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Develop a social return on investment framework for Iowa rural bridge transportation asset management

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NOMENCLATURE

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation
Officials	
ADT	Average Daily Traffic
BHI	Bridge Health Index
BMS	Bridge Management System
CGIAR	Consultative Group on International Agriculture Research
CIAT	International Center for Tropical Agriculture
CO_2	Carbon Dioxide
DOT	Department of Transportation
DTIMS	Deighton's Total Infrastructure Management System
FAO	Food and Agriculture Organization of the United National
FAS	Federal-aid Secondary
FHWA	Federal Highway Administration
GDOT	Georgia Department of Transportation
HDM-4	Highway Development and Management Model
HEIA	High Economic Impact Activities
IADOT	Iowa Department of Transportation
IRI	International Roughness Index
ISI	Institute for Sustainable Infrastructure
ISO	International Organization for Standardization
KPI	Key Performance Indicators
LCC	Life Cycle Cost
LCCA	Life Cycle Cost Analysis
MAP-21	Moving Ahead for Progress in the 21^{st} Century Act
NBI	National Bridge Inventory
NPV	Net Present Value
PSI	Pavement Serviceability Index
PV	Present Value

ROI	Return-on-Investment
ROW	Right of Way
RUC	Road Users' Cost
SROI	Social Return on Investment
T2E	Transport to Employment
TAM	Transportation Asset Management
TAT	Total Annual Traffic
TDM	Transportation Demand Management
TREDIS	Transportation Economic Development Impact System
TRIMMS	Trip Reduction Impacts of Mobility Management Strategies
TRB	Transportation Research Board
USDA	United States Department of Agriculture
VOC	Vehicle Operating Costs
VPD	Vehicles per Day

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ABSTRACT

In 2012, the U.S. Congress passed the Moving Ahead for Progress in the 21st Century (MAP-21) Act, which funds surface transportation programs and transforms the policy and programmatic framework for capital investments to guide the growth and development of the country's vital transportation infrastructure. Within many of its goals, MAP-21 supports the economic growth of the regions and requires each state to develop a Transportation Asset Management (TAM) plan (FHWA-5 2012).

Therefore, the objective of this study is to develop a framework for the Iowa Department of Transportation (IADOT) to help in the prioritization and allocation of the resources such that it supports the local economies, and more specifically, Iowa's Agricultural Economy. The proposed TAM framework is the result of a comprehensive literature review, a case study analysis and several outreach and informal interviews with stakeholders that provided the tools to help identify the user's impact as well as to determine a flexible methodology that could easily be adapted to the current practices and policies of the state Department of Transportation (DOT).

The research focuses the attention on the low-volume bridges located in the agricultural counties of Iowa because recent research has shown they have the greatest percentage of structurally deficient bridges in the nation. Many of the same counties also have the highest crop yields in the state, creating a situation where detours caused by deficient bridges on farm–to-market roads increase the cost to transport the crops. Thus, the research proposes the use of Social Return on Investment (SROI), a tool used by international institutions such as the World Bank, as an asset management metric to gauge to the socioeconomic impact on the state in an effort to provide quantified

justification to fund improvements on low-volume assets such as these rural bridges. The study found that combining SROI with current asset management metrics like Average Daily Traffic (ADT) made it possible to prioritize the bridges in such way that the limited resources available are allocated in a manner that promotes a more equitable fashion and that directly benefits the user, in this case Iowa farmers. The result is a system that more closely aligns itself with the spirit of MAP-21 to use infrastructure investments to facilitate economic growth for Iowa's agricultural economy.

CHAPTER 1 INTRODUCTION

Over the last century, the growth of the population as well as the modernizations of the agricultural industry have not just produced a boom in the economy, but also have transformed the structure of the rural and suburban zones, which rapidly increased demands on the transportation systems across the country (Friedberger 1989). However, most recently, the U.S. has overcome several economic difficulties that have challenged the governmental institutions and have put stress on the capabilities to maintain and improve the existing assets as well as to keep up with the growing needs of the users (ASCE 2013).

Good transportation systems have always been a symbol of economic growth allowing the movement of people and freight as well as permitting the markets to extend from local and regional levels to an international scale (Rodrigue, Comtois and Slack 2013). Based on the importance of trade and distribution on the growing share of the wealth, one of the goals of the federal and state governments is to support economic growth by implementing strategic plans that sustain an infrastructure that responds to the needs of the users and economic opportunities. In order to achieve this goal, the Federal Highway Administration (FWHA) has required the state agencies to develop and implement a Transportation Asset Management (TAM) plan that consists of making an inventory of their assets along with their condition and to then integrate life cycle, financial, and value engineering analyses into their decision-making process (AASHTO 2011).

The purpose of this study is to develop a framework for Iowa TAM to prioritize resource allocation on low-volume bridges in rural areas. The research will review the current mechanisms used at the state and local level to evaluate and prioritize rural bridges as well as tools available from organizations such as the World Bank and the SROI Network. Part of developing the framework is to identify the impact that rural bridges have on the users and to find a way to measure the life cycle impact and cost so it can be used as a benefit-cost metric indicator in the prioritization process for the TAM plan.

Lastly, it is important to highlight that a key component of this study is based on the analyses of the Annual Average Daily Traffic (AADT), known as the total volume of vehicles traffic of a highway or road for a year, and then divided by 365 days. It is used primarily in transportation planning and transportation engineering. One of the most important uses of AADT is to determine funding for the maintenance and improvement of the transportation grid due to its close relationship with safety risk and user's impact. Therefore, this research will closely review the use of AADT and determine how traffic counts can be used more efficiently to understand users' impact.

Content Organization

This thesis consists of a compilation of four different journal articles whose content and sequence was purposefully selected in accordance with the principal objective of the research mentioned above. Chapter 2 will furnish the reader the necessary background information to understand the remainder of the analysis, and Chapter 3 will detail the methodology used to complete the research.

The logic used to select and organize the topics of these articles consisted of seven phases. First, a conceptual methodology is developed using SROI to measure socioeconomic impact based on the literature review (Chapter 4). Second, a case study is used to pilot test the methodology using data available from the IADOT and introduces calculating the road users' cost (RUC) using HDM-4, a methodology developed and widely used by the World Bank to measure impact. At the same time, this phase presents the proposed framework to implement the methodology to the TAM plan (Chapter 5). Subsequently, due to the large variability observed in the IADOT data collected, a stochastic model was developed to quantify variability and incorporate it into the decision making process (Chapter 6). Finally, the methodology and the framework were validated by comparing the allocation of resources done using the current prioritization method versus that found using the proposed methodology (Chapter 7).

The first article (Chapter 4) was submitted to the Transportation Research Board (TRB) and was accepted for presentation at the 2014 annual meeting. This article discusses the fundamentals of SROI. Additionally, it confirms the need to integrate a socioeconomic metric to overcome Iowa infrastructure deficiency located primarily on the low-volume roads.

The second article (Chapter 5) was submitted, and recommended for publication, to the Institution of Civil Engineers Journal of Infrastructure Asset Managemen*t*. This article presents a case study analysis that compares the actual impact of two bridges with similar conditions but that differ on the AADT and different type of road. The results of the case study showed the importance of understanding the impact of the different kind of users and highlight the overrated importance given to the total AADT.

The third article (Chapter 6) was submitted and accepted for presentation at the 11th International Conference on Low Volume Roads and accepted for subsequent publication in Transportation Research Record the Journal of the TRB. A sensitivity analysis was done to understand the variation within different indicators. The article demonstrates how different resource allocation decisions could occur evaluating the risk of closing a bridge versus the risk of only reducing the posted rated capacity of the bridge. In other words, the article quantifies the socioeconomic impact created when only heavy trucks are forced to detour against that created when all traffic must detour.

Finally, a fourth article (Chapter 7) was submitted for publication to Public Works Management and Policy. This final article presents the validation of the proposed SROI framework for prioritizing rural bridges by evaluating its outcome for ninety-six bridge candidates competing for 2014 fiscal year funding and comparing it the actual allocation of 2014 funds based on the current methodology.

CHAPTER 2 BACKGROUND AND MOTIVATION

This chapter presents information that provides a better understanding of the methodologies used in the U.S. to calculate the value added in transportation projects and other methodologies used by nonprofit organizations around the world such as the SROI. The content of this chapter is used to complement and support the journal articles and proceedings papers that comprise Chapters 4, 5, 6 and 7. Furthermore, this chapter describes the motivation behind the thesis' objective, and the principal issue that is expected to be addressed with its completion.

Background

As observed on a National TAM Peer Review, the fluctuation on the designs of TAM plans is as wide as the needs of all states across the U.S.; therefore, to narrow the research, this study was developed focusing primarily on the needs of the state of Iowa, a heavy agricultural state with great deficiency on its rural transportation infrastructure. The current status of America's transportation infrastructure as well Iowa's status is better described in Chapter 4.

This section of the thesis provides the readers with background to better understand the TAM's vision and federal requirements as well as the state-of-practice of value added into infrastructural projects at a national and international level. It also presents the current tools used for asset prioritization and resource allocation at a local level.

Transportation Asset Management (TAM) and MAP-21

TAM is described by the American Association of State Highway and Transportation Officials (AASHTO) as a "strategic plan that helps the DOT to focus on the business processes for resource allocation and utilization with the objective of better decision-making based upon quality information and well-defined objectives" (Cambridge 2002).

The goals of the TAM plan are to build, preserve, and operate facilities more cost-effectively with improved asset performance; deliver to an agency's customers the best value for the public tax dollar spent; and to enhance the credibility and accountability of the transportation agency to its governing executive and legislative bodies (Cambridge 2002).

DOTs across the nation are required to develop a TAM plan to comply with the recent MAP-21 Act P.L. 112/141. The FHWA has summarized this act as follow:

> MAP-21 was signed into law by President Obama funding surface transportation programs at over $105 billion for fiscal year 2013-2014. It transforms the policy and programmatic framework for investments to guide the system's growth and development, MAP-21 creates a streamlined and performance based surface transportation program. (FHWA-5 2012)

Under this Act, each state's TAM plan must include, but is not limited to, all pavements and bridges in the National Highway System. Other roads can be included as needed, and it also encourages the states to include all infrastructures along the right-of-way. This strategy should plan for a long-term system that considers the lifecycle of the assets and identifies a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions in the most cost effective way. The plan shall include an inventory of the assets including condition, the objectives and measurements, performance gap identification, lifecycle cost and risk management analysis, a financial plan, and the investment strategies (AASHTO 2011).

National TAM Peer Exchange Results

A national peer exchange was organized by the IADOT with the intention of learning from the experiences, lessons learned, and challenges of other state DOTs during the development and implementation of their TAM plans. The FHWA provides funding for such events, and it was conducted in accordance with current FHWA (FHWA 2010) regulations. The exchange involved members of the IADOT and the author of this thesis traveling to the states of Georgia, Utah, New York, and New Jersey. Meetings were held to provide IADOT with information about each peer state's TAM program. Additionally, the Iowa delegation presented the major elements of its TAM program and received direct feedback from its peers. The potential for using SROI was one of the elements presented and the feedback gained during the peer exchange was integrated into the framework proposed in this report.

At the end of the peer exchanges, it was evident that the key to developing a meaningful TAM plan for Iowa was to depart from the current polices and methods implemented at each institution. The TAM plan does not pretend to be a clean slate; instead it encourages continuous improvement at all levels of the organization. The IADOT decided to mimic Utah's approach and restructure their organization chart to delegate responsibility for implementing the TAM plan to a specific team. Other states such as Georgia and New York modified the processes within the current organization and assigned specific members to become the TAM champions and lead TAM steering committees.

In addition to the differences in agency organizational charts, each agency has different needs which require individual goals and agency-specific input to the TAM plans. For example, New York has a great need to maintain their existing infrastructure. In order to focus on this need, the state has developed polices that help control the development of new capital projects. In contrast, Utah retains a greater flexibility to allocate resources which results in good overall condition of their assets. Additionally, Utah's assets are relatively newer than New York's and are not subjected to the same level of traffic loading.

Another example of the range in TAM plans in the nation is Iowa, which does not have direct responsibility for the inventory and the inspection of rural bridges. In contrast, New York is responsible for the technical inspection of all bridges in the state which provides a better overall knowledge of the state's infrastructure, even though it has no maintenance responsibilities. Iowa relies on county engineering departments for the total administration of the rural bridges. The reliance on external agencies combined with a lack of standardized practices across the state creates a situation where rural bridge assets are not able to compete for resources and indirectly discriminates against the agricultural sector of the state's economy. The diversity found in the peer exchange validated the notion that no single standard TAM program could possibly fit all needs. In all cases, multidisciplinary teams were responsible for the decision making and allocation of the resources, and all states needed unconditional, continuous support from agency executives and upper management.

Informal Interviews with Iowa County Engineers

Throughout the course of the research, the county engineers for Marion, Hamilton, Boone, and Story Counties in Iowa were interviewed to get a better understanding of the bridges' prioritization process at the local level, as well as to get an idea of their approach to the TAM plan.

Appendix A presents a more complete summary of the interviews by county, but in general, all four counties present a similar methodology to select the bridges that will be submitted to the state agency as candidates for resource allocation. Their prioritization methodology starts with the worse-first scenario, followed by a subjective opinion based on their knowledge of the zone and determined by the financial resources available to meet the required matching costs.

At the time the interviews were conducted, the IADOT had not developed a plan to train and communicate the TAM plan to their local agencies; therefore, there was little understanding of the TAM plan's role in the decision-making process. Nevertheless, by the end of the research, the IADOT has established a TAM County Committee that will work as a two-way communication channel between the state and local agencies.

