Spring 2012

Sustainable engineering practices in transportation projects

Kiran Rangarajan

SUSTAINABLE ENGINEERING PRACTICES IN TRANSPORTATION PROJECTS

by

KIRAN RANGARAJAN

A DISSERTATION

Presented to the Faculty of the

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

In Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

in

ENGINEERING MANAGEMENT

2012

Approved by:

Suzanna Long, Advisor
Stevens Corns
Ruwen Qin
Abhijit Gosavi
Ghulam Bham

PUBLICATION DISSERTATION OPTION

This dissertation has been prepared in the format of the publication option. Three journal articles are presented.

(1) Pages 11 to 32 "*An evaluative economic development typology for sustainable rural economic development*" is in the style required by Community Development. It has been accepted and published. The citation is:
Rangarajan, K., Long, S., Ziemer, N., & Lewis, N. (2012). An Evaluative Economic Development Typology for Sustainable Rural Economic Development. *Community Development, DOI:10.1080/15575330.2011.651728*, 1-13.

(2) Pages 33 to 68 "*The role of stakeholder engagement in the development of sustainable rail infrastructure systems*" is in the style required by Research in Transportation Business and Management. It is an invited article for the special issue on *Valuing Transportation: Measuring What Matters for Sustainability*. It has been submitted/is under review.

(3) Pages 69 to 99 "Socio-technical roadmapping as a strategic tool for transportation infrastructure planning and development" is in the style required by Technological Forecasting and Social Change. It has been submitted/is under review.

The Introduction, Literature Review, Conclusions, and Appendices A, B, and C have been added for purposes normal to dissertation writing.

ABSTRACT

Sustainability has become an important issue in transportation and infrastructure development projects. While several agencies are trying to incorporate a range of sustainability measures in their goals and missions, only a few planning agencies have been able to implement these policies and they are far from perfect. The low rate of success in implementing sustainable policies is primarily due to incomplete understanding of the system and the interaction between various elements of the system. The conventional planning efforts focuses mainly on performance measures pertaining to the system and its impact on the environment but seldom on the social and economic impacts.

The objective of this study is to first, determine the effect of project typology and selection on sustainable economic development and sustainable outcome. Second, it is to determine the elements of sustainability, various uncertainties, and risks associated with the projects. Third, it is to demostrate a feasible methodology to evaluate sustainability parameters and uncertainties and risks using relevant frameworks and analyses. Finally, provide decision makers with support tools and frameworks to help evaluate and incorporate policies and considerations in planning efforts in accordance with the regional goals and objectives.

ACKNOWLEDGMENTS

Throughout my stay here at Missouri University of Science and Technology, several people have supported me both academically and personally inspired me. I owe my deepest gratitude to Dr. Suzanna Long, who gave me an opportunity to conduct research under her supervision. Dr. Long has continuously conveyed a passion for research work and excitement for teaching. Without her guidance and persistent help this dissertation would not have been possible.

I would also like to thank my committee members Dr. Steven Corns, Dr. Ruwen Qin, Dr. Abhijit Gosavi, and Dr. Ghulam Bham, whose work demonstrated to me the concern for sustainability and systems thinking of infrastructures. They have made available their support in a number of ways and have helped me understand the subject and its importance.

In addition, I want to thank Department Chairs and Professors Dr. William Daughton and Dr. David Enke for their support in completing this work.

I want to take this opportunity to also thank HNTB Corporation for providing me with an opportunity to work on the Missouri State Rail Plan and gain valuable experience in the field.

I am grateful to all the professors and staff who have added value to my work along the way in classes or outside with their valuable suggestions and support to accomplish this work.

I would like to show my gratitude to my parents R. Rangarajan and Vatsala Rangarajan, for their faith in me and supporting me in all my endeavors. It was under their supervision that I gained the ability to tackle challenges and issues. A special thanks to my brother Ashwin Rangarajan, and all my dear friends who have been supporting me throughout my life with their love, and encouragement.

I want to specially thank Girija Govindaraju for all the love, motivation, and support she provided in completing this work, and for agreeing to take the next step in life with me.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1. INTRODUCTION

1.1 BACKGROUND

Sustainability and sustainable development have gained global prominence since 1987 after the Brundtland Commission published their report (OECD, 1987) on its importance for future infrastructure planning and developmental efforts. Sustainability is understood as moving the society to consumption levels that do not exceed the rate of regeneration (Hess & Winner, 2007). Many areas of engineering and sciences have adopted sustainability and sustainable development, including transportation engineering. While sustainability principles direct planning efforts towards an intuitive direction, it is flexible and can adapt to new issues, social, economic, and environmental conditions. Hence, a growing number of agencies describe the definition of transportation system sustainability based on the regional characteristics and planning processes (Jeon & Amekudzi, 2005). In contrast, transportation sustainability considers a broader definition that includes improving the overall quality of life, economic vitality of the region, and environmental issues and not merely the enhancement of the transportation system capabilities of the region (Jeon & Amekudzi, 2005).

Transportation consumes about one-fifth of all global energy and is equally responsible for similar amounts of greenhouse gas (GHG) emissions (Browne, 2005). This trend is growing with changes in travel pattern, where people are increasingly dependent on motor vehicles, making transportation the fastest growing source of GHG emissions in the world (Browne, 2005). Highway and railroad congestion, declining air quality, respiratory health issues, and declining access to social and economic services are clear indicators of transportation system failure and advocate for a sustainable transportation system to meet the future demand. In order to impede the existing unsustainable trends, several nations are now exploring alternate transportation options such as mass transportation systems to combat congestion, revitalize the economy, and provide sufficient capacity to transport people and goods across the nation.

Complexity is an inherent property of every transportation system, and is derived from the interactions between hardware, people, organizations, and governing agencies (Richardson, 2005). This complexity is further increased by the roles played by different modes, financial systems, technology changes, regulatory and legal bodies, and human behavior (Richardson, 2005). Despite challenges in understanding political, institutional, economic, social, environmental, and technological issues for nearly two decades, agencies are still making efforts to translate the principles of sustainability and sustainable development into policies that can flourish in the region (Goldman & Gorham, 2006).

This study starts by evaluating the impact of transportation on economic development of the region from a strategic planning perspective, and categorizes transportation and infrastructure development projects based on the Economic Development Typology (EDT) developed as part of this study. The study then characterizes the factors that constitute transportation and economic sustainability and concludes by demonstrating a methodology for measuring these factors and incorporating sustainability considerations into the planning process to achieve a predetermined end point.

1.2 RESEARCH OBJECTIVES

Sustainability has become an important issue in transportation and infrastructure development projects. While several agencies are trying to incorporate a range of sustainability measures in their goals and missions, only a few planning agencies have been able to implement these policies, and they are far from being perfect. The low rate of success in implementing sustainable policies is primarily due to incomplete understanding of the system and the interaction between various elements of the system. Conventional planning efforts focus mainly on performance measures pertaining to the system and its impact on the environment but seldom on the social and economic impacts (Jeon & Amekudzi, 2005; Deakin, 2003). From a transportation system perspective congestion, vehicle miles traveled, and environmental impacts are predominantly the indicators measured for evaluating transportation sustainability and planning efforts (Jeon & Amekudzi, 2005).

The objective of this study is multifold. First, is to determine the effect of project typology and selection on sustainable economic development outcomes. Second, it is to determine the elements of sustainability, various uncertainties, and risks associated with the projects. Third, is to demostrate a feasible methodology to evaluate sustainability parameters, uncertinaties and risks using relevant frameworks and analyses. Finally, is to recommend to the decision makers support tools and frameworks to help evaluate and incorporate sustainable policies and considerations in planning efforts in accordance with the regional goals and objectives.

1.3 RESEARCH METHODS

The result of this research is the development of the Economic Development Typology (EDT), which focuses on the importance of project selection and typology for sustainable economic development. The EDT considers various implications on the social, economic, and environmental factors at the planning stages of the project life cycle with particular emphasis on quality of life elements, the overall community resource base, and the capacity to generate spinoff projects. The study then evaluates three transportation related projects: (1) the biodiesel initiative in northern Illinois, (2) the Missouri river ferry service, and (3) the Missouri state rail planning effort as part of the sustainable engineering effort to foster economic development in the region. The success of any infrastructure planning effort depends on the ability to build consensus and amongst key stakeholders and the general public.

The stakeholder analysis framework is developed as a useful decision support tool for evaluating social factors and uncertainties that could impact the sustainable transportation planning effort. The stakeholder analysis was conducted as part of the Missouri State Rail Plan effort in the state of Missouri. The analysis gathers stakeholder perspective and understanding of the existing rail network in Missouri to determine uncertainties and risk from a socio-economic perspective.

Finally, the research defines socio-technical roadmapping as a strategic tool to encourage transportation experts and decision makers to study the transportation system from a socio-technical perspective and integrates sustainable development strategies with transportation development policies.

1.4 RESEARCH CONTRIBUTION

The contribution of this research incorporates sustainability considerations into transportation planning and infrastructure development efforts. First, the study presents an Economic Development Typology (EDT) to evaluate project type and selection based on sustainability principles. The project typology and selection framework is designed for sustainable growth in developing regions and is based on strategic evaluation of regional resources. Second, the study proposes a stakeholder engagement framework for evaluating stakeholder perceptions and identifying needs, issues, uncertainties, and risks. The framework aligns well with the transportation planning effort and emphasizes stakeholder involvement in the transportation infrastructure development decision-making process. Third, the research illustrates the socio-technical roadmapping framework to better transportation infrastructure planning and developmental efforts by integrating sustainability development principles with the socio-technical theories. These proposed decision-making tools are robust and versatile in determining uncertainties and risks during the planning process by reflecting on changing regional issues, needs, and priorities.

Integrating sustainable thinking during the transportation or infrastructure planning process will help decision makers to evaluate the system from a socio-technical perspective and not merely measure the performance characteristics, congestion, and environmental aspects. It will also help planners and experts view the system from a quality of life and economic development perspective and the alternatives developed may emerge as policies for a region for sustainable development.

1.5 DISSERTATION OUTLINE

The dissertation is presented as a publication option, which consists of three journal articles, which are presented as sections. Following the Introduction, Section 2 presents the Literature Review conducted as part of this study. Following the Literature Review section the first paper "An evaluative economic development typology for sustainable rural economic development" is presented. The article presents the Economic Development Typology (EDT) and evaluates two transportation efforts the biodiesel initiative and the Missouri river ferry service. This is followed by "The role of stakeholder engagement in the development of sustainable rail infrastructure systems" and "Socio-technical roadmapping as a strategic tool for transportation infrastructure planning and development" papers. Section 3 summarizes the findings and implications of the dissertation and concludes with future research.

2. LITERATURE REVIEW

This literature review introduces topics used to develop methodological elements used in the three articles. Additional literature review is presented for each manuscript and is not presented here.

Sustainability and sustainable development concepts have continued to evolve since being defined by the Brundtland Commission as “meets the needs of the present without compromising the ability of future generations to meet their own needs” (WECD, 1987). Since then infrastructure sustainability has gained interest amongst researchers and practitioners alike (Jeon & Amekudzi (2005); Litman & Burwell (2006); Deakin (2003); Richardson (2005); Goldman & Gorham (2006); Rangarajan, Long, Ziemer, & Lewis (2012)). The transportation sector is no stranger to sustainability and sustainable development. Several nations with more advanced economies are paying particular attention to transportation system sustainability and land use pattern (Deakin, 2003).

Transportation infrastructure development has played a critical role in economic development of a region by providing capacity to move goods and people across the region. These economic and transportation development activities ensure continuous inflow of financial and human capital that is critical for sustainable growth and development (Rangarajan et al., 2012). When rural or developing settings are considered, sustainability of development activities ensures that resources are effectively used to foster development. The goals and visions that are established as part of economic development programs often fail due to strategic mismanagement during the project selection and planning process (Murray, Alpaugh, Burgher, & Flachsbart, 2010). Very little research exists that define the important role of project typology and project selection as part of sustainable transportation and economic development. Selecting the right project at the right time becomes imperative for economic and community development.

Sustainable transportation is understood as satisfying the mobility needs of the citizens while preserving and enhancing the ecosystem, social wellbeing, and economic growth in the present and the future. Numerous efforts are being made around the world to implement sustainable practices to transportation infrastructure developmental efforts. Some of the strategies include operations management, pricing, technology improvements, clean fuels, demand management, and land use patterns (Deakin, 2003). To some extent these strategies have addressed sustainability issues in infrastructure development at a project level by focusing on economic efficiency, but they have rarely studied the interactions involving agents outside the transportation sector.

Transportation systems are complex engineering systems, namely socio-technical systems (Ottens et al., 2006), where a best match or joint optimization exists between the technical environment and the social system (Trist & Emery, 2006). Researchers characterize transportation policy development processes as siloed approaches, despite having a unified US Department of Transportation (USDOT) (Stone, Crosby, Bryson, Saunoi-Sandgreen, & Imboden, 2010). The conventional planning approach assigns the transportation problems to specialized departments with narrowly defined responsibilities (Litman & Burwell, 2006). The involvement of non-technical elements and/or public involvement and their participation in the planning process has been considered only to a limited extent (Deakin, 2003). Sustainable transportation planning requires a fundamental change in the way people solve problems; it requires an objective approach (Litman & Burwell, 2006). Public involvement in transportation is important, as decision that accurately reflect community values are made, it can contribute towards more equitable transportation solutions, create more public support for transportation policies, and induce required behavioral changes in a community (Litman & Burwell, 2006).

Infrastructures are ‘paradigmatic complex systems (Ottens et al., 2006) involving human elements in various roles and responsibilities over the life cycle of the system. Technology driven systems design all too frequently focuses on the technology or engineering problems and under-design the social or human element, which induce non-quantifiable risks into the system (Long et al., 2011; Ottens et al., 2006). The human society is non-ergodic, which further increases uncertainty as society does not settle to stable patterns, but continues to innovate, grow, and change, thereby creating an imbalance in the ecosystem (Newman, 2005). Nevertheless these social elements have a considerable influence on the functioning and outcome of the project. To an extent these elements can be studied and designed to suit the functioning of a project (Ottens et al., 2006).

The understanding of the role of citizens in transportation decision making and policy design has been limited (Tuominen & Ahlqvist, 2010). Very little research exists which has documented public opinion on transportation infrastructure developmenent or policy design (Deakin, 2003). The policies developed to address sustainability have merely integrated human behavior into transportation system (Goldman & Gorham, 2006). Furthermore, the sustainable development priorities of a region can change over time due to the level of development in the region (Amekudzi, Khisty, & Khayesi, 2009) and dynamic nature of human societies (Newman, 2005). Integrating these changes into policy design could substantially influence consumer choice and reduce uncertainties that could affect implementation.

Transportation planning studies are used to develop strategies for operating, managing, maintaining, and financing the area's transportation system to advance the area's long-term goals (USDOT, 2007). The value of technology is difficult to ascertain during the priliminary stages of the project due to various uncertianties associated with the technology (Dissel, Phaal, Farrukh, & Probert, 2006). With sustainability becoming popular traditional cost-benefit approaches and similar assessment frameworks are inadequate. The policy design process in itself must change and include sensitive non-technical elements during the planning and design phases of the projects. Thus, it is necessary to develop viable decision making frameworks and tools that allow progress towards sustainable development by introducing multidisciplinary approaches into transport policy decision making process.

I. AN EVALUATIVE ECONOMIC DEVELOPMENT TYPOLOGY FOR SUSTAINABLE RURAL ECONOMIC DEVELOPMENT

Kiran Rangarajan[a], Suzanna Long[a], Nobert Ziemer[a], and Neal Lewis[b]

[a] *Department of Engineering Management and Systems Engineering, Missouri University of Science and Technology, Rolla, MO-65409, USA*

[b]*Technology Management Department,University of Bridgeport, Bridgeport, CT-06604, USA*

Abstract

This research develops a management typology that focuses on the importance of project typology and selection as part of sustainable rural economic development. The typology includes quality of life elements, the overall community resource base, and the capacity to generate projects. It considers various implications on the social, economic, and environmental factors at a very early stage in the project life cycle. The typology also develops selection criteria for rural economic projects that include a strong risk assessment phase. Data collected from two rural economic projects are used to examine strategic planning and project selection processes. Results may be used to develop effective strategies to stimulate rural economies.

Keywords: economic development typology; Monte Carlo simulation; risk assessment; rural economic development; sustainability

1. Introduction

Economic development activities in both rural and urban settings are essential if a nation is to realize growth and prosperity. Sustainability of these economic development activities assures that the region will continue to receive the financial and human capital that is critical for further growth and development. Especially in a rural setting where population loss and economic distress are common (Murray, Alpaugh, Burgher, & Flachsbart, 2010), sustainability of economic development activities ensures that resources are effectively used to foster development. Many communities have developed goals and visions to establish an economic development program, but they often fail to achieve their goals due to strategic mismanagement during the project selection and planning process (Murray et al., 2010). Communities often select a project from a vast pool of ideas with only limited capital available for investment. Selecting the right project at the right time becomes imperative for economic and community development.

The important role of project selection as part of the economic development process for rural regions is presented in this research. Planning and creating new business development opportunities by retaining regional resources such as manufacturing facilities, strategic relationships, social networking, and human capital are essential steps for project managers to consider (Crowe, 2008). These new opportunities may in turn create demand in the service sector and create expanded opportunities in firms that are part of the supply chain. This helps facilitate a more decentralized business approach creating new alternatives to urban business clusters (Rangarajan, Ziemer, & Long, 2009a).

This research proposes a framework that allows rural decision makers to evaluate and select emerging projects based on the goals of sustainable outcomes. The framework considers various implications of the social, economic, and environmental factors of issues in the project selection phase. The research questions addressed are how are economic development projects classified? What are the characteristics of economic development projects? How should one test the feasibility of a project with numerous uncertainties? In order to accomplish these research goal, the project-based management typology (Mazouz & Belhocine, 2002) and follow-on work in PPP selection (Mazouz, Facal, & Viola, 2008) are adapted to develop an Economic Development Typology (EDT) suitable for rural and emerging economic settings.

2. Economic development typology

The project-based management typology (Mazouz & Belhocine, 2002) is based on two variables:

- ***The proximity of the target:*** This refers to the distance between a public organization and the clientele it serves. The needs of a community or region evolve with time and in response to the transformations that take place due to technology, innovation, and policies. The public service must monitor these developments and maintain the quality of service to remain competitive (Mazouz et al., 2008).
- ***The capacity to generate projects:*** This refers to the ability to transform the social demands into viable projects. In order to accomplish this, the public entity should have sufficient resources and strong political will to cater to the demand (Mazouz et al., 2008).

The EDT addresses critical issues of project evaluation and project selection for sustainable outcomes. The EDT introduces a third variable, namely Quality of Life, to the project-based typology (Mazouz & Belhocine, 2002; Mazouz et al., 2008). Quality of life has varying descriptions based on the region, society, changing needs, and the proposed improvement. When quality of life is viewed from an economic development perspective, it refers to the economic well being of the region, the lifestyle that people lead, and the environment that a region has to offer. Aspects of quality of life include issues such as education, health care, sustainable infrastructure, transportation, job creation and retention, internet, telecommunication, etc. (Easterly, 1999). Qualitative parameters such as savings in time and money, personal and family development, community readiness, and community well being are considered as well (Rice, 2005). In the typology, projects are attributed with characteristics from one of the realms of the EDT. The four elements are: Ad-hoc, Synergistic, Strategic, and Sustainable. They are identified based on the interaction among the proximity of the target, capacity to generate projects, and quality of life variables.

2.1. Elements of the Economic Development Typology

2.1.1. Ad-hoc

Projects identified as Ad-hoc are proposed based on a single project or an outcome. These projects may be capital intensive, but they possess a high capacity to generate spinoff projects. This assists job creation, community revenue generation, elevated entrepreneurial development, and improved standard of living in the region, but is driven by the local resources available. The projects address the economic and socio- economic needs of the region. However, Ad-hoc projects may not have a complete understanding of the quality of life elements. The bio-diesel project in Northern Illinois (explained in detail in the case studies section) serves as an illustration.

2.1.2. Synergistic

Projects defined as Synergistic have a significant impact on two or more issues, such as quality of life, and economic development. These projects evolve due to the emerging social needs of the region. The public agencies have a deep understanding of the quality of life elements and want to provide services that converge with their values, missions, and objectives. These projects address qualitative issues that cannot always be easily quantified, and may have low rates of return. These projects are often aligned with public work projects. They build the foundation for the region, but may have less capacity to generate projects. An example of this type is the ferry service project on the Missouri River (explained in detail in the case studies section).

2.1.3. Strategic

When economic development perspective is considered, strategic projects identify key factors that relate to or enhance the competency of the region. These forward looking projects are often capital intensive, and may involve high levels of risk. The high risks and uncertainties associated with these projects can be attributed in part to the distance between the public services and the clientele. The returns from the projects must be high in order to justify the risk. Strategic projects incorporate a sound understanding of quality of life elements and have a very high capacity to generate several spinoff projects justifying the strategic intent. The resources required for the project may be scarce in the region, but they establish a platform for development around a specific area of interest. To illustrate, the high-speed rail initiatives being developed by several states are projects with strategic intent: to travel faster, reduce congestion, be environmentally friendly, and adhere to the sustainable development outcomes. High-speed rail takes into consideration the quality of life elements, but the uncertainties and risks associated with the project may be attributed to distance between the public services and target clientele.

2.1.4. Sustainable

In this work, the definition of sustainability developed by Long et al. (2010) is considered. Long et al. (2010) assert that sustainability must include two components: environmental sustainability and organizational/user sustainability. This definition implies that when building capacity to promote long-term use of resources, quality of life elements are essential to address sustainability. Sustainable projects have a deep understanding of the quality of life elements. They have the capacity to generate spinoff projects and can only be accomplished if the service providers are close to the target clientele, analyzing the emerging needs as they evolve. The effective use of natural resources is critical in maintaining the ecological balance. Efficient use of resources requires that we foster partnerships and develop innovative processes. Sustainability is of greatest interest when rural economic development is considered. This project type maximizes resources, quality of life factors, and the ability to generate additional projects in meaningful ways that are tailored to small-scale economic development over the long term.

2.2. The EDT model

When economic development projects are scrutinized, Ad-hoc and Synergistic elements dominate when compared to Strategic because rural regions often lack the needed infrastructure to justify strategic initiatives. Figure 1 illustrates the three variables of EDT, and the elements that were derived from the interaction of these variables.

These elements of the EDT are discrete, but the projects may have attributes of two or more elements. The social, economic, and environmental factors and uncertainties may vary depending on the region where the project is being analyzed. Table 1 summarizes the main characteristics of the elements (project types) of the EDT.

