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IDENTIFICATION AND EVALUATION OF CRITICAL URBAN AND RURAL FREIGHT CORRIDORS IN THE STATE OF FLORIDA

Final Report

by

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EXECUTIVE SUMMARY

Efficient freight mobility plays a major role in the economy, and its performance is closely related to the quality of the transportation system. Requirements for funding transportation infrastructure projects often do not specify the analytical tools planners should use to request funding. Critical Urban and Rural Freight Corridors are sections of the National Highway Freight Network providing critical connectivity of goods and must have improved system performance. This research study offers a method for identifying these corridors considering temporal and spatial inputs. For this end, a multi-criteria spatial decision support system (MC-SDSS) was developed. This framework attributes a score to highway corridors (links) based on policy eligibility and prioritization. We apply the Analytic Hierarchy Process (AHP) to structure the problem and consider different stakeholder preferences and available data. The product of this study is a tool for decision-makers to optimize the selection of critical freight corridors and analyze alternatives. It also offers flexibility to manipulate the framework to meet various agency goals, using the State of Florida as a case study.

Overall, the lack of a specific methodology for identifying Critical Freight Corridors is what motivates this study. Since every State has a maximum CUFC and CRFC mileage, an efficient resources allocation procedure would result in great benefits for the agency applying the method and to the overall economy. This research study offers a method for identifying the critical freight corridors considering temporal and spatial data inputs.

We develop a method of assessing the selection of CUFC and CRFC alternatives. For this end, we propose a multi-criteria spatial decision support system (MC-SDSS) for structuring the process of designating CUFC and CRFC corridors. Additionally, the Analytic Hierarchy Process (AHP) is used to structure corridor criteria defined by the federal agency.
Although the focus is on the current CUFC and CRFC corridor selection process in Florida, the MC-SDSS and AHP-aided procedure is intended to facilitate the transportation decision-making process generically, reflective of CUFC and CRFC designation guidelines, as well as local priorities and preferences. This research seeks to develop a methodology that is useful for being applied for decision-making purposes. It also offers flexibility to manipulate the framework to meet various agency goals. It may also support existing methods of infrastructure investments.

The primary phase involves the determination of a theoretical approach for decision-making of designating CUFC and CRFC. This can include the parameters set or according to the busiest corridors for urban freight transmission, following the requirements of the National Highway Freight Network (NHFN).

To achieve the objectives proposed in this research, the following tasks were accomplished:

- **Chapter 1**: an introduction to the topic, providing an overview of the problem investigated, a brief background on the current state of freight transportation, and a description of CUFC and CRFC.
- **Chapter 2**: a literature review on statewide freight plans, freight infrastructure, and how decision support systems with MCDM and AHP are used in the transportation field. More specifically, we also investigate how spatial analysis can be integrated

with DSS, MCDM, and AHP. The literature review also serves as a base of inputs to recommendations done in the development of the method.

Chapter 3: model development in consultation with stakeholders and expert judgment to compose the knowledge base. The model formulation and data needs are detailed, as well as an automated designation method. The method offers a high degree of freedom for states to develop its own approach based on its needs and expertise.

Chapter 4: validation of the system through a case study in the State of Florida. This was achieved with the use of geo-databases based on truck data and facilities related to freight and intermodal transportation.

Chapter 5: analysis of results and scenarios proposed in the methodology. The final product of this methodology is the allocation of a score to each link. Different scenarios are explored in the results and analysis section to explore the impact of different approaches and why choosing them. Each alternative corridor and route are assessed functionally with respect to site-specific ratings of the criteria and sub criteria in a unified framework. The best corridor and route alignment alternative is identified by a composite score on the AHP ratio scale.

Chapter 6: recommendations for future expansion of this research. This research involved public and private sector stakeholders of the freight and logistics industry in the plan development process. Since the CUFC and CRFC designation process is inherently highly flexible, any modification to the proposed method is encouraged and even recommended.

1 INTRODUCTION

1.1 OVERVIEW

Efficient and safe movement of freight is vital to the rivaling economies of cities, states, and nations. Freight transportation connects businesses to markets throughout the world and has a strong influence in the global economy. Additionally, freight activity plays a major role in the process of generating income and employment. The efficiency of freight mobility depends on the quality of the transportation system and its ability to move people and goods in a fast, reliable, and cost-effective way.

The heavy vehicles that transport freight uses public streets, highways, and intermodal facilities. The presence of this type of vehicle challenges the transportation infrastructure in different aspects. First, a significant number of heavy vehicles on a highway corridor can contribute to more complicated traffic conditions. These large vehicles require wider turn angles, operate at slower speeds, and imposes increased safety concerns to other vehicles. Secondly, trucks and other heavy vehicles inherently inflict the greatest deterioration due to their large gross vehicle weights and individual axle loads (Chowdhury, et al., 2013). Overall, the heavier the vehicle, the greater the rate of infrastructure degradation of pavement, bridges, curbs, etc.

In addition, traffic congestion is considered a major infrastructure failure in the entire nation. Most bottlenecks are a result of general automobile traffic exceeding the capacity of the road rather than directly from freight traffic. In Florida, there were 19.1 thousand daily truck hours of delay in the year of 2019 (FDOT, 2020). Although truck related congestion is a small percentage of overall congestion, it accounts for a greater percentage of congestion cost due to higher value of time for freight compared to passenger vehicles. As freight movements are expected to grow significantly for the foreseeable future, its reliance on trucks will contribute on increasing congestion, making it more difficult and costly to move freight.

A fast-degrading transportation infrastructure creates an unfavorable scenario for infrastructure investments. Building new infrastructure and improving existing elements does not strictly involve technical decisions; it is an inherently political act. Key issues such as traffic congestion, pollution, land use and sprawl, and facilitating national economic growth are significantly affected by decisions about how which transportation infrastructure projects to advance. Federal requirements for funding transportation infrastructure projects usually specify the overall approach that State and regional organizations should use in planning. However, they generally do not specify what analytical tools planners should use to evaluate projects (United States General Accounting Office, 2004). Key requirements usually include developing strategic goals and objectives, considering environmental and economic factors, preparing long- and short-range plans, and ensuring an inclusive process that involves several stakeholders.

Over the years, the Federal Highway Administration (FHWA) has developed and maintained several programs that involves multiple criteria to fund freight investments throughout the country. In 2015, the Fixing America's Surface Transportation Act (FAST Act) established a series of programs to support and advance critical transportation projects (FHWA, 2015), including freight focused initiatives. Inside this scope, the National Highway Freight Network (NHFN) includes Critical Urban and Rural Freight Corridors (CUFC and CRFC). These corridors are sections of the

NHFN that provide critical connectivity of goods based on a series of criteria. Designating critical freight corridors allow increasing the state's NHFN, enabling improvements in the highway transportation system. Corridors are designated by each State in their Statewide Freight Plan. It is important that each State Department of Transportation (DOT), in cooperation with major Metropolitan Planning Organizations (MPO), have a well-defined approach for identifying and updating CUFC and CRFC segments.

Freight corridors are segments of the transportation network used by multiple freight routes and/or that plays a major role in the freight movements within the region. Critical freight corridors must have improved system performance and provide efficient access to freight intensive facilities. The CUFC and CRFC network in Florida was defined in the Florida's Freight Mobility and Trade Plan (FDOT, 2020). The plan provides a comprehensive inventory and description of Florida's freight systems and assets. As most other Statewide Freight Plans, the Florida Department of Transportation (FDOT) does not disclose the detailed process of defining CUFCs and CRFCs, stating that links were assigned according to FAST Act requirements.

Assigning a Statewide network CUFCs and CRFCs is a process that, in general, considers the policy requirements and then selects potential projects that were already envisioned. This process is often based on multiple objectives that are subjective or hard to quantify. Although the FAST Act specify a series of criteria for designating the CUFC and CRFC network, there is a high flexibility to include corridors even if they do not meet specific criteria such as truck AADT or connection to freight facilities. This leaves states with a great degree of freedom to designate these corridors. For instance, the most flexible criterion that exists for both CUFC and CRFC designation are "corridors that are vital to improving the efficient movement of freight and the economy of the State or region, as determined by the MPO or the State, whichever is applicable". This depends on previous analysis of freight intensive corridors in the State or region, a study that many states do not have. In most cases, the process of designating critical freight corridors is based on a network analysis and manual verification of eligibility. Therefore, we see an opportunity to implement systematic decisions and planning methods for advancing projects in freight transportation.

One approach to avoid ambiguity and bias in decision-making is to move towards a Decision Support System (DSS) using mathematical modeling. The DSS is an interactive, computer-based system that helps decision-makers utilize model-based, data-based, and display-based components to solve unstructured and ambiguous problems (Druzdzel & Flynn, 2010). Prioritizing a set of feasible candidate options based on multiple criteria is referred to as a multi-criteria decision-making (MCDM) problem (Liang & Wey, 2013). This research study seeks to develop a DSS for designating critical freight corridors using a MCDM method. These methods allow optimizing decisions under complex environment and formulating the problem with respect to reality.

Regarding the specifications of the CRFC and CUFC designation policy, States and MPOs are not required to submit identified corridors and facilities as a geospatial network database (FHWA, 2015). However, they are encouraged to submit the routes in a Linear Referencing System (LRS) dataset. This procedure facilitates the review process of the roadway mileage documentation in a timelier manner and with greater accuracy, efficiency, and precision. Additionally, this allows better coordination and integration with other LRS networks such as the Highway Performance Monitoring System (HPMS) and the National Highway Planning Network (NHPN). Therefore, an approach based on a Geographic Information System (GIS) is more adequate for the purpose of selecting the critical freight corridors.

Inside the scope of MCDM, one analytical approach that can be applied for solving complex problems such as selecting CUFCs and CRFCs is the Analytic Hierarchy Process (AHP). This method was first introduced by Saaty (Saaty, 1987). The AHP enables the decision maker to structure a complex problem in the form of a simple hierarchy taking in account multiple criteria. This technique allows considering information about a decision in a systematic manner with a high degree of flexibility (Badri, 1999). The AHP has been used extensively in transportation infrastructure management with the objective of integrating different stakeholder preferences and technical information to derive solutions and alternatives. When selecting the location of corridors, the decision-maker may have different perceived degree of preference (adequacy) or level of importance to the decision criteria.

This research study introduces a multi-criteria spatial decision support system (MC-SDSS) for structuring the process of designating CUFC and CRFC corridors. MC-SDSS provides a framework to integrate the database management and spatial analytics capabilities of a GIS approach with decision models for selecting alternatives. Since meeting at least one of the criteria makes a corridor eligible for designation, the decision on how to select the corridors will be aided with the AHP.

Applying this solution in a real case of selecting critical freight corridors for designation requires a series of participants and data. A GIS-based MCDM presents unique, flexible capabilities for automating and analyzing spatial decision-making issues with large sets of feasible alternatives and multiple conflicting and incommensurate evaluation criteria from varying sources to aid policy analysis and implementation (Chen, et al., 2013). A sensitivity analysis (SA) is an important step to determine the dependency of inputs on the results based on the network being studied. Therefore, we will also conduct a sensitivity analysis considering different scenarios of criteria prioritized. Finally, a practical application of the developed methodology will be conducted in a case study in the state of Florida.

The benefit of using a systematic method for critical freight corridor selection is having a more transparent designation method. The developed methodology is a tool for planners to integrate the criteria imposed by the policy with the State’s objectives and preferences. By advancing CUFC and CRFC designation method, the state may optimize its freight investment decisions, consequently strengthening the economy and improving the mobility of goods in and outside its limits. It is also a goal of this study to offers flexibility to manipulate the framework to meet various agency goals and can be adapted to any policy.

1.2 CRITICAL URBAN AND RURAL FREIGHT CORRIDORS

The National Highway Freight Network (NHFN) includes the Primary Highway Freight System (PHFS), other Interstate portions not on the PHFS, and Critical Urban and Rural Freight Corridors (CUFC and CRFC), as shown in Figure 1. These freight corridors are sections of the NHFN that provide critical connectivity of goods and, therefore, must have improved system performance and efficient movement of freight.

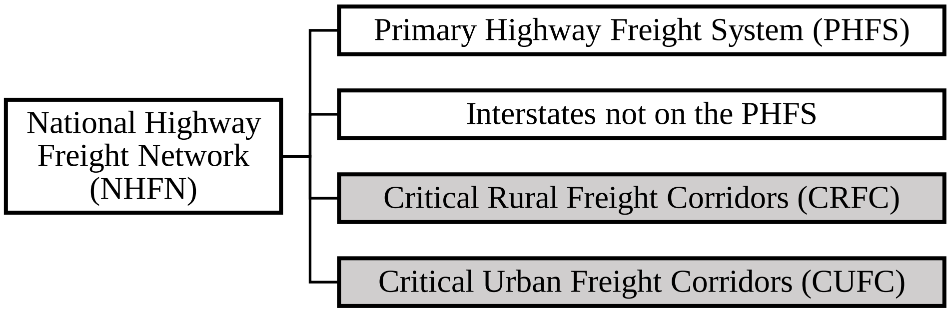

Figure 1: Components of the National Highway Freight Network

A State may designate a public road as a CRFC if the public road is not in an urbanized area. In an urbanized area with a population of over 500,000, the MPO in consultation with the State, is responsible for designating the CUFCs. In an urbanized area with a population of less than 500,000, the State, in consultation with the MPO, is responsible for designating the CUFCs.

The state of Florida selects projects to be included in their CUFC and CRFC network based on their priority, cost, and ability to improve freight mobility such as mitigating bottlenecks, congestion, and improving level of service (FDOT, 2020). In the 2020 Florida's Statewide Freight Plan criticality is defined if the route is required to complete connection from a key freight facility to the NHFN.

Designation of CUFCs and CRFCs may change as new highway freight projects are identified. Redesignation may occur conducted when projects are completed by modifying or adding sections to the Statewide Freight Plan. Removing the CUFC or CRFC designation allows mileage available for designation at another location. The overall CRFC and CUFC designation process is shown in Figure 2.