Measuring Value Added in Transportation Infrastructure

When making decisions about resource allocation for transportation asset construction and maintenance projects, engineers gather a range of performance indicators such as Bridge Health Index (BHI), the pavement serviceability index (PSI), or the international roughness index (IRI) which measure the physical condition of the assets (Cambridge 2006). Other common measures are focused on capacity such as ADT, accident rates, speed, visibility, life cycle cost (LCC), and others. While these metrics are well-accepted and widely-used, including only condition and traffic-based key performance indicators (KPI) unintentionally results in an asset management program that prioritizes projects by “worst-first” and “most traffic.” An example is the IADOT’s City Bridge Priority Point Rating Worksheet contained in Appendix B. Worst-first is the expression used for an asset resource prioritization system that waits until the assets are in their worst condition to consider them a priority (Cambridge 2002). Traffic-based systems assign priority to assets that have the greatest ADT under the fundamental assumption that improvements made will benefit more travelers. In other words, ADT is used as an objective indicator of benefit, inferring a directly proportional relationship between the number of vehicles and the return generated by the investment. When used in this context, ADT also represents the number of users who been impacted by the investment in a specific transportation project. In other words, a passenger car carrying one commuter to work is assigned the same socioeconomic value as a truck hauling cargo or produce to market, an unintentional, over-simplification of a complex process that favors urban transportation assets over similar rural assets. The current asset management decision prioritization framework essentially ignores the socioeconomic contribution that low-volume farm-to-market roads make to the economy of agricultural states like Iowa.

To measure the value added by transportation projects, methodologies such as the Transportation Economic Development Impact System (TREDIS), Trip Reduction Impacts of Mobility Management Strategies (TRIMMS), Social Return on Investment (SROI), and the Highway Development and Management Model (HDM-4) have been developed to include the social, economic, and environmental impact to the users and allows for a cost-benefit analysis. The salient aspects of the three systems are reviewed below.

TREDIS

This system translates changes in traffic volumes, vehicle occupancy, speed, distance, reliability, and safety into direct cost savings for household and business travel. Additionally it applies dynamic, multi-regional economic impact simulation to estimate impacts on employment and income growth over time. At the same time, it translates changes in market access and intermodal connectivity into effects on agglomeration, dispersion, and scale economies for industry sectors. TREDIS essentially performs the following three analyses:

- It calculates the net present value (NPV) of project benefits and costs from the differing perspectives of federal, state, and local agencies;

- It calculates the local, state, and federal tax revenue impacts of projects, programs, or policies, as well as public and private economic impacts of tax, toll, and pricing scenarios.
- It shows patterns and impacts of economic cash and commodity (tonnage and vehicle) flows to, from, and within a given study area. (TREDIS 2014)

In 2008, the Kansas DOT empaneled an interdisciplinary group of professionals to measure the economic impact of rural and urban projects. The group sought to find a methodology that modeled job creation and gross regional product, and it selected TREDIS. The model monetizes travel time, safety impacts, and access to new and expanded markets to help measure project outcomes (Turnbull 2013).

Two examples of rural projects in Kansas are the new I-35 interchange in McPherson and the expansion of US-54 in southwest Kansas from Greensburg to Haviland. The project cost for the I-35 interchange in McPherson was $13 million and the economic impact was $94 million. The project cost for the expansion of US-54 was $56 million and the estimated economic impact was $9 million. The Kansas DOT uses the economic impact figures as a general indication of a project's economic benefits to initiate projects that will more significantly benefit state and local economies. (Turnbull 2013)

One of the lessons learned from this experience was that data by itself would not draw a complete picture of the conditions. In order to make informed decisions, stakeholders need to be involved in the process which concurrently helps in the communication process and reduces resistance. (Turnbull 2013)

TRIMMS

This system estimates the impacts of a broad range of transportation demand initiatives and provides program cost-effectiveness assessment, such as net program benefit and benefit-to-cost ratio analysis. TRIMMS evaluates strategies directly affecting the cost of travel, like public transportation subsidies, parking pricing, pay-as-you-go pricing, and other financial incentives. It also evaluates the impact of strategies affecting access and travel times (TRIMMS 20014).

Florida DOT supported a study to enhance the TRIMMS model and quantify the net social benefits of a wide range of transportation demand management (TDM) initiatives in terms of emission reduction, accident reduction, congestion reduction, excess fuel consumption and adverse global climate change impacts (Concas and Winters 2009).

SROI

The methodology integrates different indicators to facilitate the infrastructure capital allocation decisions. The algorithms are designed to integrate the social value of improved infrastructure to economic growth and social equity in the impacted communities (Network 2012). International development agencies like the International Center for Tropical Agriculture (CIAT), the Consultative Group on International

Agricultural Research (CGIAR), and the World Bank (Walle 2008) strive to quantify each potential project's impact on economic, social, and safety requirements. The CIAT and CGIAR have implemented SROI as an analytic tool to assess the social impact in financial terms and quantify the broad economic effect of their projects.

A study applying SROI was done in Scotland to evaluate the "transport to employment" (T2E) scheme. In the study two groups of stakeholders were identified, and a monetary value was assigned to the first group in relation to the social benefits of increased employment to the client based upon net increased income. On the other hand for the second group, the monetary value to the state was assessed in terms of the reduction in welfare payments offset against increased tax contribution. This social value created by T2E has been assessed against the project's investment (Wright, et al. 2009).

HDM-4

The World Bank developed this model to measure the RUC in developing countries with unpaved and paved roads. This indicator is used to calculate the cost-benefit ratio of different roadway projects. The model is designed to analyze unit-road user costs using algorithms with input variables of speed, travel time, road condition, safety, type of vehicle, local economic characteristics, and emissions. The tools allow the analyst to differentiate between gravel and paved roads as well as calibrate the model to fit specific locations of interest. (WB 2013)

The Malawi National Roads Authority implemented the HDM-4 to examine the economic benefits of periodic maintenance, or rehabilitation, on specific road projects and to scope the cost of reducing the country's backlog of maintenance on both paved and unpaved roads. This analysis mode served to examine the economic viability of upgrading specific earth roads and to determine the traffic threshold at which it was economically viable to seal unpaved roads. (Le Baras, et al. 2009)

Iowa Rural Road Data Issues

The primary challenge for this research was the lack of low-volume road data. Rural roads do not receive the same level of data collection effort as primary roads. Consequently, it was necessary to create models that estimate a portion of the data needed for this research. In all cases, the estimating models maximized the use of available field data and were based on a close comparison of assets of similar size, condition, and capacity where sufficient data was found. While this condition was not unknown, it does point to the issue discussed above regarding the unintentional neglect of low-volume assets in rural locations.

Initially, the average number of trucks that use a road versus the average number of smaller vehicles was needed. This data was available for a few bridges across the state. Figure 2-1 shows IADOT's classification of a station that collects daily data throughout the year. The stations are classified by their locations as Rural Interstate, Municipal Interstate, Rural Primary, Municipal Primary, Rural Secondary, and Municipal Streets (IADOT-1 2013) and by type of device used to count the vehicles. One device can only count total volume and cannot distinguish between vehicle classes. The other device is able to distinguish three different types of vehicles based on length. The last one, which was used in this study, had the ability to differentiate counted vehicles based on the 13 vehicles classification from the FHWA Streets (FHWA-2 2013) shown in Figure 2-2.

		13 classes		3 classes		Volume only
Rural Interstate		10		10		0
Municipal Interstate		4		3		4
Rural Primary		42		35		1
Municipal Primary		4		11		10
Rural Secundary		7		7		12
Municipal Streets		4		2		8
TOTAL	**174**	**71**		**68**		**35**

Figure 2-1 Iowa Automatic Traffic Recorder Classification (Adjusted from **(IADOT-1 2013)**)

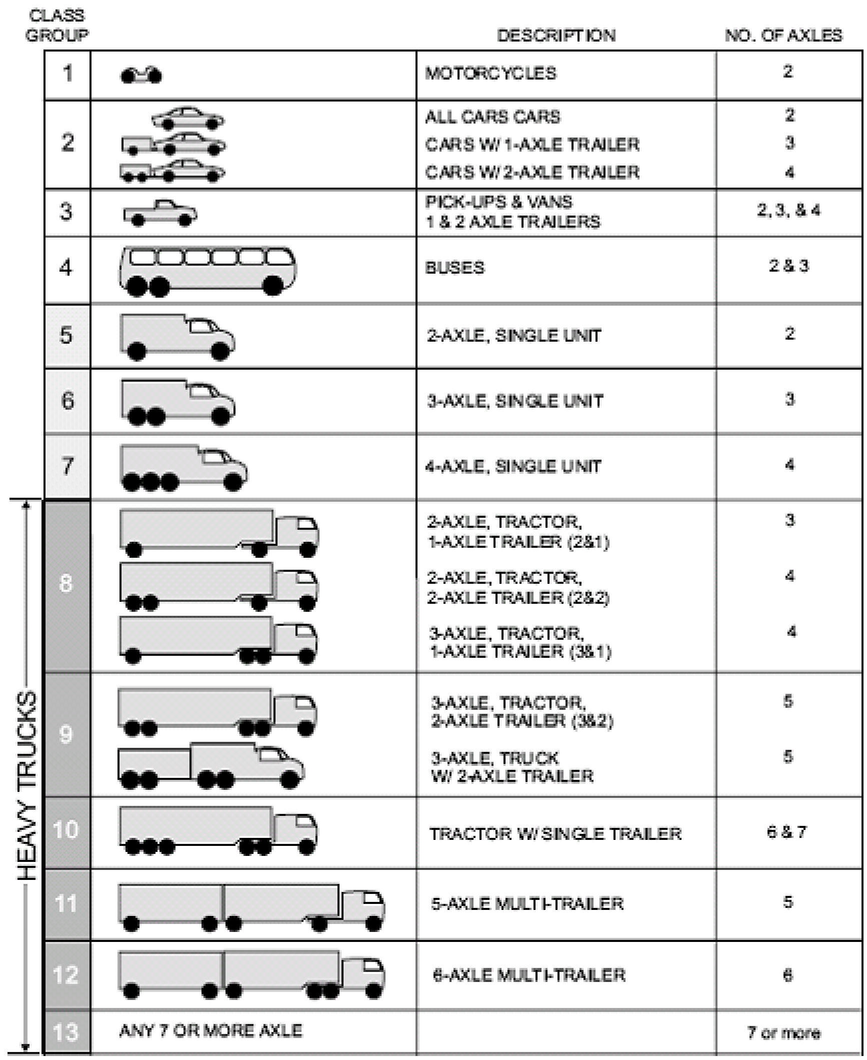

Figure 2-2 FHWA 13 Vehicle Classes (FHWA-2 2013)

For purposes of the study, the 13 FHWA vehicle classes have been divided into two groups:

- Light: Groups 1 to 7
- Heavy: Groups 8 to 13.

The methodology used to estimate the rural-road traffic in roads where the day-by-day data was not available is explained in Chapter 3.

Motivation

This research was initiated by the IADOT in response to the MAP-21 mandate to establish comprehensive TAM plans for the state (FHWA-5 2012). The preliminary literature review has noted that the current asset prioritization and resource allocation process in Iowa did not include a means to measure the socioeconomic importance of the rural roads to the state's agricultural economy. Additionally, the IADOT charged the research team with finding potential methods to better communicate the justification for future asset resource allocation decisions to both its internal and external stakeholders. Previous research had found that the concept of return on investment was both widely understood and generally accepted in public works (S. Robertson 2012). The World Bank and other institutions have used SROI and HDM-4 as a means of differentiating between diverse, potential infrastructure investments in developing countries (Raballand, Macchi and Petracco 2010). Since these nations' traffic volumes are generally low, access to advanced bridge construction technology is limited, and the networks are generally unpaved (Walle 2008), the team and its IADOT supervisors concluded that SROI had a high probability of providing an asset valuation metric that would be a good analog for the rural Iowa farm-to-market road network. Therefore, the decision was made to pursue adapting the World Bank's process for using SROI to prioritize investments in developing countries to the Iowa asset prioritization and resource allocation problem.

Thus, the federal mandate to develop a TAM plan became a potential tool to identify the users' needs and quantify the socioeconomic impact of the investments made in transportation projects. In addition, the early research noted a lack of transparency and communication between state and local transportation agencies, as well as between those agencies and their stakeholders and legislators. At the county level, project resource allocation decisions were mainly based on empirical knowledge of the needs of the zone. However, at the city and state level, the process was more methodical (IADOT-3 2013).

The institutional knowledge of how a specific asset impacts a county's economy is used by county engineers to select their project candidates; whereas, the state has no mechanism to transfer or translate that knowledge into the current project prioritization point system. The benefit of being able to use local institutional knowledge in the county-level prioritization process is lost when personnel transition in and out of the office. Additionally, county Boards of Supervisors tend to rely on long-term trusted relationships with their engineers, which create inconsistencies as these trusted professionals change. To address this issue, a standardized, transparent asset prioritization system is required to provide a more consistent decision making process.

Problem Statement

Prior to the MAP-21 TAM initiative, the state DOTs measured their performance based on reducing the number of assets in critical condition and in need of repair or replacement (TRIP 2013). That is, the allocation of the resources is done on "worst-first" basis. Current KPIs primarily measure the physical condition of the assets, ignoring the impact the assets have on rural/agricultural stakeholders, as well as to the overall economy of the state. As a result, capital improvement program decisions are unintentionally biased in favor of allocating available funding to assets having the highest level of traffic. In order to fulfill the needs of all Iowa stakeholders, it is important to measure not just the physical condition of the assets, but their social and economic impacts. The underlying premise of the TAM initiative is to move from "worse-first" to "most-needed first."

One asset class that has reached crisis proportions in the nation is rural bridges (Shoup, Donohue and Lang 2011). Iowa is the third worst state in the union with regard to structurally deficient bridges. The state has 5,371 deficient bridges out of a total nearly 25,000, which means one in five of Iowa's bridges are in need of major rehabilitation or replacement (Shoup, Donohue and Lang 2011). Because of the dearth of funding for low-volume, rural highway construction, structurally deficient rural bridges are often "posted" with lower load limits to prevent continued damage. Posting a bridge then creates a dilemma for agricultural stakeholders in that they must either detour to the next available crossing which increases fuel and operating costs of getting produce to market or reduce the size of the maximum load that can be carried over the posted bridge. Both scenarios essentially result in the same negative impact: higher fuel and operating costs and increased pollution due to the extra miles driven.

This research was built on previous work completed by international development institutions, such as the World Bank, to allocate available funding among potential projects in developing countries using SROI as a metric to measure the cost-effective allocation of development funds. The Iowa research will adapt the SROI algorithm to measure the potential impact that the closed and posted bridges have on the state's rural/agricultural transportation system. It will utilize SROI to gauge change in the potential economic growth of the agriculture in Iowa if bridge repair and replacement funding is allocated by SROI rather than ADT. The research will also explore the benefits of measuring SROI as one of the KPIs used to evaluate and allocate the resources across the overall transportation system in Iowa.

