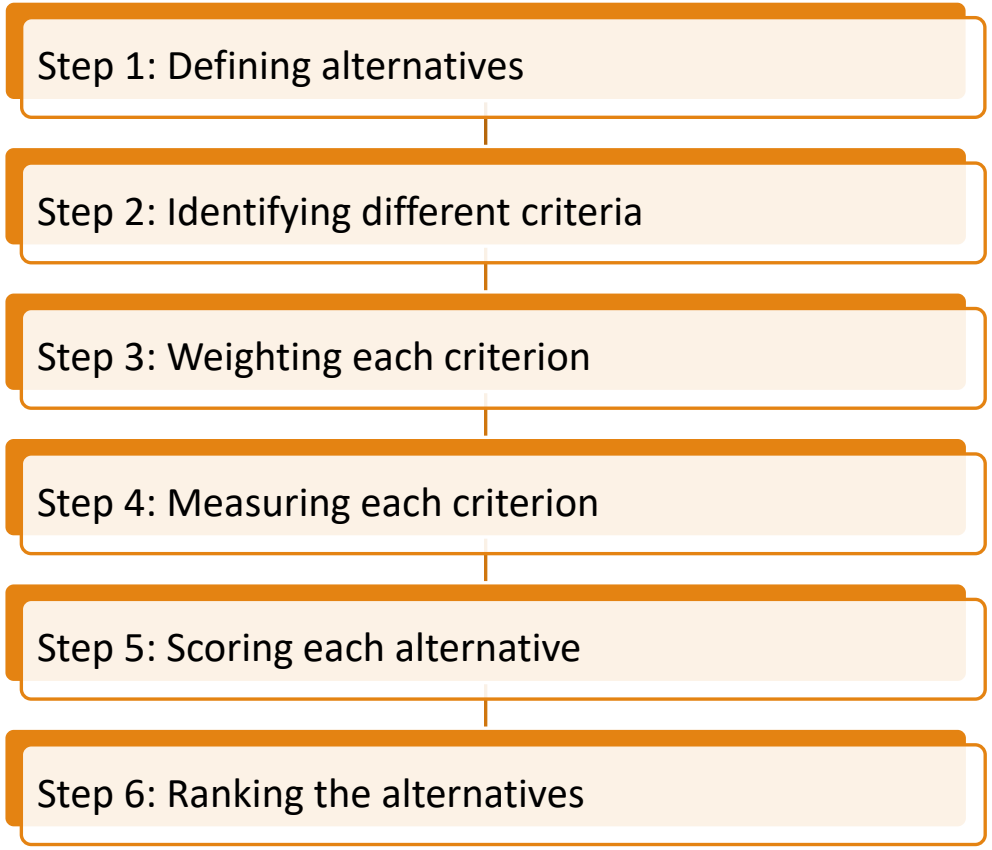
Multi-Criteria Decision Analysis

- A general class of operations research models that are associated with decision processes in the presence of several decision criteria.



Methodology

- MCDA models follow a hierarchical process as presented.



Weighting Approaches

- For weighting the criteria, several approaches are adopted in literature.
- Five points rating
  - Criteria are rated on a five-point scale ranging from (1) not important to (5) very important.
- Point allocation
  - A budget of 100 points is allocated across different criteria to reflect their relative importance.
- Pairwise comparison
  - All possible pairs of criteria are compared on a reciprocal numerical rating scale ranging from 1/9 to 9.
- In this study, we employ **pairwise comparison** method to compare the relative importance of the five criteria.

Pairwise Comparison Method

- To weight the criteria, pairwise comparison method has been adopted in this study.
- First, all possible pairs of criteria (e.g. Criteria A and Criteria B) are compared on a reciprocal numerical rating scale ranging from 1/9 to 9.

Preference rating	Definition
1	Equal importance
2	Weak or slightly important
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong
8	Very, very strong
9	Extreme importance

Pairwise Comparison Method

- Based on the stakeholders' judgement, average pairwise weights of different criteria are generated.

Criteria	1	2	3	4
1	1	4	3	6
2	1/4	1	3	5
3	1/3	1/3	1	2
4	1/6	1/5	1/2	1

Pairwise Comparison Method

- Weights of the criteria can be computed from the pairwise comparison matrix as follows:
  - Elements of each column are normalized by sum of the column
  - Elements of each row are summed to get weights column.
  - Elements of weights column are normalized at the last step

Criteria	1	2	3	4	Priorities	Normalized Priorities
1	0.57	0.72	0.4	0.43	2.12	0.53
2	0.14	0.18	0.4	0.36	1.08	0.27
3	0.19	0.06	0.13	0.14	0.53	0.13
4	0.1	0.04	0.07	0.07	0.27	0.07

Methodology

- Several methods can be employed in MCDA as follows:
  - **Weighted sum method (WSM)**
  - Weighted product method (WPM)
  - Analytical hierarchy process (AHP)
  - VIKOR Method
  - Preference ranking organization method for enrichment evaluation (PROMETHEE)
  - The elimination and choice translating reality (ELECTRE)
  - The technique for order preference by similarity to ideal solutions (TOPSIS)
  - Compromise programming (CP) and
  - Multi-attribute utility theory (MAUT).