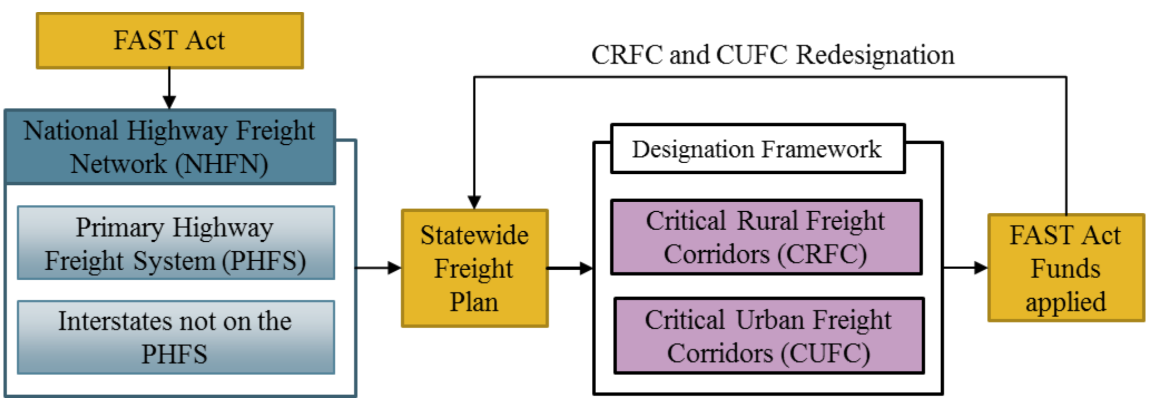

Figure 2: CRFC and CUFC designation process – upper-level framework

The difference between rural and urban corridor designation is based on the population of the area of the corridor and the agency responsible (FHWA, 2015):

- Critical Rural Freight Corridors (CRFC):
  - Roadways outside of urbanized areas (defined by the U.S. Census as having a population of less than 50,000) – designated by the state.
- Critical Urban Freight Corridors (CUFC):
  - Roadways within an urbanized area with a population of at least 50,000 but less than 500,000 – designated by the state DOT in consultation with the MPO.
  - Roadways within an urbanized area with a population of 500,000 and above – designated by the MPO in consultation with the state DOT.

Designation of CRFCs is limited to a maximum of 150 miles or 20% of the PHFS mileage in the State, whichever is greater. State and MPO designation of CUFCs is limited to a maximum of 75 miles of highway or 10% of the PHFS mileage in the State, whichever is greater. A public roadway can be designated as a Critical Rural Freight Corridor if it meets one or more of the following criteria:

A. Is a rural principal arterial roadway with a minimum of 25 percent of the annual average daily traffic (AADT) of the road measured in passenger vehicle equivalent units from trucks.
B. Provides access to energy exploration development, installation, or production areas.
C. Connects the PHFS or the Interstate System to facilities that handle more than:
   - 50,000 20-foot equivalent units per year.
   - 500,000 tons per year of bulk commodities.
D. Provides access to a grain elevator, an agricultural facility, a mining facility, a forestry facility, or an intermodal facility.
E. Connects to an international port of entry.
F. Provides access to significant air, rail, water, or other freight facilities.
G. Is vital to improving the efficient movement of freight of importance to the economy of the State.

The State is required to consult with certain MPOs to designate Critical Urban Freight Corridors inside their County boundary. A CUFC must be a public roadway that meets one or more of the following criteria:

H. Connects an intermodal facility to the PHFS, the Interstate System, or an intermodal freight facility.
I. Is located within a corridor of a route on the PHFS and provides an alternative highway option important to goods movement.
J. Serves a major freight generator, logistic center, or manufacturing and warehouse industrial land.
K. Is important to the movement of freight within the region, as determined by the MPO or the State.

Most states have defined Critical Urban and Rural Freight Corridors in their Statewide Freight Plans to advance their transportation system. A more detailed analysis of different states and their critical freight corridor designation method will be presented in the literature review.

2 LITERATURE REVIEW

This chapter comprehends is a selective literature review of reports and academic publications related to freight operations and transportation planning. The first section will investigate how each state developed Critical Urban and Rural Freight Corridors with regards to its approach and the level of detail provided, investigates research papers related to Critical Freight Corridors and its policy, and other research on the impact of freight infrastructure investments in the economy. The second section will overview related research on DSS, more specifically in AHP; other sections include tools for freight analysis and freight data sources.

2.1 FREIGHT POLICY AND PLANNING

State and regional decision-makers must consider the structure and requirements of federal programs when planning on how to advance its transportation system (United States General Accounting Office, 2004). This section overviews the background of the freight policy that this research study is based on and other related issues.

The Fixing America's Surface Transportation Act (FAST Act) has been signed in 2015 to support critical transportation projects with the objective to ease congestion and facilitate the movement of freight on the Interstate System and other major roads (FHWA, 2015). This enactment enabled States and local governments to move forward with critical transportation projects, such as new highways and transit lines. The objective of this transportation investment plan was to create greater certainty for states in terms of funding over a five-year period.

An inspection of methodologies for designating critical freight corridors for all states was conducted and is discussed in the first subsection; it also discusses how the level of detail provided in each Statewide Freight Plan varies greatly. The second subsection overviews the CUFC and CRFC designation criteria, which is essential for developing the DSS proposed in the methodology. Finally, we briefly discuss research related to other freight policies and how this could also benefit from decision support systems.

2.1.1 Statewide Freight Plans

Numerous tools and guidelines are available to assist freight analysis, including the Freight Analysis Framework (FAF) developed by the FHWA. Most states used their Primary Highway Freight Networks (PHFN) and the National Highway System (NHS) to determine which corridors in the states were important for freight routes. Some states used internal congestion maps, level of service, and information from travel demand models and traffic management center operations tools to determine potential locations.

Since FHWA does not obligate states to detail their CUFC and CRFC designation, only a few provided a thorough methodology description. Overall, States using a more detailed approach considers the impacts of freight transportation projects, seeking to maximize the relative return of investments. These include, but are not limited to, cost-benefit analysis, economic impact analysis, and regional productivity (competitiveness) analysis (O'Rourke, et al., 2015).

Some agencies responsible for designating critical freight corridors used technical analysis based on Geographic Information Systems (GIS). The Alabama Department of Transportation used a multi-variate GIS based analysis tool to identify its candidate corridors (according to the Alabama Statewide Freight Plan, 2017). The corridors that met two or more criteria for CRFCs and CUFCs would be considered as a candidate network of corridors (ALDOT, 2017). Given that the primary focus of the identified corridors is on last-mile connectivity, an assessment of access to the identified freight intensive uses (per FHWA definition) was undertaken for validation purposes. Their criteria also included minimum distances for the freight facility set by the stakeholders and technical judgement.

Arizona designated its corridors using a data-driven process considering performance, truck volume, freight tonnage, freight value (according to the Arizona State Freight Plan, 2017). The state also deemed important that the critical corridor network to be in a connected and contiguous network with the other portions of the NHFN (ADOT, 2017).

The state of Maryland utilized a Corridor Priority Tool to provide the quantitative analysis (MDOT, 2017). It used metrics of truck volume, freight density, intermodal connections, congestion, and delay. To meet federal criteria and multimodal goals they also used a method of scoring urban links to normalize the truck volumes and freight density scores. Links were sorted based on highest to lowest total scores. Results were compared to other project locations defined in the transportation plan. A strong outreach with stakeholders was also conducted throughout the whole process.

Florida Department of Transportation (FDOT) utilizes a series of data and analysis systems to support and advance freight across the state. Projects included in the National Highway Freight Program (NHFP) were selected based on their priority, cost, and ability to improve freight bottlenecks, congestion, level of service, and other factors in freight mobility (FDOT, 2020). Of the 59 total NHFP projects in the State of Florida, 8 are on the CUFC and 4 are on the CRFC network. In the Statewide Freight Plan (2020), the state looked for corridors working as dispersion freight routes to create redundancy of the network, offering multiple ways for freight traffic. Other requirements for selection of corridors included if ton volume is equal to or greater than the mean ton volume and the percentage change in ton volume is equal to or greater than the mean percentage change of ton volume throughout the district. Additionally, multimodal freight connection routes that create seamless freight mobility operations were also considered. Figure 3 shows the current CUFC and CRFC designation for the state of Florida according to the Freight Mobility and Trade Plan (FMTP) (FDOT, 2020).

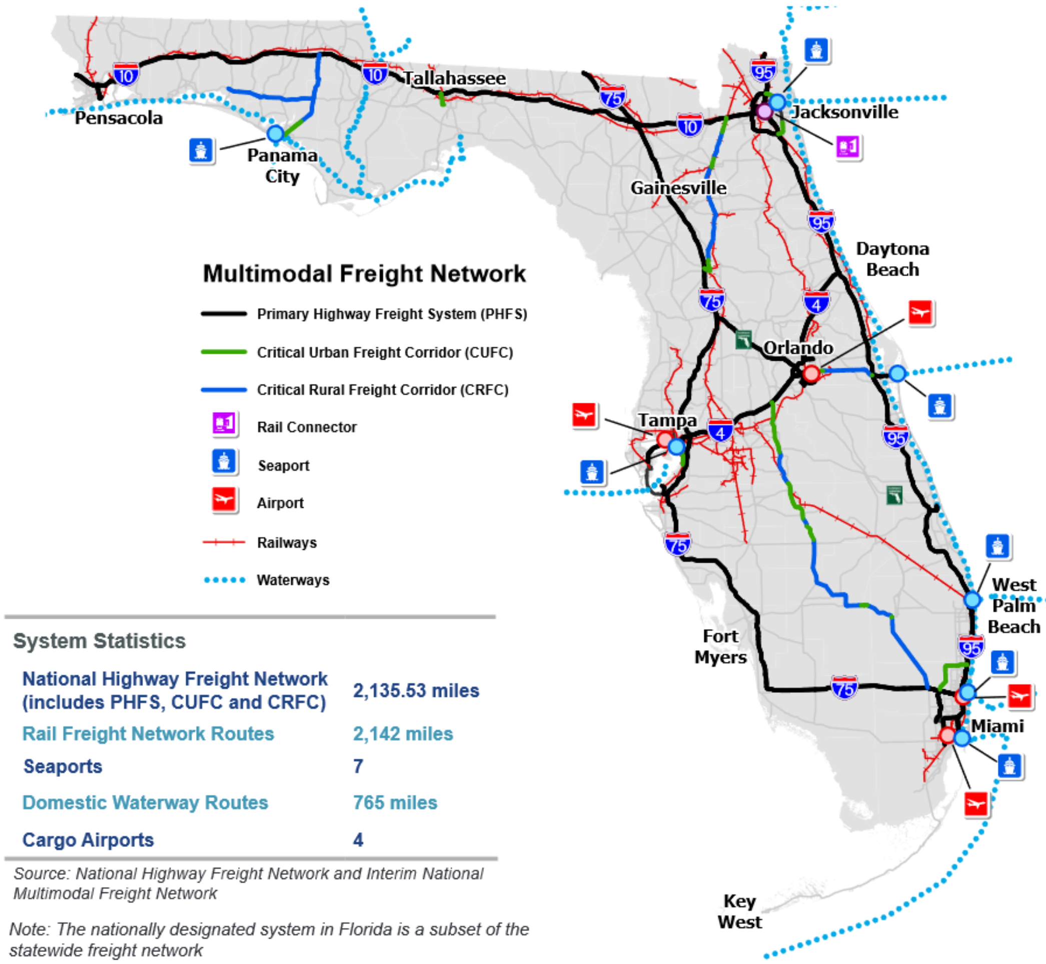

Figure 3: Florida's Critical Urban/Rural Freight Corridors

Source: Florida's Freight Mobility and Trade Plan, 2020

In summary, several designations of CUFCs and CRFCs start with the identification of projects that needs funding. It involves an analysis of the network topology to designate CUFCs or CRFCs based on planned projects and eligibility or only eligibility. This assumes that the State has already developed other studies and determined the projects needed to advance freight in the region. Examples of States that used this approach are Alaska, California, and Colorado.

A simplified approach was usually adopted by states and regions with a relatively less complex freight network and overall objectives. This involved a review with proposing agencies and/or freight specific organizations. Finally, a few states have not designated or have chosen not to designate CUFCs and CRFCs, such as Idaho and Montana.

2.1.2 Critical Freight Corridor Research

Prioritizing projects based on outcomes enables states to assign transportation investments that will impact the most in terms of cost-effectiveness. Performance-based transportation planning examines information about the transportation network and sets up a framework for developing goals and prioritizing projects according to meeting the needs of system users (National Association of Development Organizations, 2014). There are several States taking advantage of project prioritization methodologies, such as the Prioritization Resources developed by the State of North Carolina within their State Transportation Improvement Program (NCDOT, 2021).

When investigating previous research papers, there was found little interest on investigating the CUFC and CRFC designation and its impacts. In early stages of the policy implementation, Marach, Adams, & Perry (2014) proposed different approaches (mileage-based, segment-based, and weighted average) to determine whether a corridor meets one of the CRFC criteria: a rural principal arterial that has a minimum 25% of truck traffic. The three approaches are explained, assessed, and mapped for the reader to compare the resulting networks. The paper then uses policy analysis techniques to assess the advantages and disadvantages of each approach. The analysis compares the approaches based on network connectivity of the resulting CRFCs, the mileage of non-Interstate rural principal arterials, and robustness.

With a more local application, Hazel (2019) analyzed and evaluated the impact of the FAST Act on the efficiency of operation and the productivity of the City Transit Authority in Belleville, Illinois. The theoretical foundations used were based on productivity and efficiency theories in a qualitative descriptive study.

2.1.3 Freight Infrastructure Projects

Regional cooperation of multiple agencies can result in coordinated policy programs that advance a broad range of public interests. Some of those interests include improved land use decisions, increased efficiency of use of financial resources, sustainable economic growth, and generally promoting what is best in the public interest (Adams, et al., 2005). Over the years, there has been numerous programs for advancing transportation in the United States.

A regional freight model enables regional planners to test different transportation planning, economic, and policy scenarios and understand the impacts of each. To this date, many States have developed their own freight model. The Maricopa Association of Governments in Arizona developed a multi-modal freight model to better replicate the economic behaviors of establishments, shippers, and carriers by modeling travel and tour formations in the Sun Corridor mega-region (Federal Highway Adminsitration, 2017-1). Multiple agencies in the state of Maryland joined efforts to develop an operational behavior-based freight model sensitive to both long-distance freight flows and short-distance urban truck tours (Federal Highway Administration, 2017-2). The Chicago Metropolitan Agency for Planning had produced and implemented an advanced freight behavior-based model in the Chicago region, used to gain a better understanding of their needs and challenges (Federal Highway Adminsitration, 2017-3).

