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Strategic criteria for evaluating inland freight hub locations

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STRATEGIC CRITERIA FOR EVALUATING INLAND FREIGHT HUB LOCATIONS

by

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ABSTRACT

The aim of this thesis is to develop criteria that can be used to evaluate the current capabilities and sustainability of inland freight hubs. A review of the literature highlights the need for a more efficient freight distribution system to combat supply chain deficiencies and the important role that inland freight hubs play in creating this system. Also in the literature is a call for a more comprehensive approach to hub development decisions and the use of multi-criteria decision analysis. The decision to devote resources to logistics developments in a specific region must consider many factors that are both quantitative and qualitative in nature. This thesis will identify relevant criteria for inland freight hub development decisions through in-depth interviews with freight transportation experts and it will justify the use of both quantitative and qualitative data for measuring alternatives based on these criteria. The end result will be a set of criteria relevant to hub development decisions and an explanation of the procedure for comparing logistics hub capabilities. This procedure could be used for locating a new hub out of a set of potential sites or making decisions about which existing hubs should be further developed.

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TABLE OF CONTENTS

Page

LIST OF EXHIBITS

LIST OF FIGURES

SECTION

1. INTRODUCTION

Transportation systems have a large impact on the sustainability of our planet and its inhabitants. Furthermore, the economic well-being of a country is increasingly dependent upon an efficiently operating freight transportation system. Because of this dependency on an efficiently operating freight transportation system, any change in this system's performance will have major economic impacts. Currently, the U.S. transportation system is straining to keep up with demand, and bottlenecks are creating areas of congested traffic. Although the congestion has experienced temporary reduction due to the recent economic downturn, the impact that efficient freight transportation has on the economy remains vital. (Research and Innovative Technology Administration, 2010)

For transportation systems, we can define sustainability as "the ability to meet today's transportation needs without compromising the ability of future generations to meet their transportation needs." (Black 1996) According to the World Bank (1996), sustainable transportation can be divided into three categories, economic and financial, environmental and ecological, and social, with economic and financial emphasized as "playing a pivotal role" in the sustainability of transportation systems.

According to Nottebom and Rodrigue (2005), inland freight hubs are developed in order to create a modal shift from road transport to rail or barge transport and to prevent the overcrowding of seaport areas. These hubs have the logistics capabilities to facilitate modal transitions (Oberstart and DeFazio, 2008), which means that the modes that have less environmental impact and are more fuel efficient, i.e., railroads and barges, can be used more effectively while the advantages of truck and air transportation can still be realized. Inland freight hubs would improve the efficiency of the freight system by allowing freight bound for interior markets to move from the port of entry to an inland location without experiencing delays due to congestion in the port area. Therefore, building a network of inland freight hubs would likely increase the efficiency of freight movement throughout the U.S.

However, developing the logistics capabilities of hubs can be resource intensive and the benefits from this development can be difficult to predict. Because of the nature of transportation, namely the costs involved with differing lengths of travel and modes used, location and connectivity to the population are important criteria when considering the effectiveness of a particular inland port. But, there are other important criteria to consider when deciding to locate or develop an inland freight hub.

In this thesis, two papers will be presented. Paper II identifies the relevant criteria for inland freight hub development decisions through in-depth interviews with freight transportation subject-matter experts and details best practices for inland hubs. Appendix C shows freight flow data that was used as an example of data that could be used to measure alternatives based on the established criteria. Paper I uses the Analytic Hierarchy Process to combine quantitative and qualitative data in order to evaluate a set of alternatives based on these criteria. Analysis of both of these data sources should be done in order to get an overall look at the development potential of a region. Among the criteria developed from these data sources, priority levels between the criteria can be set based on the objectives of the decision makers. Once these priority levels are set, specific ways to measure a region in each of the criterion can be used to accurately measure the logistics capabilities and development potential of a particular region. Appendices A and B show pair-wise and ratio comparison tables that set these priority levels.

2. LITERATURE REVIEW

Researchers have approached location problems with a variety of quantitative models. Limbourg and Jourquin (2008) use integer programming to locate facilities with the goal of minimizing total transportation costs. Melkote (2001) also uses integer programming but identifies changes to the network structure along with identifying potential facility locations. Arnold et al (2004) formulates the location problem as a binary linear program, but solves it using a heuristic approach. Racunica and Wynter (2005) also use heuristics in their model and allow for non-linear and concave cost functions.

Quantitative modeling tends to maximize the benefits of the users and operators of terminals without consideration for community impacts. Community concerns often include environmental, economic, and quality of life effects of the project. Environmental and land use impacts have been identified (Litman, 1995 and McCalla, Slack, & Comtois, 2001), but quantifying the effects of these impacts is difficult.

In order to obtain a holistic view of the location decision, rather than a purely quantitative view, Murthy (2001) suggests good performance criteria should include both quantitative and qualitative measures as applicable to the project. Multi-criteria decision analysis (MDCA) serves as a good tool for modeling freight-related development decisions because of its flexibility to combine different types of data and different viewpoints from experts. Macharis (2005) and Vreeker (2002) have both implemented the Analytic Hierarchy Process (AHP) as a decision support tool for MDCA in port development decisions. Sirikijpanichkul (2007) presents a decision model that specifically addresses the location issue and attempts to select the optimum location based on the needs of stakeholders.

Because of the wide range of factors that affect the decision to either create new inland freight hub locations or further develop existing hubs, Multi-Criteria Decision Analysis is an effective way to consider all of the relevant criteria as well as all of the relevant stakeholders. Current models describe the methodology for evaluating and locating hubs, but they do not provide a description of how to develop the relevant criteria and how to measure alternatives based on these criteria. The importance of developing measurable criteria for sustainable transport systems is covered in Litman (2007). In this research, we use the definition of sustainability developed by Long et al. (2010). This definition clearly identifies the significance of environmental, social, and economical aspects in sustainable hub development.

Additional literature is covered in greater detail as part of the two papers included in this thesis. Literature in Paper I is covered on pages 2 and 3 and literature in Paper II is covered on pages 18-22.

PAPER

I. Strategic Decision Model: Characteristics for Sustainable Intermodal Logistic Hubs

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Abstract

This research develops a strategic decision model to evaluate the present state of a region's ability to serve as an inland freight hub and establish objectives that will develop and solidify its sustainability within the freight network. A review of the relevant literature highlights the need for a more efficient freight distribution system to combat supply chain deficiencies and the important role that inland freight hubs play in creating this system. Also in the literature is a call for a more comprehensive approach to hub development decisions. This paper will determine the relevant qualitative and quantitative criteria of hub development and evaluate the regions of Kansas City, MO, St. Louis, MO, Louisville, KY, and Memphis, TN using the Analytic Hierarchy Process (AHP).

Key Words: Freight logistics, Strategic decision making, subject-matter experts, Intermodal Hubs

1. Introduction

The ability, or inability, of the United States to handle growing freight levels is an issue of increasing concern throughout the supply chain. Because of the country's dependence on an efficiently operating freight transportation system, any change in this system's performance will have major impacts on the economy. Currently, the system is straining to keep up with demand, and bottlenecks are creating areas of congested traffic. Trucks carry more than half of the total freight by weight and over sixty-five percent by value; so much of this strain is felt on the National Highway System (NHS). In fact, without operational improvements or the addition of capacity, congested traffic miles on the NHS are projected to double by the year 2035 (Federal Highway Administration Office of Management and Operations, 2008).

One operational improvement that has been put into place to move more freight from the road to underutilized modes of transportation is the development of inland freight hubs or inland ports. In this paper, an inland freight hub is defined as a region that has the capabilities to transfer freight between at least two transportation modes: road, rail, water, or air. Serving as an interface point between these modes, inland freight hubs facilitate the transition of goods from one mode to another. These hubs have the potential to reduce highway freight congestion and increase the overall efficiency of freight movement. However, developing a region's logistic capabilities is resource intensive and the benefits from this development can be difficult to predict. In order to truly gauge the logistics development potential of a region, location and connectivity to population are important criteria. These factors are not the only critical elements, as this research will suggest, but because of the nature of transportation, namely the costs involved with differing lengths of travel and modes used, they weigh heavily on the final decision to establish a region as an intermodal center.

