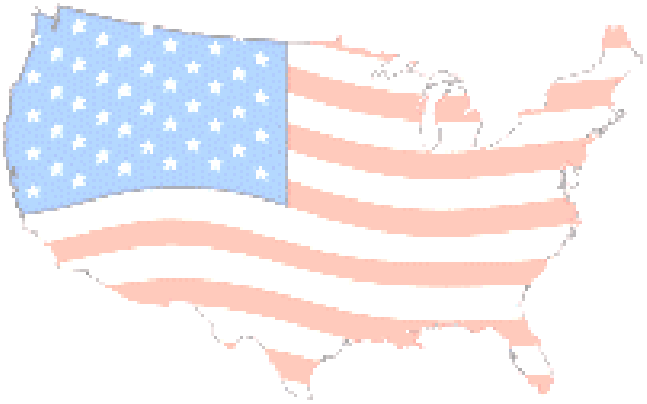
HOMELAND SECURITY FOR

RURAL TRANSPORTATION NETWORKS



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ABSTRACT

This project addresses vulnerability assessment of rural transportation networks. There are clear differences between rural and urban transportation networks including higher costs due to widely dispersed population and industry in rural networks. Exploration of rural transportation security issues is important because these networks are essential for enabling commercial shipping and linking rural residents with distant services. This research investigates whether or not the methodologies of urban assessment studies can be applied to rural transportation networks and selects preferred procedures for conducting rural transportation vulnerability assessments. After a comparative methodology analysis, the United States Department of Transportation's *Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection* is selected to be the most robust vulnerability assessment tool for rural transportation networks. A modification of this vulnerability assessment tool is developed as an alternative means of rural transportation vulnerability assessment. Two examples based on Jackson County, Arkansas are conducted to show the applicability of each methodology on a rural transportation network.

1 PROJECT DESCRIPTION

Multiple agencies including the United States Department of Homeland Security, Transportation Security Administration, and Department of Transportation (USDOT) have conducted comprehensive vulnerability assessments of rail and transit networks in high-density urban areas. This project focuses on vulnerability assessment of rural transportation networks. There are clear differences between rural transportation networks and those in urban areas including higher costs in rural areas due to widely dispersed population and industry (Stommes and Brown, 2002). Exploration of rural transportation security issues is important because these networks are essential for enabling commercial shipping and linking rural residents with distant services. This research investigates whether or not the urban assessment studies can be applied to rural transportation networks and seeks to identify appropriate scalability and adaptation procedures and/or guidelines for conducting rural transportation vulnerability assessments. Multiple modes of rural transportation including highways, inland waterways, and rail are considered.

The objective of this study is to explore existing urban transportation risk-based assessments and determine if and how these assessments can be adapted for rural transportation networks. The research tasks conducted to achieve this objective are summarized below:

Task 1: Review related urban studies

Ongoing and completed vulnerability assessment studies of transportation systems in high-density urban areas are identified, collected and reviewed to identify applicability and existing linkages to rural transportation areas. A source matrix is developed to summarize and compare the contents of each source (see Appendix 1). An annotated bibliography containing a summary or abstract of each reviewed source is presented in Appendix 2.

Task 2: Study rural transportation networks

A thorough literature review is conducted and expert opinions are considered to identify the pertinent characteristics and security needs of rural transportation networks.

Task 3: Assess adaptability and scalability of urban plans

Based on the information obtained from Tasks 1 and 2, an assessment of the adaptability and scalability of existing urban security and emergency preparedness plans for application in rural transportation networks is conducted.

Task 4: Develop rural transportation vulnerability assessment tool

Based on the results of Tasks 1 through 3, a methodology for conducting a vulnerability study for assessment of rural transportation networks is selected. In addition, a variation of this methodology is conducted.

Task 5: Identify and demonstrate Task 4 methodologies

A specific rural transportation network is selected and used to demonstrate the application of the methodologies developed in Task 4.

Task 6: Documentation and dissemination

Project results are documented in this final report.

2 RURAL TRANSPORTATION

Since the events of September 11th, 2001, much time and energy has been spent on the assessment of vulnerabilities in transportation networks. The vast majority of these efforts have been focused on urban transportation networks while rural transportation networks have been overlooked. Many methodologies have been created to assess the vulnerability of transportation networks in urban settings. Key differences exist between urban and rural transportation networks that require alterations to these methodologies. These differences include access to the conventional modes of transportation of air, rail, road, and water as well as the characteristics of demographics, geography, public transportation systems, and emergency response systems. Rural areas generally have significantly fewer resources, such as personnel and funding, with which to complete a vulnerability assessment. Rural and urban transportation systems are examined and compared in this research. A matrix comparing important characteristics of rural and urban transportation networks is presented in Appendix 3. In order to further understand rural transportation networks, a description of the characteristics common to most rural transportation networks is provided in the remainder of this section.

2.1 Rural Geographic Areas

A rural area can be defined in many ways but is most generally accepted as areas that are not classified as urban. A rural area is often defined as a city with fewer than 50,000 people or a geographic area with fewer than 2,500 people. These definitions rely heavily on data provided by the United States Census Bureau. In this research, we define a rural area as a geographic area

with less than 50,000 people. This definition is frequently used throughout the USDOT resources.

2.2 Demographics

Rural transportation networks exhibit common characteristics throughout the United States. Generally, these characteristics are results of low population densities and large distances between population centers (Maxwell, 1996). In the 2000 census, 21% of U.S. residents and 73% of counties nationwide were classified as rural (University of Arkansas Division of Agriculture (UADA), 2007; Transportation Research Board (TRB), 1998). When compared to urban areas, real wages tend to be approximately 20% lower, and poverty rates are 2.8% higher (TRB, 1998; Brown, 2004). Rural areas also have higher proportions of disabled and elderly persons (TRB, 1998). In 1999, one in fourteen rural households did not own an automobile (Rural Policy Research Institute (RPRI), 1999). Thirty-two percent of rural residents are considered transit dependent (Community Transportation Association of America, 1994).

2.3 Geography

The geography of rural areas also factors into the workings of rural transportation networks. A large proportion of the nation's land mass, 83%, is considered to be rural (TRB, 1998). Rough terrain, such as steep grades and mountain passes, require a much different transportation network than that of urban areas. Rural areas also experience more dramatic weather events which in turn significantly affects road conditions (Federal Highway Administration (FHA), 2001).

2.4 Public Transportation

Public transportation has a much different primary purpose in rural areas. In urban areas, public transportation is available primarily to reduce traffic congestion. Rural networks operate in order to provide services to transit dependent groups. Public transportation has low availability in rural areas (Maxwell, 1996). Forty percent of rural counties are not served by public transportation, and 28% of rural counties have limited service (RPRI, 1999; Hill, 1999). Despite this limited service, 93% of rural residents live within the coverage area of one of the modes of intercity transportation (air, road, rail, water) (Bureau of Transportation Statistics (BTS), 2005).

Approximately twelve hundred transportation systems operate in rural America (Maxwell, 1996). Sixty percent of these providers are public agencies. Two-thirds of these systems operate in a single county, while one-fourth operate in multi-county areas. Of rural public transportation users, 0.5% use transit service as their primary means to get to work (Brown, 2004). Rural transportation users are 62% female, 31% elderly, and 23% disabled (United States Department of Agriculture Economic Research Service (USDA ERS), 2005).

2.5 Airports

Rural airport service is quite different from urban airport service. There are far fewer rural airports per land area than in urban areas (Stamm, 2002). Greater distances are traveled by users to access these rural airports. In order to be considered a rural airport, airports must handle fewer than 100,000 departures per year and be located more than 75 miles from airports handling more than 100,000 departures annually (BTS, 1999).

2.6 Roads

Rural roads boast vast coverage in the U.S. There are 3.1 million miles of rural roads nationwide. These roads comprise 80% of national road miles and 40% of vehicle miles traveled (FHA, 2001). Rural roads tend to be narrow with 90% being two-lane or less (Hill, 1999) City and county governments are responsible for 55% of paved rural roads and 95% of unpaved rural roads (Hill, 1999). One-third of rural interstates and other rural arterials are considered to be in poor condition (FHA, 2002). Approximately half of all rural roads are paved (Hill, 1999). The dominant mode of public transportation for rural residents is the bus (USDA ERS, 2005). Nearly 80% of rural counties have no public bus service (RPRI, 1999). When bus service is available, routes are generally longer with fewer arrivals per location. Rural roads carry high volumes of freight. The vast majority of manufactured goods that are transported across state lines travel by road. Additionally, 28% of the nation's intercity freight travels by road (FHA, 2001).

2.7 Rail

Rail transportation has become almost completely dedicated to the movement of freight. Railroads move 42% of the nation's freight (Association of American Railroads (AAR), 2006b and 2006c). Rural residents have limited access to rail transit with almost six in ten residents

living outside the service of passenger rail transportation (USDA ERS, 2005). Also, fewer than 200 nonmetro areas nationwide are served by rail (USDA ERS, 2005).

2.8 Water

Rural water transportation is not easily distinguished from urban water transportation. Available in 41 states, the nation's waterway system consists of 26,000 miles of inland waterways, 275 locks, and over 9,100 commercial waterways (FHA, 2001; USDA ERS, 2005). Water transportation moves approximately 14% of the nation's intercity freight (FHA, 2001).

2.9 Rural Transportation in Arkansas

With all but twelve of its 75 counties classified as rural, Arkansas is an ideal state to serve as a case study for rural transportation research (see Figure 1) (UADA, 2007). With 48% of the population living outside of urban areas, many Arkansans rely on the rural transportation network for both the delivery of goods and daily travel (UADA, 2007). Arkansas contains many transportation assets that are vital to both the state and the country. I-40, traveling from North Carolina through Little Rock, Arkansas to California, connects the east coast to the west coast as a vital trucking lane. The Mississippi River borders Arkansas and connects Minnesota with the Gulf of Mexico. Adams Field, also known as Little Rock National Airport, recorded nearly 1.3 million departures in 2000 (USDOT BTS, 2000a). Nearly 3,700 miles of railroad crisscross the state (USDOT BTS, 2000b). Arkansas' rural transportation network is comprised of interstates, highways, railroads, small airports, and navigable rivers that make life possible in rural Arkansas.

Figure 1. Counties of Arkansas (Rural Profile of Arkansas, 2007)

3 VULNERABILITY METHODOLOGIES

Much research has been conducted regarding vulnerability assessment for transportation and critical assets of America. The literature commonly examines the vulnerability of urban areas rather than rural areas. The objective of this literature review is to summarize the research conducted in vulnerability assessment of transportation assets and examine their applicability to rural areas. The most relevant methodologies existing in the literature are examined and compared according to four questions: 1) What can go wrong? 2) What is the likelihood? 3) What are the consequences?, and 4) What can be done? (See Appendix 4). In addition, each reviewed methodology is graphically summarized in Appendix 5.

The USDOT employs a vulnerability assessment methodology, the *Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection* (USDOT Guide), based on identifying critical assets and associated risk scenarios. Countermeasures to deter, detect and delay the possible attacks are developed and compared according to their estimated costs. Stovall and Turner (2004) implemented the USDOT Guide to two communities in Alabama, Shelby County and the City of Tuscaloosa. The methodology is applied in three steps. The first two steps are information gathering and defining of critical assets. The third step is developing

countermeasures, cost analysis of each countermeasure, and developing operational security system. At the conclusion of their work, it is determined that the most important part of the effort is the information gathering step.

In addition to these applications, several other research efforts have utilized the USDOT methodology or a slight variation. As an example, the National Academy Press (1999) used the USDOT methodology for vulnerability assessment when defining research and development (R&D) projects. Their work is primarily about developing R&D strategies for improving surface transportation security. Other research utilizing a methodology similar to USDOT is conducted by Rowshan et al. (2005). They introduce a risk assessment methodology for the transportation management centers (TMC). Their risk assessment methodology includes asset identification, threat assessment, consequence assessment, vulnerability assessment, and countermeasure development. The structure of the methodology is very similar to the USDOT Guide where the main difference is the use of a formula to calculate risk. Each step of the methodology contributes to a value that is used to compute the overall risk for an asset.

It is very common to utilize a risk assessment formula to determine the vulnerability of assets. One of the most basic formulas is used in "Recommendations for Bridge and Tunnel Security" by The Blue Ribbon Panel and Tunnel Security (2003). This paper is based on tunnel and bridge vulnerabilities and recommendations for their vulnerability assessments. Each threat scenario has a risk value. The risk value of each scenario is calculated by a risk formula that primarily includes occurrence, vulnerability and importance values. Hunter et al. (2003) also define a risk formula in their study of "Lessons Learned from Utility and Infrastructure Vulnerability Assessment". Probability of attack, degree of system effectiveness and severity of the consequence are used as factors in their research. However, the main focus of their paper is project management in terms of how to organize the project team, utilize experts and integrate security into every phase of the project.

A different approach is developed by Haimes et al. (2002) in their study of "A Risk Assessment Methodology for Critical Transportation Infrastructure". Their methodology employs risk scenarios rather than critical assets. Each scenario is identified through Hierarchical Holographic Modeling (a holistic approach that helps to define main risk scenarios in an organized way). Risk scenarios are evaluated according to their likelihood and occurrence. Countermeasures are compared according to their cost and damage rates. The structure of the

methodology is different than the USDOT Guide since this research includes a diverse quantitative risk analysis. However, the methodologies are similar in that they evaluate critical assets or risk scenarios by the same factors (likelihood and occurrence).

4 USDOT VULNERABILITY ASSESSMENT METHODOLOGY FOR RURAL TRANSPORTATION

4.1 Overview

The USDOT *Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection* was prepared by the Science Applications International Corporation for the American Association of State Highway and Transportation Officials' Security Task Force (2002). The original intent of the guide was to assist State Departments of Transportation in the assessment of vulnerabilities in highway transportation. A comparison of this methodology with the others reviewed is provided in Appendix 6. A visual representation of the USDOT Guide is presented in Figure 2.

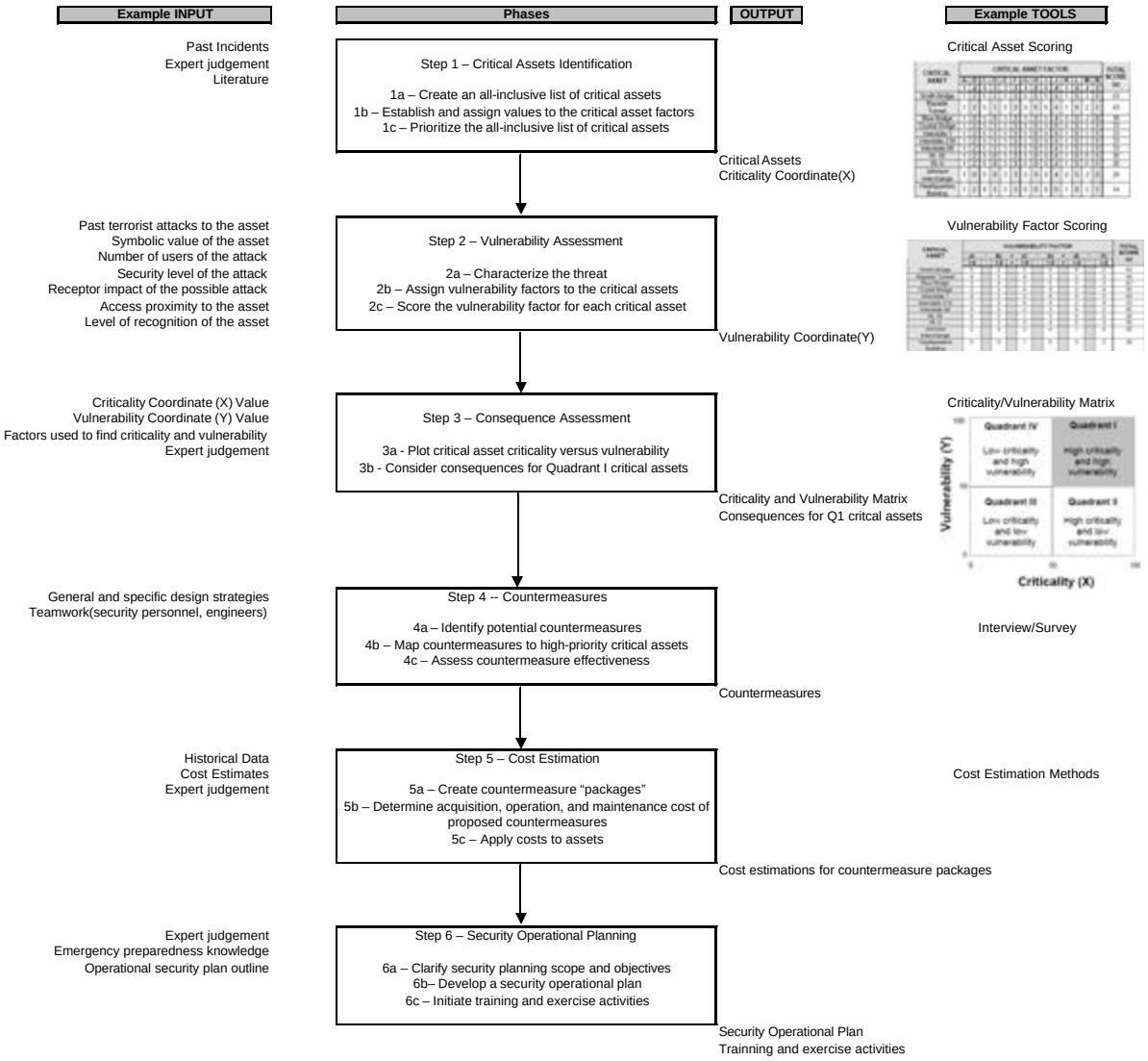

Figure 2. USDOT Vulnerability Assessment Methodology (2002)

The guide focuses on the assessment of physical asset vulnerability, development of possible countermeasures, estimation of countermeasure costs, and improvement of security operational planning. Designed to be useful by all levels of staff, the guide directs all levels of input in the vulnerability assessment process. Comprised of three phases including pre-assessment, assessment, and post-assessment, the guide begins with identification of key assets and follows through to implementation of countermeasures. Vulnerabilities generally fall into one of three categories: facilities, vehicles, and information infrastructure. The guide assumes that users have or can obtain sufficient knowledge of threats.

A team needs to be assembled to use this guide (in a rural county, this will likely be a small team or a single person). This team generally consists of threat experts, mitigation strategy personnel, vulnerability experts, and transportation professionals. Likelihood assessment is performed by threat experts and mitigation strategy personnel. Vulnerability experts and mitigation strategy personnel develop the impact assessment. Criticality assessment is performed by transportation professionals.

In order to complete the guide, many data types are necessary. These include asset, threat, vulnerability, consequence, countermeasure, cost, policy, plan, procedure, personnel, and geographic information systems data. This data may not be readily available in a rural county.

During the pre-assessment phase, critical assets are identified. Threats are analyzed, vulnerabilities are assessed, and consequences are assessed during the assessment phase. During the post-assessment phase, countermeasures are identified, costs are estimated for countermeasures, and operational security planning is reviewed. The last task is to create a report detailing these three phases. Our research focuses on the pre-assessment phase.

4.2 Step 1: Critical Assets Identification

The organization first reviews their mission statement in order to provide guidance as to which assets enable the accomplishment of that mission. Assets are then split into four categories: infrastructure, facilities, equipment, and personnel. Examples of infrastructure assets include arterial roads, interstate roads, bridges, and overpasses. Facilities assets include chemical storage areas, fueling stations, ports of entry, and weight stations. Equipment assets include hazardous materials, roadway monitoring, signal and control systems, and vehicles. Personnel assets include contractors, employees, vendors, and visitors. Asset guidelines from the USDOT Guide are provided in Table 1.

Table 1. Critical Transportation Assets (SAIC, 2002)

INFRASTRUCTURE	FACILITIES	EQUIPMENT	PERSONNEL
Arterial Roads	Chemical Storage Areas	Hazardous Materials	Contractors
Interstate Roads	Fueling Stations	Roadway Monitoring	Employees
Bridges	Headquarters Buildings	Signal & Control Systems	Vendors
Overpasses	Maintenance Stations/Yards	Variable Messaging System	Visitors
Barriers	Material Testing Labs	Vehicles	
Roads Upon Dams	Ports of Entry	Communication Systems	
Tunnels	District/Regional Complexes		
	Rest Areas		
	Storm Water Pump Stations		
	Toll Booths		
	Traffic Operation Centers		
	Vehicle Inspection Stations		
	Weigh Stations		

Criticality is then assessed for each asset. Categories of critical asset factors are deter/defend loss and damage consequences, consequences to public services, and consequences to the general public. Each asset is given a value of 0 to 5 on each critical asset factor, with 0 being not applicable, 1 being low criticality, and 5 being high criticality. Critical asset factors are then summed for each asset. This provides a ranking of assets in terms of criticality. The criticality coordinate is computed by dividing the asset's criticality sum by the maximum potential criticality and multiplying by 100 to achieve a percentage. This will be the x-coordinate when plotting criticality versus vulnerability. The lower the value of the criticality coordinate, the less critical the asset. Table 2 provides a description for each critical asset factor and an example value for each (USDOT, 2002).

Table 2. Critical Asset Factor Example Values and Descriptions (USDOT, 2002)

CRITICAL ASSET FACTOR	VALUE	DESCRIPTION
Deter/Defend Factors		
A) Ability to Provide Protection	1	Does the asset lack a system of measures for protection? (i.e., Physical or response force)
B) Relative Vulnerability to Attack	2	Is the asset relatively vulnerable to an attack? (i.e., Due to location, prominence, or other factors)
Loss and Damage Consequences		
C) Casualty Risk	5	Is there a possibility of serious injury or loss of life resulting from an attack on the asset?
D) Environmental Impact	1	Will an attack on the asset have an ecological impact of altering the environment?
E) Replacement Cost	3	Will significant replacement cost (the current cost of replacing the asset with a new one of equal effectiveness) be incurred if the asset is attacked?
F) Replacement/Down Time	3	Will an attack on the asset cause significant replacement/down time?
Consequences to Public Services		
G) Emergency Response Function	5	Does the asset serve an emergency response function and will the action or activity of emergency response be affected?
H) Government Continuity	5	Is the asset necessary to maintain government continuity?
I) Military Importance	5	Is the asset important to military functions?
Consequences to the General Public		
J) Available Alternate	4	Is this the only asset that can perform its primary function? (i.e., There are no alternate facilities that will substitute adequately if this asset is damaged or destroyed)
K) Communication Dependency	1	Is communication dependent upon the asset?
L) Economic Impact	5	Will damage to the asset have an effect on the means of living, or the resources and wealth of a region or state?
M) Functional Importance	2	Is there an overall value of the asset performing or staying operational?
N) Symbolic Importance	1	Does the asset have symbolic importance?

4.3 Step 2: Vulnerability Assessment

The next step is assessment of the vulnerability of each asset. Assets are assigned a value of 1 to 5, with 1 being less important and 5 being extremely important. Assets are scored on the vulnerability factors of visibility and attendance, access to the asset, and site specific hazards. Visibility and attendance consist of sub-elements of level of recognition and attendance/users. Level of recognition ranges from largely invisible in the community (1) to visible worldwide (5). Attendance/users ranges from less than 10 (1) to greater than 3000 (5). Access to the asset is made up of sub-elements of access proximity and security level. Access proximity ranges from no vehicle traffic and no parking within 50 feet (1) to open access for vehicle traffic and parking within 50 feet (5). Security level ranges from controlled and protected security access with a response force available (1) to unprotected and uncontrolled security access (5). Site specific

hazards are split into sub-elements of receptor impacts and volume. Receptor impacts range from no environmental or human receptor effects (1) to acute and chronic effects to environmental and human receptors (5). Volume ranges from no materials present (1) to large quantities of multiple materials present (5). Vulnerability factors are then established by multiplying sub-element values for each vulnerability factor and adding the products of each vulnerability factor. The vulnerability coordinate is then found by dividing each vulnerability factor by 75, the highest possible vulnerability score, and multiplying by 100 in order to achieve a percentage. The vulnerability coordinate is the y-coordinate when plotting criticality versus vulnerability. The lower the value of the vulnerability coordinates, the lower the vulnerability of that asset. Table 3 presents a listing of the vulnerability factors and accompanying definitions (USDOT, 2002).

4.4 Step 3: Consequence Assessment

Assets are then plotted on a criticality versus vulnerability chart. Assets with criticality coordinates less than 50 are considered low criticality and assets with criticality coordinates higher than 50 are of high criticality. This same split at 50 occurs with vulnerability coordinates following the same pattern as criticality coordinates. Assets with both high criticality and high vulnerability will appear in Quadrant I, the upper right quadrant. Figure 3 shows the quadrants and their associated criticality and vulnerability values.

Consequences of the occurrence of a disastrous event are then determined for assets falling within Quadrant I. Consequences vary from loss of life and property to loss of vital transportation infrastructures that would result in economic losses, hindered military deployment, or stalled response abilities. This research effort focuses only on Steps 1 through 3 of the USDOT Guide. Future work will continue to explore the remaining steps.