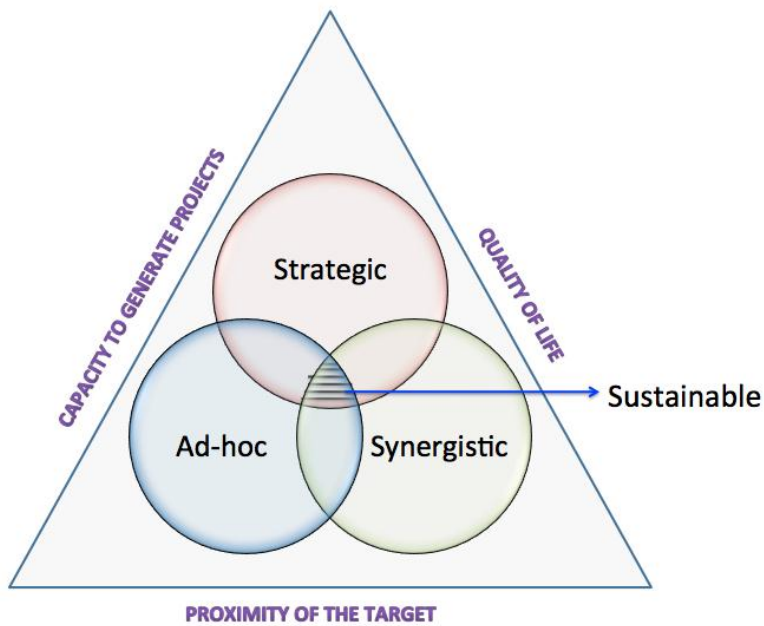


Figure 1. The economic development typology (EDT)

Selecting projects for execution requires detailed analysis and involves multiple variables that are prone to change. The EDT will help managers to classify the projects by type and identify elements that require attention to improve the sustainability of a project. Table 2 describes the sustainable criteria and the indicators that need to be considered and analyzed. This has been adapted and modified from Olsen and Fenhann

(2008). This model can help managers identify and correct infrastructure deficiencies and spur follow-on sustainable projects. The typology is not limited to new business development or infrastructure projects; existing projects can map their objectives and characteristics with the typology to better attain sustainable outcomes.

Table 1. Characteristics of the EDT elements

Ad-hoc	**Strategic**	**Synergistic**	**Sustainable**
Utilizes local resources Generates projects which are aligned with this project Reasonably capital intensive Addresses the economic & socio-economic needs of the region	Lack of local resources Strategic intent Capital intensive High risk High returns Defines competitive edge of the region Addresses the strategic needs of the region	Deep understanding of quality of life Low and slow returns Relatively less capital intensive Lesser capacity to generate projects Addresses the social & socio-environmental needs of the region	Utilizes local resources Resources should be renewable and abundant in the region Considers environmental risks and issues Capacity to generate projects which are aligned with this project Strategic intent Defines the competence of the region Deep understanding of quality of life variable New technology development, R&D Education & training Addresses sustainability needs which is a combination of social, economic, and environmental factors

Table 2. Sustainable development criteria and indicators

Dimension	Criteria	Indicators
Environmental	Air	Reducing air pollutants (SO_X, NO_X, GHG, fly ash, odour, etc.
	Land	Avoiding soil pollution, improving soil through production and use, proper disposal of waste and recycling
	Water	Improved water management, water savings, safe and reliable water distribution, purification and cleaning of water
	Conservation	Protecting and manage resources (plants, animals, minerals and biodiversity) and landscapes (forests and river basins)
Social	Employment	Creating new jobs, income generation, and maintaining existing jobs
	Health	Reduction in health diseases and risks, improving health conditions through constructing hospitals, preservation of food, reducing health damaging air pollutants, etc.
	Learning	Education and training, dissemination of information, research and development, increased awareness of renewable alternatives and reduction in using non-renewable resources (Reduce, Reuse, and Recycle)
	Welfare	Improve quality of living, working conditions, safety, community and rural upliftment, reduce congestion, poverty alleviation, and income redistribution
Economic	Growth	Support economic development and stability through initiation of entrepreneurial activities, industrial activities, investments, maintenance of infrastructure, reduction in costs, and creating new business opportunities
	Energy	Improved access, availability and quality of electricity and heating services such as coverage and reliability
	Balance of Payments	Reduction in using foreign exchange, reduction in using imported fossil fuels, increase national economic independence
Other		Support sustainable development beyond project related benefits, corporate social responsibility activities, technology and knowledge transfer, avoid business clusters, energy independence, etc.

For this research, the social and environmental analyses include mapping the project outcomes with the sustainable development indicators. It is important to note that some social and environmental analyses are qualitative in terms of how projects contribute to sustainable development. It is sometimes difficult to quantify certain benefits. These can be evaluated in terms of the public's willingness to spend money for a particular cause, such as funding a firehouse in order to save lives and property.

Net present value (NPV) and internal rate of return (IRR) are the primary methods used to validate the EDT for economic evaluation of projects. These projects are financially attractive only if their NPV is greater than zero, or if the project's IRR exceeds a minimum return. Monte Carlo simulation is also used. Monte Carlo simulation is a computerized mathematical technique that incorporates uncertainties in the decision making process, and is used to identify a range of outcomes when the project variables are uncertain. The technique generates probabilistic outcomes based on the randomness present in the project under study.

Monte Carlo simulation is used to evaluate the risk due to uncertainties in the project. The NPV and IRR are the dependent variables. NPV is defined as the current worth of a project, achieved by taking all present and future cash flows and discounting them to the present time. This is mathematically defined in Equation (1).

$$NPV = -I_0 + \sum_{t=0}^{N} \frac{CF_t}{(1+i)^t} \tag{1}$$

where I_0 = initial investment,

CF_t = Cash flow at time t,

i = required interest rate,

N = time horizon of project

The Internal Rate of Return (IRR) is defined as the interest rate where the NPV is equal to zero. This is mathematically defined in Equation (2).

$$\mathrm{NPV} = 0 = -\mathrm{I}_0 + \sum_{t=0}^{N} \frac{\mathrm{CF}_t}{(1 + \mathrm{IRR})^t} \qquad (2)$$

Monte Carlo simulation mimics what happens when inputs change. The inputs have unique characteristics, which need to be identified, including mean value, range (highs and lows), and distribution. If the actual distribution is not known, a triangular distribution is usually recommended. This is simply a triangle with three known points: the minimum, the maximum, and the mode (the most likely point in the distribution). Triangular distributions need not be symmetric, and are often asymmetric in real situations. Simulation programs use random numbers to identify a variable within the range of the input. This input number (or set of numbers when there is more than one uncertain variable) is then used to calculate the output variable (such as NPV). At this point, the first iteration is completed. The program will then identify another random input variable, consistent with the distribution provided. The output is determined a second time, and a second iteration is completed. This process is repeated (often thousands of times) and the result is an output histogram, which describes how the output varies as the inputs change.

For this research, two project opportunities are analyzed with the EDT. The projects were selected based on the fit with two common economic development strategies, industrial and self-development (Crowe, 2008). The first is a regional scale biodiesel production facility and presents a regional project application of the EDT. It illustrates a positive selection outcome lying within the sustainable region. The second project examines the feasibility of creating a ferry service to increase workforce mobility and increase economic opportunities, and showcases the process for abandoning a project. These projects demonstrate the typology and provide examples of positive and negative outcomes from the EDT process. The resulting decision tool offers guidance for project selection and management approach suitable for rural or emerging economic development.

3. Case applications of the EDT

3.1. The biodiesel initiative

3.1.1. Biodiesel project evaluation

The first case applies the EDT to a planning efforts designed to establish a mid-size biodiesel plant in northern Illinois. The biodiesel project was designed to establish a new source of economic activity within the community. The decision makers viewed this project as an opportunity to create local jobs, utilize regional biomass resources as raw materials, retain the manufacturing expertise in the region, and to generate additional economic benefits such as indirect jobs (truck transport, maintenance facilities, etc.) that would support a biodiesel refinery. As initially proposed, the project began as an Ad-hoc project with limited focus on the quality of life or on strategic intent considerations. However, advances in biodiesel technology combined with immediate benefits of using biodiesel revealed the potential to positively impact the economic performance of the region. Planning efforts expanded to include more robust funding sources and goals for sustainable outcomes. A situational partnership evolved and a Direct Finance public–private partnership model was implemented to move the project from an Ad-hoc project to a Sustainable project.

The initiatives to make the project sustainable include: (1) Effective deployment of local resources by leveraging used vegetable oil (yellow grease) from restaurants and other deep fryers, as well as agricultural wastes as feedstock to produce biodiesel. (2) Developing opportunities such as collecting yellow grease from local restaurants and other sources and transporting it to the facility. (3) Actively involve an educational institution to foster learning and to implement effective business practices to have a sustainable business model under a variety of economic conditions. (4) Retain people in the region by providing jobs to the people of the community.

The initiative is environmentally and socially sound with dependence on foreign oil reduced and a more environmentally friendly fuel produced locally. The initiative also encourages learning and provides jobs to the people of the community, thereby addressing the problem of population loss in this rural area. The financial returns must meet minimum criteria, and risks and uncertainties must be understood before the project can be considered sustainable.

3.1.2. Biodiesel initiative economic analysis

Monte Carlo simulation was used to evaluate the risk due to uncertainties in the project and to assess the financial attractiveness of the project. The NPV and IRR are the dependent variables. Table 3 shows the input variables, along with their most likely values (modes) and ranges of uncertainty. The base case values were assumed from previous research work conducted by Fortenbery (2005) and then adjusted to approximate values for the biodiesel initiative. However, due to confidentiality considerations, actual values have not been used for the simulation and analysis.

Table 3. Input variables and their uncertainties

Input Variables	Base Case	Lower Limits	Upper Limits
Initial Investment	$6,630,000	95%	110%
Quantity of Yellow Grease (lbs.)	33,750,000	80%	110%
Cost of Yellow Grease	$0.40/lb.	75%	130%
Transportation (# of Rail Cars)	160	80%	110%
Cost per Rail Car	$1,200	95%	120%
Quantity of Methanol (gal)	560,000	80%	110%
Cost of Methanol	$0.84/gal.	70%	125%
Quantity of Catalyst (lbs.)	320,000	80%	110%
Cost of Catalyst	$0.40/lb.	85%	130%
Total Fixed Expenses	$1,186,796	90%	110%
Quantity of Biodiesel Produced (gal)	4,500,000	93%	110%
Sale Price of Biodiesel	$3.65/gal.	85%	125%
NPV (based on a 5% return)	**$911,372**		
IRR	**7.5%**		

For the base case, the initial investment for the Biodiesel project is $6,630,000. The annual cash flows are found by taking the annual revenues ($16,465,000), and subtracting annual fixed costs ($1,186,796) and annual variable costs ($ 14,290,400). Cash flows are discounted using an interest rate of 5% to arrive at a before-tax NPV of $2,125,155, and an after-tax NPV of $911,372 (assuming MACRS depreciation, a 10-year Property Class, and a 35% tax rate). The fact that the after-tax NPV is significantly positive demonstrates that the project will return well in excess of a 5% after-tax return.

When the annual cash flows are applied to Equation (2), the before-tax IRR is 10.3% and the after-tax IRR is 7.5%. This demonstrates that the project will yield an after-tax return of 7.5% on the investment over the life of the project.

The computer program @Risk1 was used to perform the Monte Carlo simulations. Each input variable is allowed to vary within the range identified, using triangular distributions for all variables. Figure 2 shows the output obtained for NPV and IRR analysis from the simulation using the variables from Table 2 The NPV histogram that was generated resembles a normal distribution (in spite of the fact that none of the inputs were normally distributed), with a mean after-tax NPV of $6.4 million. The project is not assured of achieving the required rate of return; based on the statistics of the distribution, there is approximately a 68% probability of achieving an after-tax NPV greater than zero.

The IRR analysis also resembles a normal distribution with a mean after-tax IRR of 26.4%. IRR analysis again shows that the project will likely achieve the required rate of return, with an 84% probability of achieving an IRR greater than the required 5%, and an 89% probability of achieving a positive return.

The NPV and IRR means in the simulations are significantly higher than the base case values. The revenue is slightly skewed to the positive, and is more likely to be higher than lower. This positive skew raises the most likely net income significantly, increasing the NPV and IRR values.

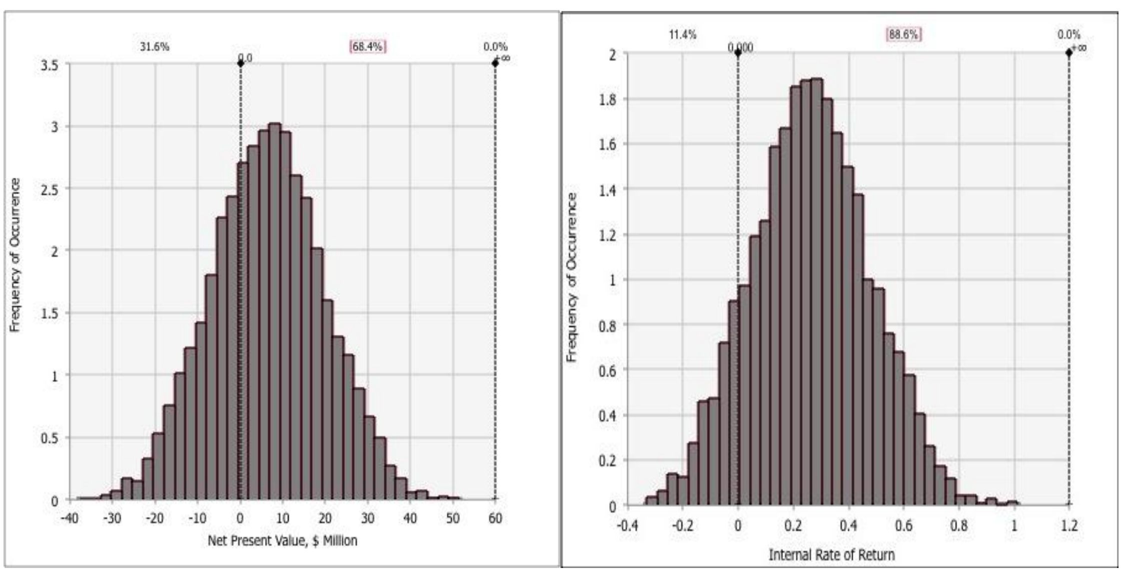


Figure 2. After tax NPV and IRR distribution, biodiesel project

Evaluation of the project using the EDT places the project firmly in the Sustainable realm. The project was selected for funding based on its capacity for sustainable growth in terms of quality of life, capacity to generate additional projects, financial stability, and related strategic factors. In this scenario, a public–private partnership provided start-up support and funding contacts.

3.2. Missouri river ferry service

The second case applies the EDT to community efforts to establish a ferry service near a small river town on the banks of the Missouri River. The population of the city is approximately 480 based on July 2008 census figures (City-Data, 2008), and has experienced a growth of 5.3% since 2000. Its estimated household income was $33,634 in 2007.

The nearest river crossings for the people to reach the economically flourishing I-70 region are at Jefferson City and Hermann, 38 miles and 25 miles away, respectively. Capital-intensive projects such as bridges or tunnels are not feasible options. Recent state budget cuts have limited public funds available for economic development projects that do not have considerable access to private funds. The sustainability of this project must be considered by balancing quality of life considerations with fiscal responsibility (Rangarajan, Ziemer, & Long, 2009b).

3.2.1. Ferry service project evaluation

From an EDT perspective, the project addresses the emerging socio-economic need of the region. There are benefits to the region in terms of quality of life and limited economic development opportunities that could emerge if a ferry service was established. A summary of project characteristics includes the development of job opportunities, reduction of response time for emergency services by approximately 20 min, community growth potential in the areas of tourism, recreation, agriculture development, a shortened distance to the I-70 region by approximately 50 miles, easier access for coal trucks to supply coal to the local power plant, easier access for farmers to take their livestock to the Callaway Livestock Center across the river, and support for AmerenUE's proposed expansion of the nearby nuclear power facility by providing easier access to temporary construction and permanent jobs at the nuclear facility.

The project is a complex blend of qualitative and quantitative factors with the social and economic factors correlated and interdependent. The project has a strong socio-economic focus, but is difficult to justify financially as quality of life parameters are difficult to quantify. This project was categorized using the EDT, and the results were validated using Monte Carlo analysis.

Table 4. Input variables and their uncertainties for the ferry service project

	Base Case	**Lower Limits**	**Upper Limits**
Total No. of Trips	17000	80%	120%
Ticket Price per Trip	$8/trip	60%	150%
Revenue from Tourism	$34,000/year	85%	115%
Fixed Expenses	$205,080/year	90%	110%
Fuel + Oil Cost per Trip	$0.76/trip	75%	135%
Capital	$3,000,000	95%	115%
Assumed Discounted Rate	5%	80%	120%
NPV	**-$3,200,000**		
IRR	**N/A**		

3.2.2. Ferry service risk analysis

The financial variables, including the uncertainties of each input, are shown in Table 4. The base case IRR cannot be calculated because under these conditions the NPV does not achieve a zero value at any discount rate. As before, the actual distribution of the input variables are unknown, so triangular distributions were used.

The NPV histogram, of the form shown in Figure 2, resembled a normal distribution with a mean of -$3.0 million. The distribution indicates essentially no probability of achieving a positive NPV with the project as it is proposed. The IRR analysis revealed a 96.5% probability of having a negative IRR, and essentially no opportunity of exceeding the required rate of return. Thus, in its current configuration, the proposed project has essentially no chance of being financially viable.

The evaluation of the project using EDT revealed severely limited opportunities for economic development in the region and is not economically viable. The project is at the early stages of a Synergistic partnership focusing on the social needs and the concerns of the region, as it has a strong emphasis on quality of life factors. However, the financial returns are far too low for the project to be justifiable and the potential to generate jobs and other income opportunities are low. Therefore, the project was not selected for further consideration and showcases important findings for decision makers regarding the proper level of balance for quality of life characteristics against financial constraints.

4. Conclusion

This work develops an EDT designed for sustainable growth in rural or emerging regions based on strategic evaluation of regional resources. The EDT helps decision makers analyze these uncertainties in the project analysis phase rather than resolving them during the execution or implementation phases. It considers the implications of the social, economic, and environmental factors at an early stage in the project lifecycle. The focus on sustainable development is a key component of economic development, yet most rural areas lack the tools and expertise to fully implement sustainable projects. The involvement of the public sector in such rural economic development opportunities is critical if we are to realize economic development and foster effective rural development. The research also suggests the need for collaborative efforts between the public and private partners to identify new business development opportunities in the rural setting from an economic development standpoint.

This work also develops selection criteria for rural economic projects that include a strong risk assessment phase. The quantitative methods employed (NPV, IRR, and Monte Carlo analyses) clearly indicate that the financial uncertainty of a project is an important parameter in determining its feasibility and sustainability. These tools help decision makers analyze alternatives when input variables are uncertain (as they usually are). The EDT is not limited to new project development activities; existing projects or ventures may use the EDT to evaluate sustainable development.

5. Future work

Future research is needed to examine complex synergistic issues that cannot be quantified easily. Even though this article presents a synergistic project that was not successful, further analyses of these projects are necessary to determine strategic options and alternatives to make synergistic projects sustainable and feasible. The uncontrollable and intangible environmental variables such as political structure, culture, and regional innovation capacity should be explored for economic development. Concepts of connectedness and a continuum between rural and urban geographies (Walzer, 2003) through development and urban sprawl should be considered. The effectiveness of global partnerships as opposed to local partnerships for rural economic development is an area of deep interest. The synergies developed through the partnership include increased access to knowledge and the potential for future projects through increased absorptive capacity (Cohen & Levinthal, 1990). Direct study of the application of this methodology to developing economies should also prove useful in extending results for use in developing countries.

References

City-Data. (2008). Retrieved March 17, 2009, from City-Data: http://www.city-data.com/city/Chamois-Missouri.html

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. Administrative Science Quaterly, 35 (1), 128-152.

Crowe, J. (2008). Economic Development in the Nonmetropolitan West: The Influence of Built, Natural, and Social Capital. Community Development, 39 (4), 51-70.

Easterly, W. (1999). Life During Growth: International Evidence on Quality of Life and Per Capita Income. The World Bank Development Research Group Macroeconomics and Growth (Working Paper WPS 2110), 1.

Fortenbery, R. (2005). Biodiesel Feasibility Study: An Evaluation of Biodiesel Feasibility in Wisconsin. University of Wisconsin, Madison, Department of Agriculture & Applied Economics, Madison, Wisconsin.

Long, S., Grasman, S., Gosavi, A., Carlo, H., Valencia, L. B., Fraser, J., et al. (2010). Using Integrated Teaming to Enhance Sustainability Supply Chain Curriculum. American Society of Engineering Management. ASEM.

Murray, S., Alpaugh, A., Burgher, K., & Flachsbart, B. (2010). Development of a Systematic Approach to Project Selection for Rural Economic Development. Journal of Rural and Community Development, 5 (3), 1-18.

Mazouz, B., & Belhocine, N. (2002, Nov-Dec). Public-Private Partnerships: An Equation to Solve through Project-Based Management. Sources, 7-9.

Mazouz, B., Facal, J., & Viola, J. M. (2008). Public-Private Partnership: Elements for a Project-Based Management Typology. Project Management Journal, 39 (2), 98-110.

Olsen, K., & Fenhann, J. (2008). Sustainable Development Benefits of Clean Development Mechanism Projects: Development of a New Methodology for Text Analysis of the Project Design Documents Submitted for Validation. Energy Policy, 36 (8), 2819-2830.

Rangarajan, K., Ziemer, N., & Long, S. (2009). Public-Private Partnerships and Rural Economic Development. IERC Proceedings. Miami: IERC.

Rangarajan, K., Ziemer, N., & Long, S. (2009). Strategic Planning and Rural Economic Development: An Evaluative Case Study Approach to the Use of Public-Private Partnerships in High Risk Transportation Projects. American Society of Engineering Management. Springfield: ASEM.

Rice, S. (2005). From Individual Development Accounts to Community Asset Building: An Exploration in Bridging People-and Place-based Strategies. Department of Urban Studies & Planning. Cambridge, MA: Massachusetts Institute of Technology.

Walzer, N. (2003). The American Midwest: Managing Change in Rural Transition. Armonk, NY: M.E. Sharp, Inc.

II. THE ROLE OF STAKEHOLDER ENGAGEMENT IN THE DEVELOPMENT OF SUSTAINABLE RAIL INFRASTRUCTURE SYSTEMS

Kiran Rangarajan[a], Suzanna Long[a], Alan Tobias[b], and Marie Keister[c]

[a] *Department of Engineering Management and Systems Engineering, Missouri University of Science and Technology, Rolla, MO-65409, USA*

[b]*HNTB Corporation, 111 North Canal St., Suite. 1250, Chicago, IL 60606, USA*

[c] *Engage Public Affairs, LLC, 7759 Crawley Drive, Dublin, OH 43017, USA*

Abstract

Numerous planning efforts are underway in the United States to evaluate rail passenger and freight capacity to promote goals of economic development, sustainability and livable communities. The success of the infrastructure planning effort depends on the ability to build consensus and support among the key stakeholders and the general public. It is essential that stakeholders with an interest in community economic development play an active role in the development of the rail network. Ample opportunity must be provided for meaningful input, and stakeholders must be aware that their issues have been heard and understood. This research investigates the impact of stakeholder attitudes and perception on rail infrastructure planning efforts in Missouri, a Midwestern state in the USA. Data collected through surveys, interviews, focus group discussions, and public meetings conducted across the state are used to develop a stakeholder engagement framework. The social factors and uncertainties that affect planning for a sustainable rail network are identified and validated using qualitative and quantitative methods. The framework developed provides guidance to transportation planners in the creation of a comprehensive rail plan.