Weighted Sum Method

- Weighted sum method follows 3 important steps:
  - Weighting of the criteria
    - Five points rating, pairwise comparison method and point allocation method are performed
  - Scoring of the criteria
    - Scoring of the criteria are performed by comparing case and control.
  - Finally, scoring and ranking the projects.

Criteria	1	2	3	4	Scores	Rank
Weights	0.53	0.27	0.13	0.07		
Project A	10	20	15	15	13.7	3
Project B	15	30	5	10	17.4	1
Project C	25	5	15	10	17.25	2

Analysis and Results

- In this study, we adopted Weighted Sum Method for scoring and ranking the three projects.
- We selected 5 measures of effectiveness as the criteria:
  - Property value change
  - Changes to job accessibility
  - Commuting time change
  - Land use type change
  - Changes to travel patterns for zero car households
- Analysis procedure consists of following steps:
  - Weighting the 5 criteria considered
  - Computing the measures of the criteria
  - Scoring the projects based on the values of the criteria and respective weights
  - Finally, ranking the projects

Weights

- An online survey is performed to receive FDOT officials' response to find relative importance of the criteria. Survey Questions are as follows:
  - Compared to "Property Value" provide a relative score (between 1/9 and 9) for job accessibility, commuting time, land use change and travel pattern change.
  - Compared to "Job Accessibility" provide a relative score (between 1/9 and 9) for commuting time, land use change and travel pattern change.
  - Compared to "Commuting Time" provide a relative score (between 1/9 and 9) for land use change and travel pattern change.
  - Compared to "Land Use Type" provide a relative score (between 1/9 and 9) for travel pattern change.
- A total of 22 expert responses are collected from the survey.

Weights

- Based on the survey, average pairwise weights of different criteria are generated.

Criteria	Property value change	Job accessibility	Commuting time	Land Use Change	Travel Pattern
Property value change	1.000	0.198	0.178	0.236	0.221
Job accessibility	5.048	1.000	0.187	0.274	0.258
Commuting time	5.619	5.360	1.000	0.280	0.235
Land Use Change	4.238	3.644	3.573	1.000	0.250
Travel Patterns	4.524	3.878	4.251	4.000	1.000

Weights

- Weights of the criteria can be computed from the pairwise comparison matrix as follows:
  - Elements of each column are normalized by sum of the column.
  - Elements of each row are summed to get weights column.
  - Elements of weights column are normalized at the last step.

Criteria	Property value change	Job accessibility	Commuting time	Land Use Change	Travel Pattern	Weights	Normalized Weights
Property value change	0.049	0.014	0.019	0.041	0.113	0.236	0.047
Job accessibility	0.247	0.071	0.020	0.047	0.131	0.517	0.103
Commuting time	0.275	0.381	0.109	0.048	0.120	0.933	0.187
Land Use Change	0.207	0.259	0.389	0.173	0.127	1.155	0.231
Travel Patterns	0.221	0.275	0.463	0.691	0.509	2.160	0.432

Weights

- Final Weights used for analysis

Criteria	Final Weight
Property value change	0.047
Job accessibility	0.103
Commuting time	0.187
Land Use Change	0.231
Travel Patterns	0.432

Value of Criteria

- Five MOEs for the three projects in consideration are set as the evaluation criteria in this analysis.
- These criteria are scored based on percentage changes of them in case and control area from year 2011 to 2017.
  - For example, commuting travel times in case area of SunRail project are 25 minutes and 20 minutes in 2011 and 2017, respectively.
  - Commuting travel times in control area of SunRail project are 30 minutes and 28 minutes in 2011 and 2017, respectively.
  - Therefore, commuting travel time reduction in case and control are 20% and 6.67%. We will identify the difference of these percentage changes, therefore, 13.33% in this case.
  - Finally, if total investment is $1,000M for SunRail project, the score of commuting travel time will be 1.33% per $100M investment.

Property Value Change (SunRail)

- The criteria are valued by the following steps:
  - At first, changes of the property value for a particular land use are estimated for case and control areas.
  - Secondly, the changes are normalized by the sum of the changes in case and control.
  - Thirdly, difference between the normalized percentages of case and control is determined.
  - Finally, scores for different regions are weighted by the budget allocations of respective region to find a single score of property value change for the project.

