# Complex transportation project management: An in-depth look at process integration, alternative financing, and sustainability

by

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# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

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## ABSTRACT

The United States depends on surface transportation for personal mobility, commerce, and shipping. Therefore, an efficient surface transportation system enhances a nation's livability and economic competitiveness. In recent years, projects have become more complex and uncertain due to increases in the number of effective project elements and interactions that can influence the project. Therefore, traditional project management that track and controls time, cost, and technical issues through the project development process cannot manage the higher risk and uncertainty associated with complex projects. Shane et al. developed five dimensions of project management for complex projects through a case study research on national and international complex projects. The research group found that finance and context are two extra dimensions that highly affect project's complexity.

The present transportation financing methods consist of a complex set of federal, state, and local revenue sources which cannot answer the present and future growing need. Therefore, introducing alternative new and innovative financing methods is important to assist states in practicing them to fulfill their growing transportation infrastructure need. In addition, with consideration to tight resources and limitations that financing issues can put on the project (e.g. long delays), project management and finance management become more vital through complex projects.

Context as a fifth complexity dimension covers a broad pool of subjects (e.g., environmental, political, social aspects). Sustainable approach, defined as an approach to satisfy current need without compromising future generations' ability to fulfil their need, is one of the nation's priorities. This priority was addressed with leadership in energy and environment design sustainability rating system for buildings in 1997, and has continued with several sustainability rating systems developed for highway infrastructures through the last decade.

This research studies complex project management strategies implementation through U.S. states' department of transportation project development process, in addition to studying two extra project complexity dimensions of finance and context (sustainability) in more detail.

# CHAPTER 1. INTRODUCTION

The transportation industry is a nation's artery of commerce and benefits national productivity, employment, and international market competitiveness (Keane 1996). Surface transportation is the major transportation mode in the U.S. and consists of 6.4 million kilometers of public roads. Transportation construction projects have been increasing in the size, length, and scope with a greater number of interactive elements. The result is that projects have become more complex, requiring a higher level of planning, management, monitoring and inspection. On the other hand, budget shortages and constraints on available developable right of way make long term planning and enlightened project management essential. Transportation planners and project managers must view the project throughout its life cycle, predicting future needs, and considering them during design and construction to minimize a complex project's disruption to current travelers and to control future life cycle costs for generations to come.

All levels of government contribute to the transportation industry. However, U.S. states have the major role in surface transportation. The Federal government provides directions and guidance for federal-aid projects and acts as the agent to promulgate design standards, economic policy, and oversight. It does it through the Federal Highway Administration (FHWA) which enforces federal funding laws and produces design tools and guidebooks. Nevertheless each state has its own authority to produce rules and standards for projects funded using state fuel funds. As a result, state-level project development processes and methods are not uniform across the country.

In this regard, the Federal government funds research studies in areas where exploration promises to enhance the nation's transportation system. Complex project management is an areas that needs research due to the increase in and the number of interactions between stakeholders in a large transportation project's development. The Strategic Highway Research Program II (SHRP 2) program's Project R-10: "Project Management Strategies for Complex Projects" produced a guidebook to help state departments of transportation (DOT) manage complex projects (Shane et al. 2012). A portion of the research discussed in this thesis attempts to assist state DOTs to apply the guidebook's strategies and tools at appropriate times in the complex project development process and is presented as a paper in chapter 4.

The Federal government and other national transportation institutes are exploring new financing methods for transportation projects to address the issues caused by revenue deficiencies in the transportation industry. This deficiency has caused several problems such as traffic congestion that negatively impact economic user costs (e.g., idle time traffic), environmental quality (e.g., higher $CO_2$emission) and society as a whole (e.g., livability and noise pollution). This revenue deficiency must be addressed in short, mid and long-term plans. Many states don't use the new methods of project financing due to lack of experience and absence of enabling legislation, or inadequate risk tolerance for new procedures. Therefore, much has been written to explain those innovative financing and articulate early-adopters' experiences using them. Most of the financial reports are quite long and written in detailed financial jargon, making them difficult for engineers without a financial background to understand. Therefore, the paper in chapter 5 is provided to address the gap between demand and supply and how it was produced. It also analyzes both traditional and innovative funding/financing methods and along with their requirements and limitations. It compares the financing methods used on 12 complex projects to provide practical examples.

The final part of the research is dedicated to sustainability rating systems for transportation infrastructure with a focus on highways. The topic synthesizes government, academic, and private organizations that have produced nearly 20 sustainability rating systems for highway projects (Eisenman 2012). The goal of the analysis is to identify a feasible solution with regards to the project context, which can satisfy economic, environmental, and social criteria while minimizing negative impact on future operations. Although each version of sustainability rating systems has a different focus they are not widely used due to their failure to gain industry acceptance. Therefore a third paper that evaluates the various rating systems' history and criteria is presented in chapter 6.

## Problem Statement

The Federal Highway Administration and others have published research reports, technical briefs and guidebooks on transportation improvement options, tools, and methods. Many times, these opportunities are overlooked by state transportation agencies simply due to a lack of familiarity and experience with these techniques (Roskin et al. 1996). States that really seem to need  these options are tend to be conservative and not willing accept the risk of exploring options that they have not had past experience with them (Freemark 2013).

This research aims to highlight three recent ideas that can be used by state DOTs to enhance their project development process. The first research paper aims to show DOTs how to apply complex project management (PM) strategies to their current project development process in a timely manner that captures the potential benefits of this new theory. The second research paper introduces funding and financing options used by different agencies and demonstrates their limitations and risks. Case studies of project financing methods are used to investigate various implementation methods. The last paper focuses on a sustainability rating systems for highway infrastructure. Here, different sustainability rating systems are evaluated and recommendations to incentivize and apply them are made.

## Research Question

This document will answer the following research questions:

- *At what points in an agency's project development process should the planning methods and execution tools found in the SHRP2 R-10 5DPM guidebook be considered and implemented?*
- *How can the recent innovative infrastructure financing methods be implemented in the Financing Dimension of 5DPM?and*
- *How can the use of sustainability rating systems in transportation project be utilized to enhance the management of complexity in the 5DPM Context Dimension?*

## Organization of the Thesis

The heart of the thesis is the three journal articles mentioned above. Although each of these chapters contains a stand-alone document, they all focus on the different aspects of complex transportation project and try to assist agencies understanding of the options for implementing project management, innovative financing, and measuring sustainability. Chapter 2 provides the background from the literature and previous research that sets the stage and provides the motivation for the research itself. Chapter 3 details the methodology used to collect the information that is analyzed in the papers.

Chapter 4 is comprised of the first paper is on implementing the complex project management guidebook developed by Shane et al. (2012). It superimposes the five-dimensional project management (5DPM) planning methods and execution tools on a generic DOT's project development process, and provides a roadmap for how the DOT can apply the 5DPM process in its project planning and development process.

The paper in Chapter 5 discusses the funding gap in transportation industry and the need for urgent action as well as future planning. The second paper also discusses traditional funding and financing options and their inability to satisfy the current needs, which highlights the importance of newly developed innovative methods. Then, the financing methods used on 12 complex projects are evaluated and the ways in which each was implemented on projects are provided as examples.

Chapter 6 contains the final paper, which is dedicated to a sustainability rating systems for highway infrastructure. It reviews the history of rating sustainability, and the way in which is used in vertical structures using the Leadership in Energy and Environmental Design (LEED) system (U.S. Green Building Council 2013). The paper discusses approximately 20 rating systems that are similar to LEED for highway industry. The rating systems are compared with each other, and a path for the future is recommended

Chapter 7 ties the three research results together and presents the conclusions of the thesis. It also discusses general research limitations. At last offers some research priorities and recommends future research.

# CHAPTER 2. BACKGROUND AND LITERATURE REVIEW

## Phase 1 Background

This section introduces the concept of project complexity and defines a complex project. It also reviews complexity factors in different industries, as well as different strategies to manage complex projects. Then it presents a potential solution for the application of 5DPM guidebook, (Shane et al. 2012) tools to the project development process of different state DOTs. This chapter helps project managers to understand different complexity factors that can affect their project. Furthermore, it provides strategies that help them to track those factors to predict possible risks and manage or mitigate them.

### *Motivation*

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In the past two decades, transportation projects have fundamentally changed. Project scope has gotten broader and larger. The project delivery period has been compressed to its shortest state (Molenaar 2006), and external factors like environmental policy and the source of construction financing have a much greater impact than in years past (FHWA 2006). Transportation project management theory is morphing from its traditional short-term focus on the purely technical to a holistic, longer term focus that includes both subjective and objective measures of project performance (Jugdev and Muller 2005). The evolving theory is being termed "complex project management" (Whitty and Maylor 2009), "an emerging natural extension of traditional project management to create a specialist profession" (CCPM 2006). The Australian College of Complex Project Managers (CCPM) defines complex projects in the following manner:

- "Complex projects are characterized [sic] by a degree of disorder, instability, emergence, non-linearity, recursiveness, uncertainty, irregularity and randomness;
- There is dynamic complexity where the parts in a system can react/interact with each other in different ways (a chess game);
- There is high uncertainty about what the objectives are, and/or high uncertainty in how to implement the objectives. The level of uncertainty will vary with the maturity of the individual/organisation;" (CCPM 2006).

The FHWA classifies complex projects as "Major Projects" and differentiates them from routine projects as follows:

- "Based on the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users signed into law on August 10, 2005, a Major Project is defined as 'a project with a total estimated cost of $500 million or more that is receiving financial assistance.' The FHWA also has the discretion to designate a project with a total cost of less than $500 million as a Major Project.
- The FHWA may choose to do so in situations where the projects require a substantial portion of the State Transportation Agency (STA)'s program resources; have a high level of public or congressional interest; are unusually complex; have extraordinary implications for the national transportation system; or are likely to exceed $500 million in total cost.
- Generally the Project Owner of a Major Project is the STA, but major projects can also be developed by other State Agencies (Toll Agencies), Local Public Agencies, and/or Private Ventures (e.g. Public Private Partnerships.) (FHWA 2010 emphasis added).

The two definitions of a complex project are very similar. The CCPM uses theoretical terms essentially describing a complex project manager's (PM's) ability to control the factors that influence project delivery: "by a degree of disorder, instability, emergence, non-linearity, excursiveness, uncertainty, irregularity and randomness." Similarly, the FHWA focuses on the monetary value as well as projects that "have a high level of public or congressional interest; are unusually complex; have extraordinary implications for the national transportation system; or are likely to exceed $500 million in total cost." Both definitions recognize the fact that complex projects are impacted by factors that are not within the PM's control and as such must be identified, assessed, and addressed in the project management plan.

In this regard, managing increased complexity makes the recognition of risk an important task, which should be followed by monitoring and tracking them through the project development (Touran 2006). Project complexity monitoring helps to identify possible risks and prepare for them so the complex project manager can avoid a crisis turning a project into chaos as discussed by the CCPM quotation above. Therefore, understanding project complexity factors and how to track and control them is necessary for complex project management team.

*Goal*

The recognition of complexity factors in different industries, to track and control them and being prepared for probable resulted risks of their change to avoid crisis is the first goal. Secondly, finding the effective time through the project development period to provide complex project management strategies training (Shane et al, 2012) for the state DOTs project manager team is the goal.

*Research Question #1*

*At what points in an agency's project development process should the planning methods and execution tools found in the SHRP2 R-10 5DPM guidebook be considered and implemented*?

1- How do complexity factors differ in other industries with five complexity dimensions and their factors?
2- What does a generalized complex transportation project development process look like for a typical DOT?
3- How can 5DPM strategies be applied within a DOT's project development processes to add value and accrue benefits?

*Complexity Definition:*

The term "complexity" has different interpretations based on the given reader's background, experience, and the context in which the term is used (Boushaala 2010). As Bennett (1991) said "complexity makes differences to the management of projects", and needs special considerations which include largely organizational issues beyond the control of project manager in addition to technical issues. Although complexity can be caused by too many interacting tasks, large size projects that can be divided into simple smaller parts and controlled by available methods are not complex and some small projects can be complex due to their components (Kerzner 2013, Whitty and Maylor 2009). "Complex originates from a Latin word of "complexus" which means entwined or twisted together. Complex also is defined as an aggregate of parts. Therefore complex can be defined as an item with two or more components or variables" (Boushaala 2010). The dictionary (Baccarini 1996) contains the following two definitions:

- *"Consisting of many varied interrelated parts:* This meaning is neatly circumscribed so that project complexity can be operationalized in terms of: differentiation the number of varied elements, e.g. tasks, specialists, components.
- *Complicated, involved, intricate:* This meaning of complexity is open to wide and diverse interpretation."

Thus, complexity is essentially a function of the magnitude of the number of interrelated parts that interact. Table 2-1 provides other definitions for complexity and complex projects found in the literature.

Table 2-1: Complexity and Project Complexity Definitions

| | |
|---|---|
| (Kerzner 2013) | Complex project has multiple structural elements interacting and changing as they progress, which includes external factors such as legal or political pressures |
| (Treasury Board of Canada 2013) | complexity could be analyzed from two perspectives of (1) apparent complexity which is related to each component or system that has a design or implementation phase which is hard to understand, and (2) inherent complexity which is related to the number of components and their interface and interaction intricacy with each other in addition to types of data and their structure nesting |
| (Kerzner 2013) | Industrial project complexity can be considered from two perspectives (1) managerial perspective relates to planning and bringing various pieces of the work in appropriate order together to form a work flow, and follow dynamic changes of this flow and their effects on interactions as they change, which cause further change in other parts of the system and (2) Operative and Technological perspective: In dealing with technical intricacies in executing each piece of a work which originates from resources used and the environment in which the work is conducted |
| (Baccarini 1996) | Project complexity can be defined as 'consisting of many varied interrelated parts' and can be operationalized in terms of differentiation and interdependency. It is worthwhile emphasizing that complexity is a distinctly different concept to two other project characteristics of size and uncertainty |
| (Gidado 1996) | In the other words project complexity has been defined as the measure of the difficulty of implementing a planned production work flow in relation to anyone or a number of quantifiable managerial objectives |
| (Mainzer 1999) | Complex system consists of many highly interrelated elements and it is dynamic, dissipative, non-linear and self-organizing. When a system is an entity that consists of various elements that are linked and that interact. The characteristics and the behavior of systems are primarily determined by the interaction among the elements and the interaction between the system and its environment, although the behavior of a complex system cannot be simply inferred from the |

Table 2-1 Continued

| | |
|---|---|
| | behavior of its components. The process is complex, when the objectives of the process are fuzzy and unstable, the boundary conditions are in constant change, basic information is incomplete and uncertain, the outcome is not well specified and the structure of the process is non-linear and includes a lot of interlinked loops. |
| (Dombkins 2006) | Complex project can be defined as an open system which is characterized by recursiveness and non-linear feedback loops, which make it sensitive to small differences in initial conditions and emergent changes; therefore, detailed long-term planning is impossible for it. |
| (Remington 2011) | Complex project also can be defined as a project characterized by uncertainty, ambiguity, and decreased levels of trust. The project also has a high risk in terms of return on investment or sponsoring organizations reputation. Complex project consists of several parts and involved with people which tend to be a source of complicacy. |
| (Kerzner and Belack 2010) | Complexity can be defined according to the number of interactions that must take place for the work to be executed, the higher number of functional units that must interact, it is harder to perform the integration. Interaction of one or more of following items can make a project complex: size and length, dollar value, uncertain requirements, uncertain scope, uncertain deliverables, complex interactions, uncertain credential of labor pool, geographic separation across multiple time zones, other factors. |

Project manager has an important role in complex projects, because, in complex space wrong decisions at critical points can push the project to chaos. In Figure 2-1 the required level of leadership based on the project space is presented, experience is an effective factor in leading a complex project (Remington 2011).

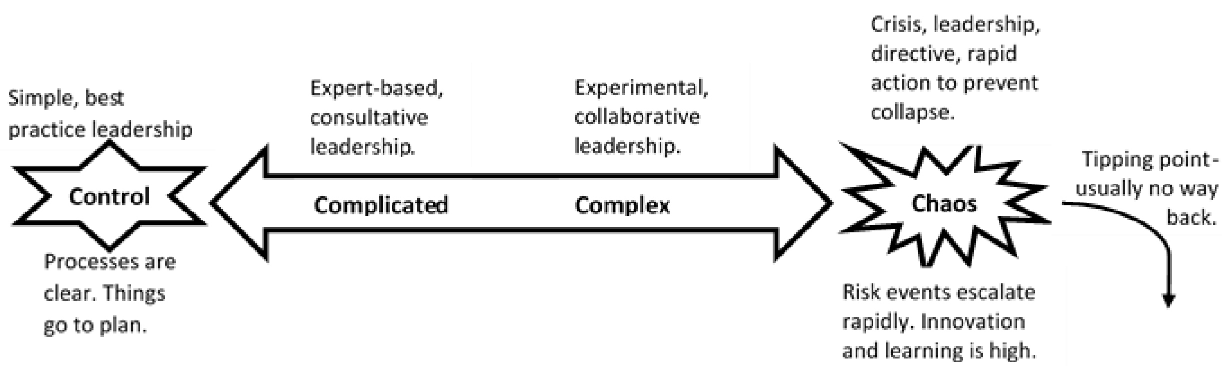



Figure 2-1: Most Projects Exist on a Continuum between Control and Chaos (Remington 2011)

Complex project management involves great deal of risk management to address the uncertainty that surrounds future events and outcomes. Risk management includes the expression of the likelihood of occurrence and the estimated impact of an event with the potential to influence the achievement of an organization's objectives (Canada government 2001).

*Differentiating Traditional vs. Complex Project Management*

Complex projects differ from traditional projects based on one or combination of several items including:

- Size, (Kerzner and Belack 2010)
- Dollar value, (Kerzner and Belack 2010)
- Uncertain requirements, (Remington 2011)
- Uncertain scope, (Remington 2011, Gransberg et al. 2013)
- Uncertain deliverables, (Remington 2011, Gransberg et al. 2013)
- Complex interactions, (Remington 2011, Schalcher 2010)
- Uncertain credentials of the labor pool, (Kerzner and Belack 2010)
- Geographical separation across multiple time zones, (Kerzner and Belack 2010)
- Use of large virtual teams, (Kezar 2013, Tomek 2011)
- Variations in organizational culture, (Tomek 2011)
- Technology change through the length of the project, (Kerzner 2013)
- multiple stakeholders, and etc.( Remington 2011, Kertzner 2012)

The fundamental characteristics of each complexity factor drives the complex project management approach that is used to control each risk, including:

- Composition of the complex project management team,
- Stakeholder involvement,

- Decision making processes,
- Linear versus non-linear thinking,
- Organizational cultural variation,
- Project management plan and methodology,
- Performance indicators used, and
- Defining success for each dimension.

Criteria to define a project as a complex project differ by agency and by industry as follows:

- Length of project delivery period is an industry-sensitive criterion. For example, the auto industry uses 3 years as the period that they assume the technology is known and will undergo a little change over the term of the project. Thus, projects take longer than 3 years become complex because of the uncontrollable change in auto technology. Similarly complex infrastructure projects typically have delivery periods that are longer than normal forcing the project team to make "business decisions" in early plans to deal with uncontrollable changes in out-years. Hence, complex projects are driven more by business decisions than pure technical project decisions (Kerzner 2013).
- Cost is another criterion used to define complex projects. The FHWA defines projects with a total estimated cost of more than $500 million or which have extraordinary implications for national transportation system as "major projects," requiring specialized project management plans (FHWA 2013).
- Other organizations such as the New York State DOT (NYSDOT) define complex projects based on criteria based on the project's importance to the transportation network

and level of "experimental" technology used that deviates from the typical agency design criteria (NYSDOT 2004).

*Project Management Dimensions*

Traditional project management is based of the three dimension of cost, time (schedule), and technical (scope) to describe the project variables that must be managed (lit cite). For complex project management different set of dimensions are proposed:

- Kerser and Belack (2010) suggested adding quality, risk, value, and image/reputation to project management triangle as shown in Figure 2-2. Their justification is the higher cost, interactions, cultural implications, uncertainty, and number of stakeholders in complex projects. The authors claim that a given dimension's importance varies from stakeholder to stakeholder and project to project. As a result, the varying importance from the stakeholder's perspective should be considered in project management plan development.

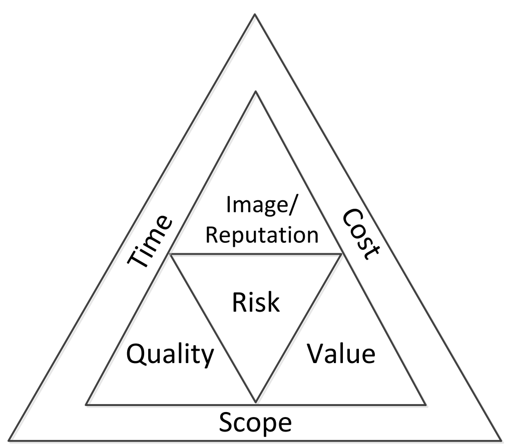



Figure 2-2: Modified triple constraint for complex projects by Kerzer and Belack (2010)

- Shane, Strong, and Gransberg (2012) proposed expanding the project management triangle by adding two extra dimensions: finance and context (Figure 2-3). Their work was based on 18 domestic and international case studies that demonstrated finance and context are two extra dimensions that require a great amount of management energy through complex project's development process and should be used in project control and risk assessment analysis (Shane et al. 2012).

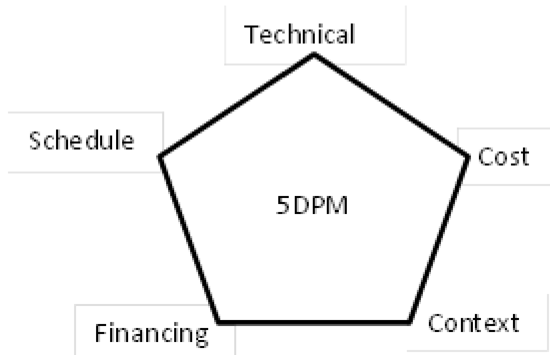



Figure 2-3: Five dimensional project management for complex projects by Shane et al. (2012)

Each of the five dimensions encompasses a few factors that must be considered during project management planning. A complete list of the factors associated with each dimension is presented in Appendix A.

*Project Management Strategies for Complex Projects*

A flexible and adaptable project management plan and a suite of execution tools to address project complexity are important to the complex project management team (Shane et al. 2012). Often, complex projects require specific plans to interface with different stakeholders throughout the term of the project. Currently, most agencies use some form of project management method, but what differentiates them from each other is the level of complexity their methods can manage. Complex projects require sophisticated project management. The literature shows that project teams need executive-level support to successfully deliver complex projects, but maintaining and institutionalizing that level of project support is difficult (Kerzner 2013). Large companies, such as IBM, want to be viewed as solution providers to their clients and this drives them to view the project management process in a broad fashion and yields execution tools including:

- Engaging with a large number of stakeholders in different phases of project management plan.
- Dealing with multiple virtual teams located across the world with different organization and environment cultures.
- Working on long-term projects that begin with an ill-defined scope and undergo numerous scope changes instead of stationary target.
- Having complex communication channels that can be different for each stakeholder (Kerzner 2013).

There are several differences between complex and traditional project management. Common differences found in the literatures include: governance by a committee, multiple stakeholders, effective communication plans, combining project-level and business decision-making, flexible project management methodology, real time reporting, and unique value driven key performance indicators (KPI) (e.g. Remington 2011, Kerzner 2013).

Three prerequisites for success in a project execution are:

- Clear understanding of the goals and objectives
- User involvement from cradle to grave (user and stakeholder involvement)
- Clear governance (decision-making process) (Kerzner and Belack 2010)

Some common strategies for complex project management in different literatures are presented in Table 2-2:

Table 2-2: Complex Project Management Strategies

| **Project management methods** | **(Remington 2011)** | **(Kerzner, Belack 2010)** | **(Kerzner 2013)** | **(Shane et al. 2012)** |
|---|---|---|---|---|
| Clear goals and scope | | √ | √ | |
| Defined success factors | √ | √ | √ | √ |
| Define success factors measurements (KPIs) | | | √ | √ |
| Communication plan | √ | √ | √ | |
| Stakeholder & public engagement | √ | √ | √ | √ |
| Manager team | √ | | √ | |
| Process check | | √ | √ | √ |
| Early cost model | | √ | √ | √ |
| Decision making process | √ | √ | √ | |
| Resource management | | √ | √ | √ |
| Selecting project team | √ | √ | √ | √ |

*Importance of Communication Plans and Project Complexity Mapping*

Many authors mention that communication planning as a core strategy for complex project management (Remington 2013).They cite the lack of communication planning as the most frequent cause of project failure, due to high number of involved parties and uncertainty in those projects.

The communication plan's approach is influenced by the source of complexity. Once the complex project's scope and goals are determined, the required pathways for communication are known. To be effective the complex PM must recognize that it is multi-layered to insure a clear path of information flow. Communication is also used to manage uncertainty in complex projects, helping stakeholders at all levels to deal with associated uncertainty of their part and building resilience across uncertainty and stakeholders. The communications network in complex project is complex in and of itself and composed of both formal and informal communications. The network contains nodes that are people or groups and ties together common interests and interdependency. Communication mapping helps to find the gaps between entities and the points where information flow halts, allowing the project manager address them. Internal team communications is as important as external communication. Human-oriented communication works better than task oriented communication in complex projects, because it is more supportive, precise, clear, and empowers knowledge sharing too (Remington 2013).

The complexity mapping tool presented by Shane et al. (2012) is an example of an effective internal communication tool, where all project teams interact with each other, share their knowledge and develop a common understanding of project progress. It can also be used as a project health check to make sure total complexity decreases as project proceeds (Shane et al. 2012).

### *Project Management Strategies for Complex Projects*

The Project Management Strategies for Complex Projects guidebook was produced as part of the SHRP 2 federal program (Shane et al, 2012). Following previous tasks several training tools provided such as webinars and power points. The research included pilot workshops in Colorado and Michigan and found that the for the 5DPM training to be effective it must be conducted early in the project development process.

Therefore the first paper of the thesis research addresses the issue of timing the implementation of 5DPM through the complex projects development (Chapter 4). The literature shows that implementing a new concept is more difficult than a making technical change, because the concept requires the engagement and training of the implementers in addition to strong management support (Morwick 2010). It also shows that implementing a new concept may also require training conduct on more than one level in order to ensure all the implementers to understand it clearly, and are able to apply to their specific piece of the complex project

(Collins 2001). Lastly, the literature cites the necessity that all employees believe that implementing the new concept will accrue benefits at their level. (Dataware 1998).