Keywords: livable communities, stakeholder analysis, stakeholder engagement, sustainable rail infrastructure planning, transportation planning

1. Introduction

The study explained in the article explores stakeholder perceptions about the existing rail infrastructure and their needs regarding rail services in the state of Missouri. The stakeholders in the study are defined as people responsible for decision making such as the mayors, city officials, transportation experts, general public, and industrial shippers and businesses who use the rail service in the state for transporting their goods. This framework developed will be part of the State Rail Plan developed by Missouri Department of Transportation (MoDOT) in accordance with the Passenger Rail Investment and Improvement Act of 2008 (PRIIA) directed by the Federal Railroad Administration (FRA) to receive intercity passenger rail funding. The State Rail Plan will establish a statewide rail vision, and identify rail infrastructure improvements that can support the existing capacity and manage the future needs of the region. The plan will also provide implementation strategies for the recommended improvements. Additionally, the planning study provides an opportunity to analyze the passenger rail network in the state and its impact as an economic driver for creating jobs and mobility of citizens.

The intent of this study is to explore the societal needs, the social factors and uncertainties that may directly contribute to the creation of a comprehensive rail plan in the state of Missouri. The success of the plan depends on stakeholder buy-in and support from railroads, key stakeholders, and general public. It is important that the stakeholders are involved early in the planning process and be informed and consulted throughout the planning process. To get a better understanding on the impact of stakeholder attitudes and perception on rail infrastructure planning efforts, a stakeholder engagement framework is created and analyzed. Data collected through interviews, surveys, focus group discussions, and public meetings across the state are used to develop the framework. The social factors and uncertainties from a stakeholder point of view are identified and validated using both qualitative and quantitative methods.

2. Social factors and uncertainties in transportation projects

The current U.S. transportation infrastructure is built on antiquated patterns of growth and consumption without regard for the needs of future generations. Innovative transportation infrastructures, such as the proposed U.S. high-speed passenger rail network, must be based on comprehensive definitions of sustainability and begin with changes in human behavior. Failure rates for technology-driven projects are high and are often linked to failures to properly manage the social elements of the change environment (Ottens et al., 2006; Rohracher, 2001).

The existing frameworks focus primarily on economic efficiency and have been used for infrastructure assessments at a project level (Tuominen & Ahlqvist, 2010). The frameworks have been limited to understanding interactions within the transportation sector and are rarely responsive to wider societal factors and concerns (Tuominen & Ahlqvist, 2010). The policy guidelines developed to address sustainability have merely integrated transportation into a larger system consisting of humans and their behavior (Goldman & Gorham, 2006). From a sustainable transportation planning perspective, Deakin (2001) suggests that very little research has been done to document the actual public opinion. Deakin (2001) also suggests that changes in policy, could substantially influence consumer choice and the uncertainties in public opinion or perception makes their implementation doubtful. The role of citizens as contributors to policy and strategic decision-making so far has been rather limited (Tuominen & Ahlqvist, 2010). In a socio-technical system, understanding customer perspective and behavior, and involving them as stakeholders for decision-making is critical to realize success. It is important to study stakeholder interaction with technology and the diffusion process, as they often tend to influence organizations willingness and potential to innovate (Brown, 2003).

Uncertainties and risks are prolific in transportation infrastructure systems, making them complex to plan, design, build and operate. Infrastructures are 'paradigmatic complex systems' (Ottens et al., 2006) involving human elements in various roles and responsibilities over the life cycle of the system. Transportation systems are forms of socio-technical systems whose success and sustainability are emphatically dependent on understanding the bond between the social and technical factors. The human element complicates the technical system with non-quantifiable risks and uncertainties that can nevertheless cause the proposed infrastructure to fail (Long et al., 2011; Ottens et al., 2006). Technology driven systems design all too frequently focuses on the technology or engineering problems and under-designs the social or human element of the system.

Social uncertainties are complex, and in most of the cases difficult to define and measure. Uncertainty is a dominant feature of human society, which is non-ergodic (Newman, 2005). Uncertainty increases because our society does not settle to stable patterns, but continues to innovate, grow, and change, thereby creating an imbalance in the ecosystem (Newman, 2005). Nevertheless these social elements have a considerable influence on the functioning and outcome of the project and to an extent can be designed to suit the functioning of a project (Ottens et al., 2006). Figure 1 shows the effect of technical elements, social factors and social uncertainties on the sustainability of transportation systems.

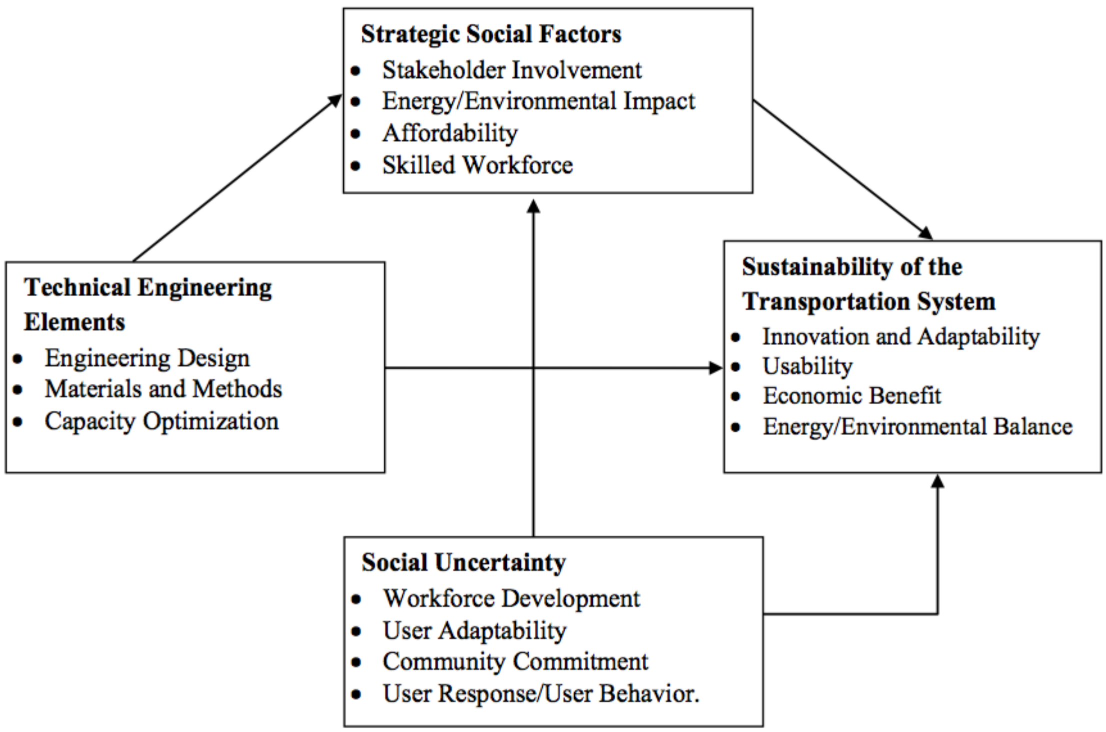


Figure 1. Social factors and uncertainties for transportation infrastructure projects

Distinction between technical and social elements in a large technological system is not a new concept. During every stage in technology development and implementation, along with technical factors, there are a host of social factors that affect the content of technologies and its implications on the society (Williams & Edge, 1996). Ottens et al. (2005) describe social elements to be complex and difficult to capture and advocate that it is critical to analyze the relationship between actors and physical elements and between other social elements. Merely establishing technologies as socio-technical or ‘socially shaped’ (Williams & Edge, 1996) is not sufficient, as it opens up questions about the shaping forces of technology, its attributes, and its influence on the sustainability of a technology. The social uncertainties such as underdeveloped workforce, lack of community commitment, or erratic user behavior can affect the stakeholder involvement, impact on environment, engineering design and related elements of the system. The existence of these uncertainties during the implementation and execution phases of a technology can influence how the social factors, and in turn the technical factors function in a system. Social and technical strategies not only influence several sustainability aspects, but also play a crucial role in defining quality of life elements (Steg & Gifford, 2005). Evaluating the feedback between the elements, the system, and the environment and observing and responding to the needs of the society will lead towards sustainable transportation development (Newman, 2005). This research develops a framework that focuses on the social elements of transportation planning and implementation by overlaying it on the socio-technical system design.

3. Stakeholder analysis framework

Stakeholders are the core constituents when it comes to transportation systems. Several acknowledge the fact that consumer preferences are key to driving transportation development trends (e.g., Deakin, 2001; Steg & Gifford, 2005; Newman, 2005). Stakeholders may have a direct influence on factors that stimulate sustainable growth and development of technology or infrastructures, and hence, given the high rate of failure of technology driven projects, the study of stakeholder involvement, behavior and perspective is worthy of scholarly attention.

Elias et al. (2002) in their well-cited article, clarify the concepts of stakeholder analysis, tested its validity, and have presented an elaborate section on its implications. In the context of transportation infrastructure planning and development, stakeholders can be identified based on the explanation provided by Freeman (1984) which suggests that, stakeholders are a group that are affected and/or affect the achivements of an organization's objectives. This explanation from Freeman (1984) indicates that stakeholders (1) are likely to be directly affected by the policies or objectives of an organization, and (2) are likely to contribute significantly towards developing policies and objectives for efficient functioning in the region.

Another important characteristic of stakeholders as acknowledged by Freeman (1984) is the fact that stakeholders are dynamic and over time, new stakeholders may join the group while others may leave the group. The stakes of the new group may change based on the emerging needs and issues during any point of time. Thus, it becomes important to review the stakeholder groups and the policies associated with transportation planning periodically to establish a sustainable development pattern. The framework has been applied and validated in the Missouri State Rail Plan example.

The stakeholder framework is a systematic procedure followed to understand and evaluate stakeholder perceptions on existing rail networks in Missouri and solicit information on needs of the region, uncertainties that exist in the region, and their willingness to use limited public resources for improving rail infrastructure in the state.

3.1. Establish strategic goals and objectives

The organization should establish strategic goals and objectives for the planning project and communicate them internally in order to ensure consistency in its engagement and strategies. The strategy should also consider stakeholder engagement and identify the issues where stakeholder engagement would benefit the organization. The plans should include a high-level scope and direction as to how the organization plans to achieve its objectives.

Based on the vision, the planning effort is driven by six major goals:

1. Promote efficient movement of passengers
2. Promote efficient movement of freight
3. Encourage intermodal connectivity
4. Enhance state and local development
5. Promote environmentally and socially responsible rail transportation development
6. Promote safe and secure railroad operations

3.2. Identify stakeholders

The organization must develop a methodology to identify and map its stakeholders to manage and achieve its objectives. The mapping process should include the relationships and strategy for managing its stakeholders. The stakeholders must be cross-functional in their roles and must influence the policy making and strategic intent of the organization. With these underlying principles a stakeholder map for the transportation rail plan was developed. The map consists of specific stakeholders who are directly or indirectly involved in the planning process (see Table 1).

Table 1. Stakeholders for the state rail plan

Internal • Department of Transportation Officials • Rail planning committee	Media • Newspapers • Television news broadcasters • Radio broadcasters	Communities • Community leaders • People who have stake in efficient movement of goods and passengers in the community
Railroads • Class I railroads • Class II railroads • Terminal railroads • Regional and local railroads • Switching railroads • AMTRAK	Political/Legal • Labour group • City representatives • Mayors • Elected Officials	Business Owners • Directly or indirectly related with railroads • Mining companies
Government • Tourism Department • City Councils • Regional Planning Organizations • Metropolitan Planning Organizations	General Public • Public transport users • Commercial road users • Other road users	Related Groups • Katy Trail • Action groups • Economic Development Organizations • Transportation Experts

3.3. Establish communication platforms

The organization must establish various platforms to communicate with the stakeholders. Multiple platforms need to be established as each stakeholder is different and they may not have access to all the platforms. It is critical for an organization to assess these issues and establish communication channels to involve all the stakeholders in the planning process. Focus group interviews, surveys, public meetings, and news articles are some of the methods that can be used to communicate with the stakeholders.

For this planning effort various forums were established to communicate appropriately with the stakeholders. The platforms included more traditional methods such as news articles, surveys, focus group interviews, and public meetings, also contemporary methods such as Facebook, Twitter, and online meeting boards to reach out to wider population.

3.4. Communicate goals and objectives with the stakeholders

It is important that an organization share with the stakeholders the strategic goals and objectives developed for the project. This ensures transparency and establishes a foundation for the organization to solicit information from its stakeholders regarding the visions, goals, and objectives. It is also important to note that not all the goals and objectives can be communicated with all the stakeholders to solicit information. The organization should direct the strategic goals and objectives appropriately to maximize output and validity. Once the strategic goals and objectives are communicated to the stakeholders, the organization must solicit information regarding various issues and needs of the region. This helps the organization understand the concerns of the stakeholders, and the behavior and practices in the region. In order to achieve these objectives an online informed stakeholder survey was deployed, and community leader workshops and public meetings were conducted in seven locations around the state of Missouri.

3.5. Identify the needs and issues

High-speed rail (HSR) represents an important proposed transportation infrastructure project with tremendous potential to reduce energy consumption and green house gas (GHG) emissions; however, the risks and uncertainties must be well considered for the planning environment to yield a sustainable solution. Understanding stakeholders' perspective and their understanding of these complex socio-technical systems are important factors to consider while developing policies and frameworks. The discussion presented below focuses on stakeholders' perspective on the rail initiative in the US and their likeliness of using these systems in the future.

3.6. Map the needs and issues with strategic goals and objectives

Mapping these issues and needs with the strategic goals and objectives developed gives the organization an opportunity to assess the effectiveness in addressing the region's issues and needs. Opportunities and risks are eminent when it comes to transportation related projects. Mapping the issues, concerns, and needs of the region might help the organization identify opportunities in the region that are necessary to address from a quality of life perspective. This will also enable the organization to identify various risks associated with the project and help develop strategies and methodologies to mitigate these risks at the planning stage of the project and not allow it to magnify during the design or implementation phases of the project. A normal suggestion or concern from the stakeholders might become a policy measure in the future.

3.7. Prioritize the needs and issues

Aligned with its strategic goals and objectives, the organization should prioritize the issues and needs that arise from the stakeholder engagement to achieve its objectives. They must establish criteria for prioritizing the opportunities and communicate these with the stakeholders. This is an ongoing effort and would involve comprehensive analysis of the planning effort from both social and technical perspective. This task also involves bringing several stakeholders under the same roof to discuss possible opportunities that would see immediate improvement to the existing freight and passenger rail services in the state.

3.8. Assess and re-define the goals and objectives

Once the opportunities, issues, and risks are prioritized, the organization must assess its vision, goals, and objectives and re-define them if required to include inputs from stakeholder engagement. The organization should communicate the modified vision, goals, and objectives to the stakeholders, which demonstrates commitment and accountability from the organization. The assessment would include another round of community leader and public meetings to communicate the final plans, solicit information on the revised goals and objectives, validate if the issues and needs of the regions have been addressed in the plan.

4. Research design and data analysis

The research design includes both qualitative and quantitative data analyses and follows the mixed methods approach (Creswell, 2003). Statistical techniques such as Mann-Whitney U-test and effect-size were used to study and validate the data from a quantitative perspective and the qualitative analysis used emprirical methods to study and analyze the system.

4.1. Informed stakeholder survey

As part of the stakeholder analysis framework, an informed stakeholder survey was developed to help understand the priorities and issues of the regions and identify the best ways for the state to invest its limited funds towards efficient transportation infrastructure improvement. The survey captured stakeholders' responses and perceptions on investing public resources to develop rail infrastructure in the state, the benefits rail brings to the community or the region, and the characteristics of rail that will enhance the socio-economic vitality of the state.

An online survey was deployed between October and November of 2011. The survey was emailed to 264 stakeholders identified and mapped using the framework. The survey consisted of Likert Scale, open ended, multiple choice, and rating scale questions, and was intended to solicit information on existing rail service in Missouri, concerns about existing services, benefits of expanding rail, and opinions about investment to enhance rail infrastructure in the state. The survey was directed to economic development organizations, regional and metropolitan planning organizations, elected officials, transportation experts, and others who have a stake in the efficient movement of goods and passengers by rail. A total of 83 responses (31.4% response rate) were collected from the survey during the specified time period.

4.1.1. Investments for improving rail infrastructure

Railroads in the US invest billions of dollars each year to build, maintain, and operate safely, efficiently, and reliably. These investments made by railroads to grow, maintain, and modernize the network are paid for by the railroads, which is unlike trucks, airlines, and barges which operate on infrastructure paid for by the taxpayers. From 1980 through 2010, railroads have reinvested $480 billion on tracks, signals, equipment, and other infrastructure (AAR, 2011) to cater to the growing demand, and maintain and modernize the rail network in the US.

In Missouri the tracks are completely owned by private railroads, and are leased to Amtrak to run passenger trains without disrupting the freight flow and compromising their competitive business. Nearly 11% of stakeholders surveyed were not aware that nearly all the intercity passenger rail in the US operates on privately owned railroads. In order to have an efficient passenger and freight rail network in the state, it is imperative that further investments have to be made to relieve congestion and modernize the tracks to run mixed traffic on these freight lines. The questions in the survey were designed to identify the stakeholders' understanding on railroad investments and their willingness to invest in maintaining, modernizing, and expanding the rail network in the state.

When asked about the awareness regarding how the present infrastructure is paid for and maintained, plurality of stakeholders (96%) agreed that the transportation infrastructure in the state does not fully "pay for themselves", but are funded through a combination of taxes, user fees, and sometimes private investment. Pluralities of stakeholders (95.1%) are of the opinion that the government should continue to invest public funds in both highways and railroads to increase capacity and relieve congestion on existing transportation networks. The stakeholders (81%) also support investing public money in partnership with the freight railroads to improve rail capacity in order to ease truck traffic on highways. Also, stakeholders (86%) appreciate the idea of public-private partnerships between government and the freight railroads for infrastructure improvement projects to improve freight and passenger rail operations. It is also interesting to note that only 12% of stakeholders are neutral, or do not have an opinion about investing public money in partnership with railroads to enhance capacity of the existing networks.

Table 2. Stakeholder's perspective on investments for improving rail infrastructure

Statement	Response
Invest public funds in both highways and railroads to increase capacity and relieve congestion on existing transportation networks	Yes = 95.1% No = 4.9%
Invest public money in partnership with freight railroads to improve rail capacity in order to ease truck traffic on highways	Strongly Oppose = 1.3% Oppose = 5.1% Neutral = 12.7% Support = 36.7% Strongly Support = 44.3%
Public-private partnerships between government and the freight railroads to build infrastructure improvement projects	Strongly Oppose = 0.0% Oppose = 1.2% Neutral = 11.1% Support = 30.9% Strongly Support = 56.8%

Community leaders and the general public strongly recognize that investments in Missouri's rail infrastructures are critical and worthwhile. They also seem to agree that such investments should be directed at both freight and passenger rail development, and that there is currently no long-term or dedicated funding source for rail. A stakeholder in a meeting pointed out that the existing funding for rail improvements in the state is like "living paycheck to paycheck". But there doesn't seem to be a clear consensus amongst the stakeholders about what should be the source of such funding or even what amounts should be invested. From the meeting comments, neither the public nor the community leaders seem to recognize where the existing public funding for rail improvements comes from or that the Class-1 railroads themselves spend billions of their own dollars on infrastructure improvements and maintenance of their rights-of-way.

There were comments; however about creating some kind of cost-benefit analysis for rail investments or at least that there should be some accounting of the public benefits and economic impacts. There was also one comment acknowledging that some states have ‘grant’ and ‘loan’ programs to help fund rail spurs for businesses. There were also comments that the State Rail Plan should include a comparison or per-mile costs of both highway and railroad improvements and maintenance costs.

Seeking out and increasing public-private partnerships was mentioned often as a way of combining dollars to improve rail infrastructure in the state. The attendees also seem to acknowledge the fact that state’s Constitution as it pertains to transportation funding should possibly change to help spur infrastructure improvements to other transportation alternatives, but nothing more specific was mentioned.

4.1.2. Benefits to the community

Numerous research studies have been published highlighting the positive impacts of rail on economic development and the benefits it brings to the communities in the region (for e.g. Amos, 2009; Murakami & Cervero, 2010). Murakami and Cervero (2010) in their well-cited work have indicated that organizations and industries in cities such as London and Paris with accessible rail networks have reported urban regeneration and creation of more innovative businesses thriving on face to face communication and exchange of knowledge. The report also suggests that secondary cities such as Lyon and Lille in France have seen greater developmental impacts than the capital Paris due to rail access.

From an economic development stand point, 81% of stakeholders are of the opinion that communities which have an Amtrak station receive economic benefits through tourism, flourishing local businesses, and access to the two biggest cities in the state: Kansas City and St. Louis. About 7% of respondents feel that access to passenger rail has no impact on economic development of the region, while 11% are unsure if the economic development in the region is due to rail access. When asked about what kind of economic benefits a community might receive due to passenger rail access (see Figure 2), stakeholders responded with (1) more visitors would travel to the community (82.5% of responses), (2) more retail development around the station (61.3% of responses), (3) more office development around the station (41.3% of responses), (4) more residential development around the station (23.8% of responses), with 8.8% responses indicating no development would occur around the station.

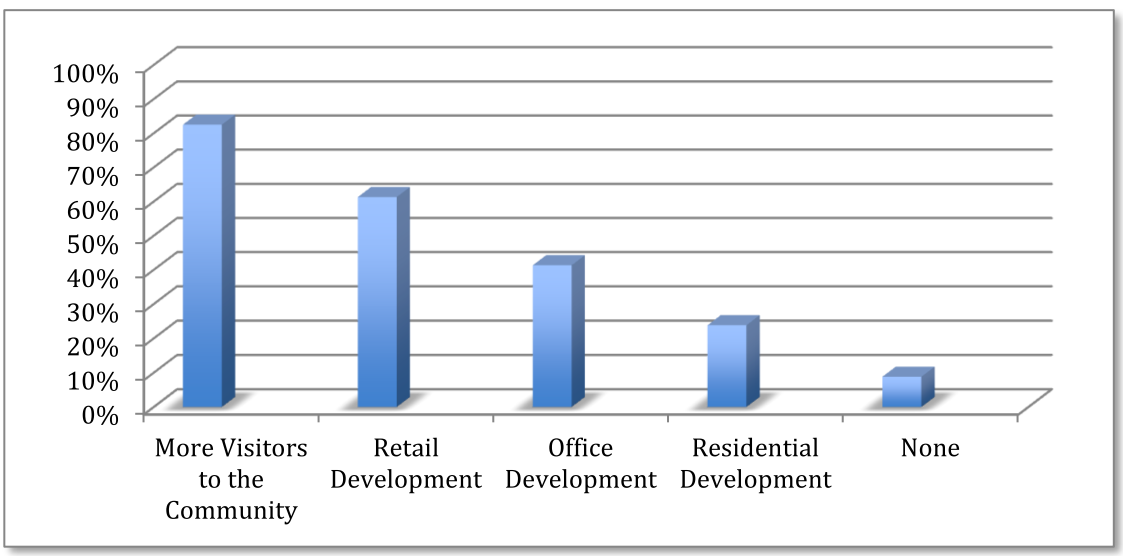


Figure 2. Economic benefits to the community with access to passenger rail

Community leaders and the general public were aware of economic, environmental, and quality of life impacts of both passenger and freight rail on the communities. The comments from the meetings and workshops indicated that attendees felt rail development in the state would reduce truck and automobile traffic on interstates and local roadways, reduce emissions that damage air quality, would provide a viable and a more fuel efficient transportation option to the residents when compared to driving and flying for short and moderate distances, and would generally support investment to passenger rail development as long as it does not impede with the movement of freight rail in the state.