Table 3. Vulnerability Factors and Definitions (USDOT, 2002)

VULNERABILITY FACTOR and DEFAULT VALUE			DEFINITION
Visibility and Attendance	LEVEL OF RECOGNITION (O)	1	Largely invisible in the community
		2	Visible by the community
		3	Visible Statewide
		4	Visible Nationwide
		5	Visible Worldwide
	ATTENDANCE/USERS (P)	1	Less than 10
		2	10 to 100 (Major incident per FEMA)
		3	100 to 1000
		4	1000 to 3000
		5	Greater than 3000 (Catastrophic Incident per FEMA)
Access to the Asset	ACCESS PROXIMITY (Q)	1	Asset with no vehicle traffic and no parking within 50 feet
		2	Asset with no unauthorized vehicle traffic and no parking within 50 feet
		3	Asset with vehicle traffic but no vehicle parking within 50 feet
		4	Asset with vehicle traffic but no unauthorized vehicle within 50 feet
		5	Asset with open access for vehicle traffic and parking within 50 feet
	SECURITY LEVEL (R)	1	Controlled and protected security access with a response force available
		2	Controlled and protected security access without a response force available
		3	Controlled security access but not protected
		4	Protected but not controlled security access
		5	Unprotected and uncontrolled security access
Site Specific Hazards	RECEPTOR IMPACTS (S)	1	No environmental or human receptor effects
		2	Acute or chronic toxic effects to environmental receptor(s)
		3	Acute and chronic effects to environmental receptor(s)
		4	Acute or chronic effects to human receptor(s)
		5	Acute and chronic effects to environmental and human receptor(s)
	VOLUME (T)	1	No materials present
		2	Small quantities of a single material present
		3	Small quantities of a multiple material present
		4	Large quantities of a single material present
		5	Large quantities of a multiple material present

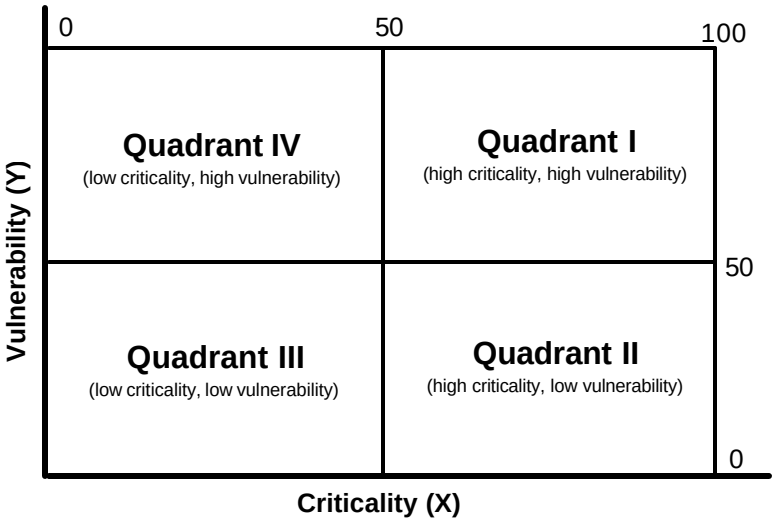

Figure 3. Criticality vs. Vulnerability Quadrants (USDOT, 2002)

4.5 Step 4: Countermeasures

Next, countermeasures are identified to protect critical assets from the threats and vulnerabilities that have been assessed. These countermeasures include site-work, building and structure, detection, and procedural elements. Countermeasure functions are then established based on whether the countermeasures deter the aggressor, detect the aggressor, or defend the critical assets from aggression. Then the critical asset categories (infrastructure, facilities, equipment, and personnel) that each countermeasure applies to are determined.

4.6 Step 5: Cost Estimation

Countermeasure packages are then created from individual countermeasures. This is done in ways that make sense operationally in reducing vulnerability for critical assets. Developing countermeasure packages allows for easier determination of costs associated with decreasing vulnerabilities for specific assets. Acquisition, operation, and maintenance costs are then determined and ranked as high, medium, or low. The critical assets, countermeasures, countermeasure costs, and countermeasure functions are then combined into a single table.

4.7 Step 6: Security Operational Planning

Finally, an operational security plan is developed. The organization should be cautious with the distribution and availability of the plan. Initiate training and exercise activities should be implemented. Elements of these programs should include awareness, training, and standards.

5 MODIFIED VULNERABILITY ASSESSMENT METHODOLOGY FOR RURAL TRANSPORTATION

5.1 Overview

In order to provide counties with the opportunity to customize emergency preparedness plans to their community, the use of the Analytic Hierarchy Process is proposed to provide the importance rankings as a modification to the USDOT *Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection* (2002). The Analytic Hierarchy Process, created by Thomas L. Saaty in 1980, is used to rank alternatives based on a pairwise comparison of their attributes. The Analytic Hierarchy Process is used to allow communities to weight factors affecting their community and rank assets by importance.

5.2 The Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is widely accepted as a useful tool in many areas, including transportation planning, portfolio selection, corporate planning, and marketing. AHP derives its strength from its ability to structure a complex, multiattribute problem hierarchically. The first stage of AHP is the construction of a decision hierarchy. The decision hierarchy is constructed by breaking down the decision problem into decision elements (such as the overall objective, attributes, and subattributes) and identifying decision alternatives. Next, the relative importance of attributes and subattributes is determined by using a pairwise comparison of the attributes. Afterward, the relative weight of each alternative with respect to each next-higher alternative is determined. Weights are determined by pairwise comparison for qualitative attributes and by performance data for quantitative attributes. Then the consistency of the pairwise comparisons is calculated. If the comparisons are found to be inconsistent, AHP may not provide accurate conclusions. Finally, the overall priority weights of each alternative are determined, providing a ranking of the alternatives (Canada et al., 1996). The information provided by AHP will allow rural counties to work with their often limited resources to assess

vulnerabilities to the best of their ability and support the development of their emergency preparedness plans.

5.3 Step 1: Critical Assets Identification

Similar to the USDOT *Guide*, a comprehensive list of critical assets must be gathered. The guidelines set forth in the USDOT Guide should be noted, but assets that fall beyond the scope of the USDOT Guide may be included as well. These guidelines are shown in Table 1. Relevant assets that are dependent on transportation networks can be included. This allows the methodology to broaden beyond transportation assets to better suit the community.

5.4 Step 2: Critical Asset Factor Selection

The USDOT Guide provides critical asset factors as shown in Table 4. The user should select only the critical asset factors that apply to their community by eliminating any factors that do not pertain to the community before the rating of assets begins.

Table 4. Critical Asset Factors (USDOT, 2002)

Category		Factor Number	Factor
Criticality	Deter/Defend Factors	A	Ability to Provide Protection
		B	Relative Vulnerability to Attack
	Loss and Damage Consequences	C	Casualty Risk
		D	Environmental Impact
		E	Replacement Cost
		F	Replacement/Down Time
	Consequences to Public Service	G	Emergency Response Function
		H	Government Continuity
		I	Military Importance
	Consequences to the General Public	J	Available Alternate
		K	Communication Dependency
		L	Economic Impact
		M	Functional Importance
		N	Symbolic Importance
Vulnerability	Visibility and Attendance	O	Level of Recognition
		P	Attendance/Users
	Access to the Asset	Q	Access Proximity
		R	Security Level
	Site Specific Hazards	S	Receptor Impacts
		T	Volume

5.5 Step 3: Decision Hierarchy

Once the critical assets and critical asset factors are determined, a decision hierarchy is constructed to illustrate the relationship between the assets and factors. The decision to be made is which assets the community should focus their resources on. AHP provides a ranking of the assets in terms of importance based on criticality and vulnerability. A general decision hierarchy is shown in Figure 4.

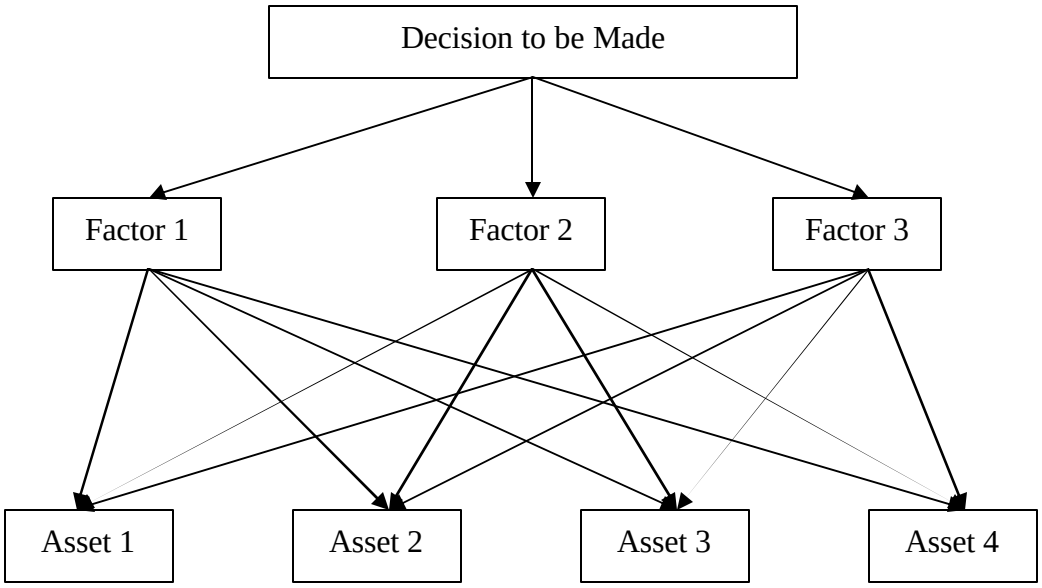

Figure 4. General Decision Hierarchy

5.6 Step 4: Pairwise Comparison Scale

The typical scale used for pairwise comparisons is shown in Table 5. This scale is used when comparing critical asset factors to one another and when comparing critical assets with respect to critical asset factors. It is acceptable to use other scales, but fewer choices tend to provide greater consistency.

Table 5. Scale for Pairwise Comparisons (Stutzke, 2004)

Descriptor	Value to Assign
Absolutely more important	9
Very strongly more important	7
Strongly more important	5
Weakly more important	3
Equally important	1
Weakly less important	1/3
Strongly less important	1/5
Very strongly less important	1/7
Absolutely less important	1/9

5.7 Step 4a: Pairwise Comparison of Critical Asset Factors

Pairwise comparison of the critical asset factors allows for the uneven weighting of these factors, whereas the USDOT Guide assumes factors are equally weighted. The question to be asked is "How much more important is Factor 1 than Factor 2 with respect to the overall security of the community?" Factor 1 is the factor associated with the rows of the matrix, while Factor 2 is the factor associated with the columns of the matrix. All factors should be assigned a value of 1 when compared to themselves. Only one relation should be filled out between each pair of factors. The other relation will be the reciprocal of the defined relation. For example, if Factor 1 compared to Factor 2 is assigned a value of 5, then Factor 2 compared to Factor 1 is assigned a value of 1/5.

Performing pairwise comparisons is more complex when being conducted by a group. One strategy to handle the increased complexity is to assign a lead assessor. This lead assessor performs the pairwise comparison individually and then seeks the compliance of the rest of the group. Another strategy is to allow each member of the group to perform the pairwise comparison individually. Afterwards, priority weights are averaged to determine the final priority weights used in the methodology. Since each comparison matrix must be checked for consistency, this strategy may prove to be time consuming when used with a large group.

After the pairwise comparison matrix is complete, the matrix is normalized by dividing each element by the sum of its column. After normalizing, the sum of each column should be one. The priority weight for each factor can then be calculated by averaging the values in each row. The priority weights constitute the principal vector.

5.8 Step 4b: Pairwise Comparisons of Critical Assets with Respect to Factors

Pairwise comparisons of the critical assets must now be made with respect to the critical asset factors. The question now becomes "How much more critical/vulnerable is Asset 1 than Asset 2 with respect to Factor 1?" Asset 1 is the asset associated with the rows of the matrix, and Asset 2 is the asset associated with the columns of the matrix. There are as many comparison matrices as there are critical asset factors. The value assigned for "Asset 1 is to Asset 2" should be the inverse of the value assigned to "Asset 2 is to Asset 1."

Now, the matrices are normalized by dividing each element by the sum of the column. After normalizing, the sum of each column should be one. Averaging each row provides the priority weights for each asset with respect to each factor.

5.9 Step 5: Consistency Ratios

When using AHP, consistency within comparison matrices is essential in providing accurate results. Local consistency ratios (C.R.s) indicate the consistency of the pairwise comparisons. A consistency ratio should be found for each comparison matrix. In order to find local consistency ratios for the pairwise comparisons, first multiply the original comparison matrix by the principal vector as seen in Equation 1.

$$[\text{Original Comparison Matrix}] \times [\text{Principal Vector}] = \text{Vector C} \qquad (1)$$

The principal vector consists of the column of priority weights found when performing the pairwise comparison. The product of the original comparison matrix with the principal vector is another vector, referred to as Vector C. Next, divide each element (e_c) in Vector C by the corresponding element $e_{\text{Principal Vector}}$ in the principal vector which is also the original priority weight. This process is shown in Equation 2.

$$e_C / e_{\text{Principal Vector}} = e_D \qquad (2)$$

The resulting elements (e_D) will create a third vector, referred to as Vector D. The next step is to average the elements of e_D in order to obtain $?_{\max}$ as shown in Equation 3.

$$\frac{\sum e_D}{k} = l_{\max} \quad (3)$$

where *k* is the number elements.

Then the consistency index, CI, is determined by subtracting the number of factors or assets associated with the matrix, N, from $?_{\max}$ and then dividing by one less than N as seen in Equation 4.

$$\frac{l_{\max} - N}{N - 1} = CI \quad (4)$$

where N is the number of rows

In order to determine the local consistency ratio, the consistency index must be divided by the random index, RI. The random index for associated values of N can be found in Table 6. The process to determine the local consistency ratio is shown in Equation 5.

Table 6. Random Indices for Associated N Values (Coyle, 2004)

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

$$\frac{CI}{RI} = C.R. \quad (5)$$

If the local consistency ratio (C.R.) is less than 0.10, the pairwise comparison is acceptably consistent. If the local consistency ratio is not less than 0.10, the comparisons should be reevaluated until the consistency is acceptable.

In addition to local consistency ratios, a global consistency (C.R.H.) ratio can be found, which applies to the entire decision hierarchy. The first step in finding the global consistency ratio is to determine the aggregate consistency index, M, using Equation 6. Factor priority weights and asset consistency indices are vectors.

$$M = FactorCI + [Factor\,\mathrm{Pr}iorityWeights] \times [AssetCI's] \quad (6)$$

The next step is to determine the aggregate random index, $\overline{M}$, as shown in Equation 7. Asset RI's will be a vector with all elements equal to the random index associated with N, where N is size of the matrix.

$$\overline{M} = FactorRI + [Factor\ \mathrm{Pr}iorityWeights] \times [AssetRI's] \quad (7)$$

The consistency of the hierarchy is acceptable if the ratio of M to $\overline{M}$ is less than or equal to 0.10. If ratio is greater than 0.10, comparison matrices should be reevaluated until the overall hierarchy is acceptably consistent.

5.10 Step 6: Overall Priority Weights of Assets

The final results of AHP come in the form of alternative priority weights. The alternative priority weights provide a ranking of alternatives, which are the critical assets used in this methodology. In order to determine the priority weight for each asset, multiply the priority weight of each attribute, or factor, by the priority weight assigned to each asset in the pairwise comparison of assets with respect to that attribute and sum the products for each asset. The higher the priority weight, the higher the importance of spending resources assessing the vulnerability of the asset. The ranking can be used as both a prioritized list and as tool to determine which assets should be assessed and which should be omitted from assessment. When using the methodology as a means of omitting assets from the assessment, it is suggested to include assets with a priority weight greater than $1/(N+1)$, where N is the number of assets. This is the level at which all assets would be recommended for further assessment if all assets were equally weighted. The goal when using this level is to include assets that are "more important than average" in further assessment.

6 CASE EXAMPLES

6.1 Scenario Description

In order to demonstrate the revised methodology, Jackson County, Arkansas is selected in order to provide a realistic example of a rural transportation network. Jackson County lies in the northeastern part of Arkansas. In the 2000 census, Jackson County had a population of 18,418 persons and a land area of 633 square miles. A map of Jackson County is provided as Figure 5.

Since Jackson County does not contain a city of 50,000 people, the county is classified as rural (Bureau of Transportation Statistics, 2005). Highway 67, Jackson County's main highway, connects Little Rock to I-55 just south of St. Louis. Newport Municipal Airport has 23 aircraft based on the field. A railroad runs through Newport that connects Texas and Missouri. Jackson County does not have public bus service or any commercial ports.

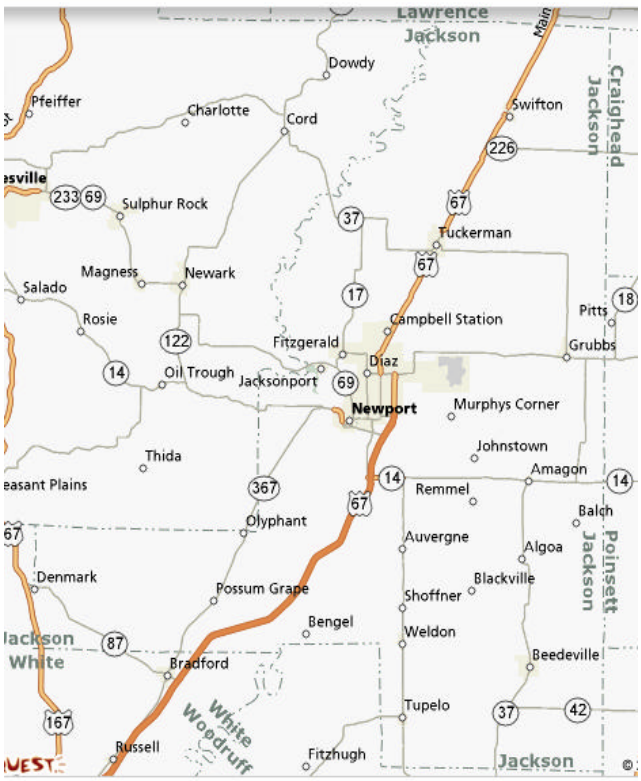

Figure 5. Map of Jackson County, Arkansas (Mapquest, 2007)

6.2 USDOT Methodology Application for Jackson County

To demonstrate the application of the *Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection* (USDOT, 2002), the USDOT Guide is utilized to assess the criticality and vulnerability of transportation assets in Jackson County, Arkansas. The results are presented and summarized in this subsection.

6.2.1 Step 1: Critical Asset Identification

Critical asset identification involves creating an all-inclusive list of critical assets, establishing and assigning values to the critical asset factors, and prioritizing the all-inclusive list of critical assets as described in Section 4.2. Public information about Jackson County is

researched in order to obtain a relatively accurate description of its critical assets. The USDOT Guide (see Table 1) is used but assets are not limited to these standards. For example, Water Supply Infrastructure is not a transportation asset but vulnerability to its disruption requires transportation support. The list of critical assets for Jackson County is shown in Table 7. The critical asset factors values are determined for each of the critical assets listed in Table 7 and are presented in Table 8.

Table 7. Critical Assets in Jackson County USDOT Methodology

CRITICAL ASSETS
Newport Municipal Airport (NMA)
Highway 67 (HWY 67)
Dams (Dams)
Emergency Operations Center (EOC)
Railroad (RR)
Emergency Responders (ER)
Water Supply Infrastructure (WSI)

Table 8. Criticality of Assets

	CRITICAL ASSET FACTOR														
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	TOTAL
CRITICAL ASSET	2	1	5	1	4	3	2	2	2	2	5	4	3	1	SCORE
Newport Municipal Airport (NMA)	1	2	1	0	1	4	2	3	3	2	0	2	2	0	23
Highway 67 (HWY 67)	2	1	1	0	2	4	1	3	3	2	3	1	1	1	25
Dams (Dams)	3	3	4	1	3	4	3	3	2	4	0	2	2	1	35
Emergency Operations Center (EOC)	1	3	3	0	3	2	1	5	3	4	5	3	4	0	37
Railroad (RR)	2	1	2	0	1	4	3	0	0	3	0	1	3	1	21
Emergency Responders (ER)	4	3	3	0	4	2	1	2	3	1	3	3	3	0	32
Water Supply Infrastructure (WSI)	3	2	5	1	1	3	2	0	0	1	0	1	1	0	20

6.2.2 Step 2: Vulnerability Assessment

Vulnerability assessment involves characterizing the threat, assigning vulnerability factors to the critical assets, and scoring the vulnerability factor for each critical asset as described in Section 4.3. The vulnerability factor for each critical asset is calculated by "Vulnerability Factor (y)" formula as shown in Table 9.

Table 9. Vulnerability Values of Critical Assets

CRITICAL ASSET	VULNERABILITY FACTOR (y)											TOTAL SCORE
	(O	*	P)	+	(Q	*	R)	+	(S	*	T)	
Newport Municipal Airport (NMA)	4		2		1		1		3		3	18
Highway 67 (HWY 67)	3		1		1		4		1		1	8
Dams (Dams)	4		2		2		5		1		3	21
Emergency Operations Center (EOC)	2		4		1		1		1		3	12
Railroad (RR)	3		3		1		4		1		1	14
Emergency Responders (ER)	2		3		2		1		1		3	11
Water Supply Infrastructure (WSI)	4		1		3		2		5		3	25

6.2.3 Step 3: Consequence Assessment

In Step 3, the most important critical assets are selected according to their criticality and their vulnerability values as shown in Table 10. The Criticality and Vulnerability Plot presented in Figure 6 is utilized to identify the most critical assets.

Table 10. Criticality and Vulnerability Values for each Critical Asset

CRITICAL ASSET	CRITICALITY		VULNERABILITY		QUADRANT
	(x)	(X)	(y)	(Y)	
Newport Municipal Airport (NMA)	23	62	18	24	IV
Highway 67 (HWY 67)	25	68	8	11	IV
Dams (Dams)	35	95	21	28	IV
Emergency Operations Center (EOC)	37	100	12	16	IV
Railroad (RR)	21	57	14	19	IV
Emergency Responders (ER)	32	86	11	15	IV
Water Supply Infrastructure (WSI)	20	54	25	33	IV

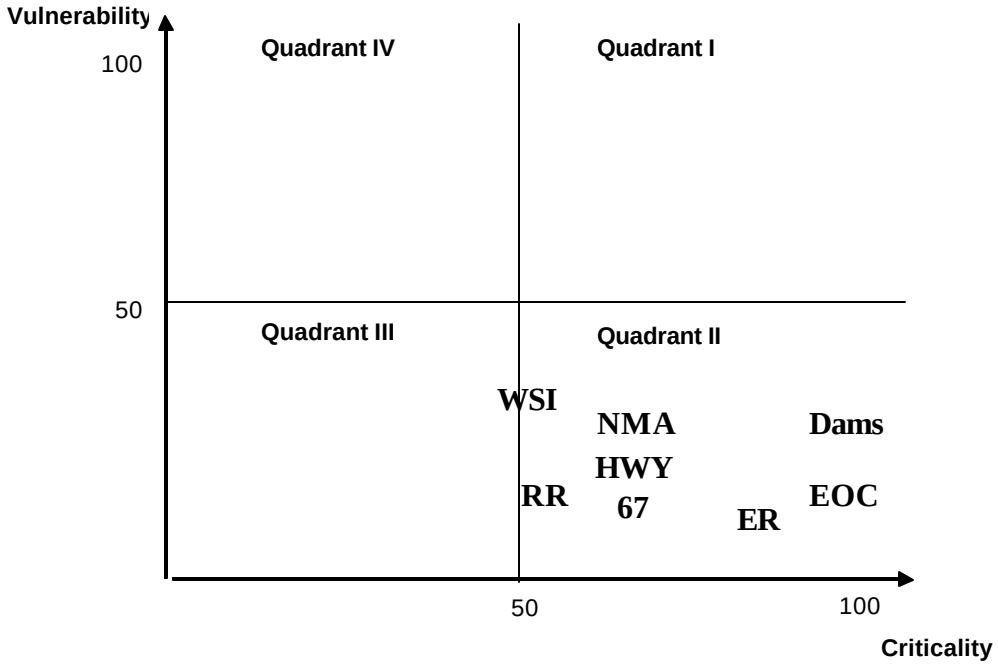

Figure 6. Criticality - Vulnerability Plot

In the USDOT methodology, the most important assets are located in Quadrant I. In our Jackson county example, all transportation assets are located in Quadrant II (high criticality, low vulnerability).

6.3 Modified Methodology Application for Jackson County

The Modified Methodology (presented in Section 5) is utilized to assess the criticality and vulnerability of transportation assets in Jackson County, Arkansas. The results are presented and summarized in this subsection.

6.3.1 Step 1: Critical Asset Identification

Critical asset identification is performed in USDOT Guide at Step 1. The same critical assets are used in this case example. The critical asset list is represented in Table 11.

Table 11. Critical Assets in Jackson County for Modified Methodology

CRITICAL ASSETS
Newport Municipal Airport (NMA)
Highway 67 (HWY 67)
Dams (Dams)
Emergency Operations Center (EOC)
Railroad (RR)
Emergency Responders (ER)
Water Supply Infrastructure (WSI)

6.3.2 Step 2: Critical Asset Factor Selection

Certain critical asset factors are omitted from the example. Specifically, factors that either did not pertain to the critical assets or did not appear to be within the control of Jackson County are omitted. The omitted factors are D, F, H, I, K, N, O, R, and S (refer to Table 2). The factors considered to be important for Jackson County are listed in Table 12.

Table 12. Factors for Jackson County

Factors	Factor Definition
A	Ability to Provide Protection
B	Relative Vulnerability to Attack
C	Casualty Risk
E	Replacement Cost
G	Emergency Response Function
J	Available Alternate
L	Economic Impact
M	Functional Importance
P	Attendance/Users
Q	Access Proximity
T	Volume

6.3.3 Step 3: Decision Hierarchy

A decision hierarchy is constructed using the identified assets (Table 11) and factors (Table 12) for this example. The resulting hierarchy is given in Figure 7.