## Phase 2 Background

The shortage of appropriate transportation infrastructure can affect the national economy and competitiveness in every nation, because of the close relationship between the transportation industry and commerce (Burwell and Puentes 2009). Surface transportation is the major transportation method in the U.S. and has had a special role in its economic power. The national Interstate Highway System, which began in 1956, is proof of the significant positive impact of surface transportation on the nation's economy, which in this case allowed new economic opportunities for the U.S. (NCHRP 2006).

Today, surface transportation is faced with a significant deficiency in investment. The current infrastructure is aged and is in need of maintenance. Maintenance costs have continually increased with time. In addition, the demand for the infrastructure to support surface transportation continues to increase but the supply hasn't grown at the same rate. Therefore, this industry needs a much higher investment to serve the society (ASCE 2011).

### *Motivation*

The effects of surface transportation on the economy and society are clear and must be rapidly addressed to continue to support the economy. Currently, surface transportation largely relies on fuel tax for revenue, which has not been inflated since 1993 in most of the states (Burwell and Puentes 2009). With growing demand and insufficient revenue, finding new and innovative financing methods becomes vital. In this regard, both the federal and a number of state governments have introduced new opportunities to help finance transportation projects. Some states have taken advantage of the new options, but others have not tried them due to a lack of understanding of the long-term potentials of the new financial instruments and concerns about the higher risk associated with these methods (Freemark 2013). Therefore, the second phase of the research aims to provide an overview for managers of transportation agencies on most of the financial options that exist, with consideration to their limitations and requirements.

*Goal*

Complex projects require that all potential financing options are considered in project planning by transportation agencies. When this does not happen, the delivery of critical transportation projects is delayed, making the project even more complex as development costs escalate. Additionally, the failure to rapidly renew deteriorated highways causes higher soft costs (e.g. traffic, congestion, pollution) to the traveling public. Therefore, this paper aims to provide a broad vision of potential nontraditional financing options to enhance agency understanding of possible financing options and their constraints. It will also furnish examples of the benefits accrued by implementing these methods in actual complex projects.

*Research Question #2*

What are the potential solutions to answer the growing need for new source of financing in the transportation industry?

1- How has the gap between supply and demand in the transportation industry been created?
2- What are the surface transportation project’s funding and financing options?
3- What is the appropriate approach to answer the need for revenue?

*Shortage in surface transportation infrastructure*

According to ASCE statement, in the 2013 ASCE Report Card, the nation's roads received grade "D", nation's bridges graded "C+", and transit graded "D". With nearly one third of roads in poor or moderate condition, and one fourth of the bridges structurally deficient or functionally obsolete, and transit system with its highest demand in the last 50 years, ASCE recommended an investment of $1.2 trillion per year for 2009 to 2014, to bring the transportation categories up to acceptable condition (ASCE 2011). These statistics show the urgent need for action in the transportation industry.

Current transportation system relies on fuel taxation for its revenue. However, those fuel taxes have not been adjusted to inflation since 1993 in most states. As alternative fuel technology for vehicles becomes more widely available, the revenue will continue to decrease. Additionally population growth and change in the urban and rural demographic structure, is creating a higher demand for mass transit. Thus, the current surface transportation capacity cannot answer current and future need. The country cannot invest all of required money to fulfill this need simultaneously, therefore the importance of short, mid, and long term infrastructure renewal plans is increased.

*Future path*

Traditional fuel tax-based financing methods have the major role in surface transportation financing, and will need modification to generate the amount of revenue required to return the nation's infrastructure to optimal operating condition. Revenue optimization seems to be the best short term plan. For example, vehicle miles traveled (VMT) fee could replace the fuel tax and charge all drivers based on the miles they travel. VMT is more compatible with social equity and has the ability to be modified for both rural and urban areas (Whitty 2007).

The literature is almost silent on the efficacy of available innovative financial methods, creating a need to evaluate their performance and alleviate agency concerns on long term liability and financial risk. Innovative financing will require enabling legislation and changes to existing capital improvement funding regulations in many states. As a result, they need to be considered in mid-term planning.

Plans to manage both demand and driver behavior can be used to produce long-term sustainable solutions (Burwell and Puentes 2009). Some financing methods such as user fees, cordon pricing, congestion pricing, variable parking fees, and high occupancy toll/high occupancy vehicle (HOT/HOV) lanes have been used as strategies to encourage citizens to use public transportation instead of private vehicles (Burwell and Puentes 2009).

Sustainable approaches need to be a priority in long term planning to overcome the investment gap. When the decision-making process is based on a broad vision that recognizes the interaction between different needs and projects, then the use of all assets to address those needs in a feasible system that can result in the significant saving for society.

Chapter 5 provides an overview available funding and financing options for the U.S. surface transportation projects. This information will help transportation agency’s planners and managers to better understand the options available and consider all probable alternatives realistically. In addition, it will encourage them to plan for using innovative methods and make them aware of the need to provide required legal, technical, and social context in advance of the projects.

## Phase 3 Background

A definition of a sustainable approach that is used in this thesis is an approach that will have the least expense for the economy, environment, and society through its life-cycle, which also does not compromise the future generation's ability to meet their own needs (Jeon 2005). Sustainability has become a hot topic in recent decades because of the increase in the nation's demand for transportation infrastructure due to population growth, consuming natural resources for decades that have decreased their supply, and the budget deficiency. Sustainability formally entered the building construction industry via the Leadership in Energy and Environmental Design (LEED) standards in 1998. A similar movement started in the transportation and infrastructure industries early in 2000 (Kassoff 2002). Many organizations have attempted to provide a rating system for transportation infrastructure similar to LEED for. These attempts have produced nearly 20 different sustainability rating systems.

### *Motivation*

Although most of transportation agencies mention sustainability as one of their priorities (Jeon 2005), and with approximately 20 sustainability rating systems for highways that cover various range of sustainability topics and phases, just a few projects and case studies have applied these systems to their operations. This fact leads one to evaluate and study different rating systems and to understand the similarity and differences of each. The goal was finding barriers to utilizing sustainability rating systems and provide recommendations that can encourage the industry to use these systems.

*Goal*

Considering how important sustainability has become to society in general, the evaluation of horizontal sustainability rating systems was selected for investigation. This phase aims to identify barriers that discourage the industry from implementing these systems by comparing the characteristics of the current suite of rating systems and to assess the impact of these systems via a national survey of heavy and highway contractors and state DOTs. Later recommendations are provided to enhance these systems' popularity among the industry and for later research areas.

*Research Question #3*

How can the practice of using sustainability rating systems in the transportation industry be increased?

1- Why are so many rating systems developed for highways in contrast with one or two for buildings?
2- What are the differences between these sustainability rating systems?
3- Why does the industry not apply these systems in their projects?
4- How can the industry be incentivized to use these systems?

*Sustainability definition and bottom lines*

Transportation sustainability does not have any formal definition but the definition that is used as a basis by FHWA and most other organizations was proposed by Brundtland (1987) "Development that meets the needs of the present without compromising the ability of future generation to meet their own needs ". Later Jeon and Amekudzi (2005) did a complete research project on the definition of sustainability and metrics that are used by the U.S. state DOTs, in addition to sixteen worldwide research projects with the goal of sustainability and its metrics, defining three bases of economy, environment and society are common bottom lines of all resources. Later in 2013, Jeon et al along with their previous research added transportation system effectiveness to three bottom lines of sustainability by multiple criteria decision making methods for long-range plans.

### *History of Sustainability Rating Systems*

Sustainability has become the hot topic for the past. The importance of addressing sustainable approaches through surface transportation infrastructure became more vital because of the large portion of energy usage and pollution production in transportation construction projects. For example, one author claims that the construction of a single lane road that is one mile long consumes the same amount of energy as that require for 50 average American households in one year (Greenroads version 1.5).

According to AASHTO statistics, the transportation sector worldwide accounts for 22% of global energy use, 25% fossil fuel use, 30% of global air pollution, and 10% of the world's Gross Domestic Product (GDP) (Eisenman, 2012). These large portions highlight the importance of considering sustainability as a factor that serves environment, society, and economic impact integrally. Hence, attempts to achieve sustainability rating systems for infrastructure started with Parsons Brinckerhoff activities in the U.S. and CEEQUAL in the U.K. in 2002-2003. CEEQUAL group attempts resulted in a sustainability rating system in three forms that are applicable to all sorts of infrastructures and Parson Brinckerhoff's work resulted in the AASHTO-PB checklist for highway construction which was published in 2007(CEEQUAL 2013, and Parsons-Brinckerhoff 2005). These initiatives were followed by the Green Highways Partnership (GHP) that started in 2004 and eventually morphed in 2007-2008 to the initial Green Roads rating system. Greenroads which later was selected as meeting GHP criteria too, originated from a master's thesis by Martina Soderlund at University of Washington in 2007. In 2008 GreenLITES was established by NYSDOT to rate their internal projects and monitor NYSDOT trend of movement to more sustainable projects. Publishing of different sustainability rating systems has continued, and achieved the highest number in 2010 with six published sustainability rating systems. After that the number of established rating systems per year decreased. In 2011-2012 two more potent rating systems, Envision for all infrastructure and INVEST for highways, were published covering project development phases more comprehensively (Eisenman, 2012). However, the contracting part is a missing point of the U.S. rating systems.

Most published systems are a version of a sustainability rating system with their own emphasizes and this trend resulted in about twenty sustainability rating systems as shown in Table 2-3. Even some of the cities or companies have their own version of a sustainability report such as City of Portland and Granite Construction Inc.

Table 2-3: Sustainability Rating Systems Origin in The U.S.

| | GHP | Greenroads | AASHTO/PB | GreenLITES | SSI | Green Street | BE2ST | SHSET | I-LAST | SIPRS | STEED | Envision | INVEST | SITES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Federal Govt. | | | | | | | | * | | | | | * | |
| State DOT | | | | * | | | | | * | | | | | |
| University | | * | | | * | | * | | | | | * | | * |
| Organization | | | | | | | | | | | | | | |
| Institute/Organization | * | | | | * | * | | | | * | | * | | * |
| Industry | | * | * | | | | | | | | * | | | |

Although these multiple rating systems help organizations to follow their own emphasis by providing a specific version of themselves, it has disadvantages such as becoming an obstacle in the way of popularity and having commercial value. Moreover, a high variety of these systems dissuade the industry to practice them, because differences are not well defined, and every industry unit cannot do their own research to find out which system fits their projects best.

*Sustainability indices:*

In research published by Shen et al. in 2011, key assessment indicators (KAI) for infrastructure project sustainability are defined as shown in Figure 2-4. KAIs help decision makers identify an optimal solution and maximum sustainability performance (Shen et al. 2011).

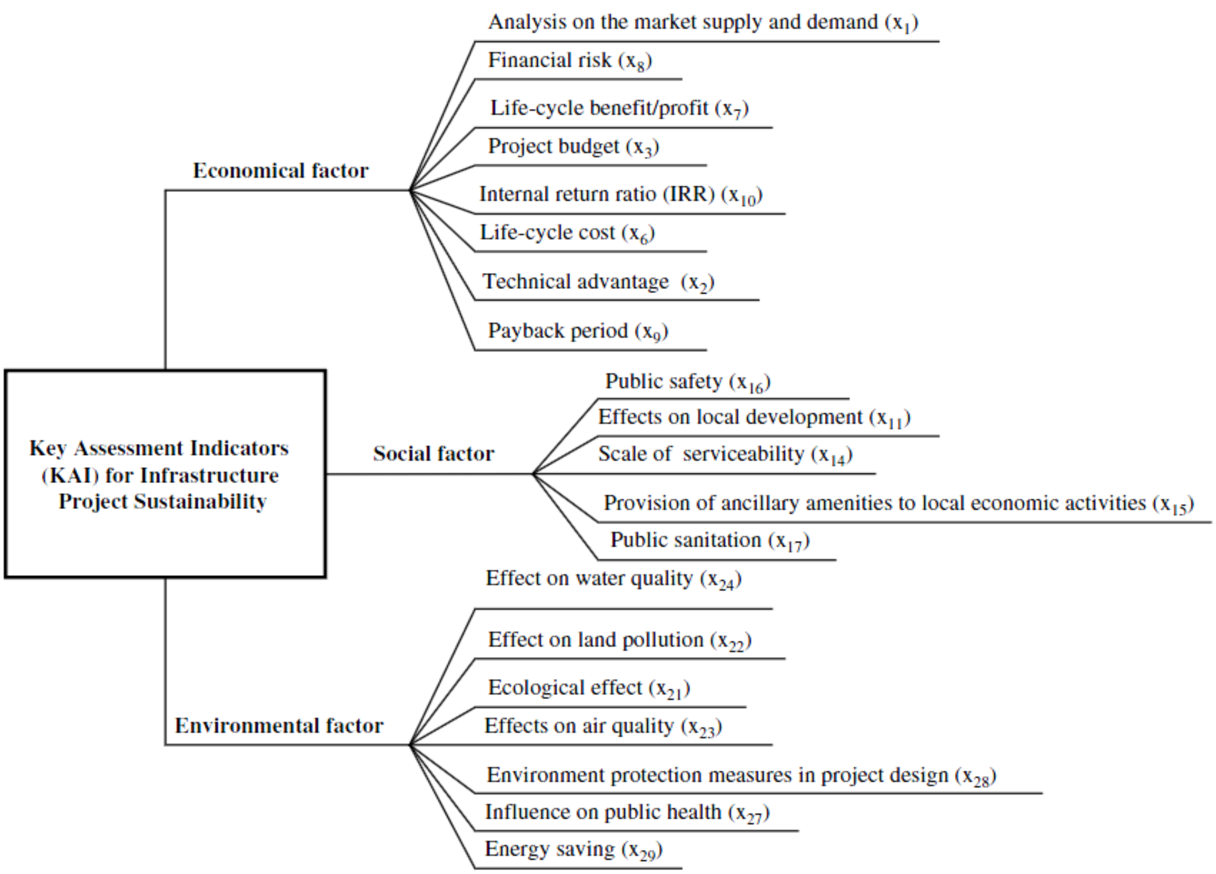



Figure 2-4: KAI for infrastructure project sustainability (Shen et al. 2011)

While studying different sustainability rating system's criteria, one point becomes apparent. Most of the studied rating systems emphasized environmental KAIs and social KAIs. Only 'Scale of serviceability' and 'Provision of ancillary amenities to local economic activities' are missed in some systems. However, most of the economic KAIs other than life-cycle benefit/profit and life-cycle cost are missed in the majority of rating systems.

Highlighted point implies giving lower attention to economic part of the projects through sustainability rating systems. Although economic benefits can be the best motivation for industry and contractors to practice these systems, it is not well evaluated in sustainability rating systems and some of them, such as GreenLITES do not have a cost life-cycle analysis.

*Horizontal Infrastructure Sustainability Rating Systems Research Limitation:*

This research is based on the common assumption that sustainability approaches decrease the life cycle cost of a project. There are few long-term case studies available to prove this assumption with real project data. Therefore the assumption is accepted based on current research on shorter term projects. The exact number of these systems is not determined because different agencies and DOTs are not aware of other agencies progress in this field, and each organization can have its own version which is not well-known (Barrella et al. 2010). The national survey of heavy and highway construction of different DOTs and contractors, received 36 of the responses.

# CHAPTER 3. OVERALL APPROACH TO RESEARCH METHODOLOGIES

The overall thesis organization is shown in Figure 3.1:

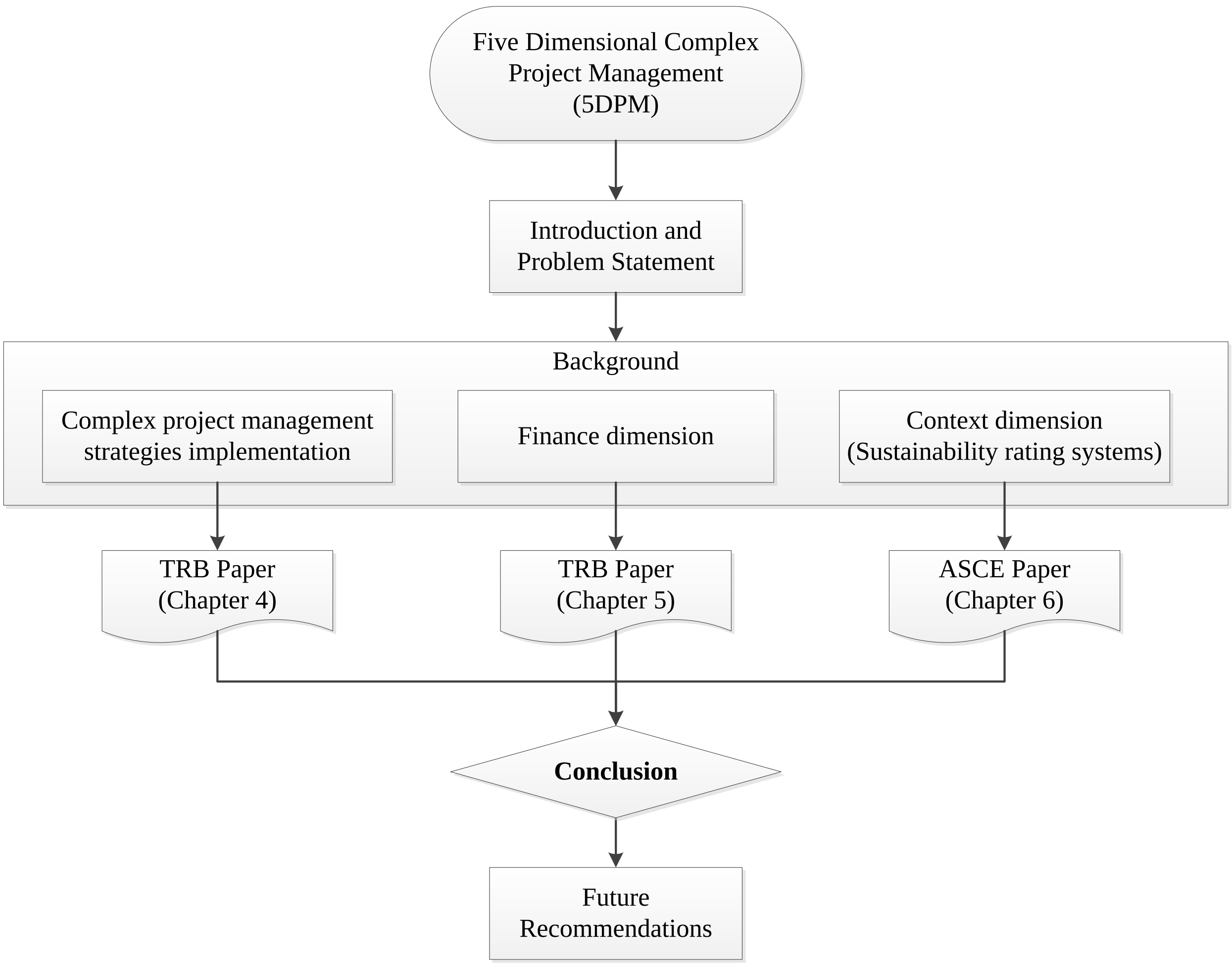



Figure 3.1: The Thesis in a Glance

The methodology takes shape at the primary stages of research after defining the scope and question of the study; it is a result of the research design phase. Methodology presents the arrangement of data gathering methods and analysis that are intended to answer the question(s). It should be flexible to accommodate the different limitations that the researcher can be faced with. The methods that are used in data gathering can affect the research results and researcher's finding, so it is important to be unbiased and test the validity of the research results by using different methods such as pilot studies (Fellows and Liu 2008). The research area for this thesis is new and in the development process, therefore real experiences and pilot studies are limited, qualitative research methods are the dominant methods that have been used. The main research instruments that were used are:

- Literature review,
- Interviews,
- Surveys, and
- Content analysis.

Literature review has been used as a main tool to determine the current knowledge, process, and state of the practice for state DOTs, or other transportation agencies. Literature review has been used in all three papers of the research, the summary of literature review for each paper is provided in the chapter two and later in the papers in shorter format will be completed. Initially the literature review has been used to define complexity, complex projects definition in different transportation agencies, different agencies structure, and complex project development process. It was also used to define complex project management strategies. The second paper of research is highly dependent on the literature review to understand the facility shortage in transportation industry and why and how it is originated and grown, in addition to understanding different traditional and innovative methods and requirements to use them. In the third paper of the research the literature review has been used to evaluate the formation and evolution history of sustainability rating systems for horizontal infrastructure.

Interviewing was chosen as one of the best qualitative methods to gather data in which the interviewer and interviewee can interact flexibly and make sure that meaning is conveyed correctly and follow up new ideas. On the other hand interviewing is time consuming and has a bias danger. Interviews can be varied in the spectrum of in-depth structured to unstructured and focus group due to its intention and research specification. The interview result can be analyzed by discourse analysis or content analysis (General Accounting Office 1991). Interviews were used in the first and third papers of research. In the first paper, semi-structured interviewing was used to verify the compatibility of research results with different DOTs development process. The interview recognized the most feasible and precise method in this paper, because interviewer needs to make sure interviewee is enough familiar with the guidebook concepts and their own process, and flexibility is one of the required characteristics in this verification interview to absorb new improving ideas. In the third area of research people that had a key role in sustainability rating systems evolution were interviewed to gather their opinion on these system's practice and future, in addition to verification of the chronological order of the systems. In this paper semi structured interviews have been used as far as researchers look for new opinions and ideas or missed papers of the history. In both interviews, questions had been sent to the interviewees in advance, that gives them enough time to think and look for required information.

A semi-structured survey has been used in the third area of research to determine level of industry practice and perspective on horizontal sustainability rating systems. This data was completed through interviews with a few critical people in the industry. Interviewing with all companies was not feasible due to high number of them and time limitation. Survey was a cross-sectional type, which collected data at one point in time (period of one month) and the sample represents a larger population. This survey consists of multi-choice and explanatory questions to gather professional's vision, opinion and perspective as much as possible (Forza 2002). The survey had been sent to more than 300 people who work in heavy and highway contractors or state DOTs and 36 responses have been received, the responses cover a good range of different contractors and DOTs. These responses can be used to estimate the level of systems practiced in the industry, in addition to highlighting the strengths and weaknesses of the systems, which can be resulted in determining a trend for now and future.

Content analysis has an important role in the first and third papers of the research to track variables and their fluctuations. In the first paper, content analysis has been used to determine complexity factors in different industries. In the third paper, it is used to determine effect area of each system's criteria and compare them.

Another method used was case study analysis, which was used in second research paper to find out what innovative financing methods are more common through DOTs and complex projects.

In this chapter, each research paper is defined and the associated methodology to answer its question is presented.

### Paper 1: Applying 'Complex project management strategies' to state DOTs complex project development process

This paper consists of two sections: In the first section complexity is defined and complexity factors in different industries are compared to check universality of five dimensions of project management (5DPM). Then different complex project management strategies by various literatures are studied, this includes the project management strategies for complex management proposed by Shane et al. (2012).

For this paper literature review and content analysis were major research methods that have been used. Figure 3-1 compares the definition of complexity in different literature studied to see different perspectives. Then through a content analysis on construction industry institute (CII) documents complexity factors of different industries are compared, which shows the broadness of 5DPM only with different emphasis in different industries. Then different literature on complex project management are studied to determine various techniques used in complex project management. A communication plan was recognized as a highlighted tool of all strategies, such as complexity mapping which is used as an internal communication tool between project groups.

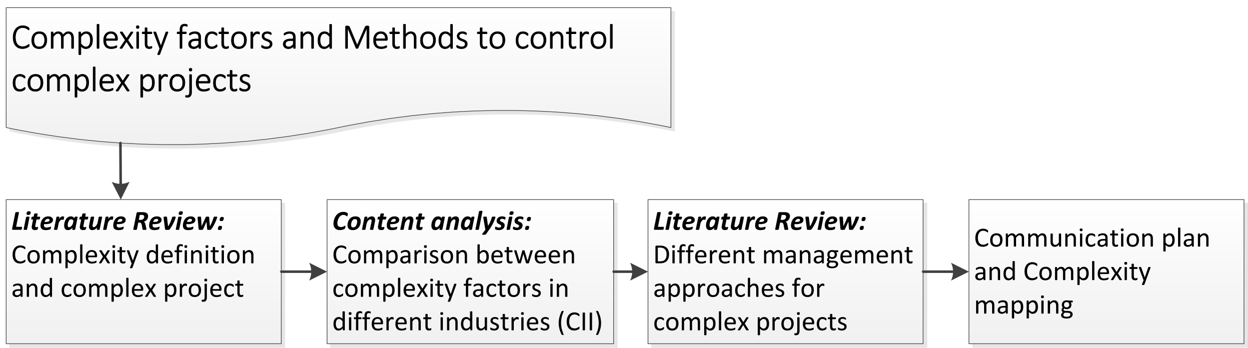



Figure 3-1: Complexity Factors and Project Management Strategies Methodology

In the next section of this paper, as shown in the Figure 3-2, complex project management strategies tool have been applied on the generalized U.S. DOTs complex project development process. Due to the different processes through the U.S. DOTs it is applied to several states with different processes and its compatibility verified by interviewing with managers of those DOTs.