4.1.3 Characteristics of rail in Missouri

The rail network in Missouri primarily consists of freight railroads with one state supported Amtrak passenger route between Kansas City and St. Louis, two Amtrak routes the Southwest Chief (Los Angeles to Chicago) making stops at Kansas City and La Plata and the Texas Eagle (San Antonio to Chicago) making stops at St. Louis and Poplar Bluff, and Illinois state supported Lincoln service which connects Chicago and St. Louis.

With these passenger rail services in Missouri, the stakeholders were asked to indicate all the concerns they have with the existing intercity passenger rail service (see Figure 3). Stakeholders responded with (1) service not frequent enough (55.4% of responses), (2) service not fast enough (51.4% of responses), (3) reliability of service-trains are not on time (44.6%), and (4) accessibility to rail via other public modes of transportation (35.1% of responses) and lack of connections with other modes of transport at stations as major concerns in the state. Amongst other problems preference given to freight operation (32.4%), lack of connections with other trains (24.3%), accessibility to rail (within 10 miles) from where you live or work (23%), and delays in freight movement (18.9%) were also selected by stakeholders as concerns with passenger rail service in Missouri.

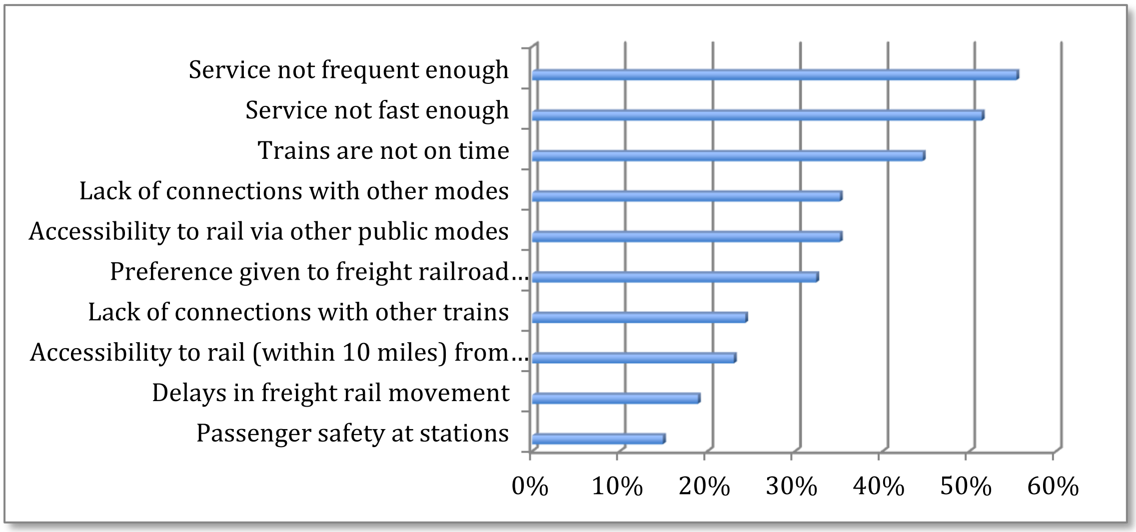


Figure 3. Concerns with existing intercity passenger rail in Missouri

When asked what are the biggest obstacles to improving passenger rail in Missouri (see Figure 4), stakeholders responded with higher funding priorities elsewhere (46.8% of responses), tax payers resistance to pay for improvements (43.6% of responses), high cost of improvement (33.3% of responses), and lack of knowledge of benefits (28.6%) were also indicated by stakeholders to be an obstacle for improvement.

The stakeholders were also asked to identify the best reasons for improving passenger rail in Missouri (see Figure 5), for which they responded with growing desire for more travel options (43.4% of responses) and growth in highway congestion (41.6% of responses) as the primary reasons. Opportunity to generate more jobs and the desire for an environmentally friendly mode of transportation were also selected by stakeholders (with 22.1% and 22.4% of responses respectively) as important factors why they would want the rail system developed in Missouri.

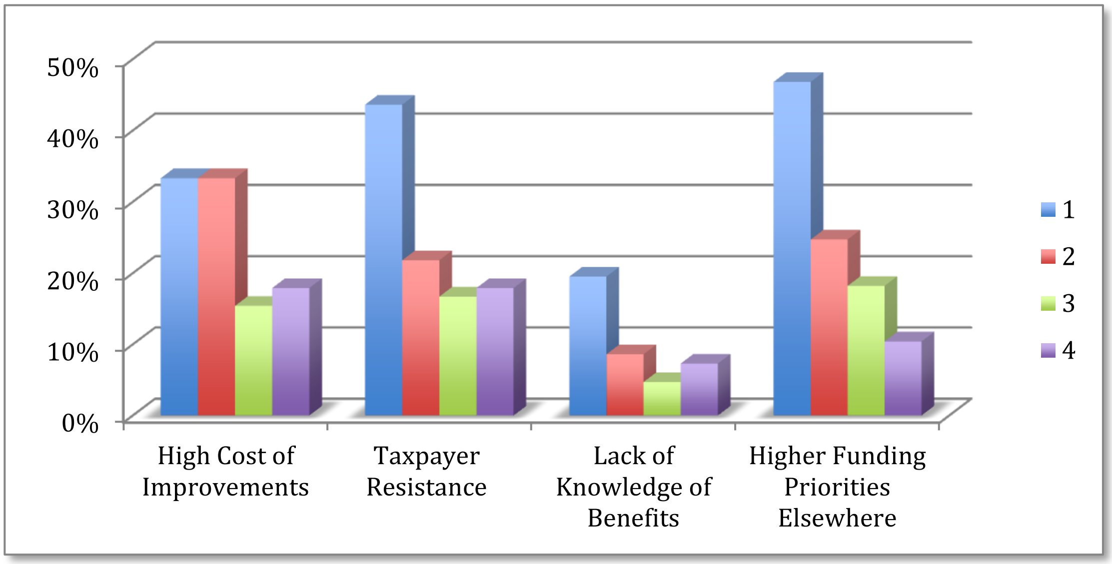


Figure 4. Obstacles to improving passenger rail in Missouri

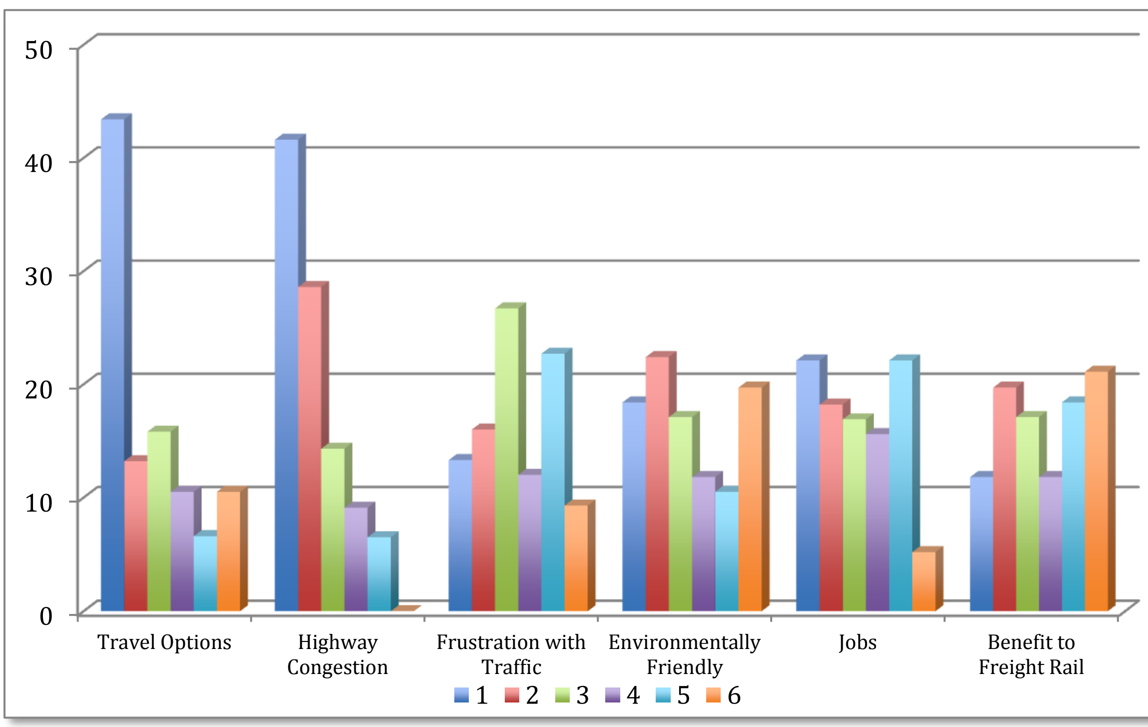


Figure 5. Reasons to improve passenger rail in Missouri

4.1.4 Stakeholder perspective based on accessibility to rail service

The Mann-Whitney statistical test was then used to analyze stakeholder perspective from the accessibility to rail service standpoint. Mann-Whitney test is used to test differences between two conditions where different participants have been used. This test is a non-parametric equivalent of the independent *t*-test and is based on the test statistic *U*, which is calculated as (Field, 2005):

$$U = N_1 N_2 + [N_1 (N_1 + 1)/ 2] – R_1$$

N_1 and N_2 are the sample sizes of the groups 1 and 2 respectively, and R_1 is the sum of ranks for group 1.

The Mann-Whitney test works by considering the differences in the ranked positions of scores in different groups. It scores the rank from lowest to highest which implies that the group with the lowest mean rank is the group with the greatest number of lower scores in it. Along the same lines, the group with the highest mean rank is the group with the greatest number of high scores. The significance values from the results are used to predict the behavior of the groups and the value of mean rankings indicate the level of significance.

The significance statistic does not indicate if the effect it measures is meaningful or important. It is also important to report the effect sizes as a standard measure of the size of the effect observed. Here Pearson's correlation coefficient *r* is used measure the effect size and is calculated using (Field, 2005):

$$r = \frac{Z}{\sqrt{N}}$$

Where, Z is the *z-score* test statistic and N is total number of observations.

The correlation coefficient of 0 means there is no effect, and a value of 1 indicates there is a perfect effect. The following is widely accepted suggestions about what constitutes a large or a small effect (Field, 2005):

r = 0.10 (small effect) the effect explains 1% of total variance

r = 0.30 (medium effect) the effect explains 9% of total variance

r = 0.50 (large effect) the effect accounts for 25% of total variance

It is important to note that *r* is not measured on a linear scale and therefore, an effect size of 0.8 does not indicate twice as big as one with effect size 0.4.

The results from the survey were split into two categories based on the access to existing rail services. The responses of stakeholders who had access to rail service were compared to responses of stakeholders who did not have access to rail service. Table 3 and Table 4 shows the Mann-Whitney test ranks and test statistics. The columns in Table 4 indicate the variables used in the analysis. Group 1 in Table 3 corresponds to stakeholders from regions who have access to rail service, and Group 2 corresponds to stakeholders from regions that do not have access to rail service.

The significance value $p <= .05$ is considered for this test.

From Table 4 it can be seen that for the following variables, exact two-tailed significant value is significant ($p < 0.05$):

- 2-Experience of traveling by rail outside US
- 3-Traveled by rail within the US in the past 5 years
- 7-Awareness that nearly all intercity passenger rail in the US operate on freight railroad tracks
- 10-If traffic grows as predicted, congestion increases on highways, and fuel costs rise, will more people ride passenger rail?
- 13-Used intercity passenger rail service in Missouri in the last 5 years
- 15-Should higher speed rail service be provided between St. Louis and Kansas City?

The value of the mean rankings from Table 3 indicate that the stakeholder group with rail access have traveled more by rail outside the US than Group 2 and also seem to indicate that their experiences (mean rank = 19.23) have also been better than that of Group 2 (mean rank = 12.55). It is not surprising to note that Group 1 (mean rank = 45.21) seem to have traveled more by intercity passenger rail in Missouri in the last five years when compared to Group 2 (mean rank = 32.34) who do not have access to rail services in the state.

Stakeholders with access to rail sevice (mean rank = 43.81) seem to have better understanding about intercity passenger rail and its operations in the US. They are also of the opinion that as traffic and congestion on highways increases and fuel costs rise, the people in their region will surely shift to rail in the future. Group 1 also seem to indicate that a higher speed rail service between St. Louis and Kansas City is required in the state and they would like to see a 220 mph new grade separated tracks when compared to Group 2 who would rather see an incremental approach to the line by improving the existing speed to 110 mph. Even though not significant from the Mann-Whitney test, Group 2 seems to indicate that they strongly support building truck only lanes on highways to ease congestion (11-Do you support building truck only lanes on highways?) when compared to Group 1.

The effect size in Table 3 for variables (2) Experience of traveling by rail outside the US and (13) Used intercity passenger rail service in Missouri in the last 5 years, are -0.385 and -0.317 respectively. This represents a medium change in perception between stakeholders who have access to rail service and stakeholders who do have not access to rail service. For variable (3) Traveled by rail within the US in the past 5 years, the effect size is -0.503, which represents a large change in perception between the two groups. For other variables the effect size represents small or small to medium change in perception between the groups. This analysis indicates that stakeholders with and without access to rail service have similar understanding of the benefits of rail, economic development due to rail, investments to improve rail service in the state, and characteristics of rail, but their willingness to use rail and their experiences of rail travel has a direct correlation to the availability of rail services in their region.

Table 3. Mann-Whitney test ranks and effect size

Variables/Statements	Response Options	Group	N	Mean Rank	Sum of Ranks	Effect Size
(1) Traveled by rail outside the US	No Yes	1	49	44.13	2162.50	-0.125
		2	34	38.93	1323.50	
		Total	83			
(2) Experience of traveling by rail outside the US	Very Poor Poor Neutral Good Excellent	1	22	19.23	423.00	-0.385
		2	11	12.55	138.00	
		Total	33			
(3) Traveled by rail within the US in the past 5 years	No Yes	1	49	49.48	2424.50	-0.503
		2	33	29.65	978.50	
		Total	82			
(4) Experience of traveling by rail within the US in the past 5 years	Very Poor Poor Neutral Good Excellent	1	43	29.02	1248.00	-0.002
		2	14	28.93	405.00	
		Total	57			
(5) Awareness that highways and passenger rail do not full "pay for themselves"	No Yes	1	48	40.66	1951.50	-0.092
		2	33	41.50	1369.50	
		Total	81			
(6) Public investments in passenger rail to make it more comparable to passenger rail services in Europe	No Yes	1	48	41.59	1996.50	-0.047
		2	33	40.14	1324.50	
		Total	81			
(7) Awareness that nearly all intercity passenger rail in the US operate on freight railroad tracks	No Yes	1	48	43.81	2103.00	-0.264
		2	33	36.91	1218.00	
		Total	81			
(8) Support Missouri invest public funds in both highways and rail capacity projects	No Yes	1	48	41.31	1983.00	-0.042
		2	33	40.55	1338.00	
		Total	81			
(9) Support public-private partnerships between Missouri and freight railroads to improve rail operations	Strongly Oppose Oppose Neutral Support Strongly Support	1	48	43.67	2096.00	-0.154
		2	33	37.12	1225.00	
		Total	81			
(10) If traffic grows as predicted, congestion increases on highways, and fuel costs rise, will more people ride passenger rail?	No Don't Know Yes	1	47	42.39	1992.50	-0.195
		2	32	36.38	1167.50	
		Total	79			

Table 3. Mann-Whitney test ranks and effect size cont.

(11) Support building truck only lanes on highways	**Strongly Oppose Oppose Neutral Support Strongly Support**	**1**	**48**	**37.63**	**1806.00**	**-0.156**
		2	32	44.81	1434.00	
		Total	80			
(12) Support investing public money in partnership with the freight railroads to improve rail capacity	Strongly Oppose Oppose Neutral Support Strongly Support	1	47	43.73	2055.50	-0.212
		2	32	34.52	1104.50	
		Total	79			
(13) Used intercity passenger rail service in Missouri in the last 5 years	No Yes	1	47	45.21	2125.00	-0.317
		2	32	32.34	1035.00	
		Total	79			
(14) Economic benefits to communities due to Amtrak train stations	No Don't Know Yes	1	48	38.35	1841.00	-0.130
		2	31	42.55	1319.00	
		Total	79			
(15) Should higher speed rail service be provided between St. Louis and Kansas City?	No Yes	1	48	44.17	2120.00	-0.262
		2	32	35.00	1120.00	
		Total	80			
(16) Which approach do you prefer for providing higher speed service between St. Louis and Kansas City?	New 220 mph (high speed approach) Improve to 110 mph (incremental approach)	1	40	28.61	1144.50	-0.144
		2	19	32.92	625.50	
		Total	59			

Table 4. Mann-Whitney test statistics

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Mann-Whitney U	728.5	72.0	417.5	300.0	775.5	763.5	657.0	777.0	664.0	639.5	630.0	576.5	507.0	665.0	592.0	324.5
Wilcoxon W	1323.5	138.0	978.5	405.0	1951.5	1324.5	1218.0	1338.0	1225.0	1167.5	1806.0	1104.5	1035.0	1841.0	1120.0	1144.5
Z	-1.141	-2.213	-4.587	-.021	-.829	-.431	-2.384	-.384	-1.388	-1.742	-1.402	-1.888	-2.825	-1.161	-2.345	-1.112
Exact Sig. (2-tailed)	.266	.038	.000	1.000	1.000	.761	.028	1.000	.179	.088	.163	.059	.006	.285	.030	.372
Exact Sig. (1-tailed)	.179	.018	.000	.506	.593	.445	.021	.540	.093	.049	.082	.030	.004	.139	.019	.204
Point Probability	.095	.006	.000	.044	.593	.217	.018	.358	.007	.020	.002	.000	.003	.049	.014	.125

4.2. Community leader workshops and public meetings

The team conducted community leader workshops and public open house meetings in seven locations around the state of Missouri between October and November 2011. The main objectives of the meetings were to share with the stakeholders and general public the vision, goals, and objectives of the rail-planning effort and to solicit information regarding their understanding of passenger and freight rail services in Missouri. The meeting goals also included sharing the results from the informed stakeholder survey and identifying the emerging needs and issues the region is facing in terms of public transportation. The feedback from the meetings was collected through comment sheets, an online-comment board, and emails. In total there were 170 comments from community leaders and general public.

4.2.1. Passenger rail service

It was clear from the meetings that awareness about passenger rail is markedly high and positive amongst those who attended the meetings, particularly in communities/regions where Amtrak service is available. The attendees indicated that for the passenger rail service to maintain growth and ridership it is important that the on-time performance should be improved. They also suggested that the existing services do not support businesses and business travelers. By increasing the number of trips with convenient arrival, departure times will promote “same-day” travel, which will benefit business travelers and promote growth and ridership. Another interesting point that came out of the meetings was about the equipment and facilities in the rail car. The attendees who use rail to travel suggested that the rail cars are old, the windows dirty, the equipment is old and crumbling, and there are no business friendly services such as Wi-Fi or Internet connectivity in the train.

It is also noteworthy that there was significantly high interest in studying the extension of rail service to other parts of the state, most notably to Branson, Springfield, Columbia, and St. Joseph.

- **Branson**: a desire that showed up in nearly every public meeting, since Branson is largely seen throughout Missouri and Midwest/Plains states as a significant resort and entertainment destination. The mention of service to Branson, Missouri was a common theme at four out of the seven public meetings.
- **Springfield**: had been studied in 2007 and not found to be feasible, but the desire for service remains significant. Numerous attendees suggested that Springfield and Branson could be served by the same route or service.
- **St. Joseph**: sits on existing rail corridors about halfway between Kansas City and Omaha, Nebraska. There used to be passenger rail service in this corridor, and several commenters expressed an interest in restoring this service.
- **Columbia:** home to the University of Missouri and is seen as a possible commuter route to St. Louis.
- **Hannibal**: There is some effort to extend the Illinois Zephyr, which currently terminates in Quincy, IL, to Hannibal. Interest was also expressed in providing rail connection to St. Louis.

The attendees also mentioned the need for commuter rail between St. Louis and nearby communities to the immediate West and even over to suburbs on the Illinois side of the Mississippi River. Interestingly, there appeared to be less awareness of the Amtrak long-distance trains that serve Missouri communities; the “Texas Eagle” with stops at LaPlata, Missouri and Kansas City and the “Southwest Chief” with stops at St. Louis and Poplar Bluff, Missouri. That could be due to the perception that these are somehow not “Missouri’s” trains, as they are not supported by the state. There were, however, a few comments about whether or not Amtrak could become a sustainable national system and recognition that other modes of transportation (highways and aviation) are heavily subsidized.

4.2.2. Freight rail service

Awareness of the role of freight rail in Missouri appears to be broad, deep and strong. This is perhaps for several reasons apparent in comments from the seven workshops and public meetings. There is recognition that Kansas City and St. Louis have historically been and continue to be major freight rail hubs and even though not mentioned specifically at the meetings, attendees seemed aware that Missouri has a rich railroading history: the home base to one former, major Class-1 railroad the Missouri Pacific (now part of the Union Pacific Railroad system) and had major freight yard and locomotive facilities for several other former railroads (Frisco, Santa Fe, Chicago-Burlington & Quincy, Wabash, Gulf-Mobile & Ohio, Norfolk & Western, Rock Island Railroad) which have since been merged into other railroads or dissolved.

In general, both stakeholders and the public see that freight rail is important to Missouri’s economy and environment, and is a key part of the state’s overall transportation system to move heavy loads off of the state’s highway grid. The attendees support the idea that any improvements to the state's rail infrastructure should benefit both freight and passenger rail and that one should not impede the other. Moving freight off of the I-70 corridor between Kansas City and St. Louis and onto rail is seen as a priority and a benefit in terms of reducing highway traffic, reducing damage to state and local roadways, and reducing air pollution from emissions. The attendees would also like to see the state do more to seek out public-private partnerships that could result in moving more freight by rail and increasing economic development in the I-70 corridor.