The SROI Primer states that measuring SROI improves the organization's impact whether seeking new funding or simply wanting to ensure that the day-to-day activities connect to the objectives. "SROI can help you understand, manage and quantify the value you are creating" (NEF 2004). In 2012 SiMPACT Strategy Group conducted a survey of non-profit, charity, social enterprise, and social purpose businesses, as well as municipal and provincial representatives, in order to clearly understand why social metrics are an important source of information sought by growing number and profile of organizations. The survey found that adding SROI to TAM, not only allowed a more objective distribution of the resources but also assisted in better communicating to stakeholders why and how the decisions are made, gaining their support and trust.

Similar methodologies have been used by organizations to evaluate the social impact of infrastructure development in undeveloped countries like Africa and South America. While the overall impact of upgrading roads and bridges can be much greater in developing communities than in developed communities, the rural nature of both groups remains the same and the experience gained internationally can be applied to the Iowa problem. For example, the CIAT implemented SROI in Africa, and states that its primary benefit is that "they do not measure outputs (standard deliverable items) but focus on outcomes (the effects caused)… SROI therefore measures the effectiveness of the intervention, not the intervention itself" (Pathik 2012). The proposed research is evolutionary in that not only does it extend the previous work, but it also follows a recent trend in some state DOTs, which initiated return-on-investment (ROI) evaluations of their Safety Service Patrol programs (Dougald and Demetsky 2008). Therefore, the notion of applying an ROI analysis to the TAM system decision-making process is both logical and potentially acceptable.

Research Questions

The research seeks to answer the following question:

Will adapting SROI to use as a socioeconomic metric in the IADOT TAM decision-making process change the outcome in a manner that provides a more equitable distribution of construction and maintenance resources?

This question is further broken-down into the following specific sub-questions.

- How does IADOT calculate the value added by transportation projects?
- Will SROI yield a result that better models the value added to stakeholders in the context of Iowa's low-volume bridges? Can SROI be integrated into the current TAM candidate project selection process for low-volume bridges in a manner flexible enough to be implemented without disturbing current internal agency TAM practices?

CHAPTER 3 RESEARCH METHODOLOGY AND VALIDATION

Chapter 3 presents a compilation of the methodology followed to produce the results contained in the articles presented in Chapters 4, 5, 6 and 7, and the validation process designed to determine the suitability of the proposed methodology and framework.

Hypotheses

The research questions articulated in the previous chapter lead to the following hypotheses, which the research methodology was designed to test:

- Since the current IADOT TAM program is primarily based on traffic volume and asset condition for capital project decision-making, low-volume assets are at a disadvantage; therefore, high economic-impact activities, such as the agricultural industries, located on low-volume assets suffer a negative impact.
- Adding SROI to current TAM KPIs as a needed asset metric will provide rational justification for allocating resources to low-volume assets that service high-impact agricultural activities and improve stakeholder communications.

Figure 3-1 explains the structure of the research process. In order to achieve the objective of this research, an intensive literature review was done throughout the entire period of the investigation in areas such as:

- Iowa Agricultural Economy

- Traffic Behaviors in Rural Zones of Iowa
- Vehicle Operating Cost/Users' Cost
- Cost-Benefits Analysis
- Prioritization Process of Bridges
- Bridge Management
- Iowa Transportation Infrastructure
- Transportation Asset Management.

To evaluate all possible alternatives, the literature review was done at a regional, sate, national and international level.

At a regional level, informal interviews were conducted with farmers and county engineers. At a state level, the IADOT Urban Engineer, the Offices of System Planning, Transportation Data Management, and System Monitoring were contacted as part of the outreach. A summary of these interviews can be found in Appendix A. Additionally, a National Peer Review with states such as New York, New Jersey, Georgia, and Utah was organized in conjunction with the IADOT Transportation Asset Management Department. A summary of the peer review can be found in Chapter 2. Last but not least, international work done by the World Bank was evaluated, as well as training on SROI in Canada.

The steps and research instruments that compose the methodology illustrated in Figure 3-1 are explained in detail in the methodology sections of Chapters 4, 5, 6, and 7.

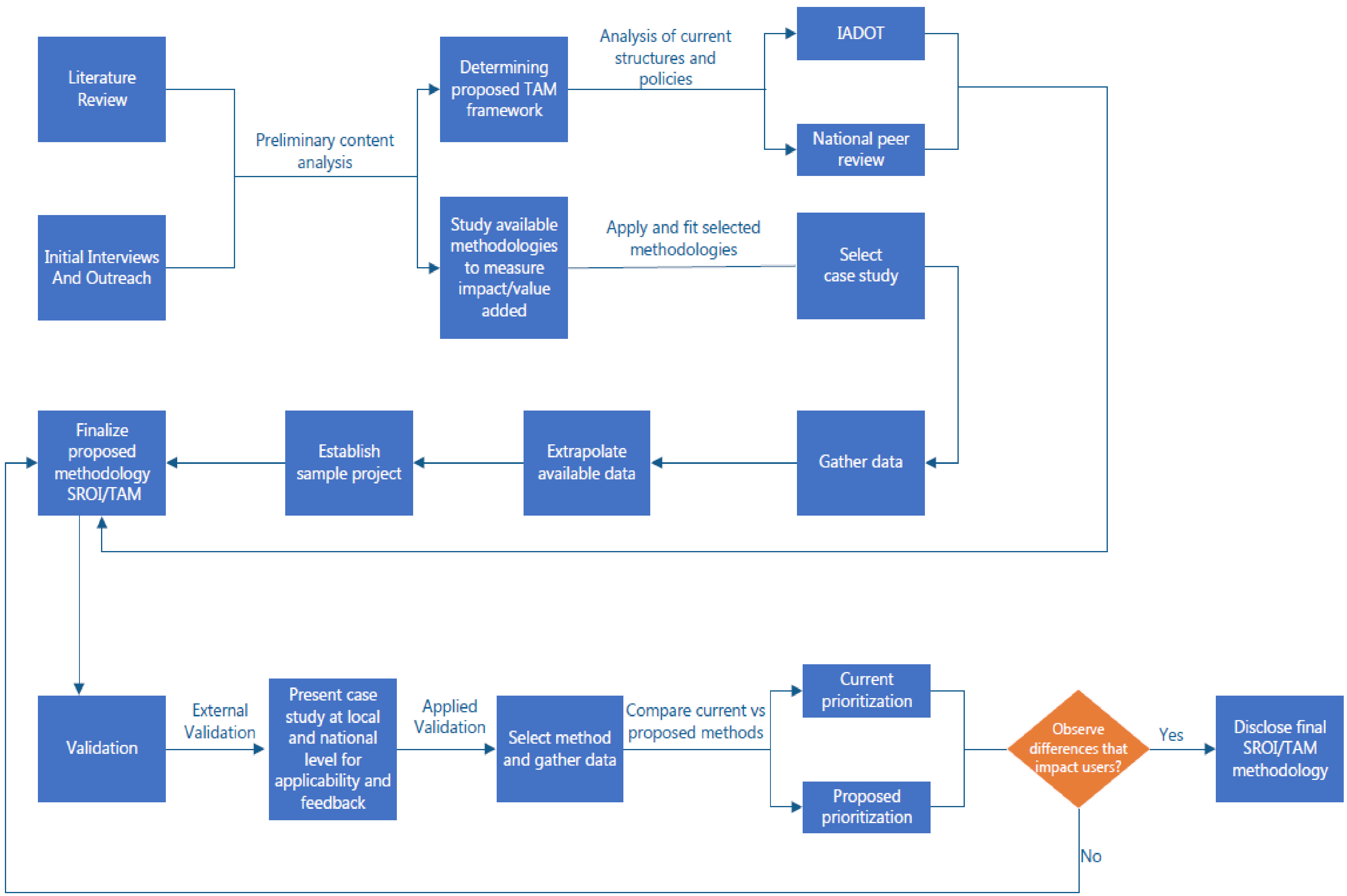

Figure 3-1 TAM/SROI Methodology and Validation Framework

Methodology for Data Gathering

Methodology to Calculate Value Added

The selection of the methodologies to be used in the calculation of the value added due to bridge replacement and maintenance projects was done using a comparison matrix (see Table 3-1). All four approaches found in the literature review were compared using nine main characteristics. The characteristics were selected as the result of a problem statement analysis that was based on the needs of the stakeholders in the context of agency performance goals.

Table 3-1 Methodology Selection Matrix

Key Characteristic	TREDIS	TRIMMS	SROI	HDM-4
Can be applied to Urban context	X	X	X	X
Can be applied to Rural context			X	X
Supports Measuring Environmental Impacts		X	X	X
Supports Measuring Stakeholders Impacts	X	X	X	X
Has been used in the Transportation Context	X	X	X	X
Provides Tools to Calculate ROI			X	
Involves LCCA of the Assets			X	
Measures Road Users Cost by Vehicle Type				X
Measures Road Users Cost by Road Type				X
Helps identify stakeholders and impacts	X	X	X	
Measure user's time cost	X	X		X
Easy to calibrate and adjust to context			X	X

A methodology was needed that was flexible enough to allow for future use to other asset classes besides rural bridges and able to be implemented under different circumstances and stakeholders. However, for purposes of this research, the analysis of the selected approach would be limited to rural bridge assets to demonstrate proof of the concept. As such, the focus of the subsequent analysis demonstrates one application which measures the impact of agricultural vehicles on asset management decisions. The analysis explores the hypothesis that the current asset management decision-making process seems to have neglected the value that agriculture brings to the state's road network as demonstrated by the finding that the road network shows greater deterioration in agricultural zones of the state (ASCE 2013). This indicates a potential bias toward rural stakeholders in zones where resources have not currently been allocated.

Based on the requirements, one key comparison was whether or not each methodology differentiated between urban and rural users. The analysis also determined whether or not the software could differentiate between gravel roads and paved roads because the literature showed that this aspect generated a different impact on the road's users. On the other hand, to cover the social aspects of the value added, the selected methodology must include variables such as safety, emissions, and value of time costs.

TREDIS and TRIMMS have been used to measure user's impact in transportation projects, but they are essentially "black boxes" where the analyst is not able to control or adapt the algorithm to model local requirements and constraints. HDM-4 and SROI provide more flexibility in the process. They allow the use of the proposed methodology in different contexts to calculate the return on the investment of alternatives which can be used to compare the impact between candidate projects. This approach can also be used as a performance measurement tool by the transportation agency to calculate the overall return on a given year's program, which in turn allows the SROI of this year's program to be compared to past years' programs.

Finally, SROI provides the tools to evaluate all possible stakeholders and their different impacts in an inclusive methodology. While HDM-4 provides an easy calibration of the algorithms providing a direct comparison of impacts based on different types of vehicles, different locations, and different types of roads. Consequently, integrating and adjusting SROI with HDM-4 provides the best conditions for the development of the proposed methodology. The combination offers the ability of being applied to different scenarios. It can measure social, economic, and environmental impacts according to the current needs of the agency and account for continuous changes in population, land use, deterioration of assets, and how resources are allocated over time.

Estimating Rural Road Traffic

The IADOT has 7 traffic count stations located on Rural Secondary Roads that can also differentiate between the 13 vehicle classes. Out of the 7 stations, only 5 stations had enough data that could be used to develop a trend that describes the relationship between traffic and agriculture in Iowa. Appendix C shows the data available for stations 300, 301, 303, 307 and 312 from 2009 to 2012.

Station 307 was selected for use in estimating traffic data for rural roads where no data exists because it had the most complete data set, and it was sited near a grain elevator which is a typical destination for rural road agricultural traffic. Figure 3-2 shows the growth in heavy trucks during the harvest months of September and October. Figure 3-3 shows the daily traffic of light vehicles which represents a more constant volume across the year when compared to the changes observed in heavy traffic. These daily traffic counts were used to model the traffic on roads used on the case studies. The roads used in the case studies only had one day of data available plus the estimated total AADT calculated by the engineers of the IADOT. These two numbers were used to estimate the daily traffic, assuming that the unknown number of vehicles is directly proportional to the traffic of a road located in similar zones, i.e. rural zones. Figure 3-4 and Figure 3-5 are the graphical representation of the application of the model. This case study is explained in detail in Chapter 5. Appendix D shows the calculated daily values for these two roads.