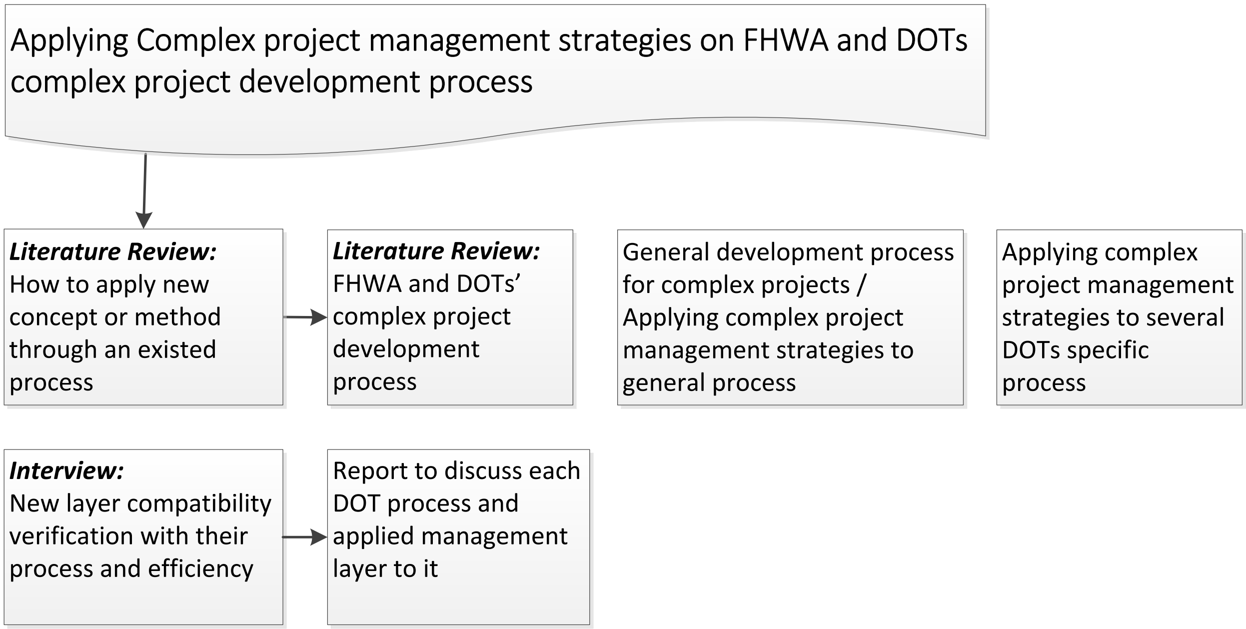



Figure 3-2: Applying Complex Project Management Strategies on the U.S. DOTs Complex Project Development Process

**Paper 2: Financing Options for the United States Surface Transportation Projects**

In the second paper of this research, the investment shortage and deficiency in transportation industry is addressed and reasons of that discussed by literature review as showed in the Figure 3-3. In the next step traditional funding and financing methods are discussed and their inability to satisfy future need is proven. After arriving to the point that transportation industry needs new financing methods innovative financing methods are introduced and their limitations and requirements are mentioned. Literature review is the main research tool used in this paper and completed with 12 complex project case studies that their financing methods are evaluated to show popularity and usage of these methods.

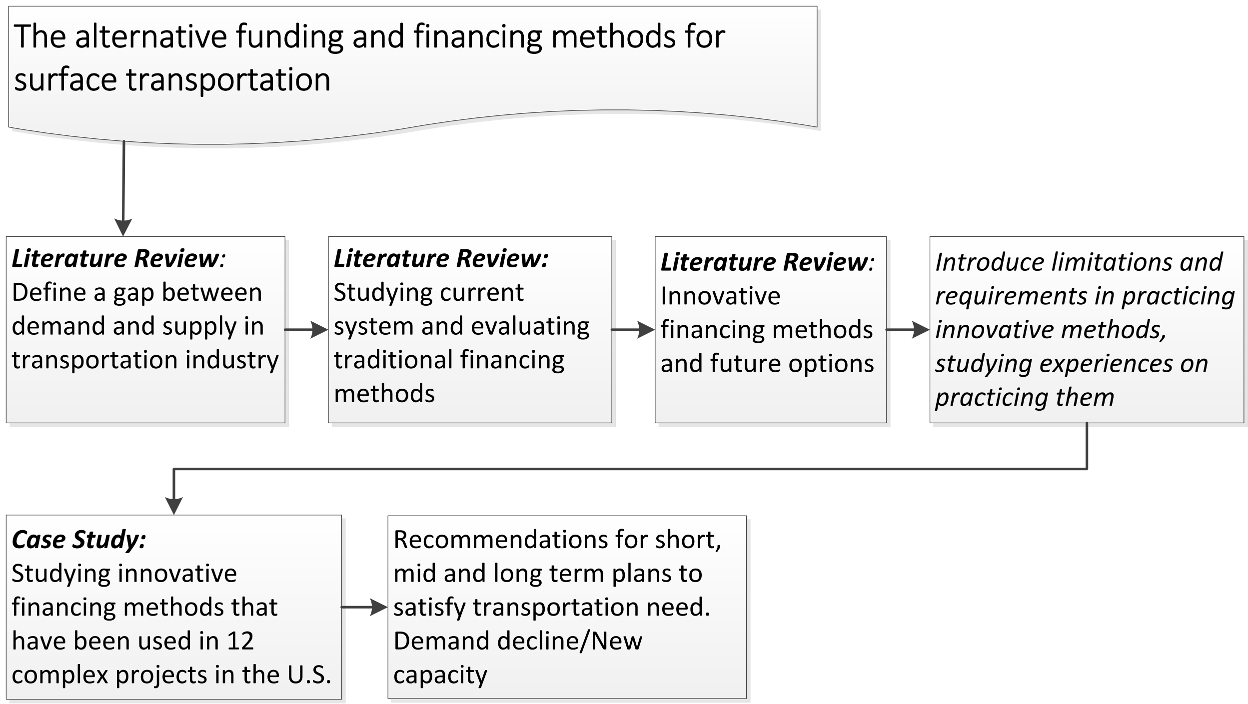



Figure 3-3: Funding and Financing Alternatives Methods for Transportation Projects

### Paper 3: Horizontal infrastructure sustainability rating systems evolution

Sustainability rating systems start with LEED for vertical structures in 1997, and expands to horizontal infrastructures around 2002-2003. As shown in the Figure 3-4 this research starts with literature review on the history and evolution of the sustainability rating systems. The history section is completed and validated through interviews with key personnel in this area. In the next step all criteria of the five selected rating systems is broken down based on their affected area, this is done by content analysis and compared with each other based on bottom lines. Later to find out the reason of a gap between these rating systems and industry, a survey for transportation industry and contractors is designed and had been done. The combination of literature review, interviews and survey lead the research group to provide recommendation for future development path.

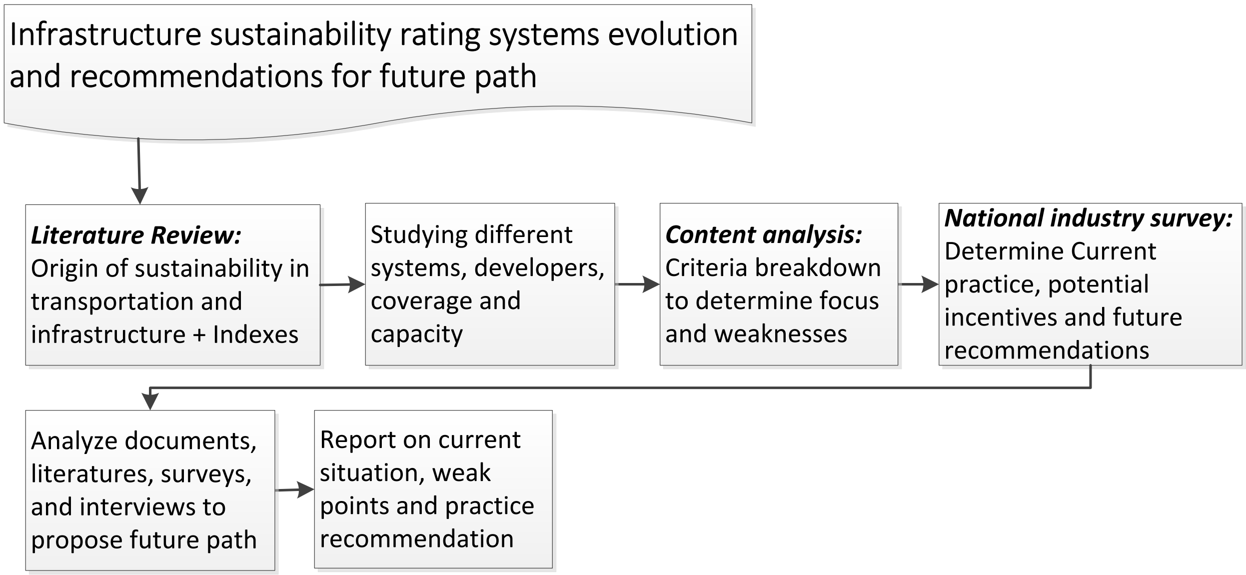



Figure 3-4: Horizontal Sustainability Rating Systems Evolution

# CHAPTER 4. COMPLEX PROJECT MANAGEMENT STRATEGIES

## Applying the Complex Project Management Process to Existing Transportation Project Development Processes

Bahrevar, E., J. S. Shane. Applying the Complex Project Management Process to Existing Transportation Project Development Processes. Submitted to 2014 Transportation Research Board, 2014.

### Abstract

Due to aging infrastructure and rapid growth, there is an increase in the size of and length of time for transportation projects, as well as an increase in renovation, replacement, and retrofitting projects, which are complicated and risk-prone. Improved project, risk, and finance management strategies and tools are necessary. For complex projects, definitions, development processes, decision-making patterns, and standard terminology differ between the various state transportation agencies (STAs). This paper attempts to generalize development processes for different STAs according to the major common steps and apply this complex project management process, which consists of complexity mapping, five complex project management methods, and 13 execution tools. Complexity mapping helps to identify and track complexity in five dimensions of project management: cost, schedule, technical, context, and finance. The five project management methods should be implemented from the earliest project stage to manage these complexities. The 13 execution tools were also developed to help manage complex projects effectively and use of these tools should be considered throughout project development and selected according to project-specific features. The development processes of three U.S. states

and the Federal Highway Administration are used to illustrate the compatibility of this complex project management process with existing project development processes.

## Introduction

The shift in U.S. infrastructure needs has largely been from building new infrastructure to replacing, expanding, or renewing existing infrastructure. The project management issues involved with infrastructure renewal are markedly different than the issues for new construction, furthering the need for a change in project management approaches for the nation's infrastructure. Not only are infrastructure renewal projects more complicated by their nature, the situation has been exacerbated by years of under-funded maintenance and replacement. In other words, what would have been a complex process under ideal circumstances has been made even more challenging because of the need for rapid renewal to avert infrastructure failures. Adding to the challenge is the fact that complexity can evolve from the interaction of many factors, not all of which will manifest them on each project.

Rapid renewal projects cover a wide spectrum of project types, varying in engineering complexity, size, modality, jurisdictional control, financing approach, contract type, and delivery method. Each project calls for a distinct project management style with teams comprised of different resident skill sets required for successful project completion.

The Second Strategic Highway Research Program (SHRP 2) Renewal Project R10, titled Project Management Strategies for Complex Projects, aimed to help transportation agencies begin to understand and manage these complex projects. To begin this project, the research team conducted a literature review to investigate what makes projects complex and what are some ways this complexity is being managed. Following the literature review, the research team visited a variety of projects to learn about ways of managing transportation project complexity.

Fifteen projects in the U.S. and three international projects were investigated through in-depth case studies to identify tools that aid managers of complex projects in delivering projects successfully. These 18 projects represented different project types, locations, sizes, and phases of development (Shane et al. 2010). The results were as follows:

- Five dimensions of project management for complex projects:
  - Cost
  - Schedule
  - Technical
  - Context
  - Finance
- Five methods that must be used on every complex project:
  - Define Project Success by each dimension as required
  - Assemble Project Team
  - Select Project Arrangements
  - Prepare Early Cost Model and Finance Plan
  - Develop Project Action Plans
- Thirteen tools that may be helpful on complex projects:
  - Incentivize Critical Project Outcomes
  - Develop Dispute Resolution Plan
  - Perform Comprehensive Risk Analysis
  - Identify Critical Permit Issues
  - Evaluate Applications of Off-Site Fabrication
  - Determine Required Level of Involvement in ROW/Utilities

- Determine Work Package/Sequence
- Design to Budget
- Co-Locate Team
- Establish Flexible Design Criteria
- Evaluate Flexible Financing
- Develop Finance Expenditure Model
- Establish Public Involvement Plan

Based on the findings of the literature review and case studies, a Guidebook and training program were developed (Shane et al. 2012). As part of the project, 10 training sessions were conducted across the country and two pilot project workshops were conducted. During the training and pilots, it became apparent that the five dimensions, five methods, and 13 tools are of interest to groups working on complex projects. However, what was not apparent was how the dimensions, methods, and tools, integrate with current project development processes, considering that each state transportation agency (STA) has its own process, which may differ from others. Additional work was done to answer this important question.

## Project Development Process

Each STA has a project development process that is individualized for its specific needs. These needs may include the centralization or decentralization of work within the agency or state legislative requirements (Intergovernmental Forum on Transportation Federal Highway Administration Office 2008). In addition, complex projects often fall outside the typical development process for an agency, either entirely or at certain points of development.

The Federal Highway Administration (FHWA) has developed a standard project development process (FHWA 2006) and a set of criteria for major projects. Major projects are those that are estimated to cost more than $500 million (Capka 2007).

While many projects that fit the criteria for major projects are complex, this definition may not fully capture all complex projects. Complex projects can differ from typical projects according to criteria such as size, development duration, public involvement, culture, location characteristics, newness, resource availability, stakeholders, communication, and the number of critical activities and critical paths (Boushaala 2010). For example, as outlined in Table 4-1, the New York State Department of Transportation (NYSDOT) defines project categories based on capital project features and divides them into these three categories: simple, moderate, and complex (NYSDOT 2004).

### Table 4-1: NYSDOT Project Categories (NYSDOT 2004)

| Project Category | Criteria | Project Types/Examples | Project Scoping Report |
|---|---|---|---|
| Simple[1] | - Projects with limited public or outside agency involvement<br>- May involve environmental issues<br>- Automatic and programmatic categorical exclusion projects<br>- SEQR type II projects<br>- Projects with one feasible alternative<br>- All element-specific projects<br>- Routine work with no unusual issues | - “Maintenance by contract” type projects, such as element specific projects (See Appendix 7. Section 2.5 of this manual for a list of element-specific projects)<br>- 1R projects<br>- 2R projects<br>- Minor bridge rehabilitation<br>- Simple culvert replacement | Initial product proposal (IPP)[2] + additional information as appropriate |
| Moderate[3] | - Projects with significant involvement of the public<br>- Usually involve environmental issues and/or outside agencies<br>- Categorical exclusion projects<br>- State Environmental Quality Review (SEQR) ActType II or Non-type II (Environmental Assessment (EA)) projects that are minor (National Environmental Policy Act (NEPA) Class II)) | - 3R projects<br>- Most highway and interchange reconstruction projects<br>- Most bridge replacement and major bridge rehabilitation projects | See note[4] |
| Complex[3] | - Projects with extensive public and outside agency involvement<br>- Almost always involve environmental issues<br>- All NEPA EA projects<br>- SEQR Non-type II (EA) projects that are not NEPA Class II | - New bridge and major highway reconstruction projects<br>- Major bridge rehabilitation<br>- Highway and interchange reconstruction projects<br>- Traffic management centers (TMCs) | See note[4] |

1 - If a simple project area has a history of environmental or community issues, it will require a more concerted public involvement effort; consideration should be given to advancing it as a moderate project.
2 - A separate project scoping report is not prepared. The initial product proposal (IPP) is modified with attached sheets containing additional project information, as needed, forming a combined scoping and design document (i.e., IPP/final design report (FDR)). Project scope approval and design approval are obtained simultaneously.
3 - Even though moderate and complex projects will follow the same format, the degree of detail and analysis will be substantially different. The format is not meant to produce voluminous reports. The objective is to have a basic framework that works for all projects and results in an appropriate level of documentation based on the project type. It provides a checklist to ensure all relevant issues are considered. For moderate projects, a simple statement with one or two lines can document that an issue has been considered and found not relevant.
4 - The project scoping report is in the format of a design report, design report/environmental assessment, or design report/draft environmental impact statement. The format serves as checklist to ensure that relevant issues are considered prior to project scope approval. The same document, with appropriate changes will be used for design approva

**Typical Project Development Process**

Figure 4-1 shows the typical traditional transportation project development process, with five phases: planning, programming and preliminary design, final design, advertisement and bid, and construction (Anderson et al. 2007).

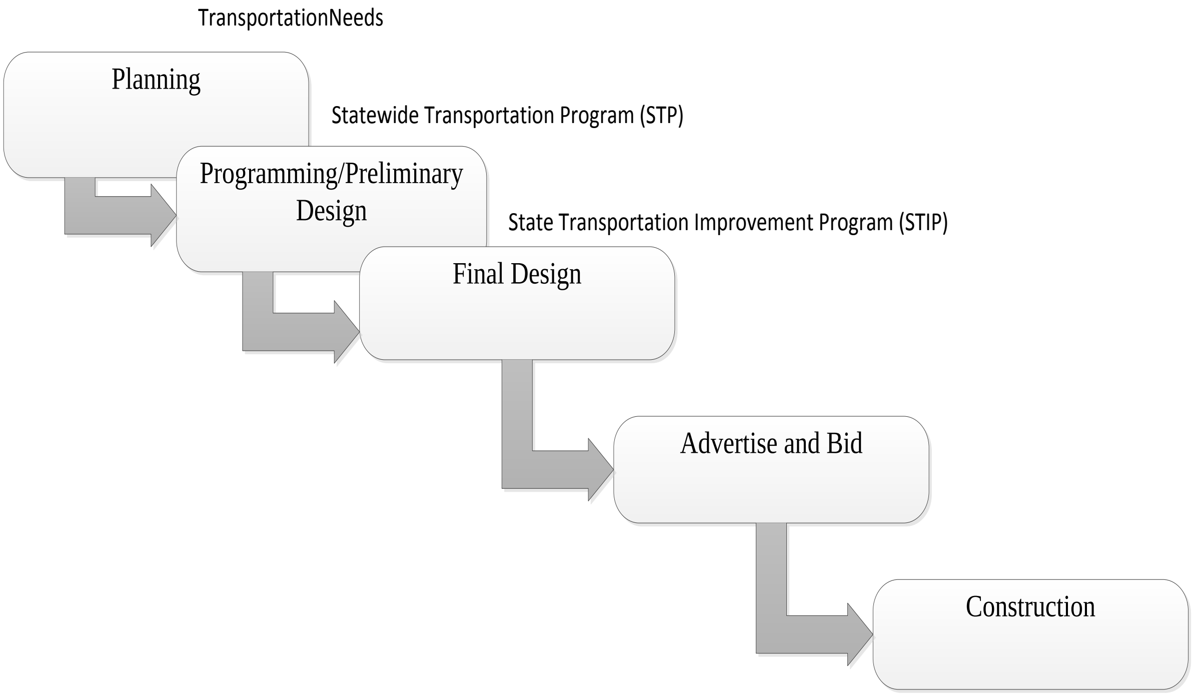



Figure 4-1: Typical transportation project development phases (Anderson et al. 2007).

After identifying needs and recognizing deficiencies, planning begins to define needs and purposes and consider public involvement, environmental issues, and interagency conditions. This phase results in a long-range plan, a statewide transportation program (STP), or a highway improvement plan (HIP), that usually covers up to about 25 years of transportation planning. The programming and preliminary design phase, which is typically the longest phase, includes environmental analysis, public hearings, economic feasibility analyses, right of way (ROW) considerations, and solution selections. This phase results in a statewide transportation improvement program (STIP) that covers four to five years of transportation planning.

In the next phase, engineering designs are completed and more detailed cost estimates are developed for advertisement and bidding processes. These first three phases may overlap because portions of the project may receive different levels of attention at different points of the development process.

In the fourth phase, the project is advertised for bidding and bids are collected and analyzed for the best value, quality, or other requested criteria.

In the fifth phase, the best bidder is selected, the contract is initiated, and construction starts with all required monitoring and quality tests.

In typical transportation projects, the fourth and fifth phases of project development are separate from the previous phases because projects are traditionally procured and delivered through the design-bid-build (DBB) method and low bid system (Anderson et al. 2007).

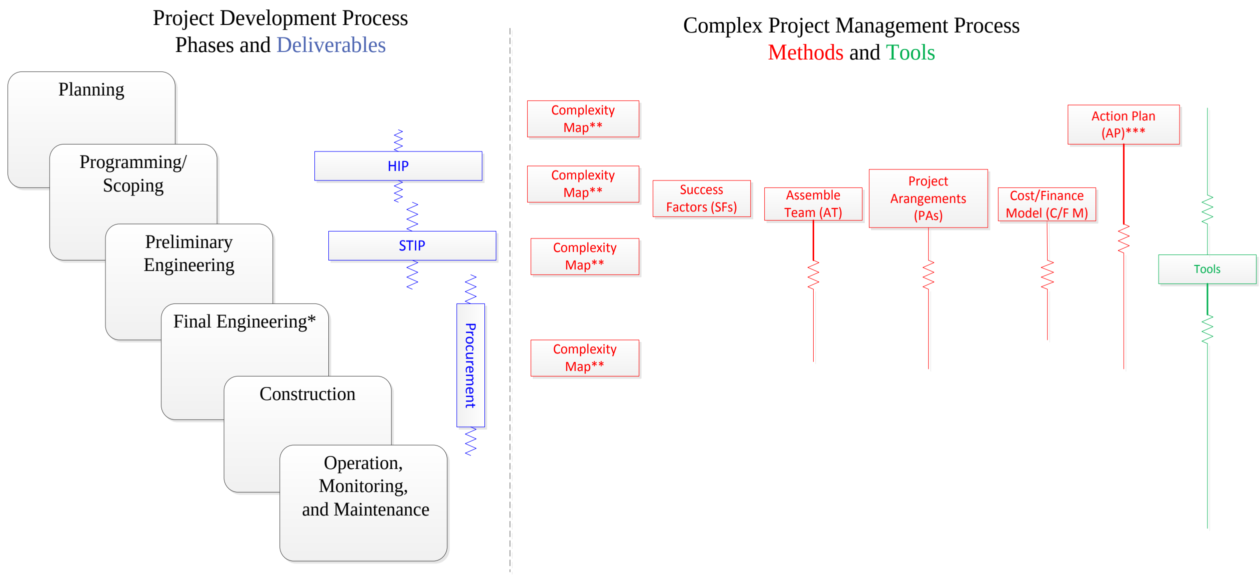
## Complex Project Development Processes

Complex transportation projects often go through slightly different development processes than typical projects. An analysis of 18 complex projects indicated that some of the steps in project development are the same as those for a typical project, which can be represented by six basic phases: planning, programming and scoping, preliminary engineering, final engineering, construction, and operation, monitoring, and maintenance (relating to after-construction obligations for some complex project contracts). These phases often overlap without a clear distinction of an endpoint and start point, given that different aspects of projects are advanced at different rates.

The HIP is usually completed during the planning or programming and scoping phase based on the transportation agency’s structure. The variation is indicated in Figure 4-2 (left side) with the “spring” graphics. Projects begin to appear in the STIP either during scoping, preliminary engineering, or up to final design. Again, the variations in timing are indicated with a “spring” graphic.

In the traditional project development process, design is completed before the bidding phase and at an earlier point in time than the construction phase. Furthermore, operation and maintenance is a separate contract in a traditional process.

With the complex project development process presented in this paper, after entering a project to the STIP (which can happen from the end of scoping or early stages of preliminary engineering to the end of the final engineering phase, depending on the delivery method and the construction manager involvement point in time), construction procurement can proceed parallel to design completion. These variations in procurement are illustrated in Figure 4-2 with procurement placed vertically versus the other deliverables shown horizontally and also with this deliverable as a “spring” graphic. The intent is to show that multiple instances of procurement for design, construction, and other services may be required in successful completion of a complex project.




* May include ROW and utilities
**Additional mapping at other major decision points
***Issue identification needs to happen throughout the process; roadblocks need to be addressed early in the process and progress should be made to reduce them

Figure 4-2: Project development and complex project management processes

### Complex Project Management Process

Shane et al. document a project management process for managing complex projects that begins with mapping the five project dimensions, which are tracked with the interaction between them documented and the effect of variation in each dimension monitored and controlled (Shane et al. 2012). By this continuous project dimension monitoring, knowledge of potential complexity, and planning for it, the probability of chaos is minimized. The right side of the Figure 2 provides an overview of the complex project management mapping process, the five management methods, and use of the execution tools throughout the process (as mentioned in the Introduction).

The complexity mapping process is the first complex project management step, and it is started from the earliest phases of the project. Communication between functional groups and providing a common understanding about the project and each of the five project dimensions are two of the complexity mapping process objectives. Up-front project complexity definition and communications help the group in allocating resources throughout the remainder of the project/process.

Tracking the fluctuation in complexity of each dimension and planning for control is another mapping objective. Therefore, mapping should be repeated several times through the project development process and at each major decision point. (The area of the complexity map should decrease with development of the project.)

Project success factors for each dimension should be defined early in project development, perhaps as soon as after entering the HIP. Success factors should not change throughout the project development process. If they do, you have a moving target, which is not the goal.

Assembling the project team should happen in the scoping phase. The project team is not limited to only STA staff that is dedicated to the project. Team members can join temporarily at various stages and from a variety of parties/organizations. The needs of the project team will change throughout project development, so this activity is continuous.

Project arrangements may be accomplished using many strategies, such as borrowing personnel from other groups, short-term contracting through traditional consulting and contracting agreements, or other types of agreements. Again, this is a method that should be considered early, starting during the scoping process and continually throughout the development process.

Another method to control the project, select the appropriate delivery method, and balance expectations with resources is to formulate an early cost and finance model, along with primary design, and then revise it continuously as the project proceeds to provide realistic perceptions of the project financial resources and situations for the management group to address.

Finally, project action plans (APs) should be developed and assigned to responsible parties as complexity and resource issues that hinder the project progress are identified.

The 13 execution tools introduced earlier should be considered continuously through the development process. Each project team should select applicable tools at appropriate times based on specific project characteristics and depending on several factors, such as the development phases, responsibilities, and the delivery method selected.

## Applying the Complex Project Management Process

To gain a better understanding of the overlay of the complex project management process on a typical STA project development process, several documented STA processes were examined and are provided in this paper with an overlay of the complex project management process.

Generally, the additional complex process steps are complexity mapping and action plans (shown with the word Map in a star and AP under that in the following figures) at each major decision point to make sure all dimensions are considered and potential complexities are identified. Success factors (SFs) and measurement criteria identification are usually established after determining project boundaries given the HIP. Other project management methods are used in the scoping and design phase according to the STA structure.

### *Federal Highway Administration Process*

The FHWA Major Project Oversight Office requires that every major project that uses federal-aid funds submit the first cost estimation review 30 days before the National

Environmental Policy Act (NEPA) documentation is submitted and the second cost estimation review before construction approval. A project management plan should be submitted within 90 days of the NEPA decision, and a financial plan should be submitted prior to construction approval.

Application of the complex project management process layer on the FHWA development process is shown in Figure 4-3 in gray stars and rectangles.