Missouri has a rich mining culture and is known to produce several minerals that are presently being transported by truck due to lack of rail infrastructure in the region. The community leaders would also like the state to provide more help and services to businesses that produce mined products in the state. The stakeholders also suggested that in order to see steady growth and economic development in the state, the government should promote and develop more intermodal opportunities where rail connects with highways and ports along the Missouri and Mississippi Rivers. Stakeholders would like to see more coordination with the railroads in developing more and better rail-served industrial development clusters in the state. In a related matter to the river ports, there is concern about the impact of seasonal flooding on the railroads as some of the lines closely parallel or cross the Missouri and/or Mississippi Rivers.

The community leaders and stakeholders advocated for a better liaison between business/shippers and the railroads to both grow business and address concerns over shipping logistics. They expressed desire and need for the for the state to work more with short-line railroad operators and to look at possibly reviving some abandoned or under-utilized rail lines as a means of fostering more economic development in the state's small cities and communities. Trucking interests also see the State Rail Plan as a way of improving the transportation system as a whole.

4.3. Map the needs and issues with strategic goals and objectives

Based on the analyses, it is clear that the stakeholders and the public have a strong awareness about benefits of rail especially those who live in communities/regions, which had access to rail service. The stakeholders and general public embrace the idea that rail infrastructure development enhances the socio-economic vitality of the region, and provides an alternate mode of transportation that is cheap and efficient. They were also aware of the economic, environmental, and quality of life impacts of both passenger and freight rail on the communities and the state.

The stakeholders consider investments for improving rail infrastructure in the state and the benefits rail brings to the communities as two important factors that need considerable attention in the state rail plan. These factors were frequently discussed in the stakeholder and public meetings and the informed stakeholder survey. The stakeholders and public are appreciative of the efforts put in place by the government to fund rail infrastructure development, but insist that the state should look for more innovative approaches to fund rail improvements without living "paycheck to paycheck" through federal grant money. Even though no specific method or approach was discussed in the meetings, it can be seen through the survey results and comments that the stakeholders support the idea of investing public money in partnership with freight railroads to improve infrastructure in the state of Missouri. The analyses have indicated thatinvestment approaches to fund rail improvements in the state are not self-sustainable, and it is imperative that the state address this financial uncertainty in the planning stage of the project.

The analysis has indicated that the stakeholders are interested to see a higher speed rail network in the state, but there are several issues in the existing network that need to be addressed and considered when planning for rail infrastructure improvements in the state. The stakeholders point out that the existing passenger rail services in the state are not designed to help businesses with low frequencies and schedule. The trains are not on time and when compared to other modes of transportation they are relatively slow between destinations. The existing trains lack connections with other trains and the rail lacks accessibility via other public modes of transportation. They also identified that several developing regions such as Columbia, Springfield, Branson, Rolla, etc. do not have connectivity to the two major cities Kansas City and St. Louis through rail. In their comments and suggestions, stakeholders feel that the state should look at providing population centers access to rail and therefore access to the bigger cities along with providing faster service between Kansas City and St. Louis.

The stakeholders also suggest that the rail planning effort consider quality of life implications and safety of the public as people with physical disabilities and older age do not have access to public transportation and have to drive on congested highways and in inclement weather. The stakeholders would also like to see the state work with short-line railroad operators and possibly look at reviving abandoned and under-utilized rail lines to foster economic development in smaller communities.

The analyses have also indicated that the obstacles for improving rail in Missouri are primarily due to higher funding priorities for other modes of transportation. As the infrastructure in the nation is crumbling, taxpayer resistance to pay for rail improvements that are not in their region is high. But the stakeholders also feel the need for an alternative mode of transportation that has the potential to create more jobs, be environmentally friendly, relieve congestion, and benefit and spur economic development to support the congested and crumbling infrastructure.

5. Conclusion

The conceptualization of transportation systems as socio-technical systems is complex and is by no means unambiguous. These are intricate systems that rely immensely on user behavior and patterns. The notion of social elements and social uncertainty is far from clear. Capturing policies, regulations, and economic and social structure in a single concept of social element is complex (Ottens et al., 2006). When sustainable planning is considered, accurate information for guidance is crucial and should take into account diverse, direct, and indirect long-term impacts.

In this article, we have conducted and outlined a stakeholder analysis framework for a transportation planning effort in Missouri. The stakeholder engagement framework developed in this article aligns well with the transportation planning effort for identifying the uncertainties, needs, issues, and risks associated with the project. The approach elevates sustainability as a primary consideration during the planning effort, with emphasis being laid on stakeholder involvement in the decision-making process. Stakeholder involvement is influential to incorporate diverse perspectives and preferences. This work investigated the variability of stakeholders' behavior and their level of satisfaction of rail service in Missouri, which may provide an insight on strengths and drawbacks of the existing service and distinguish factors that need attention when planning for infrastructure development in the state.

6. Implications for managerial practice

The study has integrated several tools and processes to describe a methodology and actual application to identify and classify stakeholders and how to analyze their interests, needs, issues, and uncertainties. With several states in the US now trying to develop the transportation infrastructure, in particular passenger and freight rail, a stakeholder analysis is imperative, as path to development cannot be generalized. The planners need to assess the needs and issues in the region to provide a comprehensive plan for infrastructure development. The study and the framework developed may provide guidance to transportation planners in the creation of a comprehensive rail plan and throughout the management of the project. The study can also be used by public transport developers and operators to adjust their policies and better tackle customer expectations and needs.

References

AAR. (2011). *Railroad Infrastructure Improvement*. Retrieved December 13, 2011, from Association of American Railroads: http://www.aar.org/KeyIssues/Infrastructure-Investment.aspx

Amos, P. (2009). *Rail Freight in Development.* Department of Internal Development. Washington D.C.: Transport Research Support.

Brown, M. (2003). Technology Diffusion and The "Knowledge Barrier": The Dilemma of Stakeholder Participation. *Public Performance & Management Review, 26* (4), 345-359.

Creswell, J. W. (2003). *Research Design: Qualitative, Quantitative, Qualitative, and Mixed Methods Approaches*. 2nd edition. Thousand Oaks, CA: Sage Publications, Inc.

Elias, A., Cavana, R., & Jackson, L. (2002). Stakeholder Analysis for R&D Project Management. *R&D Management, 32* (4), 301-310.

Deakin, E. (2001). Sustainable Development and Sustainable Transportation: Strategies for Economic Prosperity, Environmental Quality, and Equity. *Working 2001-2003*.

Field, A. (2005). *Discovering Statistice Using SPSS.* London: Sage Publications.

Freeman, R. E. (1984). *Strategic Management: A Stakeholder Approach.* Boston, MA, USA: Pitman.

Goldman, T., & Gorham, R. (2006). Sustainable Urban Transportation: Four Innovative Directions. *Technology in Society, 28*, 261-273.

Litman, T. (2008). *Sustainable Transportation Indicators.* Sustainable Transportation Indicators Subcommittee of the Transportation Research Board.

Long, S., Gentry, L., & Bham, G. (2011). Driver Perceptions and the Impact of Change Resistance on the Implementation of Variable Speed Limit Systems.

Newman, L. (2005). Uncertainty, Innovation, and Dynamic Sustinable Development. *Sustainability: Science, Practice, & Policy, 1* (2), 25-31.

Murakami, J., & Cervero, R. (2010). *California High-Speed Rail and Economic Development: Station-Area Market Profiles and Public Policy Responses*. University of California Transportation Center, The Center for Environmental Public Policy. Berkely, CA: University of California Transportation Center.

Ottens, M., Franssen, M., Kroes, P., & Van De Poel, I. (2006). Modelling Infrastructures as Socio-Technical Systems. *International Journal of Critical Infrastructure, 2* (2-3), 133-145.

Steg, L., & Gifford, R. (2005). Sustainable Transportation and Quality of Life. *Journal of Transport Geography, 13*, 59-69.

Rohracher, H. (2001). Managing the Technological Transition to Sustinable Construction of Buildings: A Socio-Technical Perspective. *Technology Analysis & Strategic Management, 13* (1), 137-150.

Tuominen, A., & Ahlqvist, T. (2010). Is the Transport System Becoming Ubiquitous? Socio-technical Roadmapping as a Tool for Integrating the Development of Transport Policies and Intelligent Transport Systems and Services in Finland. *Technological Forecasting & Social Change, 77*, 120-134.

Williams, R., & Edge, D. (1996). The Social Shaping of Technology. *Research Policy, 25*, 856-899.

III. SOCIO-TECHNICAL ROADMAPPING AS A STRATEGIC TOOL FOR TRANSPORTATION INFRASTRUCTURE PLANNING AND DEVELOPMENT

Kiran Rangarajan, Suzanna Long, and Ean-Harn Ng

Department of Engineering Management and Systems Engineering,

Missouri University of Science and Technology, Rolla, MO-65409, USA

Abstract

This article examines the concept and implementation of sustainable transportation infrastructure planning and development. It traces efforts to defining transportation systems as socio-technical systems, future studies, and policy assessment and development. The article presents a socio-technical roadmapping framework as a strategic tool for integrating socio-technical concepts with infrastructure development. The framework is tested with a rail transportation infrastructure planning and development case study conducted in Missouri. The case study reveals several uncertainties and gaps in the existing transportation system from both social and technical aspects. The roadmap illustrates the kind of partnerships, processes, and infrastructure development needed to move the existing system to a predetermined sustainable end point. The changes suggested require a considerable reevaluation of partnerships between governing agencies and organizations, along with developing innovative solutions to fund infrastructure development projects. In conclusion, decision makers and transportation experts can use this framework to align infrastructure development activities with transportation and sustainable policy development.

Keywords: infrastructure development, Missouri rail plan, socio-technical analysis, socio-technical roadmapping, sustainability, systems perspective, transport policy

1. Introduction

Roadmapping as a foresight method is relatively new to the transportation sector (Tuominen & Ahlqvist, 2010) in the area of transportation technologies for example, railroad and locomotive technology (Stodolsky, 2002) and technology scan of freight transportation industry (Moore, 1996). These examples are predominently technology oriented, which look at solving transportation problems by seeking technological developments and do not study the impact of non-technical elements on the system performance. In addition, the socio-technical analysis of transportation infrastructure is rarely covered in literature and the impact of non-technical elements on the system performance in the transportation sector is still unclear. As sustainable development gains importance in planning efforts, understanding the socio-technical nature of transportation infrastructure and developing sequential measures to attain a predetermined end point becomes necessary.

In this manuscript, we evaluate transportation infrastructure systems as complex socio-technical systems, or systems that require considerable attention from both technical and non-technical perspectives for planning purposes. We then present a socio-technical roadmapping framework as a strategic tool to encourage transportation experts and decision makers to study the transportation system from a socio-technical viewpoint. The framework is applied and validated using a rail infrastructure development effort in Missouri as an example. The conventional transportation planning frameworks such as the cost-benefit analysis and impact assessments alone are not sufficient to plan and address future transportation system challenges (Tuominen & Ahlqvist, 2010). Mapping uncertainties and risks with a broader socio-economic context is imperative for transportation system development. This article addresses the following questions:

(1) How can the socio-technical roadmapping approach be effectively utilized to develop alternatives and recommendations to propel the transportation system into the sustainability realm?

(2) What kind of strategic tools and frameworks are needed to integrate sustainable development strategies with transportation development policies?

(3) What are the various institutional, organizational, societal, and economic risks and uncertainties associated with the rail industry?

(4) What sequential measured steps are taken to attain a predetermined end point?

This article is organized as follows. The next section presents a contextual overview of the socio-technical and roadmapping theory. The socio-technical framework for a transportation system is then introduced and described as part of the methodology section. The framework is then applied to the Missouri rail example. The conclusion section presents the findings from the research followed by discussion and implications of findings. We conclude with directions for future research and practice.

2. Socio-technical roadmapping

2.1. Socio-technical Theory

Socio-technical theory is based on the idea that a best match or joint optimization exists between the task or technical environment and the social system (Trist & Emery, 2006). Socio-technical refers to the relationship between social and technical elements of a system. It is based on the theory that the interactions of social and technical factors create conditions that are either favorable or unfavorable for system performance. These interactions are comprised of the linear case and effect relationships that can be designed as part of a system and the non-linear, complex relationships that are often unexpected (Walker, Stanton, Salmon, & Jenkins, 2008). The socio-technical approach starts by studying and resolving the changes from an individual or an organizational perspective (Rohracher, 2001) and not by just studying the impact of technology on the society. Modeling and designing such a system depends on understanding the intrinsic relationship between the social and technical elements and their effect on shaping the technology. Transportation systems are forms of socio-technical systems whose efficient functioning is dependent on the communication and the relationship between infrastructure, technology and social elements.

Transportation planning studies are used to develop strategies for operating, managing, maintaining, and financing the area's transportation system to advance the area's long-term goals (USDOT, 2007). The existing transportation planning approaches use a wide range of assessment methodologies and tools for infrastructure development at a project level, but focus primarily on economic efficiency of the project (Tuominen & Ahlqvist, 2010). The non-technical elements and their participation in the socio-technical plannin[g process has been considered only to a limited extent (Deakin, 2003; Ottens, Franssen, Kroes, & van de Poel, 2006; Tuominen & Ahlqvist, 2010). The involvement of citizens and users in transportation planning and design has been limited (Deakin, 2003; Tuominen & Ahlqvist, 2010), and have been mostly considered as end users or consumers and not as contirubtors to policy making.

The value of a technology is difficult to ascertain in the early-stages of a project due to the presence of dominant risks and uncertainties associated with the technology (Dissel, Phaal, Farrukh, & Probert, 2006). Technology based projects are typically associated with high risks and require sequential investments to realize projected rewards. In addition, the uncertainties associated with technology development assert essential flexibility into managerial action (Dissel, Phaal, Farrukh, & Probert, 2006). In this fast paced technology driven era, societal changes are imminent. Policy makers and stakeholders should understand these systemic changes and develop policies, practices, and assessment frameworks that reflect on these changes. With sustainable development increasingly becoming popular, traditional cost-benefit analysis and similar assessment frameworks are inadequate and a broader societal based approach is needed. The policy design process in itself must change and include more sensitive non-technical elements during the planning and design phases of the projects.

2.2. Roadmapping theory

Roadmapping, as a foresight methodology, has been adopted by several industries and organizations to develop and communicate strategy and planning. The roadmap provides a more structured approach to communicate the relationship between technology and market strategy, to build on the organization's long-term vision. The technique allows organizations to plan during turbulent times and provides the means to focus on the environment (Phaal, Farrukh, & Probert, 2004). In their comprehensive review of the literature, Lee and Park (2005) suggest that roadmapping can be performed at either the industry or corporate level and in some cases can be extended to the entire supply chain by linking individual roadmaps into a 'meta roadmap' (Petrick & Echols, 2004). The roadmapping process is a very flexible approach that needs customization to meet the strategic intent under study (Phaal & Muller, 2009), and the roadmaps take various forms and structures based on the project or the situation under study (Lee, Kim, & Phaal, 2012).

The roadmapping process is a relatively new methodology that has been used to facilitate and communicate strategy and planning as related to a technology (Tuominen & Ahlqvist, 2010). The main benefits of roadmaps are to help organizations develop and improve planning and decision-making processes. It helps managers to develop alternatives, communicate goals and visions, stimulate investigations, and monitor the progress of a technology (Tuominen & Ahlqvist, 2010). Technology roadmapping is not a new concept. Motorola developed roadmapping more than two decades ago. It has since then received interest from practitioners and researchers alike. Numerous studies have been conducted on roadmapping to emphasize its benefits in planning technology strategy and decision making, and to identify roadmapping process improvements to maintain and advance the core competencies of an industry or an organization (for example, Lee, Kim, & Phaal, 2012; Lee & Park, 2005; Dissel, Phaal, Farrukh, & Probert, 2006; Petrick & Echols, 2004; Phaal & Muller, 2009; Phaal, Farrukh, & Probert, 2004; Tuominen & Ahlqvist, 2010).

The foresight methodologies can be further grouped under descriptive approach and normative approach. Descriptive approaches are quantitative (forecasting), do not specify a desirable predetermined end state (exploratory scenarios), and emphasize on technical feasibility and implications of technology (technical scenarios). Normative approaches on the other hand elaborate on plausible future (visions), investigate possible pathways to the desirable future (backcasting), and describe a sequence of measures designed to progress towards a desired future (roadmapping). The socio-technical roadmapping framework developed as part of this study is classified as a normative approach. When compared to backcasting methodology that starts by defining desirable future end point and then investigating the possible pathways to that point, a roadmapping approach describes a sequence of well-designed and measured steps to bring about a desirable future. This approach enables the decision makers to assess the existing uncertainties and design paths to mitigate them in the future.

Roadmapping is a flexible approach that can be customized to address a specific system or field of study. The roadmapping architecture is comprised of two key dimensions (1) time frames – typically a horizontal axis approach which may include short, medium, and long term perspectives, and (2) layers and sub-layers – typically a vertical axis approach represented by systems based hierarchical perspective (Phaal & Muller, 2009). While several designs and architecture exsits based on these two key dimensions, a key factor that defines the architecture is the focus and scope of the study. Based on the focus and scope of the study, which is transportation planning and infrastructure development, a time frame architecture approach with short, medium, and long term time frames is used. The uncertainties and gaps in the transportation planning efforts are used as factors that need to be addressed to reach the predetermined end point.

3. Methodology

This approach provides a visual means to represent the future plan of action in a chosen field of study. As stated earlier, this methodology is relatively new to the transportation sector and the socio-technical effects of the system, integrated with sustainable development policies have been seldom considered. While numerous organizations and agencies are trying to integrate sustainability into their organizational functioning and culture, few have been successful in practically implementing it. This can be attributed to the decision making process, where the organization focuses on easy-to-measure goals and impacts (Litman & Burwell, 2006), while ignoring difficult to measure social impacts and public acceptance (Deakin, 2003). While a standard set of metrics and indicators for evaluating sustainability of a system can be useful, well-articulated processes with long-term vision can help achieve the progress towards sustainable outcomes. It is also essential to note that like any other developmental effort, sustainable development can change over time. Thus, in an effort to move towards sustainable systems, it is necessary to have flexible decision making tools and frameworks, which have the potential to evaluate relationships and interactions between various elements of the system. Such frameworks should not only study the technical aspects of a system, but also consider the impact of human elements on the functioning of the system. The framework developed in this research illustrates the use of sustainable development principles in transportation infrastructure decision-making by using socio-technical roadmapping as a strategic tool.

A critical first step in designing future scenarios is to establish a time period for the study. In transportation infrastructure development, the time period is generally longer (generally 20 to 30 years) when compared to technology development in industries, which tend to have a shorter life span (three to five years). When developing future scenarios for engineering systems, logical timelines must be adopted based on the lifecycle of the product or services under study, and this can be established while conducting the feasibility analysis of the project. The overall framework comprises of four steps: (1) system analysis, (2) sustainability analysis, (3) uncertainty analysis, and (4) roadmapping. Figure 1 presents the framework for socio-technical roadmapping.

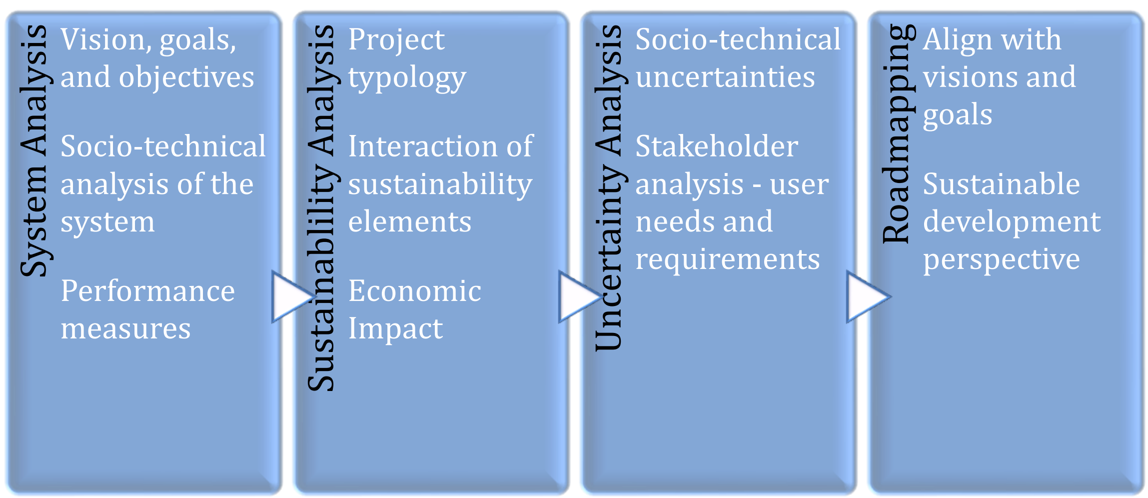


Figure 1. Overall framework of socio-technical roadmapping

In the first step, vision, goals, and objectives of the project or the field of study are established. These must be consistent and align well with the organizational strategy or policies. The existing system characteristics and conditions are then analyzed from a socio-technical viewpoint, with the efficient functioning of the system determined by relationships and interactions between various technical and non-technical elements. Numerous studies exist in the literature, which model complex engineering systems and infrastructures as socio-technical systems (for e.g., Ottens, Franssen, Kroes, & van de Poel, 2006; Trist & Emery, 2006; Tuominen & Ahlqvist, 2010). These methodologies provide a clear understanding as to how technical and non-technical elements of an engineering system interact and the influence of their relationships on the system performance. Performance measures are then established to determine the functioning of the system and will serve as a tool to gauge the progress over time.

The second step involves analyzing the project typology from a sustainability and sustainable development perspective. Project typology defines a project into one of several major classifications of projects. For methods and examples of analyzing project typology from a sustainable perspective see Rangarajan, Long, Ziemer, and Lewis (2012). It is essential to note that, the sustainable development principles and policies cannot be generalized, and they need to be tailored to specific regional or project environment. Based on the project typology, interactions between various elements can be established from a sustainability viewpoint and the level of uncertainties or risks associated with these interactions can be determined. A thematic map is then developed to study the effect of stakeholder interactions, their influence, and their behavior/actions on the decision making process. The thematic behavior/actions maps will help the experts and decision makers identify and analyze the course of action a stakeholder would take, its influence on the decision, and the overall system performance. These socio-technical gaps and uncertainties form the factors of the roadmaps, which will be analyzed to determine the possible impact they might have on the system in the future.

The third step of the framework involves analysis of system uncertainties and risks. This involves identifying various factors that could impact the functioning of the system. Examples on system uncertainties and risk analysis can be found in Newman (2005), Rangarajan, Long, Tobias, and Keister (2012), Litman, (2006). While sustainability analysis helps decision makers identify the gaps and risks that are preventing the system from achieving stability and sustainability, a detailed analysis of these socio-technical uncertainties is critical to identify policy or systemic changes to mitigate the impact of these risks on socio-technical elements and their functioning in the system.

Based on the results and findings, roadmaps are developed as part of the final step of the framework. It must be noted that the roadmaps are very specific to the project or the area of study, and they must align with the strategic vision and goals of the organization. The uncertainties and gaps are identified from socio-technical and sustainability analyses, and are used as factors in the roadmapping process. The roadmaps produced as part of this framework are a visual representation of these socio-technical uncertainties and the measures developed to attain a predetermined end point of a certain project. The roadmaps identify cross-functional process improvements that play a major part in attaining the end result.