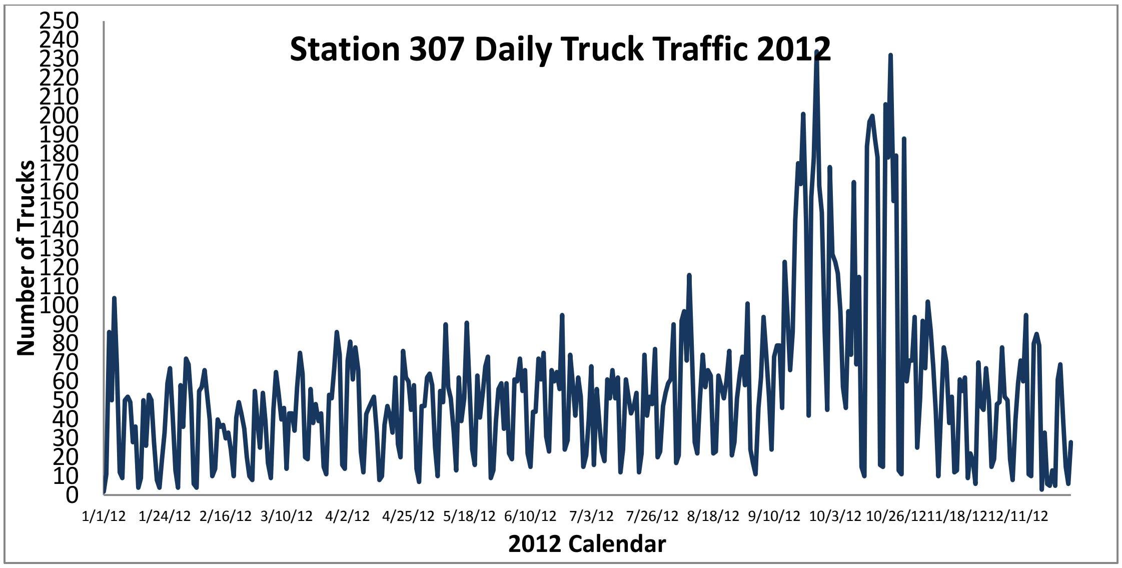

Figure 3-2 Station 307 Daily Truck Traffic 2012

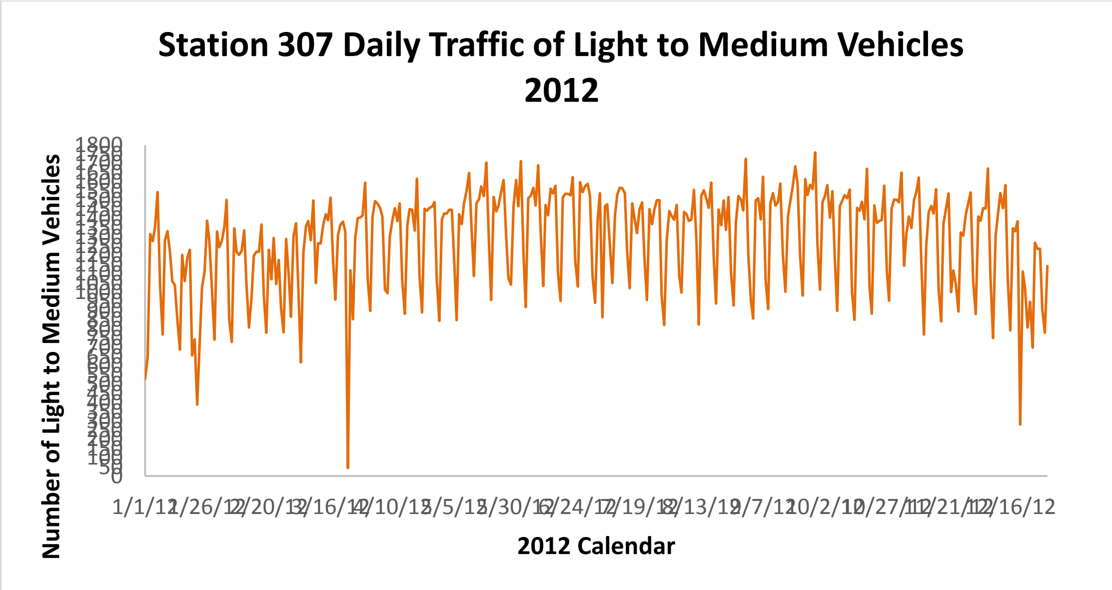

Figure 3-3 Station 307 Daily Traffic of Light to Medium Vehicles 2012

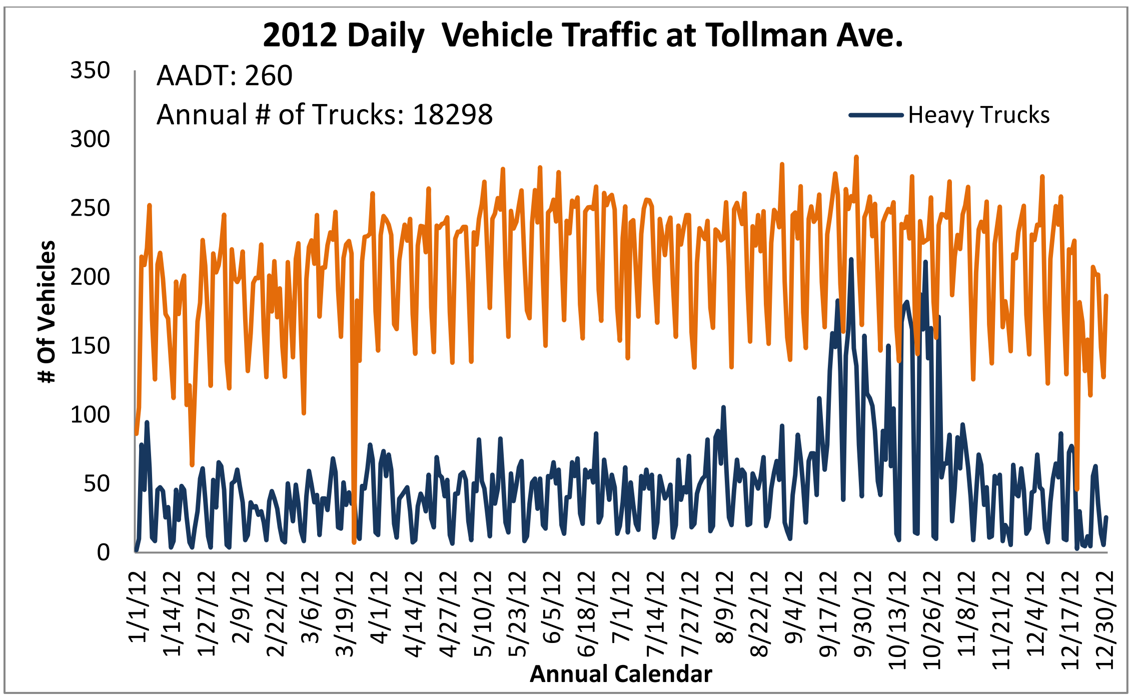

Figure 3-4 2012 Daily Vehicle Traffic at Tollman Ave.

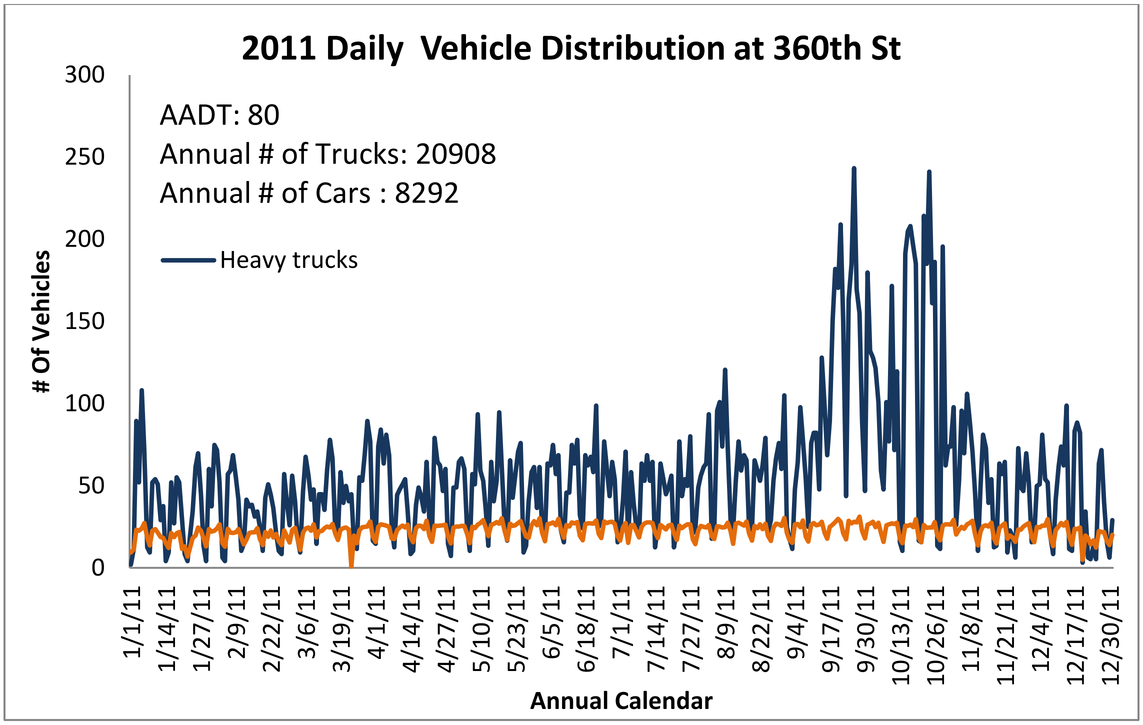

Figure 3-5 2012 Daily Vehicle Traffic at 360 St.

Validation

Validation of the finding and proposed methodology was done at two levels. The first level was an initial external validation of the literature review and case study was done at a county level via informal interviews with county engineers. Secondly, a state level validation was done to evaluate the proposed framework and methodology.

Appendix A presents the reports of the informal interview conducted with four Iowa county engineers. Within the most important outcomes of these interviews for the validation process was the feedback provided by the Hamilton County engineer. The conclusions of the initial case study involving two bridges in Hamilton County (shown in Chapter 5) were presented to the county engineer, and he was asked for his opinion. He was very familiar with these bridges and their zone of influence, and affirms having to go through the same scenario and arriving at the same conclusion as the one provided in the case study using the proposed methodology. The difference between his method of prioritization, which uses his expertise and extensive knowledge of the zone, and the method of the proposed system is the lack of tools available to provide a consistent prioritization process ensuring transparency in the process.

At a state level, the applied validation was done by testing the 2014 City Bridges Candidate List used to prioritize and allocate resources against the proposed methodology. This validation method tests for applicability and demonstrates whether implementing the proposed methodology would result in a different allocation of the resources at the same time that it increased the SROI ratio of the projects. Chapter 7 presents a complete description of the validation process.

CHAPTER 4 SOCIAL RETURN ON INVESTMENT AS AN ASSET MANAGEMENT METRIC

Presented at the Transportation Research Board: 2014 Annual Meeting Compendium of Papers. Paper 14-0399

Maria Catalina Miller[1], and Douglas D. Gransberg[2]

Abstract

State and local transportation agencies have been encouraged by the FHWA to implement a TAM program as a tool to more effectively distribute their limited resources. To evaluate and prioritize asset maintenance, rehabilitation, and replacement options, DOTs must identify specific KPIs to measure asset condition, traffic volume, and cost efficiency for comparison with other assets in their networks. Each state has specific needs, which require the agency's TAM program to be tailored specifically to the requirements of the local economy. Such is the case for states where the transportation network is a key contributor to a broad-based agricultural economy. Unlike highly urbanized states, agricultural states are dependent on their low-volume rural roads to sustain the state's economy. The authors of this paper analyze the social and economic impact that asset preservation decisions have in Iowa, a typical agricultural state, and propose a methodology for calculating the SROI to better measure the economic impact that the rural bridges have in the transportation of soy and corn across states like Iowa. The research shows that the areas with highest yield of corn and soy in Iowa are also the

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areas with the greatest percentage of rural deficient bridges, confirming the need to integrate a socioeconomic metric into the suite of condition- and capacity-based KPIs to ensure asset management resource allocation decisions do not unintentionally neglect an important sector of the state's economy, merely because the volumes of traffic are lower than in urban regions.

Introduction

When making decisions about resource allocation for transportation asset maintenance and construction projects, engineers gather a wide range of performance indicators such as the PSI and the IRI, which measure the physical condition of each asset. Other common measures are focused on capacity: ADT, accident rates, speed, visibility, LCC, etc. While the condition of assets are important, using only condition- and traffic-based KPI results in an asset management program that prioritizes projects by "worst-first" and "most traffic (Cambridge 2002). This system unintentionally ignores the sizeable contribution that rural farm-to-market roads make to the economy of agricultural states such as Iowa, Kansas, and Montana.

A similar issue is faced by international development agencies who must allocate a finite amount of resources to competing infrastructure projects in developing countries. To do so, agencies like the CIAT, The CGIAR, and the World Bank (Walle 2008) strive to quantify each potential development project's impact on economic, social, and safety requirements. The CIAT and CGIAR have implemented SROI as an analytic tool to assess the social impact in financial terms and quantify the broad economic effect of their projects. The SROI is integrated with other metrics to facilitate the infrastructure capital allocation decisions. The algorithms are designed to integrate the social value of improved infrastructure to economic growth and social equity in developing countries with agricultural economies.

U.S. organizations like the United Soybean Board, the U.S. Soybean Export Council and Soy Transportation Coalition described a similar issue in their 2012 report: Farm to Market a Soybean's Journey from Field to Consumer (Informa 2012). In this report, these organizations cite the rapidly deteriorating conditions of the U.S. transportation infrastructure system. The report argues that while the U.S. highway network is rapidly deteriorating that little attention has been focused on how the infrastructure system impacts agriculture when highway construction and maintenance resources are allocated. Informa Economics (2012) states that:

> The delivery of commodities resulting from grain and soybean farming are of significant importance to the U.S. economy. This impact can be understood first in terms of overall jobs, output, personal income and value added on the U.S. economy that depends either directly or indirectly on the haul movement of these commodities, and second in terms of the potential positive impact of investing in transportation infrastructure that facilitates the more efficient movement of these commodities.

Many states, like Georgia, emphasize traffic volume to make resource allocation decisions. Therefore, roads with low traffic volumes are at a disadvantage in competing for a share of available funding. The Georgia Department of Transportation's (GDOT) TAM strategy is to allocate resources based on need rather than distributing them equally across the state (GADOT 2011). This does not seem to be a big challenge for Georgia, which has been able to overcome state policies such as "congressional district fund balancing," which mandates an even distribution of the resources among Georgia's 13 congressional districts. The GDOT complies with the mandate by splitting maintenance funding and construction funding which allows them to balance the funds by scheduling new construction to zones where the prioritizations of maintenance funds were not allocated; however, for rural bridges, the GDOT is still allocating resources based on worse-first scenarios. Thus, urban districts with high traffic volumes may see more construction money than the rural districts where the bulk of the funding will come from the maintenance allocation.

The Iowa Context

In Iowa, the economy is based on agriculture and is dependent on the transportation network's ability to deliver those commodities to market. Thus, equitable distribution of funds becomes more complex. If low-volume roads do not receive sufficient funding to cover adequate maintenance and timely repair, rehabilitation, and replacement, a negative impact on the state's agricultural economy occurs. *The Economist* discussed the need for more ethanol plants in Iowa and highlighted how the local farmers in remote areas could not get the top prices for corn because of the high cost of transporting it to the market (Belmond 2007). "In Iowa, that region is the north-western part of the state, which enjoys high crop yields but gets 25-50 cents less per bushel because it is too far from the Mississippi river barges" (Belmond 2007). Similar issues apply to other commodities, such as soybeans and corn, across Iowa as shown in Figure 4-1 and Figure 4-2.