Table 4-2: Worlds Key to Figures

| | |
|---|---|
| AP: Develop project action plan(s) | PPMS: Project and program management system |
| AT: Assemble project team | PS&E: Plans, specifications, and estimates |
| ATP: Area transportation partnership | QC/QA: Quality control/quality assurance |
| C/F M: Prepare early cost model and finance plan | ROW: Right of way |
| DTD: Division of transportation development | SF: Define project success factors by each dimension as required |
| FOR: Final office review | SP#: State project number |
| FTA: Federal Transit Administration | SIP: State implementation plan |
| HIP: Highway improvement plan | STA: State transportation agency |
| LGA: Local government agencies | STIP: Statewide transportation improvement program |
| MPO: Metropolitan planning organization | TIP: Transportation improvement program |
| PA: Select project arrangement(s) | TPR: Transportation planning region |
| PM: Project manager | SP#: State project number |

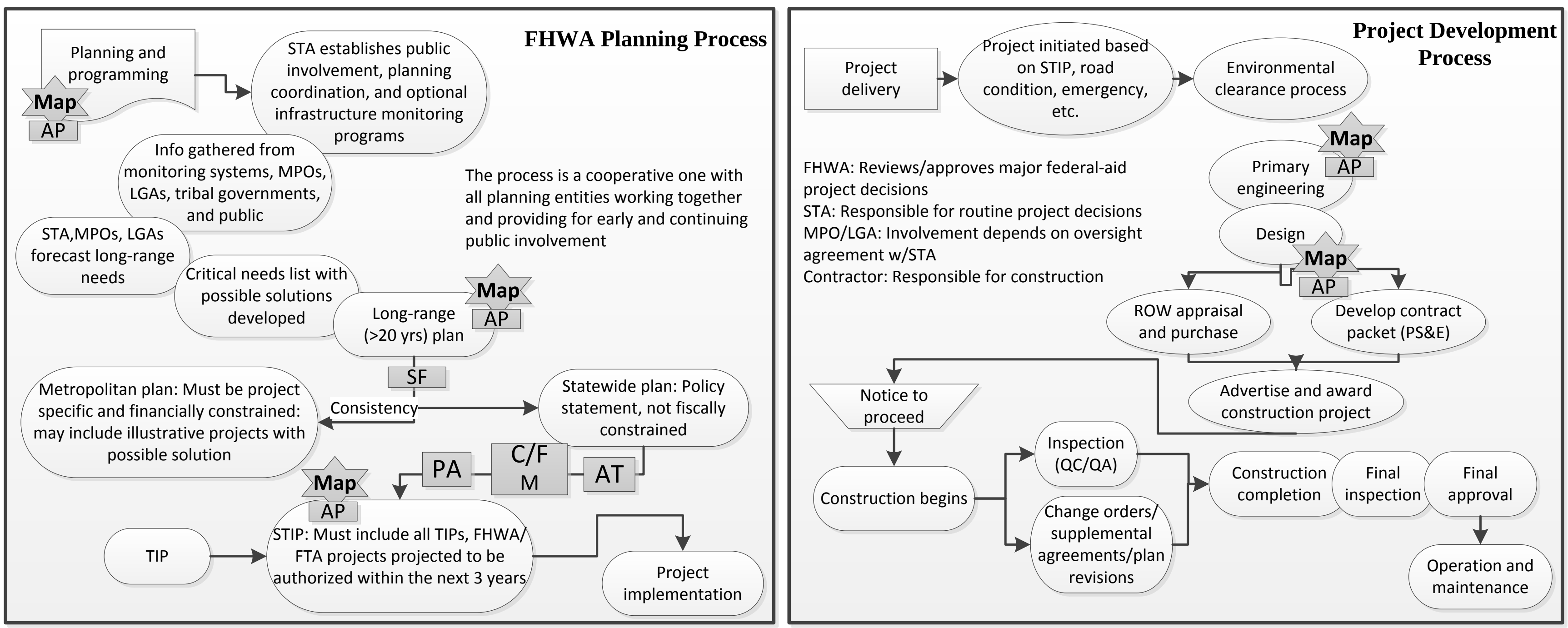



Figure 4-3: Application of complex project management layer to the FHWA project development process (FHWA 2006).

As shown in Figure 4-3, the first complexity mapping step (denoted with the word Map in a star graphic) is in planning and programming, which is followed by an action plan (AP) to identify probable constraints of the project.

Upon entering the project in the long-range plan, the complexity mapping for the project is revised and success factors (SF in the figure) are determined by the project management group. All other methods are used in the scoping and programming phase before entering the project in the STIP. After that, complexity-mapping and action planning considerations are repeated throughout the

### *Minnesota Department of Transportation Process*

The Minnesota Department of Transportation (MnDOT) commonly uses the DBB delivery method. MnDOT divides the project development process into five major phases: planning, scoping, programming, developing (which includes the change process), and letting (MnDOT 2008) as shown in Figure 4-4.

Project planning includes needs identification and prioritization, with the HIP as the deliverable. The project scoping phase starts with assigning the project manager (PM) followed by alternative development and selection. Through scoping, environmental issues are considered, project boundaries are determined, and the scoping core, baseline cost, and schedule plan are studied. The project scoping report is a deliverable of this phase. All projects, both typical and complex, need planning and scoping phases.

The third phase is project programming to decide which scoped projects will be submitted for possible funding and financing and entered into the STIP. At this point, the project is ready for further design.

Figure 4-4 shows the complex management process overlays (in gray stars and rectangles) on the MnDOT process. Again, complexity mapping and action plans occur at major decision points. With the MnDOT process, this is more often than presented in the general discussion or for the FHWA process, given that more major decision points are identified in the MnDOT process diagram.

Complex project management success factors are defined between the planning and scoping phases. The project team is assembled (AT in the figure) when the project manager is assigned to the project. A cost model and a finance plan (C/F M in the figure) are developed while considering alternatives for the project. Project arrangements (PA in the figure) are selected along with preferred alternative development and selection.

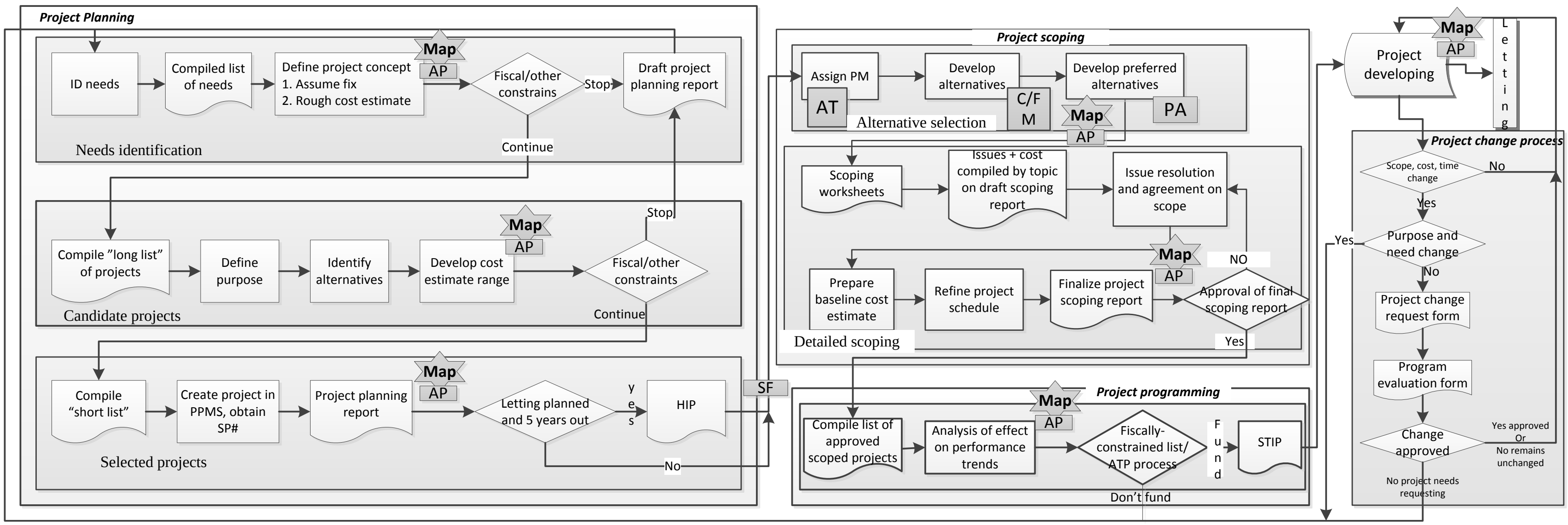



Figure 4-4: Application of complex project management layer to the MnDOT project development process (MnDOT 2008)

*Arizona Department of Transportation*

For roadway projects, the Arizona DOT (ADOT) follows the general development process that is shown in Figure 4-5 and, based on specific characteristics; each project can have extra steps that involve other organizations (ADOT 2011).

The ADOT development process consists of planning, scoping, design, construction, and operation (Li and Higgs 2008). Projects are prioritized and then enter long-range planning. ADOT develops a five-year construction program each year from the long-range planning list. ADOT performs project scoping five to seven years prior to construction and provides a scoping report. The design phase consists of several stages and value engineering happens in this phase. After this phase, the project is ready for the letting, construction, and operation phases (ADOT et al. 2008).

Figure 4-5 shows the complex management process overlays (in gray stars and rectangles) on the ADOT process. Complexity mapping and action planning start in the early stages of planning, and repeat at major decision points (which are more often in the project scoping and design phases). The success factors are defined and the team is assembled in the first meeting after entering the five-year construction program. The cost model and finance plan are prepared in the first design stage and are revised through design completion. After each design stage, the project action plan is used to recognize potential project complexities and plan for them.

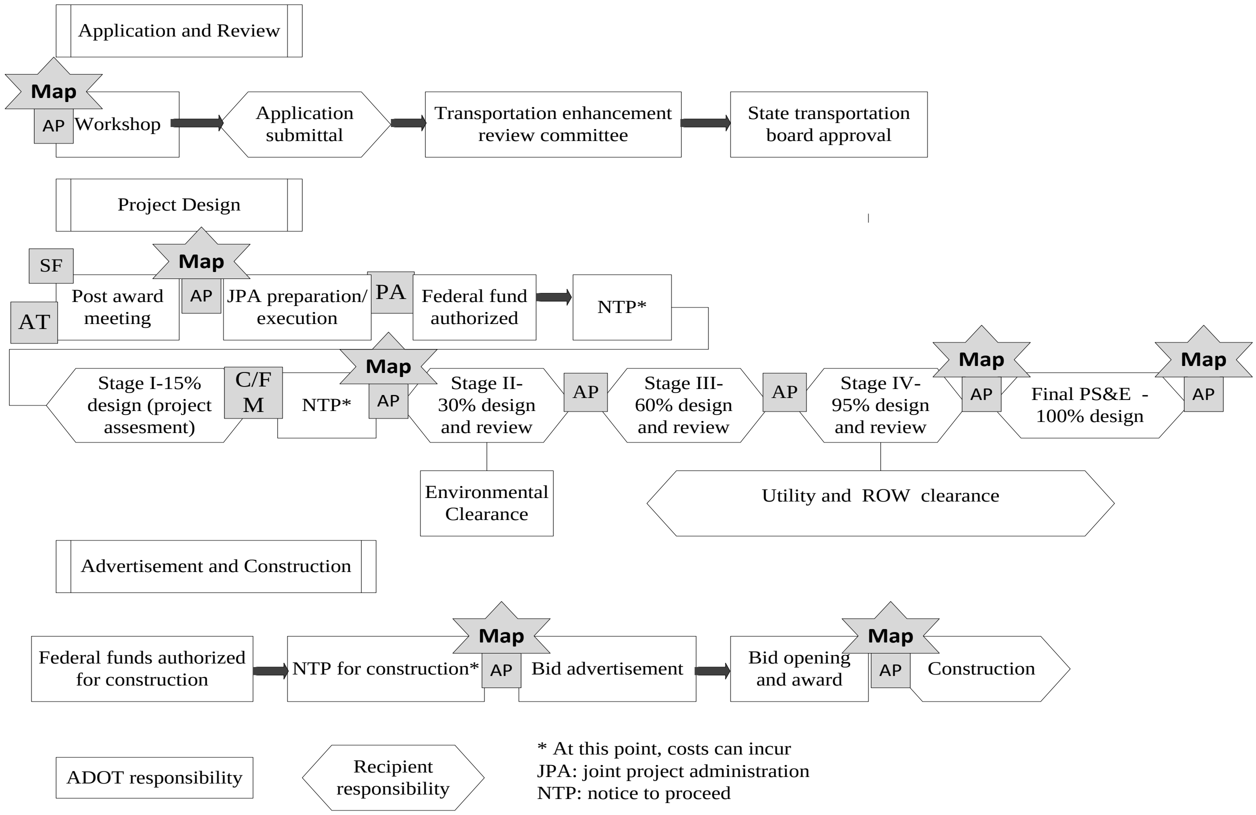



Figure 4-5: Application of complex project management layer to the ADOT project development process (ADOT 2011).

*Colorado Department of Transportation*

The Colorado DOT (CDOT) project development process consists of project scoping, budgeting, which spreads throughout the process, programming, design, advertisement and letting, and construction (CDOT 2013). The project scoping phase includes STIP project entry, design scoping review (DSR), and field inspection review (FIR). Project budgeting also starts in the scoping phase and is revised and modified in every later phase.

In the programming phase, future capacity and value engineering are considered. In the design phase, environmental, traffic, structure, materials, ROW, utilities, and other relevant considerations such as constructability are studied. After final design review, the project advertises and letting starts. The last phase is construction. The CDOT development process is shown in Figure 4-6.

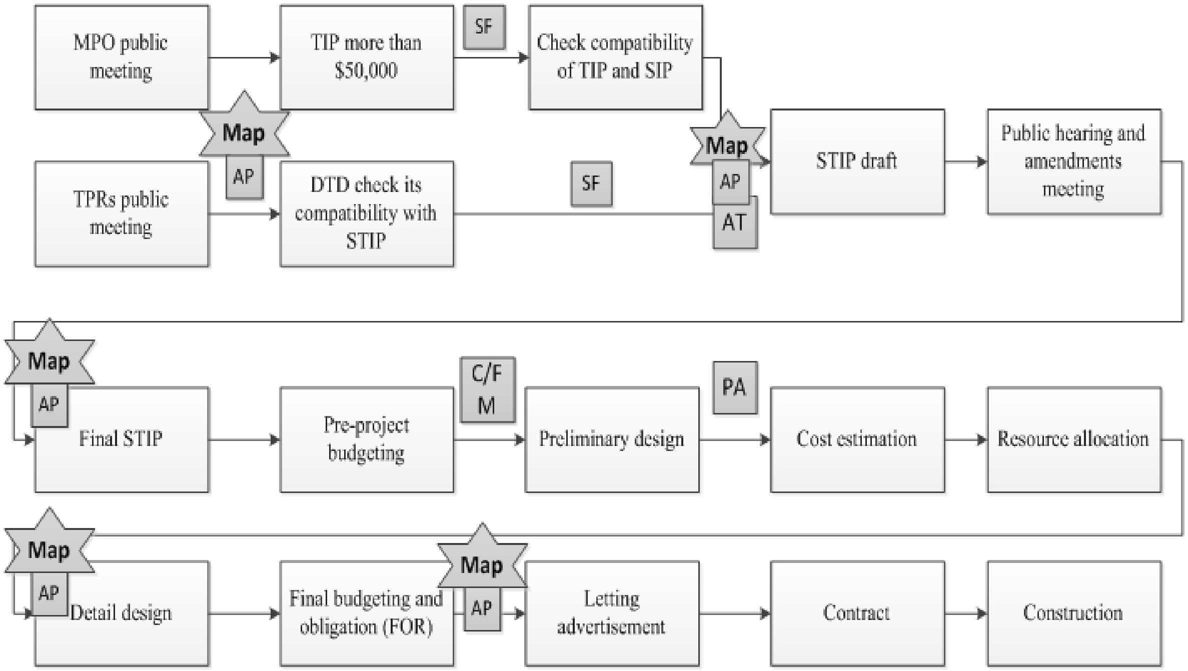



Figure 4-6: Application of complex project management layer to the CDOT project development process (CDOT 2013).

As shown, the first complexity mapping and action plan process is done before the project entering the transportation improvement program (TIP) and is repeated at major decision points throughout the process. Success factors and measurement criteria are defined and the team is assembled before STIP entry. The cost model and finance plan is prepared with pre-project budgeting and amended throughout the process until final office review (FOR).

## Conclusions

This paper generalizes state transportation agency project development processes according to the major common steps and applies the complex project management process to STA development processes. The complex project management process consists of complexity mapping, five project management methods, and 13 execution tools.

Although complex projects are not necessarily large-scale projects, the probability of complexity is greater for large projects than for small projects because more parties are involved and interact with each other. Project complexity can be tracked in five dimensions—cost, schedule, technical, context, and finance—to ensure that complexity decreases as the project proceeds and focus attention and effort on the more complex dimensions for the project, helping to avoid critical situations.

This paper demonstrates the compatibility of the complex project management process with STA development processes by applying it to the FHWA project development process and three different state DOT processes.

Project managers can overlay the complex project management development process onto their own process and find benefit in using it to track functional project complexity dimensions, detect and target potential risks that threaten project success, and plan to ensure risks are addressed as needed. The SHRP 2 Renewal Project R10 Project Management Strategies for Complex Projects Guidebook fully describes the associated complex project management strategies, methods, and tools that can be utilized and leveraged on complex transportation projects (Shane et al. 2012).

# CHAPTER 5. FUNDING AND FINANCING OPTIONS FOR SURFACE TRANSPORTATION PROJECTS IN THE UNITED STATES

Bahrevar, E., J. S. Shane, H. D. Jeong. Financing Options for Surface Transportation Projects in the United States. Accepted in 2014 Transportation Research Record, 2014.

## Abstract

The deficiency of transportation facilities in the United States has originated from an uncoordinated growth of supply and demand, continued aging of current facilities, increased maintenance and rehabilitation costs, and insufficient federal and state transportation revenues as a result of inadequate fuel taxation. This deficiency has produced congestion, heavy traffic, and pollution of many varieties especially in metropolitan areas. Therefore, national and state transportation agencies are seeking solutions by working on various potential remedies. The solutions include trying to decrease the demand for new facilities by changing consumption patterns, improving public transportation, substituting fuel taxation with more sustainable fees (such as vehicle miles traveled (VMT)), and introducing innovative financing options for transportation projects, including options with access to private capital. In this paper, different financing options are introduced and their application is analyzed through 12 case studies from complex transportation projects completed by state and federal agencies across the nation.

## Introduction

The United States (U.S.) transportation infrastructure relies on surface transportation for commerce and mobility, of which highways are a major component and have a tremendous role in economic competitiveness and overall quality of life. The lack of coordination between surface transportation demand growth and investment and capacity increases has resulted in many challenges, including traffic congestion. These challenges add indirect costs such as air and noise pollution to the transportation infrastructure.

In terms of vehicle miles traveled (VMT), surface transportation has increased 95% from 1980 while road capacities have increased by only 4%. As a result, the National Surface Transportation Policy and Revenue Study Commission recommends spending approximately three times the current amount in each of the next 50 years (Burwell and Puentes 2009). Strategies to manage, shift, and reduce demand are options that should be considered in parallel with investment increases. Both are needed to address the deficiencies in funding to meet the current spending needs in the U.S. (Burwell and Puentes 2009).

Although states account for half of all highway transportation revenues and expenditures, all levels of government contribute to funding and financing, so system efficiency requires proper collaboration among all of the agencies (Downey et al. 2008). The current transportation infrastructure relies on fuel taxation as its major source of revenue. Figure 5-1 illustrates the contributions of each level of government and sources of revenue in highway and transit funding in the U.S.

In 2004, federal government funding accounted for 20% of highway and transit funding, with 82% of that from fuel taxes. This differs greatly from the 44% state funding, which was only 38% fuel taxes, and the 30% contributed by local governments, of which only 2% was fuel taxes.

The funding deficiencies are caused by several factors including the following:

- Fuel taxes have generally not grown or been adjusted to inflation since 1993 (Burwell and Puentes 2009)

- Economical and alternative fuel vehicles (such as electric vehicles) decrease fuel tax revenue and fuel taxes do not charge drivers equally for miles traveled (Special Report 285 2006)
- Fuel taxation is regressive because rural area drivers drive longer distances and pay more fuel tax, although they pose a lower cost to society compared to drivers in metropolitan areas in terms of traffic and pollution
- Fuel tax revenue is insufficient for future needs considering constant growth in transportation infrastructure construction and maintenance costs (Burwell and Puentes 2009, Special Report 285 2006 , FHWA 2002)

These factors drive federal and state transportation agencies to seek other sources of revenue for short-term, mid-term, and long-term transportation planning in an effort to cover this gap and fund future projects. Objectives associated with innovative financing, such as maximizing the ability of states and project sponsors to leverage federal capital for transportation investment, utilizing existing funds effectively for major transportation projects, and delivering projects more quickly and with lower cost, cannot be met with traditional financing mechanisms (FHWA 2002).

A VMT tax system that charges drivers based on miles driven has been proposed as a substitute for the problematic and regressive fuel taxation. To measure miles traveled, a global positioning system (GPS) device needs to be installed (and utilized) on each vehicle. This method was tested successfully through a pilot program in Oregon (Whitty 2007). A VMT tax system is fairer because the fee structure can be adjusted to account for rural and urban areas and address the regressive nature of funding by fuel taxation (CBO 2012).

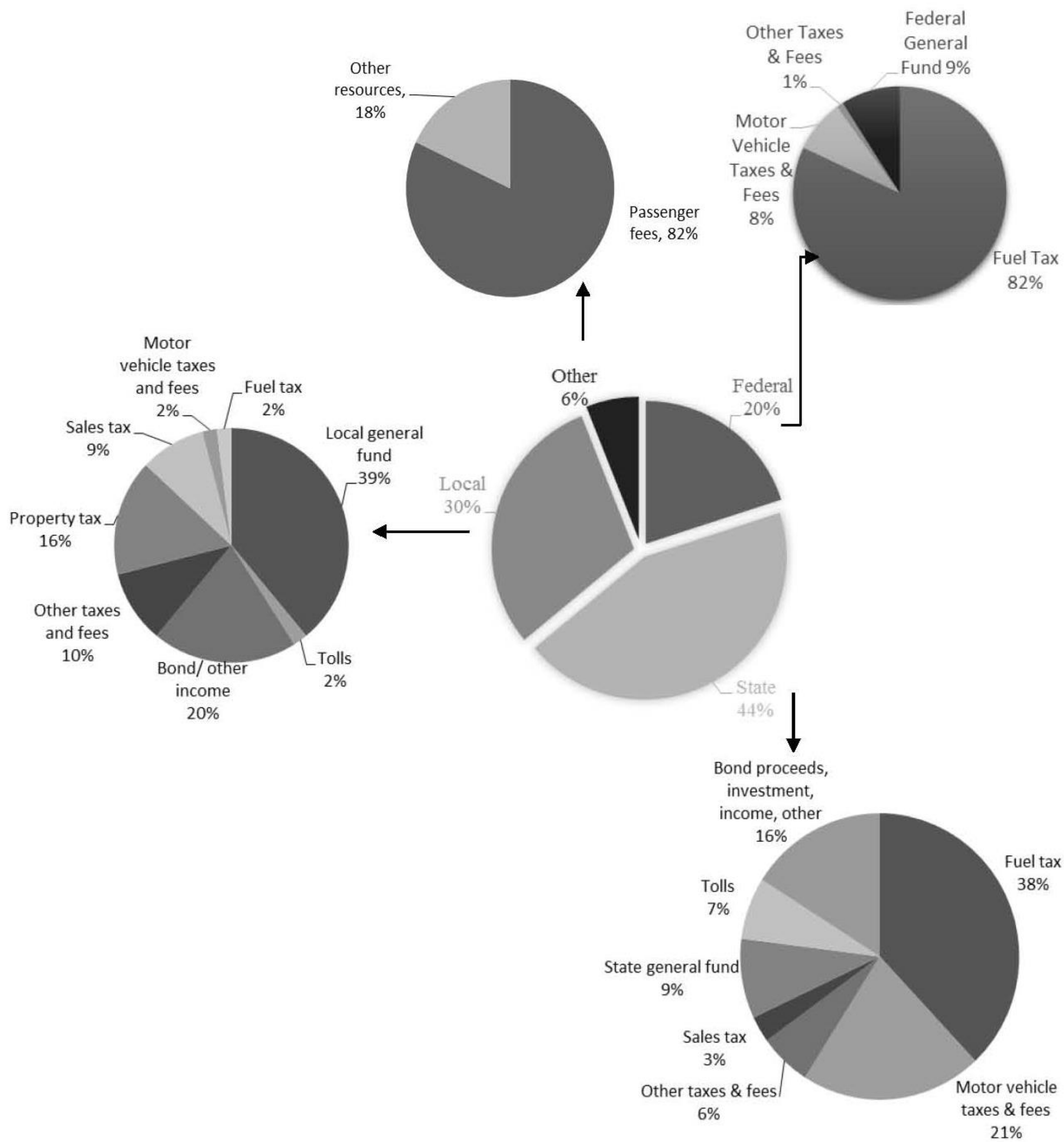



Figure 5-1: Highway and transit funding in the United States (2004) (adapted from Downey et al. 2008).

Federal and states transportation agencies have explored new sources of revenue for projects from traditional approaches to more innovative versions including new taxes, tolls, and fees, such as vehicle excise taxes, congestion pricing, rush hour fees, variable parking fees, VMT pricing, and High Occupancy/Tolls (HOT) lanes. Based on state revenue needs, all of them have explored some of these methods. However, the possibility of implementing some of these methods also depends at least to some degree on traffic density and the availability of technology.

Although a majority of the transportation budget comes from traditional options, states use innovative options to finance new projects or to accelerate project completion (Special Report 285 2006, Whitty 2007). Still, most state transportation agencies are not experienced in innovative financing options. Thus, agencies can miss opportunities when they overlook options due to lack of knowledge or expertise or when making uninformed decisions about possibly using them.

Research is needed to determine advantages and disadvantages of new and innovative options and to help state agencies make better decisions by considering all possibilities and the current cost/benefit studies on use of them. This paper presents innovative financing alternatives and discusses their use in 12 case studies.

## Background

Based on state structure, layers of responsibility, decision-making processes, and revenue sources, each agency uses a combination of traditional and innovative financing methods for surface transportation projects.

## Transportation Funding Sources

Taxes, tolls, and fees are traditional revenue sources that all states use in different combinations as a major source of surface transportation revenue. Figure 5-2 presents the various financing options in the U.S. in chronological order from top to bottom (Rall et al. 2011). The options are shown by category from left to right, starting with the more traditional options on the left and moving to the more innovative ones on the right.

Taxation is major source of revenue for federal and state governments. Property tax, fuel tax, and sales tax have been used for transportation projects for more than one hundred years. More recently, states have used excise and other taxes.

Tolling refers to charging vehicles for using a specific facility, such as a road or a bridge. While tolling is one of the oldest methods of generating revenue for transportation projects, some new types of tolling, such as congestion pricing, have been introduced in recent decades to generate revenue.