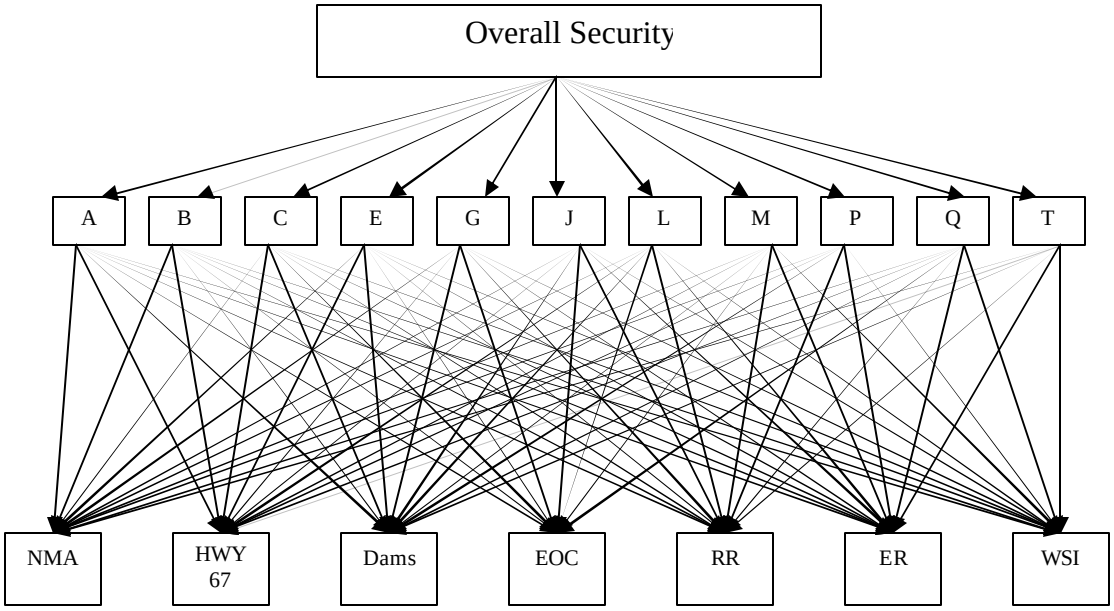

Figure 7. Jackson County Decision Hierarchy

6.3.4 Step 4a: Pairwise Comparison of Critical Asset Factors

A pairwise comparison is performed on the critical asset factors as shown in Table 13. A scale of one to ten, including even numbers, is used when comparing factors. A tentative ranking of the importance of critical asset factors was performed initially in order to ensure consistency and provide guidance due to the lack of realistic and accurate information for comparisons.

Table 13. Original Pairwise Comparison Matrix

Factors		A	B	C	E	G	J	L	M	P	Q	T
Ability to Provide Protection	A	1	1/2	1/9	1/8	1/4	1/3	1/7	1/6	1/5	1	1
Relative Vulnerability to Attack	B	2	1	1/7	1/6	1/2	1	1/5	1/4	1/3	1	3
Casualty Risk	C	9	7	1	1	5	6	2	3	4	8	10
Replacement Cost	E	8	6	1	1	4	5	1	2	3	7	9
Emergency Response Function	G	4	2	1/5	1/4	1	1	1/3	1/2	1	3	5
Available Alternate	J	3	1	1/6	1/5	1	1	1/4	1/3	1/2	2	4
Economic Impact	L	7	5	1/2	1	3	4	1	1	2	6	8
Functional Importance	M	6	4	1/3	1/2	2	3	1	1	1	5	7
Attendance/Users	P	5	3	1/4	1/3	1	2	1/2	1	1	4	6
Access Proximity	Q	1	1	1/8	1/7	1/3	1/2	1/6	1/5	1/4	1	2
Volume	T	1	1/3	1/10	1/9	1/5	1/4	1/8	1/7	1/6	1/2	1

The matrix shown in Table 13 is then normalized by dividing each element in the matrix by the sum of the column. Table 14 shows the resulting matrix. The rows were averaged in order to provide priority weights for the critical asset factors.

Table 14. Normalized Pairwise Comparison Matrix

Factors		A	B	C	E	G	J	L	M	P	Q	T	Row Sum	Priority Weights*
Ability to Provide Protection	A	0.02	0.02	0.03	0.03	0.01	0.01	0.02	0.02	0.01	0.03	0.02	0.22	**0.0197**
Relative Vulnerability to Attack	B	0.04	0.03	0.04	0.03	0.03	0.04	0.03	0.03	0.02	0.03	0.05	0.37	**0.0341**
Casualty Risk	C	0.19	0.23	0.25	0.21	0.27	0.25	0.30	0.31	0.30	0.21	0.18	2.70	**0.2452**
Replacement Cost	E	0.17	0.19	0.25	0.21	0.22	0.21	0.15	0.21	0.22	0.18	0.16	2.18	**0.1978**
Emergency Response Function	G	0.09	0.06	0.05	0.05	0.05	0.04	0.05	0.05	0.07	0.08	0.09	0.69	**0.0629**
Available Alternate	J	0.06	0.03	0.04	0.04	0.05	0.04	0.04	0.03	0.04	0.05	0.07	0.51	**0.0463**
Economic Impact	L	0.15	0.16	0.13	0.21	0.16	0.17	0.15	0.10	0.15	0.16	0.14	1.68	**0.1524**
Functional Importance	M	0.13	0.13	0.08	0.10	0.11	0.12	0.15	0.10	0.07	0.13	0.13	1.26	**0.1147**
Attendance/Users	P	0.11	0.10	0.06	0.07	0.05	0.08	0.07	0.10	0.07	0.10	0.11	0.94	**0.0853**
Access Proximity	Q	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.28	**0.0255**
Volume	T	0.02	0.01	0.03	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.18	**0.0162**
	Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11.00	1.00

* Priority Weights are equivalent to Row Averages

6.3.5 Step 4b: Pairwise Comparisons of Critical Assets with Respect to Factors

A pairwise comparison is performed for all critical assets with respect to each factor. This comparison is with respect to each factor. Comparison matrices with respect to Ability to Provide Protection and Relative Vulnerability to Attack are shown in Tables 15 and 16, respectively. Appendix 7 contains the complete set of comparison matrices.

Table 15. Original Comparison Matrix for Ability to Provide Protection

Factor A: Ability to Provide Protection	NMA	HWY 67	Dams	EOC	RR	ER	WSI
Newport Municipal Airport	1	3	6	2	4	7	5
Highway 67	1/3	1	4	1/2	2	5	3
Dams	1/6	1/4	1	1/5	1/3	2	1/2
Emergency Operations Center	1/2	2	5	1	3	5	4
Railroad	1/4	1/2	3	1/3	1	4	2
Emergency Responders	1/7	1/5	1/2	1/5	1/4	1	1/3
Water Supply Infrastructure	1/5	1/3	2	1/4	1/2	3	1

Table 16. Original Comparison Matrix for Relative Vulnerability to Attack

Factor B : Relative Vulnerability to Attack	NMA	HWY 67	Dams	EOC	RR	ER	WSI
Newport Municipal Airport	1	1/3	3	4	1/2	5	2
Highway 67	3	1	5	6	2	7	4
Dams	1/3	1/5	1	2	1/4	3	1/2
Emergency Operations Center	1/4	1/6	1/2	1	1/5	2	1/3
Railroad	2	1/2	4	5	1	6	3
Emergency Responders	1/5	1/7	1/3	1/2	1/6	1	1/4
Water Supply Infrastructure	1/2	1/4	2	3	1/3	4	1

The comparison matrices are then normalized by dividing each element by the sum of the column. The normalized comparison matrices for Ability to Provide Protection and Relative Vulnerability to Attack are shown in Tables 17 and 18. The rows are averaged in order to provide priority weights for each asset with respect to each factor. Tables 19 and 20 provide the priority weights for each asset with respect to each factor.

Table 17. Normalized Comparison Matrix for Ability to Provide Protection

Factor A : Ability to Provide Protection	NMA	HWY 67	Dams	EOC	RR	ER	WSI	Row Sum	Row Average
Newport Municipal Airport	0.386	0.412	0.279	0.446	0.361	0.259	0.316	2.459	0.351
Highway 67	0.129	0.137	0.186	0.112	0.180	0.185	0.189	1.119	0.160
Dams	0.064	0.034	0.047	0.045	0.030	0.074	0.032	0.325	0.046
Emergency Operations Center	0.193	0.275	0.233	0.223	0.271	0.185	0.253	1.632	0.233
Railroad	0.096	0.069	0.140	0.074	0.090	0.148	0.126	0.744	0.106
Emergency Responders	0.055	0.027	0.023	0.045	0.023	0.037	0.021	0.231	0.033
Water Supply Infrastructure	0.077	0.046	0.093	0.056	0.045	0.111	0.063	0.491	0.070
Sum	1	1	1	1	1	1	1	7	1

Table 18. Normalized Comparison Matrix for Relative Vulnerability to Attack

Factor B: Relative Vulnerability to Attack	NMA	HWY 67	Dams	EOC	RR	ER	WSI	Row Sum	Row Average
Newport Municipal Airport	0.137	0.129	0.189	0.186	0.112	0.179	0.180	1.113	0.159
Highway 67	0.412	0.386	0.316	0.279	0.449	0.250	0.361	2.453	0.350
Dams	0.046	0.077	0.063	0.093	0.056	0.107	0.045	0.488	0.070
Emergency Operations Center	0.034	0.064	0.032	0.047	0.045	0.071	0.030	0.323	0.046
Railroad	0.275	0.193	0.253	0.233	0.225	0.214	0.271	1.662	0.237
Emergency Responders	0.027	0.055	0.021	0.023	0.037	0.036	0.023	0.223	0.032
Water Supply Infrastructure	0.069	0.096	0.126	0.140	0.075	0.143	0.090	0.739	0.106
Sum	1	1	1	1	1	1	1	7	1

Table 19. Asset Priority Weights with Respect to Factors

Assets	Ability to Provide Protection (A)	Relative Vulnerability to Attack (B)	Casualty Risk (C)	Replacement Cost (E)	Emergency Response Function (G)	Available Alternate (J)
	Critical Asset Factors					
Newport Municipal Airport	0.3512	0.159	0.3651	0.242	0.1016	0.1681
Highway 67	0.1598	0.3504	0.2637	0.1148	0.1644	0.1164
Dams	0.0465	0.0696	0.0386	0.0573	0.0287	0.0286
Emergency Operations Center	0.2331	0.0462	0.0857	0.039	0.2422	0.0396
Railroad	0.1062	0.2375	0.1576	0.1655	0.0412	0.0581
Emergency Responders	0.033	0.0318	0.0622	0.0275	0.3549	0.3177
Water Supply Infrastructure	0.0702	0.1056	0.0269	0.3539	0.0669	0.2716

Table 20. Asset Priority Weights with Respect to Factors

Assets	Economic Impact (L)	Functional Importance (M)	Attendance/Users (P)	Access Proximity (Q)	Volume (T)
	Critical Asset Factors				
Newport Municipal Airport	0.0773	0.0932	0.0885	0.231	0.0543
Highway 67	0.3335	0.2655	0.3237	0.2969	0.3079
Dams	0.07	0.1367	0.1285	0.0822	0.0551
Emergency Operations Center	0.0315	0.0299	0.0297	0.1179	0.0551
Railroad	0.1647	0.0624	0.0403	0.1678	0.4173
Emergency Responders	0.0449	0.0417	0.0586	0.0589	0.0551
Water Supply Infrastructure	0.278	0.3705	0.3309	0.0454	0.0551

6.3.6 Step 5: Consistency Ratios

In order to determine the consistency of the comparison matrices, both between factors and between assets, local consistency ratios are computed. Equations 1 through 7 are used in this process. The determination of the local consistency ratios is shown for the comparison of factors and the comparison of assets with respect to the Ability to Provide Protection factor. The original comparison matrix for these factors is shown in Table 21.

Table 21. Original Comparison Matrix for Factors

		Factors										
Factor Definition	**Factors**	**A**	**B**	**C**	**E**	**G**	**J**	**L**	**M**	**P**	**Q**	**T**
Ability to Provide Protection	**A**	1	1/2	1/9	1/8	1/4	1/3	1/7	1/6	1/5	1	1
Relative Vulnerability to Attack	**B**	2	1	1/7	1/6	1/2	1	1/5	1/4	1/3	1	3
Casualty Risk	**C**	9	7	1	1	5	6	2	3	4	8	10
Replacement Cost	**E**	8	6	1	1	4	5	1	2	3	7	9
Emergency Response Function	**G**	4	2	1/5	1/4	1	1	1/3	1/2	1	3	5
Available Alternate	**J**	3	1	1/6	1/5	1	1	1/4	1/3	1/2	2	4
Economic Impact	**L**	7	5	1/2	1	3	4	1	1	2	6	8
Functional Importance	**M**	6	4	1/3	1/2	2	3	1	1	1	5	7
Attendance/Users	**P**	5	3	1/4	1/3	1	2	1/2	1	1	4	6
Access Proximity	**Q**	1	1	1/8	1/7	1/3	1/2	1/6	1/5	1/4	1	2
Volume	**T**	1	1/3	1/10	1/9	1/5	1/4	1/8	1/7	1/6	1/2	1

Tables 22, 23, 24 and 25 show the principal vector (the average of each row in the normalized comparison matrix), Vector C (Equation 1), Vector D (Equation 2) and a summary for the consistency of factor comparisons (Equations 3, 4, and 5) respectively. Since the local consistency ratio is less than 0.10, the comparison of factors is reasonably consistent.

Table 22. Principal Vector for Factors

Principal Vector
0.0197
0.0341
0.2452
0.1978
0.0629
0.0463
0.1524
0.1147
0.0853
0.0255
0.0162

Table 23. Vector C for Factor Comparisons

Vector C
0.2078
0.3528
2.6091
2.1091
0.6469
0.4758
1.5999
1.1957
0.8811
0.267
0.1709

Table 24. Vector D for Factor Comparisons

Vector D
11.8869
10.3378
8.5992
10.7268
11.2487
11.7373
11.2301
11.7040
12.5814
11.6064
13.5140

Table 25. Consistency Summary for Comparison of Factors

Results	Values
l_{max}	11.3793
Consistency Index (CI)	0.0379
Random Index (RI) for N=11	1.51
Local Consistency Ratio (C.R.)	0.0251

Table 26 shows the original comparison matrix for assets with respect to the Ability to Provide Protection factor.

Table 26. Original Comparison Matrix for Ability to Provide Protection

Factor A : Ability to Provide Protection	NMA	HWY 67	Dams	EOC	RR	ER	WSI
Newport Municipal Airport	1	3	6	2	4	7	5
Highway 67	1/3	1	4	1/2	2	5	3
Dams	1/6	1/4	1	1/5	1/3	2	1/2
Emergency Operations Center	1/2	2	5	1	3	5	4
Railroad	1/4	1/2	3	1/3	1	4	2
Emergency Responders	1/7	1/5	1/2	1/5	1/4	1	1/3
Water Supply Infrastructure	1/5	1/3	2	1/4	1/2	3	1

Tables 27, 28, 29, and 30 show the principal vector, Vector C (Equation 1), Vector D (Equation 2), and a summary for the consistency of asset comparisons with respect to Ability to Provide Protection (Equations 3, 4, and 5). Since the local consistency ratio for the comparison of assets with respect to the Ability to Provide Protection factor is less than 0.10, the comparison is also reasonably consistent.

Table 27. Principal Vector for Asset Comparisons with Respect to Factor A

Principal Vector
0.3512
0.1598
0.0465
0.2331
0.1062
0.033
0.0702

Table 28. Vector C for Asset Comparisons with Respect to Factor A

Vector C
2.5825
1.1674
0.3281
1.7251
0.7635
0.2350
0.4971

Table 29. Vector D for Asset Comparisons with Respect to Factor A

Vector D
7.3525
7.3055
7.0570
7.4015
7.1865
7.1176
7.0855

Table 30. Consistency Summary for Comparison of Assets with Respect to Factor A

Results	Values
l_{max}	7.2152
Consistency Index (CI)	0.0359
Random Index (RI) for N=7	1.32
Local Consistency Ratio (C.R.)	0.0272

Table 31 provides the full list of local consistency ratios for all asset comparisons. Since all consistency ratios are less than 0.10, the pairwise comparisons for the AHP analysis are all reasonably consistent.

Table 31. C.R.s for Asset Comparisons

Factors for Asset Comparisons	Local Consistency Ratios (C.R.s)
Ability to Provide Protection	0.0272
Relative Vulnerability to Attack	0.0249
Casualty Risk	0.0357
Replacement Cost	0.0320
Emergency Response Function	0.0206
Available Alternate	0.0323
Economic Impact	0.0206
Functional Importance	0.0353
Attendance/Users	0.0377
Access Proximity	0.0129
Volume	0.0014

Once local consistency ratios are established, the global consistency ratio for the entire hierarchy is found (Equations 6 and 7). The local consistency index for the comparison of factors is 0.0379 (see Table 22). Table 32 shows the principal vector for factors. Table 33 shows the consistency indices for asset comparisons with respect to factors.

Table 32. Principal Vector for Factors

Factor Principal Vector	0.0197	0.0341	0.2452	0.1978	0.0629	0.0463	0.1524	0.1147	0.0853	0.0255	0.0162

Table 33. Consistency Indices for Asset Comparisons

Associated Factor	Asset CI's
A	0.0359
B	0.0329
C	0.0472
E	0.0422
G	0.0272
J	0.0426
L	0.0272
M	0.0465
P	0.0497
Q	0.0170
T	0.0018

The *M* value is calculated as 0.0775 using Equation 6 as shown below:

$$M = FactorCI + [Factor\,\mathrm{Pr}incipleVector \times AssetCI's] = 0.0379 + 0.0396 = 0.0775.$$

Next, $\overline{M}$ is found by adding the random index for factors to the product of the principal vector for factor comparisons and a vector consisting of the random indices for asset comparisons. The random index for the comparison of factors is 1.51. Table 34 shows the principal vector for factors. Table 35 shows a vector consisting of the random index for asset comparisons.

Table 34. Principal Vector for Factors

Factor Principal Vector	0.0197	0.0341	0.2452	0.1978	0.0629	0.0463	0.1524	0.1147	0.0853	0.0255	0.0162

Table 35. Random Index for Asset Comparisons

Asset RI's
1.32
1.32
1.32
1.32
1.32
1.32
1.32
1.32
1.32
1.32
1.32

The $\overline{M}$ value is calculated using Equation 7 as shown below:

$$\overline{M} = FactorRI + [Factor\ \Pr incipalVector \times AssetRI's] = 1.51 + 1.32 = 2.83.$$

The ratio of M to $\overline{M}$ is then found in order to determine the global consistency ratio ($C.R.H. = M / \overline{M} = 0.017622$). Since this ratio is less than 0.10, the consistency of the hierarchy is acceptable.

6.3.7 Step 6: Overall Priority Weights of Assets

After consistency is ensured, the overall priority weights of the assets are determined. Overall priority weights are calculated by summing the products of factor priority weights and asset priority weights with respect to that factor. For example, the overall priority weight for Newport Municipal Airport was calculated as 0.2007 as shown below:

$\Pr iorityWeight = [0.02 \times 0..351 + 0.034 \times 0.159 + 0.245 \times 0.365 + ... + 0.016 \times 0.054] = 0.2007$. The full set of asset priority weights is shown in Table 36. A ranking of assets with respect to overall priority weights is shown in Table 37.

Table 36. Determination of Asset Priority Weights

		Factor											
		A	B	C	E	G	J	L	M	P	Q	T	Asset Priority Weights
	Factor Weight	0.020	0.034	0.245	0.198	0.063	0.046	0.152	0.115	0.085	0.025	0.016	
Assets	Newport Municipal Airport	0.351	0.159	0.365	0.242	0.102	0.168	0.077	0.093	0.088	0.231	0.054	0.201
	Highway 67	0.160	0.350	0.264	0.115	0.164	0.116	0.334	0.265	0.324	0.297	0.308	0.240
	Dams	0.046	0.070	0.039	0.057	0.029	0.029	0.070	0.137	0.128	0.082	0.055	0.068
	Emergency Operations Center	0.233	0.046	0.086	0.039	0.242	0.040	0.032	0.030	0.030	0.118	0.055	0.067
	Railroad	0.106	0.237	0.158	0.166	0.041	0.058	0.165	0.062	0.040	0.168	0.417	0.134
	Emergency Responders	0.033	0.032	0.062	0.027	0.355	0.318	0.045	0.042	0.059	0.059	0.055	0.078
	Water Supply Infrastructure	0.070	0.106	0.027	0.354	0.067	0.272	0.278	0.371	0.331	0.045	0.055	0.213

Table 37. Ranking of Assets by Priority Weight

Rank	Asset	Priority Weight
1	Highway 67	0.2396
2	Water Supply Infrastructure	0.2135
3	Newport Municipal Airport	0.2007
4	Railroad	0.1336
5	Emergency Responders	0.0785
6	Dams	0.0675
7	Emergency Operations Center	0.0666

Assets with an overall priority weight greater than 1/8, or 0.125, are recommended for further assessment $(1/(N+1) = 1/8 = 0.125)$. These assets include Highway 67, the water supply infrastructure, Newport Municipal Airport, and the railroad. These assets should be prioritized when investigating time and financial resources into developing their emergency preparedness plans.

7 Summary

The purpose of this project is to examine approaches for assessing the vulnerability of rural transportation networks. Multiple agencies including the U.S. Department of Homeland Security, the Transportation Security Administration and the USDOT have conducted comprehensive vulnerability assessments of rail and transit networks in high density urban areas. Our fundamental objective is to explore these existing urban transportation risk assessment tools and techniques and determine if and how these approaches could be adapted for rural transportation systems.

The first step was to conduct a comprehensive review of the tools and techniques used to perform risk assessments of urban transportation systems. Ten different methodologies were reviewed, analyzed, summarized and compared as part of this effort. A source matrix that summarizes and compares each technique is provided in Appendix 1. Additionally, an annotated bibliography containing a summary or abstract of all relevant techniques can be found in Appendix 2. In order to determine whether any of these tools are applicable to a rural transportation system we needed to clearly understand the differences between a rural and urban transportation systems. A thorough literature review was conducted and expert opinions consulted in order to identify the pertinent characteristics and security needs associated with rural transportation networks. A detailed comparison is provided in Appendix 3. Some significant differences are that rural areas have low population densities and large distances between population centers. Additionally, the large variation in terrain types requires that larger transportation networks and often different varieties of transportation modes be utilized when compared with urban settings. The most significant difference between rural and urban settings is that rural areas often have much fewer assets to protect.

Therefore, based on these differences, vulnerability assessment tools based on critical assets instead of risk scenarios are found to be better suited for rural settings. The USDOT's

Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection is selected to be the most robust vulnerability assessment tool for rural transportation networks. A modification of this vulnerability assessment approach was developed as an alternative means of rural transportation vulnerability assessment. The Analytic Hierarchy Process is used to provide an alternative vulnerability assessment methodology for rural communities. By allowing the exclusion of some critical asset factors, time can be saved by eliminating areas that do not affect the unique rural community being assessed. Additionally, this approach provides an opportunity to check for consistency in the process. The revised methodology provides an accurate method of determining which assets should undergo further assessments.

Finally, the methodologies are demonstrated for a specific rural community. Two examples based on Jackson County, Arkansas are constructed and analyzed to show the applicability of each methodology on a rural transportation network. Both methodologies are found to be easy to implement and provide essential information on the risk associated with the critical transportation assets in the county. This information can be used by emergency responders and county planners in the development of their county emergency response and management plans.