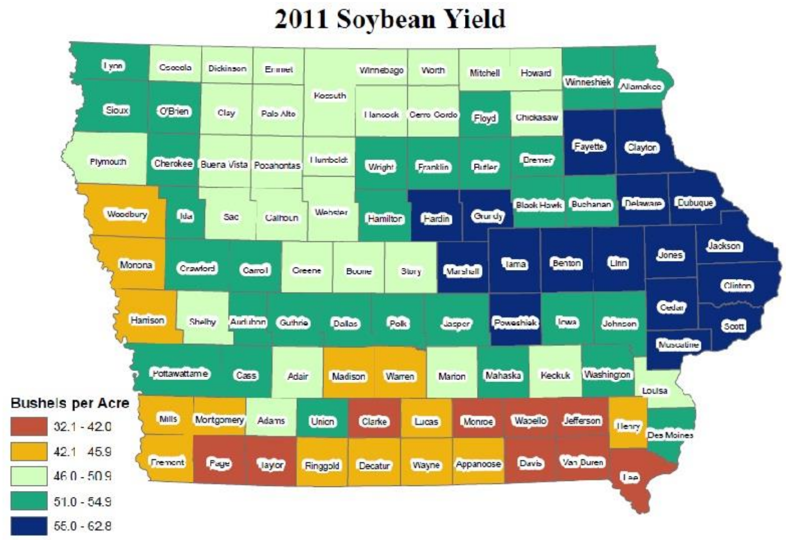

Figure 4-1 2011 Soybean Yield by Counties in Iowa (Ford 2012)

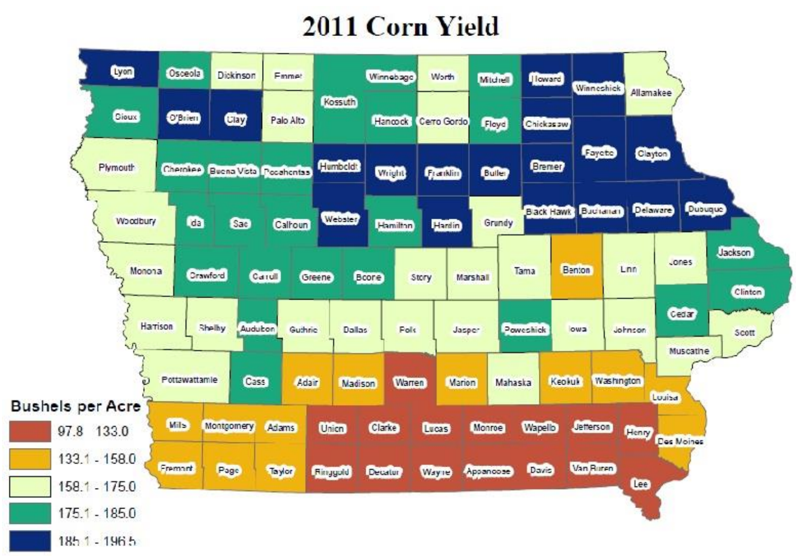

Figure 4-2 2011 Corn Yield by Counties in Iowa (Ford 2012)

According to the study which produced Table 4-1, Iowa ranks third nationwide among states with the highest percentage of deficient bridges (Davis, et al. 2013).

However, 77% of all bridges nationwide and 63.5% of all structurally deficient bridges are located in rural areas. This illustrates the potential that inadequate construction and maintenance funding to keep those rural bridges operating at their current structural load capacities could have an enormous economic impact on the Iowa economy. Furthermore, the forecast is not promising considering that the life span of a bridge is 50 years, and the current average age of American bridges is 42 years (Davis, et al. 2013). The fact that Iowa routinely increases the allowable load limits for its roads during harvest season from 24,000 to 28,000 pounds (IADOT 2012) and that the state government has eased the regulations for vehicles transporting most cash crops, allowing both oversize and overweight transport without a permit during periods of drought (Iowa 2012) testifies to the impact that agricultural production makes on the state's economy. It also underscores the need for Iowa's transportation infrastructure to be well maintained. Simply put, the state is willing to accept the long-term risk of accelerating the deterioration of structurally deficient bridges to the short-term benefits accrued when its crops are delivered to market.

Table 4-1 Ranking of Structurally Deficient Bridges (adapted from **(Davis, et al. 2013)**)

State	Rank	2013% Deficient	Total Bridges	Deficient Bridges 2013	Deficient Bridges 2011 (FHWA)	Change in Deficient Bridges Over 2011	Percent Change in Deficient Bridge total	Average Daily traffic on deficient bridges
Pennsylvania	1	24.5	22,667	5,543	6,043	-500	-8.3% better	18,994,224
Oklahoma	2	22.6	23,778	5,382	5,305	+77	15% worse	7,236,161
Iowa	3	21.2	24,465	5,191	5,440	-249	-46% better	1,728,828
South Dakota	5	20.6	5,869	1,208	1,198	+10	0.8% worse	354,303
Missouri	10	14.5	24,072	3,502	4,142	-640	-15.5% better	5,156,617
Kansas	25	10.5	25,206	2,657	2,833	-176	-6.2% better	812,743
Minnesota	32	9.1	13,109	1,191	1,151	+40	3.5% worse	2,342,495
Illinois	35	8.7	26,514	2,311	2,289	+22	1.0% worse	8,035,705
Wisconsin	36	8.2	14,094	1,151	1,153	-2	-0.2% better	2,923,488

When a bridge is found to be structurally unsound, the DOT or the county engineer typically post a new, lower load limit. This presents farmers that routinely use that structure with a dilemma having two options: reduce the size of each load to conform to the load limit or detour around the load-limited bridge and continue to haul fully loaded. Either way, the cost for transporting the crop to market increases. The following is a hypothetical example to illustrate the point.

Assume that a farmer uses a 5-axle grain body, tractor-semitrailer to haul grain to market over a route where the bridge is currently not load-limited. That vehicle would have a maximum payload of roughly 25 tons yielding a gross vehicular weight of 32 tons and would then consume 8.7 gallons of diesel fuel per thousand ton-mile (Davis, Diegel and Boundy 2013). A typical 400 acre farm in Iowa produces about 20,000 bushels of soybeans or 64,000 bushels of corn in a season. If the farmer hauls the produce 100 miles to market (the route includes an un-posted bridge), it will take 24 trips which cost a total of $2,700 for fuel alone for the soybeans, or 72 trips at $8000 for corn (diesel fuel priced at $4.00/gallon). If the bridge is allowed to deteriorate to a point where the DOT posts it as limited to 20 tons, and the farmer must detour an additional 20 miles to use a bridge rated to carry his maximum payload, the fuel cost for the soybeans goes up to $3,200;corn to $9,600. Figured another way, the farmer's fuel cost per ton of produce goes from $4.45 to $5.35. Thus, the cost of grain is directly impacted by the failure to maintain an asset because the amount of traffic it carried was too low to permit it to effectively compete with higher volume roads and bridges in the state's network.

Figure 4-3, Table 4-2, and Table 4-3 show the distribution of structurally deficient bridges across the U.S. The report from which the graphic originated found that 63.5% of these bridges are located in rural counties where the economy depends on them to carry the nation's food supply to market (Daily Yonder 2011). Extrapolating the hypothetical example for Iowa across the rest of the nation leads one to infer that current TAM systems that mainly utilize engineering condition and traffic data to prioritize construction and maintenance budgets are missing a huge component in the decision-making process. Even for a TAM plan that implements detour distances as a way to measure the users' impact, there are several factors missing such as greater vehicle operation cost and lower speed/longer commute time on gravel roads versus pavement roads as well as the percentage of vehicles that will get impacted due to bridge posting (i.e. heavy versus lighter vehicles).

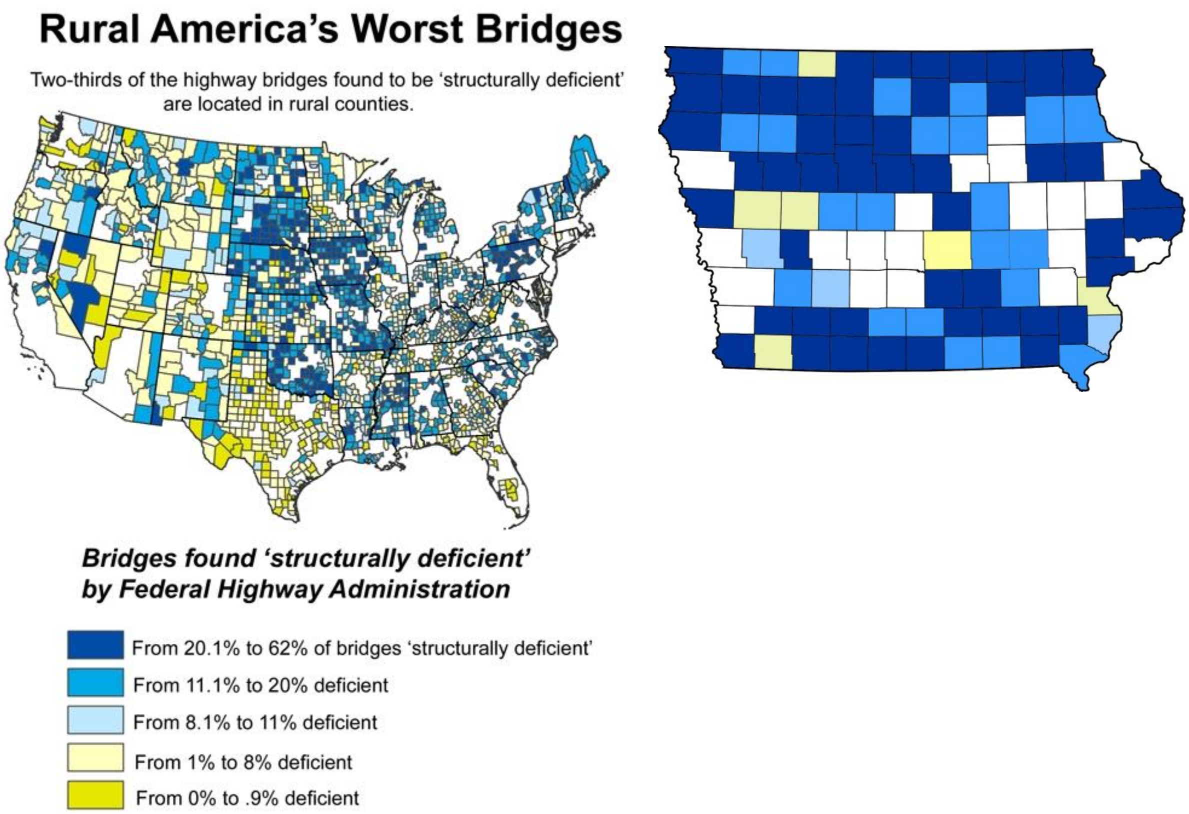

Figure 4-3 Distribution of Rural Structurally Deficient Bridges (adapted from **(Daily Yonder 2011)**)

Table 4-2 Iowa Rural Counties with the Worst Bridges - National Rank (adapted from **(Daily Yonder 2011)**)

National Rank	County	Total Bridges	Bridges needing repair	Percent of bridges needing repair	2011 Soybean Yield Bushels/acre	2011 Corn Yield Bushels/acre
7	Allamakee	202	94	46.50%	51.0-54.9	158.1-175
11	Winneshiek	111	49	44.10%	51.0-54.10	185.1-196.5
13	Decatur	210	91	43.30%	42.1-45.9	97.8-133
19	Lyon	203	79	38.90%	51.0-54.9	185.1-196.5
20	Pocahontas	535	208	38.90%	46.0-50.9	175.1-185.0
22	Kossuth	209	80	38.30%	46.0-50.10	175.1-185.1
23	Union	255	96	37.60%	51.0-54.9	97.8-133
34	Hamilton	276	97	35.10%	51.0-54.10	175.1-185.1
36	Montgomery	149	52	34.90%	42.1-45.9	133.1-158.0
39	Wapello	167	58	34.70%	32.1-42.0	97.8-133

Returning to the Iowa context, Allamakee County is ranked seventh in the nation for the worst bridges in the rural counties. Additionally, Allamakee is within the counties with high production of corn and soy as shown in Figure 4-1 and Figure 4-2. Taking the soy and corn yield data with the county's overall bridge condition leads to the conclusion that an agricultural state like Iowa needs to build a function that portrays the needs of its agricultural industry for the transportation network into its TAM resource allocation process to ensure that the infrastructure needs of the state's economy are kept in a condition that supports rather than hinders growth.

Therefore, the purpose of this paper is explore the utility of the cost-benefit framework used by the CIAT and CGIAR, known as the SROI (Sova, et al. 2012) as a comprehensive way to measure the impact of the asset condition on the community. The notion is not to replace the current condition- and traffic-based metrics but rather to add SROI as a third component of the resource allocation decision-making process. The remainder of the paper will first explain the mechanics of SROI, and then it will demonstrate its use via a case study example.

Social Return on Investment

Private and public entities have realized that they need to be able to value social outcomes in monetary terms. Hence, organizations like SROI Network have developed methodologies to satisfy the need of measuring the social impact. SROI Network was formed in 2008 in the United Kingdom with the mission of promoting the use and development of the SROI methodology internationally. SROI is a framework based on "social generally accepted accounting principles" that can be used to quantify and understand the social, economic, and environmental outcomes. This methodology has been used by both governmental and nongovernmental organizations to forecast the value created if the development projects attain their intended outcome. The output is a metric that can be used to compare prospective projects and make the resource allocation decision.

A study applying SROI was done in Highland, Scotland to evaluate the T2E scheme. In this study a monetary value was assigned to the first stakeholder in relation to the social benefits of increased employment to the client based upon net increased income. On the other hand, a second stakeholder was identified and the monetary value to the state was assessed in terms of the reduction in welfare payments offset against increased tax contribution. This social value created by T2E has been assessed against the project's investment (Wright, et al. 2009).

The SROI framework is based on seven principles (Network 2012) Figure 4-4

IMPACT = Outcome – Deadweight – Drop Off

$$\textbf{SROI} = \frac{\text{Total Present Value of the Impact}}{\text{Present value of the Project}}$$

Figure 4-4 SROI Principles

1. Understand the different kinds of stakeholders and their motivations on the project. In the case of transportation projects, the taxpayers play an important role as users and sponsors of the infrastructure. The DOTs are primarily responsible for administering resources and executing projects. Local and federal governments act as auditors and sponsors. Furthermore, users want to understand why and how the project's prioritization has been made and the DOTs have the challenge to factually communicate these decisions.
2. Understand the change if a project is implemented, including all geographic and financial zones of impact. In the context of rural bridges, changes on gas consumption, vehicle deterioration, transportation time, and emitted CO_2 (carbon dioxide) are some of the indicators that can be measured and valuated. These changes are known as the outcomes of the activity.
3. Value the things that matter. Financial proxies should be used in order to recognize the value of the outcome. Many outcomes are not traded in markets; therefore, their value is not recognized.