The National Freight Fluidity Program is an initiative by USDOT to better understand how our transportation system supports freight movement. This national effort aims to add the perspectives of shippers, carriers, and receivers by focusing on supply chains and understanding the end-to-end performance of an individual freight trip or shipment moving across multiple modes and jurisdictions. A clear view of freight fluidity leads to strategic transportation system investments that directly improve supply chain performance and the country’s economic competitiveness (United States Department of Transportation, 2019).

The Virginia Department of Transportation (2021) created the SMART SCALE for prioritizing transportation projects by evaluating each project's merits using key factors. These include improvements to safety, congestion reduction, accessibility, land use, economic development, and the environment. The evaluation focuses on the degree to which a project addresses a problem or need relative to the requested funding.

2.1.4 Freight and the Economy

Efforts to measure the economic impact of freight transport improvements or deterioration are the exception rather than the norm. Politano & Roadifer (1989) used standard highway data input and derives industrial output, earnings, and employment impacts of addressing or not addressing highway construction or rehabilitation needs on a variety of highway systems. This input-output, or inter-industry model, is a 10-step approach that can capture productivity benefits from transportation related projects in terms of total earnings and number of jobs for each industry.

An example of initiatives for determining the economic impacts of projects and regulations in transportation is the truck weight limits in Montana. This study completed in 1999 used the regional econometric model REMI (Hewitt, et al., 1999). Another example is the Chicago Regional Econometric Input-Output Model (CREIM) to estimate the economic impact of capacity limitations at rail terminals and a hypothetical bottleneck reduction construction program.

Seetharaman, Kawamura, & Bhatta (2003) developed a study to quantify the economic benefits of freight policy. An input-output (I-O) method was developed to evaluate direct, indirect, and induced economic impacts of cost changes in motor carrier transportation. This method has been used to study the potential impacts of the 2020 Regional Transportation Plan (RTP) in a six-county region of Chicago, Illinois.

Adams et al. (2005) developed the Upper Midwest Freight Corridor Study. This study examines several aspects of regional freight transportation including, capacity, performance measures, administrative issues, demand/usage, and best practices. Phase One of consisted of data collection and a description of the scope of freight issues across the region.

Several researchers investigate the monetary value of the impacts brought on by the change in traffic volumes in urban areas. The work developed by Kawamura & Mahajan (2005) seeks to aid public agencies in evaluating projects in relation to the net benefit to the entire society, including the localized impact on neighboring communities. The study attempts to quantify the cumulative impacts of vehicle traffic, both passenger cars and trucks, by using the hedonic price analysis of the relationship between property values and the traffic along selected arterial corridors in Chicago, Illinois.

The freight box concept developed by Eisele & Schrank (2010) estimates the economic impact of congestion on freight (trucking) by investigating available data. The three axes of the relationship for trucks are geographic area (area under study), commodity type (vehicles of interest), and time. Commodity types are identified per the Standard Classification of Transported Goods (SCTG) and truck types.

Cost-benefit analysis is a method based on economic welfare theory with the objective to compare the total benefits and costs of projects or policies. In contrast, multi-criteria analysis (MCA) does not transform all impacts into a common value which is considered to express public welfare. Instead, the aim is to rank different alternatives according to decision makers‘ or stakeholders‘ preferences. The advantages of MCA is evident when impacts cannot be monetized or quantified. Gühnemann, Laird, & Pearman (2011) developed a method that incorporates CBA elements in an MCA framework as tool for decision makers to synthesis results with clear rules for the prioritization of projects for investment.

The Infrastructure Management report (Project A and Project B) by Schroeder et al. (2012), develops a comprehensive freight-based prioritization framework. The objective is to identify freight infrastructure needs critical to maintaining economic vitality by incorporating economic metrics associated with infrastructure performance and level of service.

In the area of broaden reviews, O'Rourke, Beshers, & Stoc (2015) provides a review of approaches, methods, and tools that can be used to evaluate the economic impact of freight improvements. This is a point of reference to assist practitioners and decision makers, providing an overview of the methods used in this area. It reviews three different types of analyses: 1) benefit-cost analysis, 2) economic impact assessments, and 3) analyses focused on estimating the impact of transportation on industry productivity and competitiveness.

Cui, Dodson, & Hall (2015) presents a broad discussion of the links between urban freight transport and urban planning through an overview of the literature in the field. The paper discusses key problems confronting planning and policies for urban freight transport in relation to its importance, impacts, interrelationship between stakeholders, institutions, influencing factors and challenges.

Eisele et al. (2016) describes the freight fluidity concept with the premise that efficient freight mobility is closely linked to the economic vitality of a region and the country. This paper presents a definition of freight fluidity for the State of Maryland, provides a framework for implementing freight fluidity, describes multimodal data sources, and presents calculation procedures for the highway (truck mode). Researchers demonstrated the value of the freight fluidity methods for freight investments and statewide decision-making.

Jiang et al. (2017) proposed a structural equation model (SEM) to consider the bi-directional relationship between multimodal transportation investments and economic development. Travel demand is added as an endogenous variable in the model system. The SEM model system is formulated with variables that reflect transportation supply in geographically adjacent areas to investigate spatial spillover effects. Empirical analysis based on a panel dataset at the regional level in China from 1986 to 2011 is conducted. The different economic growth levels shown in the results can be associated with phases of economic development, transportation investment policy, transportation infrastructure service level, spillovers from other regions, as well as reform policies carried out by the central government.

The REMI TranSight is dynamic model that allows testing alternative transportation changes and predicting short and long-term effects on economic and demographic aspects that will result from completing the project (Regional Economic Models, Inc. (REMI), n.d.). It also integrates travel demand models with regional economic models and evaluates economic benefits from both individual cost savings and accumulated business benefits. Additionally, it can assist governments in determining fund allocation to a particular transportation upgrade with a cost-benefit analysis.

2.2 DECISION SUPPORT SYSTEMS

Several researchers have used decision support systems (DSS) for solving transportation problems. Traditional investment selections include profile and checklist methods, scoring methods, cost-benefit analysis, and mathematical programming models. The latter includes methods such as Multi-Objective Decision-Making, Multi-Attribute Utility Theory, Goal Programming, and Analytical Hierarchy Process.

For instance, the work developed by Avineri, Prashker, & Ceder (2000) was founded with the discussion about the process of transportation projects selection, which takes place under an uncertain and fuzzy environment. In this research, developed in 2000, authors present a technique for the selection of transportation projects using the fuzzy sets theory. This multiple objective process rates projects on a quantitative and qualitative basis using linguistic variables. To describe appropriately a given transportation policy, both fuzzy weighted average and noncompensatory fuzzy decision rules are used in the proposed approach. In addition, this work contains a case study of a selection process of interurban road projects in Israel.

Barfod, Salling, & Leleur (2011) combined cost-benefit analysis (CBA) with multi-criteria decision analysis (MCDA) for the assessment of economic and strategic impacts of transportation projects. Specifically, a composite model for assessment (COSIMA) is presented as a DSS. Authors argue that this COSIMA DSS ensures that the assessment is conducted in a systematic, transparent, and explicit way.

In the dissertation of Schlickmann (2018) a DSS was developed combining a land use and transport model with a MCDA model. This system was assessed in a small case study involving Bus Rapid Transit (BRT) and Light Rail Transit (LRT) projects in Boston, Massachusetts. The author discourses that the DSS can cover a variety of decision aspects, expert opinions, sensitivity, and risk analysis. It aims to reflect uncertainties and exogenous conditions that may significantly affect the costs and the benefits of a project in a more accurately and realistically way. Consequently, it facilitates public debate about investment alternatives since it makes it possible to present the decision problem to the affected community and decision-makers.

New ways of obtaining inputs for designating Critical Freight Corridors can be explored with the expansion of new technologies and availability of data. The purpose of this section is to review research that could potentially aid in critical freight corridor identification. This includes, but is not limited to, different freight project prioritization methodologies, freight analysis tools, and data sources.

2.2.1 Analytic Hierarchy Process

The Analytic Hierarchy Process AHP is a general theory of measurement used to derive ratio scales from both discrete and continuous paired comparisons. These comparisons may be taken from actual measurements or from a fundamental scale which reflects the relative strength of preferences and feelings (Saaty, 1987). AHP ranks decision items using comparisons between pairs in a matrix. This produces weighting scores that measure how much importance items and criteria have with each other.

The AHP is a means for modeling unstructured problems in the economic, social, and administrative sciences. It involves three basic steps: (i) problems are decomposed; (ii) comparative judgments are made on decomposed levels; and (iii) synthesis is obtained through eigenvectors measuring relative importance (Shim, 1989). In general, a hierarchical model descends from an overall objective, down to criteria, down further to sub-criteria, and finally to the alternatives from which the choice is to be made. Typically, scoring and weighting systems are used in MCDM.

AHP has been applied to a wide range of decision problems involving multi-criteria decision-making, planning and resource allocation, and conflict resolution. Therefore, we include in this review only the work applied to the transportation sector.

Badri (1999) proposed the use of the AHP and multi-objective goal-programming methodology as aids in strategic global facility location-allocation decisions. First authors present the AHP as a standalone method. Then, a combined AHP and goal programming (GP) model is presented to consider additional criteria in decision-making process. A comparison of the AHP-only and the combined AHP-GP solutions reveals that the solution of the combined model is superior for solving the problem of global location-allocation decisions.

A similar route selection method, but in public transportation, was developed by Banai (2006) for Memphis, Tennessee. An AHP-aided procedure was developed to facilitate the public transportation decision-making process generically, reflective of federal guidelines and local priorities and preferences. Each alternative corridor and route are assessed functionally with respect to site-specific ratings of the criteria and sub criteria in a unified framework. The best corridor and route alignment alternative is identified by a composite score on the AHP ratio scale. A sensitivity analysis was also presented to show how changes on the importance of the criteria or participant group priority influences the trade-offs among the criteria and the outcome. Authors highlighted an advantage of this AHP method as using verbal rating scales instead of step or linear function types to compensate for the vagueness of the available estimates inherent in the variable measured. Therefore, alternative rating methods of AHP allow the flexibility of estimation in the face of incomplete information.

Arslan (2009) presents model taking in account public involvement and public oversight to aid in selecting appropriate transportation projects for implementation. A hybrid model of fuzzy logic and the AHP is proposed. In the discussion of this work, authors state that the transportation planning process begins with problem definitions and project needs. Comprehensive definitions of problems and extensive discussions of project scopes help to clarify many issues involved in the process. However, when it comes to making decisions, judgmental statements usually remain imprecise, particularly if decision makers are the citizens participating in the process. Fuzzy logic is a useful method for manipulating information that is incomplete and imprecise.

Also proposed by Saati, the Analytic Network Process (ANP) is a nonlinear form of AHP. Banai (2010) applied this method for evaluating land use-transportation systems to evaluate LRT route alignment alternatives. The ANP was applied to the problem of light rail route selection with station area land use and property value among multiple criteria.

Nguyen et al. (2015) proposed a method for evaluating complexity in transportation projects. Authors deduced the six components of project complexity, namely sociopolitical, environmental, organizational, infrastructural, technological, and scope. The Fuzzy AHP method was employed to determine the weights of the components and parameters of project complexity. The proposed method allows a more efficient allocation of resources among transportation projects within a company.

An example of a combination of route selection using AHP was proposed by Ammarapala et al. (2018). The developed method selected potential rural roads to support cross-border shipment in Thailand. Authors identified different key factors affecting rural roads selection and conducted interviews with expect to evaluate the factors. The seven key factors and their identified importance weights were used to rank potential rural roads for cross-border shipment development.

The study conducted by Hamurcu & Eren (2018) evaluated monorail projects in accordance with urban needs and three different budget scenarios. The AHP was used in the evaluation process of the projects and the goal programming (GP) model was used for the selection process. The result of this research was the selection of the monorail projects planned for the city of Istanbul, Turkey.

Suksuwan & Trangkanont (2018) created a conceptual framework of route project improvement execution plan for southern Thailand' decision-making on project investment prioritization. The focus group interview method collected 1) factors influencing transportation investment projects and 2) a score attribution to each criterion. To rank the important criteria, the questionnaire was developed to gain the data of pairwise comparison and the AHP method was applied to analyze the data.

2.2.2 Spatial DSS, MCDM, and AHP

Geospatial data are data connected to a location, a place on the earth. The network topology is the computational representation of a transportation system as a network of nodes and interconnecting links representing roadways. Spatial DSS, also called SDSS, combine spatial and non-spatial data, the analysis and visualization functions of Geographic Information Systems (GIS), and decision models in specific domains, to compute the characteristics of problem solutions, facilitate the evaluation of solution alternatives and the assessment of their trade-offs (Keenan & Jankowski, 2019). GIS techniques and procedures have an important role to play in analyzing problems with spatial implications. Indeed, GIS is often recognized as a spatial DSS (Malczewski, 2010).

The same can be applied in MCDM, also referenced as Spatial Multi-Criteria Decision-Making (SMCDM) or Geographic Information System-based Multi-Criteria Decision Analysis (GIS-MCDA). Multi-criteria analysis is generally defined as a support for decisions allowing the comparison of different alternatives or scenarios according to several criteria. Spatial multi criteria decision-making refers to the application of multi criteria analysis in spatial context where alternatives, criteria and other elements of the decision problem have explicit spatial dimensions. The GIS-MCDA is as a process that combines spatial data and value judgments/preferences to obtain information for decision-making (Malczewski, 2010). These two techniques are combined to achieve more efficient and visually complete results in multi criteria decision-making.