Fees are a third traditional finance option and they are generally more significant for state and local governments. While vehicle registration fees have been a common funding source, VMT has been proposed recently for future transportation projects as a substitute for fuel taxes (FHWA 2009).

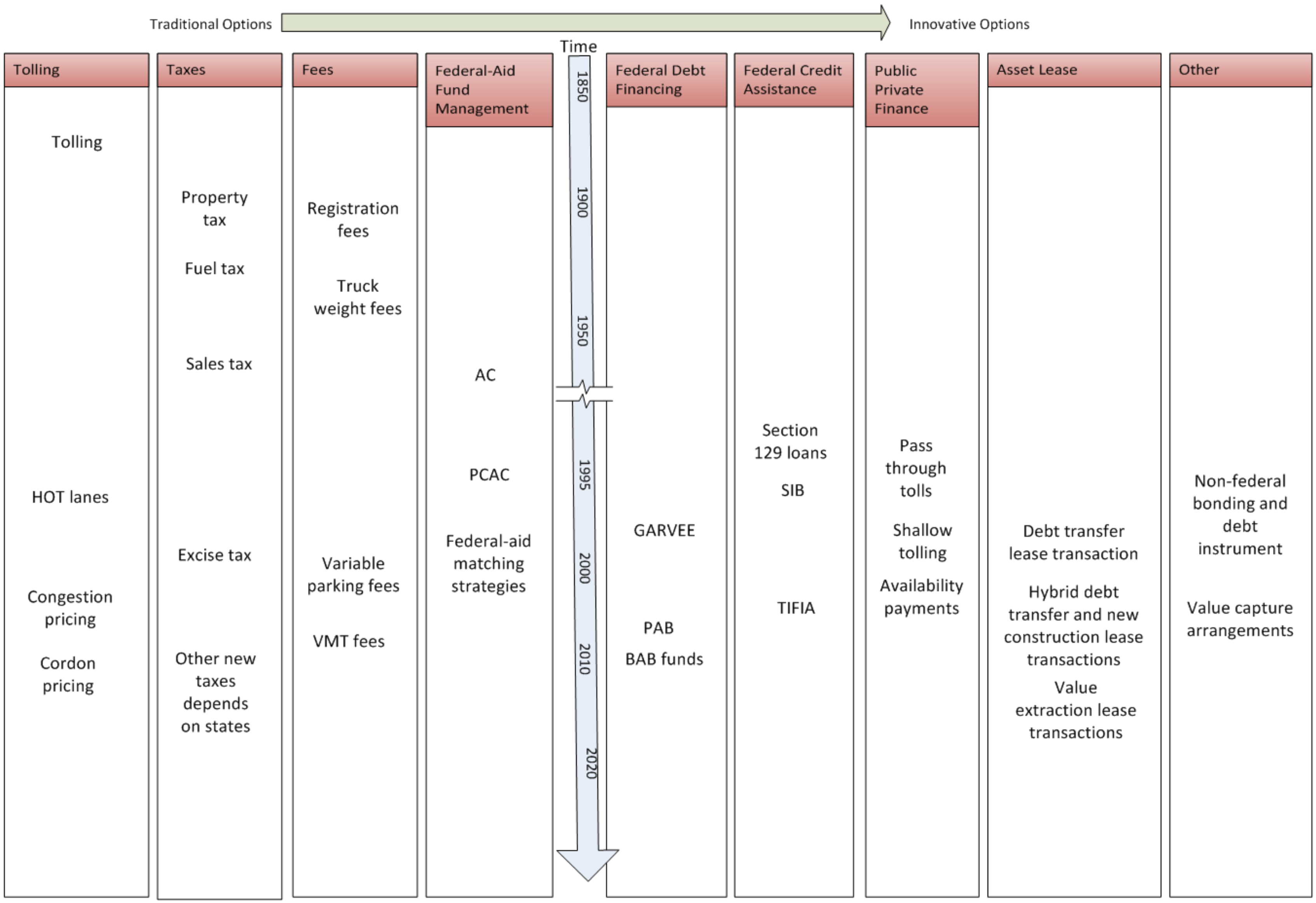


Figure 5-2: Alternative financing options for surface transportation projects (FHWA 2002, Rall et al. 2011, and FHWA 2013).

## Innovative Funding and Financing Options

Since the 1990s, states have increased their use of alternative innovative financing options to increase revenues and cover needs. The following sections discuss the six major financing option categories. Each type of option includes several tools for use.

### *Federal-Aid Fund Management*

State and local governments are required to fund at least 20% of federal-aid projects. Three federal-aid fund management tools provide states with flexibility in timing, obligations, and reimbursement restrictions related to the funding. Projects using these mechanisms should meet Title 23 requirements (FHWA (Title 23) 2012).

- Advance Construction (AC) provides states with the ability to start projects concurrently in the absence of sufficient federal aid and, when federal funding becomes available, change to federal aid and be reimbursed for the expended funds.
- Partial Conversion of Advance Construction (PCAC) allows states to convert, obligate, and receive reimbursement for only a portion of the federal share, so they can deliver the project more quickly.
- *Fe*deral-Aid Matching Strategies, through flexible match, tapered match, and toll credits, allow states to increase investments and accelerate projects (*FHWA 2002, FHWA 2013*).

### *Federal Debt Financing*

Some projects are so large and expensive that funding needs exceed current year grant funding. If only current year funding is used, it may consume the entire year's federal aid and delay other planned projects, or it may exceed a single year's allocation to the state. On these projects, debt financing is a common solution. Although borrowing funds puts interest and other debt costs to the project, it prevents costs from delay caused by inflation, wasted fuel, and deferred economic development. Three innovative debt financing tools are covered here.

- Grant Anticipation Revenue Vehicles (GARVEEs) are bonds/securities paid back by future revenue. Two types of GARVEE options are specific for highway projects and meet Title 23 specifications (FHWA (Title 23) 2012). Direct GARVEEs are reimbursed directly by federal assistance. Indirect GARVEEs are not considered federal financing tools, and these may be reimbursed from project revenues. States can use GARVEEs to access capital markets, accelerate construction timelines, and spread the costs of the facility over its useful life (FHWA 2002, NCHRP 20-5 2009, FHWA 2013).
- Private Activity Bonds (PABs) involve the private sector in tax-exempt municipal bonds. PABs are limited to $15 billion per project to provide private developers with tax-exempt interest rates that lower the cost of capital and enhance investment prospects. Involving private investors generates new sources of money, ideas, and project efficiency (NCHRP 20-5 2009, FHWA 2013).
- Build America Bonds (BABs) are tax credit bonds issued by the Treasury Department. The two forms of BABs, tax credit and direct payment, were first issued in 2009. The interaction between the involved parties determines the form of the BAB. The interest rate for tax credit BABs is one percent higher than for direct payment BABs (FHWA 2013).

### *Federal Credit Assistance*

Federal credit assistance tools provide project developers with larger capital, accelerating the project, and reduce the risk of investors, reducing the interest rate. Federal credit assistance works as follows for loans: first, where federal highway funds are borrowed directly, and second, in credit enhancements, where federal funds are kept available on a standby basis. Federal credit assistance tools exist in three forms:

- Section 129 Loans allow federal participation in state loans to support Title 23 eligible projects that have toll, excise tax, sales tax, real or incremental property tax, motor vehicle tax, or other beneficiary fees as revenue streams, to improve credit market access or capture lower interest rates
- State Infrastructure Banks (SIBs) manage state infrastructure investment funds and give states the capacity to use their funds efficiently and to leverage federal resources by attracting non-federal public and private investments
- The Transportation Infrastructure Finance and Innovative Act (TIFIA) provides direct loans, loan guarantees, or standby lines of credit for nationally- or regionally-significant projects that meet its criteria, for 33% of the total cost of the project (*4, FHWA (Title 23) 2012, Dierkers and Mattingly 2009, FHWA 2013*)

Projects that use Section 129 loans do not need to meet all federal requirements for SIB loans to obtain benefits of credit assistance tools, such as lower interest rates (*FHWA 2013*).

SIBs are established by federal-aid surface transportation funds or matching states funds in 33 states and are one of the signs of the state level of activity in transportation development (Burwell and Puentes 2009). SIB repayments from federal and non-federal sources are required to meet Title 23 or Title 49 requirements (FHWA 2012). SIBs are more flexible than other tools and can be used to complete existing federal, state, or local transportation projects. SIBs provide assistance in the forms of loans (e.g., loans at subsidized rates and/or with flexible repayment provisions, subordinated loans, short-term construction or long-term debt financing); credit enhancement (e.g., capital reserves and other security for bond or debt instrument financing, letters of direct pay or stand-by credit, lines of credit, bond insurance and loan guarantees); and other forms (GARVEEs, certificates of participation or lease purchase agreements, direct and indirect interest rate subsidies) (Puentes and Thompson 2012).

A TIFIA is reimbursed in whole or in part by non-federal sources, such as tolls, user fees, or special assessments (such as taxes) (FHWA 2013).

*Public Private Finance*

Public-private partnership (PPP) contracts are powerful tools for states to access private capital, improve efficiency, accelerate projects with lower cost, share project risk, and manage and develop transportation infrastructure. These contracts differ based on the portion and responsibility of each public and private part.

Twenty-nine states and Puerto Rico have enacted authority for state transportation agencies to consider and conduct PPPs for highway projects. PPP contracts based on repayment mechanisms are classified into three types: toll concessions, shallow toll concessions, and payment concessions.

With toll concessions, where the concession is reimbursed by collecting tolls on a facility, the maximum toll amount is usually determined in the contract. With this method, the concessioner accepts the risk of revenue upside or downside.

With shallow toll concessions, where the concessioner receives a set payment from a public agency called the “shallow toll” for each vehicle that uses the facility, the traffic risk is transferred to the concessioner. Therefore, the concessioner has a strong incentive to provide a high quality service level to attract traffic.

Finally, availability payment concessions are used for projects on which tolling is not suitable and the concessioner receives periodic availability payments (which is usually higher in primary years due to construction cost) from the federal payment for operation of a facility at the specified performance level; if the standards are not met, the payment could be reduced (Rall et al. 2010, FHWA 2013, FHWA 2012).

Although PPP contracts have various benefits for states, they face some public opposition based on concerns about higher tolls and decreased public control over vital transportation facilities (Burwell 2009).

### *Asset Lease*

Asset lease is a specific type of PPP, where an existing publicly-financed toll facility, such as a road, bridge, or tunnel, is leased to the private sector for a determined period of time (usually 25 to 99 years). The private sector collects tolls and operates the facility, pays for its maintenance, or improves it. The private sector needs to pay an up-front concession fee, which could be used for improving other transportation projects. Long-term lease options can be categorized into three groups:

- Debt transfer lease transaction requires the private concessionaire to maintain the facility and cover later capital repairs to address safety and condition issues through the lease period. The concession fee is used to pay the facility debts with no additional funds for the public sector.
- Hybrid debt transfer and new construction lease transactions are where the private sector pays the facility public debt and agrees to complete new extensions to the toll facility.
- Value extraction lease transactions are where the concession fee pays all public debt of the facility and a sizable amount remains for the public sector to use for other needs. In

this category the private concessioner is responsible for maintenance and capital improvements of the facility through the concession period (Burwell 2009, Rall et al. 2011, FHWA 2013).

*Other Innovative Finance Options*

In addition to the previous five financing options, some other practical innovative financing options that have been used are discussed in this section.

- Non-federal bonding and debt instruments, such as tax-exempt municipal debt is an innovative finance option. Some bonds in this category are municipal/public bonds (tax exempt bonds issued by state or local government), revenue bonds (a type of public bond), limited and special tax bonds (a form of municipal bond such as tax increment financing), nonprofit 63-20 financing (tax exempt status results from partnerships between nonprofit public benefit corporations and public agencies in issuing a private debt), private bond issues (taxable bonds), and certificates of participation (tax exempt bonds issued by state entities and secured with a revenue stream) (FHWA 2013).
- Value capture revenue is an option that works based on the relation of the transportation network and urban land value. Improving transportation projects increases the values of local properties because of improved access, and this option works based on capturing some part of this value increase as revenue for later improvements. Special assessments or special taxes that work based on assessing taxes on parcels that directly benefit from transportation improvement is the most prominent value-capture tool in the U.S. Other value-capture methods include development impact fees (DIFs), which are one-time charges levied on new developments, developer contributions, and tax increment financing (Levinson and Istrate 2011).

A number of other financing options are available to transportation agencies. Some of these options can be used to control and manage demand and driver behavior. For example, congestion or cordon pricing and variable parking fees can discourage drivers from using their private vehicles to access downtown or crowded areas and lead them to use public transportation instead. These options may require less investment for improvement (e.g., new buses), decrease the demand for new infrastructure, and reduce the rate of environmental pollution production. Transportation agencies must plan for short-term, mid-term, and long-term funding needs. Short-term plans may take the form of increasing fuel taxes and implementing other taxes, tolls, or fees. Mid-term plans could provide the context for access to other revenue options, such as preparing legal requirements for use of each tool, or being equipped with technologies needed for tools such as electronic tolling. Long-term planning should address the implementation of fuel tax replacement and explore additional innovative options for financing surface transportation needs (Burwell 2009).

## Case Studies

To learn more about innovative financing option applications and results, 12 projects were selected from the Second Strategic Highway Administration Program (SHRP 2) Project Management Strategies for Complex Projects case studies. The researchers selected these projects from different locations, with different sizes, and in different phases of development (Shane et al. 2010). The financial information and financing options for each project were examined for this paper.

*I-95/New Haven Harbor Crossing*

The I-95 New Haven Harbor Crossing is a Connecticut Department of Transportation (ConnDOT) multi-modal transportation program to enhance traffic conditions and road improvements along 7.2 miles of I-95 in the greater New Haven, Connecticut area. I-95 was carrying 140,000 vehicles per day (VPD), which was more than three times the designed traffic volume. This project included replacing a "Q" bridge with a new extra-dosed bridge. The project construction consisted of 12 separate contracts. The total cost was funded 88% by the Federal Highway Administration (FHWA) with the remainder by state and local governments in the forms of discretionary funds and state special transportation funds (STFs).

*Oklahoma City I-40 Crosstown*

The I-40 Crosstown project was 4.5 miles of a 10 lane interstate to replace the existing elevated interstate. The estimated project cost was approximately $650 million. The project was financed through federal dollars and state funds.

Ft. Lauderdale I-595 Corridor Roadway Improvement*s*

The Ft. Lauderdale I-595 Corridor Roadway Improvements project in Florida included reconstruction of 10.5 miles of the I-595 main line and all associated improvements to frontage roads and ramps. In 2010, the Florida DOT (FDOT) found a design-build-finance-operate-maintain (DBFOM) contract, which is a form of PPP, could be the best delivery method option, bringing considerable cost savings over the life of the project. In addition, the highway will reach traffic capacity 15 years sooner compared to traditional methods.

This project was the first DBFOM project in the nation for a 35 year period, and availability of the financing would speed up the construction schedule, making it attractive. The project was eligible for federal funding and received a TIFIA loan.

Financing challenges that FDOT faced were the legislative process, federal funding, revenue generation, advance construction, cordon/congestion pricing, PPP, risk analysis, and global participation. Public perception and acceptance, which can be difficult with PPP projects, was not a problem given the period is not long (35 years) and the toll is set by FDOT.

*St. Louis New Mississippi River Bridge*

The Mississippi River Bridge project, through collaboration of Missouri and Illinois, consisted of building a new, four-lane, long-span, cable-stayed bridge and roadway connections. Severe traffic made the redesign and expansion a priority.

The design-bid-build (DBB) delivery method was selected with 5 design contracts and 31 construction contracts. Some of those contracts use 100% state program funds, while others have a mix of state capital appropriations, GARVEE bonds, and federal appropriations.

Breaking the project into fundable phases helped the project proceed. Waiting for the transportation bill was the major financing issue of the project. The dual state appropriations, plus program funds from both states and federal appropriations, complicated the tracking of cost allocations to different project components and funding lines.

The Missouri side of the project was funded by GARVEE bonds and program funding for “State Works,” and the Illinois side was funded by transportation bill appropriations provided in the Illinois capital bill in 2008 and state appropriations used for interchanges.

*North Carolina Turnpike Authority Triangle Expressway*

The Triangle Expressway is the combination of two projects consisting of 19 miles of new roadway with modern toll facilities. The total awarded value of the project was $583 million in a design-build (DB) contract for capital cost (construction and right-of-way/ROW) and operation and maintenance costs.

The project used bonding for financing. However, the market collapse simultaneously with bidding document release became an issue for the bond rating. Cost overrun was another concern that the North Carolina DOT (NCDOT) agreed to pay, which helped the project with the market rating on the bond market. If everything under the control of DB concessioner is completed on time, they receive an extra $2 million.

*Texas State Highway 161/President George Bush Turnpike (PGBT) Western Extension*

Texas State Highway (SH) 161 is a four-phase project that consists of an 11.5 mile tollway. The Texas DOT (TxDOT) is responsible for phases 1 and 2, and part of 3, and the North Texas Tollway Authority (NTTA) is responsible for part of the third phase in addition to the fourth phase.

The NTTA will operate and maintain the tollway and generate the revenues from it. TxDOT will continue to maintain and operate the frontage roads, which were Phase 1 and portions of Phase 2 of the project. These two organizations share the SH 161 revenue equally. The NTTA financed the estimated $601.5 million Phase 4 through a Transportation Investment Generating Economic Recovery (TIGER) TIFIA loan issued for $393 million and toll revenue bonds.

*Denver T-REX*

T-REX is a public transportation expansion project consisting of 17 miles of highway expansion and improvements to I-25 and I-225 in Colorado and 19 miles of light rail developments along these routes.

A DB contract was selected because of schedule savings with the least inconvenience to the public and a single point of responsibility. The project was financed through two federal sources (*Federal Transit Administration/*FTA and FHWA), the Colorado DOT (CDOT), the regional transportation district (RTD), and local agencies. CDOT used bond sales to finance highway portions of the project.

Given that T-REX was a multimodal project, there were a number of restrictions on how the money could be split and used. The marketing campaign of this project worked well and the project was in the daily news.

### *Capital Beltway*

The Capital Beltway project in northern Virginia consists of four 14 mile high occupancy vehicle/high occupancy toll (HOV/HOT) lanes and reconstruction and improvement of 11 interchanges and 50 bridges.

The project delivery method is PPP with a DBFOM contract for an 85 year concession period. The total project cost is $2.068 billion, which is financed by PAB (28.5%), TIFIA loan (28.5%), Commonwealth of Virginia grant (19.8%), Virginia DOT (VDOT) change order (4%), interest income (2.4 %), and private equity (16.8%) financing alternatives. The concessionaire receives revenue of the project through electronic tolling for 80 years. The independent financing team works with an innovative project delivery group to consult on financing of the project.

### *Ohio River Bridges*

The Ohio River Bridges project links Louisville, Kentucky and southern Indiana. The project consists of two long-span bridges across the Ohio River. The Kentucky side involves a new downtown interchange in Louisville and a new east-end approach that includes a tunnel and reconfiguration of existing interchanges. The Indiana side has a new approach and a new 4.2 mile highway.

After FHWA authorization in 2003, the cost estimate was revised and increased to $4.1 billion, two times the previous estimate, and this change put the project on hold until a feasible financial plan and funding sources could be obtained. The delivery method will be DB contracts and traditional methods.

At first, traditional financing methods were sufficient for the project but, after cost increases and inflation in 2003, they needed to consider all innovative methods. Indiana has some money in tolling that can be used, but Kentucky does not. GARVEE bonds in two stages were the major financing source that have been used for design and ROW purchasing. Estimated funding availability mentions GARVEE, the Transportation Equity Act for the 21st Century High Priority Program (TEA-21 HPP), Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users High Priority Projects (SAFETEA-LU HPP) and discretionary grant, annual federal appropriation earmarks, and future federal discretionary programs as planned funding sources for Kentucky and federal aid formula and state transportation funds, TEA-21 HPP, SAFETEA-LU HPP, annual federal appropriation earmarks, and future federal discretionary programs as likely Indiana funding sources. Project toll-based funding is another revenue source of the project. Some innovative methods such as VMT fees, tolling, congestion pricing, franchising, and private financing were other options considered. Inflation, change orders, and delays are major financing risks of the project.

### *Doyle Drive*

The Doyle Drive project, also known as Presidio Parkway, is a one and a half mile gateway to the Golden Gate Bridge, including new roadway, structures, bridges, tunnels, and a depressed roadway section. The project includes eight different contracts. To begin construction sooner, achieve seismic safety faster, and shorten the construction and original schedule, the project was divided into two major phases: the first phase delivery method is traditional delivery or a design-bid-build (DBB) contract and the second phase contract is DBFOM (which is type of PPP) with a 30 year period.

The project is financed through a number of sources such as federal grants, the American Recovery and Reinvestment Act, the California State Highway Operations and Protection Program (SHOPP), California Transportation Congestion Relief Program (TCRP), California State Local Partnership Program (SLPP), San Francisco Proposition (Prop) K sales tax, the regional improvement program, Metropolitan Transportation Commission bridge tolls, Surface Transportation Program (STP) and Congestion Mitigation and Air Quality (CMAQ) funds, the Golden Gate Bridge Highway and Transportation District, and regional improvement programs of the Transportation Authority of Marin (TAM) and the *Sonoma County Transportation Authority* (SCTA).

*Detroit River International Crossing*

The Detroit river International Crossing is a joint U.S./Canadian bridge and roadway project that connects I-75 in Detroit, Michigan with Highway 401 in Windsor, Canada. The owners considered a DBFOM contract, authorization to sell revenue bonds, and lease payments, but are using a PPP to make a self-sustaining structure that does not use public taxes. This project relies on tolling revenue for its financing.

*Washington, DC and Baltimore Intercounty Connector (ICC)*

The Intercounty Connector (ICC) is a new 18.8 mile stretch of east-west highway that includes construction of numerous new highway interchanges and bridges. It is a state-of-the-art, toll-operated, multi-modal roadway with limited points of access. The project consists of five DB construction contracts financed by several funding sources including GARVEE bonds, authority toll revenue bonds and cash, TIFIA loans, state general funds, the state transportation trust fund, special federal funds, and funds from GARVEE sales.

## Discussion and Results

Based on these 12 projects in different phases of development/completion, use of new and innovative financing options is obviously beneficial, especially on complex and large projects. As summarized in Table 5-1, all projects have used some combination of traditional and innovative options.

Although federal debt financing tools are the most common tools used, federal credit assistance tools and other innovative financing options and tools are being used. Use of PPP financing is growing fast, which decreases the dependency on tax-related options, and could help reach sustainable project performance, as in surface transportation projects that can pay for themselves.

Table 5-1: Case Study Financing Options (Shane et al. 2010)*

| Case Study | Traditional Methods | | | Innovative Methods | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Tolling | Tax | Fees | Federal aid fund management tools | Federal debt financing tools | Federal credit assistance tools | Public private finance mechanism | Asset lease | Other innovative finance mechanisms |
| I-95/New Haven Harbor Crossing | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ |
| Oklahoma City I-40 Crosstown | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ |
| Ft. Lauderdale I-595 Corridor | ✓ | | ✓ | ✓ | | ✓ | ✓ | | ✓ |
| New Mississippi River Bridge | ✓ | ✓ | ✓ | | ✓ | | | | ✓ |
| North Carolina Triangle Expressway | ✓ | ✓ | ✓ | | ✓ | | | | |
| Texas 161 Western Extension | ✓ | ✓ | ✓ | | | ✓ | | | |
| Denver T-REX | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ |
| Capital Beltway | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Ohio River Bridges | ✓ | | ✓ | | ✓ | | ✓ | | ✓ |
| Doyle Drive | ✓ | | ✓ | | ✓ | | ✓ | | ✓ |
| Detroit River International Crossing | ✓ | | ✓ | | | | ✓ | | |
| Maryland Intercounty Connector | ✓ | ✓ | ✓ | | ✓ | ✓ | | | ✓ |

* Based on case study research report and information available online; doesn't necessarily include all possible methods or new methods that are being use.

Each of these innovative financing options has some advantages, but also faces some opposition from the general public and state transportation agencies. Opposition originates from concerns about customer fees for transportation infrastructure, ownership and management of key transportation facilities, and the private sector absorbing the benefits associated with ownership.

Furthermore, state agencies need state legislatures to pass laws that allow use of innovative transportation financing options. In addition, because many state agencies are not experienced with these options or do not have skilled human resources in relevant areas, their requests may be ignored.

However, the problematic deficiencies in transportation infrastructure drive states to find ways to employ these innovative financing options. The FHWA and other responsible organizations try to help state agencies by providing them with reports, instructions, and research on available financing options. These agencies also draw on work from other states and international cases to avoid repetitive mistakes.

Attempts to minimize the need for new facilities by shifting demand to other areas that require less investment (e.g., public transportation) are a top priority. The second area of this effort is replacing fuel taxation by VMT fees that charge road users based on miles traveled, which can also be utilized in support of environmental concerns. In low traffic density areas, specifically for lower numbers of paying drivers, the traditional options face real problems in reimbursing transportation bills and need federal support and innovative financing options accessibility to perform satisfactorily (Downey et al. 2008).

# CHAPTER 6. SUSTAINABLE HIGHWAY INFRASTRUCTURE RATING SYSTEMS: GENESIS, EVOLUTION, AND ENVISIONED 'NATIONAL' MODEL

Bahrevar, E., J. E. Alleman, P.E., F. ASCE, J. S. Shane, M. ASCE, K. Gopalakrishnan, M. ASCE. Sustainable Highway Infrastructure Rating Systems: Genesis, Evolution, and Envisioned 'National' Model. Will be submitted to Journal of Urban Planning and Development (ASCE), 2014.

## Abstract

This paper examines the genesis, evolution, and projected future for both rating and checklist systems used to assess and advance sustainable highway infrastructure systems. Seventeen (17) options established within just the past decade are listed within this paper, with varying levels of maturity ranging from '*early and as yet un-applied'* to '*established with 100's and perhaps even 1000's of uses*.' Six (6) US and one (1) UK versions within the latter, mature group of more well-known, and more widely used alternatives are specifically reviewed and compared. In addition, the results of an industry-focused 'highway rating system' survey intended to gauge the levels of familiarly and perspective within the construction industry sector will be presented. Lastly, the paper provides an overview assessment of various nuances with these current options, as well as concluding with a set of recommendations intended to advance an envisioned goal of consolidating these options into a more coordinated future 'national' rating strategy.