   For this exercise let's assume the following proxies:

   - Vehicle operating cost (VOC) of $1.97 per mile (Barradas 2011; Skorseth 2000) distributed the following way:

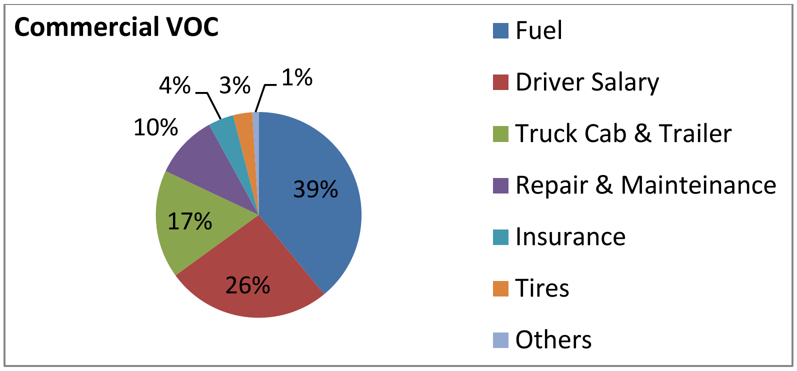

Figure 4-5 Commercial VOC Distribution. (Adapted from **(Barradas 2011)**)

- CO_2 footprint: heaviest trucks consume an average of 8.7 gallons per thousand ton-miles (Davis, Diegel and Boundy 2013), and diesel emits 22.4 pounds of CO_2 per gallon (FHWA-6 2012). This implies that an average loaded truck could produce 194.88 pounds of CO_2 per thousand ton-mile.
- The price of corn is $6.70 per bushel, and the price of soy is $14.2 per bushel (ISUEO 2013). One ton of corn represents 39.368 bushels, while one ton of soybeans equal 36.744 bushels (weight could vary depending of the content of moisture on the grain). A common semitrailer would hold between 900 and 1000 bushels of corn (Pioneer 2013). In summary, one trip of a semi-truck fully-loaded with corn could be valued at $6,700.

4. Only include what is material. Determine what information and evidence must be included in the accounts to give a true and fair picture, such that stakeholders can draw reasonable conclusions about impact.
   - Capacity of bridges in tons
   - Average loaded trucks in tons
   - Ratio of travel distance in miles/detour distance in miles

- Average traffic throughout harvesting season

5. Do not over-claim
6. Be transparent
7. Verify results

Items 5 to 7 are in place to ensure the reliability of the results.

The SROI framework requires identifying the inputs, outputs, and outcomes. In this case the inputs would correspond to the cost of the maintenance needed to bring the bridges to a capacity that satisfies the needs of the users. The outputs would be the number of maintained bridges. And the outcomes, or the final goal, would be to reduce the transportation cost of the agricultural product as well as reduce the CO_2 emitted during this process. Once these three elements have been identified then the outcome, or the impact, can be calculated. “In time of austerity, outcomes-based evaluation and SROI are highly effective tools that increase the ability of a service provider to understand the value of their work from the perspective of their investor alongside the perspective of their clients and the key stakeholders of their clients” (S. Robertson 2012).

Calculating SROI

To calculate the value of the impact of investing in a given infrastructure project, one must first calculate percentages for peripheral impacts. These are termed Deadweight, Attributions, and Drop-off. The Deadweight is a percentage of the outcome that would have happened even if the project had not been built. For example, users seeking out more cost efficient routes or vehicles could have reduced the VOC and the CO_2 emissions. Attributions are the percentage of the outcome that was caused by other organizations or departments. An example would be a county making an improvement on other infrastructure along the route. Lastly, the Drop-off is used to account for loss of asset serviceability due to normal aging. This is also calculated as a fixed percentage of the remaining level of outcome at the end of each year.

SROI is best described by example. For this exercise, the following scenario is used:

- An agency is considering whether or not to allocate funding for a rural bridge. It is in danger of being posted with a maximum weight limit of 15 tons.
- The bridge's ADT is 80 vehicles per day (VPD), of which 48 are light vehicles that won't be affected by the detour if the bridge is posted; therefore, 32 heavy vehicles are forced to detour if the bridge is posted.
- The detour adds 10 miles to the route.
- 10 miles x $1.97 of VOC = $19.7 per trip x 32 vehicles = $630 daily or $230,096 annually.

Total Outcome (or Impact) = Cost – Deadweight – Attributions (Equation 1)

Deadweight = 0% (assuming no other changes have been made)

Attributions = 0% to the maintenance of the roads

Therefore, Total Outcome = $230,096 – 0 – 0 = $230,096 per year

Note: The Drop-off is calculated when subtracting the annual deterioration while projecting into the future.

There are three steps in calculating the SROI:

1. Projecting into the future.
2. Calculating the NPV.
3. Calculating the ratio.

1. Projecting into the future:

Assuming the rural bridge has a 75-year life span and a deterioration of 0% annually due to periodic maintenance that helps retain the required load capacity on the bridge. The total impact is calculated as shown in Equation 2.

Total Impact = $\sum_{\mathbf{t=1}}^{\mathbf{life\ span}} \mathbf{Impact\ at\ end\ of\ year\ 1(1 - deterioration\ rate)^{t-1}}$

(Equation 2)

Total Impact = $\sum_{t=1}^{75} 230{,}096\ (1-0)^{t-1}$ = \$17,257,200

2. Calculating the NPV

Present value (PV) = $\sum_{\mathbf{t=0}}^{\mathbf{(life\ span-1)}} \left(\frac{\mathbf{Impact\ at\ end\ of\ year\ 1(1-deterioration\ rate)^{t}}}{\mathbf{(1+r)^{t+1}}}\right)$ (Equation 3)

PV = $\sum_{t=0}^{74} \left(\frac{(230{,}096\ (1-0)^{t}}{(1+0.04)^{t+1}}\right)$ = \$5,448,767

Assume a discount rate of 4% (r = 0.04 as set by FHWA (FHWA-4 2003)).

Assume the following Life Cycle Cost Analysis (LCCA) of replacing a two-span steel girder bridge with a single-span steel girder bridge:

Table 4-3 LCCA (adapted from **(Shirolé 2006)**)

Activities	**PV**	**Year**	**Expenditure in dollars**
Initial New Construction	$552,038	0	$552,038
Annual Maintenance	$23,680	75	$1,000
Special M & R	$22,819	20	$50,000
Rehab: re-decking, etc.	$101,378	38	$450,000
Special M & R	$5,141	58	$0
Salvage Value	$0	75	$0
Sum of PV	$705,056		

NPV = [Total PV of benefits] - [Value of investments]

NPV = 5,448,767 – 705,056 = $4,743,711

3. Calculating the Ratio :

$$\text{SROI} = \frac{\textbf{Total Present value of benefits}}{\textbf{Value of investments}} \qquad \text{(Equation 4)}$$

$$\text{SROI} = \frac{5{,}448{,}767}{705{,}056} = 7.73 \times 100 = 773\%$$

This demonstrates the benefit of replacing the bridge is six times greater than the given investment.

Once the SROI has been calculated these rates could be integrated to the TAM plan to compare and prioritize the different assets. In the case that two bridges, one in a rural area and one in an urban area, both with similar BHI, detour distances, and replacement cost but with different ADT are being evaluated for maintenance prioritization, the SROI could play a special role in differentiating the actual impact on the users.

The intention of the following hypothetical example is to compare a scenario where the currently used KPI in a TAM plan are similar between both bridges with the only difference being their location, which not only implies a difference on the ADT, but also a different economic impact to the users.

- The structural bridge condition is such that it has to be posted to a 15 ton maximum weight.
- The urban bridge has an ADT of 600 with an estimate of 10% trucks. 540 vehicles of the total ADT weigh below 15 tons. The impact or outcome of implementing a rehabilitation project will only account for 60 vehicles.
- The rural bridge has an ADT of 400 with an estimate of 20% light vehicles. In this case the impact or outcome will be for 80 vehicles.
- Other differences in the economic impact are as a consequence of greater vehicle deterioration and lower speeds on gravel routes versus pavement routes.

In order to not over claim the impact of rehabilitating a bridge it is necessary to withdraw the users that are not impacted, or in this case the lighter vehicles that will not need to detour.

The intent of this paper is to set up a conceptual idea with possible scenarios where the SROI could be a potential aid to add factual data to the decision-making process; therefore, real data and complete outcomes have not yet been analyzed. Indeed, it is not hard to create a hypothesis concluding that the outcome of the rural bridge could be higher than the urban bridge in this scenario.

Case Study Example

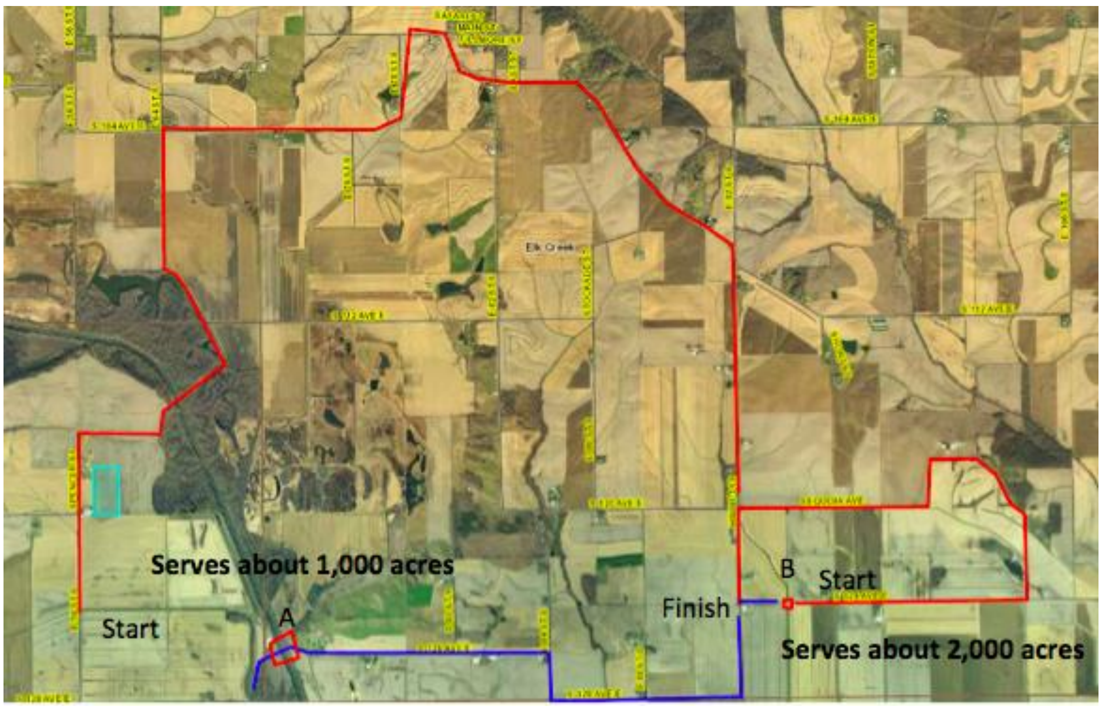

Figure 4-6 Jasper County Iowa

This case study is the result of an interview with one of the farmers of Jasper County in Iowa, and it supports the importance of involving the stakeholders in the SROI process. The impact of bridges A and B from Figure 4-6 were analyzed. Prior to doing the interview, it could be assumed that bridge A would have a wider zone of impact. However, it appears that because this bridge has been closed for so long, the farmers have already found efficient alternative routes (i.e. Deadweight) to transport their grain, which could possibly reduce the number of acres impacted by the bridge. Due to ADT counts taken prior to the closing of the bridge and input from some local farmers, the local DOT has decided to schedule bridge A for replacement and postpone the replacement of bridge B. Let's look what the recommendation could have been after applying SROI to the decision making process.

Table 4-4 Bridge A and B Facts

Bridge	**Condition**	**Length (Linear Foot)**	**Detour (Miles)**	**Travel without Detour**	**increase due to detour**	**Estimated Cost**	**acreage within the zone of**	**Total production of Bushels**
A	Closed	236	10.5	3.5	200%	1,500,000	1,000	50,000
B	Closed	32	4	.3	33%	400,000	2,000	1000,000

Note: This case study is only considering the impact to the farmers hauling soy and corn to the grain silos and does not include the heavy trucks transporting the grain for feeding, chemicals, fuel, or any other vehicles that could potentially use these bridges.

<u>Bridge A:</u>

It requires 50 trips to haul all the grain from the fields to the silos. There are seven miles of detour distance, for a total of 350 miles at $1.97 VOC. Therefore, the impact of fixing bridge A is $689 per harvesting season with a life span of 75 years.

PV of Total Impact $=\sum_{t=0}^{74}\left(\frac{(689(1-0)^{t}}{(1+0.04)^{t+1}}\right) = \$16,315$ (Equation 3)

NPV = 16,315 – 1,500,000 = -$1,483,685

SROI $=\frac{16,315}{1,500,000}$ = 0.0108 x 100 = 1.08% return (Equation 4)

Bridge B:

It requires 100 trips to haul all the grain from the fields to the silos. There are 3.7 miles of words detour distance, for a total of 370 miles at $1.97 VOC. Therefore, the impact of fixing bridge B is $729 per harvesting season with a life span of 75 years.

PV of Total Impact $=\sum_{t=0}^{74}(\frac{(729(1-0)^{t}}{(1+0.04)^{t+1}})$ = $17,263 (Equation 3)

NPV = 17,263- 400,000 = -$382,737

SROI $=\frac{17,263}{400,000}$ = 0.043 x 100 = 4.32% return (Equation 4)

Looking only at the impact the bridges have on the trucks transporting corn and soy, bridge A provides only a 1.08% return while bridge B provides 4.32% of return. As a consequence, if the DOT had decided to replace bridge B they could have saved $1,100,000 and impacted more users at the same time.