Several researchers combined AHP with GIS to assist in the decision-making process. The paper by Sadasivuni et al. (2009) was developed for freight transportation. It addresses a GIS-based decision-making framework focusing on environmental and early planning needs in a high impacted transportation corridor. It implements AHP into a geospatial analysis framework to support geo-spatial decision-making in generating and selecting paths for roadway options. In this approach, each decision factor is represented as a thematic geospatial layer with attributes that express criteria being considered. Pair-wise comparisons of criteria give rise to relative ranking of criteria. The results show close similarity to results generated by use of traditional methods but were generated using automated approaches. Benefits to this methodology is generating transportation alternatives in an efficient and systematic manner and enables multiple scenarios to be simultaneously considered in the transportation planning process to facilitate decisions.

The paper developed by Brunner, Kim, & Yamashita (2011) determined optimal transit alignment between the competing Salt Lake and Airport alignments in Honolulu, Hawaii. A uniform grid structure was developed into a grid map. The grid data and survey results were entered into the AHP structure to produce an index of suitability that could be plotted in the GIS environment to indicate optimal alignments for the rail transit system based on public preferences and technical criteria.

Another combination of AHP with spatial considerations was found in the research by Kim, Wunneburger, & Neuman (2013). The aim of this application is to determine the most suitable corridor for new transport infrastructure by employing a spatial DSS. The system was tested in a prototype corridor parallel to Interstate 35 between San Antonio and Austin, Texas. Authors defined the method as a spatial decision support system (SDSS). The proposed SDSS employs GIS to map strategic social, economic, and environmental characteristics. This overlay of features enables the assessment of locations that are most and least suitable for regional transportation networks and urban-scale growth.

A discussion on methods and the importance of a sensitivity analysis in GIS-based MCDM was presented by Chen, Yu, & Khan (2013). This study developed a methodology, which is the extension of a previous work (Chen, et al., 2010), to a more comprehensive framework to analyze weight sensitivity caused by both direct and indirect weight changes. Authors used the one-at-a-time (OAT) technique. In the OAT analysis, the impact of changing the values of each factor is evaluated in all interactions. This is methodologically simple, computationally cheap, and easy to develop.

In the area of transit development, Eldeebl, Elmitiny, & Darwish (2015) developed a new methodology for improving public transit planning through the development of a transit suitability map using the AHP, a spatial multi-criteria analysis, and GIS. This research created a Transit Suitability Tool with a mapping application for public transportation planning which can be used to compare alternatives and prioritize transportation projects.

Ghavami (2019) introduces an integrated methodology to evaluate the transportation network performance during disasters by developing a multi-criteria spatial decision support system (MC-

SDSS). The developed MC-SDSS is a fully integrated system of GIS and MCDM methods. Based on the decision-making model (intelligent, design, and choice), four criteria were selected as indicators for evaluating the TNP in disaster situations, namely capacity, accessibility, vulnerability, and importance criteria. Criteria maps are generated by GIS tools, the experts' preferences about the criteria are acquired by AHP comparison matrix, and a ranking of the roads are prepared and visualized on the MC-SDSS. Finally, authors conduct a sensitivity analysis using the One-At-Time approach to determine the robustness of the results due to the variation or uncertainty resulting from changing the important scales of the criteria in the AHP pairwise comparison matrix.

2.2.3 Freight Analysis Tools

Although different methods of DSS are widely employed for supporting analysis and decisions, there are several other methods for assisting in freight analysis. As an example, the TOSTADA is a concept with map layers to understand the full effects of transportation spending (Schrank & Lomax, 2014). It shows information about congestion, safety, pavement condition, bridge quality, and freight value. This concept utilizes geographic information system (GIS) tools as a base for identifying appropriate improvements and illustrate investment costs and benefits. These maps can be visually stacked to provide analysts with consistent information on several important topics in one view.

Bachmann, Kennedy, & Roorda (2015) presented a new method for estimating regional trade flows using transportation survey data describing commodity origin–destination flows. Authors converted observed commodity flows in survey data to production–consumption trade flows that are consistent with the multi-regional input–output framework. A case study in the Province of Ontario in Canada demonstrates the feasibility of the method and shows that the estimated pattern of trade flows is maintained after adjustments to satisfy accounting constraints.

Eisele et al. (2016) developed a three-part methodology to estimate truck freight value. Researchers found that there was a correlation between commodity value and truck delay. Higher commodity values are associated with a larger population, and the latter is associated with more traffic congestion. Researchers also developed and tested in the city of Milwaukee a transferrable method to investigate freight value along specific corridors in an urban area. Authors also presented policy implications of the freight information.

2.3 KEY TAKEAWAYS

After an extensive literature review, a specific methodology for identifying Critical Freight Corridors was not found, and this is the core motivation of this research study. Therefore, this study will offer a method for identifying the critical freight corridors considering different quantitative and qualitative inputs. Then, the model is expected to expose eligible corridors and highlight most suitable options based on a series of predefined parameters. As found in the literature, this is a method of spatial decision support system (SDSS). The overlay of different GIS features will enable the assessment of the most suitable corridors for CUFC and CRFC designation. It will also exclude corridors that are not eligible, narrowing down the analysis. In this case, factor selection will not be a necessary step, since the policy on which the CUFC and CRFC are applied already has a defined set of criteria to be met.

3 METHODOLOGY

This methodology started on a careful analysis of all Statewide Freight Plans and their methods for designating CUFCs and CRFCs. States vary in their transportation needs and system requirements, particularly regarding multimodal freight transportation. Therefore, the developed framework is intended to be adapted for any state and to include redesignation. This means that some of the recommended elements may not be relevant to every State, and as such, do not have to be considered. The overall methodology is shown in Figure 4.

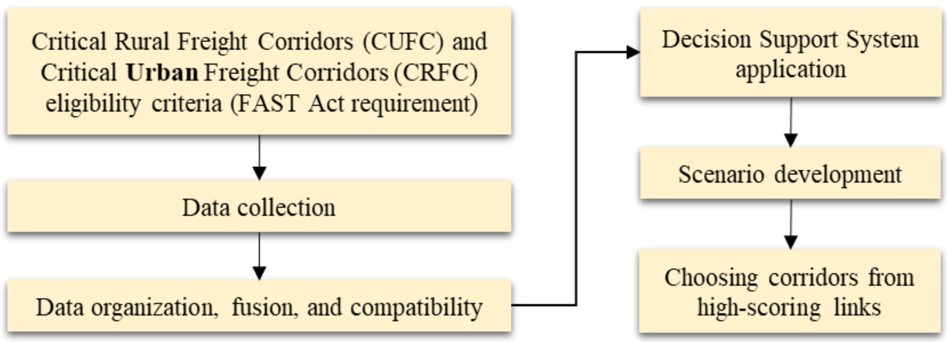

Figure 4: Overall methodology flowchart

The developed methodology was based on current practices for designating CUFCs and CRFCs. Based on our research, the proposed solution is to rank the corridors based on the policy's criteria, their characteristics, and the geometric structure of the transportation network. We consider the road transportation network as a graph containing a pair of links (roads) and nodes (intersections).

The quality of a decision support system depends on both the quality and extent of its knowledge included. The proposed model has three main components: system input (corridor importance rating), the inference element which performs constraints priority ranking and treatment priority setting through a decision analysis tool, and the system output, which is the final score of corridors.

3.1 MODEL DESCRIPTION

The computational aspects of the AHP method involve several steps outlined by Saaty (Saaty, 1987). The graphical representation of the problem in terms of the overall goal, criteria, and decision alternatives is presented in Figure 5. Details about the criteria will follow. Located at the first level of the hierarchy, the overall goal is to select the most adequate location for CUFCs and CRFCs. At the second level, the criteria imposed by this specific policy are identified by their codes. Table 1 shows the identification codes and corresponding criteria description for defining CUFCs and CRFCs, according to FHWA requirements and guidance. Finally, the third level consists of the corridor alternatives, link combinations in this case, for each type of freight corridor, namely rural and urban. Among the criteria, the terms "provides access", "connects", and "serves" are translated into links that provides direct access to the mentioned facilities. Therefore, a direct connection of the corridor and the facility is required for eligibility.

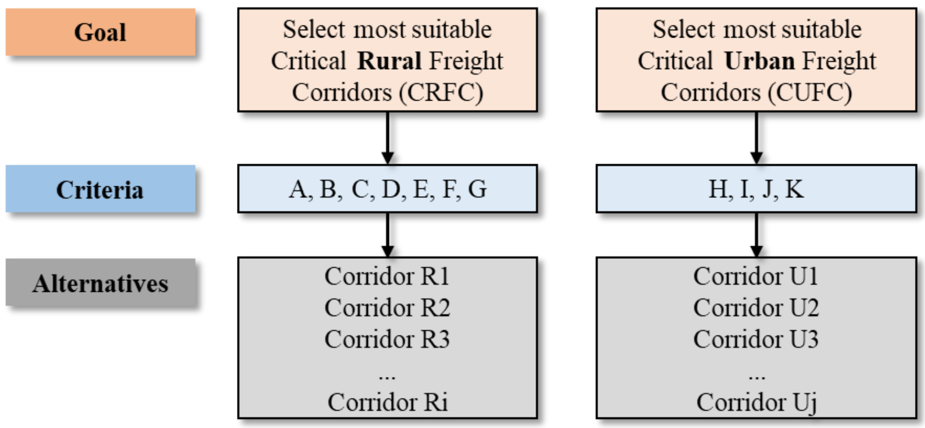

Figure 5: Problem hierarchy

Table 1: CRFC and CUFC Codes and Criteria

Type of Corridor			Type of Eligibility	
ID	**Type**	**Criteria**	**ID**	**Description**
R	Rural	Is inside an area with a population less than 50,000 Pop < 50.000	**A**	Rural principal arterial roadway with a minimum of 25% of the AADT of the road measured in passenger vehicle equivalent units from trucks
			B	Provides access to energy exploration development, installation, or production areas
			C	Connects the PHFS or the Interstate System to facilities that handle more than: 50,000 20-foot equivalent units per year; or 500,000 tons per year of bulk commodities
			D	Provides access to a grain elevator, an agricultural facility, a mining facility, a forestry facility, or an intermodal facility
			E	Connects to an international port of entry
			F	Provides access to significant air, rail, water, or other freight facilities
			G	Corridor that is vital to improving the efficient movement of freight of importance to the economy of the State
U	Urban	Is inside an area with a population over 50,000 Pop ≥ 50.000	**H**	Connects an intermodal facility to the PHFS, the Interstate System, or an intermodal freight facility
			I	Located within a corridor of a route on the PHFS and provides an alternative highway option important to goods movement
			J	Serves a major freight generator, logistic center, or manufacturing and warehouse industrial land
			K	Corridor that is important to the movement of freight within the region, as determined by the MPO or the State

3.2 MODEL FORMULATION

The model developed for selecting critical corridors seeks to rank links based on their eligibility to be designated as a CRFC or CUFC. This methodology uses a weighted multi-criteria analysis (WMCA) approach to derive a transparent formulation of decision-making. Each corridor should receive its score based on whether it is a Rural or Urban corridor. Details on how to determine this rural/urban feature will be discussed in a subsequent section, where data needs will be described.

For calculating the score of Critical Rural Freight Corridors (CRFC), the formulation is as follows. The criteria for rural corridors are converted as shown in Table 2.

$$S_{CRFC} = \sum_{R=1}^{7} C_R W_R \qquad (1)$$

Where,

S_{CRFC} is the score of the Critical Rural Freight Corridor

$C_R \begin{cases} 1, & for\ criteria\ met \\ 0, & otherwise \end{cases}$

W_R is the weight of each criterion

Table 2: Criteria corresponding variables for rural corridors

Criteria ID	A	B	C	D	E	F	G
$\boldsymbol{C_R}$	C_1	C_2	C_3	C_4	C_5	C_6	C_7
$\boldsymbol{W_R}$	W_1	W_2	W_3	W_4	W_5	W_6	W_7

For calculating the score of Critical Urban Freight Corridors (CUFC), the formulation is as follows. The criteria for corridors classified as urban are converted as shown in Table 3.

$$S_{CUFC} = \sum_{U=8}^{11} C_U W_U \qquad (2)$$

Where,

S_{CUFC} is the score of the Critical Urban Freight Corridor

$C_U \begin{cases} 1, & for\ criteria\ met \\ 0, & otherwise \end{cases}$

W_U is the weight of each criterion

Table 3: Criteria corresponding variables for urban corridors

Criteria ID	H	I	J	K
$\boldsymbol{C_U}$	C_8	C_9	C_{10}	C_{11}
$\boldsymbol{W_U}$	W_8	W_9	W_{10}	W_{11}

3.3 WEIGHTING METHOD

The developed methodology requires a scale for expressing the desired importance of the criteria based on perceived importance. This is defined according to the State's needs and objectives, as well as the expertise of the professionals involved. While any scale can be used, a commonly used scale is the one proposed by Saati in his original description of the AHP (Saaty, 1987). The 9-point scale shown in Table 4 is used for pairwise comparison in the method.