## Introduction

As described by Jeon and Amekudzi (2005), there are four overlapping objectives for sustainable transportation, including: 1) environmental integrity, 2) conservation of economic resources, 3) social quality of life, and 4) system effectiveness. Collectively, these factors have a significant level of world-wide impact, where the metrics for transportation infrastructure relative to energy use, pollutant release, and economic success are substantial (e.g., with these systems globally representing 22% energy and 25% fossil fuel demands, 30% air pollution emission, 10% gross domestic product, etc.) (Eisenman, 2012). Therefore, the current circumstance where seventeen (17) sustainable highway, or more broadly horizontal infrastructure, rating options have been created to advance the sustainability of these transportation systems, let alone that so much time and energy has been expended by the responsible governmental officials, academics, industrial leaders, etc., clearly reflects the perceived significance of this issue.

The breadth of these alternative rating systems, though, likely stems from the following range of intertwined factors:

1) There are a large number of issues to be considered in regards to sustainable transportation (e.g., covering management, environmental, biological, engineering, financial, societal, cultural, archeological, historical, architectural, geographic, political, etc. aspects),
2) These factors are inherently complex, often overlapping, and often have widely varying levels of relevance when comparing particular site-specific projects,
3) There are multiple variations with the intended application of these systems (e.g., urban *versus* rural, etc.), as well as with their focus (i.e., most are intended for highway-only

ratings, but some are intended for a full range of horizontal infrastructure applications covering rail, airports, etc.).

4) There are also variations with how the responsible, authoring developers for these systems would prioritize their rating factors, as well as how these ratings might then be used to award certification levels which recognize and reward as it were higher sustainability outcomes.
5) Even then, a checklist rather than rating points may be used, where the goal may not be to award certification levels *per-se* but where the system still intends to proactively guide project development towards sustainable measures.
6) The decision-making process with considering, and ultimately rating these factors, or qualifying the significance of impacts being assessed, is exceedingly challenging and often complicated by competing, emotional perspectives, and
7) These optional rating strategies were created in discrete, independent fashion with little (if any) coordination between their authors (Barrella 2010).

In retrospect, what is clearly evident is that all of these rating or checklist options were created with good intent for advancing future highway sustainability. Indeed, their collective push to advance the future sustainability of our highway systems is driven by a compelling set of associated benefits. The following background and overviews for these systems will accordingly highlight their evolution and envisioned future merger into a more coordinated national program.

## Background

*Early Project Impact Assessment Concerns*

The background aspects of 'what, why, when, and who' behind our current focus on sustainable highway and transportation systems all revolve around a recognition that highways are an essential horizontal infrastructure element. These highways must be built and maintained as an enduring asset, but at the same time they impose inevitable, recurring, significant resource demands on a decade-, if not century-, level scale which must be sustainably met.

In terms of 'what', there is no formal, single definition for 'sustainable transportation,' but the United Nation's Brundtland Commission (United Nations 2012) offered the following explanation which seems appropriate even though the original context was that of sustainability as a whole *versus* the narrower highway infrastructure: *"Development that meets the needs of the present without compromising the ability of future generation to meet their own needs."* (World Commission on Environment and Development 1987).

As for 'why', sustainability has long been a factor with highway development at local, country, and state levels given that they have always been faced with constrained budgets, public pressures, and lack of adequate resources. For instance, highway agencies have employed the use of stormwater best management practices, materials recycling, etc. for decades. In turn, the results of a national US study conducted by Barrella et al. (2010) demonstrate that nearly all DOT's recognize this issue as a compelling program goal, and have sustainability advocacy language within their core mission statements.

The 'when' details, though, are less easy to lay out, as there is no easily identifiable single point in time for the origin of interest with, and concern about, building and maintaining sustainable infrastructure. In retrospect, it would certainly be fair to acknowledge that the Persian, Greek, Roman, and Egyptian Empires were pro-actively building long-lived, durable infrastructure several millennia before the notion of sustainability was conceived. However, even as recent as the late 19$^{th}$ and mid- to early-20$^{th}$ centuries, and with large-scale construction underway across our nation for rail, power, dam, and transportation systems, it would be fair to say that project challenges with resource depletion, environmental abuse, and societal conflict were still only marginally recognized at best, and largely ignored. Indeed, in that yesteryear era, there was little concern about what we would describe today as 'sustainable' outcomes. As such, our modern shift towards addressing sustainability goals largely did not begin until well into the 20$^{th}$ century, and in the case of highway systems seemingly not even until the early 21$^{st}$ century.

In retrospect, the 1969 U.S. EPA's National Environmental Policy Act (i.e., NEPA; US Environmental Protection Agency (2013)) can probably be cited as the seminal turning point which triggered the original shift towards what we today view as sustainable project goals, prominently introducing a new regulatory demand for the completion of 'environmental impact assessment' investigations. Within the following few years, various checklist, matrix, and flow diagram strategies were developed (Herricks, 2003), intent on formalizing the quantitative and qualitative process by which the magnitude and significance of project impacts would be assessed. One such noteworthy version, the so-called 'Leopold Matrix' (Leopold, *et al.*, 1971) (by the son of legendary environmentalist Aldo Leopold) offered a particularly relevant, and still widely cited, process whose core assessment factors covered three broad aspects [i.e., 1) environment, 2) biological, and 3) societal topics]. At that point in time, roughly two decades prior to the practice of considering what eventually became known as 'triple bottom line' project elements, the Leopold Matrix probably played an early, catalytic role in eventually kick-starting the advent of our modern sustainability rating systems.

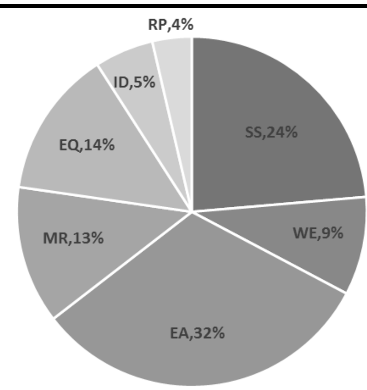
*Genesis of Sustainable Vertical Building Assessment*

The practice of sustainable green building (i.e., vertical system) assessment (i.e., Leadership in Energy and Environmental Design, or more commonly referred to as LEED) was launched in 1998 by the U.S. Green Building Council (USGBC 2013)), and this effort undoubtedly had yet another motivating impact on the following start of horizontal rating systems. As a voluntary, third-party certification system, LEED has undergone several subsequent revisions, and as of today this process has evolved into the benchmark for the design, construction, and operation of high-performance green buildings here in the US and even within several international locations.

There are seven (7) categories considered during LEED assessment and certification, as listed in Table 6-1. The 'Energy and Atmosphere' topic dominates this process with just under one-third of the points, well in keeping with LEED's namesake 'energy' and 'environment' elements.

Table 6-1: LEED Major Rating Category Topics (USGBC 2013)

| # | LEED Major Rating Category Topics | Point |
|---|---|---|
| 1 | Sustainable Sites (SS) | 26 |
| 2 | Water Efficiency (WE) | 10 |
| 3 | Energy and Atmosphere (EA) | 35 |
| 4 | Materials and Resources (MR) | 14 |
| 5 | Indoor Environmental Quality (EQ) | 15 |
| 6 | Innovation in Design (ID) | 6 |
| 7 | Regional Priority (RP) | 4 |



The degree of impact which LEED has had on the subsequent development of ‘highway’ and horizontal infrastructure rating system is readily evident in comparing their respective rating categories (i.e., as described in this paper’s following review of the Greenroads, GreenPAVE, and GreenLITES systems). Yet another element of ‘carryover’ from LEED to at least one of the highway rating systems (i.e., see following Greenroads discussion) is that LEED has a separate set of project prerequisites which must be completed (i.e., for no credit) outside the actual rating categories and their credit-earning measures. Three additional points worth noting. First, LEED certification levels are all based on a set point threshold (e.g., Gold and Platinum certifications have 60 and 80 point limits, respectively) as opposed to normalized percentile benchmarks. Second, LEED’s latest version (i.e., Version 3 released in 2009) was upgraded to incorporate the latest technology in building science, and in doing so they elevated the topics of reduced energy demand and $CO_2$ emission as high priorities. Third, detailed analyses of LEED-level green buildings have confirmed that they do provide significant reductions in energy and water demands, plus greenhouse gas emissions as compared to conventional buildings. (Kats 2003).

### *Genesis of Sustainable Horizontal Infrastructure Assessment*

The first-ever sustainable horizontal infrastructure rating program appears to have been started in Great Britain in 2003. This system’s ‘CEEQUAL’ name stands for, ‘Civil Engineering Environmental Quality Assessment & Award Scheme’, and as the name implies this system was intended to broadly cover all civil works (i.e., *versus* focusing on highway systems). This system’s awards was established for civil and infrastructure projects both within the UK and at international levels. CEEQUAL was established by the UK's Institute of Civil Engineers (ICE) and this initiative has subsequently attracted a high level of collaboration by a range of partnering organizations, including the Association for Consultancy and Engineering (ACE), the Civil Engineering Contractors Association (CECA), and Australian Green Infrastructure Council (AGIC). CEEQUAL also started another collaborative effort with the American Society of Civil Engineers (ASCE) in 2009, after which ASCE subsequently created their own so-called 'SIPRS' rating system (i.e., see following Table 6-3). ASCE subsequently pursued yet another expansion of their own collaborative efforts with two additional US partners [i.e., the American Council of Engineering Companies (ACEC) and the American Public Works Association (APWA)], which then jointly founded an entirely new Institute for Sustainable Infrastructure (ISI) and who along with Harvard University contributed yet another new rating system (i.e., Envision) described in more detail later in this paper.

The CEEQUAL rating system includes nine (9) rating categories, as shown in Table 6-2:

Table 6-2. CEEQUAL Sustainability Rating System Overview (CEEQUAL 2013)

| # | CEEQUAL Major Rating Category Topics |
|---|---|
| 1 | Project Strategy |
| 2 | Project Management |
| 3 | People and Communities |
| 4 | Land Use and Landscape |
| 5 | Historic Environment |
| 6 | Ecology and Biodiversity |
| 7 | Water Environment (Fresh & Marine) |
| 8 | Physical Resources: Use and Management |
| 9 | Transport |

The breakdown of CEEQUAL certification levels is given later in Figure 2, along with a comparative breakdown of similar award thresholds for the other rating systems reviewed within the paper.

### Overview of Current Sustainable Highway and/or Horizontal Infrastructure Assessment Systems

Including the preceding CEEQUAL system, seventeen (17) rating and/or checklist systems intended to promote sustainable highway and/or horizontal infrastructure development have now been developed during the past decade. The following Table 6-3 provides a summary review which demonstrates the breadth of these options in terms of their chronological starting points, plus general details regarding their primary responsible agencies, their intended use, and their total point numbers.

Table 6-3. Chronology of Sustainable Highway and/or Horizontal Infrastructure Rating and Checklist Systems

| # | Name of Rating System | Primary Responsible Agency(s) | Mode of Intended Use | | Total Points | Year Started |
|---|---|---|---|---|---|---|
| | | | Rating Only | Rating and Certification | | |
| 1 | CEEQUAL | Institution of Civil Engineers (ICE) | | ☑ | ? | 2004 |
| 2 | AASHTO-PB | Parsons-Brinckerhoff | Checklist | | N/A | 2005 |
| 3 | Green roads *(MS Thesis)* | University of Washington | | ☑ | 36 | 2006 |
| 4 | Green Roads (Washington State) | Green Highway Partnership | | ☑ | 54 | 2007 |
| 5 | STARS (Version 0.4) | AASHE * | | ☑ | 109 | 2007 |
| 6 | Greenroads | University of Washington & CH2MHILL | | ☑ | 118 | 2010 |
| 7 | GreenLITES | New York Department of Transportation | | ☑ | 290 | 2008 |
| 8 | GreenPAVE | Ontario (CAN) Ministry of Transportation | | ☑ | 36 | 2008 |

Table 6-3 Continued

| | | | | | | |
|---|---|---|---|---|---|---|
| 9 | Green Guide for Roads | Canada Green Building Council(CaGBC)+Stantec | ☑ | | ~78 | 2009 |
| 10 | SSI Guidelines and Performance Benchmarks | The Sustainable Sites Initiative | | ☑ | 250 | 2009 |
| 11 | Green Streets | USEPA | | ☑ | ? | 2009 |
| 12 | $BE^2ST$-in-Highways | University of Wisconsin & Wisconsin DOT | | ☑ | 12 | 2010 |
| 13 | I-LAST | Illinois DOT & Illinois Joint Sustainability Group | ☑ | | 233 | 2010 |
| 14 | SIPRS | ASCE, ACEC, APWA | ☑ | | 88.5 | 2010 |
| 15 | STEED | H.W. Lochner, Inc | ☑ | | 47 | 2010 |
| 16 | Envision | Institute Sustainable Infrastr.(ISI) and Zofnass Center (Harvard Univ.) | | ☑ | 809 | 2011 |
| 17 | INVEST | FHWA | ☑ | | 613 | 2012 |

Note: * AASHE: Association for the Advancement of Sustainability in Higher Education

**Exemplary US System Details**

*Overview of Highlighted Rating Systems*

Within the long list of sustainable highway rating systems, a limited number have proven to have levels of popularity and/or are more well-known based on their specific characteristics, or their numbers of completed case studies, or for their involved developers. Table 6-4 accordingly offers a summary of the responsible rating system developers, as well as their partners, whose efforts generated six (6) of the more well-known US rating options. The same details for the earlier British CEEQUAL option are also given within this table for comparative purposes.

Table 6-4: Comparative Overview Details of Highway and Horizontal Infrastructure Sustainability Rating and Checklist Systems

| | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| | **CEEQUAL** | **AASHTO-PB** | **Greenroads** | **GreenPAVE** | **GreenLITES** | **Envision** | **INVEST** |
| Developed by | Institution of Civil Engineers + UK Government + CRANE | AASHTO + Parsons Brinckerhoff | University of Washington + CH2M HILL +Government Organizations | MTO (Ontario Ministry of Transportation) | NYSDOT | Institute for Sustainable Infrastructure (ISI) + Harvard's Zofnass Program | FHWA |
| Private Sector | 23,24 | 25 | 7,10,15,16, 17, 18,19 | 2,10,18,20 | | 1,2,3,4,5,6,7,8, 9, 10,11,12,13,14 | 10,21,22 |
| Academia | | | 4,5 | | | 1,2,3 | 4,6 |
| Government Agency | 6 | | 1,2,3 | 5 | 4 | Future corporation with FHWA | 1 |
| Association | 3,8,9,10,11 | 7 | 2,4 | 2,5,6 | | 1,2,3 | 3,7 |

**Private Sector:** 1 - Arcadis, 2 - Arup; 3 - Autodesk; 4 -Black and Veatch; 5 - Burns & McDonnell; 6 - Golder Associates; 7 - Granite, 8 - Halcrow; 9 - HNTB, 10 - CH2M HILL ; 11 - The Louis Berger Group, 12 - MWH; 13:NV5; 14 - Power Engineers; 15 - Royal HaskoningDHV, 16 - Perttet Inc.; 17 - Ledcor CMI Inc.; 18 - KPG Inc; 19 - UNI-GROUP U.S.A.; 20 - SSPCo; 21 - High Street Consulting Group; 22 - Webkey LLC; 23 - CRANE; 24 - GLENIGAN; 25 - Parsons Brinckerhoff

**Academia:** 1 - Harvard Graduate School of Design; 2 - University of Florida; 3 - University of Texas at Austin; 4 - University of Washington; 5 - Transportation Northwest (Transnow); 6 - Texas A&M Transportation Institute.

**Government Agency:** 1 - FHWA; 2 - Washington State Transportation Improvement Board (TIB); 3 - Oregon department of transportation; 4 - NewYork State Department of Transportation; 5 - Ontario Ministry of Transportation (MTO/CAN); 6 - UK government

**Association:** 1 - American Council of Engineering Companies (ACEC); 2 - The American Public Works Association (APWA); 3 - The American Society of Civil Engineers (ASCE); 4 - Institute of Transportation Engineers (ITE); 5 - Ontario Hot Mix Producers Association (OHMPA); 6 - The Ready Mixed Concrete Association of Ontario (RMCAO); 7 - AASHTO; 8 - Construction Industry Research and Information Association (CIRIA); 9 - Association for Consultancy and Engineering (ACE); 10 - Civil Engineering Contractors Association(CECA); 11 - Australian Green Infrastructure Council (AGIC)

Two of these options were created by single developers, including AASHTO-PB (i.e., largely established by Parson-Brinckerhoff) and GreenLITES (i.e., created by the New York State DOT). In all other cases, the involved, authoring team members had a considerably more complex makeup, including partners drawn from public agency, private sector, professional association, and academic backgrounds. Harvard and the University of Washington were prominent academic partners with three options, and in the case of industry there have been recurring, noteworthy contributions with multiple systems made by CH2MHILL, Arup, Granite Construction, Stantec (Canada), and KPG, Inc. More detailed reviews of these six (6) North American rating systems listed in Table 6-4 are given in the following narrative.

*'AASHTO-PB' System*

The AASHTO-PB 'checklist' is believed to have been originally created late in 2005 by Parsons-Brinckerhoff, and was subsequently selected as the winning entry for a US-level national competition held in conjunction with the 2006 PIARC Contest (i.e., the Permanent International Association of Road Congresses). This 'PB' checklist entry for the contest's 'sustainable development' award category was submitted to AASHTO (i.e., who served as the US representative for this program) and in doing so the checklist appears to have then morphed into its current 'AASHTO-PB' name. In the years leading up to this contest and award-winning 'checklist' effort, Parsons-Brinckerhoff played a prominent role in guiding the transportation industry in its efforts to upgrade future environmental stewardship. For example, in 2002 their Vice-President and Highway Program Manager (Kassoff 2002) presented US Senate hearing testimony focused on 'environmental streamlining' of the regulatory process for next-generation highways, and by 2003 the company had started a series of training workshops designed to advance the rapidly evolving concept of 'context sensitive solutions' (CSS) as a key factor in the design of future transportation systems.

In retrospect, this first-ever US 'assessment tool' for promoting sustainable highway systems was highly comprehensive in it coverage, including the six (6) rating categories listed in Table 6-5:

Table 6-5. AASHTO-PB Sustainability Rating System Major Sections (Parson-Brinckerhoff 2005)

| # | **AASHTO-PB Major Rating Category Topics** |
| --- | --- |
| 1 | General Policies and Practices |
| 2 | Regional and Systems Planning |
| 3 | Project Planning |
| 4 | Detailed Design |
| 5 | Construction |
| 6 | Operation and Maintenance |

There are several noteworthy aspects with this 'checklist' and its assessment categories. First, while several of the following (>2006) rating systems were largely patterned after LEED, the circa-2005 AASHTO-PB system included an entirely original set of rating category topics. Second, the inclusion of a 'construction' rating category with the AASHTO-PB checklist conveys an unquestionably forward thinking element. Admittedly, the checklist does not cover a number of issues which would then receive emphasis in subsequent rating systems (e.g., where the checklist does not address advanced pavement technology, cool pavement, light pollution, etc.), but this situation is certainly reasonable given the method's early timeframe.  Third, while the checklist was not intended to serve as a prescriptive tool, it was designed to provide a pro-active "options and opportunities" framework, where specific questions would be raised about various sustainable highway possibilities, and where these options might then be gauged in regards to how important they might be for including within a project. And while the checklist metrics were developed according to sequential project phases, it was recognized that some activities might well occur in multiple phases. Therefore, advice was given that project managers should consider future project phases at an early point relative to the project's full chronological development, intent on maximizing integration of sustainability goals throughout the full project.

While not intended as a rating assessment process by which direct project comparisons or certifications might be developed, the checklist does have a 'scoring' system of sorts where one to three points are allocated per each checklist topic based on perceived importance.

*'Green roads' (2006), 'Green Roads' (2007), and 'Greenroads' (2010) Systems*

Although today's 'Greenroads' sustainable highway rating system is presently managed by the Greenroads Foundation (Muench, et al. 2011), there were a number of other parties who had a hand in its original creation and evolution. As shown in Table 6-6, there were several sequential versions, including a 'Green Roads' edition in 2006 promoted by the Green Highways Partnership (GHP 2010). The original forum event which then led to this 'partnership' had been held a year earlier, as a voluntary public-private initiative focused on advancing sustainable transportation as well as improving this industry's environmental performance. While GHP recognized the Washington DOT as the source of this 'Green Roads' strategy, much the same process planning effort (i.e., with nearly identical rating categories) was underway at the same time at the University of Washington (Soderlund, 2007). The exact sequence and due degrees of credit for these initial steps with 'Green roads,' 'Green Roads,' 'Greenroads' development remains a bit clouded. It would be fair to say, though, that these early versions collectively kick-started the continuing evolution of the eventual 'Greenroads' system (i.e., with versions V0.95 in 2009, V1.5 in 2011, and V2.0 upcoming in 2014), where these later versions were initially spearheaded by the University of Washington and CH2MHILL, and more recently managed by the Greenroads Foundation.

Table 6-6: Evolving 'Green Roads' and 'Greenroads' Sustainability Rating System Version Details (GHP 2010, Soderlund 2007, Muench et al. 2011)

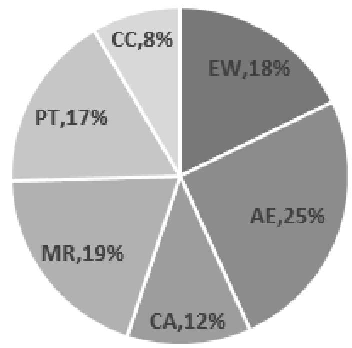
**Major Rating Category Topics For Chronological 'Green Roads' and 'Greenroads' Versions**

| # | **Green Roads** [GHP] *(circa 2007)* | **Pre-Greenroads** [Univ. Wash., RE: Soderland MS Thesis] *(circa 2007)* | **Greenroads** [Univ.Wash & CH2MHILL] *(circa 2010)* | **Greenroads** [Greenroads Foundation] *(tentative future, 2013)* |
|---|---|---|---|---|
| 1 | Sustainable Design | Sustainable Alignment | Access and Equity | Access and Livability |
| 2 | Material and Resources | Material and Resources | Materials and Resources | Materials and Designs |
| 3 | | | Pavement Technologies | |
| 4 | Energy and Environmental Control | Energy and Environmental Control | Environment and Water | Environment and Water |
| 5 | Stormwater Management | Stormwater Management | | |
| 6 | Construction activities | Construction Activities | Construction Activities | Construction Activities |
| 7 | Innovation | Innovation in Design | Custom Credits | Creativity and Effort (TBD) |
| 8 | | | | Utilities and Controls |

As presented in Table 6-7, therefore, the current Greenroads system features six (6) current rating categories, of which 'access and equity' (25%) and 'materials and resources' (19%) have the highest rating levels.

Table 6-7. Greenroads Sustainability Rating System Overview (Muench et al. 2011)

| # | Greenroads Major Rating Category Topics | Point Breakdown |
|---|---|---|
| 1 | Environment & Water (EW) | 18% |
| 2 | Access & Equity (AE) | 25% |
| 3 | Construction Activities (CA) | 12% |
| 4 | Materials & Resources (MR) | 19% |
| 5 | Pavement Technology (PT) | 17% |
| 6 | Custom Credit (CC) | 8% |



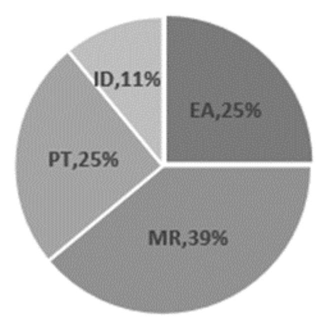

Aside from the evident cross-over linkage between these 'horizontal project' Greenroads categories and the 'vertical project' LEED rating topics (i.e., comparing Tables 1 and 7), Greenroads was also unique in following LEED's lead with stipulating eleven (11) project requirements which had to be uniformly met before rating points would be awarded.

*'GreenPAVE' System*

GreenPAVE was developed in 2008 by the Material Engineering Research Office with Ontario's (CAN) Ministry of Transportation (MTO) (Chan and Tighe 2010), and its use has a heavy emphasis on the environmental sustainability of their regional pavement projects. Based on a review of the major rating categories with which it was established, it would appear that this system was developed as an amalgamation of multiple, preceding plans (i.e., Greenroads, GreenLITES, and LEED), as well as their own Ontario pavement experience in three project phases (i.e., design, construction, and innovation). While the MTO was solely responsible for its origin, industry contributors were subsequently used to check the employed point weighting system. One of the unique differences with the GreenPAVE system is that it was the first option designed for a do-it-yourself assessment process, unlike the preceding alternatives which all relied on third party project review. Whether measured, though, by total points (i.e., approximately 34), or simplified levels of major rating categories [i.e., see Table 6-8, with four (4) core rating topics], or its high level emphasis on 'materials and resources' (i.e., covering 39% of all points) and far higher consideration of project 'economics', GreenPAVE does offer a number of procedural innovations. On the other hand, this system's reduced rating categories do not offer points for either management activities or life cycle cost analysis, and it has the lowest societal coverage of all rating systems.

Table 6-8. GreenPAVE Sustainability Rating System Overview (Chan and Tighe 2010)

| # | GreenPAVE Major Rating Category Topics | Point Breakdown |
|---|---|---|
| 1 | Pavement Technology (PT) | 25% |
| 2 | Materials & Resources (MR) | 39% |
| 3 | Energy and Atmosphere (EA) | 25% |
| 4 | Innovation and Design (ID) | 11% |

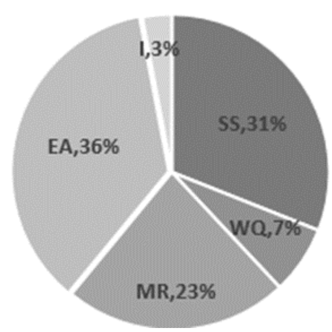



*'GreenLITES' System*

The New York State Department of Transportation (NYSDOT) created its GreenLITES (Green Leadership in Transportation and Environmental Sustainability) as a tool to integrate sustainability into all levels of planning, design, construction and maintenance operation within their state program. GreenLITES has been published in incremental steps, starting in 2008 (McVoy et al. 2010). GreenLITES's major emphasis is on the project design phase, and it also features construction quality monitoring as a rating item (NYSDOT 2010). GreenLITES was originally developed as an internal sustainability management and performance measurement to compare NYSDOT projects, and in doing there was an implicit intention to determine weak points which need more effort. Further refinements, though, upgraded this system into an advanced, multi-level sustainability certification program. As presented in Table 6-9, GreenLITES has five major rating categories, with which 'energy and atmosphere' (36%) and 'sustainable sites' (31%) dominate its point allocations. An interesting recent development with this system is that it was used as the platform for a similar DOT-level version created in Georgia (i.e., Peachroads). Yet another unique feature of the GreenLITES system, though, is that it does not cover life cycle cost analysis, and moreover it provides a fairly limited consideration of project management.