Conclusions

Current KPIs used in TAM plans to prioritize projects by needs do not account for the socioeconomic impact that rural infrastructure contributes to the economy of the agricultural states. Over the years the ADT has been one of the indicators that help make a final decision while comparing bridges in similar conditions; therefore, the rural infrastructure has had a tremendous deterioration to the point that 63% of the deficient bridges are located in the rural areas.

As a consequence of bridge deterioration, farmers are experiencing higher production costs due to longer detours and, therefore, higher VOC. Not only is the deterioration on the gravel roads more of a problem than in the urban areas with pavement roads, but also the traffic distribution between lighter and heavy trucks is considerably different. Reducing the capacity of an urban bridge will probably still allow 90% of the traffic to continue with their normal route, while if a rural bridge has its allowable maximum weight lowered its possible that only 60% of the normal traffic can still use that route.

Adding SROI to TAM funding decisions would add value to the process by giving the engineer a more balanced view of network impacts than just capacity and condition. Consequently the DOT could potentially save resources that could be assigned to assets with greater impacts on the users.

The SROI looks at the outcome produced by the projects and requires the input of the stakeholders to ensure their needs are being met, aligning with the ultimate goal of the TAM which is to move from a decision making process based on “worst-first” to “most needed first”.

CHAPTER 5 INTEGRATING SOCIAL IMPACT TO BRIDGE'S ASSET MANAGEMENT PLANS

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Abstract

Understanding the socioeconomic impacts that rural bridges have on states that are dependent on agricultural industry provides a valuable perspective for public transportation agencies to prioritize the allocation of bridge maintenance funds. Currently, low-volume bridges are at a disadvantage for being allocated maintenance funding in typical asset management programs due to the low ADT statistics. The authors propose a methodology to quantify the socioeconomic impact of low-traffic bridges on farm-to-market roads using SROI for making asset management funding decisions. It also demonstrates how these rates can be used as a key performance indicator. It provides several alternatives to incorporate the SROI to current project prioritization processes and better allocate scarce maintenance funding. The authors found that factors like road surface type and percentage of heavy vehicles influence a given asset's SROI, potentially justifying investing in a low-volume bridge over others with higher traffic volumes. The authors concluded that current processes for asset management resource allocation

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are unintentionally overlooking the contribution of a farm state's economy by relying on traffic volume as the primary measure of network utility.

Introduction

Funding replacement, rehabilitation, and maintenance projects on low-volume roads has always been problematic (Raballand, Macchi and Petracco 2010). One study cited the prevailing concept that "using these [state and federal construction and maintenance] funds on projects other than major highways will result in crippling gridlock" (Gann, et al. 2012). This statement eloquently articulates an institutional bias toward using ADT as the primary performance measure for making TAM decisions. While the validity of allocating funds to projects that impact the largest number of vehicles is not in question, it neglects the contribution made by an individual vehicle to the community's economy. In states whose economies are driven by agriculture, the value of the farm-to-market road network, more specifically the ability of its bridges to carry crop-laden trucks, is significant. One report found that "trucks account for 91 percent of the ton-miles of all fruit, vegetables, livestock, meat, poultry, and dairy products in the U.S." (TRIP 2011). If the cost of transporting foodstuffs is reduced by asset management decisions to keep rural bridges operating at their maximum rated capacity, society's cost of living will decrease proportionally. Thus, it is important that public asset managers have a tool that measures an asset's socioeconomic impact as well as its ADT and technical condition. The objective of this paper is to explore the use of the World Bank's concept to understand cost-benefit ratios and the use of the SROI framework (Raballand, Macchi and Petracco 2010) to provide a rational metric to measure the socioeconomic impact of resource allocation decisions on low-volume, farm-to-market roads.

In 2012, the MAP-21 Act (§1203; 23 USC 150(a)) made performance management for federal-aid highway projects mandatory (FHWA-5 2012). Among the goals cited in the legislation were the following:

- "To improve project decision-making
- To improve the national freight network
- To strengthen the ability of rural communities to access … markets
- To support regional economic development" (FHWA-5 2012).

All TAM plans should be based on long-term strategic views that explicitly identify the need, including the customer's need (Cole 2005). Adding a socioeconomic metric to the TAM resource allocation decision process promises to address the first goal by improving project decision-making. The U.S. Department of Agriculture (USDA) reported that the annual value of the U.S. agricultural economy is $2.2 trillion and predicted that "demand for U.S. agricultural products will increasingly be for processed products, such as flour, which rely on increased domestic transportation… [and those] commodities will likely favor trucks as the primary mode of transport" (USDA 2010). Hence, recognizing the importance of transportation to the nation's rural economy will potentially satisfy the MAP-21 goal to improve the national freight network. Finally, raising the visibility of the socioeconomic impact of rural bridges and roads in the TAM decision-making process should serve to support MAP-21's last two goals on strengthening rural access to markets and supporting regional economic development.

Changing the TAM Economic Paradigm

The accelerating deterioration of the nation's infrastructure has driven state DOTs to better understand the importance of using the TAM to prioritize and effectively distribute available construction and maintenance funds. To implement a better decision-making process with a focus on both business and engineering practices for resource allocation, many state DOTs including Idaho, Michigan, and Virginia have developed work plans through the use of their bridge management system (BMS) data. The BMS allows them to examine routes, ADT, location of the bridges, and develop a BHI to rate the structures in the National Bridge Inventory (NBI) (Hearn, Pan and Casey 2013). At the same time, the AASHTO Transportation Asset Management Guide encourages a long-term financial forecast and an analysis of how the assets will be cost-effectively managed throughout their life cycles (AASHTO 2011). Moreover, states like Iowa are adding detour distances to their analysis as a way to include the impact to the users if a given bridge is structurally deficient and must post a lower weight limit than it was designed to carry. But in many cases rural bridge projects on low-volume roads do not receive the necessary funds due to either the disproportional values of ADT between highways and rural roads or, in some cases, because the low-volume bridges are often the responsibility of county engineers for whom transportation asset management training has not yet been made available. Research has shown that without a formal resource allocation methodology, low-volume road and bridge projects are prioritized on a "worse-first" basis or based on political and private pressure to allocate resources to projects with higher public visibility (Koechling 2004).

States like Iowa, whose primary economy is based on the production of corn and soybeans, also rank among the top five states with the highest percentage of structurally deficient bridges. Moreover, 77% of all bridges nationwide and 63.5% of all structurally deficient bridges (Davis, et al. 2013) are located in rural areas illustrating the potential that inadequate construction and maintenance funding to keep those rural bridges operating at their current structural load capacities could have an enormous economic impact on a state's economy. Furthermore, the forecast is not promising since the average life span of a bridge's deck is 50 years, and the current average age of American bridges is 42 years (Davis, et al. 2013; Uddin, Hudson and Hass 2013).

U.S. organizations like the United Soybean Board, the U.S. Soybean Export Council, and Soy Transportation Coalition described a similar issue in their 2012 report: Farm to Market a Soybean's Journey from Field to Consumer (Informa 2012). These organizations confirm the rapidly deteriorating conditions of the U.S. transportation infrastructure system and argue that little attention has been focused on how the infrastructure system impacts agriculture when rural assets do not receive a fair share of highway construction and maintenance funding.

According to Informa Economics (2012), the delivery of commodities resulting from grain and soybean farming are of significant importance to the U.S. economy. This impact can be understood in terms of overall jobs, output, personal income and value added on the U.S. economy that depends either directly or indirectly on the haul movement of these commodities. Secondly, there is a potentially positive impact of investing in transportation infrastructure that facilitates the more efficient movement of these commodities.

One author investigated the impact on farmers' income in rural Iowa due to crop transportation costs. "In Iowa, that region is the north-western part of the state, which enjoys high crop yields but gets 25-50 cents less per bushel because it is too far from the Mississippi river barges." (Belmond 2007). This area of Iowa also has the state's highest percentage of structurally deficient bridges (Davis, et al. 2013). While Belmond did not connect the two facts, it leads to the inference that the high cost of transporting crops from north western Iowa may be in part due to the detours farmers must make in their heavy trucks around posted or closed low-volume bridges to get their crops to market.

Measuring the Impact

The roads with the lowest ADT are typically unpaved, and the challenge for the TAM programs is how to equitably incorporate low-volume roads in the fund allocation prioritization process. The first step to understand the impact of gravel roads versus paved roads is to identify the differences between heavy trucks and lighter vehicles driving on either gravel or paved roads. In order to do that the following indicators have been considered:

- RUC of trucks on gravel roads
- RUC of trucks on pavement/concrete roads
- RUC of light vehicles on gravel surfaced roads
- RUC of light vehicles on pavement/concrete roads
- Rate of heavy trucks versus light vehicles on gravel roads in agricultural zones
- Rate of heavy trucks versus light vehicles on paved roads that are not located in agricultural zones.

Computing Social Return on Investment

The SROI Network was formed in 2008 in United Kingdom with the mission of promoting the use and development of the SROI methodology internationally. The SROI is a framework based on "social generally accepted accounting principles" that can be used to quantify and understand the social, economic, and environmental outcomes (NEF 2004). This methodology has been used by both governmental and nongovernmental organizations to forecast the value created if the developed projects attain their intended outcome. The output is a metric that can be used to compare different prospective projects and make the resource allocation decision.

The framework is based on seven principles (Network 2012):

- Understand the different kinds of stakeholders and their motivations on the project.
- Understand what the changes are if a project is implemented.

- Value the things that matter. Financial proxies should be used in order to recognize the value of the outcome. Many outcomes are not traded in markets, and as a result their value is not recognized.
- Only include what is material. Determine what information and evidence must be included in the accounts to give a true and fair picture, such that stakeholders can draw reasonable conclusions about the impact.
- Do not over-claim.
- Be transparent.
- Verify results.

Measuring the outcome will allow state DOTs to measure their performance based on the actual impact instead of the inputs and/or outputs. To better explain the difference between inputs, outputs, and outcome, assume the input is the amount of money that is allocated every year to maintain bridges, and the outcome is the number of bridges that are able to be maintained with that money. It would be misleading to use the amount of money invested in maintenance as a performance indicator to prove the interest of the institution for the wellbeing of the bridges and the community. The reason is that the increase in money needed for maintenance could be the result of severe deterioration of the infrastructure which requires a higher investment. On the other hand, a small amount of resources allocated for maintenance does not necessary imply a better infrastructure since it could easily mean a procrastination of their responsibilities. Similar to the interpretation of the money/inputs, the number of bridges maintained/outcome could be misused as a performance indicator. Therefore, this study highlights the importance of focusing on the actual impact those inputs and outputs have on the stakeholder in order to measure the actual outcome and draw accurate conclusions about the performance of the organization.

To calculate the value of investing in a given infrastructure project, one must first identify and calculate the Total Impact. In this process, the Deadweight, Attributions, and Drop-off are withdrawn in order to prevent inflation of the actual impact. These terms are defined as follows:

- Deadweight: The percentage of the outcome that would have happened even if the project had not been built. For example, users seeking more cost-efficient routes or vehicles could have reduced the RUC and the CO_2 emissions.
- Attributions: The percentage of the outcome that was caused by other organizations or departments. An example would be a county making an improvement on other infrastructure along the route.
- Drop-off: A factor used to account for loss of asset serviceability due to normal aging. This is also calculated as a fixed percentage of the remaining level of outcome at the end of each year. (Network 2012)

Thus, the total impact is calculated using Equation 1 (Network 2012)

Total Impact = Outcome –Deadweight – Attributions – Drop off (Equation 1)

There are three steps in calculating the SROI:

1. Projecting into the future :

$$\text{Total Impact} = \sum_{t=1}^{(life\ span)} Impact\ at\ end\ of\ year\ 1\left(1 - deterioration\ rate\right)^{t-1} \qquad \text{(Equation 2)}$$

2. Calculating the NPV:

$$PV = \sum_{t=0}^{(life\ span-1)} \left(\frac{Impact\ at\ end\ of\ year\ 1\left(1-deterioration\ rate\right)^{t}}{(1+r)^{t+1}}\right) \qquad \text{(Equation 3)}$$

3. Calculating the ratio

$$\text{SROI Index} = \frac{\text{Total PV of benefits}}{\text{Value of investments}} \qquad \text{(Equation 4)}$$

For the following case study, the authors have assumed that no changes to the types of vehicle that will use the road are foreseen and no improvements are planned to the road other than the maintenance of the bridge itself; therefore, the values of deadweight and attributions can reliably be assumed to be zero for both bridges. This is valid for forecasting the impact of projects, where these changes cannot be predicted. On the other hand, if the SROI is used to evaluate a project's impact after the project has been executed, it is imperative to account for any changes that could affect the total impact generated by the project. This will provide accuracy and transparency to the study.

Case Study

In order to evaluate the level of impact and provide indicators for prioritization and resource allocation, this case study was used to calculate and compare the SROI of two low-volume bridges in Hamilton County, Iowa. This scenario is a typical situation where a local agency must choose one of two bridge projects to allocate the maintenance funding. For purposes of illustration, the two bridges are assumed to have similar structural conditions, giving them similar life-cycle costs. When a bridge is found to be structurally unsound, the transportation agency typically posts a new, lower load limit. This presents a dilemma for the heavy vehicles that use that structure. The farmer has two choices: reduce the size of each load to conform to the load limit or detour around the load-limited bridge fully loaded. In essence, the decision is between making more trips and making longer trips.

Lighter vehicles can still use the bridge, which effectively reduces the number of travellers that are inconvenienced and subsequently the probability that the agency will suffer criticism for its decision to reduce the load capacity of the bridge. As a result, the calculation of user costs will not faithfully portray the true impact because the prevailing agency practice is to use the average RUC rather than the RUC for heavy vehicles (IADOT 2013). This issue intensifies as the percentage of heavy vehicles increases. It also becomes very critical if the bridge remains posted during the harvest season where the daily percentage of heavy vehicles might easily become the majority of the traffic needing to cross the bridge. In Iowa, the governor makes an annual temporary dispensation for farm vehicles to exceed load limits during harvest season (Swoboda

2013; Branstad 2013). This act, which potentially subjects bridges to further deterioration, confirms the pressing need to recognize the effect of posted structurally deficient low-volume bridges and the value of including an economic factor in the asset maintenance, repair, and replacement project authorization decision.