Table 4: Weight scale definition

Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment moderately favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgements	When compromise is needed

Source: Saaty, 1987

In the case of defining CUFC and CRFC, the main scales of importance (1, 3, 5, 7, and 9) should be used as this is enough for this solution. In case more detail is needed, intermediate values can be applied. With this scale defined, corridor alternatives are compared against each other with respect to one decision criterion at a time. Then, through a specific procedure, criteria should be compared against each other. This process leads to a comparison matrix, which results in the *eingevectors* that represents the weights, and consistency ratios. It was demonstrated that the characteristic vector (or eigenvector) solution is a suitable method for determining the relative weights that arise from paired comparisons (Banai, 2006). To perform the pairwise comparisons, we should organize scores in a square matrix to calculate the relative priority of each factor. For rural classification, the method is shown in the following equation, where λ_R is the eigenvalue corresponding to rural corridors.

$$\begin{bmatrix} C_{1,1} & C_{1,2} & C_{1,3} & C_{1,4} & C_{1,5} & C_{1,6} & C_{1,7} \\ C_{2,1} & C_{2,2} & C_{2,3} & C_{2,4} & C_{2,5} & C_{2,6} & C_{2,7} \\ C_{3,1} & C_{3,2} & C_{3,3} & C_{3,4} & C_{3,5} & C_{3,6} & C_{3,7} \\ C_{4,1} & C_{4,2} & C_{4,3} & C_{4,4} & C_{4,5} & C_{4,6} & C_{4,7} \\ C_{5,1} & C_{5,2} & C_{5,3} & C_{5,4} & C_{5,5} & C_{5,6} & C_{5,7} \\ C_{6,1} & C_{6,2} & C_{6,3} & C_{6,4} & C_{6,5} & C_{6,6} & C_{6,7} \\ C_{7,1} & C_{7,2} & C_{7,3} & C_{7,4} & C_{7,5} & C_{7,6} & C_{7,7} \end{bmatrix} \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ W_4 \\ W_5 \\ W_6 \\ W_7 \end{bmatrix} = \lambda_R \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ W_4 \\ W_5 \\ W_6 \\ W_7 \end{bmatrix} \quad (3)$$

For the urban classification, the calculation is shown in the following equation, where λ_U is the eigenvalue corresponding to urban corridors.

$$\begin{bmatrix} C_{8,8} & C_{8,9} & C_{8,10} & C_{8,11} \\ C_{9,8} & C_{9,9} & C_{9,10} & C_{9,11} \\ C_{10,8} & C_{10,9} & C_{10,10} & C_{10,11} \\ C_{11,8} & C_{11,9} & C_{11,10} & C_{11,11} \end{bmatrix} \begin{bmatrix} W_8 \\ W_9 \\ W_{10} \\ W_{11} \end{bmatrix} = \lambda_U \begin{bmatrix} W_8 \\ W_9 \\ W_{10} \\ W_{11} \end{bmatrix} \quad (4)$$

The AHP method of eigenvectors or relative weights are calculated according to Saaty (1987), and a sample can be found in the papers by Sadasivuni et al. (2009) and Chen, Yu, & Khan (2010).

The weight attribution should follow each State's current knowledge base and objectives. The equal importance approach should be chosen if the state does not have any preference over any of the parameters. This can mean that the state would like to evaluate all options available to compose its CUFC and CRFC network. Additional factors such as truck volume, upcoming projects, or emerging opportunities may also be considered to select final corridors.

To formulate a solution, stakeholders must attribute weights to the objectives, or, in this case, the different criteria. In this case, when one criterion has a low value, other criteria may offset it. In this case, for example, a corridor deemed important to the movement of freight within the region or State (such as criteria G and K) can receive a higher weighted score, even if the envisioned project in the corridor has less benefits than other projects. Weights should be given in collaboration with multiple decision-makers. An example of this step will be presented in the case study.

3.3.1 Sample Pairwise Comparison

As an example, for the pairwise comparison, a stakeholder wishes to generate corridors based on its proximity to warehouses. Therefore, the criteria "J: Serves a major freight generator, logistic center, or manufacturing and warehouse industrial land" should be prioritized over all other criteria. The pairwise comparison is shown in Table 5.

Table 5: Example of pairwise comparison for prioritizing criteria J

	H	I	J	K
H	1.00	1.00	0.11	1.00
I	1.00	1.00	0.11	1.00
J	9.00	9.00	1.00	9.00
K	1.00	1.00	0.11	1.00

In the table/matrix above, the rows correspond to the criteria being prioritized and the columns correspond to the criteria being compared. In row J, the attributed score of 9 in a cell means that criterion J is much more important than criteria H, I, and K. In Column J, values of less than 1 means that criteria H, I, and K are much less important than criteria J. The values in the diagonal will always be 1 as equal criterion are not compared. The standardized matrix of this example is shown in Table 6. This scoring system gives the weight of criteria J as 75% and all other criteria receive 8.3%.

Table 6: Example of standardized matrix for prioritizing criteria J

	H	I	J	K	Weight
H	0.08	0.08	0.08	0.08	8.3%
I	0.08	0.08	0.08	0.08	8.3%
J	0.75	0.75	0.75	0.75	75.0%
K	0.08	0.08	0.08	0.08	8.3%

In the case of this example, since we only did one comparison (prioritized J over all others), we do not need to test for consistency. If other combinations of preference are conducted, the consistency test must be applied, adopting a threshold of less than 10% of inconsistency. According to Saati (1987), the random consistency index (RI) for Rural corridors is 1.32 (n = 7 criteria) and for Urban corridors is 0.90 (n = 4 criteria). If necessary, the Consistency Index (CI) and Consistency Ratio (CR) are calculated as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1} \qquad (5)$$

$$CR = \frac{RI}{CI} \qquad (6)$$

3.4 MODEL INPUTS

An aggregation of several data sources and applied methods can be used for generating the input information. A comprehensive and consistent network analysis ensures that the process will be accurate, and redesignation will be straightforward. We attribute identification codes to determine the type of corridor. For each criterion, a certain type of data or group of data is necessary to determine its eligibility. First, the census population is the area input defining if the corridor is Rural or Urban. After this first definition, the model should use the corresponding formulation previously defined in the Model Description. The detail of necessary data by criteria is shown in Figure 6.

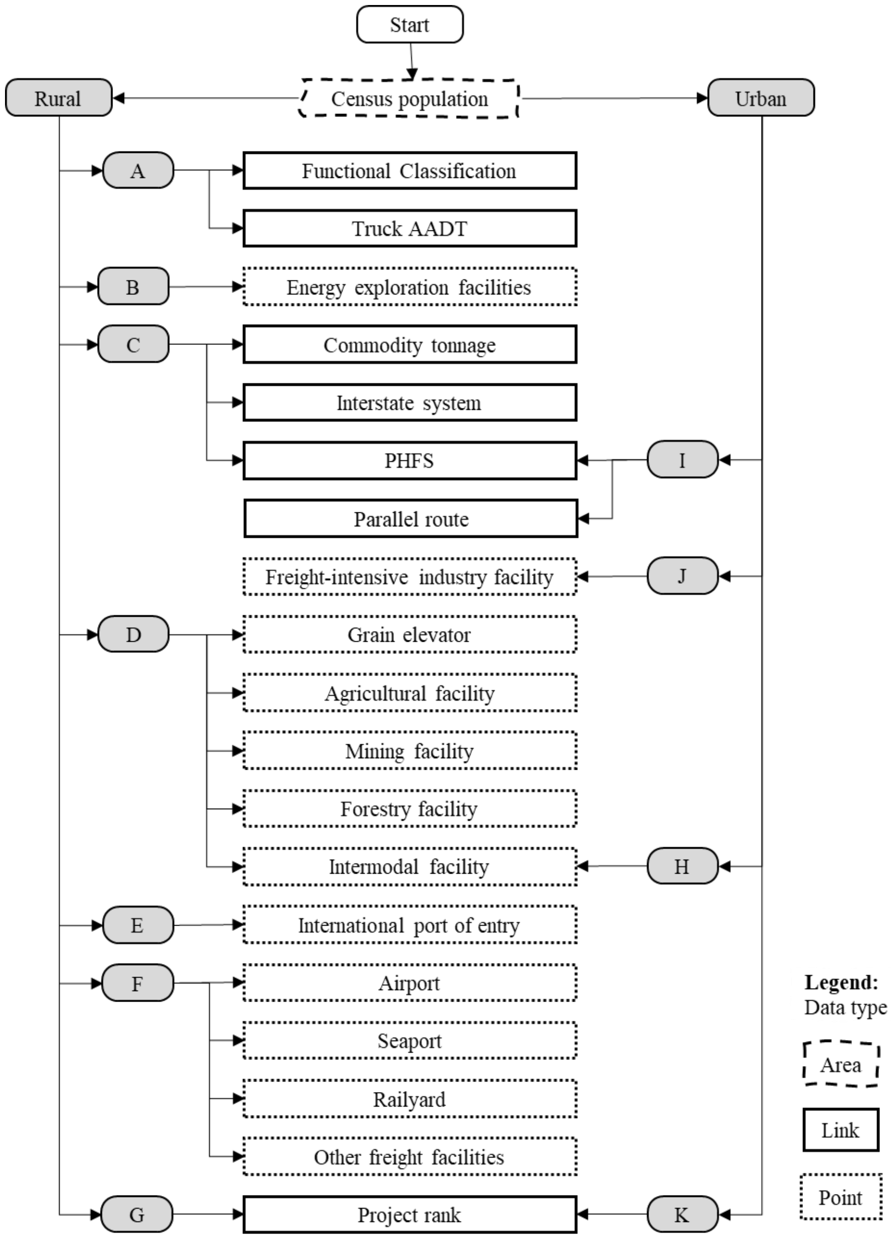

Figure 6: Data needed for each criterion

The Bureau of Transportation Statistics (BTS) reports several information needed for this research study application. However, it does so on a national level for most of the needed data. Therefore, an effort would be required to either disaggregate some reported data into state-level sources, or to replicate such sources in the state level. This is particularly true for safety-related information related to highways. The urban-rural classification is a delineation of geographic areas provided by the United States Census Bureau. This identifies both individual urban areas and the rural areas of the nation. It defines urbanized areas with a population of 50,000 or more (Ratcliffe, et al., 2016), a number compatible with the CUFC and CRFC designation criteria.

Functional classification and basic mobility data can be obtained from several sources. The FHWA provides open access to annual average daily traffic (AADT) of general traffic and trucks, estimated capacity, volume-capacity ratio, speed, and delay information for a large freight highway network with future projections. AADT is often found in State's databases. Truck AADT can be found as a direct count or as estimated percentages. The quality of the Highway Performance Monitoring System (HPMS) data, which were used to identify Truck AADT, varies greatly from State to State and depends upon the quantity and location of counts, the age and frequency of counts, and the upkeep of counting equipment.

In the case corridors are to be selected based on existing planned freight projects, the developed approach should also take as an input an infrastructure project ranking. This should attribute a rank or score for different projects based on existing practices among the group of professionals conducting the analysis. The rank should reflect the professional evaluation of which project is more important to the state. Simplified analysis tools should be developed specifically to the location of the study. Among other aspects, it should leverage available resources to estimate economic effects of freight transportation improvements.

3.5 AUTOMATED DESIGNATION METHOD

Implementing an automated method for critical corridor identification allows a faster and more accurate designation and redesignation. This can be developed in any programming language. This section will be organized by a description of each step of the program for replicating the automated methodology.

The first step is data organization and fusion to generate a unified link database. For this, either a GIS approach or a programmatic fusion can be performed. The latter allows reutilization of the solution in the future for corridor redesignation. To get the information if the link connects a freight facility, we should generate different paths between the links and the freight facilities. If the points do not connect with the network, another approach is to create a buffer around the link and get the number of facilities, needing a distance parameter. One can use the suggested parameters/threshold for the criteria presented in Table 7. The distances are based on current practices found in the Statewide Freight Plan analysis conducted in section 2.1.1 and recommendations of stakeholders.

Table 7: Suggested parameters by critical freight corridor criteria

Type	Criteria	Suggested Threshold
Rural	A	Rural principal arterial and Truck AADT > 25%
	B	Within 2 miles of an energy facility
	C	Within 1 mile of a road with 2017 commodity tonnage above 500 kilotons and within 1 mile of PHFS or Interstate System
	D	Within 2 miles of at least one freight intensive facility*
	E	Within 1 mile of an international port of entry
	F	Within 2 miles of major airport, seaport, or railyard
	G	Project rank
Urban	H	Within 1 mile of an intermodal facility and the PHFS or Interstate System
	I	2017 commodity tonnage above 500 kilotons and is a parallel route to the PHFS within 25 miles
	J	Within 2 miles of a freight-intensive industry with over 1,000 employees*
	K	Project rank

For obtaining accurate results, the quality of the input data is essential for any approach for CUFC and CRFC definition. The inputs that feed the model are the ones described in the previous section (3.4). Each link must have the described set of information to conduct the analysis. The first step of the program is shown in the flowchart of Figure 7.

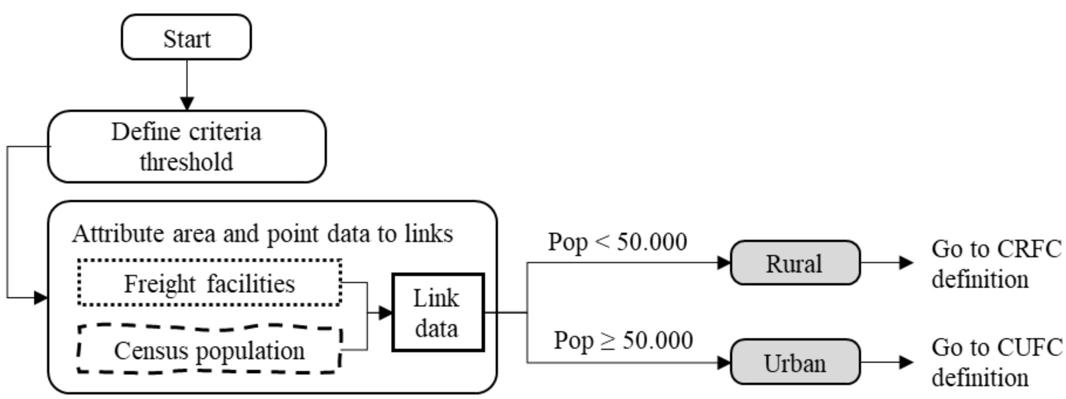

Figure 7: Flowchart of first step of program

The first step of the program is to use the link information of the population of the area to determine if the corridor is Rural or Urban. In the case of CUFC and CRFC designation, the population divider is 50.000. The subsequent function should be separated for links labeled by rural or urban.

For determining if a criterion is applicable (true) or not (false) a simple comparison operator is enough. The link database design can attribute one column for each criterion starting with a null value (zero). This is equivalent to the weight value C_R or C_U. The program should change the value to 1 (one) if the criterion is met in each interaction. This method identified eligible candidates and highlighted locations with freight activity. A schematic flowchart of decisions for links classified as Rural is presented on Figure 8.