Location theory gives a general economic basis on how to locate facilities and quantitative methods combine this theory with optimization models to locate potential sites. These methods are used in various ways to analyze freight transportation networks and optimize the location of hubs given a set of supply and demand points. Although these optimization models provide an adequate foundation for approaching location decisions, this paper works off the idea that qualitative data exists that is relevant to inland freight hub development decisions and must be used along with this quantitative data in order to get a complete understanding of a region's ability to establish and maintain logistic capabilities.

Four regions, Kansas City, MO, St. Louis, MO, Memphis, TN, and Louisville KY, have been chosen as comparative inland freight hubs based on their existing infrastructure and economic environment. Quantitative data, such as the number of interstate highways and class I railroads serving the region will be used along with qualitative data, such as the support of development agencies and local industry, to measure each region's development potential. Qualitative factors will be measured through the coding of interview responses and quantitative factors will be measured through various primary data sources. Analysis of both of these data sources must be done in order to get an overall look at the development potential of a region. Among the qualitative and quantitative characteristics that have been identified, priority levels should be set in order to gauge the importance of one element over another. Information will be gathered on how the priorities should be set through in-depth interviews with freight experts in each of the comparison regions. The Analytic Hierarchy Process (AHP) will then be employed to synthesize both sets of data to create a comprehensive decision model for developing intermodal logistics hubs.

The structure of the paper is as follows. Section 2 will review the literature relevant to locating and developing intermodal logistics hubs. Section 3 will describe the methodology. Section 4 will show the results of using the Analytic Hierarchy Process to evaluate each region's hub development potential. Section 5 will conclude with recommendations for further research.

2. Literature Review

Location theory shows how space enters economic relationships. Specifically, it addresses transportation costs and their effects on the location decision. There is an incentive to economize transportation activities because the associated costs directly affect the prices that a firm must charge for its outputs (McCann and Sheppard, 2003).

The economies of scale that are realized at the inland freight hubs serve as the basis for their introduction into the network (Campbell, 1996) A inland freight hub looked at as a single facility can be considered both a cost-decreasing and cost-increasing facility depending on whether the freight is moving into or outside of a region. For freight moving outside of the region, the inputs into the hub are high-cost drayage trucks that serve the local freight market. The freight delivered by this truck is converted into relatively lower cost per unit freight by being placed on a train or a barge and sent to its final destination. For freight moving into a region, the freight arrives as relatively lower per unit cost train or barge freight and is converted into high-cost drayage freight. In both instances it is most efficient to locate the facility close to both the demand and supply of drayage freight because this would keep the distances these trucks travel to a minimum. This theoretical application provides an ideal basis for terminal locations to be identified, but the real world introduces many constraints to the decision.

A major constraint to this situation is the growing time sensitivity of freight transportation. With the popularity of just-in-time inventories, freight movement is needed to be very flexible and very fast. Truck transportation is considered the most flexible while air transportation is the fastest. However, these modes also demand a higher per unit cost of transporting the goods compared with rail and barge transportation. So the balance of speed and cost of delivery must be considered because they will have major implications about the kind of infrastructure needed.

Another constraint is the limited amount of resources that both public and private organizations can devote to transportation related infrastructure. Arnold et al. (Arnold, 2004) show that budget constraints will have a direct effect on the decision of whether to build new facilities or to modify the existing network in order to better connect existing facilities. Some methods assume that the transportation network they are locating a terminal on is relatively fixed, so models are used to optimize locations on this existing network (Limbourg, 2008). These models use spatial aggregation and commodity flow data on the network to identify potential intermodal sites. Other methods allow the underlying network topography to change (Melkote, 2001). Along with identifying potential facility locations, this model identifies potential additions to the network.

Although many different decision models have been applied to hub development initiatives, there is not a distinctive model that recognizes and validates the most crucial criteria for these decisions. Furthermore, there is a clear benefit to taking into account multiple stakeholders, however, if the AHP is used, the issue of choosing the importance level of one stakeholder over another could have social and political ramifications for decision makers. The goal of this research is to create one definitive model that will involve the critical elements of hub development decisions as confirmed by experts in this field.

3. Strategic Partner Decision Model

The methodology used in this paper adapts the technique developed by Saaty (1999). The decision to devote resources to logistics developments in a specific region must consider many factors that are both quantitative and qualitative in nature. Purely quantitative models or purely qualitative discussions would not give the decision maker a comprehensive idea about the development opportunities in a region. Therefore, it is important to combine the two sources into one model, and the AHP presents an effective method for doing that.

3.1 Model Overview

The methodology will consist of five main steps: (1) Determine the objective for the decision model (2) Determine the relevant criteria to use when judging the alternatives (3) Validate this criteria with subject matter experts (4) identify the alternatives (5) Judge the alternatives based on the criteria.

(1) Specify the objective

Because of the wide range of applications for the AHP, it is important to first identify exactly what the overall objective is for the decision model. Some researchers have been interested in choosing between development alternatives at one specific hub (Macharis, 2005; Dooms, 2003). Here, the goal is to choose between a set of hubs based on which location presents the best alternative for overall logistics development and sustainability potential.

(2) Determine the relevant criteria to use when judging the alternatives

This step will utilize existing literature, observations, and data gathered from subject-matter experts to determine what characteristics an intermodal logistics hub location needs to possess in order to be effective. Then, the relative importance of each characteristic will be determined with pair-wise comparisons between all of the criteria.

(3) Identify alternatives

The area of interest in the study is the Midwestern United States so a set of four intermodal logistics hubs were selected within this region. These hub regions are Kansas City, MO, St. Louis, MO, Louisville, KY, and Memphis, TN. The regions were selected based on their comparable populations, infrastructure, logistics development initiatives, and location in the Midwest United States. Other locations could have been selected for comparison, but the selected sites were observed by the authors to mostly closely meet our initial criteria.

(4) Judge the alternatives based on the criteria

At this point, the hierarchy is complete and the alternatives are ready to be evaluated and compared against each other through pair-wise comparisons.

3.2 The Analytic Hierarchy Process

The model of the AHP was developed by Thomas L. Saaty (1999) with the purpose of creating an intuitive structure for making decisions. Although the model itself is relatively simple, it has the potential to be applied in a wide variety of complex decisions. Its endless opportunities for application stem from both its straightforward structure and its ability to combine qualitative and quantitative data. Data, both quantitative and qualitative, can be compared using either the scale they are measured in or through the use of a pair-wise comparison scale. (Exhibit 1)

Exhibit 1: Pair-wise comparison scale. Adapted from Saaty (1999)

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Demonstrated importance	An activity is favored strongly over another
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	For compromise between above values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it
Reciprocals of above	If activity *i* has one of the above nonzero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A comparison mandated by choosing the smaller element as the unit to estimate the larger one as a multiple of that unit

Using the AHP, logistic hub development decisions can be structured according to the most relevant criteria. (Exhibit 2) Among these criteria, judgments about their relative importance can be made in order to further enhance the accuracy of the model. One major advantage of the AHP is that modifications to the model can be made with relative ease, so if there are significant differences based on the region, then adjustments can be made to this model to suit the situation.

4. Subject-Matter Expert Interview Protocol

The interviews conducted for this research were significant in the creation of the decision model because they provided expert insights into the characteristics necessary for hub development. Key decision makers from logistics development organizations were identified and interviewed from each of the regions mentioned. The information gathered from these interviews will be used in determining both the characteristics of logistics hubs and the priority level of these characteristics.

The questions were developed with the purpose of determining the important criteria for making hub development decisions. Although some of the details of the questions were tailored for the specific region, the general interview protocol was as follows:

(1) What are the most important factors that contribute to the development of an intermodal logistics hub?

(2) Which factors are the most sensitive to deficiencies i.e. which characteristics will have the most negative impact on a region if they are weak or non-existent?

(3) How does the presence of economic development agencies impact hub development?

(4) Do community concerns, such as pollution and traffic congestion, have a large impact on the progress of development projects?

(5) Does the size and quality of the workforce weigh heavily on development decisions?

From these interviews, some fundamental elements that influenced the capabilities of intermodal logistics hubs were identified. These elements were the transportation infrastructure in the region and the size and proximity of the market served by the region.

Infrastructure represents the ability of the region to physically move the freight while the proximity and size of the market represents the supply and demand of freight in the region. Both of these elements are basic factors in determining the development potential of an intermodal logistic hub and if a region is deficient in one of these areas, their abilities for logistics development will be severely diminished.