In the following section, the socio-technical roadmapping framework is applied and validated using the rail infrastructure development effort in Missouri. The study emphasizes on the infrastructure development effort and identifies meaningful sustainable alternatives and policies, and their relationship with the non-technical elements and evolving stakeholders. Further, the framework can be used as a strategic tool to gain better understanding of the transportation system as a socio-technical engineering system, and help decision makers identify uncertainties and risks that could potentially impact the sustainability of the system.

4. Case example: Missouri rail plan

The rail infrastructure in Missouri has played an important role in the economic vitality of the region by moving both freight and people across and beyond the state boundaries. Missouri's position as a global freight hub and opportunities for passenger rail development are seen as drives for economic development in the region. This example focuses on developing socio-technical roadmaps of the future rail infrastructure system in Missouri. The desired end point of the project is to establish a well-connected freight and passenger rail network to move people and freight across Missouri. The end point was based on the vision of Missouri Department of Transportation (MoDOT) to provide safe, environmentally friendly transportation options supporting efficient movement of freight and passengers while strengthening communities and advancing global competitiveness through intermodal connectivity. The time frame for this study was established for 20 years (2031) based on the initial feasibility analysis, which is consistent with the Midwest regional rail initiative (MWRRI, 2004).

The socio-technical roadmapping process is comprised of (1) studying the existing rail system from a socio-technical standpoint, (2) a sustainability analysis of the system, (3) identifying cross-functional uncertainties and risks, and (4) providing alternatives and recommendations as part of the roadmapping process; (see Figure 1).

4.1. System analysis

The conceptualization of the transportation infrastructure system as a socio-technical system is comprised of studying technical elements, social elements, actors and the relationships or interactions between them (Ottens, Franssen, Kroes, & van de Poel, 2006). The findings from the socio-technical analysis were validated by comparing the findings with previous rail studies, reports, and other documents identifying proposed and planned Missouri rail infrastructure development alternatives and investments. The review was not limited to the Missouri study, but also included publicly available research reports, strategic studies, and foresights at the national level. Then a comprehensive review of existing rail infrastructure in Missouri was conducted. This task involved studying various rail corridors in Missouri, the railroads that operate on these corridors, the commodities that are shipped, corridor characteristics such as speed, train control system, number of trains per day, average tonnage hauled and number of tracks. The data regarding track layout, train control systems, regulated freight and passenger train speeds, number of trains per day, and tonnage value were then obtained to estimate the level of service and demand for each rail corridor. In order to accomplish this task, the Association of American Railroads (AAR, 2007) methodology to estimate corridor capacity was used.

4.1.1. Results of system analysis

Capacity analysis provides an approximation of infrastructure improvements and investments needed to meet the projected growth and demand for rail transportation in the future. The train control system used in Missouri corridors varies widely from manual to automated systems, which also determines the theoretical capacity of the corridor (AAR, 2007). The capacity of the corridor was represented in terms of level of service and demand. The demand of the rail corridor is expressed as the number of trains per day. The level of service is defined as the ratio of the number of trains per day to the theoretical maximum. The capacity analysis of the rail corridors in Missouri revealed that most of the Class I railroad corridors are running at capacity or above their theoretical capacity, and several Class II and regional railroad corridors are near their theoretical capacity.

From a social perspective, all the actors and stakeholders who have a direct and indirect impact on the functioning of the rail transportation system were identified. In addition, several social factors that have a direct impact on the transportation planning were determined from studying existing reports and studies, public meetings, focus group interviews and surveys conducted (Rangarajan, Long, Tobias, & Keister, 2012). The results of the system analysis are presented in Table 1.

4.2. Sustainability analysis

The factors determined by the scoio-technical analysis were then used as the inputs in the sustainability analysis. When this infrastructure development effort was analyzed from a sustainable development perspective by aligning it with the Economic

Development Typology (Rangarajan, Long, Ziemer, & Lewis, 2012), it clearly falls in the realm of *Strategic* projects. Strategic projects are often capital intensive, and involve high levels of risk. These risks and uncertainties can be attributed to the distance between the clientele and the public services. Strategic projects are also characterized to have a very high capacity to generate spin off projects justifying their intent and also have a strong understanding of the quality of life elements. Even though the resources required to develop the projects are scarce in the region, they have the potential to establish a platform for economic development.

Table 1. System analysis – Missouri rail transportation system

Elements	Data Sources	Factors
Technical	Existing reports and studies AAR capacity analysis MoDOT database Railroad database Waybill data Commodity flow survey FAF data	Level of service Demand Corridor/track characteristics Tonnage hauled Forecasted growth data
Actors	Existing reports and studies MoDOT database	MoDOT Railroads Federal Railroad Administration Amtrak State government Elected officials City Land owners Conservationists Other freight modes Other passenger modes Freight users Passenger users
Social	Public meetings Focus group interviews Surveys Existing reports and studies	Quality of life Equality Economic considerations Accessibility Environmental concerns Cost Time Safety Affordability

4.2.1. Results of sustainability analysis

In an effort to understand the distance between the target clientele and governing agencies and organizations, focus group meetings and interviews were conducted with all railroad operators in Missouri. Interview questions were designed to solicit information regarding operational and service characteristics, commodity flow, safety, anticipated areas of growth, capacity of rail lines, scheduling principles, organizational policies for including passenger rail movement, congested rail segments, and planned infrastructure improvements to mitigate congestion on the corridors. Analyses of the interview questions revealed a common theme among railroad operators in Missouri. As railroads in the US are privately owned, the railroad operators were reluctant to share information regarding operational and service characteristics, scheduling, general characteristics of the rail corridor, and capacity and demand of the rail corridors, due to competitive nature of the industry. These uncertainties in the operational and service conditions represent a huge gap in the transportation planning and sustainable development.

From a technical systems perspective, the existing rail infrastructure was tested with 2031 (20 year) growth figures. In order to accomplish this task, the commodity growth and rail tonnage data were forecasted using Moody's forecast method. This value was then applied to the capacity generation model to determine the 2031 level of service and demand. The future capacity analysis of the Missouri rail corridors suggest that Class I railroads will be running above their theoretical capacity, and Class II and regional railroads will be near theoretical capacity when no additional tracks are added. The analysis revealed growth in all the corridors in Missouri, and identified gaps in the existing infrastructure and the train control system, suggesting lack of potential to sustain future growth. Infrastructure improvements are imperative to maintain existing service and to cater for future growth in both freight and passenger services in the state.

In order to move the project from the *Strategic* realm to the *Sustainable* realm of the Economic Development Typology (EDT), understanding railroad operations and services, and estimating the socio-economic uncertainties were imperative. Based on these issues and information, a thematic stakeholder behavior/action map was developed to study the effects of stakeholder interactions on the rail transportation decision-making process as shown in Figure 2. The thematic behavior map shows the interaction between the stakeholders and the action/decision they would take during a decision making process. In addition, the distance between the governing agencies and target clientele must reduce, and the policy makers must consider the emerging needs and issues of the region to develop sustainable alternatives. To accomplish this task, detailed uncertainty analysis was conducted, and is presented in the subsequent section.

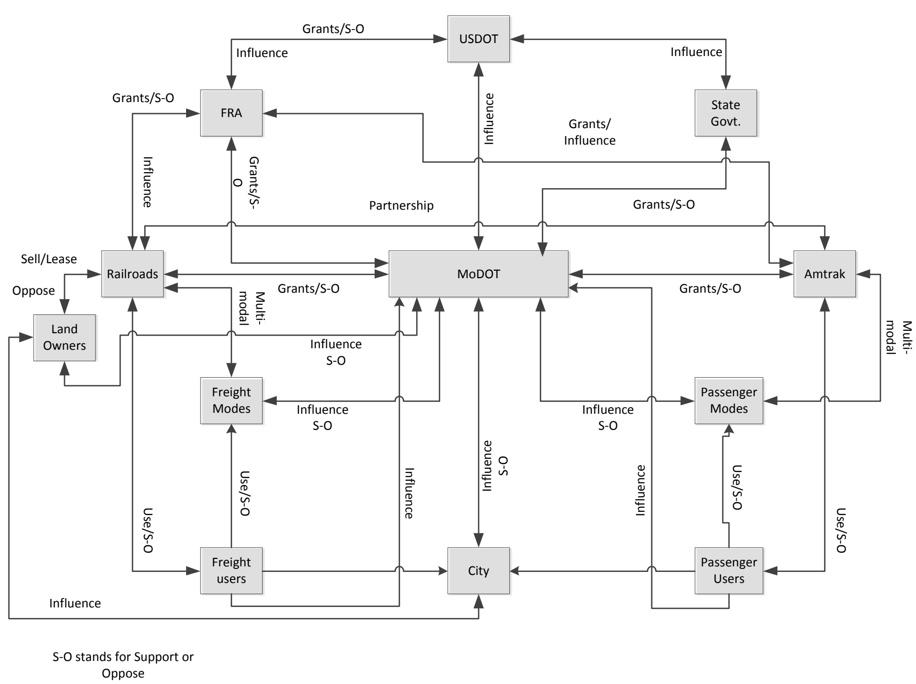


Figure 2. Thematic stakeholder behavior/action map

4.2.2. Economic impact

The economic impact analysis included studying the benefits of preserving the current services and the investments needed to support the existing service through the lifespan of the study (2031). Moody's growth factors were applied to the existing conditions to obtain forecasts. The analysis indicates Missouri's rail network is expected to carry 805,000 passengers and 311 million tons (71% is through traffic) in 2012. If cars and trucks made all these trips, it would place an additional 137 million vehicle miles of travel on Missouri's highways in 2012. Over the lifespan of the study (2012 to 2031), this number is estimated at 3.5 billion vehicle miles. The increase in vehicle miles translates to $1.07 billion in overall costs over the lifespan of the study.

Since 2007, $347 million has been approved for railroad improvements in Missouri. Of this amount $268 million is part of a four-state joint-application for three new train sets. Approximately 92% of approved funds are from federal grants and programs and the rest is split between the host railroad and the state. As the funding availability from federal agencies fluctuate from year to year, relying heavily on a single source for funding increases the uncertainty in planning efforts. In order to maintain existing services and to expand these services to other parts of the state, additional funds and investment portfolios need to be created. This is a huge uncertainty and the need for innovative approaches and public private partnerships to solve infrastructure development funding problems is necessary.

4.3. Uncertainty analysis

Risks and uncertainties are prolific in infrastructure development efforts, making them complex systems to plan, design, build, and operate. Transportation systems are socio-technical systems that are dependent emphatically on the relationships between social and technical elements (Rangarajan, Long, Tobias, & Keister, 2012). Figure 3 shows the effect of uncertainties on strategic factors and sustainability of transportation systems. To determine the effect of these uncertainties on the sustainability of the transportation system, a stakeholder analysis was conducted.

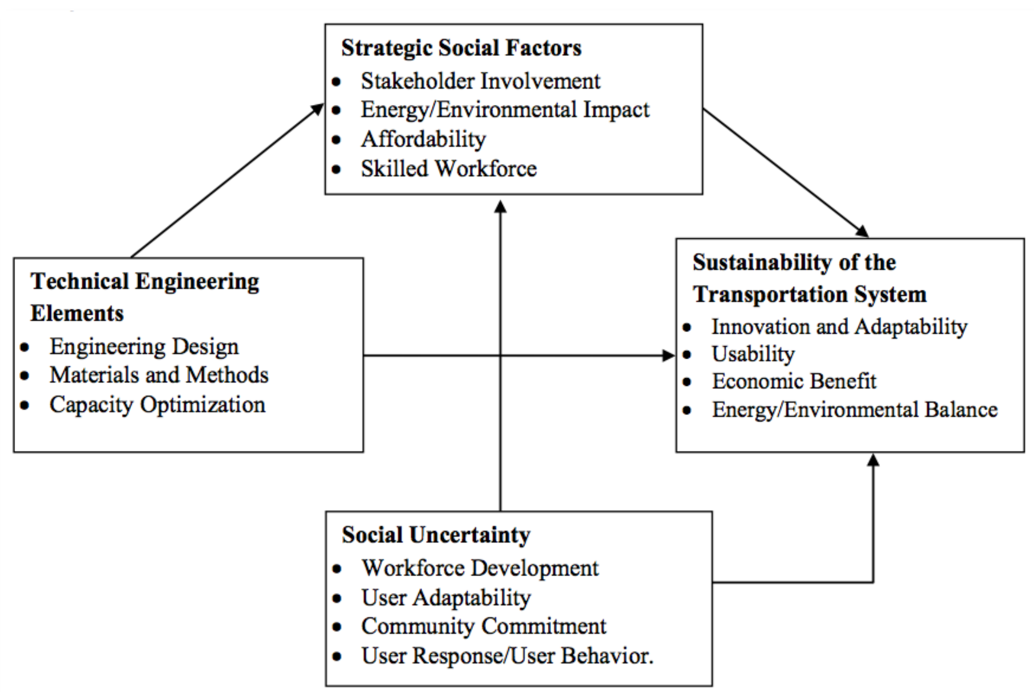


Figure 3. Social factors and uncertainties for transportation infrastructure projects (Rangarajan, Long, Tobias, & Keister, 2012)

4.3.1. Stakeholder analysis

As part of the stakeholder analysis, an informed stakeholder survey was developed and public meetings were conducted to identify and analyze the needs, priorities, and issues of the regions (Rangarajan, Long, Tobias, & Keister, 2012). The survey was designed to identify and capture best alternatives to invest limited funds towards efficient transportation infrastructure improvement from a stakeholder's perspective. The benefits of rail and the enhancement to the socio-economic vitality of the region were among other things captured in the survey. The survey was directed to regional and metropolitan planning organizations, economic development organizations, transportation experts, elected officials, and others who have a stake in the efficient movement of goods and passengers by rail (Rangarajan, Long, Tobias, & Keister, 2012).

4.3.1.1 Results of stakeholder analysis

The highlights of the stakeholder study (Rangarajan, Long, Tobias, & Keister, 2012) are briefly discussed in this section. The stakeholders and general public embrace the idea that socio-economic vitality of the region is enhanced by rail infrastructure development. They are also of the opinion that improving rail infrastructure in the state and the benefits rail brings to the communities are two important factors that need considerable attention in the transportation planning effort. They insist that the state should look for innovative approaches to fund infrastructure efforts without living "paycheck to paycheck" through federal grant money. The analyses indicates the existing investment approach is not self-sustainable, and the stakeholders are of the opinion that the state should address this financial uncertainty in the planning stage of the project.

The stakeholders point out that the existing passenger rail services in the state are not designed to help businesses with low frequencies and unplanned schedules. In their comments and suggestions, stakeholders feel that the state should provide connectivity and access from rural settings to population centers along with providing faster service between urban cities in the state. The rail planning effort must also consider quality of life implications and public safety as people with physical disabilities and older age do not have access to public transportation and have to drive on congested highways and in inclement weather. In an effort to foster economic development in smaller communities, the stakeholders would also like to see the state work with short-line railroad operators and possibly look at reviving abandoned and under-utilized rail lines. The analysis also indicates that higher funding priorities for other modes of transportation as one of the primary obstacles for improving rail in Missouri.

4.4. Socio-technical roadmaps for rail infrastructure development

Based on the various analyses conducted in previous steps, Table 2 was developed showing the various factors and the uncertainties associated with those factors. These factors and uncertainties are analyzed and sequential measures are developed to mitigate the same in the roadmapping process.

The socio-technical roadmapping process requires simultaneous consideration of technology, market, and the interaction between them over time. This concept of socio-technical mapping helps planners and policy makers understand the dynamics involved in transportation technologies, their applications, and their relationship with the actors in the system. In a complex socio-technical system such as transportation, which is capital intensive, emerging technology poses new and dynamic challenges to policy and decision makers, and other stakeholders who are responsible for effective functioning of the technology. These challenges also alter the relationship between the public and private entities involved in the system and gives rise to changes in traditional processes. Changes in technology also foster development of new operational practices and business approaches to solve emerging issues and needs.

Table 2. Socio-technical factors and uncertainties in the rail transportation system

Factors	Uncertainties
Organizational	• Extent of interaction • Willingness to communicate • Willingness to cooperate • Public private partnership • Willingness to enter into contractual agreements
User Needs	• Low cost • Accessibility • Spatial coverage • Environmentally friendly • Efficient • Convenient • Quality of life • Alternate mode of transport
Technologies	• Train control system • Train technology • Scheduling technology • Alternate energy • Loading and unloading technology • Information and communication technology
Infrastructure	• Capacity • Life • Infrastructure characteristics • Sustain growth • Intermodal facilities • Stations • Docks and yards
Investment/Financial	• Existing methods • Future opportunities • Public private partnerships • Innovative approaches
Performance Measures	• Sustainability indicators • Performance evaluators

The following section presents the results of the Missouri example in the form of socio-technical roadmaps, which integrates sustainable development practices in its framework. When rail infrastructure development or capacity improvement is considered, capital expansion is an expensive measure. In addition, environment and land use regulations, limited financial resources, deficient infrastructure, and other factors such as the need for alternative modes of passenger transportation, congestion, and demand has led the railroads and the government to reevaluate the railroad capacity. A cost-effective scenario is to evaluate the existing capacity and invest on incremental improvements that could potentially increase the capacity on the existing corridors.

The vision of the roadmap as stated earlier is to provide safe, environmentally friendly transportation options supporting efficient movement of freight and passengers, while strengthening communities and advancing global competitiveness through intermodal connectivity. As the first step in a roadmapping process, the predetermined end point for this project is set at having an improved freight and passenger railroad network with greater capacity and spatial reach to sustain future growth in Missouri, and be compliant with the national strategy for sustainable rail infrastructure improvement. Based on the socio-technical, sustainability, and uncertainty analysis six factors namely organizational constraints, user needs, technologies, infrastructure, investment/financial, and performance measures are identified as factors of the roadmap. Addressing these measures through sequential planning is critical to attain the desired end point. The socio-technical roadmap for rail transportation development in Missouri is shown in Figure 4.

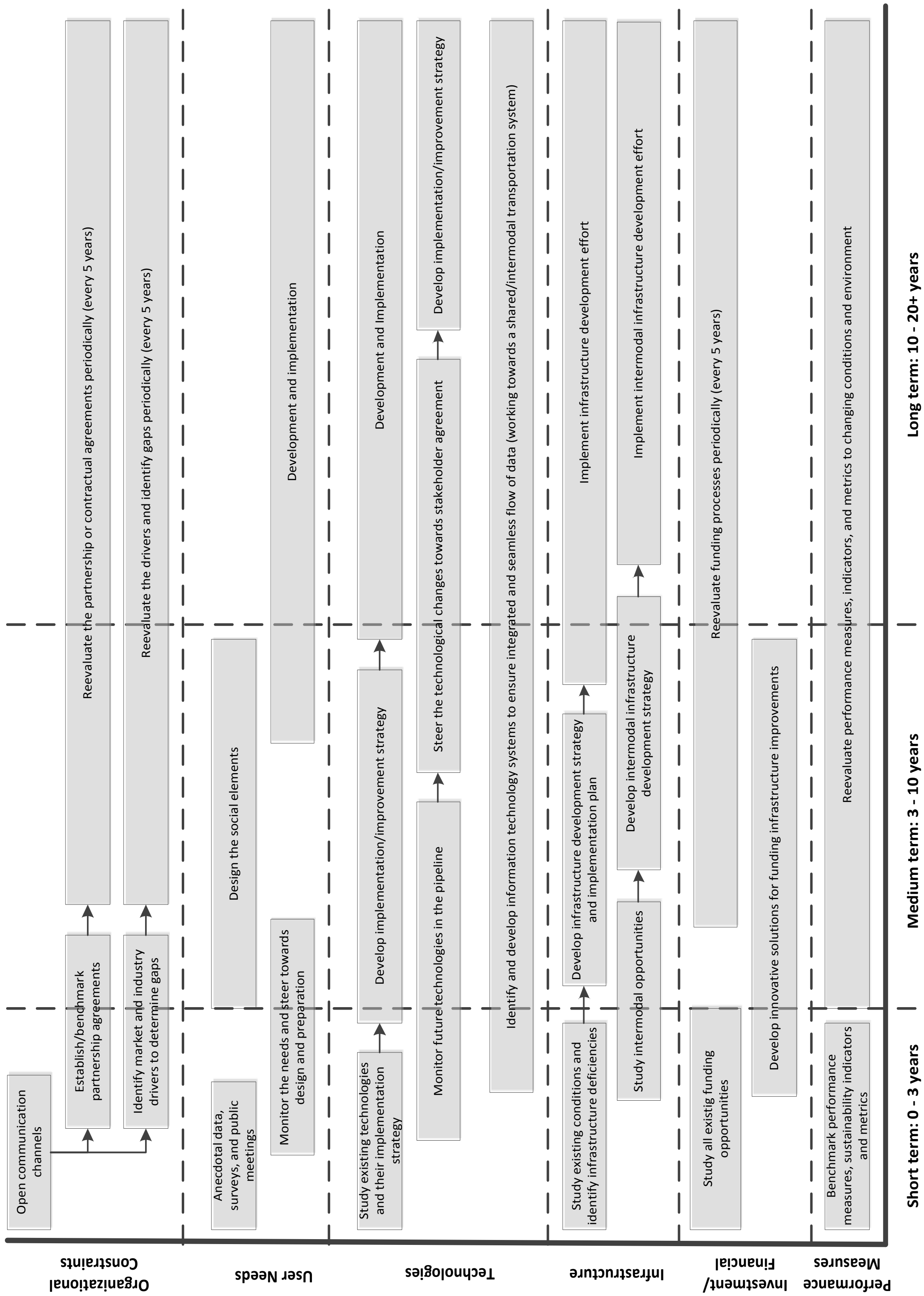


Figure 4. Socio-technical roadmap for rail infrastructure development in Missouri

4.5. Discussion

From the sustainability analysis, organizational constraints seem to possess the key to solving numerous issues in the rail sector in Missouri. The distance between the clientele and the governing agencies and the distance between various governing agencies may be the reason for apparent gaps and uncertainties in the Missouri rail transportation system. The willingness of the organizations and agencies to interact, cooperate, reduce uncertainties, and the extent of interaction are drivers that could potentially affect the sustainability of the system. These could also potentially mitigate uncertainties in addressing user needs, technologies, infrastructure development, and investments or financial factors.

In the short term, which is around 3 to 5 years, the organizations (railroad owners, truckers, maritime, and air transportation) and governing agencies (department of transportation – federal and state) must focus on opening communication channels to exchange information and establish trust and partnerships to identify market and industry drivers. This enables the governing agencies to study and identify infrastructure deficiencies, study the technology in use and its implementation strategy, study existing funding options and opportunities, and monitor user needs to understand and design socio-technical elements of the system. Also, developing innovative solutions for funding technology and infrastructure improvements and to realize user needs and requirements are necessary steps that need to start simultaneously in the short term in collaboration with railroad organizations. It is also important to benchmark performance measures, sustainability metrics, and indicators to track and study the progress of system performance. Since the end point is an established intermodal system, it is necessary to study all possible opportunities that exist to develop a well-connected intermodal system. This can only be accomplished with partnerships between organizations and governing agencies.