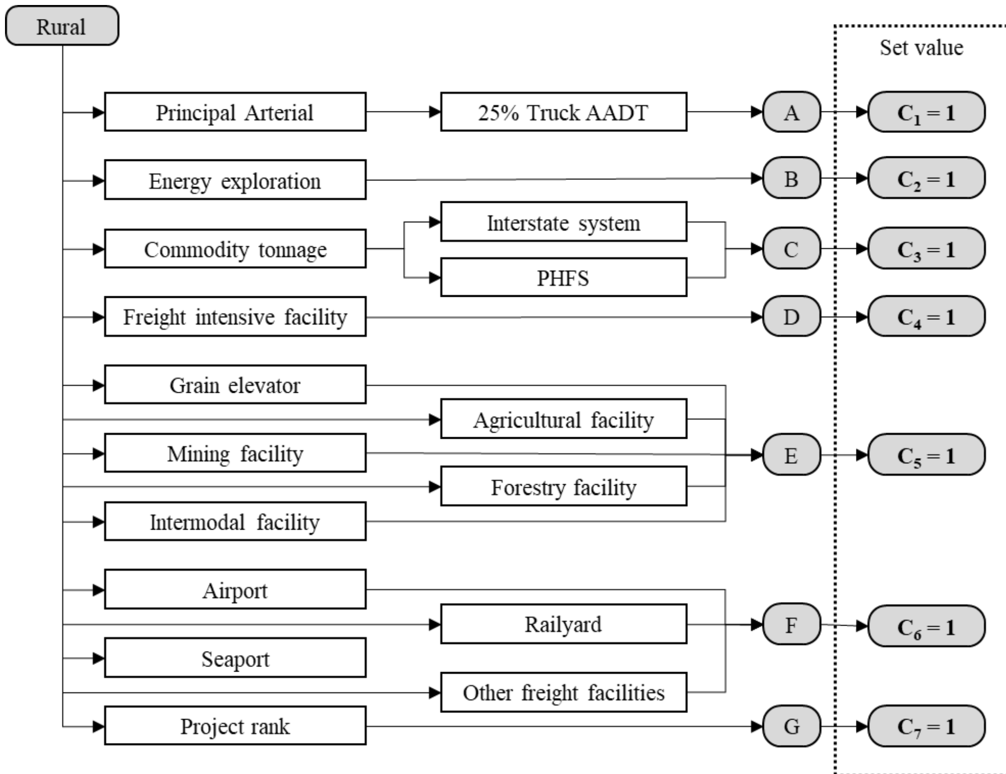

Figure 8: Rural Corridor Classification Flowchart

A schematic flowchart of decisions for links classified as Urban is presented on Figure 9.

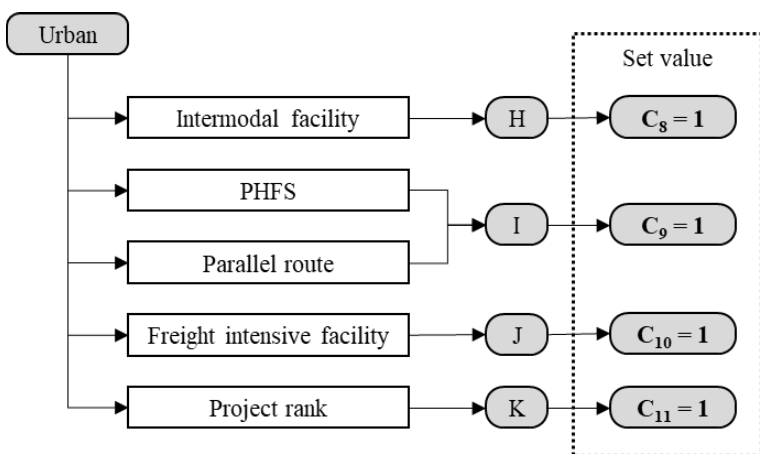

Figure 9: Urban Corridor Classification Flowchart

After obtaining all values of C_R and C_U, the next step is to multiply them with the corresponding weight values. The sum of all factors should generate one score for each link, either in the Urban or Rural classification. The final software architecture flowchart of this step is shown in Figure 10.

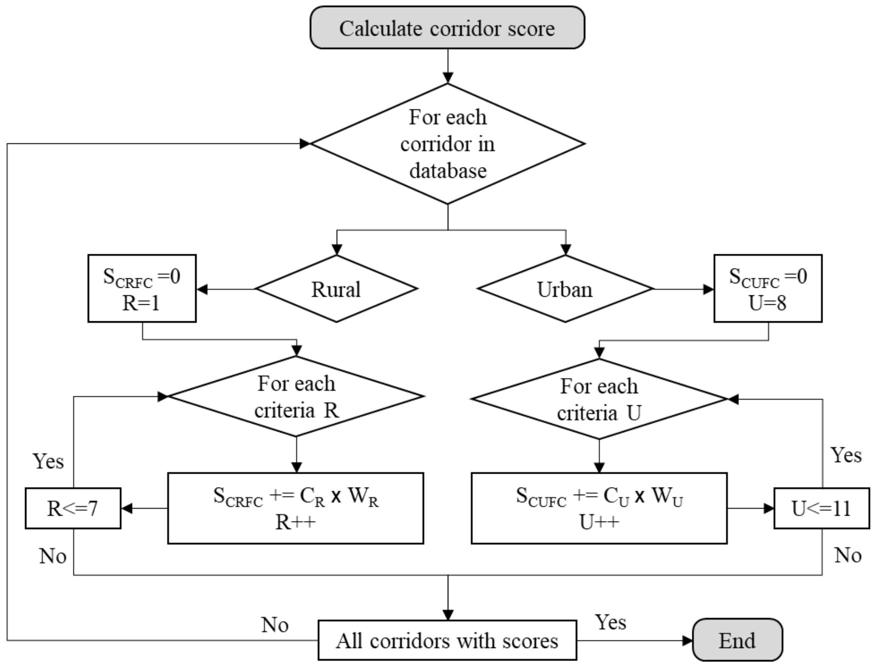

Figure 10: Final score calculation flowchart

The stakeholder may choose to view all scores and analyze which areas are the top choices for corridor designation. Another option is to consider maximum mileage in the analysis process. For this policy, designation of CRFCs is limited to a maximum of 150 miles or 20% of the PHFS mileage in the State, whichever is greater. State and MPO designation of CUFCs is limited to a maximum of 75 miles of highway or 10% of the PHFS mileage in the State, whichever is greater.

4 CASE STUDY: STATE OF FLORIDA

The State of Florida was used as a case study to test the applicability of the method. The developed automated designation method was adapted to fit the information available for the State. Florida has CUFC and CRFC designations defined in the Florida's Freight Mobility and Trade Plan (FDOT, 2020). Different scenarios were discussed with stakeholders from the public and private sector. It is expected from the method to generate critical corridors based on different weighting criteria. The objective is to offer a tool for planners to consider the economic importance of freight corridors to strengthen the economy and improve the mobility of goods.

4.1 DATA AND SCOPE

To apply this methodology in a case study, the first step is to gather the information previously described in Figure 6. This section describes the data used for this analysis, on which the scope is the state of Florida. In summary, the data used was:

- Population data of urban and rural areas.
- Statewide road network, with the corresponding functional classification, truck AADT, and commodity tonnage, and Interstate System or PHFS identification.
- Freight facilities: ports, airports, seaports, intermodal, energy exploration, mining.

4.1.1 Urban and Rural Classification

The Census Bureau identifies two types of urban areas: Urbanized Areas (UAs) of 50,000 or more people; and Urban Clusters (UCs) of at least 2,500 and less than 50,000 people. The 2010 Census classification was used for the urban-rural classification parameter due to this being the most updated version of the urban-rural classification. For this research, only urbanized areas within the state of Florida were selected. A list of all urbanized areas within the state of Florida is shown in Table 8.

Table 8: Urbanized areas in Florida

UACE10	Urbanized Area Name	POP 2010	Designation
63838	North Port--Port Charlotte, FL	169,541	State
13510	Cape Coral, FL	530,290	MPO
84024	Spring Hill, FL	148,220	State
23311	Deltona, FL	182,169	State
64567	Ocala, FL	156,909	State
80400	Sebastian--Vero Beach South--Florida Ridge, FL	149,422	State
80416	Sebring--Avon Park, FL	61,625	State
67105	Palm Bay--Melbourne, FL	452,791	State
77230	St. Augustine, FL	69,173	State
32167	Gainesville, FL	187,781	State
42346	Jacksonville, FL	1,065,219	MPO
96697	Winter Haven, FL	201,289	State
39758	Homosassa Springs--Beverly Hills--Citrus Springs, FL	80,962	State
65863	Orlando, FL	1,510,516	MPO
56602	Miami, FL	5,502,379	MPO

UACE10	Urbanized Area Name	POP 2010	Designation
87787	Titusville, FL	54,386	State
71479	Port St. Lucie, FL	376,047	State
86599	Tampa--St. Petersburg, FL	2,441,770	MPO
08974	Bonita Springs, FL	310,298	State
46828	Lakeland, FL	262,596	State
67134	Palm Coast--Daytona Beach--Port Orange, FL	349,064	State
45451	Kissimmee, FL	314,071	State
48799	Leesburg--Eustis--Tavares, FL	131,337	State
79606	Sarasota--Bradenton, FL	643,260	MPO
31060	Fort Walton Beach--Navarre--Wright, FL	191,917	State
86464	Tallahassee, FL	240,223	State
45937	Lady Lake--The Villages, FL	112,991	State
98182	Zephyrhills, FL	66,609	State
67294	Panama City, FL	143,280	State
68482	Pensacola, FL--AL	340,067	State

4.1.2 Transportation Network

The State of Florida maintains a relatively large number of open-source data available to the public. The road layer used is the base map of roadways available in FDOT's geodatabase (FDOT, 2020). All data projection is UTM 17, and the datum is NAD 83. A pre-selection of attributes is performed by both adding information from other layers and removing unnecessary data.

The Functional Classification provides spatial information on the assignment of roads into systems. Florida uses the Federal Functional Classification System, which is common to all states. The two-digit Functional Classification (FUNCLASS) code is the assignment of roadways into systems according to the character of service they provide in relation to the total roadway network. This information can provide the likelihood that freight vehicles will choose the link in its route. In general, freight trucks are more likely to use major highways than local roads, unless connecting to freight facilities. FDOT's functional classification also provides a division of rural and urban roads.

The Annual Average Daily Traffic (AADT) is the total volume of traffic on a highway segment for one year divided by the number of days in the year. The first identified problem with using AADT network is that the links are not connected. Therefore, a process of assigning the AADT values was conducted to the base network. This data was used with the reference year of 2019.

The Florida Statewide Model Version 6.0 (FDOT, 2018) was used for the parameters of freight tonnage being transported. This dataset provides data from 2010, which is the most recent version of the model, and forecasts for 2040.

The Primary Highway Freight System (PHFS) can be found under FHWAs description of the National Highway Freight Network (NHFN) (FHWA, 2020). This attribute can be transferred to the base network under a number of techniques such as spatial joins and data aggregation. Routes that are parallel to the PHFS and the NHFN, providing redundancy to the freight system, were selected. This process consists of selecting whole segments and evaluating if they are parallel to the mentioned network or not.

The rural and urban classification was inserted in the base network as a parameter that takes the value of 1 for links in urban areas and 0 for links in rural areas. Joining information for datasets provided by FDOT is performed with the code ROADWAY. This is a unique 8-character identification number assigned to a roadway or section of a roadway either on or off the State Highway System for which information is maintained. The final set of attributes of the Florida base map are shown in Table 9. To compose the scenario

Table 9: Preliminary Florida Network Attribute Description

Attribute	Description
FID	Internal feature number
Shape	Feature geometry
Length	Length in coverage units
ROADWAY	8-character identification number
FUNCLASS	FDOT's Functional Classification
AADT_T	Truck AADT (percentage)
URBAN	Indicator of urban or rural classification (1 = urban, 0 = rural)
COMM_TON	Commodity Tonnage
INTERSTATE	The link is inside the interstate system
PHFS	The link is inside the PHFS
PARALLEL	The link is a parallel route providing redundancy to the freight system

The map of the preliminary road network and the urban and rural classification is shown in Table 10.

Table 10: Florida base network – preliminary visualization

4.1.3 Freight Facilities

In the category of freight facilities, we include all point data indicated in the section describing system inputs. Joining this layer with the link information (as previously shown in Figure 7) was completed using the neighbor analysis by finding the minimum distance to facilities. The number and type of facilities was also included in the road network layer.

For information about energy exploration, we used information from the US Energy Information Administration (EIA, 2020). This information included the following facilities in the State of Florida: Biodiesel Plants, Crude Oil Rail Terminals, and Petroleum Product Terminals. For other energy facility types, either data was not available or there are no facilities in the study area. The database for the state of Florida includes three biodiesel plants, one crude oil rail terminal, and 45 petroleum product terminals.

Regarding information about grain elevators, and facilities exploring natural resources (agricultural, mining, and forestry), only active mines and mineral plants were found. This can be found in the U.S. Geological Survey database of mineral resources online spatial data (USGS, 2021). A total of 168 active mines and mineral plants were selected within the study area.

The map of Intermodal Freight and Terminal Facilities is a public feature layer described as the transport of freight in an intermodal container using rail, ship, truck, or air. A total of 107 intermodal freight facilities and 157 intermodal terminal facilities were selected for Florida. All selected freight facilities have the truck mode involved. These are a combination of Rail & Truck, Air & Truck, Port & Truck, Truck - Port – Rail, and Truck only.
In the category of airports, seaports, railyards, these are provided in the Florida Geographic Data Library (FDOT, 2020). International ports of entry are listed by the U.S Customs and Border Protection (CBP, 2021).

Due to the large number of points included, a map of a sample area of the State of Florida in the Miami-Dade and Broward counties is shown in the map of Figure 11. This includes the road network and all freight facilities appearing in the area.

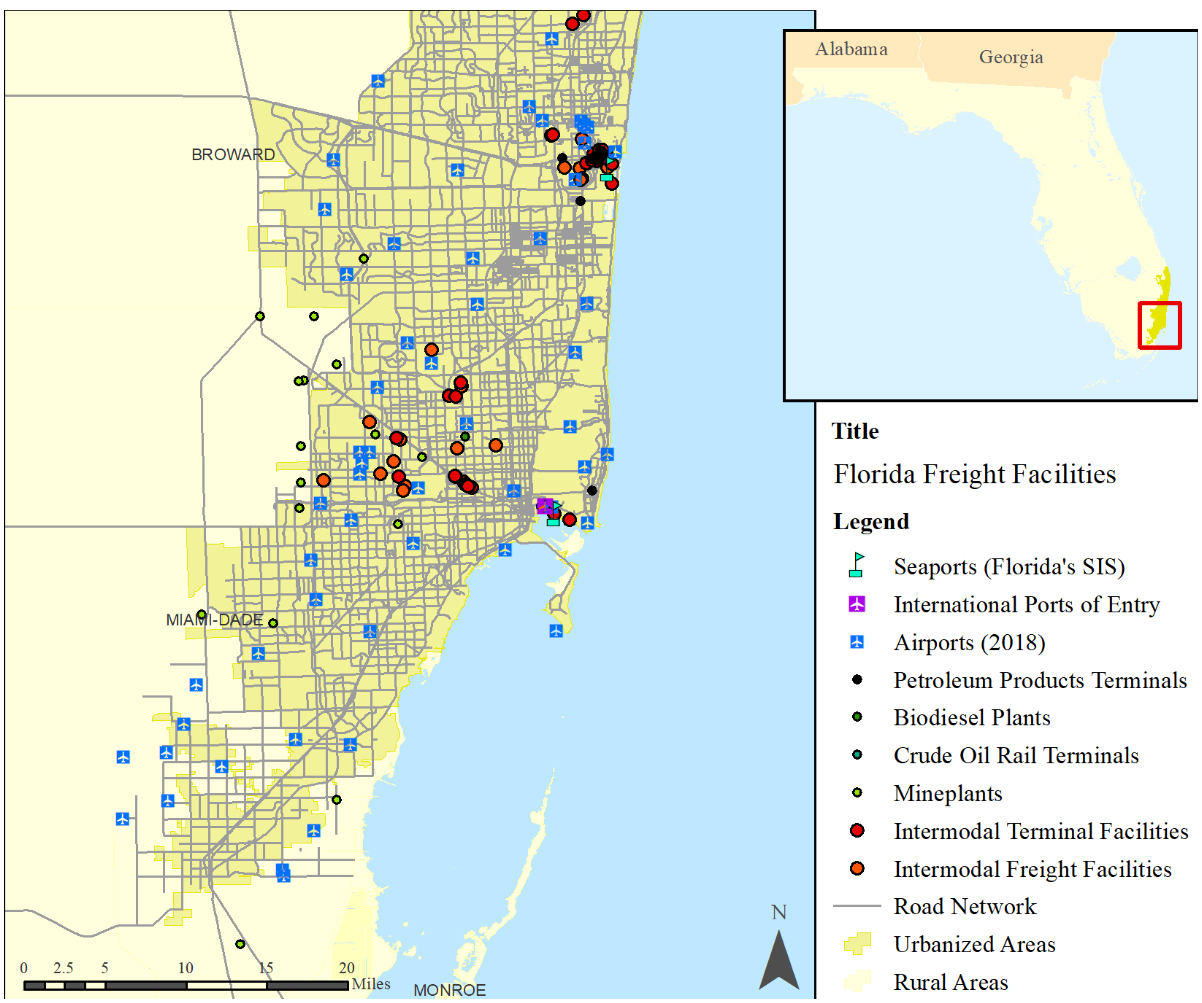

Figure 11: Sample data – Miami-Dade and Broward Counties, Florida

4.1.4 Freight Projects

Florida describes its Project Prioritization and Selection in the Freight Mobility and Trade Plan (FDOT, 2020). The process starts with the identification of projects, project classification and funding eligibility screening, and concludes with qualitative and quantitative evaluation. This method also describes the quantitative scoring measures and criteria and data source. After each project is given a quantitative score and a qualitative score corresponding to each objective, a weighted average score determined by the FLFAC is computed. Projects are ranked by their total score, either qualitative or quantitative, as determined in assessing the projects against the supporting FMTP objectives and freight performance measures.

To test the developed methodology, the projects listed in the highway mode were selected. These are shown in Figure 10. Again, these were extracted from the Freight Mobility and Trade Plan. The location was taken from the FDOT 2021 Five Year Work Program (FDOT, 2020).

Table 11: Projects selected in Florida for analysis

District	County	Description	Length	Project Type	Fiscal Year
1	Highlands	ADAPTIVE SYSTEM ON US 27 FROM HIGHLANDS AVE TO SEBRING PKWY	5.719	ATMS - ARTERIAL TRAFFIC MGMT	2021
1	Polk	SR 25 (US 27) FROM CR 630A TO PRESIDENTS DRIVE	4.920	ADD LANES & RECONSTRUCT	2025
1	Polk	SR 25 (US 27) FROM HIGHLANDS COUNTY LINE TO CR 630A	8.758	ADD LANES & RECONSTRUCT	2021
2	Dist/St-Wide	I-295(SR9A) @ US17 TO SOUTH OF WELLS ROAD	2.537	INTERCHANGE - ADD LANES	2024
2	Duval	I-295 INTERCHANGE @ COLLINS ROAD	0.129	INTERCHANGE - ADD LANES	2021
2	Duval	US301(SR200) @ I-10 IMPROVEMENTS	0.585	INTERCHANGE RAMP (NEW)	2025
3	Bay	SR 20 FROM WASHINGTON COUNTY LINE TO SR 75 (US 231)	23.449	PD&E/EMO STUDY	2022
3	Bay	SR 75 (US 231) FROM SR 30A (US 98) 15TH ST TO SR 368 23RD STREET	4.270	ADD LANES & RECONSTRUCT	2022
3	Walton	SR 20 FROM KING ROAD TO CR 3280 BLACK CREEK BLVD	7.747	ADD LANES & RECONSTRUCT	2024
3	Walton	SR 20 FROM OKALOOSA COUNTY LINE TO WASHINGTON COUNTY LINE	31.988	PD&E/EMO STUDY	2021
3	Washington	SR 20 FROM SR 79 TO BAY COUNTY LINE	3.223	PD&E/EMO STUDY	2021
7	Hillsborough	US 41/SR 45/S 50TH ST @ CSX GRADE SEPARATION SOUTH OF CAUSEWAY BLVD	2.891	NEW BRIDGE CONSTRUCTION	2025

4.2 RESULT SCENARIOS

Using the developed methodology, different critical freight corridors can be obtained based in a different combination of weights attributed. Potential candidates for Critical Urban and Rural Freight Corridors can be assessed based on the number of criteria met by each segment. Additional factors such as truck volume, upcoming projects, or emerging opportunities may also be considered to select final corridors. For each scenario, at least one criteria of the Rural and Urban category were selected.

4.2.1 Equal Weighted Criteria

The first scenario generates a network of critical corridors considering all criteria equally. The equal weighted criteria consider all criteria impacting equally in the result. This approach should be chosen if the state does not have any preference over any of the parameters. In this case, the state would evaluate all options available to compose its CUFC and CRFC network.

According to the scale adopted for this research study, applying a scale of importance 1 for all criteria is the case for this scenario. This attributes an equal importance, where the activities contribute equally to the objective. Therefore, the pairwise comparisons for both urban and rural criteria is a matrix of ones.

4.2.2 Combination of Criteria

We analyze how giving a preference to different criteria impacts the results. These scenarios were derived after a consultation with stakeholders from the public and private sectors in Florida. They suggested scenarios based on the State's current and future needs.

Different combinations of corridors by individual criterion can generate different critical corridors based on several factors such as professional judgement and availability of data. In this solution, each criterion is attributed a higher importance score and all others will be attributed an equal criteria score.

Benefit to Freight Intensive Facilities

Offering infrastructure advance to freight intensive facilities can stimulate industry growth in the state. For this focus, there are specific options in both urban and rural criteria. By analyzing the criteria previously defined in Table 1, we selected the following criteria:

- Rural (CRFC): criteria "C" states that a roadway is eligible if it "connects the PHFS or the Interstate System to facilities that handle more than (i) 50,000 20-foot equivalent units per year; or (ii) 500,000 tons per year of bulk commodities". This is straightforward an option that reflects corridors of freight intensive facilities.
- Urban (CUFC): criteria "H" deems eligible any corridor that "connects an intermodal facility to the PHFS, the interstate system, or an intermodal freight facility". In this case, broadening the threshold can also be used, as judged by the agency.

Benefit to Intermodal Facilities

This scenario seeks to designate critical corridors based on intermodal facilities. This is a broad definition, as several criteria can be deemed as benefitting intermodal locations. According to criteria from Table 1, we selected the following:

- Rural (CRFC): criteria "D" lists a series of facility types that generate freight. This includes agricultural facilities, mining facilities, forestry facilities, and intermodal facilities. Florida has more intermodal facilities in comparison with other mentioned facilities.
- Urban (CUFC): criteria "H" establishes that a roadway is eligible for designation if it "connects an intermodal facility to the PHFS, the interstate system, or an intermodal freight facility".

Benefit to International Ports of Entry

This combination seeks to select corridors based on whether they serve international ports of entry. According to criteria from Table 1, we selected the following:

- Rural (CRFC): criteria "E" states that any corridor that "connects to an international port of entry" is eligible.
- Urban (CUFC): criteria "J" includes corridors serving "a major freight generator, logistic center, or manufacturing and warehouse industrial land". An international port of entry can be considered a major freight generator if it is a commercial port.

Intensive Use Corridors by Volume

This combination seeks to select corridors based on how intensive the freight activity in the corridor is. Parameters that reflect high freight activity is a high annual average daily traffic of trucks. According to criteria from Table 1, we selected the following:

- Rural (CRFC): criteria "A" states that a roadway is eligible for designation if it "is a rural principal arterial roadway and has a minimum of 25% of the annual average daily traffic of the road measured in passenger vehicle equivalent units from trucks (FHWA vehicle class 8 to 13)".
- Urban (CUFC): For links classified as urban, the second eligibility criteria identified by the code "I" states that a corridor is eligible to be designated as a CUFC if it "is located within a corridor of a route on the PHFS and provides an alternative highway option important to goods movement". This, among all options, can be considered a route of high activity.

Energy Exploration Focused

If the state seeks to improve the freight activity based on energy exploration, this scenario should be considered. A focus on this aspect can take into consideration the parameters involving energy exploration. According to criteria from Table 1, we selected the following:

- Rural (CRFC): criteria “B” is related to the energy sector. A roadway which “provides access to energy exploration, development, installation, or production areas” is eligible for designation as a CRFC. Therefore, this criterion yields a set of corridor candidates that connects to energy facilities. Corridors may be extended to connect to the National Highway Freight Network or Priority Highway Freight System depending on the destination of these commodities within or outside of the state.
- Urban (CUFC): there is no aspect that reflects energy exploration in the urban category. Therefore, the broad criteria of code “K” will be used. This allows eligibility for corridors that are “important to the movement of freight within the region, as determined by the MPO or the State”. This would require a previous analysis of areas in urban centers with a high activity of freight vehicles for energy exploration.

4.2.3 Final Weights by Scenario

The final weight definition for each scenario is shown in Table 12. The listed weights were loaded in the automated designation model (programmatic approach) as a direct input. The importance of 5 “Essential or strong importance” was attributed to the selected criteria for each scenario since other values higher than 1 did not impact greatly on the results. In theory, any other value with a higher importance than 1 (which attributes equal importance) would suffice.

Table 12: Scenario Weights Attributed to Criteria

Result Scenario	Rural							Urban			
	A	B	C	D	E	F	G	H	I	J	K
Equal weights	1	1	1	1	1	1	1	1	1	1	1
Benefit to Freight Intensive Facilities	1	1	5	1	1	1	1	5	1	1	1
Benefit to Intermodal Facilities	1	1	1	5	1	1	1	5	1	1	1
Benefit to International Ports of Entry	1	1	1	1	5	1	1	1	1	5	1
Intensive Use Corridors by Volume	5	1	1	1	1	1	1	1	5	1	1
Energy Exploration Focused	1	5	1	1	1	1	1	1	1	1	5

4.3 IMPLEMENTATION AND OUTPUTS ARCHITECTURE

The overall procedure for developing this solution using data from the State of Florida is shown in Figure 12. All procedures are covered by the automated designated method described in a previous section.

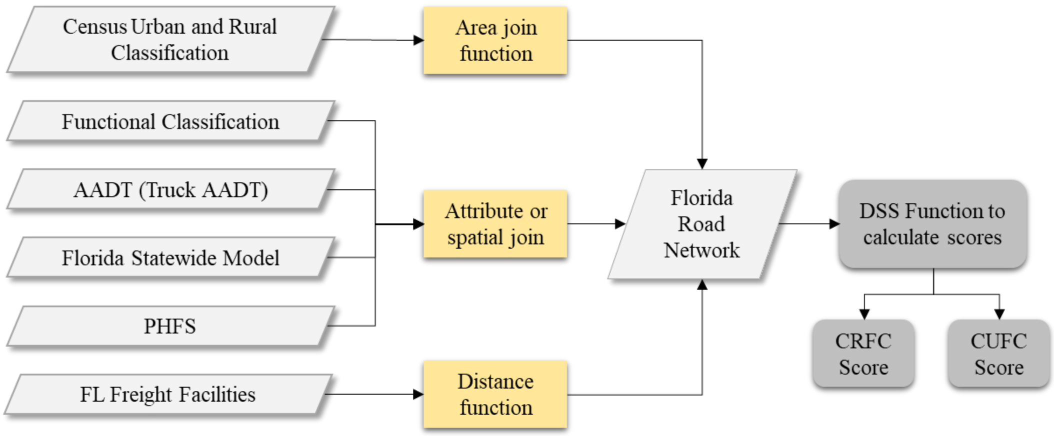

Figure 12: Steps to calculate CRFC and CUFC score

To test the proposed methodology, the Python language was used to implement the developed solution. Python is a popular programming language that supports several development methods and purposes (Python Software Foundation, 2021). This solution was implemented in the PyCharm environment (Jet Brains, 2021). The program was developed on a Microsoft Windows 10 home with a processor Intel Core i7 1.80 GHz. For the GIS data, ArcMAP version 10.6.1 was used to perform the database configuration (ESRI, 2021). The final database for Florida is shown in Table 13.

Table 13: Final Florida Base Map Attribute Description

Decision criteria	Parameter	Description	Values	# of features	Total length (miles)
-	ID	Unique identifier	1-42961	42961	36784.50
-	ROADWAY	8-character identification number	01000002 - 94900009	-	-
-	DISTRICT	FDOT District code	1 - 7	-	-
-	COUNTY	FDOT County name	Text	-	-
-	LENGTH_ MILES	Length of the segment in miles	Decimal	-	-
R/U	C_URBAN	Criteria of urban or rural classification (1 = urban, 0 = rural)	Urban = 1	33474	19787.78
			Rural = 0	9487	16996.73
-	FUNCLASS	FDOT Functional Classification	01, 02, 04, 06 - 09, 11, 12, 14 - 19	-	-
A	C_RPRINCIP	Criteria: rural principal classification (01, 02, 04)	Rural principal = 1	1461	3507.76
			Not rural principal = 0	41500	33276.75
-	TAADT	Annual Average Daily Traffic of Trucks	-		
A	C_TAADT	Criteria: Truck AADT => 25%	Truck AADT => 25% = 1	179	530.70
			Truck AADT < 25% = 0	42782	36253.80
B	C_ENERGY	Criteria: the link is a connection to an energy facility	Connects = 1	7570	3131.00
			No connection = 0	35391	33653.50
C	C_INTERSTA	Criteria: if the link is a part of the interstate system	Interstate = 1	696	974.29
			Not interstate = 0	42265	35810.21
C	C_PHFS	Criteria: the link is a part of the PHFS	PHFS = 1	1402	1714.93
			Not PHFS = 0	41559	35069.57
D	C_FACILITY	Criteria: the link is a connection to a grain elevator or a natural resource exploration facility	Connects = 1	5671	4385.53
			No connection = 0	37290	32398.97

Decision criteria	Parameter	Description	Values	# of features	Total length (miles)
-	FAC_TYPE	Type of facility	grain elevator, agricultural, mining, forestry	-	-
D/H/J	C_INDUSTRY	Criteria: the link is a connection to either an intermodal or a terminal facility	Connects = 1	10838	5161.04
			No connection = 0	32123	31623.47
H	C_CONN	Criteria: the link is a connection to either the PHFS or the interstate system	Connects = 1	10566	7389.04
			No connection = 0	32395	29395.46
I	C_PARAL	Criteria: a link is a paralel route to the NHFN	Is paralel = 1	184	235.92
			Not paralel = 0	42777	36548.58
D	C_FACILITY	Criteria: the link is a connection to a grain elevator or a natural resource exploration facility (agricultural, mining, or forestry)	Connects = 1	5671	4385.53
			No connection = 0	37290	32398.97
F	C_ASR	Criteria: the link is a connection to an aiport, seaport, or railyard	Connects = 1	11503	8089.82
			No connection = 0	31458	28694.69
-	ASR_TYPE	Type of ASR facility	aiport, seaport, railyard	-	-
E	C_IPE	Criteria: the link is a connection to an international port of entry (IPE)	Connects = 1	506	161.18
			No connection = 0	42455	36623.32
G/K	C_PROJECT	Criteria: the link has a project that can be funded by the policy	Project = 1	56	102.03
			No project = 0	42905	36682.47

The weight variables (W_R or W_U) must be multiplied with the corresponding criteria variable (C_R or C_U), which stands for the binary variable for criteria met or not. Each link should have either a CUFC score or a CRFC score. Links with a null score are not eligible for CUFC and CRFC designation according to the automatic evaluation.

The database of the scenarios consists of the link ID, length, and all criteria fields (C_*). The automatic approach will calculate the scores for each scenario and create new columns with the parameters. For the developed solution, the following columns are created for each scenario:

- S_CRFC_<scenario number>: CRFC Score for the scenario
- S_CUFC_<scenario number>: CUFC Score for the scenario
- SCORE_<scenario number>: Consolidated score (CRFC for rural and CUFC for urban) for the scenario

5 RESULTS AND ANALYSIS

As previously mentioned, results can be displayed either with the maximum corridor mileage or without it, therefore showing the overall rank. The sensitivity and map results of scenarios is described regarding the total score. In this final analysis, we show results considering the maximum CUFC and CRFC mileage. This simulates a final network that would be ready for designation. The mileage of eligible corridors is shown in Table 14**Error! Reference source not found.**. This also demonstrate the changes in the results when the input variables are changed. In this case, the input being changed is the weight attributed to the criteria.

Table 14: Eligible miles of critical freight corridors by scenario

#	Scenario	Rural (CRFC)		Urban (CUFC)	
		Mileage	% of total	Mileage	% of total
1	Equal weighted criteria	4,900.79	13.3%	4,972.39	13.5%
2	Benefit to Freight Intensive Facilities	1,141.43	3.1%	2,274.74	6.2%
3	Benefit to Intermodal Facilities	2,053.76	5.6%	2,274.74	6.2%
4	Benefit to International Ports of Entry	795.10	2.2%	4,803.20	13.1%
5	Intensive Use Corridors by Volume	974.31	2.6%	2,422.07	6.6%
6	Energy Exploration Focused	1,003.58	2.7%	2,296.59	6.2%
-	Total Florida network mileage	16,996.73	46.2%	19,787.78	53.8%

From the previous table, we can observe that the equal weighted criteria (**Scenario 1**) generate the highest percentage of corridors eligible for designation. This generates a vast network of eligible CUFC and CRFC, which is logical since the state has several freight facilities and alternate routes to access these facilities. Therefore, using this approach for a DSS in a large state such as Florida would not be optimal. The scenarios that provided a benefit to freight intensive facilities (**Scenario 2**) and intermodal facilities (**Scenario 3**) presented relatively similar results. This was because, in Florida, most freight intensive facilities are also intermodal facilities.

Since we use GIS approach, we then analyze the mapping aspects of this decision support system. Figure 13 shows how focusing on each criteria enabled the visual representation of the solution to generate results.

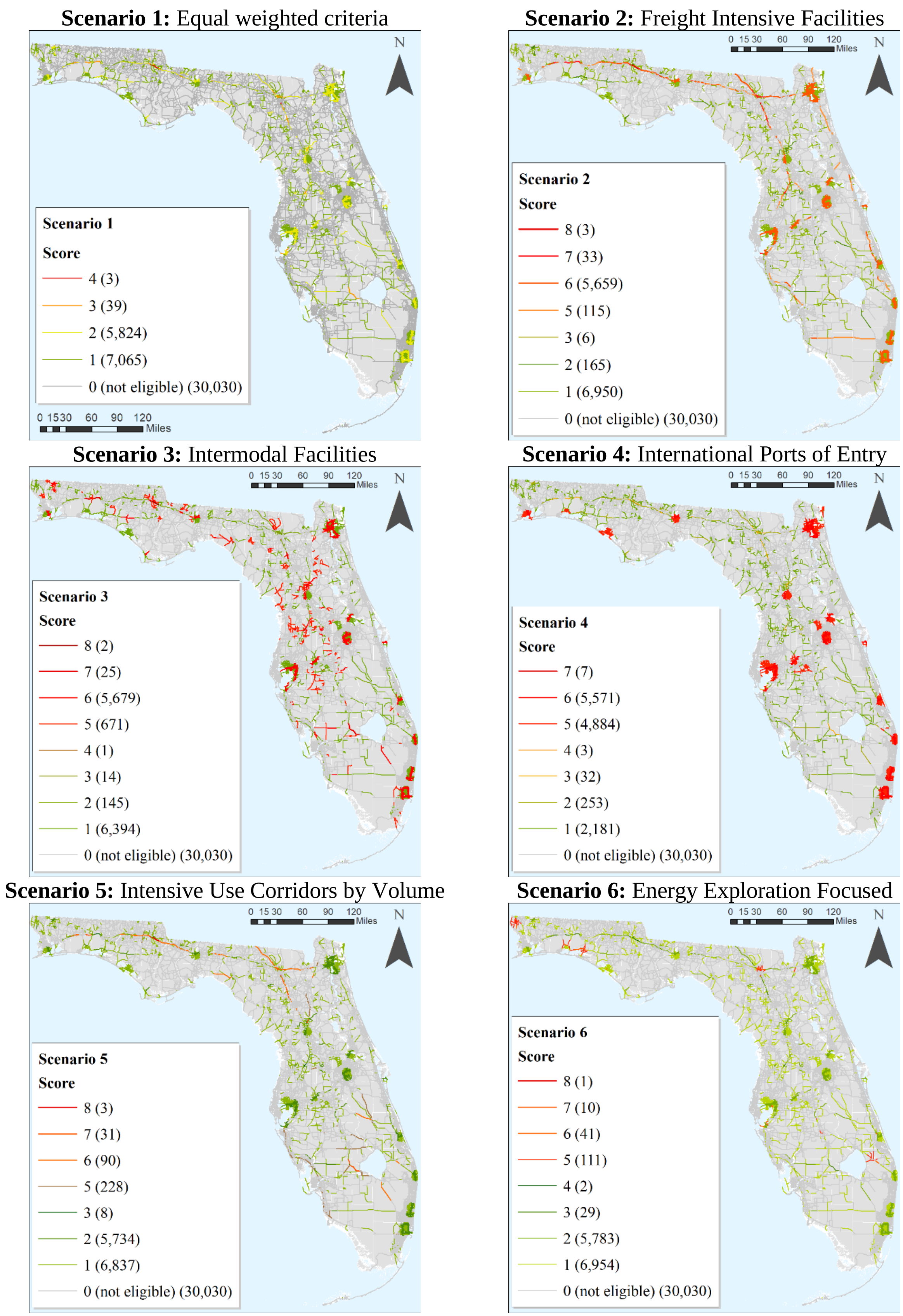

Figure 13: Map visualization of scenario results

As Florida has several freight intensive facilities, **Scenario 2** also generates a relatively large selection of links eligible for criticality designation. In this case, a minimum distance threshold would derive a higher range of links eligible due to the relatively large number of facilities handling the specified number of bulk commodities. Focusing on these two criteria and giving a benefit to access freight intensive facilities should be used for any state seeking to advance this type of facility.

Scenario 3 results in a relatively smaller number of links eligible for designation. Focusing on intermodal facilities has a similar effect as offering a benefit to freight intensive facilities. In this case, broadening the search for links that serve multimodal freight can offer a wider range of benefits that extends to other modes such as rail and air cargo. This scenario should be considered for states seeking to get broader benefits from advancing multimodality.

According to data reported by the U.S. Energy Information Administration (2018), the State of Florida is not a major energy producer in the country. Therefore, good way to benefit the activity in the state would be to analyze **Scenario 6**. This scenario of benefiting energy exploration could be considered by high energy producing states or any other state seeking to advance this activity.

In conclusion, the developed methodology was successful on selecting the eligible corridors in Florida as well as incorporating the State's needs and stakeholders' inputs in an automated way. Conversely, the current process of designating critical freight corridors in the State of Florida, and most of the other States, is based on a network analysis and manual verification of eligibility, per their CUFC and CRFC designation process. Although this is suitable for this purpose, it does not allow analyzing alternatives for corridor designation.

6 FINAL REMARKS

The developed framework is a tool for transportation planners and stakeholders of the public sector to designate Critical Urban and Rural Freight Corridors (CUFC and CRFC) considering their parameters and access to freight facilities. The methodology incorporates different preferences from stakeholders regarding the criteria related to this policy. Indirect benefits from applying the developed framework in different agencies is a more assertive decision and analysis of alternatives for designating the State's CUFC and CRFC network to strengthen the economy and improve the mobility of goods. The methodology also offers flexibility to manipulate the framework to meet various agency goals, allowing subtracting certain criteria when data is not available for evaluation or the inclusion of sub-criteria when a more thorough analysis is required.

This research study offers a systematic methodology for identifying and designating CUFC and CRFC. The automation of decisions for policy and planning is a trend being applied in transportation with the objective of facilitating and adding transparency to various decision-making processes. Additionally, the proposed solution can also be adapted for any future policies that follow the same format. Since every State has a maximum corridor mileage, an efficient resources allocation procedure would result in great benefits for the agency applying the method and to the overall economy.

For this solution, we opted to use a Decision Support System (DSS). Since submitting CUFC and CRFC network in a geospatial network database is encouraged by the regulating organ (FHWA), we also opted to integrate the spatial and database capabilities of using a Geographic Information System (GIS) approach; this is also defined as a spatial decision support system (SDSS). Additionally, we combined the Analytic Hierarchy Process (AHP) to structure the planning and decision-making process involving CUFC and CRFC corridor selection. Combining all this information, this research study introduces a multi-criteria spatial decision support system (MC-SDSS) for structuring the process of designating CUFC and CRFC corridors. A GIS-based MCDM was proven to be efficient in automating and analyzing the problem, which pertains to a spatial decision-making issue with a large set of feasible corridors, multiple conflicting criteria, and several stakeholders involved.

We conducted a preliminary scenario analysis by projecting different scenarios discussed with stakeholders in the State of Florida to demonstrate the applicability of the method. Although the focus is on the corridor selection using Florida as a case study, the developed SDSS can be used by any state as it reflects general CUFC and CRFC designation and it can incorporate State's priorities and preferences. In contrast with the current State's critical freight corridor designation process, the proposed approach is based on an automated method, making the corridor selection process faster and more comprehensive. Therefore, if the State used the developed methodology for identifying the critical freight corridors considering temporal and spatial inputs, small refinements could be conducted to adjust to any preferences of the stakeholders.

Although the developed DSS is intended to be used for supporting corridor designation, the implementation of this approach in a real life CUFC and CRFC designation process imposes a series of challenges. This included, but it is not limited to, the subjectivity of choosing parameters for advancing freight projects according to different interests. Another limitation is regarding the availability of data and expertise of the team.

For further investigation of the applicability of the study and the developed framework, another state designation could be conducted. In the section where we discuss Statewide Freight Plans, which are the documents that define each State's CUFC and CRFC, when applicable, we see that the level of detail for freight analysis in each state varies greatly. Florida is one of the few states that has several resources and data for this type of analysis. Applying the methodology on a database of another state would be extremely beneficial.

A future research study should investigate the traffic condition of the first-/last-mile routes of the corridors to seek if there is a demand for employing any solution to enhance the traffic flow. A simulation model of the first-/last-mile connector would be required to explore the traffic condition of the area and investigate the need for improving the mobility of those links. The proposed methodology should be evaluated on one major highway intermodal connector in Florida which has a considerable amount of freight traffic. The proposed solution can be simulated in a macroscopic level to investigate the impacts of investments.

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