Land availability was another issue that came up with all of the interviewees. This aspect represented the expansion capabilities of a region. Without available land for warehouses, terminals, and other related buildings or infrastructure, the development opportunities would stagnate. This is especially evident at the West Coast ports of Los Angeles and Long Beach. Although this area is a key hub for freight coming into the U.S., the development potential here is relatively non-existent because there is no room for expansion. However, this issue is not at a critical stage like this in the Midwest region. All interviewees cited this element as an important one but made it clear that room for expansion existed in their region.

Economic development organizations were also mentioned as important factors to hub regions. The existence of these organizations were said to play a big role in the time it took for projects to progress from the conceptualization stage to the building and implementation stage. Regions that have strong developmental agencies are able to attract development because the project implementation process is very efficient. These agencies also serve as connection points between the region and other organizations looking for good locations to locate logistics-related facilities. Often, location consultants are hired to find the best location for a business and these regional development agencies can help provide the necessary data to these consultants so that they can make an informed decision.

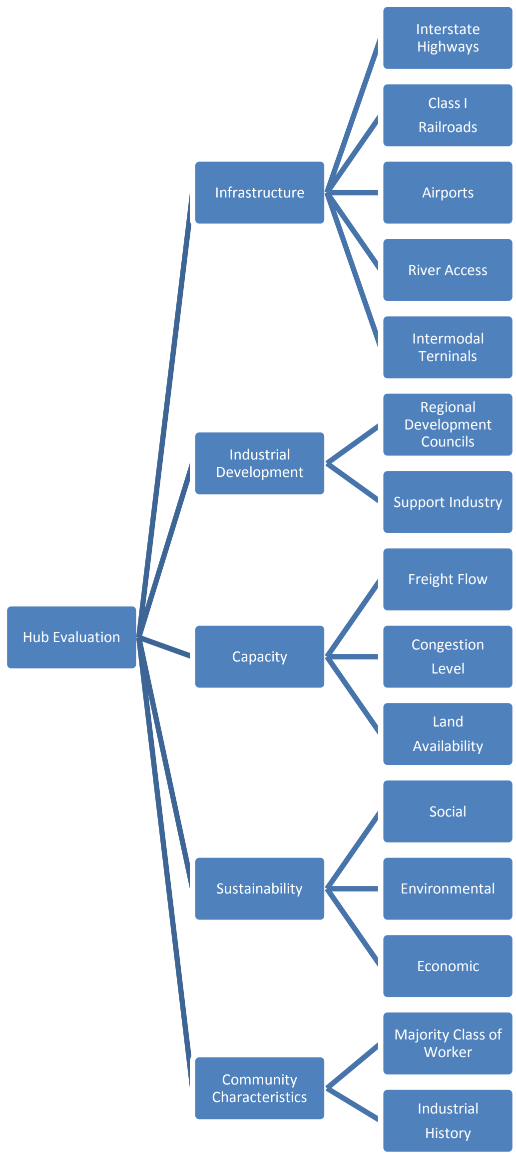
The demographics of a region and the history of industrial development there will play a big role in the community’s attitudes towards logistics development activities. One interviewed expert referred to his region's history as a transportation hub and cited this as a critical factor in the acceptance from the community of expansion and development. Another expert explained that the major demographic of his region was working class and that development was expected and encouraged because of the job opportunities that were usually created. Both of these situations contribute to the public's general understanding and acceptance of logistics-related developments.

Other factors were mentioned by the interviewees but were identified as being less critical than the previously mentioned factors. For instance, the regulatory environment was said to definitely play a part in development decisions, but it usually was not the critical element that determined whether or not to go forth with the project. Likewise, the supply of labor was said to directly affect hub development, but that most of the time shortages in labor could be overcome.

5. Criteria Identification and Weighting

From the interview findings, an initial structure for the AHP has been constructed. (See Exhibit 2)

Exhibit 2: AHP Structure



The first level of criteria shows the main points that were mentioned by the interview respondents. After these were identified, sub criteria were developed in order to further define the main criteria. A description of each of the main criteria follows:

Infrastructure: This criterion measures the region's the movement of freight possible. The alternative with better access to highways, railroads, etc. will be more capable of supporting new logistics developments.

Industrial Development: This criterion measures the level of support that logistics developments get from both regional economic development agencies and local industry. Alternatives that have strong support from both of these groups will be more receptive to logistics developments.

Capacity: This criterion measures the ability of a region to expand. New logistics developments will likely require more land and infrastructure so alternatives with excess capacity will be more capable of supporting new logistics developments.

Sustainability: This criterion measures the region's long-term ability to sustain itself socially, economically, and environmentally with the addition of new logistics developments. The economic portion refers to proximity to market characteristics mentioned in the interview findings. Social sustainability refers to the community's continued acceptance of the region's logistics developments. And, environmental sustainability refers to the sensitivity of the regional environment to industrial developments.

Community Characteristics: This criterion takes into account the demographics of a region. Areas that are made up mostly of industrial laborers and have a history of industrial development will be most receptive to logistics developments.

Pair-wise comparisons are used to determine the relative importance of the main criteria,. Exhibit 3 shows the pair-wise comparisons for the criteria using the scale from Exhibit 1. Exhibit 4 shows the result of these comparisons and their final weights. This paper will not go into detail about the formulas for finding the final weights. For the formulas, see Saaty (1999).

Exhibit 3: Pair-wise comparisons of criteria

Criteria Comparisons	Infrastructure	Indus. Development	Capacity	Sustainability	Comm. Characteristics
Infrastructure	1	3	2	1.5	5
Indus. Development	.33	1	.5	.33	3
Capacity	.5	2	1	.5	3
Sustainability	.67	3	2	1	4
Comm. Characteristics	.2	.33	.33	.25	1

Exhibit 4: Final criteria weights

Hub Criteria	Weight
Infrastructure	35%
Industrial Development	12%
Capacity	18%
Sustainability	29%
Community Characteristics	6%

6. Evaluation of Alternatives Discussion

The interview findings identified the relevant criteria and the coding of their responses provided inputs for establishing priority levels among them. The hierarchy created can now be applied to the set of regions that have been identified for comparison.

In order to compare the regions, data related to the criteria was needed. For infrastructure, highway, railroad, and waterway networks were analyzed along with the locations of airports and intermodal terminals. Exhibit 5 shows the infrastructure characteristics of each region.

Exhibit 5. Infrastructure characteristics

	Highways	Class I Railroads	River Access	Intermodal Terminals
Kansas City	I-29, I-70, I-35	KCS, BNSF, UP, NS, CP	Missouri	BNSF, UP, KCS
St. Louis	I-70, I-44, I-55	KCS, BNSF, UP, NS, CSX	Missouri, Mississippi	BNSF, NS, CSX, UP
Louisville	I-65, I-64	CSX, NS	Ohio	NS
Memphis	I-40, I-55	NS, BNSF, UP, CN, CSX	Mississippi	CN-CSX, BNSF

KCS = Kansas City Southern, BNSF = Burlington Northern Santa Fe, UP = Union Pacific, NS = Norfolk Southern, CSX = CSX Transportation

Industrial development was measured based on the existence of dedicated logistics development organizations in the region and the supporting logistics industry, such as distribution and warehousing firms.

Freight flow data from the Federal Highway Administration's Freight Analysis Framework were used to evaluate freight flow and the interviewee discussions were used to gauge congestion levels and land availability in order to get an overall measure of regional logistics capacity. Exhibit 6 shows the projected 2010 freight flows originating in and destined for each region.

Exhibit 6. 2010 total projected freight flows by weight (kt)

	Truck	Rail	River	Air
Kansas City	158,112	31,177	80	25
St. Louis	215,145	15,501	24,669	43
Louisville	175,189	8,058	13,299	70
Memphis	122,966	16,582	37,126	60

Sustainability characteristics were captured through the interviews along with an analysis of each region's market reach. The findings from the interviews were also used to understand each region's community characteristics.

Depending on the alternatives that have been chosen for comparison, the main points of difference will vary from case to case. For instance, the regions considered in this model were relative equals in terms of community characteristics, environmental and social sustainability, congestion levels, and land availability. The main differences were in infrastructure, industrial development, freight flow, and proximity to market. However, the characteristics of the comparison would change if different regions were considered, such as coastal regions where congestion and land availability become more important points of difference.

7. Discussion of Results and Key Findings

The regions were compared using the same procedure for comparing the criteria and the results are shown in Exhibit 7. The percentages under each criterion are the result of pair-wise comparisons between each of the regions based the main criteria. The final column shows the overall priority or development potential for the region and was found by combining the criteria weights, from Exhibit 4, with the resulting regional priorities levels found in the first five columns of Exhibit 8. Here, the strengths of each region relative to the main criteria are shown as well as the overall strength of that region compared to the other alternatives.