Table 6-9. GreenLITES Sustainability Rating System Overview (NYSDOT 2010)

| **GreenLITES Major Rating Category Topics** | **Point Breakdown** |
|---|---|
| Sustainable Sites (SS) | 31% |
| Water Quality (WQ) | 7% |
| Materials & Resources (MR) | 23% |
| Energy and Atmosphere (EA) | 36% |
| Innovation (I) | 3% |

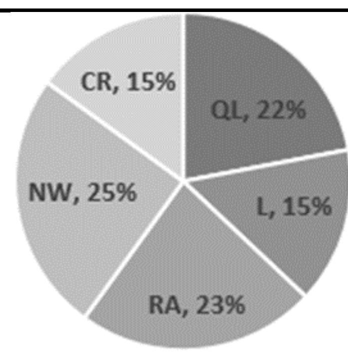


*'Envision' System*

As described earlier, Envision system is the collaborative product of the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School and the Institute for Sustainable Infrastructure (ISI), and was launched in 2011. (ISI and Zofnazz 2012) This product consists of project checklist and sustainability rating system. Funding for this effort is primarily provided by three organizations, including the American Council of Engineering Companies (ACEC), the American Public Works Association (APWA), and the American Society of Civil Engineers (ASCE), but this effort also has a significant investment coming from industry (i.e., see preceding Table 4). The Envision rating process addresses five (5) category topics, as shown in Table 6-10, with which its 'natural world' and 'resource allocation' topics are the most highly rated aspects.

Table 6-10. Envision Sustainability Rating System Overview (ISI and Zofnass 2012)

| # | Envision Major Rating Category Topics | Point Breakdown |
|---|---|---|
| 1 | Quality of Life (QL) | 22% |
| 2 | Leadership (L) | 15% |
| 3 | Resource Allocation (RA) | 23% |
| 4 | Natural World (NW) | 25% |
| 5 | Climate and Risk (CR) | 15% |



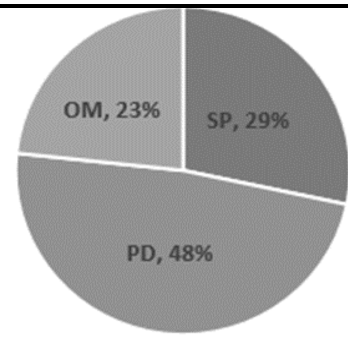

As with Greenroads and CEEQUAL, Envision operates as a third-party, for-fee sustainability audit system, and similarly provides awards at four certification levels. Similarly, the breadth of Envision's coverage (i.e., applicable to all horizontal 'civil works' infrastructure) follows that of its CEEQUAL predecessor (i.e., unlike most other US systems which are specific to highway projects). One particularly unique aspect of Envision system, though, is that it allows weighting of rating credits based on levels of achievement within each criteria (e.g., ranging from 2 points for 'improved' and 25 points for 'restorative' achievement levels).

*'INVEST' System*

The first version of the INVEST tool was originally referred to as the FHWA Sustainable Highways Self-Evaluation Tool, with its contracted developers (i.e., Professor Stephen Muench at the University of Washington and CH2MHILL's Tim Bevan) being selected in order to assimilate their unique Greenroads experience. In turn, the following INVEST (i.e., Infrastructure Voluntary Evaluation Sustainability Tool) version was launched by the Federal Highway Administration's sustainability system group in October 2012, as a collaborative product of federal and state government officials, local agencies, university faculty, professional associations, and industry (Bevan et al. 2012). INVEST's development was intended to represent a collation of best practices drawn from the other rating systems and also incorporates considerable stakeholder feedback and revision guidance. INVEST is comprehensive and commensurately complex, in that it considers the full life-cycle of a project and is evaluated on the basis of sixty (60) criteria split between three major rating category areas (i.e., see Table 6-11). INVEST is not required, and it was not intended to encourage direct project comparisons. Instead, INVEST was developed as a free, voluntary tool intended to help transportation agencies self-evaluate project sustainability, where sustainable options are suggested such that they might be considered in consort with a both short- and long-sustainable decision-making process. A notable difference with INVEST is that it does not have a certification system.

Table 6-11. INVEST Sustainability Rating System Major Sections (Bevan et al. 2012)

| # | INVEST Major Category Topics | Point Breakdown |
|---|---|---|
| 1 | System Planning (SP) | 29% |
| 2 | Project Development (PD) | 48% |
| 3 | Operation and Maintenance (OM) | 23% |




**Overview of Specific Rating System Nuances**

1) **Overall System Maturity and Stature Levels** – A number of these seventeen (17) rating and checklist systems have fairly low levels of visibility and use, to the point where they exist moreso in name without pragmatic adoption. The Envision, GreenLITES, Greenroads, and INVEST options (listed in alphabetical order), though, have far higher levels of generally acknowledged prominence and anticipated future utility.

**2) Overall System Focus** – While two (2) of the systems reviewed within this paper focused on the broader range of 'civil works' and full infrastructure (i.e., CEEQUAL and Envision), the remaining four (4) systems had a specific coverage of highway-only infrastructure.

**3) Relative System 'TBL' Emphasis** – While preparing this paper, an effort was made to qualitatively calibrate the five (5) reviewed sustainability 'rating' systems (i.e., Greenroads, GreenPAVE, GreenLITES, Envision, and INVEST, versus the AASHTO-PB checklist) on the basis of their respective point allocations distributed amongst the 'triple bottom line' focus areas, as well as their perceived consideration of system efficiency, project management, and innovation. This 'TBL' emphasis breakdown is visually depicted in Figure 6-1. The 'environmental' aspect was notably dominant in four (4) of the earlier rating systems. Interestingly, though, the latest, INVEST, option's 'TBL' breakdown shows a decidedly different, and seemingly more uniformly distributed, pattern.

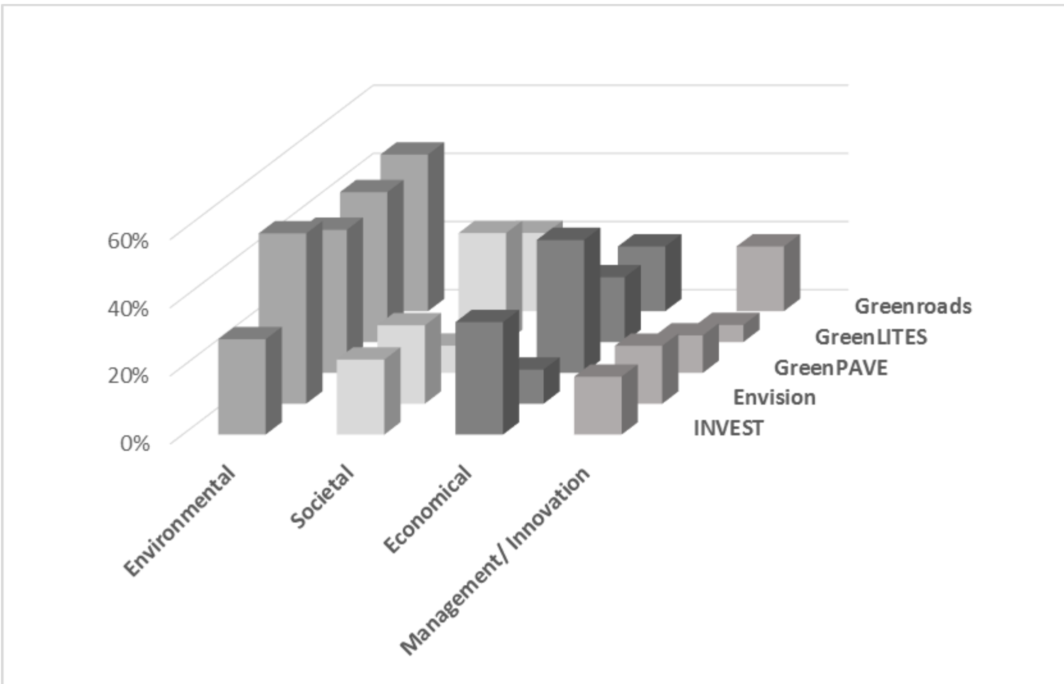



Figure 6-1: Qualitative assessment of sustainable highway rating system 'triple bottom line' focus

**4) Mandatory Versus Voluntary Systems** –Most of the reviewed rating options were designed as voluntary systems to help transportation agencies to consider alternative sustainable approaches. GreenLITES is a notable exception, having been created specifically for NYSDOT projects, and is applied with all of their new highway project improvements.

**5) Self- Versus 3rd Party-System Assessment -** Half of the reviewed systems (i.e., CEEQUAL, Greenroads, and Envision) involve 3rd party assessment, while two others (i.e., GreenLITES and GreenPAVE) are intended for their own programmatic use.

**6) System Project Requirements versus Rating Point Allocations** – The Greenroads rating system is the only one of our specifically reviewed options which has mandated 'project requirements,' in a fashion which directly mirrors its predecessor LEED system.

**7) System Coverage RE: Construction –** There is a considerable range of rating coverage given to 'construction' within the highway rating systems. For example, the construction phase is well covered in INVEST. Conversely, GreenLITES provides less attention to this issue, but this circumstance may reflect differences in their rating goals.

**8) System Coverage RE: Life Cycle and Life Cycle Cost Analysis –** LCA analysis is notably included with the Greenroads, Envision and INVEST rating system, and INVEST notably goes even further with its inclusion of life cycle cost analysis (LCCA). Conversely, neither GreenPAVE nor GreenLITES include LCA assessment. The absence of LCA with either of these latter options likely stems from their lower levels of consideration given to lifetime operation and maintenance factors.

**9) Variations in Certification Outcomes** – The following Figure 6-2 schematic provides a visual comparison of rating point breakdowns relative to their varying certification levels. While INVEST provides one of the most comprehensive point allocation systems (i.e., at 613 total points), this system neither uses a third-party certification entity nor does it duly designate certified projects, and as a result it is not included in this schematic. CEEQUAL (≥60%) and GreenRoads (≥50%) have the highest percentile expectations for top-rated project certifications. Conversely, the breakdown for GreenLITES has the lowest benchmarks, seemingly intending to incentivize their participants with a less-demanding threshold by which more of their projects might pro-actively receive such recognition.

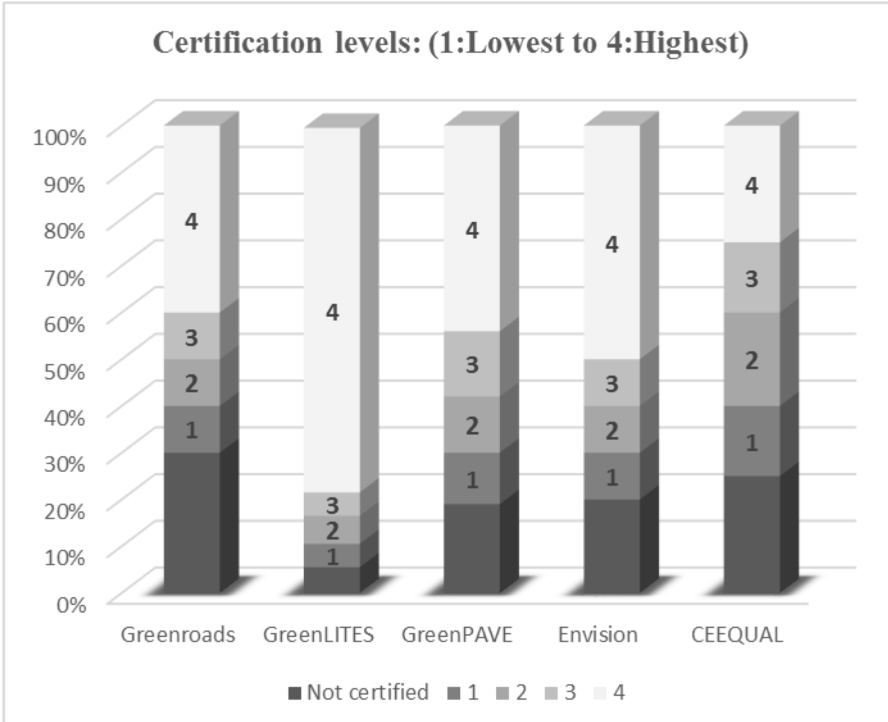



**Figure 6-2.** Percentile comparison of sustainability rating system certification levels

**10) Normalized versus Non-Normalized Rating Outcomes** – In some instances (e.g., CEEQUAL, Green Guide for Roads, BE$^2$ST-in-Highways, and Envision) rating systems use a normalized point assessment strategy based on the total 'applicable' (rather than maximum possible) points for the project. On the other hand, a number of rating systems (e.g., GreenLITES, Greenroads, and STARS 0.4) do not normalize their systems, and subsequently designate certification awards based on points derived relative to the system's maximal point capability. This variation between normalized and non-normalized systems is particularly important with smaller projects, where award outcomes might not be reached with smaller projects where they would have more limited opportunities to secure a necessary level of rating points.

## Industry Survey Perspectives

While preparing this overview paper, an eleven-question survey was completed with the original intent of gauging the level of familiarity and execution with sustainability strategies and sustainability rating systems within the specific highway construction industry. This survey was distributed to ~300 engineering and management representatives (i.e., the majority were Iowa State University construction engineering graduates or industry advisory council members), who were affiliated with national (~200 different firms) big heavy and highway contractors, or whose DOT, professional transportation organization, etc. positions provided close familiarity with this industry's sustainability perspectives. In turn, thirty-six (36) responses were received, and while this number is admittedly not a significant sampling pool the survey's findings were still considered valid as a qualitative guide to this industry's general level awareness of, and commitment to, sustainability goals and related rating systems. The analysis outcomes revealed by this survey, therefore, were as follows:

- That there is a generally pervasive sense of familiarity within the highway construction industry as to concept of sustainability. This outcome matches that of yet another national survey reported by Barrella et al. (2010).
- That the level of practice and implementation with sustainability initiatives, let alone sustainable rating system use, is apt to fall within a lesser range of moderate to low.
- That a majority of survey responses appeared to show a lack of enthusiasm about the sustainability rating system process and anticipated results.

- That the same majority of responses believed that upcoming research and pilot testing in relation to promoting sustainability goals was needed using real, proof-of-concept projects, and with which these results might then validate the use, efficiency, and benefits of these rating systems.
- Roughly two-thirds of the survey respondents were familiar with the AASHTO-PB sustainability checklist system. Familiarity levels with all other rating systems were much lower, with Greenroads (2nd) and INVEST (3rd) at 35% and 15% levels respectively.

Judging from the overall ‘mood’ of these survey responses, there was a consistent undercurrent that the construction industry has not yet recognized and gravitated towards benefits which might be accrued with the concept of sustainability as a whole, let alone their adoption and participation in sustainable rating systems. This survey also revealed yet another prevalent industry concern that this process, and use of rating systems, would need to provide a means for reimbursing industry efforts when they incurred higher cost and time expenditures. Another economic perspective cited by several of these industry survey responses what they were as yet unconvinced that sustainable highway rating systems and strategies would yield lower net life cycle costs (i.e., of a sort previously confirmed with LEED use). Again based on an overview of this survey’s feedback, there was also a recurring sense that these industry representatives would prefer a sequential prioritization of social concerns, competitiveness, economic incentives, and environmental issues as the hierarchic goals for future applications of sustainable highway ratings systems. Interestingly, while it appears that none of the current rating systems emphasize these latter priorities, these industry ‘motivations’ appeared to be more in line with the most newly developed option, INVEST, whose more distributed ‘TBL’ focus appears more compatible with these needs. Additional survey feedback in relation to project delivery issues touched on the prevalence of Design-Bid-Build (DBB) contracting as the dominant delivery method for surface transportation, and the fact that this delivery method does not have enough flexibility to properly pursue a sustainability approach. Indeed, sustainability goals are better suited to collaborative, like-minded, sustainability-motivated interactions between design and construction group at the very start of a project, as would also be the case with assimilating public involvement at this same, early project stage. In this same vein, the survey feedback similarly noted that DBB contracts do not require any sort of incentivized life cycle cost analyses throughout the life of the project, and that as a result the monetary benefits of a sustainable approach will be overlooked. Indeed, only 53% of the survey responses appeared to be using LCCA analysis on even an occasional basis for their decision making.

In response to a survey question touching on contract bid selection strategies seemingly best suited to sustainability goals (see adjacent Figure 6-3), over half of the responses mentioned changing the selection criteria from 'low-bid' to 'best-quality' as the best solution for incentivizing contractors to use rating methods. This point revealed a perceived sense of industry concern regarding the weakness of current delivery methods and contracting systems in terms of pro-actively advancing future sustainable approaches. Therefore, states

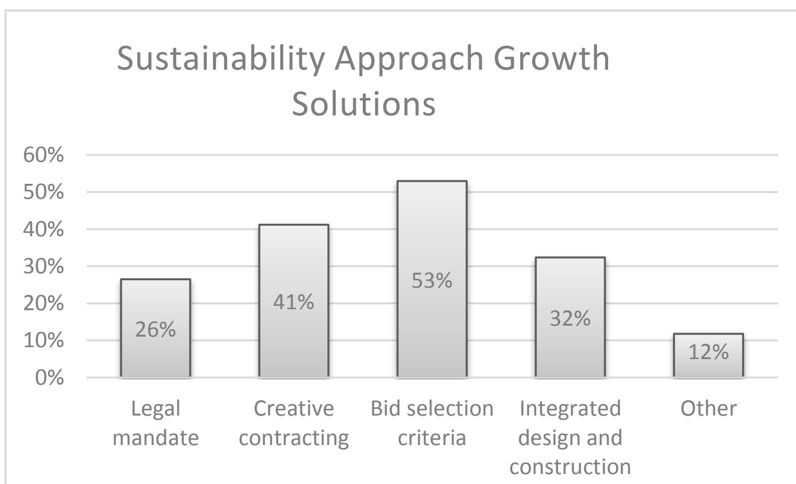



Figure 0-3. Industry-based suggestions for prioritization of solutions to incentivize industry to practice highway sustainability rating systems

could conceivably provide legal and execution context to bid selection practices which would promote sustainability goals and approaches as well as using sustainability rating systems.

The survey's narrative input also contained multiple suggestions that sustainability goals could be advanced by focusing future efforts more on design, planning, and construction phases, as well as on developing credible case study reviews to fully validate feasibility and cost aspects. In addition, nearly three-quarters of the responses (72%) suggested that 'real dollars' should be used as the sustainability criteria 'economic' measurement unit rather than basing 'cost' on a converted 'value' tied to greenhouse gas (i.e., $CO_2$) emission. These responders suggested that multiple criteria might represent the best feasible practice as far as trying to quantify 'cost' value in relation to societal and livability goals, while at the same time expressing concern that environmental issues (e.g., $CO_2$ emission reductions) are often inherently difficult to quantify on cost-benefit terms.

## Conclusions and Recommendations

There are both good and bad aspects with the evolution of sustainable highway rating systems witnessed in the US over the past decade. On the 'good' side of this ledger, the mere fact that such a large number of these assessment options have been developed validates a strong sense of commitment within the transportation sector to advance a common goal of highway sustainability. Indeed, whether for highways alone, or the broader context of sustainable horizontal infrastructure, these topics have undoubtedly attracted significant attention (Barrella et al., 2010).

When viewed from a negative, hindsight perspective, though, the 'sustainability' of this initiative with developing and applying these highway rating systems as a whole appears less than optimal. In fact, whether this process collectively represents a sustainable effort is arguable, and it would surely appear that further refinement is warranted to fully advance these goals. For example, these options largely evolved with limited (if any) complementary oversight and coordination, which might otherwise have avoided undue repetition of effort while pro-actively refining and advancing successive outcomes. More often than not, however, these options appear to have been conceived independently in a fashion which incorporated little in the way of synergistic, evolutionary growth and refinement. Furthermore, there has undoubtedly been a significant level of duplicative time and funding expended on these multiple rating systems, at a time when discretionary state budget funds have grown extremely tight.

At this point, therefore, it would appear that a reasonable next step would be to consider developing (or rebuilding) a future 'national' sustainable highway rating system, whose levels of flexibility, comprehensiveness, and equitable TBL coverage would best suit its future application. To varying degrees, one or more of the existing rating systems might well feel that they are poised for, or already pursuing, this sort of national stature. Whether or not one of these options serves as the nucleus, therefore, or whether an entirely new system is forged, the following recommendations, are accordingly offered to guide and improve this 'national' rating process development effort beyond those features found in the current systems:

1) That this system should elevate the level of initial project planning given to demand management strategies which would promote alternative options other than simply building new highway infrastructure. For example, user-fee practices (e.g., HOV and VMT fees, or congestion pricing) could be pursued to reduce peak period highway use and/or shift demand to alternative transportation modes.

2) That specific tools, indexes, and measurement criteria should be sought which would more carefully characterize point allocation requirements. In turn, this shift towards more defined rating criteria could reduce the uncertainty of personal judgment otherwise applied to the ratings.
3) That more effort needs to be invested with mid- to long-range case study assessment to confirm the real benefits of sustainable highway practices (i.e., cost savings involved with energy and emission reductions, etc.). This knowledge will both improve industry confidence in these practices, and could be used to guide weightings given to category ratings relative to these real benefits.
4) That the ratings, points, awards, etc. should be prioritized to guide sustainable highway development towards those practices with the highest return on investment.
5) That the process should be designed to advance sustainability goals at all levels and all modes and with all stakeholders involved with highway development (i.e., covering both large and small projects, low-density rural and high-density urban locations, vehicular- and multi-modal focused users, etc.).
6) That the rating assessment should evaluate and promote sustainable development covering a system's entire lifetime (e.g., covering the project's holistic carbon footprint, LCCA analysis, etc.).
7) That opportunities to establish contractor incentives for their use of sustainable construction practices should be pursued (e.g., switching from standard, low-bid selection methods to best- quality or incentivized/de-sensitized contracting methods (which include '$CO_2$ emission' as a quantified contracting item).

8) That creative strategies should be explored to integrate all phases of project development (e.g., planning, design, construction, and maintenance), which will provide long term life-cycle benefits.

9) That continued efforts should be made to promote the sustainability-minded education of all societal stakeholders whereby their understanding, appreciation, and final demand for these sustainability goals can be advanced.

10) That INVEST's approach with ensuring all state DOT's have an ongoing opportunity to participate in and contribute to this evolving national-level sustainability rating system should be assuredly continued.

One last bottom line recommendation for starting this envisioned, next-generation national system would be to establish a moratorium on starting any new rating systems, or modifying existing versions. This action would be a necessary precedent for starting an immediate next-step effort to lay out short-, medium-, and long-term plans for this system's upcoming consensus development effort.

# CHAPTER 7. CONSOLIDATED CONCLUSIONS AND LIMITATIONS

## Conclusions and Recommendations

According to recent research, the transportation industry faces a significant facility shortage in different areas such as maintenance of current infrastructures, building new infrastructure, and environmental stewardship. Adequate budget and investments are not available for maintaining and supplying for this high and growing demand. In this situation, minimizing waste and disturbance through large scale and integrated planning becomes much more important. As long as less pollution will be produced, lower budgets are needed to clean it, or if future development can be predicted and considered in current planning and design, much of the rework future projects will be declined.

These facts reveal the importance of large-scale vision and an examination of each project as a package of products for a life cycle period which can interact with other assets. Sustainable approaches can help the project to produce lower current and future costs (including social, environmental, and economic cost). In this realm projects become more complex and problematic which highlights the role of effective complex project management and communication plan that can consider all short and long life cycle of the project and predict risks and concerns that a project can produce. On the other hand, such approaches will affect the project through its development phase and operation.

In this era some limitations such as financing flow or political issues can create more complexity with the projects. Complex project management needs to be more flexible and try to predict and prepare for probable and unknown-unknown risks that affect the project development plan and operation period. It cannot be done in a manner other than monitoring and tracking all dimensions of the project through time and having strong and effective communication plans internally and externally to account for all contingencies. On the other hand financial limitations can dictate many pressures to the project and prevent them from proper plan development. In this regard all financial options, including traditional and innovative methods, should be seriously considered to minimize financing costs and limitations, although by sharing a risk, benefits will shared too.

This thesis intends to provide a larger vision on options and opportunities that could be used to develop a better and more practical transportation system by focusing on complex project management and two new dimensions of finance and context. Looking at projects as life cycle long packages can help to plan from broader perspectives. Although there are limitations and pressures, there are also opportunities available that are overlooked by states because of the lack of experience and expertise, in addition to unwillingness to abandon traditional methods and accept a risk of new opportunities. In this regard, education and training have an enormous role in informing states and stakeholders about different aspects of the new opportunities and to incentivize and help them to use the appropriate options for their needs. Unfortunately, more conservative and inactive states are those who strongly need these methods and options to fulfil their demand.

The conclusion of each paper is provided in the relevant chapters. The following bullets are overall conclusions that could be used for future steps to ease practice of proposed ideas:

- Replacing best feasible option with a perfect and ideal option (satisfaction instead of perfectionism)

- Integrated and sustainable planning should penetrate to higher levels of planning, such as transportation improvement plan (TIP) which is a 20 years perspective of a state projects.
- Planning and evaluating alternatives for life cycle of the project instead of the development period
- Invest in the application of new methods and approaches on more pilot projects:
  - To monitor and find its weaknesses to modify
  - To gather required data for later research and indexes
  - To model its implementation as an example
  - To advertise for a method by succeeding in a real project
- Effective communication in all levels
  - Academia and research parties: to work on each research area in a multi-location team and avoid wasting time and budget on similar research
  - Internal and external in project development team: in planning and development
  - With public and stakeholders to minimize the external risks and pressures
- Tracking complexities and risks through whole phases of the project
- Educating and training two involved parties:
  - Transportation agencies: to make them familiar with new opportunities and their benefits and incentivize them to comply.
  - Public and stakeholders: to inform them about achievements and provide a higher expectation and social expectation according to using sustainable approaches, in addition to providing commercial value for management and sustainability system tools to incentivize agencies and contractors.

- Providing stronger connection between academia and industry for a better understanding of a real need and available facilities
- To provide better vision that generates feasible and applicable solutions for real needs instead of ideal ways that never be used.
- To implement new approaches and methods of integrated development process is the best and necessary path which can brings much time and cost saving in addition to better quality. Using contracting methods that involve all phases' parties from the primary steps can help to minimize a number of reworks and not feasible options and designs. In this regard, the trend of movement from design-bid-build delivery method to design-build to design-build-finance-operate- maintenance and LEAN delivery method seems as a positive and necessary trend to have integrated process. Although weak points and probable problems of these methods should be recognized and addressed to lead to more efficient methods. Therefore, state governments need to prepare the legal and social context for deploying these methods.