In the medium term, these partnerships between railroad organizations and governing agencies must be reevaluated periodically (every 5 years). Monitoring the needs and designing these complex social elements is a key task that ties in developing implementation and improvement strategy for both technology and infrastructure systems. Further, developing innovative funding solutions and alternatives, and reevaluating the same periodically ensures continuous investment capabilities to fund improvements. In order to establish intermodal connectivity between transportation modes, it is imperative to improve and establish hubs at strategic locations. Developing plans and implementation alternatives with strategic focus for intermodal infrastructure development is a key step that needs to be accomplished in the medium term. Also, it is important to develop information technology systems to ensure an integrated and seamless flow of data between operators.

In the long term, the transportation system improvement plans and implementation strategy developed for technology, infrastructure, information systems, user needs, and investment options are executed to reach the desired end point. The performance measures and indicators are used to track these system changes periodically. The partnership between the transportation organizations and governing agencies must be reevaluated periodically to bring in measures and policies to continue on the sustainable path.

5. Conclusions

Based on the Missouri example, it is apparent that the transportation infrastructure is a socio-technical system involving actors, actor networks and their interaction with the technical elements. This proposed socio-technical system is by no means simple and problem free. When an infrastructure is modeled as a socio-technical system, a social element can be analyzed as relationships between actors and physical systems or as relationships between actors (Ottens, Franssen, Kroes, & van de Poel, 2006). It can also be treated as social elements or behavior of a group of people with similar interests or bound by some legal factor that organizations have established. In this example social elements have been defined as actors and their interactions with other actor groups and technical elements. From the sustainability analysis, which places the project in the strategic realm, the distance between the governing agencies and target clientele has been identified as the critical factor that is hampering the sustainability of the system. Moreover, the quality of life elements have been identified as critical drivers to stakeholder buy in.

Based on the roadmapping process, we argue that organizational uncertainty plays a very critical role in the functioning of a system. The relationship between stakeholders and their willingness to cooperate and share information plays a critical role in defining several measures planned for reaching the desired endpoint. The partnerships between organizations and governing agencies can help planners and designers develop strategies for technology, infrastructure, and investment improvement and implementation. The uncertainties identified in the analyses were the theme in our roadmapping process. The analyses revealed that the gaps in the system were not only from a technical or technology perspective, but also from a planning perspective. The steps identified in the roadmapping process deals with mitigating these anomalies in the system by building partnerships between public and private entities, keeping other stakeholders and actors in mind.

To conclude the socio-technical roadmapping method, which includes the sustainability component was applied and validated with a transportation infrastructure development example in Missouri. It provides managers and decision makers an interactive and visual foresight and stimulates future discussion on transportation visions, policies, services, and processes in a collaborative manner. The framework can be used as tool for future studies and to model complex socio-technical systems and determine the path to sustainability of a system.

6. Future work

The interactions between the actors and the level of influence between the actors need to be modeled and studied further. We believe the relationships and influence between the actors may have a considerable effect on the sustainability of the system, and a strategic tool to quantify the relationship needs to be developed. The impact of actor influence on the roadmapping process needs to be investigated further.

Acknowledgement

We would like to take this opportunity to thank Missouri Department of Transportation (MoDOT) and HNTB Corporation for giving us the opportunity to work on the Missouri State Rail Plan.

References

AAR. (2007). *National Rail Freight Infrastructure Capacity and Investment Study*. Cambridge Systematics, Inc. Cambridge, Massachusetts: Association of American Railroads.

Deakin, E. (2003). Sustainable Development and Sustainable Transportation: Strategies for Economic Prosperity, Environmental Quality and Equity. *Working Paper 2001-03*.

Dissel, M., Phaal, R., Farrukh, C., & Probert, D. (2006). Value Roadmapping. *Technology Management for the Global Future* (pp. 1488-1495). Istanbul: IEEE.

Goldman, T., & Gorham, R. (2006). Sustainable Urban Transport: Four Innovative Directions. *Technology Society, 28*, 261-273.

Lee, J. H., Kim, H.-i., & Phaal, R. (2012). An Analysis of Factors Improving TEchnology Roadmap Credibility: A Communications Theory Assessment of Roadmapping Process. *TEchnological Forecasting & Social Change*, *79*, 263-280.

Lee, S., & Park Y. (2005). Customization of Technology Roadmaps According to Roadmapping Purposes: Overall Process and Detailed Modules. *Technology Forecasting & Social Change, 72*, 567-583.

Litman, T. (2006). Issues in Sustainable Transportation. *International Journal of Global Environmental Issues, 6* (4), 331-347.

Litman, T., & Burwell, D. (2006). Issues in Sustainable Transportation. *International Journal of Global Environmental Issues*, *6* (4), 331-347.

Newman, L. (2005). Uncertainty, Innovation, and Dynamic Sustainable Development. *Sustainability: Science, Practice, & Policy*, *1* (2), 25-31.

Midwest Regional Rail Initiative (MWRRI). (2004). *Midwest Regional Rail System: A Transportation Network for the 21st Century*. Midwest Regional Rail Initiative.

Moore, M. (1996). Technology Roadmapping in the Canadian Transportation Sector. *Transportation Research Forum, 38th Annual Meeting* (pp. 533-542). San Antonio, Texas: Transportation Research Board.

Ottens, M., Franssen, M., Kroes, P., & van de Poel, I. (2006). Modelling Infrastructures as Socio-technical Systems. *International Journal of Critical Infrastructure, 2* (3), 133-145.

Petrick, I. J., & Echols, A. E. (2004). Technology Roadmapping in Review: A Tool for Making Sustainable New Product Development Decisions. *Technological Forecasting & Social Change*, *71* (1-2), 81-100.

Phaal, R., & Muller, G. (2009). An Architectural Framework for Roadmapping: Towards Visual Strategy. *Technological Forecasting & Social Change, 76*, 39-49.

Phaal, R., Farrukh, C., & Probert, D. (2004). Technology Roadmapping: A Planning Framework for Evolution and Revolution. *Technological Forecasting and Social Change, 71*, 5-26.

Stodolsky, F. (2002). *Railroad and Locomotive Technology Roadmap.* Center for Transportation Research, Argonne National Laboratory, Energy Systems Division. U.S. Department of Energy.

Rangarajan, K., Long, S., Ziemer, N., & Lewis, N. (2012). An Evaluative Economic Development Typology for Sustainable Rural Economic Development. *Community Development, DOI:10.1080/15575330.2011.651728*, 1-13.

Rangarajan, K., Long, S., Tobias, A., & Keister, M. (2012). The Role of Stakeholder Engagement in the Development of Sustainable Infrastructure Systems. *Working Paper*.

Rohracher, H. (2001). Managing the Technological Transition to Sustainable Construction of Buildings: A Socio-technical Perspective. *Technology Analysis & Strategic Management, 13* (1), 137-150.

Tuominen, A., & Ahlqvist, T. (2010). Is the Transport System Becoming Ubiquitous? Socio-technical Roadmapping as a Tool for Integrating the Development of Transport Policies and Intelligent Transport Systems and Services in Finland. *Technological Forecasting & Social Change, 77*, 120-134.

Trist, E., & Emery, F. (2006). *Sociotechnical Systems Theory.* Armonk, NY: Odyssey.

U.S. Department of Transportation (USDOT). (2007). *The Transportation Planning Process: Key Issues* (Vols. FHWA-HEP-07-039). Washington, D.C.: U.S. Department of Transportation.

Walker, G., Stanton, N., Salmon, P., & Jenkins, D. (2008). A Review of Sociotechnical Systems Theory: A Classic Concept for New Command and Control Paradigms. *Science, 9* (6), 479-499.

3. CONCLUSIONS

3.1 SUMMARY

As the interest in sustainable development and transportation system sustainability grows, many communities and regions are implementing sustainable measures as part of transportation infrastructure development. Previous findings from the literature indicated that the existing frameworks focuses on transportation from a technological efficiency as well as environmental impacts, and less on social impacts and the economic efficiency of the system. The review also suggests that sustainable development policies and frameworks depend on the region and are bound to change with time. This requires developing versatile and robust tools to understand the regional priorities as a function of time.

Through the Economic Development Typology (EDT), the study evaluated the importance of project typology and selection for sustainable growth in rural and emerging settings. The EDT considers the implications of the social, economic, and environmental factors at an early stage in the project life cycle. The study establishes the need for collaborative efforts between the public and private partners to identify new development opportunities from an economic development perspective. In order to foster effective infrastructure development it is imperative that the gap between the governing agencies and target clientele be reduced. The strong risk assessment phase developed as part of the selection criteria, can help decision makers analyze the project uncertainties in the planning phase rather than resolving them during the implementation phase. The results clearly indicate that financial uncertainty of a project is an important parameter in determining feasibility and sustainability. These tools also help decision makers analyze lucrative alternatives when uncertainties are associated with input variables and data. The EDT is not limited to new project development efforts; existing infrastructure projects or ventures can use the EDT to evaluate sustainable development.

The sustainability analysis of the rail transportation infrastructure development effort in Missouri places the project in the strategic realm of the EDT. The distance between the governing agencies and the clientele and the quality of life elements are critical drivers to increase stakeholder buy in which could potentially affect the sustainability of the system. When sustainable planning is considered, accurate information for guidance is crucial and this should take into account diverse, direct, and indirect long-term impacts. The conceptualization of transportation systems as socio-technical systems is complex and ambiguous. As classification of elements as social and determining the social uncertainty and the factors affecting it are far from being clear. Even capturing the policies, regulation, and economic and social structure as social elements is complex (Ottens, Franssen, Kroes, & van de Poel, 2006) due to spatial and time constraints. These factors are dynamic and are dependent on the region and time of study.

The stakeholder analysis framework developed as part of a transportation planning effort in Missouri aligns well with the transportation planning effort for identifying the uncertainties, needs, issues, and risks associated with projects. The framework elevates sustainability as a primary consideration with emphasis on stakeholder involvement in the decision-making process. It captures the perceptions of various stakeholders and involves them early in the transportation planning and design phase of the project. This ensures comprehensive understanding of the regional issues and needs, and designing the system that addresses these concerns.

Based on the Missouri State Rail Plan example, it is apparent that the transportation system is a socio-technical one involving several actors, actor networks, and their interaction with the technical elements. When an infrastructure is modeled as a socio-technical system, the social element can be analyzed as relationships between actors and physical systems or as relationships between actors of the system (Ottens, Franssen, Kroes, & van de Poel, 2006). The thematic stakeholder behavior/action map developed as part of this study aligns well with the socio-technical principles to determine the relationship between actors and their influence on the decision making process. The study identifies organizational uncertainty as a key player in determining the successful functioning of a system. The socio-technical roadmapping analysis of Missouri infrastructure revealed that the gaps in the transportation system are not only from technical perspective, but also from a planning perspective. The partnerships between organizations (railroad owners, truckers, etc.) and governing agencies (Department of Transportation) can help planners and designers develop strategies for technology, infrastructure, and investment improvement and implementation.

To conclude, the study has integrated several tools and processes to determine project typology, stakeholder analysis, and the process to reach a predetermined end point. With several states in the US now trying to develop the transportation infrastructure, in particular freight and passenger rail, a stakeholder analysis is imperative, as the path to development cannot be generalized. The framework may provide guidance to policy makers and transportation experts to adjust policies and better tackle customer expectations and needs. It provides managers and decision makers an interactive and visual foresight and stimulates future discussion on transportation visions, policies, services, and processes in a collaborative manner. The framework can be used as a tool for future studies and to model complex socio-technical systems and determine the path to sustainability of a system.

3.2 FUTURE RESEARCH

The future research section directly addresses some of the limitations of this study. Future research is needed to study the complex synergistic issues that cannot be quantified easily. The controllable and intangible environmental variables such as political structure, culture, and regional innovation capacity should be explored for economic development.

The interactions between the actors and the level of influence between the actors need to be modeled and examined further. The relationships and influence between actors may have a considerable effect on the sustainability of the system. A strategic tool to quantify this interaction and relationship needs to be developed. The impact of actor influence on the socio-technical roadmapping process needs to be investigated further.

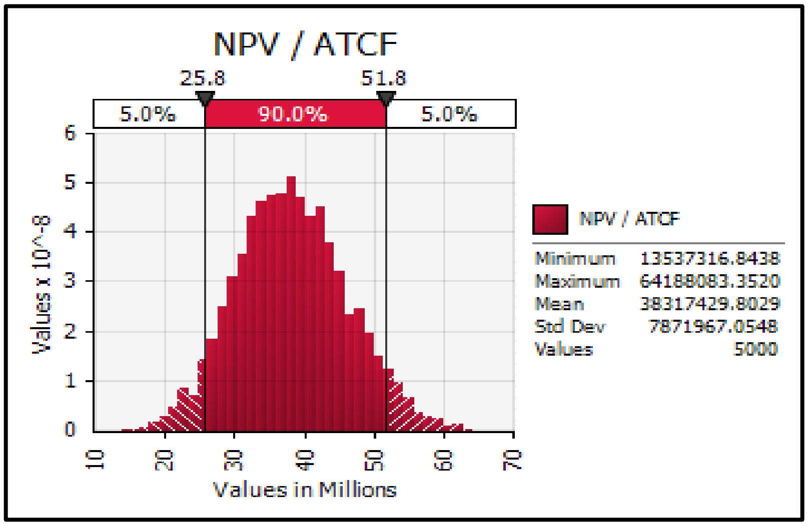
Finally, direct study of the application of this methodology to developing economies should also prove useful in extending results for use in developing countries.

APPENDIX A.

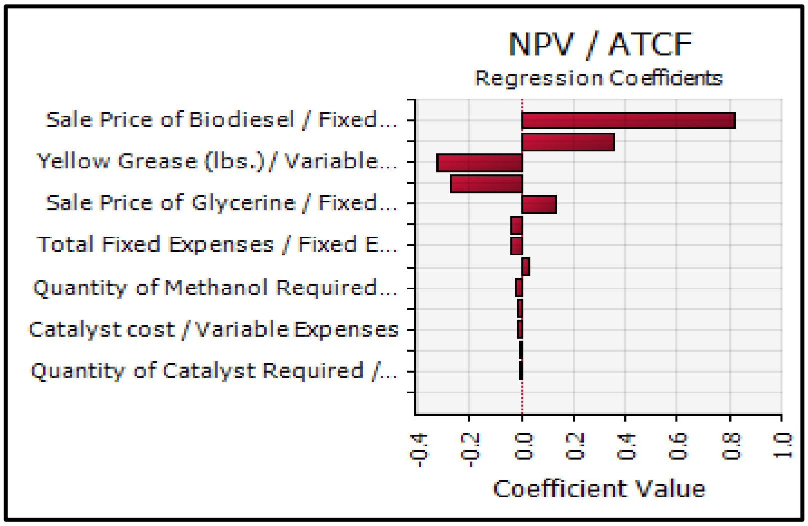
MONTE CARLO SIMULATION RESULTS

1.0 The Biodiesel Initiative

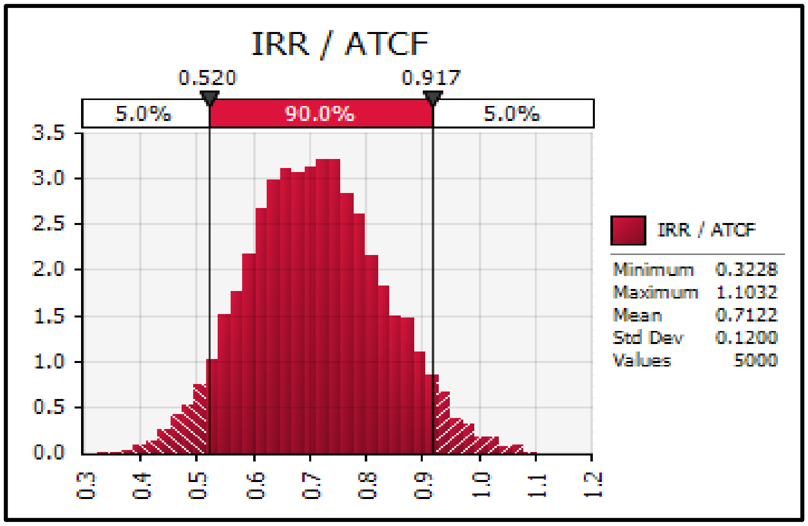
Net Present Value (NPV) - Histogram



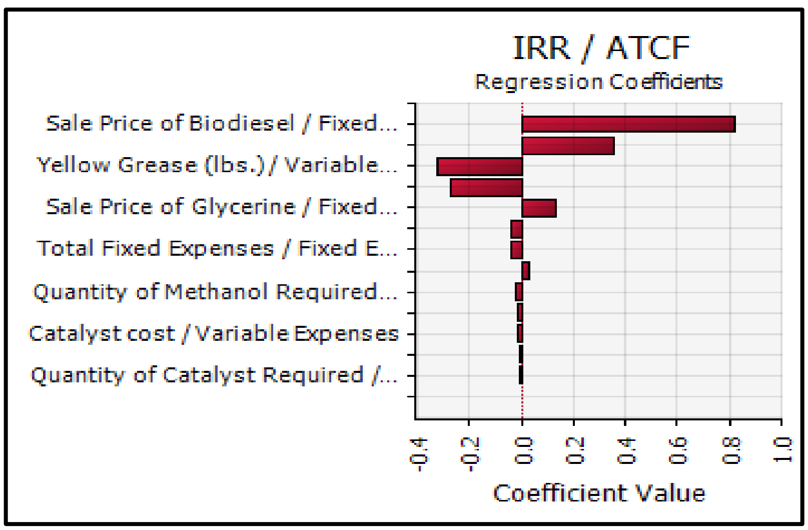
NPV – Sensitivity Analysis



Internal Rate of Return (IRR) - Histogram

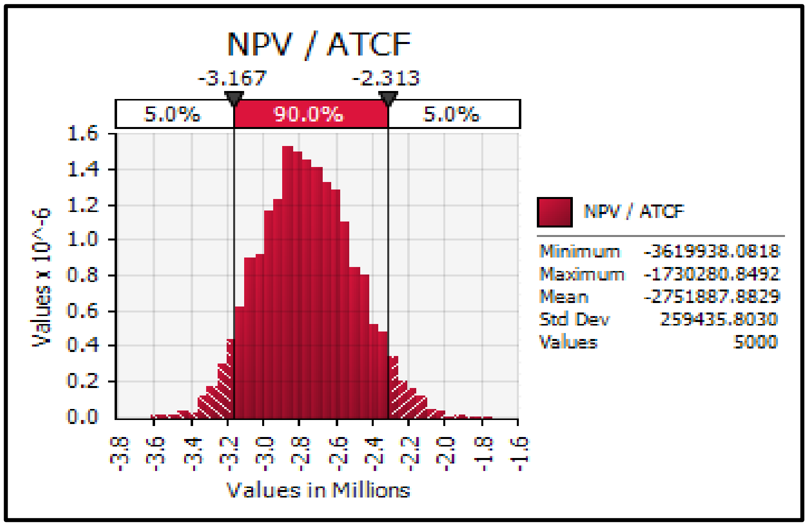


IRR – Sensitivity Analysis

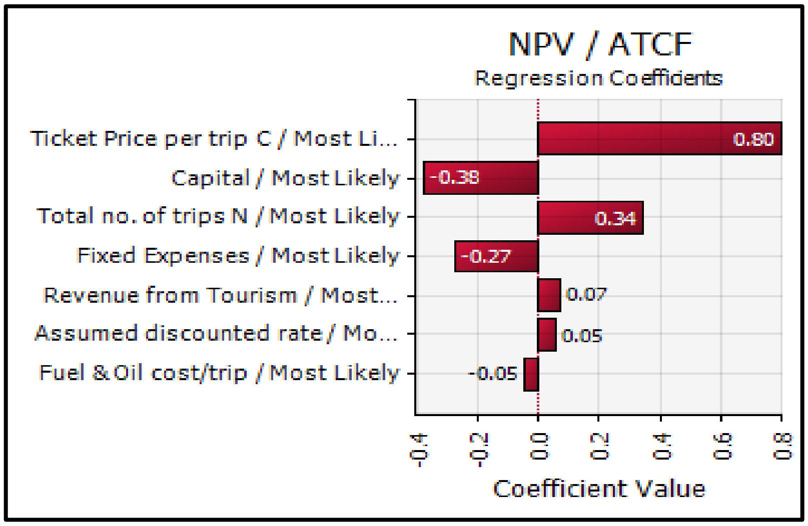


2.0 Missouri River Ferry Service

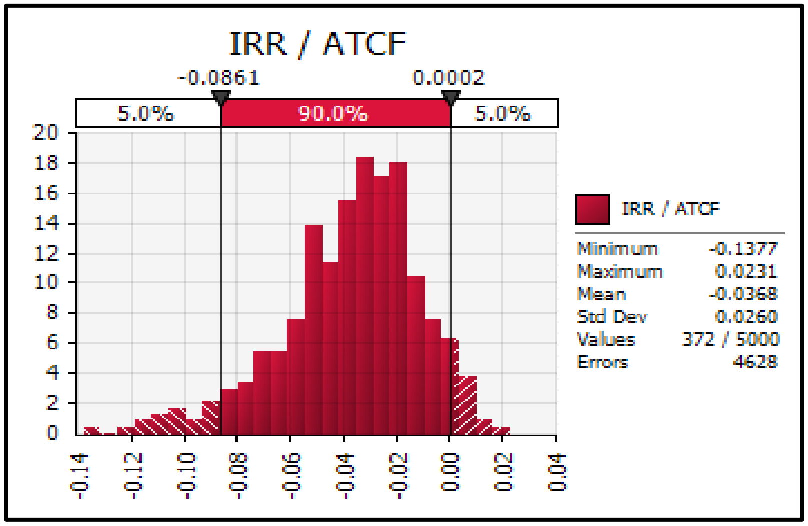
NPV - Histogram



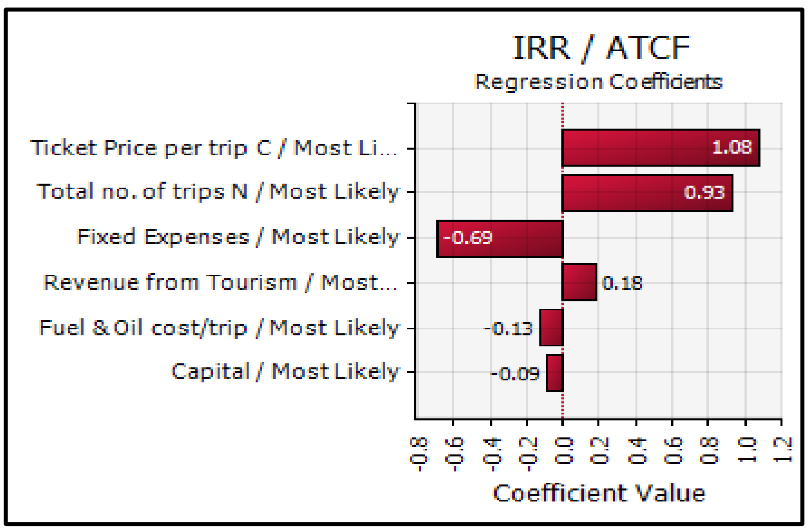
NPV – Sensitivity Analysis



IRR - Histogram



IRR – Sensitivity Analysis



APPENDIX B.

STAKEHOLDER SURVEY RESULT

Do you currently have convenient access to Intercity/Amtrak passenger rail service where you live or work?		
Answer Options	**Response Percent**	**Response Count**
Yes	59.0%	49
No	41.0%	34
Don't Know	0.0%	0
	answered question	**83**
	skipped question	**0**

Do you currently have access to a Intercity/Amtrak passenger rail station via intercity bus or local or rural public transit?		
Answer Options	**Response Percent**	**Response Count**
Yes	34.9%	29
No	59.0%	49
Don't Know	6.0%	5
	answered question	**83**
	skipped question	**0**

Do you currently have access to a Intercity/Amtrak passenger rail station via intercity bus or local or rural public transit?		
Answer Options	**Response Percent**	**Response Count**
Yes	34.9%	29
No	59.0%	49
Don't Know	6.0%	5
	answered question	**83**
	skipped question	**0**

How would you rate the experience/s of traveling by passenger rail outside the US?		
Answer Options	**Response Percent**	**Response Count**
Excellent	63.6%	21
Good	30.3%	10
Neutral	3.0%	1
Poor	3.0%	1
Very Poor	0.0%	0
	answered question	**33**
	skipped question	**50**

Have you traveled by rail within the US in the past 5 years?		
Answer Options	**Response Percent**	**Response Count**
Yes	68.3%	56
No	31.7%	26
	answered question	**82**
	skipped question	**1**

How would you rate the experience/s of traveling by passenger rail within the US in the past 5 years?		
Answer Options	**Response Percent**	**Response Count**
Excellent	14.0%	8
Good	57.9%	33
Neutral	21.1%	12
Poor	7.0%	4
Very Poor	0.0%	0
	answered question	**57**
	skipped question	**26**

Are you aware that highways and passenger rail operations do not fully "pay for themselves", but are funded with a combination of taxes, user fees and sometimes private investment?		
Answer Options	**Response Percent**	**Response Count**
Yes	98.8%	80
No	1.2%	1
	answered question	**81**
	skipped question	**2**

Do you think the U.S. should make public investments in passenger rail to make it more comparable to passenger rail services in Europe?		
Answer Options	**Response Percent**	**Response Count**
Yes	84.0%	68
No	16.0%	13
	answered question	**81**
	skipped question	**2**

Are you aware that nearly all the intercity passenger rail in the US operates on privately owned freight railroad tracks?		
Answer Options	**Response Percent**	**Response Count**
Yes	88.9%	72
No	11.1%	9
	answered question	**81**
	skipped question	**2**

As global trade and freight movement has increased, Missouri's highways have grown more congested. During the past few years, Missouri Department of Transportation (MoDOT) has invested public funds in both highways and rail capacity projects to relieve this congestion. Do you support this approach?		
Answer Options	**Response Percent**	**Response Count**
Yes	95.1%	77
No	4.9%	4
	answered question	**81**
	skipped question	**2**

MoDOT has participated in public-private partnerships with the freight railroads to improve both freight and passenger rail operations. Examples include the Sheffield Flyover, Argentine Connector rail viaduct projects in Kansas City, and new siding near California. Do you support this approach to transportation investments?		
Answer Options	**Response Percent**	**Response Count**
Strongly Support	56.8%	46
Support	30.9%	25
Neutral	11.1%	9
Oppose	1.2%	1
Strongly Oppose	0.0%	0
	answered question	**81**
	skipped question	**2**

If MoDOT has the opportunity to invest in additional passenger rail routes, prioritize potential destinations in order of importance to you. (1 being highest priority and 4 being lowest priority)						
Answer Options	**1**	**2**	**3**	**4**	**Rating Average**	**Response Count**
Springfield	32	18	13	15	2.14	78
Branson	17	25	16	18	2.46	76
St. Joseph	12	14	28	24	2.82	78
Hannibal	14	12	14	35	2.93	75
Other (please specify)						17
					answered question	**78**
					skipped question	**5**

If traffic grows as predicted, highways become more congested, and fuel costs rise, do you think more people will ride passenger rail?		
Answer Options	**Response Percent**	**Response Count**
Yes	83.5%	66
No	8.9%	7
Don't Know	7.6%	6
	answered question	**79**
	skipped question	**4**

Do you support building truck only lanes on highways?		
Answer Options	**Response Percent**	**Response Count**
Strongly Support	20.0%	16
Support	32.5%	26
Neutral	27.5%	22
Oppose	10.0%	8
Strongly Oppose	10.0%	8
	answered question	**80**
	skipped question	**3**

Do you support investing public money in partnership with the freight railroads to improve rail capacity in order to ease truck traffic on highways?		
Answer Options	**Response Percent**	**Response Count**
Strongly Support	44.3%	35
Support	36.7%	29
Neutral	12.7%	10
Oppose	5.1%	4
Strongly Oppose	1.3%	1
	answered question	**79**
	skipped question	**4**

If there were no state constitutional or statutory barriers on how state money was spent for transportation purposes, how would you spend those taxpayer dollars? Show what percentage of the transportation budget you would allocate to the following needs: (Total should add up to 100%) Decimals and special characters ($, %, etc.) are not allowed			
Answer Options	**Response Average**	**Response Total**	**Response Count**
Maintain highways and bridges	37.43	2,620	70
Build new highways and bridges	16.72	1,020	61
Maintain existing passenger rail service	9.96	508	51
Improve frequency/reliability on existing passenger rail routes	9.28	557	60
Introduce passenger rail service on new routes on existing freight railroad right of way (speeds up to 110 mph)	12.47	773	62
Introduce new, high speed rail in separate right of way (speeds up to 220 mph)	11.24	562	50
Improve bus transit access around existing and new passenger rail routes and stations	6.67	320	48
Upgrade freight railroad tracks, signals and railroad crossings	8.00	432	54
Build truck-only lanes on highways	6.90	338	49
Split funds evenly among all improvements listed above	15.83	285	18
Other	8.50	85	10
		answered question	**75**
		skipped question	**8**

Have you used intercity passenger rail service in Missouri in the past 5 years?		
Answer Options	**Response Percent**	**Response Count**
Yes	50.6%	40
No	49.4%	39
	answered question	**79**
	skipped question	**4**

What factors influenced your decision to use passenger rail? (Check all that apply)		
Answer Options	**Response Percent**	**Response Count**
Cost	67.5%	27
Convenient Schedule	40.0%	16
Appeal of the Rail Experience	80.0%	32
Ease of Use	57.5%	23
Environment Friendly	52.5%	21
Alternative to Highway Traffic	65.0%	26
Other (please specify)		2
	answered question	**40**
	skipped question	**43**

Do you think that communities that have an Amtrak train station receive an economic benefit from that station?		
Answer Options	**Response Percent**	**Response Count**
Yes	81.0%	64
No	7.6%	6
Don't Know	11.4%	9
	answered question	**79**
	skipped question	**4**

If passenger rail service were improved or newly introduced to your community, what type of economic benefits would you expect to see, if any, at the train station? (Check all that apply)		
Answer Options	**Response Percent**	**Response Count**
More retail development around the station	61.3%	49
More office development around the station	41.3%	33
More residential development around the station	23.8%	19
More visitors would travel to our community	82.5%	66
None	8.8%	7
	answered question	**80**
	skipped question	**3**

Please indicate your concerns with the current intercity passenger rail in Missouri. (Check all that apply)		
Answer Options	**Response Percent**	**Response Count**
Too many stops	13.5%	10
Not enough stops	10.8%	8
Service not frequent enough	55.4%	41
Service not fast enough	51.4%	38
Reliability of service – trains aren't on time	44.6%	33
Passenger safety on the trains	4.1%	3
Passenger safety at stations	14.9%	11
Accessibility to rail via other public modes of transportation	35.1%	26
Accessibility to rail (within 10 miles) from where you live or work	23.0%	17
Lack of connections with other trains	24.3%	18
Lack of connections with other modes of transport at stations	35.1%	26
Preference given to freight railroad operations	32.4%	24
Delays in freight rail movement	18.9%	14
Railroad crossing safety	9.5%	7
Whistle noise	2.7%	2
No concerns with the current intercity passenger rail in Missouri	6.8%	5
Other (please specify)		10
	answered question	**74**
	skipped question	**9**

In your opinion should higher speed rail service be provided between St. Louis and Kansas City?		
Answer Options	**Response Percent**	**Response Count**
Yes	76.3%	61
No	23.8%	19
	answered question	**80**
	skipped question	**3**

If Missouri decides to spend its resources to improve existing passenger rail service, please indicate your preference in each of the following ways:			
Answer Options	**Yes**	**No**	**Response Count**
New equipment {locomotives, rail cars, etc.}	59	11	70
More frequent service	61	10	71
Station improvements	41	18	59
Automatic ticket vending machines	51	13	64
Real time train status information at stations	60	8	68
Attendants at more stations	25	28	53
Wi-Fi access	52	9	61
Customer services/ Other amenities	37	18	55
		answered question	**76**
		skipped question	**7**

What are the biggest obstacles to improving passenger rail in Missouri? (1 being the biggest obstacle and 4 being the lowest obstacle)						
Answer Options	**1**	**2**	**3**	**4**	**Rating Average**	**Response Count**
High cost of improvements	26	26	12	14	2.18	78
Taxpayer resistance to pay for it	34	17	13	14	2.09	78
Lack of knowledge of benefits	15	22	19	21	2.60	77
Higher funding priorities elsewhere	36	19	14	8	1.92	77
Other (please specify)						3
					answered question	**78**
					skipped question	**5**

What are the best reasons to improve passenger rail in Missouri? (1 being the best reason and 6 being not a good reason)							
Answer Options	**1**	**2**	**3**	**4**	**5**	**6**	**Response Count**
Growing desire for more travel options	33	10	12	8	5	8	76
Growth in highway congestion requires more transportation solutions	32	22	11	7	5	0	77
Growing frustration with traffic	10	12	20	9	17	7	75
Desire for environmentally friendly options	14	17	13	9	8	15	76
Opportunity to generate more jobs with freight and passenger rail investments	17	14	13	12	17	4	77
Public funds to improve passenger rail also provide benefits to the freight rail system	9	15	13	9	14	16	76
						answered question	**77**
						skipped question	**6**

APPENDIX C.

CAPCAITY GENERATION METHODOLOGY

1.0 Methodology to Determine Current Capacity

The methodology proposed provides a first approximation of the railroad capacity and level of service to determine the infrastructure improvements and investments that will allow railroads to meet the future growth and demand. The congestion on a corridor can be determined by calculating the volume to capacity ratio. Several assumptions were made during the calculation, and these assumptions are consistent with the National Rail Freight Infrastructure Capacity and Investment Study. To determine the volume to capacity a large number of factors such as number of tracks, yard capacity, siding length, track speed, locomotive type, and terrain need to be estimated. Due to the lack of completeness, consistency, and privacy of railroad data only three factors namely, ratio number of tracks, train control system, and train type were used (AAR, 2007) to determine the current capacity in Missouri.

1.1 Tracks

Most of the railroad lines in Missouri are single tracked with multiple sidings along the lines for the trains to pass each other. A limited number of lines or sections have multiple tracks to ease congestion. Please see Figure 1 for details on number of tracks in Missouri.

1.2 Train Types

The train type data is essential in determining the speed of the train and the spacing of trains on the track to avoid congestion and delay. It is well known that different trains operate at different speeds due to various factors affecting that system for example, the terrain, track curvature, locomotive type, braking capabilities, etc. The single train type increases capacity of a line due to uniform speed, length, and braking characteristics when compared to multiple train types, which reduces the capacity due to different characteristics of each train type. For this study, multiple train type, which includes a mix of merchandise, intermodal, passenger, and coal, has been assumed to be running on each line due to lack of availability of accurate data.

1.3 Train Control Systems

The train control system plays a very important role in determining the system characteristics and also affects the system capacity. The control system is used to maintain safe spacing between trains during meeting and passing on the same track. There are three major types of train control systems (AAR, 2007):

- **Automatic Block Signaling (ABS) –** is a train control system which determines when a train can advance to the next block of tracks. A block is defined as a segment of track with traffic control signals at each end. The length of the track segment is dependent on the length of the train and the distance required to stop the train safely. A railroad dispatcher cannot control ABS control system remotely.
- **Centralized Traffic Control (CTC) and Traffic Control System (TCS) –** are train control systems, which utilizes electrical circuits embedded in the tracks to monitor the location of the train. CTC and TCS increase capacity and automatically prevent trains from entering track segments already occupied by other trains there by maintaining a safe operational condition. CTC and TCS can be controlled from a remote location, which is generally a central dispatching office.
- **No Signal (N/S) and Track Warrant Control (TWC) –** are very basic train control systems that require the train crew to obtain warrants or permission to

enter the track segment. These are typically used on low volume tracks instead of using expensive ABS or CTC/TCS train control systems.

There are eight combinations of number of tracks and train control systems that are commonly used across the primary corridors in the US. Table 1 lists these combinations and also provides a practical maximum train count for both multiple train types and single train type that can be run on these corridors. A typical corridor with two main tracks governed by ABS can handle up to 53 trains per day, which is a mix of intermodal, coal, mix merchandise/bulk trains, and passenger trains. The same corridor if serving a single train type for example, intermodal trains can operate at a capacity of about 80 trains per day.

Table 1. Average Capacities of Freight Rail Corridors (Trains per Day) (AAR, 2007)

		Trains per Day	
Number of Tracks	Type of Control System	Practical Maximum if Multiple Train Types Use Corridor	Practical Maximum if Single Train Type Uses Corridor
1	N/S or TWC	16	20
1	ABS	18	25
2	N/S or TWC	28	35
1	CTC or TCS	30	48
2	ABS	53	80
2	CTC or TCS	75	100
3	CTC or TCS	133	163
4	CTC or TCS	173	230
5	CTC or TCS	248	340
6	CTC or TCS	360	415

Typically in Missouri the rail corridors consists of one or two main tracks with sidings to meet and pass on the same track, and are governed by N/S or TWC, ABS, or CTC or

TCS train control systems. For this study, practical maximum if multiple train types use corridor numbers are considered, as accurate and complete data on the train types run on these corridors were not available.

Each corridor in the Missouri rail system was assigned a capacity based on the train type, train control system, and number of main tracks. Current corridor volumes were compared to the corridor capacity from Table 1 and the Level of Service (LOS) grade was determined by calculating the volume to capacity ratio for each corridor. The LOS grades are shown in Table 2.

Rail corridors operating at LOS A, B, or C are typically operating below capacity. The corridor has sufficient unused capacity, which can be used to accommodate maintenance, failure, and other interruptions. Corridors operating at LOS grade D are operating close to the capacity and can only accommodate moderate maintenance work. Corridors with LOS grade E are at capacity and have very limited capabilities to accommodate any kind of maintenance work. LOS grade F is above capacity, which indicates substantial delays due to congestion and is characterized with unstable train flows. A rail corridor that is operating at a volume to capacity ratio of 0.7 is operating at 70% of its theoretical maximum capacity. In some cases this is considered to be the practical capacity of the corridor because a portion of the theoretical maximum capacity is lost to maintenance, weather delays, equipment failures, and other factors (AAR, 2007).

Table 2. Volume to Capacity Ratio and Level of Service (LOS) Grades (AAR, 2207)

	LOS Grade	Description		Volume/Capacity Ratio
	A B C	Below Capacity	Low to moderate train flows with capacity to accommodate maintenance and recover from incidents	0.0 to 0.2 0.2 to 0.4 0.4 to 0.7
	D	Near Capacity	Heavy train flow with moderate capacity to accommodate maintenance and recover from incidents	0.7 to 0.8
	E	At Capacity	Very heavy train flow with very limited capacity to accommodate maintenance and recover from incidents	0.8 to 1.0
	F	Above Capacity	Unstable flows; service breakdown conditions	> 1.0

In order to estimate the volume by capacity ratio, the number of trains in the corridor data is essential, and is typically confidential and difficult to obtain. While this data is difficult to obtain, certain assumptions can be made to get an approximate range for number of trains in the corridors. The following section describes how the range of number of trains can be obtained from other parameters.

The capacity of a corridor as stated earlier depends on a lot of factors, which include the terrain, train type, railroad operating procedure, length of locomotives and rail cars, speed of the tracks, control system, and power of the locomotives. Complete information on all the factors are very difficult to obtain but can be determined by making assumptions that may vary based on the region, railroad operator, and regulations governing it. The approximate number of trains running in a corridor can be calculated using the equation:

$$T = \frac{MGT * 1000{,}000}{G * N * 365} \tag{1}$$

Where,

T = Trains/Day

MGT = Mega Gross Tonnage (Traffic Density on the corridor each year)

G = Gross Tons (Each car load)

N = Number of cars in a train

BIBLIOGRAPHY

AAR. (2007). *National Rail Freight Infrastructure Capacity and Investment Study*. Cambridge Systematics, Inc. Cambridge, Massachusetts: Association of American Railroads.

AAR. (2011). *Railroad Infrastructure Improvement*. Retrieved December 13, 2011, from Association of American Railroads: http://www.aar.org/KeyIssues/Infrastructure-Investment.aspx

Amekudzi, A., Khisty, J., & Khayesi, M. (2009). Using the Sustainability Footprint Model to Assess Development Impacts of Transportation Systems. *Transportation Research Part A, 43*, 339-348.

Black, J. A., Paez, A., & Suthanaya, P. A. (2002). Sustainable Urban Transportation: Performance Indicators and Some Analytical Appraoches. *Journal of Urban Planning and Development, 128* (4), 184-210.

Browne, M. (2005). Special Issue Introduction: Transport Energy Use and Sustainability. *Transport Reviews, 25* (6), 643-645.

Deakin, E. (2003). Sustainable Development and Sustainable Transportation: Strategies for Economic Prosperity, Environmental Quality and Equity. *Working Paper 2001-03*.

Dissel, M., Phaal, R., Farrukh, C., & Probert, D. (2006). Value Roadmapping. *Technology Management for the Global Future* (pp. 1488-1495). Istanbul: IEEE.

Goldman, T., & Gorham, R. (2006). Sustainable Urban Transport: Four Innovative Directions. *Technology Society, 28*, 261-273.

Hess, D., & Winner, L. (2007). Enhancing Justics and Sustainability at the Local Level: Affordable Policies for Urban Governments. *Local Environment, 12* (4), 379-395.

Jeon, C., & Amekudzi, A. (2005). Addressing Sustainability in Transportation Systems: Definitions, Indicators, and Metrics. *Journal of Infrastructure Systems, 11* (1), 31-50.

Lee, J. H., Kim, H.-i., & Phaal, R. (2012). An Analysis of Factors Improving TEchnology Roadmap Credibility: A Communications Theory Assessment of Roadmapping Process. *TEchnological Forecasting & Social Change, 79*, 263-280.

Litman, T. (2008). *Sustainable Transportation Indicators*. Sustainable Transportation Indicators Subcommittee of the Transportation Research Board.

Litman, T., & Burwell, D. (2006). Issues in Sustainable Transportation. *International Journal of Global Environmental Issues, 6* (4), 331-347.
Long, S., Gentry, L., & Bham G. (2011). Driver Perceptions and the Impact of Change Resistance on the Implementation of Variable Speed Limit Systems.

Newman, L. (2005). Uncertainty, Innovation, and Dynamic Sustainable Development. *Sustainability: Science, Practice, & Policy, 1* (2), 25-31.

Murray, S., Alpaugh, A., Burgher, K., & Flachsbart, B. (2010). Development of a Systematic Approach to Project Selection for Rural Economic Development. *Journal of Rural and Community Development, 5,* 1-18.

Ottens, M., Franssen, M., Kroes, P., & van de Poel, I. (2006). Modelling Infrastructures as Socio-technical Systems. *International Journal of Critical Infrastructure, 2* (3), 133-145.

Petrick, I. J., & Echols, A. E. (2004). Technology Roadmapping in Review: A Tool for Making Sustainable New Product Development Decisions. *Technological Forecasting & Social Change, 71* (1-2), 81-100.

Stone, M., Crosby, B., Bryson, J., Saunoi-Sandgreen, E., & Imboden, A. (2010). Technology and Collaboration for Effective Transportation Policy: The Case of the Urban Partnership Agreement. *The Association for Public Policy Analysis and Management* (pp. 1-35). Boston, MA: The Association for Public Policy Analysis and Management.

Rangarajan, K., Long, S., Ziemer, N., & Lewis, N. (2012). An Evaluative Economic Development Typology for Sustainable Rural Economic Development. *Community Development, DOI:10.1080/15575330.2011.651728*, 1-13.

Rangarajan, K., Long, S., Tobias, A., & Keister, M. (2012). The Role of Stakeholder Engagement in the Development of Sustainable Infrastructure Systems. *Working Paper*.

Richardson, B. (2005). Sustainable Transport: Analysis Framework. *Journal of Transport Geography, 13*, 29-39.

Rohracher, H. (2001). Managing the Technological Transition to Sustainable Construction of Buildings: A Socio-technical Perspective. *Technology Analysis & Strategic Management, 13* (1), 137-150.

Tuominen, A., & Ahlqvist, T. (2010). Is the Transport System Becoming Ubiquitous? Socio-technical Roadmapping as a Tool for Integrating the Development of Transport Policies and Intelligent Transport Systems and Services in Finland. *Technological Forecasting & Social Change, 77*, 120-134.

Trist, E., & Emery, F. (2006). *Sociotechnical Systems Theory.* Armonk, NY: Odyssey.

Walker, G., Stanton, N., Salmon, P., & Jenkins, D. (2008). A Review of Sociotechnical Systems Theory: A Classic Concept for New Command and Control Paradigms. *Science, 9* (6), 479-499.

World Commission on Environment and Development (WECD). (1987). *Our Common Future*. Oxford, England: Oxford University Press.

VITA

Kiran Rangarajan was born on February 1, 1983 in Bhadravathi, Karnataka in the southern part of India.

He received his Bachelor of Engineering degree in Electrical and Electronics Engineering from M.S. Ramaiah Institute of Technology – Bangalore, India in July 2005. He worked with Infosys Technologies Ltd. – Bangalore, India as a Software Engineer from September 2005 to June 2007.

He started his Master of Science program with Engineering Management Department at Missouri University of Science and Technology in January 2008. His primary areas of interests are in Business Marketing, Marketing Research, Project Management, and Strategic Management of Technology and Innovation. He received his Masters in Engineering Management in August 2009.

Kiran Rangarajan entered the PhD program in Engineering Management at Missouri University of Science and Technology in the Fall of 2009. His main area of research is in strategic development of sustainable practices in transportation. He received his Ph.D. in May 2012.

Mr. Kiran Rangarajan worked as a teaching assistant and research assistant for 2 years in the Engineering Management Department at the Missouri University of Science and Technology.