It is important to note that, because of the many similarities between these regions, there is not one dominant region with regards to hub development. However, the differences between the alternatives can easily be seen by looking at their specific strengths or weaknesses in each of the criteria categories. Hub development decisions often come down to a few alternatives that seem very close in their development potential. The model this research presents can specifically identify which criterion makes a distinction between the alternatives that are being considered. Developers looking for a location for their transportation-reliant activities can use this model to make these distinctions between their alternatives and choose the location based on their specific needs. Regional development organizations or local governments can also use this model to see how their region compares against others in terms of intermodal transportation capabilities and determine what areas should be slated for improvement.

Overall, this model provides a structure for determining the strengths and weaknesses of a region for intermodal hub development. The importance of each criterion and the alternatives chosen for comparison will vary based on the conditions and decision makers, but the overall structure is relevant for all hub development decisions.

Exhibit 7. Regional comparisons and overall priority levels

	Infra-structure	Capacity	Industrial Develop-ment	Sustainabili-ty	Communi-ty Charac-teristics	Overall Priorities
Kansas City	31%	23%	28%	20%	25%	**28%**
St. Louis	32%	26%	18%	23%	25%	**25%**
Louisville	11%	24%	28%	29%	25%	**18%**
Memphis	26%	27%	28%	29%	25%	**29%**

8. Conclusions

This paper combined quantitative and qualitative data relevant to logistics development using the Analytic Hierarchy Process and used subject-matter expert interviews to develop and validate the criteria used in this hierarchy. The model was applied to regions in a specific geographic area, but it is relevant and adaptable universally. The resulting model gives decision makers a comprehensive tool for approaching logistics development decisions by giving them the ability to compare potential hub regions based on relevant criteria.

9. Further Research

The AHP model can be combined with other models to strengthen its decision-aiding capabilities. Optimization techniques, such as linear programming, goal programming, and network optimization, could serve to add to the relevance of the model used in this paper.

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II. Sustainability Criteria for Inland Hub Location Development

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Abstract

This research develops criteria that can be used to evaluate the capabilities and sustainability of inland multimodal freight hubs. It addresses the need for a more efficient freight distribution system to combat supply chain deficiencies and explores the important role that inland freight hubs play in improving the livability and economic vitality of a region. The research develops a comprehensive approach to hub development decisions for multi-criteria decision analysis. Data gathered from subject-matter experts is used to determine the relevant qualitative and quantitative criteria needed to evaluate the sustainability of inland freight hubs. Decision makers can use the findings presented to assess inland hub locations more effectively.

Key Words: Freight logistics, Strategic decision making, subject-matter experts, Intermodal Hubs

1. Introduction

Transportation systems have a large impact on the sustainability of our planet and its inhabitants. For transportation systems, we can define sustainability as “the ability to meet today’s transportation needs without compromising the ability of future generations to meet their transportation needs.” (Black, 1996) Not only do these systems impact the surrounding environment, they also affect the access that people have to economic and social opportunities. According to the World Bank (1996), sustainable transportation can be divided into three categories, economic and financial, environmental and ecological, and social, with economic and financial emphasized as “playing a pivotal role” in the sustainability of transportation systems.

The economic well-being of a country is increasingly dependent upon an efficiently operating freight transportation system. Prior to the economic downturn in 2008, the United States’ freight transportation system had been straining to keep up with demand, and bottlenecks were creating areas of congested traffic. Because trucks carry more than half of the total freight by weight and over sixty-five percent by value, much of this congestion was on the National Highway System (NHS). In 2008, the Federal Highway Administration predicted that without operational improvements or the addition of capacity, congested traffic miles on the NHS would double by the year 2035 (Federal Highway Administration Office of Management and Operations, 2008). Although the congestion has been significantly reduced due to the economic downturn, the impact that efficient freight transportation has on the economy remains vital. (Research and Innovative Technology Administration, 2010) It is essential that the system be improved to facilitate economic growth and avoid delays caused by congestion.

According to Nottebom and Rodrigue (2005), inland freight hubs are developed in order to create a modal shift from road transport to rail or barge transport and to prevent the overcrowding of seaport areas. These hubs have the logistics capabilities to facilitate modal transitions; thus, contributing to the reduction of highway congestion and increasing the efficiency of freight movement. (Oberstart & DeFazio, 2008) However, developing the logistics capabilities of hubs can be resource intensive and the benefits from this development can be difficult to predict. Because of the nature of transportation, namely the costs involved with differing lengths of travel and modes used, location and connectivity to the population are important criteria when considering the effectiveness of a particular inland port. But, there are other important criteria to consider when deciding to locate or develop an inland port.

Quantitative data, such as the number of interstate highways and class I railroads serving the region, should be used along with qualitative data, such as the support of development agencies and local industry, to measure a region's logistics development potential. Analysis of both of these data sources must be done in order to get an overall look at the development potential of a region. Among the criteria developed from these data sources, priority levels between the criteria can be set based on the objectives of the decision makers. Once these priority levels are set, specific ways to measure a region in each of the criterion can be used to accurately measure the logistics capabilities and development potential of a particular region.

This paper will identify relevant evaluation criteria for inland freight hub development. Criteria are determined and validated through in-depth interviews with freight transportation subject-matter experts at existing inland hubs. The criteria presented illustrate the use of both quantitative and qualitative data for evaluating freight hub location alternatives. Decision makers can use these results to more effectively determine the sustainability of regional hub alternatives.

2. Background

2.1 Current state of the U.S. freight transportation system

The U.S. has the most extensive freight transportation network in the world, with nearly three times more paved road miles and railroads than the next closest country (Research and Innovative Technology Administration, 2010). The relatively larger area, lower population density and highly populated urban areas of the U.S. put higher demands on the network so the size of this network is justified; however, the freight transportation capabilities of the U.S. are not invulnerable to deficiencies. According to the U.S. Department of Transportation, the efficiency of the transportation network is not growing apace with the volumes of freight utilizing the system (Federal Highway Administration Office of Management and Operations, 2008). Because much of this freight volume is international, ports of entry have experienced the highest levels of congestion. This, in turn, has stimulated the development of inland freight hubs. These hubs relieve some of the congestion at ports of entry by allowing international freight to be consolidated or deconsolidated in areas with excess freight capacity. This has been documented in previous results published by Hesse and Rodrigue (2004) and Lipscomb and Long (2008).

With projections of up to a seventy percent increase in freight volumes moving throughout the U.S. by 2020, addressing the issue of freight congestion will involve a mixture of adding capacity, preserving existing infrastructure, and improving operating efficiencies (United States Government Accountability Office, 2008). All three of these strategies can be accomplished through the addition of new, strategically located inland ports or the development of existing inland multimodal freight hubs. Building an efficient network of inland freight hubs would therefore increase the efficiency of freight movement throughout the U.S.

The goals of a sustainable freight transportation system are not only focused on operational efficiency; reducing energy consumption and decreasing the environmental impact of these activities are also important goals. Because inland ports facilitate the exchange of freight between modes, they also allow for better utilization among the transportation modes. This means that the modes that have less environmental impact and are more fuel efficient, i.e., railroads and barges can be used more effectively while the advantages of truck and air transportation can still be realized. However, local to the hub, there is a potential for increased environmental impact because emissions are concentrated in this area due to higher freight flows. Therefore, it becomes important to locate and develop inland ports considering both the region’s ability to facilitate freight activity and the overall impacts that freight activity will have on the region.

The popularity of just-in-time inventories places additional pressure on the freight transportation system by demanding flexibility and quick responsiveness. Truck transportation is considered the most flexible while air transportation is the fastest; however, these modes also demand a higher per unit cost of transporting the goods compared with rail and barge transportation. The balance of speed and cost of delivery must be considered since they will have major implications for the kind of infrastructure needed. Grasman (2006) details a quantitative research modeling study that determines which combination of transport modes will minimize either cost or lead time.

As the freight network expands, both regional developers and private businesses will need a method for assessing the transportation strengths and weaknesses of a region. Regional developers want to leverage strengths and address weaknesses while businesses want to identify the location that best suits them for their transportation-related activities. Developing inland freight hubs is resource-intensive and there is risk involved with possible under-utilization; therefore, the location of these developments must be chosen considering a wide range of factors.