## Limitations

Due to its broad scope, this research is affected by multiple limitations in each phase, which are listed in the relevant chapters. Overall, time restriction and lack of required data and case studies were two major limitations that made us to change the path of the research several times. Assuming all of these research approaches are on areas that do not have sufficient findings, results would be changed due to later pilot studies results and details. The recommendations are valid based on the current situation and may lose credit as more data are revealed.

**Recommendations for Future Research**

All three papers included in this thesis aim to help a transportation project teams broaden their methodological perspectives and see all alternatives and evaluate them to achieve the best options through developing a project. Furthermore, each paper attempts to lead a project team to see each project as a package that should be considered through its life cycle and not only the development, design, or construction phases. In addition, research can help to accelerate this transmission to integrated planning, development, and operation phases.

- In all three papers, lack of experience is a major obstacle that disturb public and industry trust; therefore the following future research is recommended:
    - Case studies in all three sections to recognize weaknesses and check its efficiency and primary assumptions.
    - Track all the information of case studies to be able to prove the systems application benefits by statistical and analytical analysis with real data.
- Provided methods in all three papers need extra primary efforts in project development, which should be justified and feasible:
    - Provided methods following ideal process, so there is a need for more feasibility analyses due to current minimization of extra work. Thus, research on the sensitivity of results in relation to the amount of extra work can help to prioritize options.
    - Some of the tools, such as financing methods or sustainability rating systems, need legal and social support to be implemented. For example some flexible contracting methods can incentivize and contain contractor’s needs in

implementing sustainability rating systems. In this area some research needs to be done to clarify best solutions to prepare a context for implementing them.

- Research to provide tools to measure criteria and produce proper indexes. In this approach, personal judgments will be minimized.

Research to substitute those criteria and items that eliminate small teams or contractors with some affordable criteria which are not scale sensitive, and are affordable for smaller organizations too.

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# APPENDIX A: FACTORS IN FIVE DIMENSIONS OF COMPLEXITY IN COMPLEX PROJECT MANAGEMENT (SHANE ET AL. 2012)

Factors of five complexity dimensions of a complex project are presented in the following tables (Shane et al. 2012):

**Cost Factors:**

| Cost Factors |
|---|
| Contingency usage |
| Risk analysis |
| Estimate formation |
| Owner resource cost allocation |
| Cost control |
| Optimization's impact on project cost |
| Incentive usage |
| Material cost issues |
| User costs/benefits |
| Payment restrictions |

**Schedule Factors:**

| Schedule Factors |
|---|
| Timeline requirements |
| Risk analysis |
| Milestones |
| Schedule control |
| Optimization's impact on project schedule |
| Resource availability |
| Scheduling system/software |
| Work breakdown structure |
| Earned value analysis |

**Technical Factors:**

| Technical Factors |
|---|
| Scope of the project |
| Owner’s internal structure |
| Prequalification of bidders |
| Warranties |
| Disputes |
| Delivery methods |
| Contract formation |
| Design method |
| Reviews/analysis |
| Existing conditions |
| Construction quality |
| Safety/health |
| Optimization impact construction quality |
| Typical climate |
| Technology usage |

**Context Factors**

| Context Factors | |
|---|---|
| Public | Marketing |
| Political | Cultural impacts |
| Owner | Local workforce |
| Jurisdictions | Utility coordination |
| Designer(s) | Railroad coordination |
| Maintaining capacity | Resource availability |
| Work zone visualization | Sustainability goals |
| Intermodal | Environmental limitations |
| Social equity | Procedural law |
| Demographics | Local acceptance |
| Public emergency services | Global/national economics |
| Land use impact | Global/national incidents |
| Growth inducement | Unexpected weather |
| Land acquisition | Force majeure events |
| Local economics | |

**Finance Factors**

| Financing Factors |
| --- |
| Legislative process |
| Uniformity restrictions |
| Transition to alternate financing sources |
| Project manager financial training |
| Federal funding |
| State funding |
| Bond funding |
| Borrowing against future funding |
| Advance construction |
| Revenue generation |
| Vehicle miles traveled fees |
| Cordon/congestion pricing |
| Monetization of existing assets |
| Franchising |
| Carbon credit sales |
| Public-private-partnerships |
| Use of commodity-based hedging |
| Global participation |
| Risk analysis |
| Financial management software |

# APPENDIX B: VALIDATION INTERVIEW EXAMPLE

Accommodation of applied ‘project management strategies for complex projects’ guide book strategies on selected DOTs project development process are validated through phone interviews with selected DOT’s (e.g. AZ, CO, IA, MD, MN) project managers. Following the Interview of Maryland DOT is presented as an example.

Interviewee version:

This interview is designed for transportation professionals familiar with the five dimensional project management (5DPM) concept and the SHRP2- R10 methods and tools for complex project management.

**Interview Purposes:**

- To verify the documented project development process accurately reflects the general process utilized by transportation agencies for complex projects.
- To verify that the 5DPM concept, the complexity mapping exercise, the planning methods, and project tools are a generally applicable practice for the effective management of complex projects.

**State:** Maryland

**Interviewer:**

**Date:**

**Interviewee:**

**Interviewee Title/ Position:**

**Work Experience in State DOT:** ….. Years

**Approximate Number of projects interviewee has been involved with:** ….. Projects,

**Highlight projects:** …

**Interviewee Contact Information:** Email:

Phone: (- - -) - - - - - - -

Address:

1- Are you familiar with the five-dimensional project management (5-DPM) concept, complexity mapping, and the 5 planning methods and 13 project execution tools? (Table 1[1])

☐Yes, ☐No

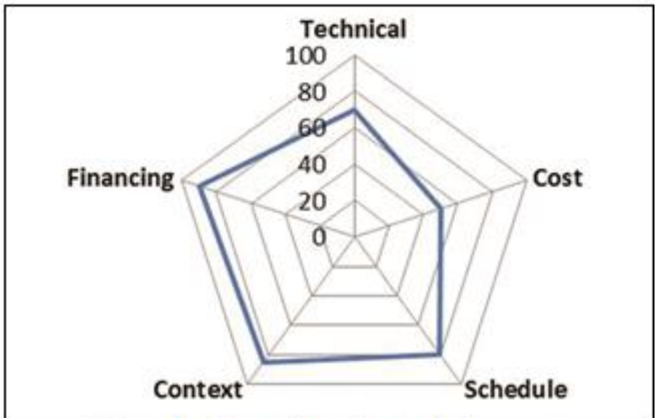



Figure 1: Example of complexity map

2- Do you have a specific definition for a complex project in your department of transportation (DOT)?

☐Yes, ☐No

If yes, please provide the definition (also please provide supporting documentation, i.e., website): …………………………….

Indicate in which dimensions your DOT differentiates between traditional and complex projects:

| **Dimension** | **Difference** |
|---|---|
| Cost | |
| Schedule | |
| Technical | |
| Finance | |
| Context | |

a. Does your DOT follow different project development and delivery processes for "normal" versus "complex" projects?

☐Yes, ☐No

3- Does the attached Project Development Process Flowchart describe the complex project development process within your organization? (Fig. 2, it is attached to the end of the questions)

[1] Table is attached at the end of the questions.

☐Yes, ☐No

If “No” please explain the complex project development process of your agency. We would appreciate any on-line resources you may provide which further explain the unique process used for complex projects (e.g websites, agency publications, etc.)

a. Do you normally complete all the identified steps in the flowchart?

☐Yes, ☐No

What steps are usually not completed in each phase?

| Phase | Differences |
|---|---|
| Needs Identification | |
| Planning | |
| Engineering | |
| Programming | |
| Execution | |
| Project Done | |
| Evaluation | |

b. Do you have any other key steps which are not mentioned here?

☐Yes, ☐No

If your answer is yes, please describe those steps and their location in the project development process?

(*Some minor steps are not mentioned in summary development diagram, but please determine if any decision point or major step is missing.)

4- Does your agency have integrated project team meetings at the early stages of the project life cycle (e.g after the Transportation Improvement Program (TIP) but before procurement/funding) with the internal functional groups?

☐ Yes ☐ Yes, but all functional groups do not participate. ☐No

a. Do you think you have sufficient scope in the TIP for determination of the critical success factors for complex projects?

☐ Yes ☐ No (too soon) If No, when would be an appropriate time? ____

5- When is the project manager assigned to the project?

| | |
|---|---|
| Planning | |
| Programming/Scoping | |
| Preliminary Engineering | |
| Final Engineering | |

| | |
|---|---|
| Construction | |
| Operation, Monitoring, Maintenance | |
| Other (Please mention the time) | |

a. Do you differentiate between project developer and project manager in your DOT (project developer just works until the submission of final scoping report)?

☐Yes, ☐No

b. Does project manager usually change through the course of the development process in your DOT?

☐ Yes, ☐ No

If yes please explain how often ……., when ….. , and why……..

c. Is the project team selected at that time (please refer to Figure 2 for exact time)?

☐ Yes, ☐ No, (☐Before, ☐After, Please show the approximate time on the development process flowchart)

6- How many times through the development process do you have the meeting with the functional groups (technical, managers, financial, estimators, ROW, bridge, environmental, etc.)?

☐ Often (seasonal) , ☐ Sometimes (per 6 month or a year) , ☐ Rarely (one per each phase of planning, scoping, engineering, State Transportation Improvement Program (STIP), and letting) , ☐ None,

a. Do you think it is possible to have comprehensive meetings through developing process?

☐ Yes, ☐ No

7- Is the core project team identified before the State Transportation Improvement Program (STIP) draft is submitted?

☐ Yes ☐No

a. Do you think your agency could assemble the project team early in the project development process as identified in the 5DPM program?

☐ Yes, ☐ No,

If "No" please show on the flowchart your best fitted time suggestion for this method, and justification:

8- Do you think the cost modeling and finance (F/CM) method is located in an appropriate location, (e.g does the project team have enough funding/finance and cost information to develop a model at the early stages of project development)?

☐ Yes, ☐ No,

If no, where it should be transformed to (please show on the flow chart)? Explanation:

9- Where is the best point to locate project arrangement (PA) method? (Show on the flowchart)

(*Please refer to Table 1 for Project arrangement method recalling)

10- Do you think the 5DPM complexity mapping, analysis and planning methods fit within your agency's existing project development processes?

☐ Yes, ☐ No,

a. If not, how can you change it to be adopted with your routine process?

11- Do you have project team meetings at the decision points indicated in the project development flow chart where complexity map revision and action plan are located?

☐ Yes, ☐ At some of them (please mention), ☐ No

12- Do you think the 5DPM process and the associated methods and tools are helpful in identifying complex project issues earlier and therefore managing project risk better?

☐ Yes, ☐ No, (we currently consider all the steps normally in our projects)

13- How long averagely take for the project to pass through the process and each development step separately?

Total time: … years

Need identification and Planning Avg. time: … months; (Entering Transportation Improvement Program)

Project scoping Avg. time: … months; (Entering State Transportation Improvement Program (STIP))

Design Avg. time: … months; (Ready for letting)

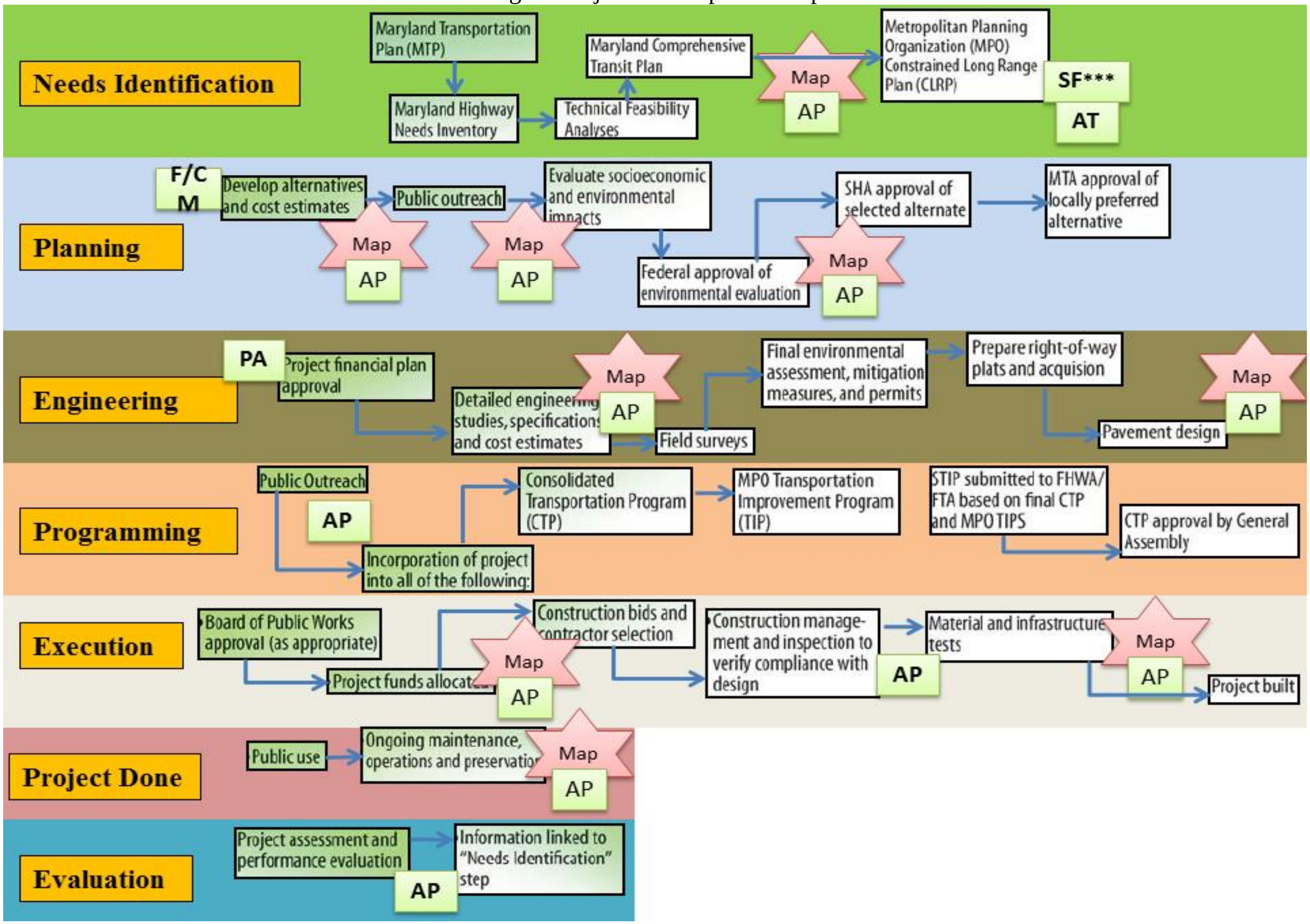
Advertisement and letting process Avg. time: … months (General Contractor is selected)

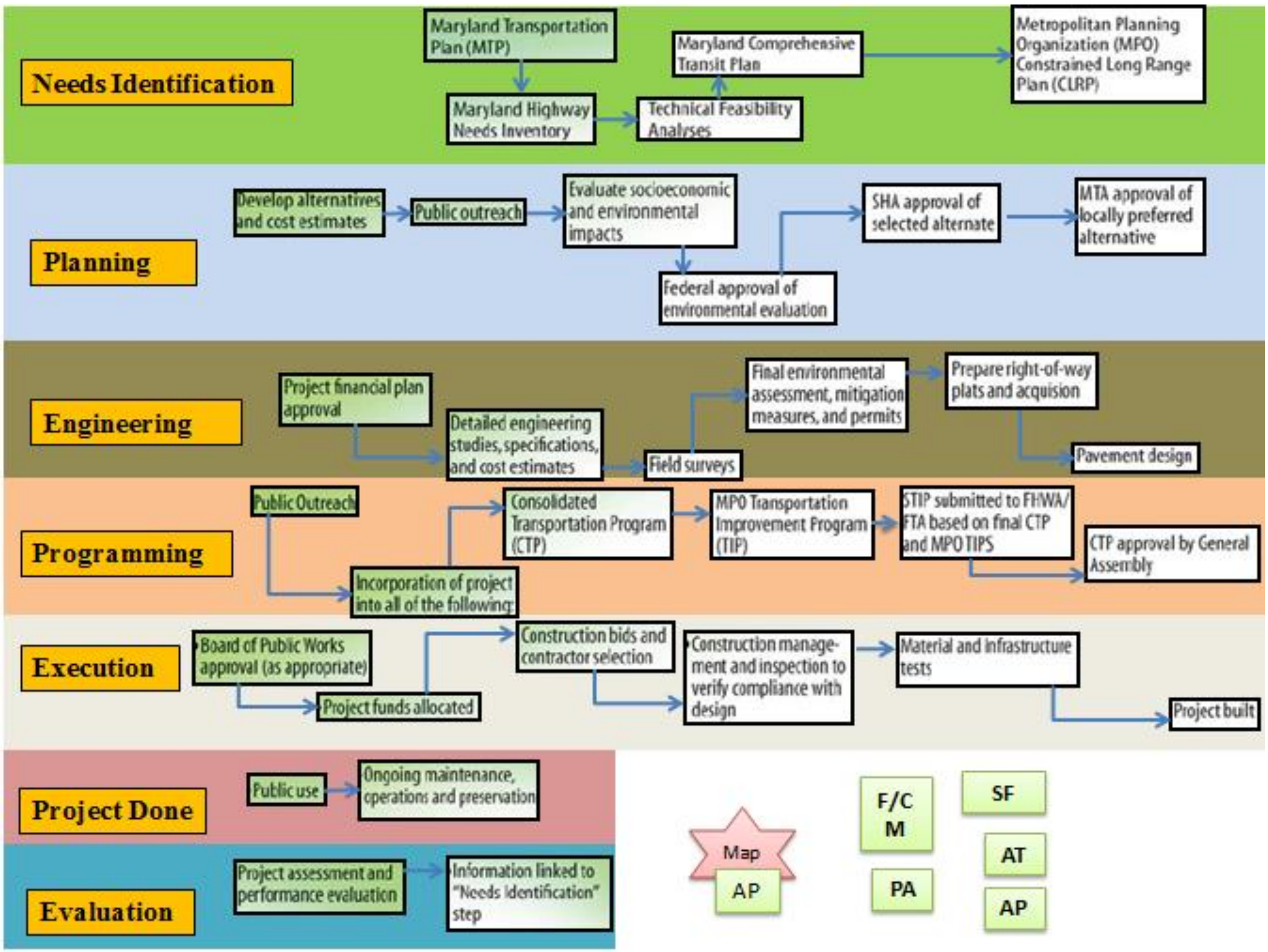
- At the end of the Development Process Flowchart a bare flowchart and complexity map and methods sign are provided if you want to change and provide your own version.

Table 1: 5 Methods and 13 Executive Tools

| Methods | Execution Tool (project team) |
|---|---|
| 1. Critical Success Factors (SF): Integrate identified project success factors into comprehensive risk analysis and mitigation plan at the execution phase. Make certain that risks affecting critical project success factors are identified, analyzed, and mitigated. | 1. Incentivize Critical Project Outcomes<br>2. Develop Dispute Resolution Plan |
| 2. Project Team (AT): Director of the DOT formally empowers the designated project team to operate outside the agency hierarchy. | 3. Perform Comprehensive Risk Analysis<br>4. Identify Critical Permit Issues |
| 3. Project Arrangement (PA): Calculate road user costs and translate into cost of schedule delay or acceleration, which can be included in contracting language. | 5. Evaluate Applications of Off-Site Fabrication<br>6. Determine Required Level of Involvement in ROW/Utilities |
| 4. Early Cost Model and Finance Plan (F/CM): Understand available funds and establish scope, budget, and schedule that are viable, and plan to track the schedule and mitigate the risk. | 7. Determine Work Package/Sequence<br>8. Design to Budget<br>9. Co-Locate Project Team |
| 5. Project Action Plans (AP): Understanding the influence of external factors such as legislators and how to direct this influence positively through the project. | 10. Establish Flexible Design Criteria<br>11. Evaluate Flexible Financing<br>12. Develop Finance Expenditure Model<br>13. Establish Public Involvement Plan |

Fig. 1: Project Development Map





Needs Identification
Maryland Transportation Plan (MTP)
Maryland Highway Needs Inventory
Technical Feasibility Analyses
Maryland Comprehensive Transit Plan
Metropolitan Planning Organization (MPO) Constrained Long Range Plan (CLRP)
Planning
Develop alternatives and cost estimates
Public outreach
Evaluate socioeconomic and environmental impacts
Federal approval of environmental evaluation
SHA approval of selected alternate
MTA approval of locally preferred alternative
Engineering
Project financial plan approval
Detailed engineering studies, specifications, and cost estimates
Field surveys
Final environmental assessment, mitigation measures, and permits
Prepare right-of-way plats and acquision
Pavement design
Programming
Public Outreach
Incorporation of project into all of the following:
Consolidated Transportation Program (CTP)
MPO Transportation Improvement Program (TIP)
STIP submitted to FHWA/ FTA based on final CTP and MPO TIPS
CTP approval by General Assembly
Execution
Board of Public Works approval (as appropriate)
Project funds allocated
Construction bids and contractor selection
Construction management and inspection to verify compliance with design
Material and infrastructure tests
Project built
Project Done
Public use
Ongoing maintenance, operations and preservation
Evaluation
Project assessment and performance evaluation
Information linked to "Needs Identification" step
Map
AP
F/C
M
PA
SF
AT
AP

# APPENDIX C: SPECIAL IOWA STATE UNIVERSITY SURVEY RE: SUSTAINABLE HIGHWAY RATING SYSTEMS

## Special Iowa State University Survey RE: Sustainable Highway Rating Systems

Background: This survey addresses the current development of 'horizontal' sustainable rating systems (e.g., for highway infrastructure) in the U.S. This sort of rating process was originally inspired by the successful adoption of the 'LEED' rating system for 'vertical' (i.e., building) structures in the late 1990's. While LEED ratings have become the standard approach for buildings, though, the evolution of horizontal infrastructure sustainable rating systems has followed a far more complicated process, with more than a dozen options created in just the past few years. The goal of this survey, therefore, is to gauge the levels of familiarity and application these various rating systems have reached in relation to the heavy and highway construction industry, while at the same time assessing personal perceptions in regards to the value, significance, and focus of these efforts. The results of this survey will, in turn, be consolidated into a published assessment of present and future paths for these initiatives.

The following five aspects of this survey should be highlighted:

1) This survey is only being sent to Iowa State alumni (who would hopefully be willing participants!)
2) This survey is intended for people who have experience within the surface transportation industry
3) We realized that some survey recipients may have no not have prior experience with these highway sustainability rating systems; however, we would still appreciate your constructive feedback to our questions
4) The majority of our eleven survey questions can be quickly answered by clicking check boxes
5) Some questions have text boxes with which you can add further narrative, if you'd like to do so

Furthermore, if you are willing to recommend this survey to any other construction industry friends, we would greatly appreciate your help with disseminating the following URL address such that they might participate in this survey.

Online Survey URL: http://fluidsurveys.com/surveys/elika/sustainable-highway-rating-system/

Participant Details:

Name of your company? ________________

Years of experience within highway industry: ________

Survey Questions:

**1]** Please mark whichever rating systems you are familiar with, or let us know if you have used or heard of another rating system that is not mentioned here.

☐ CEEQUAL
☐ Greenroads
☐ AASHTO
☐ GreenLITES
☐ GreenPAVE
☐ Greenguides
☐ I-LAST
☐ ASCE-SIPRS
☐ Peachroads
☐ INVEST
☐ Envision
☐ Other systems:

Names?

**2]** In your experience, are you familiar with any company which does use, or intend to use, horizontal infrastructure sustainability rating systems?

Please mention name of the companies and name of the used rating systems in chronological order.
☐ Yes; at the following company(ies):
☐ Yes; using the following rating system(s):
☐ No

**3]** Whether or not your company uses any of these rating systems, would you say that your company considers sustainability issues at any level of the project development process?

NOTE: please check all that apply
☐ Yes; in planning / ☐ Yes; in design / ☐ Yes; in construction / ☐ Yes; in preservation and maintenance
☐ No

**4]** On a personal level, what would you consider to be the level of attention given to 'sustainability' as a whole within your company?

☐ High...and we have a specifically responsible group to address these issues
☐ Moderate and perhaps growing
☐ Low and infrequent (based on contract requirements)
☐ Very little, if any (e.g., we have no incentive, they are not affordable, etc.)
☐ Other, please specify:

**5]** Please describe limitations of using these sustainability rating systems? (i.e., what issues would you feel might hamper the use of these sustainability rating systems?)

e.g., industry doesn't believe in their influence, absence of mandatory requirement, contract condition weakness, no incentive, lack of assigned specialist for this work, etc.

**6]** What type of contracts does your company often use? (NOTE: click all that apply)

☐ Design-bid-build
☐ Design-build
☐ PPP
☐ CMGC/ CM at risk
☐ Lump sum
☐ A+B
☐ A+B+I/D
☐ Other, please specify...

7] Does your company use life cycle analysis (LCA) and life cycle cost analysis (LCCA) as a tool to help decision making?

☐ Yes, in all contracts / ☐ Yes, in specific types of contract (please mention):
☐ No

**8]** What criteria should be used for sustainability rating and LCA/LCCA analysis?
Whether your company does, or does not, use these tools, in your opinion which criteria would be better suited to an analysis and decision making process relative to advancing sustainability?

☐ Carbon dioxide emission levels
☐ Real dollars
☐ Other, please specify:

**9]** If sustainability rating systems have been used or are being considered by your company, which of the following key factors would you consider are warranted?

☐ Economic issues: (e.g., value engineering, LCCA)
☐ Environmental issues: (e.g., $CO_2$ emission mitigation)
☐ Societal issues: (e.g., promoting community benefits)
☐ Competitiveness: (e.g.: having a chance to successfully compete for contracts)
☐ Other, please specify:

**10]** What would you personally consider to be the prospective strengths and weaknesses of horizontal infrastructure sustainability rating systems from different aspects (e.g.; focus areas, valuation and weighting different criteria, measurement criteria, economic feasibility and constructability, etc.)?

Note: If possible, please use examples to clarify your points

**Strength?**

**Weaknesses?**

**11]** What strategy would you feel should be followed to advance the future use of these horizontal rating systems?

☐ Establishing a legal mandate which requires a specified rating system
☐ Creative contracting with incentive-disincentive elements (A+B+I/D)
☐ Alternative bid selection criteria changing low-bid to best-quality
☐ Adopting new strategies to integrate construction parties into the project design phase
☐ Other, please specify: