Criticality Assessment Metrics of Arkansas's Highway System using the Analytical Hierarchy Process (AHP) Model

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INTRODUCTION

- The transportation system is especially **vulnerable** to natural and human-made disasters having effects on mobility, safety and the economy.

- States are developing methods to assess transportation system **resiliency** and to use such assessments to help prioritize projects that enhance system resiliency.

- This study provided **ARDOT** with a foundational resiliency assessment of the state-maintained roadway network with considerations for passenger and freight traffic.

- The resiliency assessment identified critical links and corridors using repeatable, **data-driven** methods that can used to support project prioritization and selection.

BACKGROUND

- The ability of a transportation network to continue functionality despite adverse conditions caused by disruptions, as well as the ability to quickly recover to normal operating conditions, is measured by its resiliency.

- Determining asset criticality is the first step in resiliency assessment. Criticality is a measure of the importance of an asset to the resilience of the system (Flannery, 2017).

- Measurement of resiliency entails criticality assessment to identify and rank important network links.

- The Analytical Hierarchy Process is a multicriteria decision making approach in which factors are arranged in a hierarchical structure.

- It is an unequal weighting approach developed by Thomas L. Saaty which was used to combine the criticality criteria in a way that reflected the importance of each criterion to ARDOT's priorities.

OBJECTIVES

Determine the unequal weights of each criticality assessment metric using the AHP Model.

Identify the most important criteria to measure the criticality of Arkansas's highway system.

Compute the numeric criticality value (metric) for each transportation network link operated by ARDOT

THE ANALYTICAL HEIRARCHY PROCESS MODEL

- The main steps of AHP used for this study are;

1. Setting up the decision problem into a hierarchical structure consisting of the goal and criteria.
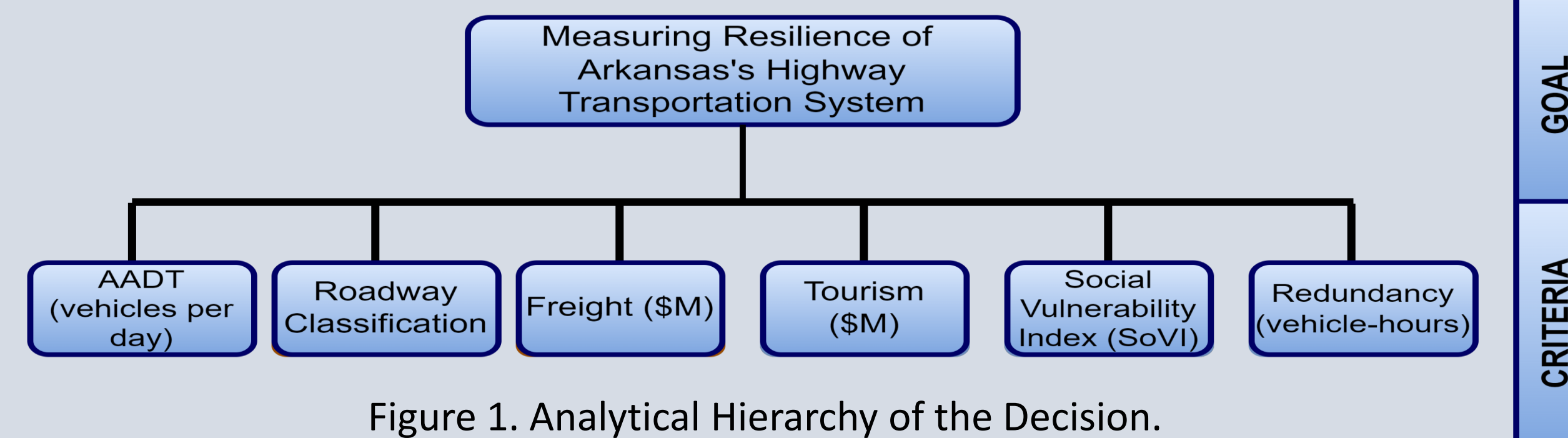

Figure 1. Analytical Hierarchy of the Decision.

2. Collecting the input data by pairwise comparisons of the criteria through the questionnaire survey.

Scale	Judgement of preference	Description
1	Equally important	Two factors contribute equally to the objective
3	Moderately important	Experience and judgment slightly favor one over the other
5	Strongly important	Experience and judgment strongly favor one over the other
7	Very strongly important	Experience and judgment very strongly favor one over the other, as demonstrated in practice
9	Extremely important	The evidence favoring one over the other is of the highest possible validity
2,4,6,8	Intermediate preferences between adjacent scales	When compromise is needed

Table 1. The Saaty Scale for Pairwise Comparisons.

With respect to Goal: **MEASURING RESILIENCE OF ARKANSAS HIGHWAY TRANSPORTATION SYSTEM**
Using the scale from 1 to 9 (where 9 is extremely and 1 is equally important), please indicate (X) the relative importance of options **A** (left column) to options **B** (right column).

A Options	Extremely	Very Strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very Strongly	Extremely	B Options
Annual Average Daily Traffic (AADT)	9	8 7	6 5	4 3	2 1 2	3	4 5	6 7	8 9	Roadway Classification
Annual Average Daily Traffic (AADT)	9	8 7	6 5	4 3	2 1 2	3	4 5	6 7	8 9	Freight
Annual Average Daily Traffic (AADT)	9	8 7	6 5	4 3	2 1 2	3	4 5	6 7	8 9	Tourism
Annual Average Daily Traffic (AADT)	9	8 7	6 5	4 3	2 1 2	3	4 5	6 7	8 9	Social Vulnerability Index
Annual Average Daily Traffic (AADT)	9	8 7	6 5	4 3	2 1 2	3	4 5	6 7	8 9	Redundancy
Roadway Classification	9	8 7	6 5	4 3	2 1 2	3	4 5	6 7	8 9	Freight
Roadway Classification	9	8 7	6 5	4 3	2 1 2	3	4 5	6 7	8 9	Tourism
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Social Vulnerability Index	9	8 7	6 5	4 3	2 1 2	3	4 5	6 7	8 9	Redundancy

Figure 2. Questionnaire Survey to compare the relative importance of the criteria .

3. Obtaining the consistency ratios from the individuals' set of judgements and aggregation of the individual judgements (AIJ) for each set of pairwise comparisons into an "aggregate hierarchy" using the geometric mean.

4. Computing the overall criteria weights were using the AHPy library in python via the eigenvalue method.

CRITERIA LEVELS

- The six criteria for the criticality metric are combined in an unequally weighted approach via the **Analytical Hierarchy Process (AHP).**
- The overall criticality of the of links are computed from this approach.