2.2 Location theory

The economies of scale that are realized at inland freight hubs and their ability to facilitate intermodal movements serve as the basis for their introduction into the network (Campbell, 1996). Location Theory provides the foundation for this idea by explaining how space enters economic relationships. Specifically, it addresses transportation costs and their effects on the location decision. There is an incentive to economize transportation activities because the associated costs directly affect the prices that a firm must charge for its outputs. In its simplest form, location theory states that a firm will decide to locate a facility based on how it will change the weight of its inputs (McCann and Sheppard, 2003). For example, a company that adds weight to their inputs will have an incentive to locate closer to the point of consumption, whereas a company that decreases the weight of their inputs will locate closer to the supply.

Instead of changing the weights of inputs, an inland port changes the per-unit transportation costs of its inputs by moving freight from one mode to another. There is an incentive to minimize total shipping costs by converting relatively higher cost per unit freight, such as truck freight, to lower cost per unit freight, such as rail freight. In this way, An inland port, looked at as a single facility, can be considered both a cost-decreasing and cost-increasing facility depending on whether the freight is moving into or outside of a region. For freight moving outside of the region, the inputs into the hub are high-cost drayage trucks that serve the local freight market. The freight delivered by this truck is converted into relatively lower cost per unit freight by being placed on a train or a barge and sent to its final destination. For freight moving into a region, the freight arrives as relatively lower per unit cost train or barge freight and is converted into high-cost drayage freight. In both instances it is most efficient to locate the facility close to both the demand and supply of drayage freight. The Fermat-Weber location problem introduces the problem of locating facilities optimally by finding the geometric mean of a graph given cost and distance data. However, no explicit formula exists to solve for this location.

Weiszfeld Algorithm provides one way to approximate the optimal location. The algorithm, typically used in facility location planning, can be adapted to calculate the optimized location of a city or freight center in relationship to the flow of materials between it and relevant trade partners. The distance between the proposed optimal location and the actual location is considered waste and is a quantitative measure of sustainable freight flow.

2.3 Gaps in existing location decision models

Researchers have approached location problems with a variety of quantitative models. Limbourg and Jourquin (2008) use integer programming to locate facilities with the goal of minimizing total transportation costs. This method not only uses aggregated supply and demand points, but also accounts for commodity flows and their geographic location in order to determine the optimal location of intermodal terminals on a given network. Melkote (2001) also uses integer programming but identifies changes to the network topology along with identifying potential facility locations. Arnold et al (2004) formulates the location problem as a binary linear program, but solves it using a heuristic approach. Racunica and Wynter (2005) also use heuristics in their model and allow for non-linear and concave cost functions.

Existing tools including location theory and other quantitative location decision models provide guidance for hub locations, but do not provide qualitative information regarding livability and sustainability vital for determining community readiness. In order to obtain a holistic view of the location decision, rather than a purely quantitative view, Murthy (2001) suggests good performance criteria should include both quantitative and qualitative measures as applicable to the project. And, Bontekoning et al. (2004) extensively reviewed current intermodal research and recognized that a more multidisciplinary approach is needed in modeling intermodal terminal location decisions. Management and policy theory were two areas they identified that needed to be considered more thoroughly. Multi-criteria decision analysis (MDCA) serves as a good tool for modeling freight-related development decisions because of its flexibility to combine different types of data and different viewpoints from experts. Macharis (2005) and Vreeker (2002) have both implemented the Analytic Hierarchy Process (AHP) as a decision support tool for MDCA.

Piantanakulchai (2003) uses the AHP in conjunction with a Geographical Information System (GIS) to aid in location and alignment decisions.

The AHP has also been used as a way to gather input from different stakeholders of potential transportation development projects (Macharis, 2005; Dooms & Macharis, 2003). Sirikijpanichkul (2007) presents a decision model that specifically addresses the location issue and attempts to select the optimum location based on the needs of stakeholders. Dooms (2003) presents a similar model that takes into account the short and long-term objectives of multiple stakeholders, but it does not specifically address the location decision. This model identifies the key stakeholders in the port's long term strategy and a way to include these parties in the decision making. Henesey et al. (2003) also uses this approach and incorporates Multi Agent Based Simulation to provide a foundation for inland port decision makers.

The needs of all the stakeholders involved in a multimodal terminal location project can be complex. Quantitative modeling tends to maximize the benefits of the users and operators of terminals without consideration for community impacts. Community concerns often include environmental, economic, and quality of life effects of the project. Environmental and land use impacts have been identified (Litman, 1995; McCalla, Slack, & Comtois, 2001), but quantifying the effects of these impacts is difficult. The economic effects of transportation facilities are often unclear due to the complexities of these impacts. Although a more efficient freight network would be beneficial for any region, the possible side effects of multimodal terminals, such as noise pollution, decreased land values, and stimulation of urban sprawl, can outweigh these benefits (Litman, 1995). Likewise, if jobs are created as a result of increased multimodal development, but traffic congestion increases, the net effect of the development itself could be negative.

Finding the balance point between all of the relevant criteria can be difficult and, often, a partnering opportunity can enhance a good location's potential or even super cede a deficient location's disadvantages. Lipscomb and Long (2008) suggest that hub development decisions should take advantage of the synergies created through strategic partnerships. They specifically cite the partnership between the Port of Prince Rupert, Canadian National railroad, and the Port of Memphis as a development that was effective both because of location factors and the collaboration that took place between these organizations.

Because of the wide range of factors that affect the decision to either create new inland freight hub locations or further develop existing hubs, Multi-Criteria Decision Analysis is an effective way to consider all of the relevant criteria as well as all of the relevant stakeholders. Current models describe the methodology for evaluating and locating hubs, but they do not provide a description of how to develop the relevant criteria and how to measure alternatives based on these criteria. The importance of developing measurable criteria for sustainable transport systems is covered in Litman (2007). In this research, we use the definition of sustainability developed by Long et al. (2010). They assert that sustainability must include two components, *Environmental Sustainability* and *Organizational/User sustainability*. Their two-part definition is below.

Environmental sustainability "*is the effective utilization of resources and ecosystem services over the long term as part of supply chain design elements. Under a sustainable approach, the transformation process takes into consideration the conservation of all resources for generations to come, and is typically associated with flexible, reconfigurable, and green/ renewable practices.*"

Organizational/User sustainability "*includes three components: societal needs for sustainable resource utilization, the elements of learning and business practices required to promote use of innovations over the long term, and the processes necessary to foster long-term supply chain partnerships committed to operating under multiple economic and socio-political conditions.*"

This definition clearly identifies the significance of environmental, social, and economical aspects in sustainable hub development. This paper will develop relevant criteria for inland freight hub evaluations and determine metrics for each of them.

3. Criteria Development

3.1 Subject-matter expert interviews

Interviews were conducted with 18 transportation professionals actively working with multimodal freight. Respondents were selected to gain perspective from multiple categories of experts including economic development, freight managers, state DOTs, facility administration, port authority representatives, and MPOs. The interviews conducted for this research provided expert insights into the characteristics necessary for hub development. The respondents in the interviews were identified through contacts with six transportation-oriented organizations from three inland hub locations, Kansas City, MO, Louisville, KY, and Memphis, TN. These organizations represented both the public and private sectors and included transportation engineering consultants, non-profit economic development organizations, and port authorities. The respondents were interviewed for their perspectives on what contributed to a region's logistics capabilities and the information gathered from these interviews was used in determining both the characteristics of logistics hubs and the level of importance of these characteristics. The cumulative responses from each respondent category were compiled to create a single response representing each organization. This was done to further protect anonymity of response.

A closed-ended questionnaire was considered but ultimately rejected to remove interviewer bias. Many factors contribute to the freight transportation capabilities of a region so it was important not to direct the focus of the respondent. Instead, a narrative interview protocol was established using open-ended questions designed to encourage thoughtful responses by subject-matter experts. Interviews typically were an hour in length and began with a general question about which factors they felt contributed the most to the development and sustainability of an inland freight hub. Then, they were asked to elaborate on these factors so the researchers could understand them better and determine how they could be measured. Subsequent questioning was designed to determine in-depth responses to assist with model development and analysis.