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APPENDIX 1 – Source Matrix

Table 38. Source Matrix

NO	Sources	Year	Scope of the Study	Literature Review	Methodology	Cases	Physical Security	Security by Regulations	Emergency Plans	Characteristic of	Cite
1	*A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection*, Science Applications International Corporation (SAIC) Transportation Policy and Analysis Center, Vienna, VA, May 2002	2002	Assess the vulnerabilities of physical assets, Develop possible countermeasures, Estimate the capital and operating costs of countermeasures, Improve security operational planning for better protection against future acts of terrorism	-	DOT' s Vulnerability Assessment	Short examples	-	-	-	-	-
2	*Stovall, M. E., Turner, D. S. (2004). Methodology for Developing a Prioritized List of Critical and Vulnerable Local Government Highway Infrastructure*,	2004	Determining the applicability of the methodology adapted from *A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection*.	+	DOT' s Vulnerability Assessment	Shelby County and the City of Tuscaloosa, ALABAMA	-	-	-	-	* A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection * Guide to Updating Highway Emergency Response Plans for Terrorist Incidents * National Needs Assessments for Ensuring Transportation Infrastructure Security * Recommendations for Bridge and Tunnel Security
3	*Little, R. G. (2004, June). Holistic Strategy for Urban Security. Journal of Infrastructure Systems*, 10.	2004	How to secure urban cities from a holistic point of view, physical security of the assets in urban cities are explained. A basic framework to mitigate and respond future attacks is given.	+	-	-	Physical Protection Strategies for Buildings	-	-	-	-
4	*National Academy Press (1999). Improving Surface Transportation Security: A Research and Development Strategy*	1999	This report focuses on developing a strategic vision of an R&D program for the long term, and recommends a process for achieving that vision.	-	DOT' s Vulnerability Assessment, Establishing a Research and Development Strategy	Some Specific Research and Development Topics, A Likely Course of Development of Chemical and Biological Attacks	-	-	-	Surface Transportation R&D	-

NO	Sources	Year	Scope of the Study	Literature Review	Methodology	Cases	Physical Security	Security by Regulations	Emergency Plans	Characteristic of	Cite
5	*Jenkins, B. M. (2001), Protecting Public Surface Transportation Against Terrorism and Serious Crime*: An Executive Overview. San Jose, CA: Mineta Transportation Institute College of Business	2001	Lessons learned from: ~~Volume I:~~ the "best practices" for protecting public surface transportation--facilities, equipment, and passengers--against terrorist attacks and other major violent crimes. Volume II: case studies, a chronology of terrorist attacks and major criminal assaults on surface transportation and an annotated bibliography of publications dealing with surface transportation security. ~~Volume III:~~ further research added four more case studies	-	-	-	Station and Vehicle Design, Security Technology	The Security Force	Emergency Response Teams, Crisis Management Plans	-	-
6	*Deterrence, Protection and Preparation, Committee on Science and Technology for Countering Terrorism, Transportation Research Board, Washington, D.C., 2002*	2002	Characteristics of transportation and their implications, key research and technology needs are provided and advices for TSA is given at the end	-	-	Security System Concept for Shipping Containers	Technology needs for transportation	Research needs for transportation, Advices to TSA	-	Public Transportation	-
7	*Communication of Threats: A Guide, Public Transportation Security: Volume 1, Transportation Research Board, Washington, D.C., 2002*	2002	This volume offers information on a variety of approaches to improving the sharing of threat information and based on a SURVEY that 12 transportation authorities are involved.	-	-	-	Communication system	TIF (Threat Information Forum)	Communication in Emergency	Information System	-
8	*National Needs Assessment for Ensuring Transportation Infrastructure Security, Ham, D.B., Lockwood S., Science Applications International Corporation (SAIC) Transportation Policy and Analysis Center, Vienna, VA, October 2002*	2002	Three key security planning program areas are explained: Protecting critical mobility assets, Enhancing traffic management capabilities, and Improving state DOT (Department of Transportation) emergency response capabilities.	-	-	No case, but Bridge and Tunnel Vulnerability and Countermeasures are explained in detail	Bridges and Tunnels' physical security	Traffic operation regimes, emergency manegement regimes	DOT's role in Emergency Response	Weapons of Mass Destruction, threat assessment, critical& recognizable assests& bridges	* A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection * A Guide to Updating Highway Emergency Response Plans for Terrorist Incidents

NO	Sources	Year	Scope of the Study	Literature Review	Methodology	Cases	Physical Security	Security by Regulations	Emergency Plans	Characteristic of	Cite
9	*Guide to Updating Highway Emergency Response Plans for Terrorist Incidents, Brinckerhoff, Rockville, MD, May 2002*	2002	This Guide provides preliminary guidelines for planning for enhanced emergency response to terrorist incidents, especially those involving WMD. DOT's role and responsibilities, internal arrangements and external relationships are explained in detail.	-	-	9/11 Case Studies (New York, Virginia, Maryland, East Cost)	Necessary Equipments for Emergency Response	DOT's responsibiities, external relations for emergency response	DOT's role in Emergency Response, internal arrangements, external relationships	Weapons of Mass Destruction	* A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection
10	*Haimes, Y.Y. (2002). Roadmap for Modeling Risks of Terrorism to the Homeland. Journal of Infrastructure Systems, 8, 35-41*	2002	The homeland system and the terrorist networks system, state variables	+	HHM, modeling infrastructure interdependencies	Terrorist attack risks (HHM)	-	-	-	state variables of homeland system and terrorist network system	-
11	*A Risk Assessment Methodology for Critical Transportation Infrastructure, HAIMES,Y.Y., LAMBERT, J.H., KAPLAN, S., PIKUS, I., & LEUNG, F., Virginia, March 2002*	2002	This study offers a methodological framework to identify, prioritize, assess, and manage risks	+	RFRM (Risk Filtering, Ranking and Management Methodology)	Five case studies of selected transportation infrastructures in the Common wealth of Virginia	-	-	-	-	* Emergency Preparedness for Transit Terrorism * Improving Surface Transportation Security: A Research and Development Strategy
12	*Downey, Mortimer L. (2004, March). The Challenge of Transportation Security. Supply Chain Management Review, 8, 9-10.*	2004	This article explains why transportation is the new kind of treat. It gives very short explanations about characteristic of transportation and what should be done.	-	-	-	Sensors (that are capable of field identification of nuclear, chemical, or biological agents.)	-	-	Public Transportation	-

NO	Sources	Year	Scope of the Study	Literature Review	Methodology	Cases	Physical Security	Security by Regulations	Emergency Plans	Characteristic of	Cite
13	*Hu, Pat (2004). Integrated Solutions for Secure Transportation: A Concept. 2004 Tulane Engineering Forum* , New Orleans, LA	2004	This is a presentation that includes ORNL's tools and procedures for risk assessment, preparedness, and response.	-	-	Some examples	Integrated solutions	-	-	-	-
14	*Volpe Center (2003). Risk Assessment and Prioritization. Volpe Journal 2003.*	2003	This article is about the risk assessment of critical infrastructure, including transportation, and provides examples of some of the Volpe Center's assessments.	-	-	Some examples from Volpe Center Assessments	-	-	-	-	* Surface Transportation Vulnerability Assessment
15	*A Self-Study Course on Terrorism-Related Risk Management of Highway Infrastructure, NCHRP Report 525. Transportation Research Board, Washington, D.C., 2005*	2005	The report is designed to assist bridge and structures engineers and managers in identifying critical highway assets and their potential vulnerabilities, developing possible countermeasures to prevent or ameliorate threats to such assets, and determining the capital and operating costs of such countermeasures.	-	DOT' s Vulnerability Assessment	Blue River City Vulnerability assessment	-	-	-	-	* A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection
16	*Horowitz, Barry M., & Haimes, Yacov Y. (2003). Risk-Based Methodology for Scenario Tracking, Intelligence Gathering, and Analysis for Countering Terrorism. System Engineering, 6, No 3*	2003	This paper is one step forward study of Haimes' "A Risk Assessment Methodology for Critical Transportation Infrastructure".	+	RFRM (Risk Filtering, Ranking and Management Methodology) + Bayesian Analysis	HHM Food-Poisoning Scenario - Bayesian Analysis	-	-	-	-	* A Risk Assessment Methodology for Critical Transportation Infrastructure
17	*U.S. Department of Transportation. July 2003. Vulnerability Assessment Methodologies Report. Office for Domestic Preparedness. Washington, DC.*	2003	This paper is based on how vulnerability assessment should be. It explains the criteria for analysis of various methodologies.	-	(Government risk assessment methodology list is given in appendix.)	-	-	-	-	Characteristics of Risk Methodologies	-
18	*Pearce, Vincent P. (2002, September). Surface Transportation Security Lessons Learned From 9/11, Institute of Transportation Engineers. ITE Journal, 72, 38.*	2002	Volpe Center and Science Applications International Corporations (SAIC) prepared detailed case studies which are Advanced Preparations and Planning, Institutional Coordination, Communication, The Role of advanced Technologies, Redundancy and Resiliency and Operating Decisions.	-	-	Advanced Preparations and Planning, Redundancy and Resiliency	-	+	+	Institutional Coordination, Communication	-

NO	Sources	Year	Scope of the Study	Literature Review	Methodology	Cases	Physical Security	Security by Regulations	Emergency Plans	Characteristic of	Cite
19	*Fink, Camille N.Y. (2002, August). Anti-Terrorism Security and Surface Transportation Systems: A Review of Case Studies and Current Tactics. Department of Urban Planning, University of California, Los Angles*	2002	London, Tokyo and France bombing are explained shortly. Developing emergency plans, addressing vulnerabilities and terrorism mitigation is mentioned. At the end cost issue is considered under how much security need is required.	-	-	London, Paris and Tokyo terrorist bombing attacks	-	+	+	-	* A Guide to Highway Vulnerability Assessment
20	*Rowshan, Shahed & Sauntry, William C. & Wood, Thomas M. & Churchill, Bruce & Levine, Steve R. (2005). Reducing Security Risk for Transportation Management Centers, Journal of the Transportation Research Board, No 1938, 17-24.*	2005	This paper provides general recommendations include taking the time to conduct a comprehensive risk assessment; reviewing, updating, and revising the risk assessment on a regular basis; correcting simple physical vulnerabilities; and training employees in security awareness.	-	Traffic Management Center (TMC) Risk Assessment Methodology	-	-	-	-	-	* A Guide to Physical Security Risk Management for Transportation Management Centers * A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection
21	*Englot, Joseph M., (January, 2004). Prioritization and Design Criteria. TRB Workshop on Recommendations for Bridge and Tunnel Security.*	2004	It is a presentation about risk assessment methods for bridges and tunnels from Blue Ribbon Panel. This paper is a presentation of most significant parts of "Recommendations for Bridge and Tunnel Security".	-	6 step to prioritize security improvements	-	-	-	-		* Recommendations for Bridge and Tunnel Security
22	*Recommendations for Bridge and Tunnel Security, The Blue Ribbon Panel and Tunnel Security, September 2003*	2003	This paper is based on tunnel and bridge vulnerabilities and recommendations for the vulnerability assessments.	-	6 step to prioritize security improvements	An example how to use Risk assessment	-	Institutional Recommendations	-	-	-
23	*Stamm, B. Hudnall (September/October, 2002). Terrorism Risks in Rural and Frontier America. IEEE Engineering and Medicine and Biology.*	2002	Terrorism risks and threats in rural areas are explained. Characteristics of rural areas are given and which of them are the main threats and the potential targets for the terrorist attacks are described.	-	-	-	-	-	-	Characteristics of Rural America	-
24	*Hunter, Milton & Chernikoff, Rochelle & Wood, Tom & Malvey, Mike (Jul. 2003). Lessons Learned from Utility and Infrastructure Vulnerability Assessment. American Society of Civil Engineers, v1, pg 197 – 213.*	2003	Critical factors and methods about infrastructure are overviewed in that paper	-	Sandia Method	Paper is based on Water Infrastructure	-	Legislative Actions that are taken are explained short	-	-	-

NO	Sources	Year	Scope of the Study	Literature Review	Methodology	Cases	Physical Security	Security by Regulations	Emergency Plans	Characteristic of	Cite
25	*Little, Richard G. & Weaver, Elise A. (2005). Protection from extreme events: Using a socio-technological approach to evaluate policy options. Int. J. Emergency Management, v2, no 4*	2005	This paper presents some ways to define vulnerabilities of some physical structures or areas against terrorist attacks and natural disasters. Three tools are introduced for goal setting and decision making.	+	Judgement Analysis, Taylor-Russell Diagram, the system dynamics model	Building physical security is explained while using method	Building physical security (but not in detail)	-	-	-	-
26	*Gangi, M. Di (2004), Approaching the analysis of transport networks in emergency conditions for the design of evacuation plans. Management Information Systems, v9, p 485-494*	2004	This paper recommends a quantitative method in order to figure out if the infrastructure of an area is strong enough for evacuation procedure.	+	Simulation of different situations	An application of adequacy of arcs in an area	-	-	-	-	-
27	*Haimes, Yacov Y. (2006), On the Definition of Vulnerabilities in Measuring Risks to Infrastructures, Risk Analysis, v26, no 2*	2006	Assessment of risks to a vulnerable system is stated in that paper. Basic definitions of risk assessment terms such as vulnerability, intent, capability, threat and risk are introduced.	-	-	-	-	-	-	USA systems	-
28	*Santos, Joost R. & Haimes, Yacov Y. (2004). Modeling the Demand Reduction Input-Output (I-O) Inoperability Due to Terrorism of Interconnected Infrastructures. Risk Analysis, v 24, no 6*	2004	This paper builds interdependency analysis to show economic loses caused by terrorism and tries to define interdependencies between sectors with the help of a quantitative model.	-	Inoperability Input-output Model (IIM)	Air Transportation example	-	-	-	-	-
29	*Sarda, Priya & Lambert, James H. (2004). Risk-Based Model for Tracking Complexity in System Vulnerability Analysis. IEEE Systems and Information Engineering Design Symposium*	2004	A method for tracking model complexity in system vulnerability analysis is explained. The method builds on the collection of risk scenarios describing known vulnerabilities of systems and system components.	+	A method for tracking model complexity in system vulnerability analysis	An application of the method is shown.	-	-	-	-	-
30	*U.S. Department of Transportation. March 1999a. Guide to Establishing an Information System Protection Program (DOT H 1350.250). Washington, D.C.*	1999	The aim of this guide is provide assistance for Department of Transportation in order to develop an Information System Protection Program	-	Five Principles of Risk Management	-	-	-	-	-	-

NO	Sources	Year	Scope of the Study	Literature Review	Methodology	Cases	Physical Security	Security by Regulations	Emergency Plans	Characteristic of	Cite
31	*Transportation Research Board. 2005. Guidance for Transportation Agencies on Managing Sensitive Information (NCHRP Report 525). Washington, D.C.*	2005	This paper is prepared as a guide for DOTs of the states in order to show how to manage sensitive information	-	Five step plan for secure sensitive information	Examples of State Legistation to Exempt Selected Sensitive Transportation-Related Information	-	+	-	Sensitive Information that the DOTs have	-
32	*A letter from the President (Fall 2002). It's a Long Road to Security. Eno Transportation Foundation, v56, 5-7*	2002	This is a letter from President after September 11 attacks to inform public establishment of Homeland Security Department and how the security works on transportation is going on	-	-	-	-	Establisment of Homeland Security	-	-	-
33	*Okasaki, Nancy W. (August 2003). Improving Transportation Response and Security Following a Disaster. Institute of Transportation Engineers.*	2003	This paper focus on coordination of transportation providers in case of emergency like terrorism and transportation response plan	-	-	-	-	+	+	-	-
34	*Critical Foundations Protecting Americas Infrastructures (October 1997). The Report of the President's Commission on Critical Infrastructure Protection. Washington, D.C.*	1997	The purpose of this study is to define vulnerabilities better to be able be ready for threads.The paper focus on information sharing and building partnership, and recommendations to prevent impediments of legal procedures.	-	Five functional areas (explanation is based on organizational structure)	Sector Summary Reports(Energy, Banking and Finance, Physical	-	+	-	Threats, Vulnerabilities and Responsibilities	-
35	*Transportation Research Board of the National Acedemies (May-June 2005). Transportation Security Training and Education. Tr News, no 238.*	2005	This source is a periodical for every two months. This one is issuing education and training in emergency and evacuation conditions	-	-	-	-	-	+	-	-

NO	Sources	Year	Scope of the Study	Literature Review	Methodology	Cases	Physical Security	Security by Regulations	Emergency Plans	Characteristic of	Cite
36	*U.S. Department of Transportation. May 2004. Effects of catastrophic Events on Transportation System Management and Operations.Comparative Analysis (DOT-VNTSC-FHWA-04-03). Cambridge, MA.*	2004	This paper is a very good guide for emergency preparedness. DOT and FHWA prepared this report to be able respond effectively to major incidents.	-	Plan of Actions for Emergency Preparadness	Results of six major catastrophic events within USA are	-	+	+	-	-
37	*U.S. Department of Transportation. April 2002. Effects of catastrophic Events on Transportation System Management and Operations. New York City-September 11. Cambridge, Massachusetts.*	2002	This is a report prepared by US DOT's Volpe Center in order to show the actions taken against the terrorist attack in New York City on September 11.	+	Plan of Actions for Emergency Preparadness	Results of New York terrorist attack are exampled.	-	+	+	-	-
38	*Homeland Security (December 2004). National Response Plan.*	2004	This report establishes a comprehensive all-hazards approach to enhance the ability of the US to manage domestic incidents on organizational basis.	-	-	-	-	+	+	-	-
39	*Garrick, B. J., Hall, J. E., Kilger, K., McDonald, J. C., O'Toole, T., Probst, P. S., Parker, E. R., Rosenthal, R., Trivelpiece, A. W., Arsdale, L. A. V & Zebroski, E. L.. (2004). Confronting the Risks of Terrorism: Making the Right Decisions. Reliability Engineering and System Safety, v86, p 129-176.*	2004	This report gives information about definitions of treat and vulnerability, quantitative risk assessment (QRA), decision making to combat terrorism and recommendations and implementations.	+	QRA and overall analytical framework for action	Electricity case	+	-	-	Attacks	-

APPENDIX 2 – Annotated Bibliography

1) United States Department of Transportation (2002), *A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection,* Science Applications International Corporation (SAIC) Transportation Policy and Analysis Center, Vienna, VA.

This guide is prepared for identifying risks for critical assets in the states and develops countermeasures to deter, detect and delay the possible attacks. After estimating possible costs for each countermeasure, the best one is chosen and an operational security planning is developed based on these countermeasures. This paper mainly focuses on 6 steps methodology that provides these results. First step is developing a list that includes all the critical assets in related district and evaluating their criticality value. Second step is about vulnerability and all the assets are evaluated according to their vulnerability. Third step is defining the location of the asset in the criticality and vulnerability plot which helps to define the most significant assets in the area. In fourth step, countermeasures are determined and effectiveness of them is assessed. Fifth step is for cost estimation of the countermeasures and in the last step is developing security operational planning.

2) Stovall, M. E. and Turner, D. S. (2004), *Methodology for Developing a Prioritized List of Critical and Vulnerable Local Government Highway Infrastructure*

This paper is the implementation of *"A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection"* to 2 counties of Alabama that are Shelby County and City of Tuscaloosa. These case studies are separated to three phases. The first one is gathering information for the case study. Then second one is defining critical assets, then defining criticality and vulnerability of each one. Third step is defining countermeasures, cost analysis of each one and developing operational security system. While these studies are practiced, the members of this study are divided into four groups in order to get better results. At the end of the study it is seen that first and second steps of the study is worked well, but there are some lacking parts for third step.

This study mainly focuses on how to apply this methodology other than details of the steps of methodology. At the end of these case studies there are results which indicate good and lacking parts of the methodology. Also some recommendations for this methodology are given.

3) Little, R.G. (2004), Holistic Strategy for Urban Security. *Journal of Infrastructure Systems*, Vol. 10.

This paper gives information about how to secure urban cities from a holistic point of view. Especially it focuses on physical security of the assets in urban cities. It develops some physical protection strategies such as standoff, blast resistance in buildings or sensors can be used to protect the buildings from attacks. On the other hand the paper highlights that "what kinds of precautions should be taken" issue should be dealt with instead of "how to strengthen the assets to protect them from an attack". It gives a basic framework to mitigate and respond future attacks. Other than these, people and the institution factors are significant contributors to provide security.

4) National Academy Press (1999), Improving Surface Transportation Security: A Research and Development Strategy

This paper is more about developing R&D strategies for improving surface transportation security. In vulnerability assessment part, a general methodology which belongs to DOT is explained. Also possible attack types are described. With the help of that information, R&D projects are defined. This report focuses on developing a strategic vision of an R&D program for the long term, and recommends a process for achieving that vision. The goal is to present a strategy rather than a shopping list of projects. Several specific R&D topics are discussed, but the report cannot and does not seek to be complete at that level.

5) Jenkins, B. M. (2001), *Protecting Public Surface Transportation against Terrorism and Serious Crime*: An Executive Overview. San Jose, CA: Mineta Transportation Institute College of Business

Since transportation system is so accessible, it is one of the best targets for terrorist attacks. This paper explained the results and the consequences learned from a review of surface transportation security assessment. This review includes how to protect facilities, passengers from possible attacks and, a chronology of terrorist attacks and major criminal assaults on surface transportation and an annotated bibliography of publications dealing with surface transportation security. The station and vehicle design is also explained in the paper.

6) *Deterrence, Protection and Preparation* (2002), Committee on Science and Technology for Countering Terrorism, Transportation Research Board, Washington, D.C.

Firstly, this paper focuses on characteristics of transportation and their implications. With the help of common specifications of transportation types, it develops a systematic approach to security, building security into operations, and layering security measures to deter--and to protect against--terrorist attack. Then key research and technology needs for transportation security system research operations are explained. At the end the paper provides some advises to TSA (Transportation Security Administration). "Executive summary of Making the Nation Safer" is given as an appendix.

7) *Communication of Threats: A Guide* (2002), Public Transportation Security: Volume 1, Transportation Research Board, Washington, D.C.

This volume offers information on a variety of approaches to improving the sharing of threat information and based on a SURVEY that 12 transportation authorities all over US are get involved. Current practices, operational needs, technologies for threat information dissemination, and system functional requirements are discussed. TIF (Transportation Information Forum) is explained. Effective strategies for sharing analyzed and

unanalyzed reports of suspicious activities and a path to an interoperable set of national, regional, and local threat-information forums are proposed.

8) Ham, D.B. (2002), *National Needs Assessment for Ensuring Transportation Infrastructure Security,* Lockwood S., Science Applications International Corporation (SAIC) Transportation Policy and Analysis Center, Vienna, VA.

"This study, conducted under the auspices of the Transportation Security Task Force of the American Association of State Highway and Transportation Officials (AASHTO), examines three key security planning program areas: Protecting critical mobility assets, Enhancing traffic management capabilities, and Improving state DOT (Department of Transportation) emergency response capabilities. Program for protection of critical mobility assets focuses on bridge and tunnel vulnerabilities and the countermeasures to cope with them. Program for enhancement of traffic management capabilities emphasizes on regimes that should be implemented. Program for improvement of state DOT emergency response shows what DOT's roles and shortcomings are and what can be done in emergency response."

9) Brinckerhoff (2002), *Guide to Updating Highway Emergency Response Plans for Terrorist Incidents,* Rockville, MD.

This guide focuses on response plans for terrorist incidents. It provides information on current emergency management, DOT's role in emergency preparedness and the new terrorist threat faced by the United States. It also provides guidance for updating state plans, procedures, roles, and activities in a checklist format. It suggests the most critical issues, indicates the key considerations to pursue with external entities, and identifies the areas in which the existing plans and procedures may require modification in light of the characteristics of terrorism scenarios.

10) Haimes, Y.Y. (2002), Roadmap for Modeling Risks of Terrorism to the Homeland. *Journal of Infrastructure Systems*, Vol. 8, 35-41

"This paper offers a holistic risk assessment and management framework for modeling the risks of terrorism to the homeland. Two major interconnected systems are addressed: the homeland system and the terrorist networks system. In modeling the two systems, the centrality of state variables is highlighted. Interdependencies between civilian and military infrastructure are shown. Infrastructure interdependencies are modeled in the paper. It is worth noting that the community of risk analysts has been developing and applying systems-based methodologies and tools for many years. The roadmap presented in this paper builds on the findings of many prior analyses."

11) Haimes,Y.Y., Lambert, J.H., Kaplan, S., Pikus, I. and Leung, F. (2002), *A Risk Assessment Methodology for Critical Transportation Infrastructure*, Virginia.

"Infrastructure protection typifies a problem of risk assessment and management in a large-scale system. This study offers a methodological framework to identify, prioritize, assess, and manage risks. It includes the following major considerations: (1) a holistic approach to risk identification; (2) prioritization of a large number of risks or risk scenarios; (3) structured solicitation and effective integration of expert judgment into qualitative and quantitative analyses to supplement limited data availability; (4) extreme and catastrophic event analysis; and (5) use of multiobjective framework to evaluate management options (i.e., analyzing trade-offs among noncommensurate, conflicting objectives such as risk and cost). The methodology was illustrated using five case studies of selected transportation infrastructures in the Commonwealth of Virginia."

12) Downey, M.L. (2004), The Challenge of Transportation Security. *Supply Chain Management Review*, Vol. 8, 9-10.

"The Transportation Research Board formed a special Transportation Panel, made up of transportation and security experts, to identify the research and technology resources needed to strengthen response capability. The attributes of the transportation system are precisely what make it attractive as a terrorist target. It is open and accessible, by design. It is global in its reach but institutionally diverse with many providers and operators. And it can be brutally efficient, whether moving sneakers or weapons of mass destruction. A comprehensive approach to security is needed that can meet these special challenges. It needs to be technologically sophisticated but operationally robust in harsh settings. It must be layered, not relying on any single point of interdiction. It should have "curtains of mystery," leaving the terrorist to guess as to the points and means by which passengers and cargo will he screened. Finally, it must he smart and comprehensive - going beyond gates, guards, and guns, which are important elements in security but less than a total system. Supporting these requirements will strain the capabilities of existing technology, but it is a challenge that can be met."

13) Hu, P. (2004), Integrated Solutions for Secure Transportation: A Concept. *2004 Tulane Engineering Forum*, New Orleans, LA

This is a presentation prepared by the Oak Ridge National Laboratory of the US Dept. of Energy on securing US transportation. It includes ORNL's tools and procedures for risk assessment, preparedness, and response. Detectors, sensors, GIS and geo-spatial data layers are some of the examples of ORNL's tools.

14) Volpe Center (2003), Risk Assessment and Prioritization. *Volpe Journal*.

This article is about the risk assessment of critical infrastructure, including transportation, and provides examples of some of the Volpe Center's assessments. It gives brief explanations for Volpe Center and "Surface Transportation Vulnerability Assessment". Then it explains assessments made by Volpe Center about Ports, GPS (Global Positioning System), FAA (Federal Aviation Administration).

15) Transportation Research Board *(*2005), *A Self-Study Course on Terrorism-Related Risk Management of Highway Infrastructure,* NCHRP Report 525., Washington, D.C.

This report is designed to provide a general background in terrorism-related risk management for highway infrastructure. The report is also designed to assist bridge and structures engineers and managers in identifying critical highway assets and their potential vulnerabilities, developing possible countermeasures to prevent or ameliorate threats to such assets, and determining the capital and operating costs of such countermeasures. This report also includes implementations of the vulnerability assessment for bridges and tunnels that is based on "A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection".

16) Horowitz, B.M. and Haimes, Y.Y. (2003). Risk-Based Methodology for Scenario Tracking, Intelligence Gathering, and Analysis for Countering Terrorism. *System Engineering,* Vol. 6, No 3

This paper is one step forward study of Haimes' "A Risk Assessment Methodology for Critical Transportation Infrastructure". In addition to RFRM methodology, it adds Bayesian Analysis in order to measure the reliability of the threat information. It helps how to intervene the threat across organizational structure. There is a case study at the end to show how Bayesian Analysis is used.

17) U.S. Department of Transportation, (2003), *Vulnerability Assessment Methodologies Report*. Office for Domestic Preparedness. Washington, DC.

This paper is based on how vulnerability assessment should be. It explains the criteria for analysis of various methodologies. A project made for developing the model criteria for what an effective vulnerability assessment methodology should be is remarked. Some kinds of software tools that are used for risk assessment are introduced in the paper. At the end a list of government methodologies and glossary of risk assessment terms are given.

18) Pearce, V.P. (2002), Surface Transportation Security Lessons Learned From 9/11, *Institute of Transportation Engineers. ITE Journal,* Vol. 72, 38.

Volpe Center and Science Applications International Corporations (SAIC) prepared detailed case studies of surface transportations in New York City and Washington. These case studies include an assessment of findings which has been grouped into six categories. These are Advanced Preparations and Planning, Institutional Coordination, Communication, The Role of advanced Technologies, Redundancy and Resiliency and Operating Decisions. The paper does not include detailed information of entire case studies. It gives an overview about what examined in that case, what is the organizational structure and what lacked at time of terrorist attacks.

19) Fink, C.. (2002), *Anti-Terrorism Security and Surface Transportation Systems: A Review of Case Studies and Current Tactics*. Department of Urban Planning, University of California, Los Angles

The events of September 11 brought the issue of transportation security and terrorism to the forefront of policy and government. Public surface transportation systems are especially vulnerable because they are by nature open and accessible. They also serve large numbers of people in extensive networks. Case studies of particular systems and incidents offer examples of effective planning and response as well as gaps in security systems. Systems in London and Paris have experienced bombing attacks. Tokyo was the location of a chemical attack. Preparation against terrorist attacks involves assessments of vulnerabilities, mitigation of weaknesses in the system, and the development of effective response and emergency plans. Cost factors are a particular concern for transit officials. The use of design elements, closed-circuit television, training, and exercises, together with the establishment of close relationships with other local, state, and federal agencies, appears to be the most cost-effective security option.

20) Rowshan, S., Sauntry, W.C., Wood, T. M., Churchill, B. and Levine, S.R. (2005). Reducing Security Risk for Transportation Management Centers, *Journal of the Transportation Research Board*, No 1938, 17-24.

"The Transportation management center (TMC) risk assessment methodology (RAM) introduced in this paper is based on the best practices of several proven RAMs. Its components include asset identification, threat assessment, consequence assessment, vulnerability assessment, and countermeasure development. The research team selected 10 TMCs as a basis for gathering best practices and common challenges. As initial data were developed for the 10 centers, three sites were chosen to participate in more comprehensive on-site vulnerability assessment. This paper provides general recommendations include taking the time to conduct a comprehensive risk assessment; reviewing, updating, and revising the risk assessment on a regular basis; correcting simple physical vulnerabilities; and training employees in security awareness."

21) Englot, J.M. (2004), Prioritization and Design Criteria. *TRB Workshop on Recommendations for Bridge and Tunnel Security.*

It is a presentation about risk assessment methods for bridges and tunnels from Blue Ribbon Panel. It references "Recommendations for Bridge and Tunnel Security" source that is prepared by Blue Ribbon Panel on Bridge and Tunnel Security. It gives World Trade Center Towers as an example. It also includes 6 steps methodology to prioritize security improvements. It also provides steps to prioritize security improvements. This paper is a presentation of most significant parts of "Recommendations for Bridge and Tunnel Security".

22) Blue Ribbon Panel and Tunnel Security (2003), *Recommendations for Bridge and Tunnel Security*

This paper is based on tunnel and bridge vulnerabilities and recommendations for the vulnerability assessments. Also it focuses on planning, design and engineering between key topics in infrastructure security. The reason for that is this issue is unique for the bridges and the tunnels. Recommendations fall into three categories which are institutional, fiscal and technical. Planning, design and engineering recommendations are made as near term, mid term and long term. Six step processes to define vulnerabilities are explained and a case study is made as an application.

23) Stamm, B.H. (2002), Terrorism Risks in Rural and Frontier America. *IEEE Engineering and Medicine and Biology.*

Terrorism risks and threats in rural areas are explained in this paper. Characteristics of rural areas are given in detail and which of them are the main threats and the potential targets for the terrorist attacks are described. Water and food supply from rural areas, industrialization and the number of facilities, health care and availability of HAZMAT teams in rural areas plays a part of national security. Since transportation and the industrial product supply from rural to urban areas makes rural vulnerability more important. Some recommendations are given at the end against the issue discussed in the paper.

24) Hunter, M., Chernikoff, R., Wood, T. and Malvey, M. (2003), Lessons Learned from Utility and Infrastructure Vulnerability Assessment. *American Society of Civil Engineers*, Vol. 1, pg 197 – 213.

Critical factors and methods about infrastructure are overviewed in that paper. Philosophy of a project is explained in terms of how to organize the team, using experts and integrating security into every phase of project. Sandia Method is used as a vulnerability assessment. Water Infrastructure is given as an example while the steps of vulnerability assessment are explained.

25) Little, R.G. and Weaver, El.A. (2005), Protection from extreme events: Using a socio-technological approach to evaluate policy options. *Int. J. Emergency Management*, Vol. 2, No. 4

This paper presents some ways to define vulnerabilities of some physical structures or areas against terrorist attacks and natural disasters. Also it gives the definition of risk assessment at the beginning. Three tools are introduced for goal setting and decision making. Judgment analysis, Taylor-Russell diagram and the system dynamics models are these three techniques to assess the vulnerabilities and to decide to take action against them or not. These techniques are continuation of each other since judgment analysis provides the safety indicators, while Taylor-Russell diagram examines the consequences of different choices of safety indicator versus security performance and the systems dynamics model simulates different scenarios to compare the regulatory environments.

26) Gangi, M.D. (2004), Approaching the analysis of transport networks in emergency conditions for the design of evacuation plans. *Management Information Systems*, Vol. 9, 485-494

This paper recommends a quantitative method in order to figure out if the infrastructure of an area is strong enough for evacuation procedure. The application in the paper is a simulation model that calculates the efficiency of the arcs in a city while an evacuation situation. Eighteen different situations are considered and the response of the effectiveness of the arc usability is indicated. The application in that paper is a kind of verification to calculate the adequacy of the arcs.

27) Haimes, Y.Y. (2006), On the Definition of Vulnerabilities in Measuring Risks to Infrastructures, *Risk Analysis*, Vol. 26, No. 2

This paper gives the basic definitions of risk assessment terms such as vulnerability, intent, capability, threat and risk. Then it emphasizes on what are the significant aspects of a risks assessment that the decision maker should be careful. Since every sub-system

of a system has its own substate variables, the same scalar unity may be not adequate for all sub-systems. In sum, assessment of risks to a vulnerable system is stated in that paper.

28) Santos, J.R. and Haimes, Y.Y. (2004), Modeling the Demand Reduction Input-Output (I-O) Inoperability Due to Terrorism of Interconnected Infrastructures. *Risk Analysis,* Vol. 24, No. 6

Terrorist attack to a country mainly influences its economy. Since interconnectedness and interdependencies of the sectors will affect each other, one attack to an individual industry causes bad influence on overall economy. So this paper tries to define interdependencies between sectors with the help of a quantitative model. Two case studies are applied to 12 and 483 sectors in order to show the interdependencies. In sum, this paper builds interdependency analysis to show economic loses caused by terrorism.

29) Sarda, P. and Lambert, J.H. (2004), Risk-Based Model for Tracking Complexity in System Vulnerability Analysis. *IEEE Systems and Information Engineering Design Symposium*

"We describe a method **for tracking model complexity** in system vulnerability analysis. The method builds on the collection of risk scenarios describing known vulnerabilities of systems and system components. We introduce the concept of an interaction as a mapping between a risk scenario and one or more system components. An interaction is direct when the mapping is obvious. An interaction is indirect when the mapping can make use of nonobvious relationships among system components. Indirect interactions characterize the rippling effects of a risk scenario and are used to identify the nonobvious interdependencies. With the above foundation, the method extends traditional process control charts to track evolving knowledge of scenarios and systems. The charts signal the emergence of anomalous variation in emerging knowledge of system vulnerability. The method is applied iteratively to avoid situations of surprise in an emerging model (scenarios and systems) of system vulnerability. An application of the method is discussed."

30) U.S. Department of Transportation (1999a), *Guide to Establishing an Information System Protection Program (DOT H 1350.250)*. Washington, D.C.

The aim of this guide is provide assistance for Department of Transportation in order to develop an Information System Protection Program. It refers to the study of General Accounting Office (GAO) on eight nonfederal organizations. Risk Management and its five steps that are used by these organizations are described based on practical explanations. Information system protection elements are examined with a short explanation of each element.

31) Transportation Research Board. 2005. *Guidance for Transportation Agencies on Managing Sensitive Information (NCHRP Report 525).* Washington, D.C.

Since the information that transportation agencies have can be deadly if it is in the wrong hands. So this paper is prepared as a guide for DOTs of the states in order to show how to manage sensitive information. It mainly focuses on "How to identify sensitive information that must be protected" and "How to control access to sensitive information responsibly". What kinds of sensitive information DOTs have and which of them needs to be protected and the five steps for information protection policy are explained in the report. These five step protection plan is a specific plan that can be used for information protection only (It is not transferable to other type of protection plans).

32) A letter from the President (2002), It's a Long Road to Security. *Eno Transportation Foundation*, Vol. 56, 5-7

This is a letter from President after September 11 attacks to inform public establishment of Homeland Security Department and how the security works on transportation is going on. The president states that trying to define risks for transportation is like trying to diagnose the risk for heart attack. It is so hard to provide security to every point of transportation due to cost and bureaucracy but still many security plans are implemented.

Managing security concerns are very significant in order to provide security to every phase of transportation and support economic growth.

33) Okasaki, N.W. (2003), Improving Transportation Response and Security Following a Disaster. *Institute of Transportation Engineers.*

This paper focus on coordination of transportation providers in case of emergency like terrorism and transportation response plan. Emergency Response Plans should include responsibilities of organizations, threat identification and assessments and so forth. Standardized Emergency Management is used by many of the agencies. Transportation Response Plan and the responsibilities of Metropolitan Transportation Commission are explained briefly.

34) Critical Foundations Protecting Americas Infrastructures (1997), The Report of the President's Commission on Critical Infrastructure Protection. Washington, D.C.

Since the complexity and development of infrastructure in USA is increasing, interdependencies between them also getting higher. This type of interconnectedness and also more spreadable threat information makes risks higher in today's world. The purpose of this study is to define vulnerabilities better to be able be ready for threads. New vulnerabilities and types of threads are explained in detail. The paper focus on information sharing and building partnership, and recommendations to prevent impediments of legal procedures. In order to achieve infrastructure assurance, the paper shows five functional areas and gives details based on organizational structure, partnerships and dynamic interaction.

35) Transportation Research Board (2005). Transportation Security Training and Education. *Tr News,* N.o 238.

This source is a periodical for every two months. This one is issuing education and training in emergency and evacuation conditions.

Assessing Transportation Security Training: Since all the transportation agencies and assets have interconnectedness, an attack to one of the component of transportation will affect a wide variety of elements. So reliable and trained staff will be the key point to protect the critical assets within transportation. Training needs and training programs are explained. Implications of the training programs in many states and contribution of the research agencies and universities are exampled in the article.
Developing and Expanding a Security Curriculum for Frontline Transportation Workers: This article is about how to increase awareness and security of the transportation areas. It includes some short examples that are implemented in some states.

36) U.S. Department of Transportation (2004*), Effects of catastrophic Events on Transportation System Management and Operations. Comparative Analysis. (DOT-VNTSC-FHWA-04-03).* Cambridge, MA.

DOT and FHWA prepared this report to be able respond effectively to major incidents. Results of six major catastrophic events within USA are compared and effects on transit systems are examined. The details of the condition of the transportation system and key decisions by Agency on and after emergency time are given for Blackout in New York City and Great Lakes Area, Terrorist Attack in New York City and Washington, Rail Tunnel Fire in Maryland and Earthquake in California. Priorities in emergency conditions and the plan of actions to be able respond catastrophic events are the main inference of the paper. Plan of actions covers operating implementations, coordination and communication between agencies, role of technology and the system redundancy and resilience issues. This paper is a very good guide for emergency preparedness.

37) U.S. Department of Transportation (2002), *Effects of catastrophic Events on Transportation System Management and Operations. New York City-September 11. Cambridge, Massachusetts.*

This is a report prepared by US DOT's Volpe Center in order to show the actions taken against the terrorist attack in New York City on September 11. Terrorist Attack in New

York City and Washington, Rail Tunnel Fire in Maryland and Earthquake in California cases which had different effects on transportation system are examined and the action plans in case of emergency are built. Pre-event, Day of Event and Post event activities related to taking actions and key agency responsibilities are detailed first as a starting point to findings and conclusions. Based on New York terrorist attack observations are explained in order to show what is worked well and not. Future improvements learned from that experience and the action plan in case of emergency conditions are determined. Agencies that will have the initial duty in emergency conditions and intuitional coordination are defined in detail as a guide. This paper is a very good guide for emergency preparedness.

38) Department of Homeland Security (2004), *National Response Plan.*

"The National Response Plan establishes a comprehensive all-hazards approach to enhance the ability of the United States to manage domestic incidents. The plan incorporates best practices and procedures from incident management disciplines—homeland security, emergency management, law enforcement, firefighting, public works, public health, responder and recovery worker health and safety, emergency medical services, and the private sector—and integrates them into a unified structure. It forms the basis of how the federal government coordinates with state, local, and tribal governments and the private sector during incidents."

39) Garrick, B.J., Hall, J.E., Kilger, K., McDonald, J.C., O'Toole, T., Probst, P.S., Parker, E.R., Rosenthal, R., Trivelpiece, A.W., Arsdale, L.A.V & Zebroski, E.L. (2004), Confronting the Risks of Terrorism: Making the Right Decisions. *Reliability Engineering and System Safety,* Vol.86, 129-176.

This report gives information about definitions of treat and vulnerability, quantitative risk assessment (QRA), decision making to combat terrorism and recommendations and implementations. QRA is explained in five steps and the report focuses on third step which is "identification, analysis, and development of the most likely terrorist attack

scenarios, including their consequences". The reason is being the most significant input for decision making phase. Tools for decision making process such as Bayes theorem, Event and Fault trees…etc. are examined. Methodology explained in the paper is used in the case given about the electricity and the interconnectedness. The final phase of the paper focuses on information challenging and sharing.

APPENDIX 3 – Rural vs. Urban Transportation Network Comparison Matrix

Table 39. Rural vs. Urban Transportation Network Comparison Matrix

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Air	Number of Airports	135 rural destinations served by Essential Air Service program (mostly West) (USDA ERS, 2005, A)		
		Essential Air Service subsidized rural communities: 109 mainland, 33 Alaska, and 3 Hawaii (BTS, 2005, B)		638 airports total, 432 in mainland states, 195 in Alaska, and 11 in Hawaii (BTS, 2005, B)
		141 airports in rural/frontier counties (Stamm, 2002, A)	287 airports in urban counties (Stamm, 2002, A)	
	Access	71% of rural population has access to air service (BTS, 2005, B)		
		Regional carriers serve 95% of all airports receiving commercial air service in North America (FHA, 2001, A)		
	Passengers	71 million passengers boarded airplanes operated by regional airlines in 1998 (FHA, 2001, A)		
	Freight			Air freight moves low volumes, items are low weight and high-value-added items (FHA, 2001, A)
	Classifying Airports	IF: 1) Fewer than 100,000 commercial passengers departed from the airport during the second preceding calendar year and; 2) Either of the following statements is true: a) The airport is not located within 75 miles of another airport from which 100,000 or more commercial passengers departed during the second preceding calendar year. b) The airport was receiving essential air service subsidies as of August 5, 1997 (BTS, 1999, A)		

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Arkansas	Counties	63 of 75 counties were classified as nonmetropolitan in the 2000 census (UADA, 2005, A)	12 of 75 counties were classified as metropolitan in the 2000 census (not explicitly stated, assumed from rural) (UADA, 2005, A)	75 total counties (UADA, 2005, A)
	Roads	nearly 80% of county roads are in rural areas (UADA, 2005, A)		
		68,425 miles of county roads total (UADA, 2005, A)		
		40 miles per 1,000 people in rural areas (UADA, 2005, A)	10 miles per 1,000 people in urban areas (UADA, 2005, A)	
	Population	51% lived in a nonmetropolitan county in 2000 (UADA, 2005, A)		
		48% of population identified as rural in 2000 census (UADA, 2005, A)		Population of 2,673,398 in 2000 (UADA, 2005, A)
	Elderly (65 and older)	Elderly account for 16% of rural population (UADA, 2005, A)	Elderly account for 12% of urban population (UADA, 2005, A)	
	Poverty	Rural areas had a poverty rate of 18% in 1999 (UADA, 2005, A)	Urban areas had a poverty rate of 14% in 1999 (UADA, 2005, A)	
	Commuters	26% of rural Arkansas commuted in 2000 (UADA, 2005, A)	28% of urban Arkansas commuted in 2000 (UADA, 2005, A)	23% of all Arkansan workers commuted in 2000 (factors in nonmetropolitan residents) (UADA, 2005, A)
		5% increase in rural commuters from 1990 to 2000 (UADA, 2005, A)	4% increase in urban commuters from 1990 to 2000 (UADA, 2005, A)	
		50% or more of workers in 6 rural counties commuted out of county in 2000 (UADA, 2005, A)	50% or more of workers in 4 urban counties commuted out of county in 2000 (UADA, 2005, A)	50% or more of workers in 10 counties commuted out of county in 2000 (UADA, 2005, A)

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Buses	Intercity Bus Availability	Dominant mode of transportation for most rural passengers (USDA ERS, 2005, A)		
		4,300 locations currently served by intercity bus (USDA ERS, 2005, A)		
				49% of All Americans report living within 1/4 mile of a transit stop (context suggests all ground transit stops: bus, rail, and subway) (STPP, 2002, A)
		89% of rural population served by long-distance bus service (USDA ERS, 2005, A), (BTS, 2005, B)		
		3,179 total intercity bus stations serving rural areas (serving a rural area does not imply located in rural area that is served) (see Table 3 of document for specifics) (BTS, 2005, B)		
		Nearly 80% of rural counties have no public bus service (RPRI, 1999, A)	2% of metro counties have no public bus service (RPRI, 1999, A)	
		4,500 communities with daily bus service (unspecific whether applies only to rural or to entire nation, due to context - assumed rural) (FHA, 2001, A)		
	Bus Funding	TEA-21(see Federal Support) provides $2 million in 1999 for the Rural Transportation Accessibility Incentive Program which supports "over-the-road" bus service (Brown, 1999, A)		
	Intercity Bus Funding	Fed. Gov. requires >15% of annual nonmetro public transportation funding spent on intercity bus (USDA ERS, 2005, A)		
	Types of Bus Service			Long distance bus service - travel of 50 miles or more (BTS, 2002, C)
				Over-the-road bus service
				No public bus service
				Daily bus service
	Major Bus Carriers			Greyhound Lines, Inc. (60%) (BTS, 2005, B)

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Definition (by source)	(USDA Economic Research Service, 2005, Rural Transportation at a Glance)	Counties that are located outside the boundaries of metro areas and have no cities with >=50,000 residents (USDA ERS, 2005, A)	(1) Core counties with >=1 cities with population >50,000 or with a Census Bureau-defined urbanized area and a total metro population of >=100,000; (2) Fringe counties economically associated with core counties (USDA ERS, 2005, A)	
	(Bureau of Transportation Statistics, 2005, Rural Scheduled Intercity Transportation)	any area that the Census Bureau did not identify as either an "urbanized area" or an "urban cluster" (BTS, 2005, B)	Towns, cities, or other places, or more than one contiguous place with a population of >= 50,000; urban clusters are places of 2,500 to 50,000 that lie outside urbanized areas, may be far from urban areas (BTS, 2005, B)	
	(Transportation Research Board, 1998, Assessment of the Economic Impacts of Rural Public Transportation), via Census Bureau	Areas that are not urban; metropolitan rural are found in urbanized areas (counties with a city of 50,000 or more) or rural areas in counties that are adjacent to a county with a city of 50,000 or more and are economically and socially integrated with the county containing the central city (TRB, 1998, A)	1) Incorporated and unincorporated places of 2,500 people or more; 2) the urban fringe around cities of 50,000 or more (TRB, 1998, A)	
	(Transportation Research Board, 1998, Assessment of the Economic Impacts of Rural Public Transportation), via Beale Codes of USDA	Nonmetropolitan counties (codes 4 through 9): urban population of 20,000 or more, adjacent to a metropolitan area (code 4); urban population of 20,000 or more, not adjacent to a metropolitan area (code 5); urban population of 2,500 to 19,999, adjacent to a metropolitan area (code 6); urban population of 2,500 to 19,999, not adjacent to a metropolitan area (code 7); completely rural (no places with a population of 2,500 or more) adjacent to a metropolitan area; completely rural (no places with a population of 2,500 or more) no adjacent to a metropolitan area (TRB, 1998, A)	Metropolitan counties (codes 0 through 3): central counties of one million persons or more (code 0); fringe counties of metropolitan areas of one million persons or more (code 1); counties in metropolitan areas of 250,000 to 1,000,000 persons (code 2); counties in metropolitan areas of less than 250,000 persons (code 3) (TRB, 1998, A)	

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Definition (by source)	(Maxwell, 1996, Assessment of Arkansas Economic Impacts of Rural Public Transportation)	places with populations less than 2500 citizens (as defined by the Census Bureaus for the 1990 United States Census) (Maxwell, 1996, A)		
	(Federal Highway Administration, 2001, Planning for Transportation in Rural Areas)	for highway functional classification and outdoor advertising regulations, anything outside of an area with a population of 5,000; for planning purposes, areas outside of metropolitan areas >= 50,000 in population (FHA, 2001, A); Basic Rural - counties or regions with few or no major population centers of >= 5,000 people; Developed Rural - dispersed counties with >=1 population centers of >= 5,000 people; Urban Boundary Rural - counties or regions that border metropolitan areas and are highly developed (FHA, 2001, A)		
	(Community Transportation Association of America, 1994, Status Report)	Area that is not urban (population <50,000) (CTA, 1994, A)	Population >= 50,000 (CTA, 1994, A)	
	(Community Transportation Association of America, 1995, Atlas)	Outside of an urbanized area of 50,000 or more population (CTA, 1995, B)		

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Definition (by source)	(University of Arkansas Division of Agriculture, 2005, Rural Profile of Arkansas)	Nonmetropolitan - area and population not located in any Metropolitan Statistical Area; Rural - all territory, population, or housing units not classified as urban, may be metropolitan or nonmetropolitan (UADA, 2005, A)	Metropolitan Statistical Area - city with 50,000 or more inhabitants, or the presence of an Urbanized Area and a total population of at least 100,000 (75,000 in New England); Urban - within an urbanized area or urbanized cluster, consists of 1) core census block groups or blocks that have a population density of >= 1000 people/square mile and 2) surrounding census blocks that have an overall density of >= 500 people/square mile; Urban Cluster - population of >= 2,500 but < 50,000; Urbanized Area - population > 50,000 people (UADA, 2005, A)	
	(United States Department of Agriculture, 1996, Rural Roads and Bridges)	Counties with less than 85% urbanized population (USDA, 1996, B)		
	Errors in definitions	Two types of errors: 1) including areas as rural that are not rural and 2) excluding areas from the rural category that are rural: Census Bureau's definition avoids second error but is less effective in dealing with first error (TRB, 1998, A)		

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Demographics	Population	82.4 Million rural residents (BTS, 2005, B)		
		56.2 million people in rural America (Stamm, 2002, A)		
		91 million people live outside of urbanized areas (CTA, 1994, A)	94 million in large-urban areas, 38 million in medium-urban areas, 26 million in small urban areas (CTA, 1994, A)	
		21% of nation's population is rural (50 million people), 18% of jobs and 14% of earnings come from rural areas (FHA, 2001, A), (Hill, 1999, A), (TRB, 1998, A)		
		21% of population identified as rural in 2000 census, 20% lived in nonmetropolitan counties (UADA, 2005, A)		
		25% of population lives in rural area in West, 44% in South, 43% in Midwest, 28% in Northeast (CTA, 1994, A)		
		2,288 counties classified as rural or nonmetropolitan in 1990 census (TRB, 1998, A)		3,141 counties and county equivalents (TRB, 1998, A)
		lower population density than urban areas (Maxwell, 1996, A)	Density per square mile: large urban area = 3,413, medium urban area = 2,091, small urban area = 1,714 (CTA, 1994, A)	
		41% of rural population lives close enough to urban centers to be considered part of a metropolitan area (CTA, 1994, A)		
	% Car Access	92.7% of rural households had access to a car in 2000 (USDA ERS, 2005, A), (Brown, 2004, D)	88.9% of urban households had access to a car in 2000 (USDA ERS, 2005, A), (Brown, 2004, D)	
		Nearly 57% of the rural poor do not own a car (RPRI, 1999, A)		89.7% of American households have access to an automobile (STPP, 2002, A)
		1 in 14 households in rural America has no vehicle (RPRI, 1999, A)		96% of public assistance recipients have no personal automobile (RPRI, 1999, A)
	Employment	Real wages are about 20% lower in rural areas (TRB, 1998, A)		
		Service sector accounts for 51% of the rural workforce (TRB, 1998, A)		
		Farm employment makes up 7.6% of the rural workforce (TRB, 1998, A)		

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Demographics	Economic County Types	For non-metro counties: Farming - 556 counties derive 20% or more of their earned income from farming; Mining - 146 counties accounted for about half of the nonmetro mining jobs in 1989; Manufacturing - 506 counties received more than 30% of their earnings from manufacturing; Government dependent - 224 counties specialized in government activities, 25% of earnings from government jobs came from Federal jobs; Service - 323 counties that derived 50% or more of their earned income from the services sector, accounted for 83% of new nonmetro jobs between 1979 and 1989; Nonspecialized - 484 counties did not qualify for any specialization type (TRB, 1998, A)		2,276 non-metro counties total, 1,197 classified, 17 counties could not be classified due to data suppression (TRB, 1998, A)
	County Policy Types	Rural county policy types: Retirement-destination - experienced 15% or more immigration of persons 60 or older in the 1980's; Federal lands - 30% or more of the land is owned by the Federal Government, 270 counties in 1987; Commuting - 481 counties in which more than 40% of workers commuted to jobs in other counties in 1990, 65 percent of commuting counties in South and 28% in Midwest; Persistent poverty - 765 counties with 20% or more of their population living below the poverty line; Transfers-Dependent - 381 counties in 1993, economies largely based on unearned income for government transfer payments (social security, unemployment insurance, Medicare, Medicaid, food stamps, government pensions, and welfare benefits), 3/5 of transfers-dependent counties also fall in persistent poverty category (TRB, 1998, A)		

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Demographics	Disabled	11 million people, 21.5% of rural population (Brown, 2004, D)	38.8 million people, 18.8% of urban population (Brown, 2004, D)	
	Elderly	18% of rural drivers are 64 or older (Hill, 1999, A)	8% or urban drivers are 64 or older (Hill, 1999, A)	
		7.8 million people, 13.8% of rural population (Brown, 2004, D)	25.6 million people, 11% or urban population (Brown, 2004, D)	
	General Characteristics	Contain greater percentages of males, whites, elderly, persons in poverty, households with income below the national median, homeowners, and car owners (TRB, 1998, A)		
	Transit Dependent	29 million or 38% in rural areas (CTA, 1994, A)	47 million or 62% of transit dependent live in urban areas (CTA, 1994, A)	76 million transit dependent nationally (CTA, 1994, A)
		32% of rural residents are classified as transportation dependent, 36% of nonmetropolitan residents are classified as transportation dependent (CTA, 1994, A)	30% of urban residents are transportation dependent (CTA, 1994, A)	
		1/4 of households without a vehicle are outside of urbanized areas (CTA, 1994, A)		
		1 in 13 rural households is transportation dependent (CTA, 1994, A)	1 in 10 of households in small and medium urbanized areas is dependent1 in 6 households in large urbanized areas is dependent (CTA, 1994, A)	
		29 million transportation dependent persons (38% of all transportation dependent) are rural residents (CTA, 1994, A)		76 million transportation dependent persons, 10.6 million households without a vehicle (CTA, 1994, A)
	Reason for Traveling	78% of trips greater than 150 miles are for pleasure (Hill, 1999, A)		
	Poverty	7.9 million people, 14.6% of rural population (Brown, 2004, D)	26 million people, 11.8% of urban population (Brown, 2004, D)	
	Average Age	Average age of rural traveler is 46 (Hill, 1999, A)	Average age of urban traveler is 40 (Hill, 1999, A)	

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Federal Support	Funding	$1.18 Billion provided to rural areas by Transportation Equity Act for the 21st Century (TEA-21) between 1998 and 2003 with an additional $456 million available to both rural and urban areas (Brown, 2004, D)		Section 5310 of Federal Transit Act provides assistance for elderly and disable through nonprofit organizations or lead agencies (available to both rural and urban areas) (Brown, 2004, D)
		Less than 10% of federal spending for public transportation goes to rural communities (RPRI, 1999, A)		
		Section 18 of the Federal Transit Act provides $133 million to rural areas; Section 18 still accounts for <3% of Federal Transit Administration budget (CTA, 1994, A)		$217.9 Billion authorized for all Federal surface transportation programs between 1998 and 2003 (USDA ERS, 2005, A)
		the majority of rural public roads (about 77%, based on mileage) are classified as local or rural minor collectors and are therefore ineligible for regular Federal Surface Transportation Program (the second largest highway aid program covered by TEA-21) funding (Brown, 1999, A)		TEA-21 guarantees that each State will receive at least a 90.5% return on the share of money it contributes to the Highway Trust Fund (Brown, 1999, A)
		TEA-21 increases 1999 funding for the main rural transit program (Section 5311) to nearly $180 million (Brown, 1999, A)		
		TEA-21 provides $2.25 billion from 1999 to 2003 for the Appalachian Development Highway System, a program that provides aid for the construction of highways and access roads in Appalachia (Brown, 1999, A)		
		Source of Operating Revenue for rural operations - State/Local=40%, Section 18=24%, Fares/Contributions=15%, Human Services Programs=14%, In-kind=2%, Other=5% (CTA, 1994, A)		Many funded under Section 5311 of the Federal Transit Act - a formula grant program (available to both rural and urban areas) (Brown, 2004, D)

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Federal Support	USDOT Programs			Transportation Equity Act for the 21st Century (TEA-21) provided $171 billion for the Nation's highways through 2003 (Brown, 1999, A)
		Rural Transportation Initiative, May 1999; Intermodal Surface Transportation Efficiency Act (ISTEA) (FHA, 2001, A)		Transportation Equity Act for the 21st Century (TEA-21); Wendell H. Ford Aviation Investment and Reform Act for the 21st Century (AIR-21) (FHA, 2001, A)
Federal Support - Section 18	Purpose	Section 18 of the Federal Transit Act, created to assist transit in "areas other than urbanized areas" (CTA, 1994, A)		
	Providers	1,162 providers, 40% of network is in Midwest and 29% is in South (CTA, 1994, A)		
		1147 providers providing service, 58% public bodies, 37% nonprofit agencies, 3% private companies, 2% tribal entities (American Indian agencies) (CTA, 1994, A)		
		.3% have no vehicles, 24% have 1 to 2 vehicles, 22% have 3 to 5 vehicles, 22% have 6 to 10 vehicles, 31% have over 10 vehicles (CTA, 1994, A)		
		26% have city/town coverage, 52% have county wide coverage, 21% have multi-county coverage, 1% have intercity only coverage (CTA, 1994, A)		
	Service	Section 18 services 773 cities with a population between 10,000 and 50,000, comprising 15% of rural population (23% in West, 17% in Midwest, 14% in South, 9% in Northeast) (CTA, 1994, A)		
		Serves 1,841 of nation's 3,095 rural counties, 53 million people or 60% of rural population (CTA, 1994, A)		
	Ridership	Females-62%, Elderly and Disabled-11%, Other Elderly-25%, Other Disabled-13%, All Other-51% (CTA, 1994, A)		

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Federal Support - Section 18	Purpose for Riding	Employment-20%; Medical-14%, Nutrition-9%, Shopping-13%, Social Services-8%, Other Personal-15%, Other-21% (CTA, 1994, A)		
	Vehicle Types	53% vans (8 to 15 seats), 21% small buses (16 to 24 seats), 9% medium buses (25 to 35 seats), 6% large buses(>35 seats), 11% other (CTA, 1994, A)		
	Handicap Accessible	40% of vehicles are equipped with wheelchair lifts or ramps (CTA, 1994, A)		
	Vehicle Age	48% of vehicles are over-aged (CTA, 1994, A)		
	Trips by Route Type	For City/Town, County-wide, Multi-county respectively: Fixed-Route- 84%, 44%, 28%; Demand Response- 14%, 31%, 46%; Subscription- 1% 18%, 23%; Other- 1%, 2%, 3% (CTA, 1994, A)		
	Total Trips	95 million trips for Section 18 (CTA, 1994, A)		

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Geography	Challenging Characteristics	Long distances between population centers (FHA, 2001, A), (Hill, 1999, A)		
		Long distances and rough terrain (Maxwell, 1996, A)		
		steep grades and mountain passes (FHA, 2001, A), (Hill, 1999, A)		
		more dramatic weather events and effects on road conditions (FHA, 2001, A), (Hill, 1999, A)		
		dispersed system with high unit costs for service delivery, operations, and maintenance (FHA, 2001, A), (Hill, 1999, A)		
		A sparse and patchy telecoms infrastructure (Hill, 1999, A)		
	Land Mass	over 80% of U.S. is rural, 41% of land in U.S. is farmland (Stamm, 2002, A)		
		83% of the nation's land is considered rural (FHA, 2001, A), (Hill, 1999, A), (TRB, 1998, A)		
		2,300 of approximately 3,000 counties are rural (FHA, 2001, A), (Hill, 1999, A)		
		nearly 3.5 million square miles covered by Section 18 of the Federal Transit Act (CTA, 1994, A)		

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Public Transportation	Availability	Public transportation is available in 60% of rural counties (USDA ERS, 2005, A), (Brown, 2004, D)		Only 4% of the nation's 4 million miles of roads are now served by transit, either through buses or parallel train lines (STPP, 2002, A)
		40% of rural counties are not served, 28% have limited services (<25 trips /year/carless household) (Brown, 2004, D), (RPRI, 1999, A)		
		38% of rural residents live in areas without any public transportation (FHA, 2001, A), (Hill, 1999, A)		
		28% of rural residents live in areas with negligible service (Hill, 1999, A)		
		lower than in urban areas (Maxwell, 1996, A)		
		75.5 million rural residents (93% of the 82.4 million total rural residents) live within the coverage area of at least one of the four intercity public transportation modes (air, bus, rail, ferry) with 3/4 of these residents having access to more than one mode (BTS, 2005, B)		
	Number of People Served	Nonmetro Population: 20.1 million people unserved; 14.9 million people have minimal service (<=25 trips/carless household); 7.4 million people have average service (25 to 50 trips/carless household); 11.1 million people have above average service (>=50 trips/carless household) (CTA, 1994, A)		
	Number of Systems	1,200 transportation systems in rural America (Brown, 2004, D), (Maxwell, 1996, A)		
		1,600 local (unspecific whether this is rural or entire nation) agencies provide rural and public transportation services using 10,000 vehicles (mostly buses and vans) (FHA, 2001, A)		
	Benefit/Cost Ratio	3.1 to 1 - for every additional dollar spent on transit, rural areas derive $3.1 in benefits (Brown, 2004, D)		

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Public Transportation	Public/Private/Nonprofit Providers	60% of rural providers are public agencies, 1/3 nonprofit groups, and <5% are private companies or tribal entities (USDA ERS, 2005, A), (Brown, 2004, D)		
	Reasonable Coverage	<= 25 miles of bus, rail or small airport; <= 75 miles from medium and large hub airports (BTS, 2005, B)		
	Rides per Carless Household	All Rural Areas- 38 rides per carless household; Rural Areas: Northeast - 34, Midwest - 49, South - 24, West - 84 (CTA, 1994, A)	Large-urban - 1,223; Medium urban - 445; Small-urban - 231 (CTA, 1994, A)	
	Scope of systems	2/3 of rural systems operate in a single county, 1/4 of rural systems operate in multi-county areas (USDA ERS, 2005, A), (Brown, 2004, D)		
	Usage	.5% of nonmetro residents use transit services as their primary means to get to work (Brown, 2004, D)		
	Types of Routes	Some fixed-route and fix-ed route with deviation systems, demand-response systems are more common than in urban areas (Maxwell, 1996, A)		
	Primary Purpose	To provide services to transit-dependent groups (Maxwell, 1996, A)	To reduce traffic congestion (Maxwell, 1996, A)	
	Typical Users	Rural Public Transportation Users; Female - 62%, Elderly - 31%, Disabled - 23% (USDA ERS, 2005, A)		

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Rail	Major Passenger Rail Carriers			Amtrak and the Alaska Railroad (BTS, 2005, B)
				Amtrak is the sole intercity U.S. passenger rail carrier in the continental U.S. (AAR, 2006, C)
		180 destinations served by Amtrak are in nonmetro counties (Brown, 1997, E)		Amtrak's national passenger rail network stretches 24,000 miles across 45 states and serves approximately 530 communities (Brown, 1997, E)
	Passenger Rail Availability	almost 6 in 10 live outside service area of rural rail; for people for which passenger rail is available, <1% have access to only rail; <200 nonmetro areas served (USDA ERS, 2005, A)		Amtrak serves 520 locations and the Alaska Railroad serves 20 locations (BTS, 2005, B)
		34.6 million rural residents (42% of rural population) live within coverage area of Amtrak and the Alaska Railroad (BTS, 2005, B)		8.3% of households surveyed have subway service availability (STPP, 2002, A)
		Amtrak - 24,000 miles across 45 states serving 530 communities, 180 destinations in nonmetropolitan communities, provides coverage to 10% of locations with intercity bus service (FHA, 2001, A)		
	Freight Carrying Railroads Types			Class I railroads account for 70% of the industry's mileage operated, 89% of its employees, and 93% of its freight revenue (AAR, 2006, C)
				Regional railroads are linehaul railroads with at least 350 route miles (AAR, 2006, C)
				Local linehaul carriers operate less than 350 miles and earn less than $40 million per year (AAR, 2006, C)
				Switching and Terminal (S&T) carriers are railroads than primarily provide switching and/or terminal services (AAR, 2006, C)

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Rail	Rail Freight Transport			558 common carrier freight railroads (AAR, 2006, C), (AAR, 2004, A)
				Well over 90% of U.S. freight railroads are privately-owned and operated (AAR, 2006, C)
				Major U.S. freight railroads receive little appreciable government funding (AAR, 2006, C)
				Coal, used to generate electricity, accounted for 43% of tonnage and 20% of revenue for Class I railroads in 2004 (AAR, 2006, C)
				140, 806 miles of operate railroads (AAR, 2004, A)
				31,323,652 carloads of freight originated (AAR, 2004, A)
				1,991,825,148 tons of freight originated (AAR, 2004, A)
				Employs 176,899 workers in rail freight and 250,752 total rail workers (AAR, 2004, A)
		45% increase from 1990 to 2001 (USDA ERS, 2005, A)		
		19,660 miles of regional freight railroads; 27,500 miles of local freight railroads; move 40% of intercity freight; move 70% of motor vehicles shipped from manufacturing; move 65% of nation's coal used to generate 56% of electricity; move 40% of nation's grain and farm products (FHA, 2001, A)		
		Freight railroads move 42% of our nation's freight (measured in ton-miles) (AAR, 2006, C)		
		Union Pacific is the largest rail freight company in the U.S. (Brown, 2002, C)		

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Rail	Class I Railroads			in 2005, Class I railways were the BNSF Railway, CSX Transportation, Grand Trunk Corporation, Kansas City Southern Railway, Norfolk Southern Combined Railroad Subsidiaries, Soo Line Railroad, and Union Pacific Railroad (AAR, 2006, B)
				in 2004, Class I railroads operated 121,400 miles (97,662 miles not including trackage rights) of railroad (AAR, 2006, B)
				in 2004, Class I railroads had 22,015 locomotives and 473,773 freight cars in service (AAR, 2006, B)
				in 2004, 30.09 million carloads originated and 1.844 billion tons originated producing 1.663 trillion ton miles (AAR, 2006, B)
	Hazardous Materials	Railroads transport around 1.8 million carloads of hazardous materials each year (AAR, 2006, D)		

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Roads	Bridge Condition	Off-system (local) bridges have deficiency rates over twice that of their on-system (federal) counterparts (STPP, 2003, B)		83,000 bridges (14%) are structurally deficient (STPP, 2003, B)
		Of the 456,000 rural bridges, 26% were deficient in 2003 (USDA ERS, 2005, A)		
		>450,000 rural bridges, nearly half the rural bridges longer than 20 feet are structurally deficient (FHA, 2001, A)		
		1/5 of rural bridges are deficient (FHA, 2002, B)		
		nearly 40% of rural bridges maintained by counties and towns have restrictions posted or are closed (USDA, 1996, B)		
		According to survey, 55.3% of 203,490 bridges under the responsibility of rural county and town highway administrators are open, 5.2% are open but should be posted (restricted by weight limits), 38.1% are posted, and 1.4% are closed (USDA, 1996, B)		
		in West, 78.3% of bridges of length >= 20 feet that are under the responsibility of rural and county and town highway administrators are open while 41.1% in South are open (USDA, 1996, B)		
		nearly 1/2 of bridges >= 20 feet that are maintained by counties and towns are not in good condition (USDA, 1996, B)		
		69.2% of county bridges < 20 feet met minimum tolerable condition, 19.9% were in intolerable condition or worse (USDA, 1996, A)		
		Town bridges < 20 feet had 62.6% reported as meeting minimum tolerable condition or worse and 26.5 % were in intolerable condition (USDA, 1996, B)		

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Roads	Bridge Condition	70.7% of county bridges >= 20 feet and 81.8% of town bridges >= 20 feet meet minimum tolerable limits to be left in place as is; 29.3% of county and 18.2 % of town bridges >=20 feet were rated as intolerable, from National Bridge Inventory (USDA, 1996, B)		
		nearly 45% of local bridges are rated as inadequate (Brown, 1999, A)		
	Bridge Type	16.2% of local bridges >= 20 feet were timber bridges, with 50.7% of timber bridges being located in the South (USDA, 1996, B)		
	Bridge Responsibility	203,490 bridges of length 20 feet and longer are under prime responsibility of county and town highway administrators (USDA, 1996, B)		
	Road Condition	<14% of rural roads were in poor or mediocre condition in 2002 (USDA ERS, 2005, A)	~29% of urban roads were in poor or mediocre condition in 2002 (USDA ERS, 2005, A)	
		40% of county roads are inadequate for current travel (FHA, 2001, A)	68.4% of the nation's urban and suburban roads are in less than good condition (STPP, 2003, C)	50% of roadway miles remain in less than good condition (STOP, 2003, C)
		1/3 of rural interstates and other rural arterials are in poor or mediocre condition (FHA, 2002, B)		
		7.3% of county road mileage and 8.5% of town mileage was rated 9 (new or perfect) while 1.4% of county mileage and 2.2% of town mileage was listed as closed and awaiting repairs (USDA, 1996, C)		
		34.1% of county mileage and 1/3 of town mileage were rated as having limited failures and a barely adequate surface or worse (USDA, 1996, C)		

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Roads	Road Condition	Based on 739 miles in the average county, 86 miles need resurfacing, 28 miles need widening and resurfacing, and 16 miles of new construction is required to accommodate population growth (USDA, 1996, C)		
		47.8% of county mileage and 42.5% of town mileage was rated as having less than an adequate surface with normal maintenance (USDA, 1996, C)		
		nearly 50% of county roads are rated as inadequate (Brown, 1999, A)		
	Road Freight Transport	43% increase for intercity truck shipments between 1990 and 2001 (USDA ERS, 2005, A)		
		Vast majority of manufactured goods are shipped into and out of states by truck (FHA, 2001, A)		
		move 28% of nation's intercity freight (FHA, 2001, A)		
	Road Coverage	Rural roads comprise 80% of national road miles and carry 40% of vehicle miles traveled (FHA, 2001, A), (Hill, 1999, A)		approximately 920,000 miles of roads of the 3.9 million miles of roads are eligible for Federal funding (Brown, 1999, A)
		Approximately 4 million miles of rural roads (Hill, 1999, A)		
		3.1 million rural road miles (FHA, 2001, A), (RPRI, 1999, A)		3.9 million road miles of US public highway network (RPRI, 1999, A)
		50% of rural roads are paved and 90% are 2-lane or less (FHA, 2001, A)		
		81% of US public highway miles pass through rural communities (NADO, 2004, A)		
	Road Responsibility	City/county governments are responsible for 95% of unpaved and 55% of paved roads (FHA, 2001, A), (Hill, 1999, A)		
		States responsible for rural transit systems (FHA, 2002, B)		States responsible for 10 to 20% of roads in their state (FHA, 2002, B)

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Roads	Road Types	48.1% of the road mileage maintained by counties and 34.0% of town mileage has either an earth or loose aggregate surface (USDA, 1996, C)		
		90% of rural roads are 2-lane or less (Hill, 1999, A)		
		Only 50% of rural roads are paved (Hill, 1999, A)		
		Most two lane roads are narrow and some are gravel and dirt roads (Maxwell, 1996, A)		
		earth, gravel (loose aggregate), low bituminous (oil and chip), high bituminous (hot mix), paved, or concrete (USDA, 1996, C)		

Rural vs. Urban Transportation Network Comparison Matrix				
Category	**Characteristic**	**Rural Transportation Network**	**Urban Transportation Network**	**Entire Transportation Network**
Water	Dams			170 lock sites and 210 lock chambers nationwide (Brown, 2002, C)
	Inland Waterway System Stats			Total: 26,000 miles, 275 locks, >9,100 commercial waterway facilities (USDA ERS, 2005, A)
				25,000 total miles of navigable inland waterways (Brown, 2002, C)
	Hydroelectric Dams			50 nationwide (Brown, 2002, C)
	Major Interstate Ferry Carriers			Alaska Marine Highway System (BTS, 2005, B)
	Freight			moves 14% of nation's intercity freight (FHA, 2001, A)
	Ports			the nation has over 300 ports that have about 3,700 cargo and passenger terminals (USGAO, 2005, A)
	International Trade			More than 95% of the nation's non-North American foreign trade arrives by ship (USGAO, 2005, A)
	Availability			41 states, 16 state capitals, and all states east of the Mississippi River are served by commercially navigable waterways (FHA, 2001, A)
State/Regional Statistics		see www.ctaa.org/ntrc.rtap.pubs/atlas (CTA, 1995, B)		
Emergency Response		Slower emergency response - 1 1/2 times that of urban response (Hill, 1999, A)		
		5% of crashes unreported for more than 30 minutes (Hill, 1999, A)		

APPENDIX 4 – Methodology Matrix

Table 40. Methodology Matrix

6 Questions	A Risk Assessment Methodology for Critical Transportation Infrastructure (11)	A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection (1)	Deterrence, Protection and Preparation (6)	Holistic Strategy for Urban Security (3)
1. What can go wrong?	- Phase I Scenario Identification - Phase II Decision maker Filtering	- Step 1 Asset Identification - Step 2 Threat Identification		
2. What is the likelihood?	- Phase III Qualitative Filtering	- Step 2 Vulnerability Identification		
3. What are the consequences?	- Phase IV Multi-criteria Evaluation - Phase V Quantitative Ranking	- Step 3 Key Asset Selection		
4. What can be done?	- Phase VI Risk Management	- Step 4 Countermeasures	- Key Research and Technology Needs - Layered Defenses - Emphasis on Adaptability, Dual Use, and Exploitation of Existing Capabilities - Broad-Based, Unconventional Thinking on Threats and Responses	- Physical Protection Strategies - A Rational Basis for Urban Security
5. What are the trade-offs?		- Step 5 Cost Estimation		
6. What are the impacts to future options?		- Step 6 Security Operational Planning		

6 Questions	Protecting Public Surface Transportation against Terrorism and Serious Crime: An Executive Overview (5)	Roadmap for Modeling Risks of Terrorism to the Homeland (10)	Communication of Threats: A guide (7)	National Needs Assessment for Ensuring Transportation Infrastructure Security (8)
1. What can go wrong?		- Identifying Risks by HHM		- Threat Assumptions
2. What is the likelihood?				- Bridge and Tunnel Vulnerabilities
3. What are the consequences?				
4. What can be done?	- Station and Vehicle Design - The Security Force, Security Technology		- Surveys for Security	- Countermeasure program, program for DOT Emergency Response
5. What are the trade-offs?				
6. What are the impacts to future options?				

6 Questions	Reducing Security Risk for Transportation Management Centers (TMCs) (20)	Lessons Learned from Utility and Infrastructure Vulnerability Assessments (24)	Recommendations for Bridge and Tunnel Security (22)	Protection from extreme events: Using a socio-technological approach to evaluate policy options (25)
1. What can go wrong?	- Asset Identification - Development of Scenarios	- Planning	- Determine Threats	
2. What is the likelihood?	- Target Attractiveness - Vulnerability Assessment	- Threat Assessment		
3. What are the consequences?	- Consequence Assessment	- Facility Characterization	- Determine the consequence	
4. What can be done?	- Countermeasure Development - Mitigation	- Security System Effectiveness - Risk Analysis - Proposed Upgrades	- Mitigation	- Judgment Analysis - Taylor-Russell Diagram - The System Dynamics Model
5. What are the trade-offs?			- Estimate cost of mitigation	
6. What are the impacts to future options?				

6 Questions	Effects of catastrophic Events on Transportation System Management and Operations (36)	Guide to Establishing an Information System Protection Program (30)	Guidance for Transportation Agencies on Managing Sensitive Information (31)	Critical Foundations Protecting Americas Infrastructures (34)
1. What can go wrong?		- Assess risk and determine needs		
2. What is the likelihood?				- Policy Formulation
3. What are the consequences?				
4. What can be done?	- Plans of Actions for Emergency Preparedness - Priorities in case of emergency	- Establish a central management focus - Implement appropriate policies and related controls - Promote awareness - Monitor and evaluate policy and control effectiveness	- Five step protection plan to manage sensitive information security	- Prevention and Mitigation - Information Sharing and Analysis - Counteraction (incident management) - Response, Restoration, and Reconstitution (consequence management)
5. What are the trade-offs?				
6. What are the impacts to future options?				

6 Questions	Confronting the Risks of Terrorism: Making the Right Decisions (39)	Improving Surface Transportation Security: A Research and Development Strategy (4)
1. What can go wrong?	- Intelligence gathering	- Identification of assets - Screening of the criticality of assets
2. What is the likelihood?	- Information processing	- Assessment of the vulnerability of assets in each scenario
3. What are the consequences?	- Identification, analysis, and development of the most likely terrorist attack scenarios, including their consequences	- Assessment of the impact of an attack in each scenario - Categorization of scenarios by likelihood of loss and severity of impact
4. What can be done?	- Implementation of actions	- Review of consistency - Identification of potential countermeasures
5. What are the trade-offs?	- Decision making on actions to combat terrorist attacks	
6. What are the impacts to future options?		

APPENDIX 5 – Summary of Methodologies

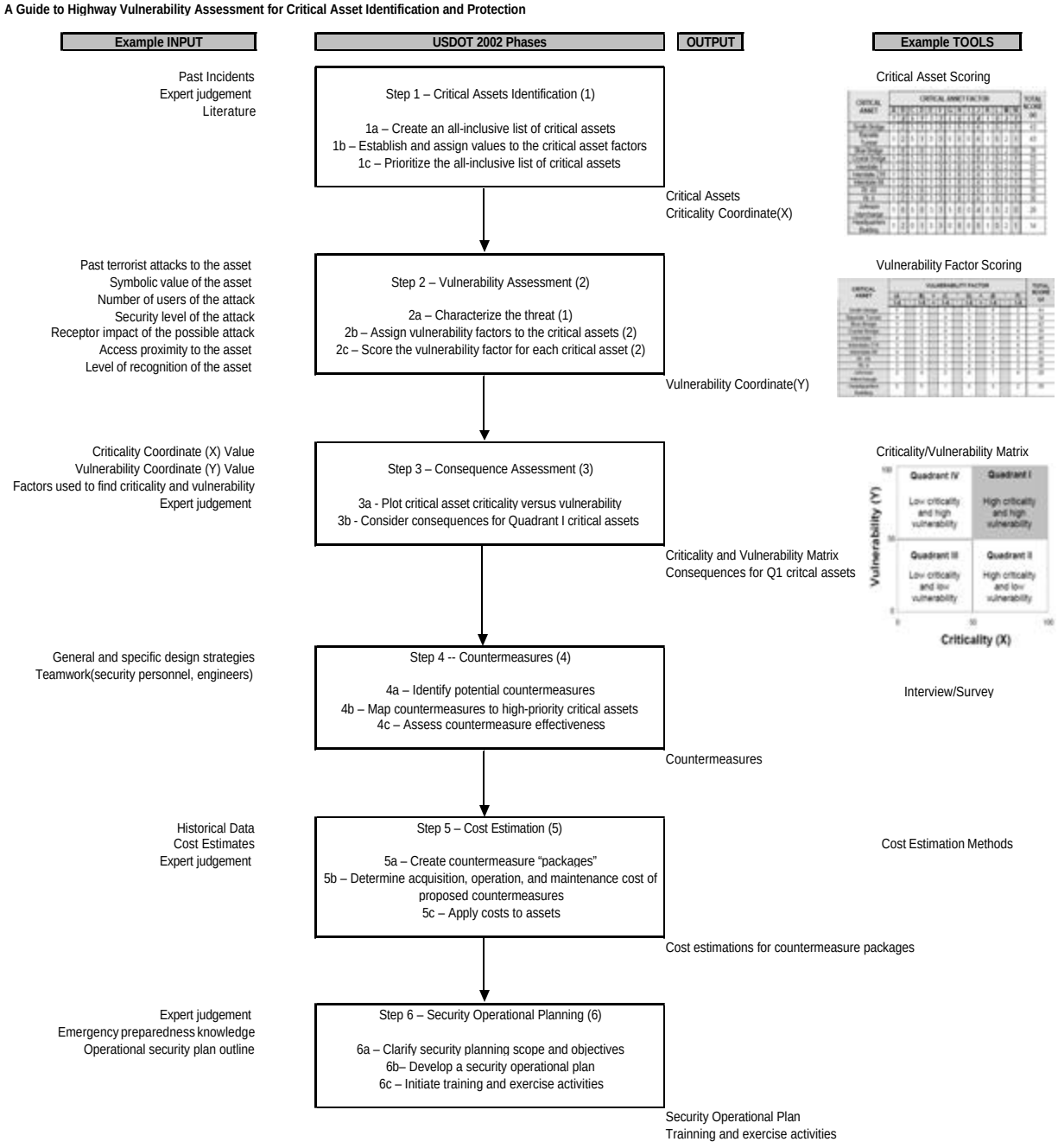

Figure 8. A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection

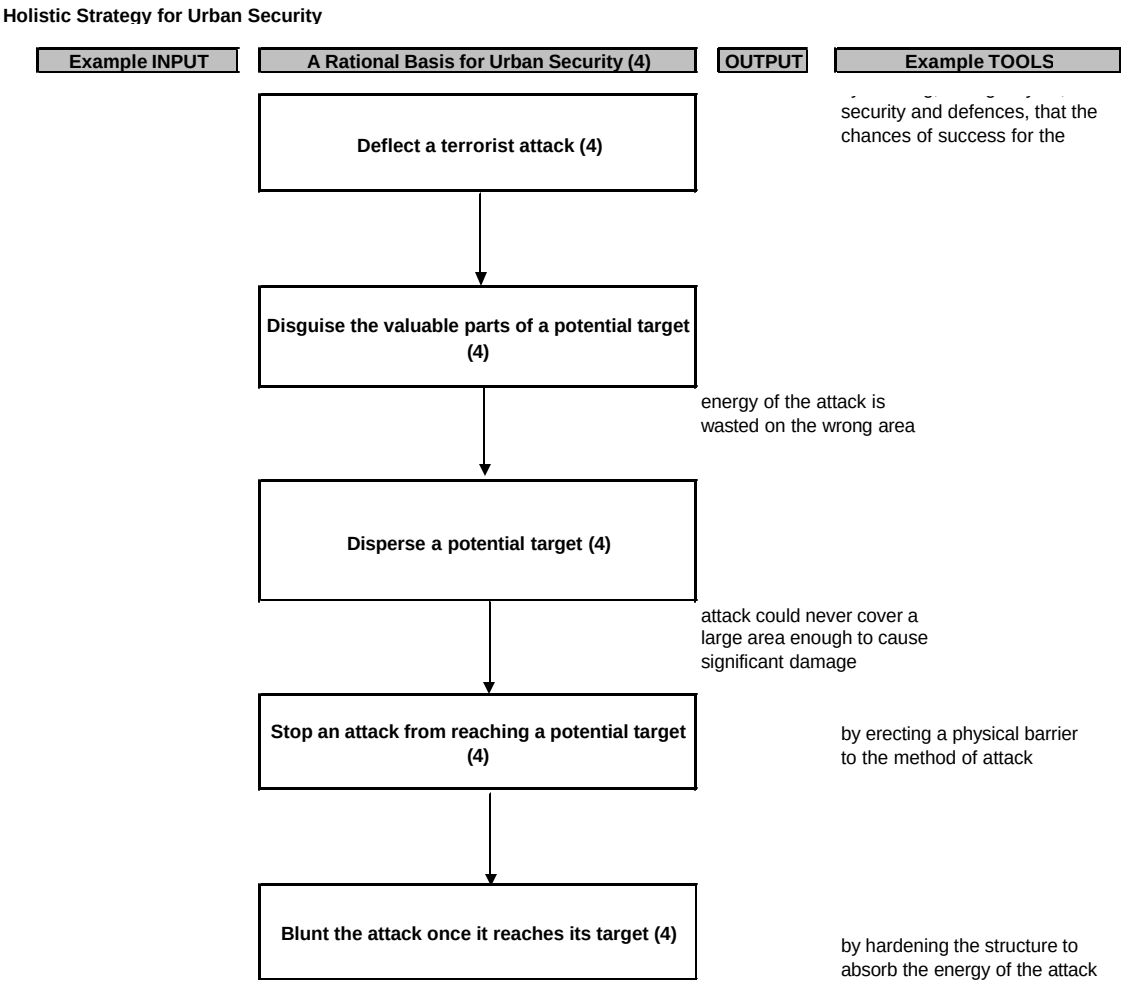

Figure 9. Holistic Strategy for Urban Security

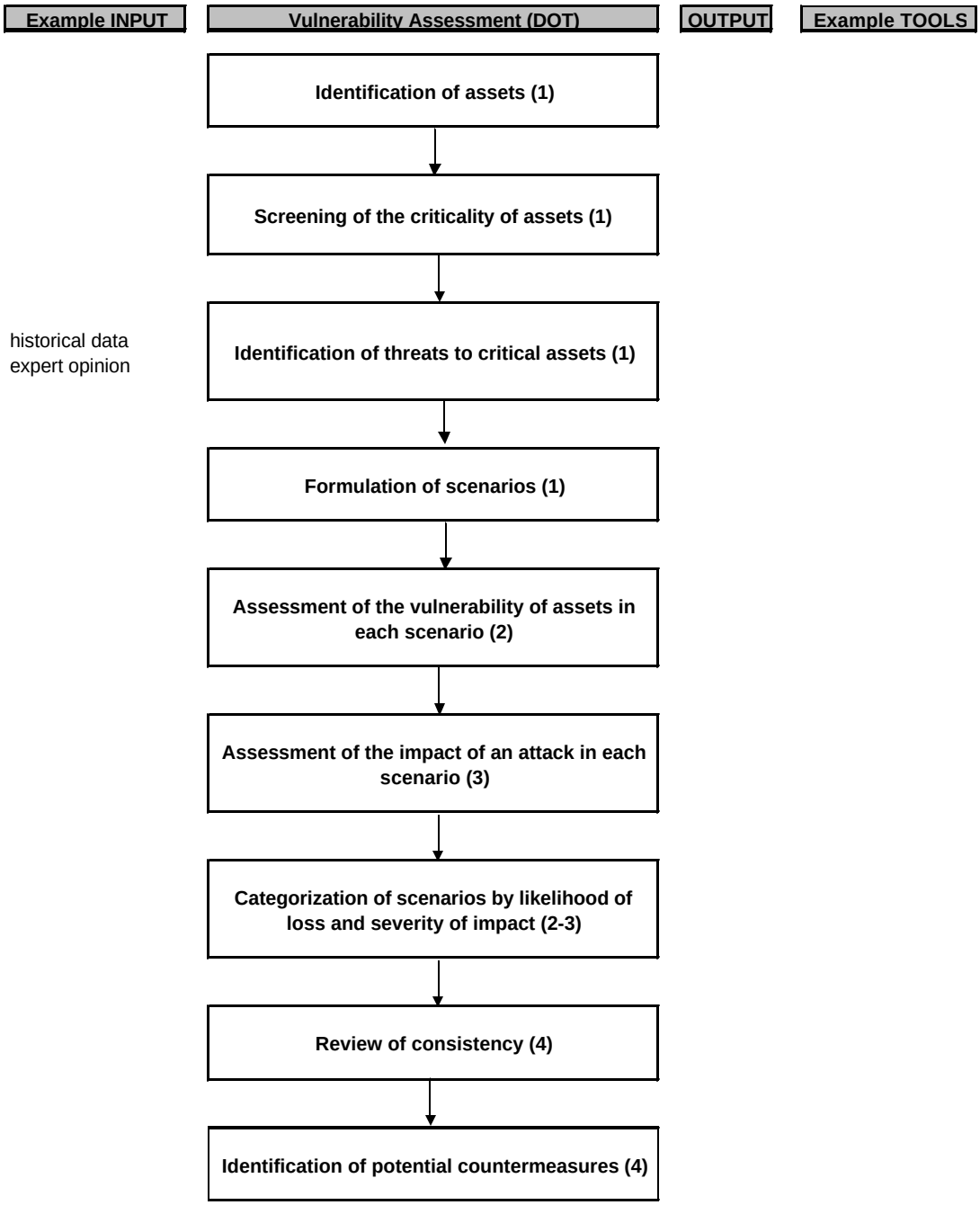

Figure 10. Improving Surface Transportation Security: A Research and Development Strategy

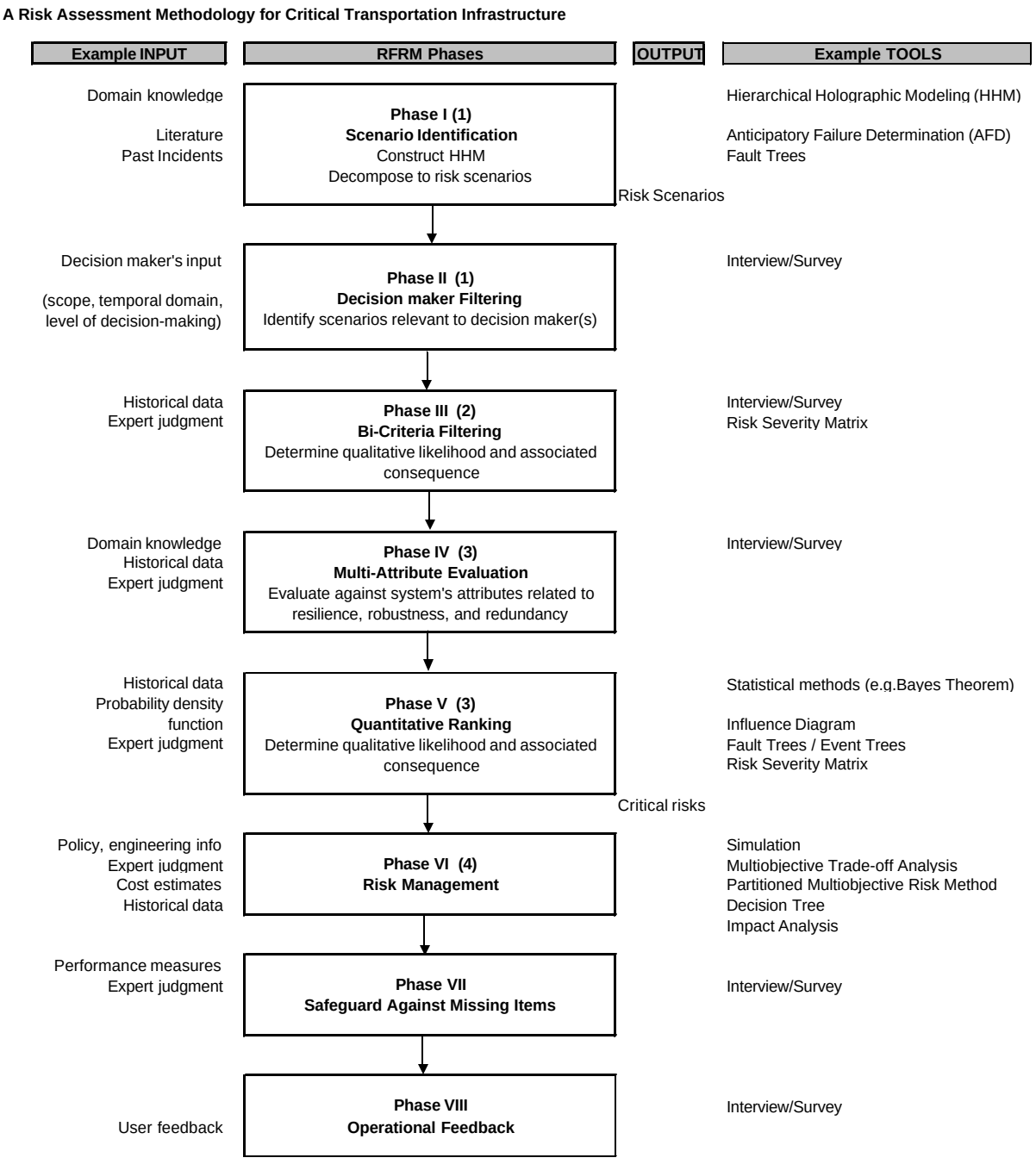

Figure 11. A Risk Assessment Methodology for Critical Transportation Infrastructure

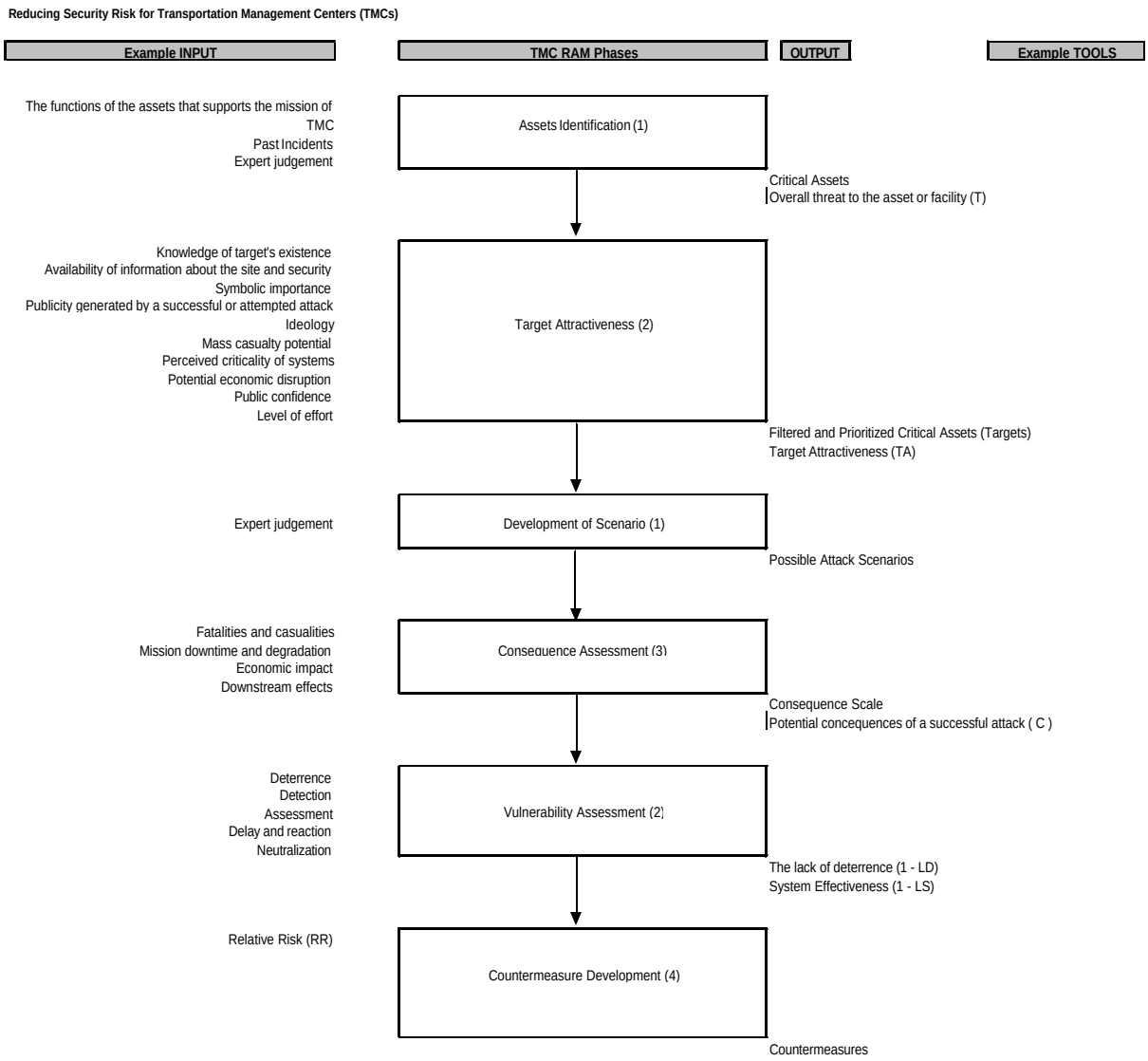

Figure 12. Reducing Security Risk for Transportation Management Centers (TMCs)

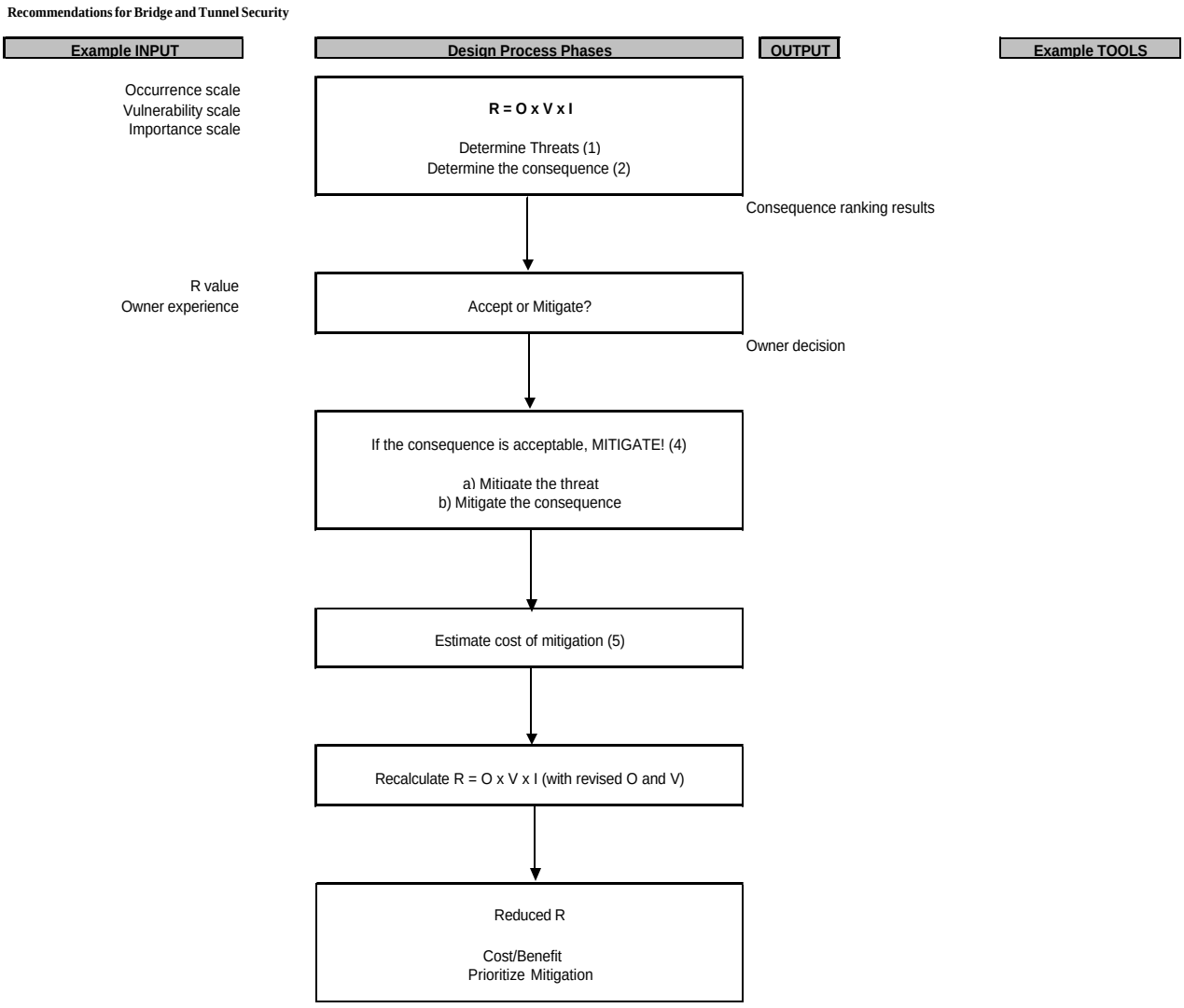

Figure 13. Recommendations for Bridge and Tunnel Security

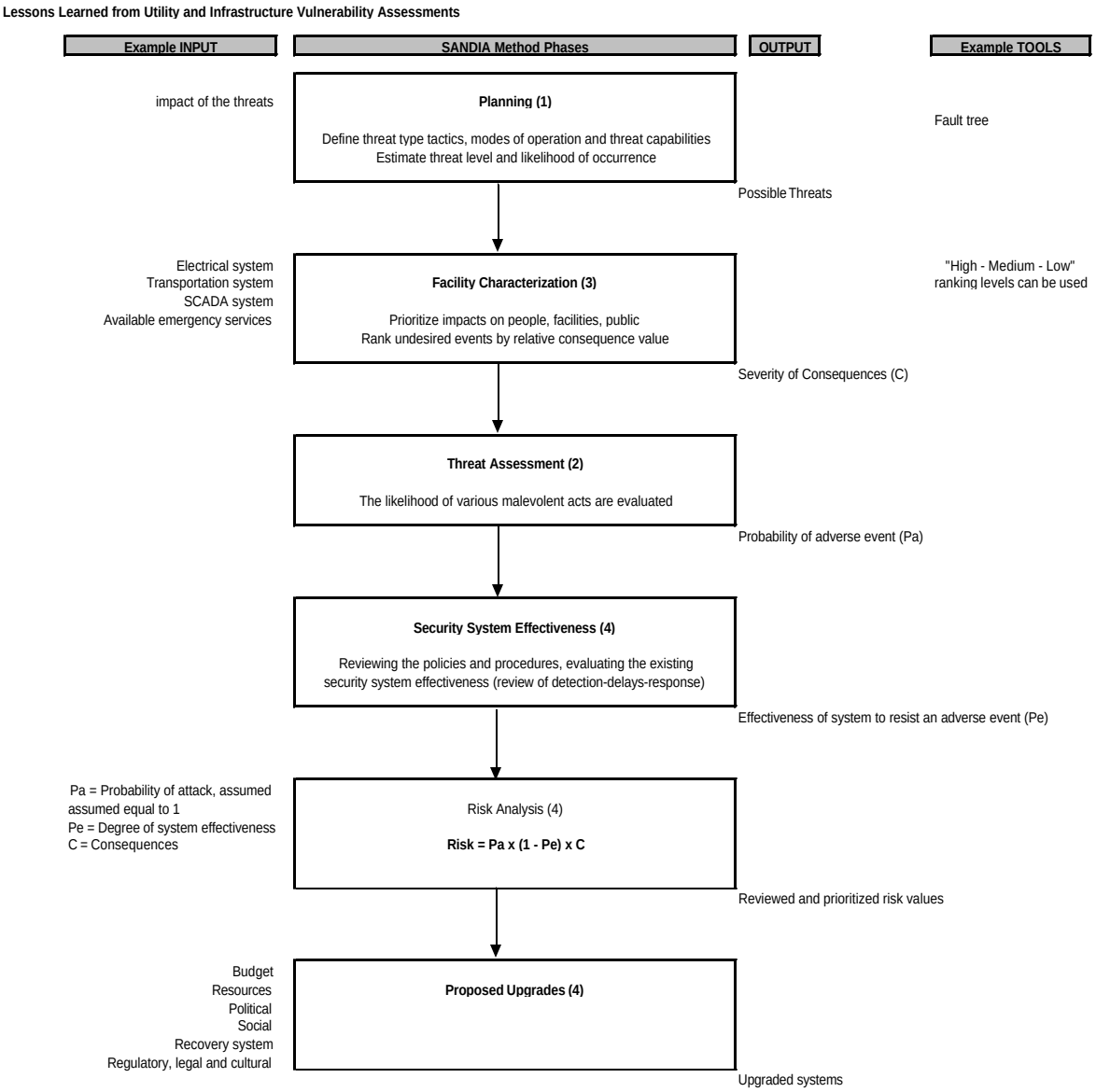

Figure 14. Lessons Learned from Utility and Infrastructure Vulnerability Assessments

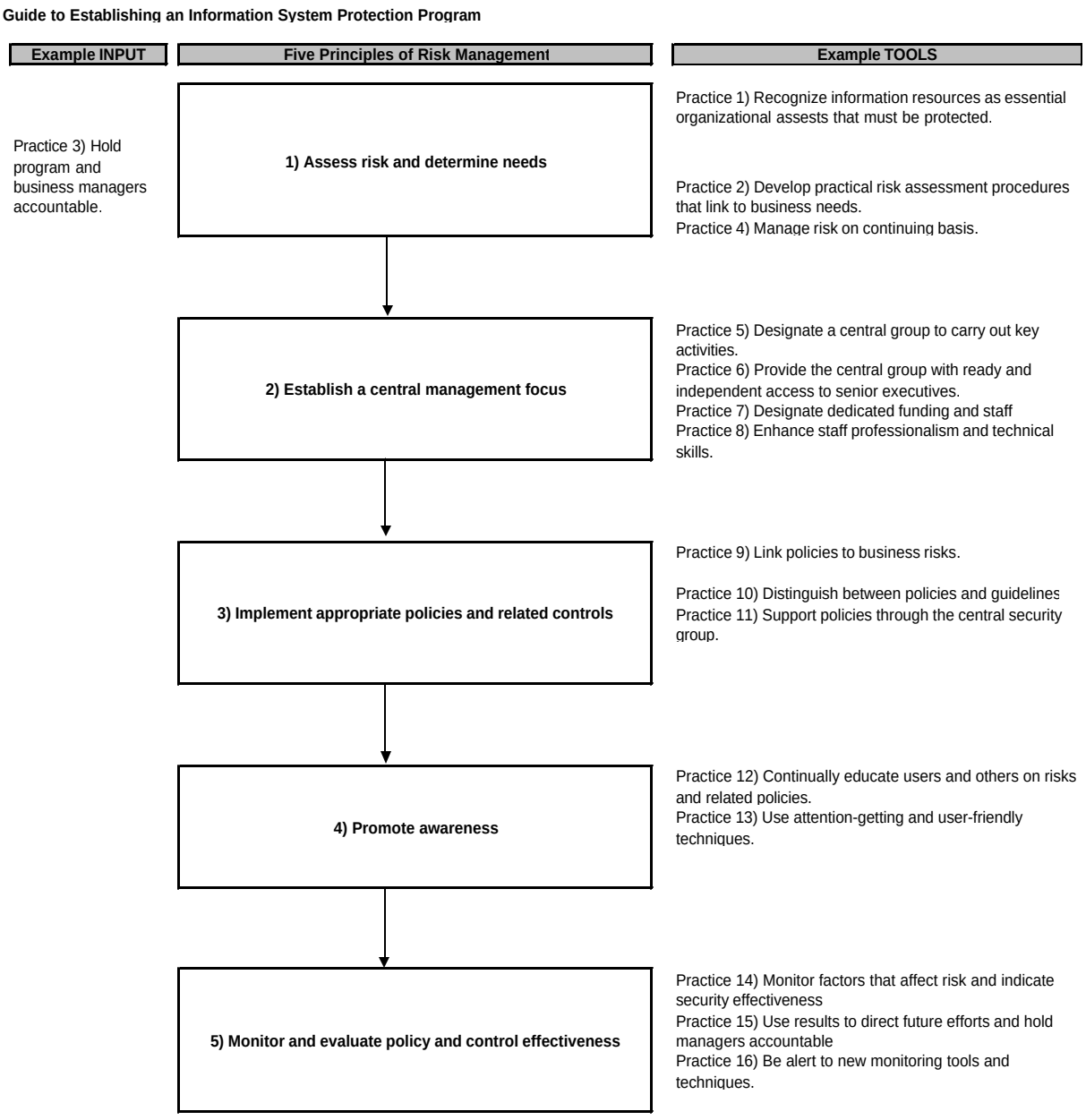

Figure 15. Guide to Establishing an Information System Protection Program

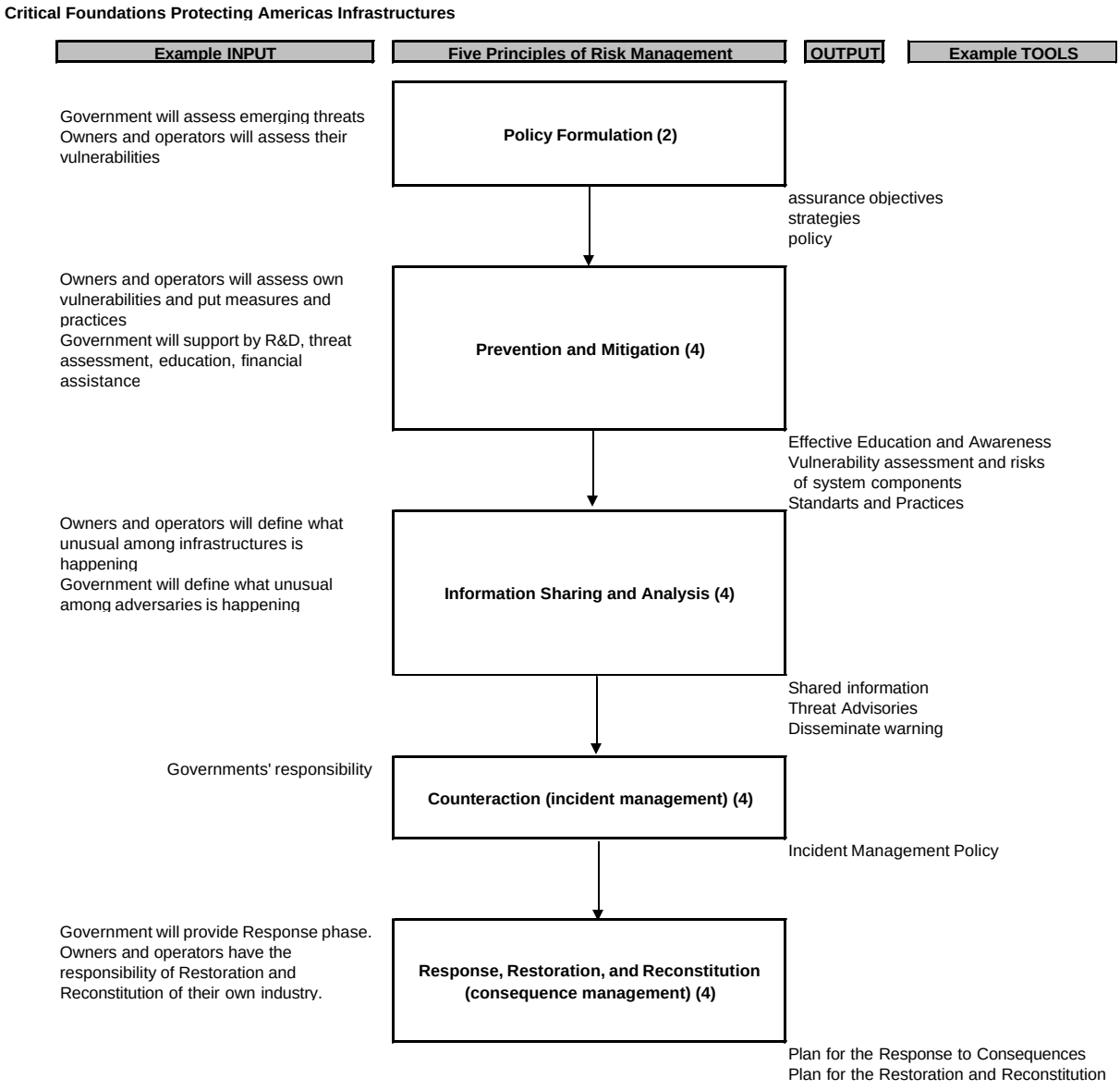

Figure 16. Critical Foundations Protecting Americas Infrastructures

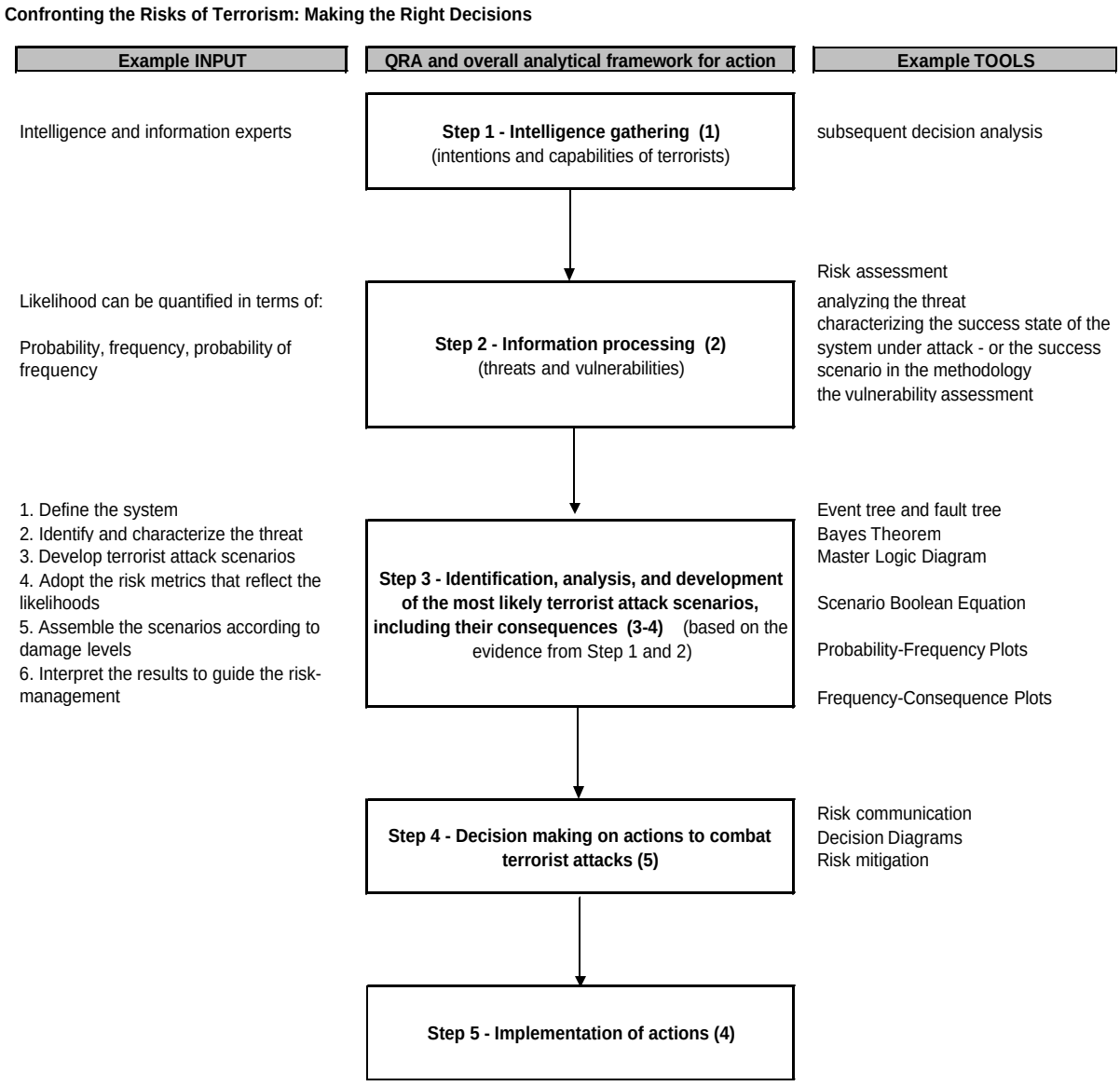

Figure 17. Confronting the Risks of Terrorism: Making the Right Decisions

APPENDIX 6 – Approach Differences for Methodologies

Table 41. Approach Differences for Methodologies

Question 1. What can go wrong?

A Risk Assessment Methodology for Critical Transportation Infrastructure (11)	• HHM method used to identify scenarios. From risk head topics to subtopics and risk scenarios • For each scenario target, consequence and duration are identified. • The scenarios are eliminated according to three characteristics given in the Phase II. • Phase I and Phase II are not quantitative approach.
A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection (1)	• The methodology offered is for highway vulnerability. • It uses a quantitative scale prioritize the critical assets in terms of the critical factors. • There is not any quantitative approach to characterize the threat. • Threat assumptions are used to assign vulnerabilities to the assets.
Roadmap for Modeling Risks of Terrorism to the Homeland (10)	• HHM is suggested in that paper. • Five levels of analysis is suggested which are five state variables to be considered to develop risks in HHM. • Not quantitative technique.
National Needs Assessment for Ensuring Transportation Infrastructure Security (8)	• The characteristics of threats and key assumptions are explained. • Not quantitative. • About transportation infrastructure threats
Reducing Security Risk for Transportation Management Centers (TMCs) (20)	• It is a method for Transportation Management Centers. • A quantitative approach is not mentioned, but the resulting value will be TA in the RR formula. • Scenarios should include type of attack, the weapon employed, the route used by adversary
Lessons Learned from Utility and Infrastructure Vulnerability Assessments (24)	• Fault tree is suggested in order to calculate the risks. • No example • Quantitative method • Used for risks of Infrastructure
Recommendations for Bridge and Tunnel Security (22)	• Not quantitative • Used for bridges and tunnel security
Guide to Establishing an Information System Protection Program (30)	• Short description • General method, but used for information security
Confronting the Risks of Terrorism: Making the Right Decisions (39)	• Which threats are considered the most serious? • What is the supporting evidence for those threats? • The answers should be in the form of targets, weapons and delivery systems. (A form as an input QRA(Quantitative risk analysis))
Improving Surface Transportation Security: A Research and Development Strategy (4)	• It is about transportation security. (overall) • Examples are given • Mainly focused on attack scenarios. • Quantitative example is not given • Key assets are selected according to the loss • Eight steps and short description for overall vulnerability assessment, mainly about how to develop research and development strategy

Question 2. What is the likelihood?

A Risk Assessment Methodology for Critical Transportation Infrastructure (11)	• Each risk scenario is evaluated by likelihood and impact. • Likelihood, impact versus risk scenarios matrix is developed.
A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection (1)	• Quantitative technique • Vulnerability factors are defined and assign the critical assets • At the end every asset has a value of vulnerability
Reducing Security Risk for Transportation Management Centers (TMCs) (20)	• Factors are given that will increase target attractiveness • No example is given • The resulting value will be TA in RR formula. • Factors to assess vulnerability is defined • The resulting values from vulnerability assessment will be (1 – LD) and (1 – LS) in RR formula
Lessons Learned from Utility and Infrastructure Vulnerability Assessments (24)	• Quantitative result • Probability of adverse event is calculated • No example
Critical Foundations Protecting Americas Infrastructures (34)	• Not quantitative • No example
Confronting the Risks of Terrorism: Making the Right Decisions (39)	• Which threats are considered the most serious? • What is the supporting evidence for those threats? The answers should be in the form of targets, weapons and delivery systems. (A form as an input QRA(Quantitative risk analysis))
Improving Surface Transportation Security: A Research and Development Strategy (4)	• It is about transportation security. (overall) • Quantitative example is not given • Factors for vulnerability assessment are not given. • Eight steps and short description for overall vulnerability assessment, mainly about how to develop research and development strategy.
National Needs Assessment for Ensuring Transportation Infrastructure Security (8)	• Not a method, some examples of vulnerabilities • Bridge and Tunnel vulnerabilities

Question 3. What are the consequences?

A Risk Assessment Methodology for Critical Transportation Infrastructure (11)	• Risk scenarios are evaluated according to the criteria defined • Likelihood is quantified as a probability in that phase.
A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection (1)	• Quantitative approach • Vulnerability versus criticality matrix is developed • Critical assets are located in that matrix
Reducing Security Risk for Transportation Management Centers (TMCs) (20)	• It is a method for Transportation Management Centers. • Potential consequences of a successful attack (C) value will be determined and used in RR formula • Consequences types are determined.
Lessons Learned from Utility and Infrastructure Vulnerability Assessments (24)	• Used for risks of Infrastructure • Consequence analysis is made by taking into account interdependencies of systems • The resulting value will be used a s value of C (severity of consequences)
Recommendations for Bridge and Tunnel Security (22)	• Consequence assessment • Not quantitative
Confronting the Risks of Terrorism: Making the Right Decisions (39)	• Quantitative method • Frequency-Consequence Plots can be used as an example tool • Probability-Frequency Plots • Scenarios are the input for that phase
Improving Surface Transportation Security: A Research and Development Strategy (4)	• It is about transportation security. (overall) • Quantitative example is not given • Eight steps and short description for overall vulnerability assessment, mainly about how to develop research and development strategy.

Question 4. What can be done?

A Risk Assessment Methodology for Critical Transportation Infrastructure (11)	• Quantitative method • Explained by examples Methods used; • Multi-objective Trade-off Analysis • Partitioned Multi-objective Risk Method • Decision Tree • Impact Analysis
A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection (1)	• Not quantitative • Identifying countermeasures and categorizing them • Measuring the effectiveness of the countermeasures subjectively
Deterrence, Protection and Preparation (6)	• Not quantitative • It is about key research and technology needs for transportation security • Short description of the method
Holistic Strategy for Urban Security (3)	• Not quantitative • Short description of the method • With the help of likelihood versus consequence matrix (according to the risk level) countermeasures are determined
Protecting Public Surface Transportation against Terrorism and Serious Crime: An Executive Overview (5)	• Not a method, some suggestions • Not quantitative • Physical and technological precautions
Communication of Threats: A guide (7)	• Not a method, a survey • Not quantitative • Survey results or suggestions coming from surveys help to develop countermeasures
National Needs Assessment for Ensuring Transportation Infrastructure Security (8)	• Not quantitative • Countermeasure types and examples are given • Mostly about bridges and tunnels
Reducing Security Risk for Transportation Management Centers (TMCs) (20)	• Not quantitative • Types of countermeasures according to the level of risks • Short description of what can be done
Lessons Learned from Utility and Infrastructure Vulnerability Assessments (24)	• Used for risks of Infrastructure • Short description of the step The resulting value will be used a s value of P_E (effectiveness of the system to resist an adverse event)
Recommendations for Bridge and Tunnel Security (22)	• Not quantitative • Examples are given
Protection from extreme events: Using a socio-technological approach to evaluate policy options (25)	• Quantitative analysis • Risk attributes are the inputs • Simulation of the model helps to decide the best choice

Guide to Establishing an Information System Protection Program (30)	• Not quantitative • Some examples and suggestion are given for what can be done
Guidance for Transportation Agencies on Managing Sensitive Information (31)	• Not quantitative
Critical Foundations Protecting Americas Infrastructures (34)	• Short description • Not quantitative
Effects of catastrophic Events on Transportation System Management and Operations (36)	• Not quantitative • Some examples and suggestion are given for what can be done
Confronting the Risks of Terrorism: Making the Right Decisions (39)	• Quantitative methods • More than 4 methods are included.
Improving Surface Transportation Security: A Research and Development Strategy (4)	• Countermeasures are discussed while deciding on R&D strategies • Eight steps and short description for overall vulnerability assessment, mainly about how to develop research and development strategy.

APPENDIX 7 - Original Asset Comparison Matrices

Table 42. Original Asset Comparison Matrices

Factor A : Ability to Provide Protection	NMA	HWY 67	Dams	EOC	RR	ER	WSI
Newport Municipal Airport	1	3	6	2	4	7	5
Highway 67	1/3	1	4	1/2	2	5	3
Dams	1/6	1/4	1	1/5	1/3	2	1/2
Emergency Operations Center	1/2	2	5	1	3	5	4
Railroad	1/4	1/2	3	1/3	1	4	2
Emergency Responders	1/7	1/5	1/2	1/5	1/4	1	1/3
Water Supply Infrastructure	1/5	1/3	2	1/4	1/2	3	1

Factor B : Relative Vulnerability to Attack	NMA	HWY 67	Dams	EOC	RR	ER	WSI
Newport Municipal Airport	1	1/3	3	4	1/2	5	2
Highway 67	3	1	5	6	2	7	4
Dams	1/3	1/5	1	2	1/4	3	1/2
Emergency Operations Center	1/4	1/6	1/2	1	1/5	2	1/3
Railroad	2	1/2	4	5	1	6	3
Emergency Responders	1/5	1/7	1/3	1/2	1/6	1	1/4
Water Supply Infrastructure	1/2	1/4	2	3	1/3	4	1

Factor C: Casualty Risk	NMA	HWY 67	Dams	EOC	RR	ER	WSI
Newport Municipal Airport	1	2	8	5	3	6	9
Highway 67	1/2	1	6	5	3	4	7
Dams	1/8	1/6	1	1/3	1/5	1/2	2
Emergency Operations Center	1/5	1/5	3	1	1/3	2	4
Railroad	1/3	1/3	5	3	1	3	6
Emergency Responders	1/6	1/4	2	1/2	1/3	1	3
Water Supply Infrastructure	1/9	1/7	1/2	1/4	1/6	1/3	1

Factor E: Replacement Cost	NMA	HWY 67	Dams	EOC	RR	ER	WSI
Newport Municipal Airport	1	3	5	6	2	7	1/2
Highway 67	1/3	1	3	4	1/2	5	1/4
Dams	1/5	1/3	1	2	1/4	3	1/6
Emergency Operations Center	1/6	1/4	1/2	1	1/5	2	1/7
Railroad	1/2	2	4	5	1	6	1/3
Emergency Responders	1/7	1/5	1/3	1/2	1/6	1	1/8
Water Supply Infrastructure	2	4	6	7	3	8	1

Factor G: Emergency Response Function	NMA	HWY 67	Dams	EOC	RR	ER	WSI
Newport Municipal Airport	1	1/2	4	1/3	3	1/4	2
Highway 67	2	1	6	1/2	5	1/3	3
Dams	1/4	1/6	1	1/7	1/2	1/8	1/3
Emergency Operations Center	3	2	7	1	6	1/2	4
Railroad	1/3	1/5	2	1/6	1	1/7	1/2
Emergency Responders	4	3	8	2	7	1	5
Water Supply Infrastructure	1/2	1/3	3	1/4	2	1/5	1

Factor J: Available Alternate	NMA	HWY 67	Dams	EOC	RR	ER	WSI
Newport Municipal Airport	1	2	6	5	4	1/3	1/2
Highway 67	1/2	1	5	4	3	1/4	1/3
Dams	1/6	1/5	1	1/2	1/3	1/7	1/7
Emergency Operations Center	1/5	1/4	2	1	1/2	1/7	1/6
Railroad	1/4	1/3	3	2	1	1/6	1/5
Emergency Responders	3	4	7	7	6	1	1
Water Supply Infrastructure	2	3	7	6	5	1	1

Factor L: Economic Impact	NMA	HWY 67	Dams	EOC	RR	ER	WSI
Newport Municipal Airport	1	1/5	1	3	1/3	2	1/3
Highway 67	5	1	6	7	3	7	1
Dams	1	1/6	1	3	1/3	2	1/5
Emergency Operations Center	1/3	1/7	1/3	1	1/5	1/2	1/7
Railroad	3	1/3	3	5	1	4	1/2
Emergency Responders	1/2	1/7	1/2	2	1/4	1	1/6
Water Supply Infrastructure	3	1	5	7	2	6	1

Factor M: Functional Importance	NMA	HWY 67	Dams	EOC	RR	ER	WSI
Newport Municipal Airport	1	1/4	1/2	4	2	3	1/5
Highway 67	4	1	3	7	5	6	1/2
Dams	2	1/3	1	5	3	4	1/4
Emergency Operations Center	1/4	1/7	1/5	1	1/3	1/2	1/7
Railroad	1/2	1/5	1/3	3	1	2	1/6
Emergency Responders	1/3	1/6	1/4	2	1/2	1	1/7
Water Supply Infrastructure	5	2	4	7	6	7	1

Factor P: Attendance/Users	NMA	HWY 67	Dams	EOC	RR	ER	WSI
Newport Municipal Airport	1	1/5	1/2	4	3	2	1/5
Highway 67	5	1	4	7	7	6	1
Dams	2	1/4	1	5	4	3	1/4
Emergency Operations Center	1/4	1/7	1/5	1	1/2	1/3	1/7
Railroad	1/3	1/7	1/4	2	1	1/2	1/7
Emergency Responders	1/2	1/6	1/3	3	2	1	1/7
Water Supply Infrastructure	5	1	4	7	7	7	1

Factor Q: Access Proximity	NMA	HWY 67	Dams	EOC	RR	ER	WSI
Newport Municipal Airport	1	1	3	2	1	4	5
Highway 67	1	1	4	3	2	5	6
Dams	1/3	1/4	1	1	1/2	1	2
Emergency Operations Center	1/2	1/3	1	1	1	2	3
Railroad	1	1/2	2	1	1	3	4
Emergency Responders	1/4	1/5	1	1/2	1/3	1	1
Water Supply Infrastructure	1/5	1/6	1/2	1/3	1/4	1	1

Factor T: Volume	NMA	HWY 67	Dams	EOC	RR	ER	WSI
Newport Municipal Airport	1	1/7	1	1	1/7	1	1
Highway 67	6	1	6	6	1/2	6	6
Dams	1	1/6	1	1	1/7	1	1
Emergency Operations Center	1	1/6	1	1	1/7	1	1
Railroad	7	2	7	7	1	7	7
Emergency Responders	1	1/6	1	1	1/7	1	1
Water Supply Infrastructure	1	1/6	1	1	1/7	1	1