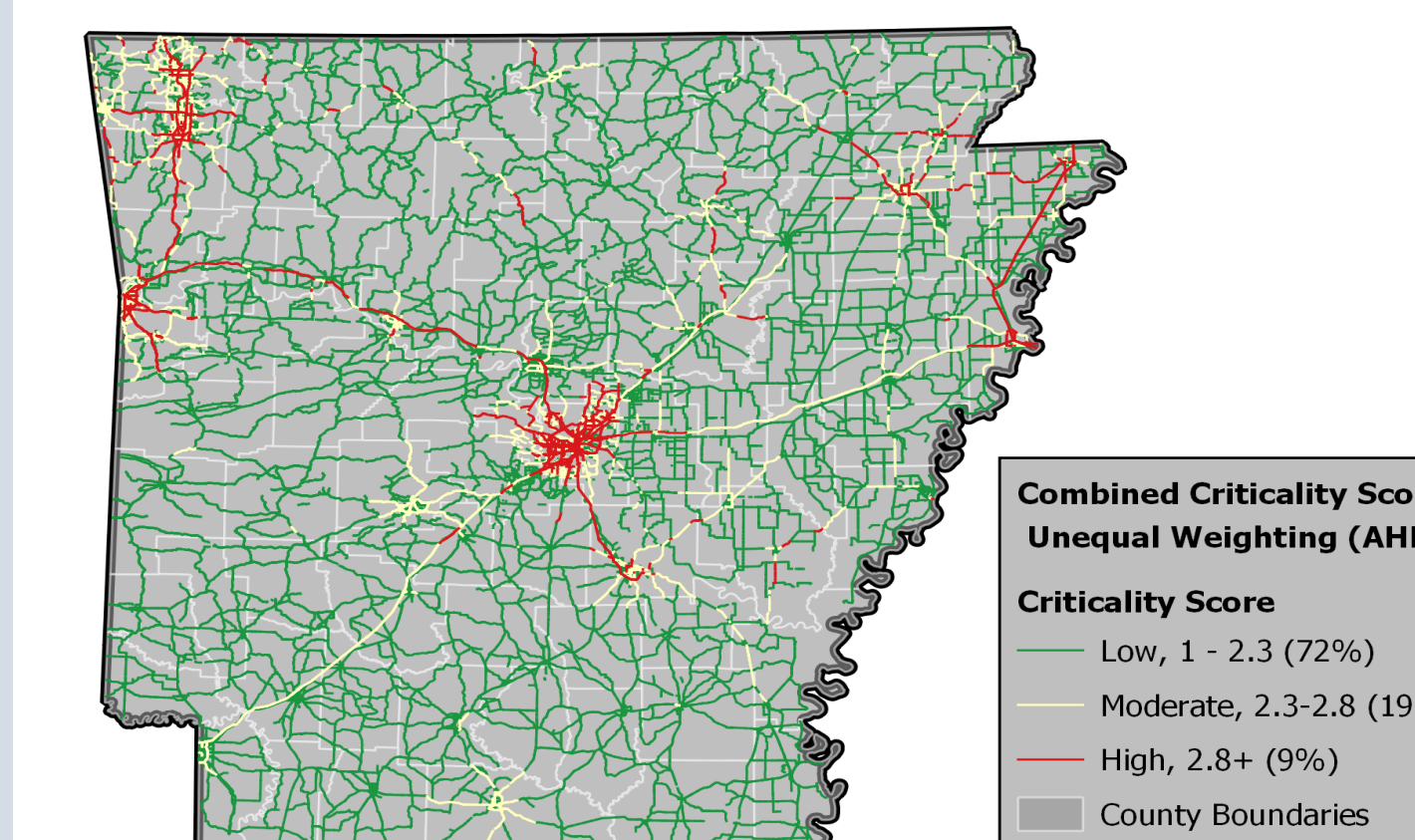|	Criticality Score					
	1	2	3	4	5	
Criteria	Very Low Impact	Low Impact	Moderate Impact	High Impact	Very High Impact	Weight
Redundancy	<=200	201-788	789-1870	1871-7500	>7500	**0.333**
Freight	<=800	801-2085	2086-3898	3899-12250	>12250	**0.235**
Annual Average Daily Traffic (AADT)	<=720	721-1900	1901-4600	4601-15000	>15000	**0.177**
Roadway Classification	Major Collector	Minor Arterial	Principal Arterial	Freeway Expressway	Interstate	**0.146**
Social Vulnerability Index (SoVI)	-4.49--2.93	-2.92--1.24	-1.23-0.67	0.68-2.51	2.52-5.40	**0.06**
Tourism	<=85	86-270	271-567	568-928	>928	**0.049**

CRITICAL SITES

Figure 2. Combined Criticality Score for Arkansas's Highway System.

The top 5 most critical links are;

1. US 67/167 from AR 440 to South Redmond Road, *Pulaski County.*

2. Garrison Avenue, *Sebastian County*

3. I-55 from US 70 to the I-55 Memphis-Arkansas Bridge, *Crittenden County.*

4. I-430 from S. Shackleford Road to Stagecoach Road and from the I-40 to Crystal Hill Road (AR 100) interchange, *Pulaski County.*

5. I-40 from Crystal Hill Road to West Military Drive, *Pulaski County.*

CONCLUSIONS

- This is a data driven and repeatable methodology that can be adopted by any state, federal, state, local and private authorities and agencies for measuring the criticality of system-wide transportation highways .

- The combined most critical and most vulnerable segments were recommended as case study locations.

- The cost to improve the link and/or asset was estimated and compared to the estimated costs of not improving the link and/or asset.

- Types of improvements and appropriate detour routes to follow if the link and/or asset were to become non-operational were recommended.

ACKNOWLEDGEMENTS