3.2 Relevant criteria identification from subject-matter expert interviews

Table 1 includes the top criteria identified by each organization. The top two criteria were physical infrastructure and proximity to population. The respondents emphasized these as the fundamental elements that influenced the capabilities of inland ports. Infrastructure is made up of the roads, railroads, airports, and multimodal terminals that give a region access to markets. Richardson (2005) reinforces the interview responses by identifying infrastructure along with availability of rail service and road infrastructure capacity as factors that affect the sustainability of any transportation system.

Proximity to market represents how close a region is the supply and demand of freight. These factors have some interaction with each other because a larger population reach will call for better transportation infrastructure, and better infrastructure will increase region's accessibility to its surrounding population. Both of these elements are basic factors in determining the development potential of a multimodal logistic hub and if a region is deficient in one of these areas, their abilities for logistics development will be severely diminished.

Land availability was identified by half of the organizations. This aspect represented the expansion capabilities of a region. Without available land for warehouses, terminals, and other related buildings or infrastructure, the development opportunities would stagnate. This is especially evident at the West Coast ports of Los Angeles and Long Beach. Although this area is a key hub for freight coming into the U.S., the development potential here is relatively non-existent because there is no room for expansion.

Government and industry support were also mentioned in the interviews and supported by Richardson (2005) as important factors to the sustainability of inland hub regions and transportation systems in general. The support from the government was said to play a big role in accelerating the progression of logistics projects from the conceptualization stage to the building and implementation stage. Regions that have strong government developmental agencies are able to attract logistics development because the project implementation process is very efficient. These agencies also serve as connection points between the region and other organizations looking for good locations to locate logistics-related facilities. Often, location consultants are hired to find the best location for a business and these regional development agencies can help provide the necessary data to these consultants so that they can make an informed decision.

The supply of labor was also mentioned as a variable in hub development. Without a supply of quality workers that could operate equipment to move the freight and manage the overall freight system, the region's logistics capabilities would be significantly diminished.

Relevant characteristics outside of the top three factors all explored some element of inland hub effectiveness. The community characteristics of a region and the history of industrial development there will play a big role in the community's attitudes towards logistics development activities. One interviewed expert referred to their region's history as a transportation hub and cited this as a critical factor in the acceptance from the community of expansion and development. Another expert explained that a large portion of their region's population were employed in freight related occupations, so development was expected and encouraged because of the job opportunities that were usually created. Both of these situations contribute to the public's general understanding and acceptance of logistics-related developments.

3.3 Description of criteria and measurement methods

In this section, criteria identified through interviews with subject matter experts are explored in greater detail. Two levels of criteria are presented. The first level criteria were identified directly from the narrative interviews. In addition, second level criteria are presented that were outside of the top responses, but still had significant ranking or were established in the literature. Each criterion is given a definitive name, a description, and a specific measurement method. Table 2 provides a summary.

3.3.1 First-level criteria:

Infrastructure:

This criterion measures a region's capacity to move freight and access to different transport modes. A region with better access to highways, railroads, etc. will be more capable of supporting new logistics developments. This criteria includes comprehensive analysis of access to renewable energy sources and sustainable technology.

Infrastructure can be measured simply by identifying the highways, railroads, and waterways and the existing airports and multimodal terminals in the region and determining the capacity that each one can handle.

Proximity to Market:

This criterion identifies the market reach of a region. The unofficial standard for this, mentioned by one respondent, was the one-day market reach by truck. Based on average truck speeds on major freight corridors (U.S. Department of Transportation Federal Highway Administration, 2006) and hours of operation rules for truck drivers (Federal Motor Carrier Safety Administration, 2010) which allow for eleven hours of driving per day, one-day travel distance for trucks is approximately 600 miles. The population located within this distance from a given region is its proximity to market measurement. This criterion also includes analysis of appropriate modal selection to address issues of environmental sustainability.

Land Availability:

This criterion measures the ability of a region to expand. New logistics developments will likely require more land and infrastructure so alternatives with excess capacity will be more capable of supporting new logistics developments. Included in an analysis of this criterion is an evaluation of land usage and appropriateness for development based on environmental factors and protected land classifications or status.

Government and Industry Support:

This criterion measures the level of support that logistics developments get from both regional economic development agencies and local industry. Alternatives that have strong support from both of these groups will be more receptive to logistics developments.

Industrial development was measured based on the existence of dedicated logistics development organizations in the region and the supporting logistics industry, such as distribution and warehousing firms.

Labor Supply:

This criterion takes into account the demographics of a region. Areas that are made up mostly of industrial laborers and have a history of industrial development will be most receptive to logistics developments.

Regional demographic information gathered from the Bureau of Labor Statistics can be used to understand its employment characteristics. Of the total non-farm employment, the proportion of people with jobs in manufacturing, trade, transportation and utilities, and mining, logging and construction can be used as a measure of the region’s industrial worker population.

3.3.2 Second-level criteria

Distance Between Origin and Destination:

Although none of the interview respondents explicitly stated that "distance between origin and destination" was an important variable for hub evaluation, it is closely related to the supply and demand aspects of market reach. Richardson (2005) identifies this as an indicator of sustainability. Building from this concept, freight flow data can be analyzed to form a measure of sustainability for an inland freight hub. The Federal Highway Administration compiles freight data from several different sources to make estimates on freight flows between regions. The result is an origin-destination matrix that shows the amount of freight, by tonnage and dollar value, moving between 114 regions and 17 international gateways within the U.S. This data can be used to measure economic sustainability evaluates a proposed freight location with regards to its historic freight flows. This indicates the waste that is involved with moving freight in to and out of the region.

Congestion:

Congestion was not specifically mentioned by the respondents, but there is considerable research to support this factor as relevant to inland port success. Government studies highlighting the significance of freight congestion at ports and distribution hubs include reports from the Federal Highway Administration (Freight Story, 2008) and the U.S. Government Accountability Office (Oberstart & DeFazio, 2008). Richardson (2005) also suggests that congestion is a main indicator of transportation sustainability. The American Transportation Research Institute (ATRI) measures congestion in what they consider freight significant corridors. (American Transportation Research Institute, 2008) In their annual reports, ATRI uses data collected from wireless onboard communications systems within trucks to gather information about truck position and speed. Each of the corridors that they analyze is given a “Total Freight Congestion Value” that is calculated as the sum of the hourly product of miles per hour below free flow and vehicle population by hour.

Table 1 provides a summary for the identified criteria.

Exhibit 1. Criteria summary table

Criteria	Description	Measurement Method	Data Sources
Infrastructure	Capacity to move freight access to transport modes	Identify highways, railroads, waterways, airports, and intermodal terminals	Infrastructure maps, U.S. Dept. of Transportation
Proximity to market	Market reach, one-day market reach	Find population within 600 mile radius of alternative region	U.S. Census Bureau
Land Availability	Land available for transportation logistics development	Identify vacant land, buildings/land available for re-development, etc.	Region-specific real estate data
Govt. and industry support	Government support of transportation developments and size of regional transportation/distribution industry	Identify regional economic development councils, especially those with transportation emphasis. Find the number and size (by revenue or employment) of local industry.	Region-specific data on government organizations and industries
Labor Supply	Industrial labor supply able to meet expanding transportation developments	Identify the proportion of a region's workers that have the skills for transportation jobs	Bureau of Labor Statistics
Origin/Destination Distances	Distance between freight flows to and from a region	Use freight flow data in Weiszfeld's algorithm to compare the near optimal location with the region's actual location	Freight Analysis Framework, FHWA
Congestion	Delays in freight movement caused by congested traffic	Use congestion indices to measure congestion levels of freight significant corridors. Other corridors will require primary data collection from local experts.	American Transportation Research Institute

The criteria identified through this research provide a strong roadmap to sustainable freight hub location evaluation. Rather than responding to a list of pre-determined factors, the subject matter experts interviewed self-selected phrases, issues, and relevant factors to present. The vast majority stressed the importance of understanding the regulatory and societal issues facing freight hub location, including community readiness, environmental sustainability and economic vitality.

3.4 Strategic decision model for inland hubs

The decision to devote resources to logistics developments in a specific region must consider many factors that are both quantitative and qualitative in nature, and the decision must consider a variety of stakeholders. Purely quantitative models or purely qualitative discussions do not give the decision maker a comprehensive view of the development opportunities in a region. Therefore, it is important to combine the two sources into one model to accommodate the needs of different stakeholders. The criteria developed from this research can be easily integrated into a strategic decision model. A variety of well-documented analysis tools exist for evaluating the strategic decision model developed. The Analytic Hierarchy Process, discussed in section 2.2, is one such method. Figure 1 presents a preliminary strategic decision model using the criteria that have been established in this research.