Region	Land Use	Property Value Change in Case ($ per Acre)	Property Value Change in Control ($ per Acre)	% Change (Case)	% Change (control)	% change (Case-Control)	% Area	Weighted Property Value Change (%)
Downtown	Single Family	456,558	315,503	59.13	40.87	18.27	53.89	35.40
	Multi-Family	1915,108	381,978	83.37	16.63	66.74	5.67	
	Retail	570,925	163,763	77.71	22.29	55.42	21.20	
	Industrial	237,311	76,954	75.51	24.49	51.03	13.03	
	Instituti-onal	340,343	100,801	77.15	22.85	54.30	6.21	

Job Accessibility (SunRail)

- Scoring of job accessibility has been performed based on difference of percentage change of number of accessible jobs in case and control area.

Region	Change in Case per unit area	Change in Control per unit area	% Change in Case	% Change in Control	% Change	Investment in $million	% Change/$ 100million
Downtown	66958.60	80805.96	45.31	54.69	-9.37	176.47	-2.38
Outside Downtown Phase I	12733.35	38325.90	24.94	75.06	-50.12	529.41	
Phase II	68855.06	50796.25	57.55	42.45	15.09	294.12	

Travel Time Change (SunRail)

- Commuting travel time change is scored based on percentage changes of commuting time in case and control from 2011 to 2017.

Region	% Reduction in Case	% Reduction in Control	% Reduction (Case - Control)	Investment in $million	% Change/$100million
Downtown	-2.66	-1.05	-1.61	176.47	-0.52
Outside Downtown Phase I	-11.76	-4.62	-7.14	529.41	
Phase II	-6.86	-2.95	-3.91	294.12	

Land Use Change (SunRail)

- To estimate the score for land use change, changes of total vacant area from 2011 to 2017 in case and control area were used.

Region	Change of Vacant Area in Case (Acre/sqmile)	Change of Vacant Area in Control (Acre/sqmile)	% Change in Case	% Change in Control	% Change (Case-Control)	Investment in $million	% Change/ $100million
Downtown	17.36	3.41	83.57	16.43	67.14	176.47	6.62
Outside Downtown Phase I	24.29	6.53	78.80	21.20	57.61	529.41	
Phase II	62.93	6.57	90.54	9.46	81.08	294.12	

Zero Car HH Travel Pattern (SunRail)

- To score zero car households travel pattern change, public transportation share changes in case and control area were used.

Region	% Change of Public Transport Share in Case	% Change of Public Transport Share in Control	% Change (Case-Control)	Investment in $million	% Change/ $100million
Downtown	-0.40	-4.95	4.55	176.47	0.47
Outside Downtown Phase I	1.01	-0.66	1.68	529.41	
Phase II	11.24	0.87	10.37	294.12	

Overall Scoring

- Final step of the multicriteria decision analysis is overall scoring of the projects and rank them based on their scores.
- Overall scoring of the projects is performed by weighting the scores of the criteria.

Criteria	Property value change	Job accessibility	Commuting time	Land Use Change	Travel Pattern	Overall Score	Rank
Weights	0.047	0.187	0.103	0.231	0.432		
SunRail	1.99	0.00	-0.52	6.62	0.47	1.729	1
I-4 Expan.	0.88	1.23	-0.07	0.97	-0.11	0.332	2
Juice Bike	1016.7	0.00	1161.9	-13600	4911.9	-754.599	3

MCDA Results

- Multi-criteria analysis methodology adopted for this study to identify overall performances of the three projects
- Three projects were scored on the basis of criteria scores and their respective weights
- Results show that SunRail project is the highest scored project among these three projects. In contrast, Juice bikeshare project is the least scored project
- I-4 expansion project was also found to have a net positive rating

Things to consider for application

- The emphasis of our research is on devising a methodology and framework for conducting project evaluation
  - Relying on extensive data compilation and analysis
  - Employing state of the art Multi Criteria Decision Analysis methods
- However, there is subjectivity in
  - MOEs selected and
  - Change criteria employed
- Case can be made that public health based MOEs are more appropriate
  - We did not consider them as data at a high resolution are harder to obtain
  - But in the presence of such data, it might offer more useful results

Things to consider for application

- In analyzing data, it is possible to arrive at non-plausible results due to the inherent complexity of the process being considered.
- For instance, the job accessibility measured for SunRail project offered negative values, indicating that job accessibility has reduced due to SunRail project.
- In such events, it is important that we evaluate the result as engineers and possibly ignore the MOE or consider alternative MOEs.
  - In our case, we considered SunRail impact on job accessibility as 0 for further computations.
- The results for Juice system need to be considered with an abundance of caution as the spatial distribution is smaller (relative to the other projects).
- For the land use type change MOE, it is possible to consider changes at a finer resolution such as single family to multi-family (if any) and so on. However, in our context these changes were minimal.

Next Steps

- Upload all three webinars and associated material (reports and documentation) on the website

- Send a follow up survey to receive feedback on
  - Content and approach
  - Presentation materials
  - Webinar modalities
  - Other feedback

Questions