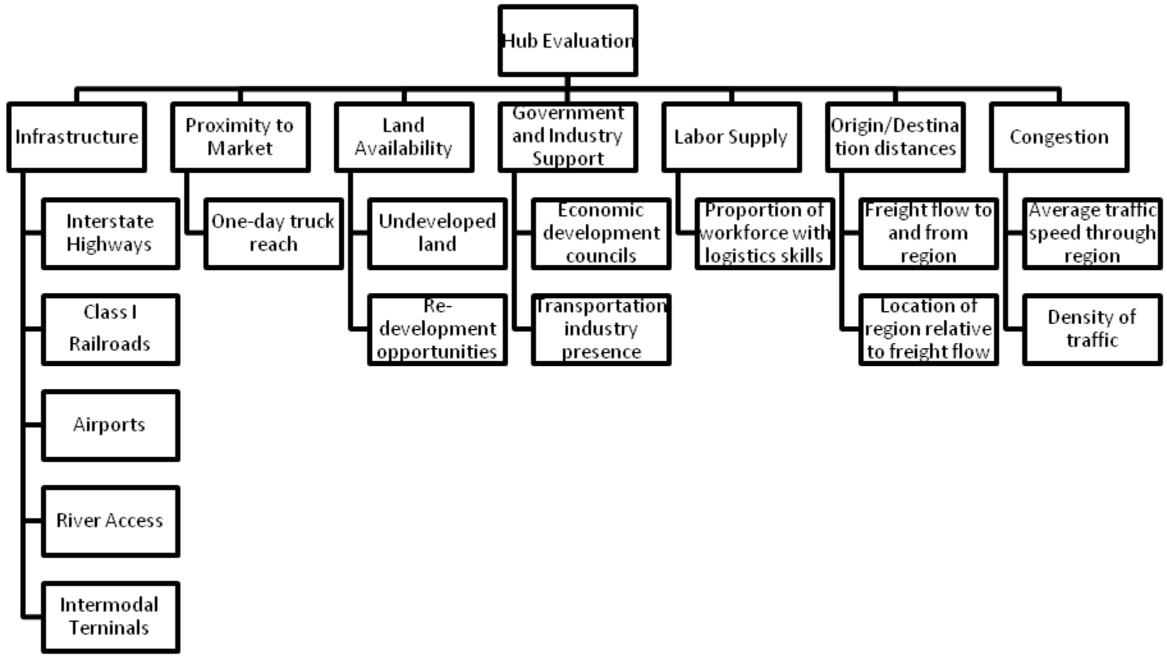

FIGURE 1 Strategic decision model.

The first and second level criteria established by this research serve as the decision anchors for the model and are weighted most heavily in the decision process. Related decision factors are indicated below the relevant criteria. Linkages exist between the primary and sub-criteria, but are not indicated as part of the model. Proper weightings for these linkages should be established through future research to fully utilize the decision model. The model presented in the figure is intended as a starting point for the development of additional lower level criteria based on regional scenarios.

4. Discussion of Results and Key Findings

Decisions to locate new logistics facilities or infrastructure generally involve significant resources and a variety of stakeholder groups. Determining which criteria are the most important must be done with all of the stakeholders in mind. For instance, a private railroad company will have different priorities than the community in which they want to locate a new facility. The railroad company will be more focused on their profits while the community will be focused on the economic benefits that they will receive and the environmental costs that they will incur. Therefore, it is important to gain an accurate perspective from each stakeholder group to determine the priority that each identified criteria should receive.

It is apparent that only looking at one criterion is not sufficient for getting a comprehensive look whether or not a location can serve the present and future needs of the transportation system. Rather, all of the criteria must be considered according to the needs of the stakeholders.

This research establishes “best practices” from existing multimodal facilities that can aid developers of new locations in evaluating the potential of a region for improving multimodal freight capabilities and stimulating regional economic growth. The criteria identified provide an important baseline in determining the sustainability of a potential site as a long-term multimodal freight hub based on quantitative factors, such as freight flows, labor supply, and existing infrastructure and qualitative factors, such as community readiness and livability.

5. Conclusion and Future Research

Hub development decisions often come down to a few alternatives that seem very close in their development potential. Using the criteria developed in this paper along with a multi-criteria decision analysis tool allows decision makers to more effectively make distinctions between inland freight hub capabilities. Developers looking for a location for their transportation-reliant activities can use this procedure to make these distinctions between their alternatives and choose the location based on their specific needs. Regional development organizations or local governments can also use this process to see how their region compares against others in terms of multimodal transportation capabilities and determine what areas should be slated for improvement.

Overall, the criteria developed in this research provide a solid basis for determining the strengths and weaknesses of a region for multimodal hub development. The importance of each criterion and the alternatives chosen for comparison will vary based on the conditions and decision makers, but the criteria are relevant for all hub development decisions.

The methodology presented in this paper considers many important aspects of inland freight hubs, but it relies heavily on having accurate data. Freight data is not nearly as complete as it could be and further research into getting more accurate and more up-to-date data is warranted. There is also value in obtaining more perspectives relating to the criteria that are important to measuring the sustainability of inland hubs. Additional research should expand the number of subject matter expert interviews in order to validate or modify the criteria established in this research. In addition, evidence of co-linearity, proper weightings between primary and secondary criteria should be established to fully utilize the model.

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SECTION

3. THESIS CONCLUSIONS AND FUTURE WORK

This thesis described the state of the U.S. freight transportation system and emphasized the importance of this system for sustainable economic development. Inland hubs were identified as vital to the well-being of the freight transportation system and building an efficient network of hubs was established as an effective way to increase the efficiency of freight movement throughout the U.S. However, locating these hubs haphazardly negates this effectiveness and, therefore, it becomes important to locate and develop inland ports considering both a region's ability to facilitate freight activity and the overall impacts that increased freight activity will have on the region. A methodology for developing criteria, with both quantitative and qualitative elements, was then created that established the relevant criteria need for evaluating the sustainability of inland freight hubs. These criteria were developed through in-depth subject-matter expert interviews, and metrics for each of the criterion were identified in order to accurately evaluate alternatives based on them. (See Table 1 on page 23 for criteria identification and Table 2 on page 31 for criteria definitions and metrics.) Because the respondents of the interviews were all from well-established inland hubs that had river access and connections to ocean ports, there is a degree of bias involved in the findings. Future research should address this bias by getting more diverse perspectives.

Using the identified criteria with the Analytic Hierarchy Process a strategic decision model was created to make distinctions between the capabilities of potential inland freight hub locations. As an example, four potential locations for intermodal freight development were chosen and then evaluated based on the established criteria. Through pair-wise comparisons, the criteria were first prioritized and then the alternatives were evaluated based on these priorities also using pair-wise comparisons. (See pages 8-10.) The analysis of the four regions showed that Kansas City had the most potential for successful logistics development. However, it was noted that because of the many similarities between the comparison regions, there was not one dominant region with regards to hub development. The differences between the alternatives could easily be seen by looking at their specific strengths or weaknesses in each of the criteria categories. Hub development decisions often come down to a few alternatives that seem very close in their development potential and the results of the example showed specifically which criterion made the distinction between the alternatives that were being considered.

The decision model created in this thesis gives decision makers a comprehensive tool for approaching logistics development decisions by providing them a structure for determining the strengths and weaknesses of a region for intermodal hub development. Developers looking for a location for their transportation-reliant activities can use this procedure to make distinctions between their alternatives and choose the most effective location based on their specific needs. Regional development organizations or local governments can also use it to see how their region compares against others in terms of intermodal transportation capabilities and determine what areas should be slated for improvement.

Overall, the procedure to both establish criteria and evaluate alternatives developed in this thesis provides a solid basis for determining the strengths and weaknesses of a region for intermodal hub development. The importance of each criterion and the alternatives chosen for comparison will vary based on the conditions and decision makers, but the criteria are relevant for all hub development decisions.

APPENDIX A

PAIR-WISE COMPARISON TABLES

Highway Access	Kansas City	St. Louis	Louisville	Memphis	**Final Priority**
Kansas City	1	0.5	1	2	**22%**
St. Louis	2	1	2	4	**44%**
Louisville	1	0.5	1	2	**22%**
Memphis	0.5	0.25	0.5	1	**11%**
Sum	4.5	2.25	4.5	9	

Intermodal	Kansas City	St. Louis	Louisville	Memphis	**Final Priority**
Kansas City	1	1.5	4	2	**41%**
St. Louis	0.67	1	3	1.5	**29%**
Louisville	0.25	0.33	1	0.5	**10%**
Memphis	0.5	0.67	2	1	**20%**
	2.42	3.5	10	5	

River Access	Kansas City	St. Louis	Louisville	Memphis	**Final Priority**
Kansas City	1	0.25	0.33	0.25	**8%**
St. Louis	4	1	2	1	**36%**
Louisville	3	0.5	1	0.5	**20%**
Memphis	4	1	2	1	**36%**
Sum	12	2.75	5.33	2.75	

Airport Access	Kansas City	St. Louis	Louisville	Memphis	**Final Priority**
Kansas City	1	0.67	0.67	1	**20%**
St. Louis	1.5	1	1	1.5	**30%**
Louisville	1.5	1	1	1.5	**30%**
Memphis	1	0.67	0.67	1	**20%**
	5	3.33	3.33	5	

Railroad Access	Kansas City	St. Louis	Louisville	Memphis	**Final Priority**
Kansas City	1	0.5	4	1	**25%**
St. Louis	2	1	5	2	**44%**
Louisville	0.25	0.2	1	0.25	**7%**
Memphis	1	0.5	4	1	**25%**
Sum	4.25	2.2	14	4.25	

Regional Development	Kansas City	St. Louis	Louisville	Memphis	**Final Priority**
Kansas City	1	3	1	1	**30%**
St. Louis	0.33	1	0.33	0.33	**10%**
Louisville	1	3	1	1	**30%**
Memphis	1	3	1	1	**30%**
	3.33	10	3.33	3.33	

Support Industry	Kansas City	St. Louis	Louisville	Memphis	**Final Priority**
Kansas City	1	1	1	1	**25%**
St. Louis	1	1	1	1	**25%**
Louisville	1	1	1	1	**25%**
Memphis	1	1	1	1	**25%**
	4	4	4	4	

Population Reach	Kansas City	St. Louis	Louisville	Memphis	**Final Priority**
Kansas City	1	0.67	0.33	0.67	14%
St. Louis	1.5	1	0.5	1	21%
Louisville	3	2	1	2	43%
Memphis	1.5	1	0.5	1	21%
	7	4.67	2.33	4.67	

Land Availability	Kansas City	St. Louis	Louisville	Memphis	**Final Priority**
Kansas City	1	1	1	1	**25%**
St. Louis	1	1	1	1	**25%**
Louisville	1	1	1	1	**25%**
Memphis	1	1	1	1	**25%**
	4	4	4	4	

APPENDIX B

RATIO COMPARISON TABLES

Freight Flow	Truck	Rail	River	Air	**Final Priorities**
Kansas City	0.235	0.437	0.001	0.124	**20%**
St. Louis	0.320	0.217	0.328	0.217	**27%**
Louisville	0.261	0.113	0.177	0.353	**23%**
Memphis	0.183	0.233	0.494	0.305	**30%**

Congestion	Congestion Index	**Final Priorities**
Kansas City	842,858	**16%**
St. Louis	1,193,975	**11%**
Louisville	918,778	**14%**
Memphis	226,090	**59%**

Labor	Total Non-farm	Trade Transportation and Utilities	Proportion	**Final Priorities**
Kansas City	959.8	191.8	20%	**0.23**
St. Louis	1,276.90	239.5	19%	**0.22**
Louisville	584.2	125.1	21%	**0.25**
Memphis	584.6	155.8	27%	**0.31**

APPENDIX C

FREIGHT FLOW DATA FOR SELECTED REGIONS

St. Louis, MO

Origin	Destination	SumOf2002
MO St Lo	MO rem	10074.05
IL St Lo	IL rem	6236
IL St Lo	IL Chica	5613.506
IL St Lo	IL rem	5476.74
MO St Lo	IL rem	4437.24
MO St Lo	LA New O	3729.02
IL St Lo	IL rem	3633.58
IL St Lo	LA New O	3486.73
MO St Lo	KY rem	1938.088
IL St Lo	MO rem	1888.44
MO St Lo	AR	1811.317
MO St Lo	IN rem	1565.89
MO St Lo	AL Birmi	1259.04
IL St Lo	IN Chica	1087.19
IL St Lo	IL Chica	1071.53
MO St Lo	IN India	1068.63
MO St Lo	GA Atlan	1005.39
IL St Lo	OH Cinci	974.33
MO St Lo	TN rem	879.905
IL St Lo	TN rem	763.71
MO St Lo	IA	675.6
IL St Lo	IN Chica	674.2
MO St Lo	TN rem	658.74
MO St Lo	IL Chica	656.589
MO St Lo	WV	650.45
IL St Lo	IN Chica	636.04
MO St Lo	IL Chica	627.95
IL St Lo	NE	582.36
MO St Lo	KS Kansa	524.68
MO St Lo	WI rem	503.8
IL St Lo	IN rem	484.95
IL St Lo	IN India	442.43
MO St Lo	MO Kansa	429.6

Kansas City, MO/KS

Origin	Destination	SumOf2002
KS Kansa	NE	11307.94
MO Kansa	MO rem	5044
KS Kansa	KS rem	4613.46
MO Kansa	KS rem	3075.54
MO Kansa	AR	2714.665
KS Kansa	MO rem	2287.28
MO Kansa	NE	2026.67
MO Kansa	MO rem	2015.943
MO Kansa	NE	1629.81
MO Kansa	MO St Lo	1452.45
MO Kansa	IA	1244.47
MO Kansa	TX Dalla	1230.17
MO Kansa	TX Dalla	1176.7
MO Kansa	TX rem	1023.76
MO Kansa	OK Tulsa	980.717
KS Kansa	KS rem	961.82
MO Kansa	IA	928.35
MO Kansa	TX rem	791.8
MO Kansa	AR	762.25
KS Kansa	IA	665.36
MO Kansa	OH rem	661.13
MO Kansa	IL rem	571.823
KS Kansa	NE	569.48
MO Kansa	AL Birmi	561.58
MO Kansa	OK rem	546.092
MO Kansa	IL Chica	502.25
MO Kansa	IN rem	439.93
MO Kansa	TN Nashv	425.32
KS Kansa	LA New O	423.53
MO Kansa	MN Minne	398.7
MO Kansa	CA Los A	373
MO Kansa	KS rem	366.26
MO Kansa	CO rem	365.53
MO Kansa	VA rem	337.53
KS Kansa	MO St Lo	311.95
MO Kansa	IL St Lo	307.334

Louisville, KY

Origin	Destination	SumOf2002
KY Louis	KY rem	6061.1
KY Louis	IN rem	3819.265
KY Louis	WV	1102.258
KY Louis	OH Cinci	885.794
KY Louis	TN rem	642.1
KY Louis	TN Nashv	587.274
KY Louis	IN India	569.425
KY Louis	MO St Lo	422.995
KY Louis	MI Detro	351.808
KY Louis	IL Chica	347.978
KY Louis	OH Colum	296.949
KY Louis	MI rem	295.82
KY Louis	GA Atlan	281.682
KY Louis	IL rem	266.47
KY Louis	OH Dayto	212.88
KY Louis	SC rem	203.876

Memphis, TN

Origin	Destination	SumOf2002
TN Memph	AR	7841.526
TN Memph	MS	6402.537
TN Memph	TN rem	4620.77
TN Memph	TX Houst	4309.861
TN Memph	TN Nashv	2598.85
TN Memph	MO rem	1782.316
TN Memph	LA New O	1071.302
TN Memph	LA rem	944.706
TN Memph	AL rem	914.809
TN Memph	IL rem	632.575
TN Memph	TX rem	606.321
TN Memph	KY rem	597.079
TN Memph	GA Atlan	504.502
TN Memph	GA rem	463.375
TN Memph	PA rem	418.776

VITA

Robert Tyler Lipscomb was born in Joplin, Missouri. He lived and attended high school in Carthage, Missouri. Upon graduating high school, he attended college at Maple Woods Community College and completed an Associate in Arts degree as well as earning Academic All-American Honors while playing for the school's baseball team. He later attended Missouri Southern State University and earned a Bachelor's Degree in Business Management in 2008.

In 2009, Tyler moved to Rolla, Missouri and began pursuing a Master's Degree in Engineering Management at the Missouri University of Science and Technology. In July 2010, Tyler completed his Master's Degree requirements.