Table 5-1 contains the details of a life-cycle cost analysis on a bridge that is the same type as the Hamilton County bridges. It was completed by the FHWA and will be used to illustrate the approach for quantifying project costs to compute the SROI benefit/cost ratio. The discount rate used for this analysis was set by the authors at 3% based on typical, established values ranging from 3 to 5 percent (FHWA-4 2003).

Table 5-1 LCCA of a Similar Bridge
Estimated Cost of a Similar Bridge with CIP deck

ITEM	COST
Initial Costs	$375,642
Annual Maintenance	$250 / Year
Inspections (Required Every Two Years)	$200 / Occurrence
Five Year Increment Scheduled Maintenance	$1,000 / Occurrence
Crack Repair, Patching, Joint Sealant (Inspect / Repair / Replace)	
25 Year Scheduled Maintenance	$25,000
Surface Grinding and Overlay	
50 Year Scheduled Maintenance	$45,000
Re-deck Bridge	
75 Year Scheduled Maintenance	$25,000
Surface Grinding and Overlay	
100 Year CIP Design Life Reached	$375,642
Demolish and Rebuild CIP Bridge	
120 Year UHPC Design Life Reached	$0
120 Year Residual Value of CIP Bridge	$297,313
User Costs Associated with Construction and Maintenance	$233,842
Consist of Driver Delay Costs, Vehicle Operating Costs, and Accident Costs	
TOTAL LCC	**$662,756**

Vehicle Operating Cost

Gravel roads' economic impact on agriculture is directly related to the additional RUC that the farmers pay to transport their products. The World Bank developed the HDM-4 Road Users' Costs Model to measure the RUC in developing countries with unpaved and paved roads, and it furnishes an excellent tool to quantify RUC on Iowa farm-to-market roads. The model is designed to calculate unit road user costs using algorithms with input variables of speed, travel time, and emissions (WB 2013).

The road associated with each bridge was classified by the type of surfacing: paved or gravel. The first step is to calibrate the HDM-4 model for each road condition. Table 5-2 shows the salient parameters used in the calculations. Assumptions have been made for the information that was not available. Other data such as the AADT was gathered from the Iowa DOT in 2011.

Table 5-2 Roads Parameters

Road Characteristics			Gravel Road	Paved Road
Road Condition	Road Roughness (IRI, m/km)		4	2
	Carriageway Width (m)		7	7
Road Geometry	Rise & Fall (m/km)		1	1
	Number of Rise & Fall per km (#)		1	1
	Horizontal Curvature (degrees/km)		3	3
	Super-elevation		2	2
Speed Adjustments Factors	Speed Limit (km/hour)		80	50
	Speed Limit Enforcement (#)		1.1	1.1
	Roadside Friction (#)		1	1
Rolling Resistance Factors	Percent Time Driven on Water (%)		20	20
	Percent Time Driven on Snow (%)		20	20
	Paved Roads Texture Depth (mm)		1.5	0.7
Road Traffic	Vehicle Description and AADDT	Medium Car	23	210
		Articulated trucks	57	50
		Total	80	260

Bridge A is located on the paved road with an AADT of 260 vpd. Bridge B is located on a gravel road with an AADT of 80 vpd. One of the limitations of this study is the limited data that was collected on low-volume roads; therefore, the vehicle classification has been grouped into two major categories following the manner in which the data was collected. A more detailed explanation of the two major categories is provided in the next section. The RUC was calculated for these two general groups. Figure 5-1 shows the difference in RUC per mile between gravel and paved roads as well as by type of vehicle. Table 5-3 Parameters to Calculate Road User Cost for Bridge A. Table 5-3 and Table 5-4 show the factors included in the RUC calculation.

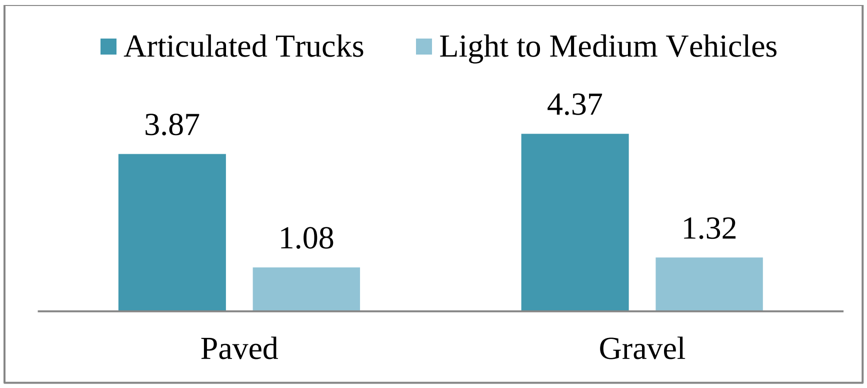

Figure 5-1 RUC $/Mile by Vehicle Type and Road Surface

Table 5-3 Parameters to Calculate Road User Cost for Bridge A
Unit Road User Costs for Roughness Equal to 4 IRI, m/km

	Medium	**Articulated**
	Car	Truck
Road User Costs ($/vehicle-km)	0.673	2.398
Vehicle Operating Cost ($/vehicle-km)	0.421	2.299
Fuel ($/vehicle-km)	0.144	0.541
Lubricants ($/vehicle-km)	0.004	0.02
Tire ($/vehicle-km)	0.004	0.042
Maintenance Parts ($/vehicle-km)	0.087	0.918
Maintenance Labor ($/vehicle-km)	0.047	0.362
Crew Time ($/vehicle-km)	0	0.219
Depreciation ($/vehicle-km)	0.115	0.13
Interest ($/vehicle-km)	0.02	0.031
Overhead ($/vehicle-km)	0	0.036
Value of Time Cost ($/vehicle-km)	0.246	0.075
Passenger Time ($/vehicle-km)	0.246	0.072
Cargo Time ($/vehicle-km)	0	0.003
Emissions Cost ($/vehicle-km)	0.006	0.024
Road Safety Cost ($/vehicle-km)	0	0
Road User Cost (%)	100.00%	100.00%
Vehicle Operating Cost (%)	62.50%	95.90%
Value of Time Cost (%)	36.60%	3.10%
Emissions Cost (%)	0.90%	1.00%
Road Safety Cost (%)	0.00%	0.00%
Vehicle Speed (km/hr)	73.1	83.7
Daily Traffic (vehicles/day)	210	50

Table 5-4 Parameters to Calculate Road User Cost for Bridge B

Unit Road User Costs for Roughness Equal to 4 IRI, m/km

	Medium Car	**Articulated Truck**
Road User Costs ($/vehicle-km)	0.82	2.709
Vehicle Operating Cost ($/vehicle-km)	0.467	2.57
Fuel ($/vehicle-km)	0.168	0.513
Lubricants ($/vehicle-km)	0.004	0.02
Tire ($/vehicle-km)	0.005	0.041
Maintenance Parts ($/vehicle-km)	0.096	1.035
Maintenance Labor ($/vehicle-km)	0.05	0.385
Crew Time ($/vehicle-km)	0	0.34
Depreciation ($/vehicle-km)	0.115	0.132
Interest ($/vehicle-km)	0.028	0.048
Overhead ($/vehicle-km)	0	0.056
Value of Time Cost ($/vehicle-km)	0.346	0.116
Passenger Time ($/vehicle-km)	0.346	0.111
Cargo Time ($/vehicle-km)	0	0.005
Emissions Cost ($/vehicle-km)	0.007	0.023
Road Safety Cost ($/vehicle-km)	0	0
Road User Cost (%)	100.00%	100.00%
Vehicle Operating Cost (%)	56.90%	94.90%
Value of Time Cost (%)	42.20%	4.30%
Emissions Cost (%)	0.90%	0.90%
Road Safety Cost (%)	0.00%	0.00%
Vehicle Speed (km/hr)	52	54
Daily Traffic (vehicles/day)	23	57

Calculating the AADT by vehicle type

The line between heavy and light vehicles was based on the FHWA 13-vehicle classification (FHWA 2011) and the IADOT classification. The IADOT considers heavy vehicles to be those within classes 8 and 13 of the FHWA classification scheme. These include vehicles with single trailers of three or more axles, as well as multiple trailers with five or more axles. (FHWA 2011). The second category includes vehicles classified between 1 and 7, which includes motorcycles, passenger cars, two axle/4 and 6-tire units, buses, and three or more axle single units.

Data on low-volume roads is collected once a year by the IADOT, and the AADT is calculated using adjusting factors (IADOT 2013). For this study, it was necessary to calculate the total number of cars and trucks throughout the year. Higher AADT roads in agricultural zones, where data is collected daily, were used to model weekly traffic volumes across the calendar year. These numbers were then used to calculate equivalent weekly traffic patterns on low-volume roads. The resultant weekly traffic volumes/patterns for the roads crossing Bridge A and Bridge B are shown in Figures Figure 3-4 2012 Daily Vehicle Traffic at Tollman Ave. and Figure 3-5 2012 Daily Vehicle Traffic at 360 St.

The distribution of traffic shows the potentially high impact of agricultural product traffic during the harvest season between September and October. More significant is the difference in the ratio between heavy trucks and lighter vehicles on each of the roads. In summary, Bridge B, which is located on a gravel road and has an AADT of 80, has a greater volume of heavy trucks at 20,908 per year versus 18,298 heavy trucks on Bridge A, which is located on a paved road with an AADT of 260. As a result, the loss of Bridge B due to uncorrected structural deficiencies that either reduces its capacity or closes it altogether is proportionately higher even though its AADT is far lower than Bridge A. This is the paradox faced by DOT TAM managers. The effect is complicated by the fact that the typical DOT maintenance funding system is fraught with an absence of Pareto efficiency (Mathur 1991). In other words, a single given project cannot be funded without losing the potential benefit accrued by using those funds to improve another worthy project (Barr 2012). In layman's terms, road maintenance funding is essentially a zero-sum game (Cui, et al. 2008).

In the above example, it would be hard for asset managers to justify replacing Bridge B before replacing Bridge A which has three and a half times the AADT because the difference in heavy vehicle usage is invisible when expressed as a volume of trucks. Bringing visibility to the real cost of ignoring assets like Bridge B requires a mechanism to link the socioeconomic impact to asset condition. SROI is one such mechanism that promises to generate credible information regarding asset management funding decisions (Galveston 2013; SVAC 2012).

Analysis of SROI

As shown in Table 5-5, Bridge B has a lower AADT of 80. However, heavy trucks represent 72% of the total traffic which resulted in an SROI of 18.8. Bridge A has an AADT of 260 with 19% heavy trucks which resulted in an SROI of 9.93.

Since no changes to the types of vehicle that will use the road are foreseen and no improvements are planned to the road other than the maintenance of the bridge itself, the values of deadweight and attributions can reliably be assumed to be zero for both bridges. In the same way, the drop-off is also not considered because routine maintenance has been accounted for in the LCCA, and no further loss of serviceability should occur if the bridge is repaired and restored to its original design capacity.

Table 5-5 SROI Index for Bridges A and B

	Bridge A	**Bridge B**
Road Type	Paved	Gravel
AADT	260	80
Detour Distance (miles)	3.75	5.5
Number of Heavy trucks/year	18,298	20,908
RUC of Trucks/mile	$3.87	$4.37
Total Annual RUC due to detours	$265,550	$502,524
Total Impact (PV) using equation 3	$6,578,759	$12,449,573
Total LCC	$662,756	$662,756
SROI Index using equation 4	**9.93**	**18.8**

Transportation Asset Management Application

DOTs across the nation are adapting their current TAM to comply with the recent MAP-21 legislation. It is a complex process, and it is important for agencies to introduce tools that are compatible with their current organization and the systems in place within their state (Cambridge 2005). Each agency has different needs and different stakeholders' interests. For example, southern states such as Georgia and Florida produce agricultural products all year due to favorable weather. As a result, traffic on farm–to-market roads does not have the seasonal peaks like the harvest-season peaks seen in northern states such as Iowa, Minnesota, and Nebraska. In southern states, the impact of the winter on the user costs is not as pronounced as it is on northern dairy states such as Wisconsin, where production continues all year-round and production costs rise as a result of the impact of winter road conditions on transportation costs. As seen in the case study, the SROI can be used as a TAM metric, and it provides a flexible tool that can be applied at different levels through the decision-making process. Figure 5-2 illustrates the flexibility of the proposed implementation of the SROI by overlaying it on the IADOT's TAM process and marking the key decision points.

TAM Framework Figure 5-2:

All decision making processes should have a foundation on the goals and objectives expressed in the annual strategic plan. External factors such as politics and customers' expectations exert significant influence on the goals and objectives. Once the goals are established, each DOT develops an inventory of the conditions of their current assets, such as bridges, pavements, signs, etc.

Understanding the assets' condition is critical to identify the needs of the system. With the use of new technologies and methodologies, technical aspects as well as traffic and financial indicators can be measured and integrated. Currently, DOTs are evaluating and integrating data with automated tools such as Deighton's Total Infrastructure Management System (DTIMS) (UDOT 2012). These tools help not only to integrate the different indicators within an asset, but also cross correlate all asset types to obtain the needs of the system as a whole.

The use of models and deterioration curves provides an understanding of trends that could help forecast current and future expenditures. This information is extremely important for the financial and planning department to apprehend the funding availability. Once the assets management department prioritizes their assets and selects potential candidates, it is time to identify the resources needed as well as the resources available to develop a project. This is a multidiscipline process that involves the selection of treatment and funding available to obtain the most cost-efficient plan.

A successful TAM plan requires interdisciplinary team work involving the designing, planning, financial, and maintenance departments working toward the same goal. As expressed by Uddi, Hudson and Hass (2013), the capital costs for construction are a fraction of the operating and maintenance costs associated with service life. The DOTs must commit to long term projects from the design and planning stages, ensuring financial and logistic support during the life cycle of the assets.

At this point the projects are ready for execution. However, once the projects have been developed, the DOTs' responsibility does not stop. In order to evaluate the decision-making process, to communicate to the stakeholders how the resources have been allocated, and to re-evaluate the next cycle's goals and objectives, the institution must have the capability to measure not only the outputs (number of miles, number bridge, or dollars expended in maintenance), but also to be able to measure the outcomes of their efforts. In other words, they must be able to measure what really matters to the stakeholders.

The proposed framework in Figure 5-2 has been developed based on recommendations from the FHWA as well as current organizational models of state DOTs in the U.S. (Cambridge 2002).

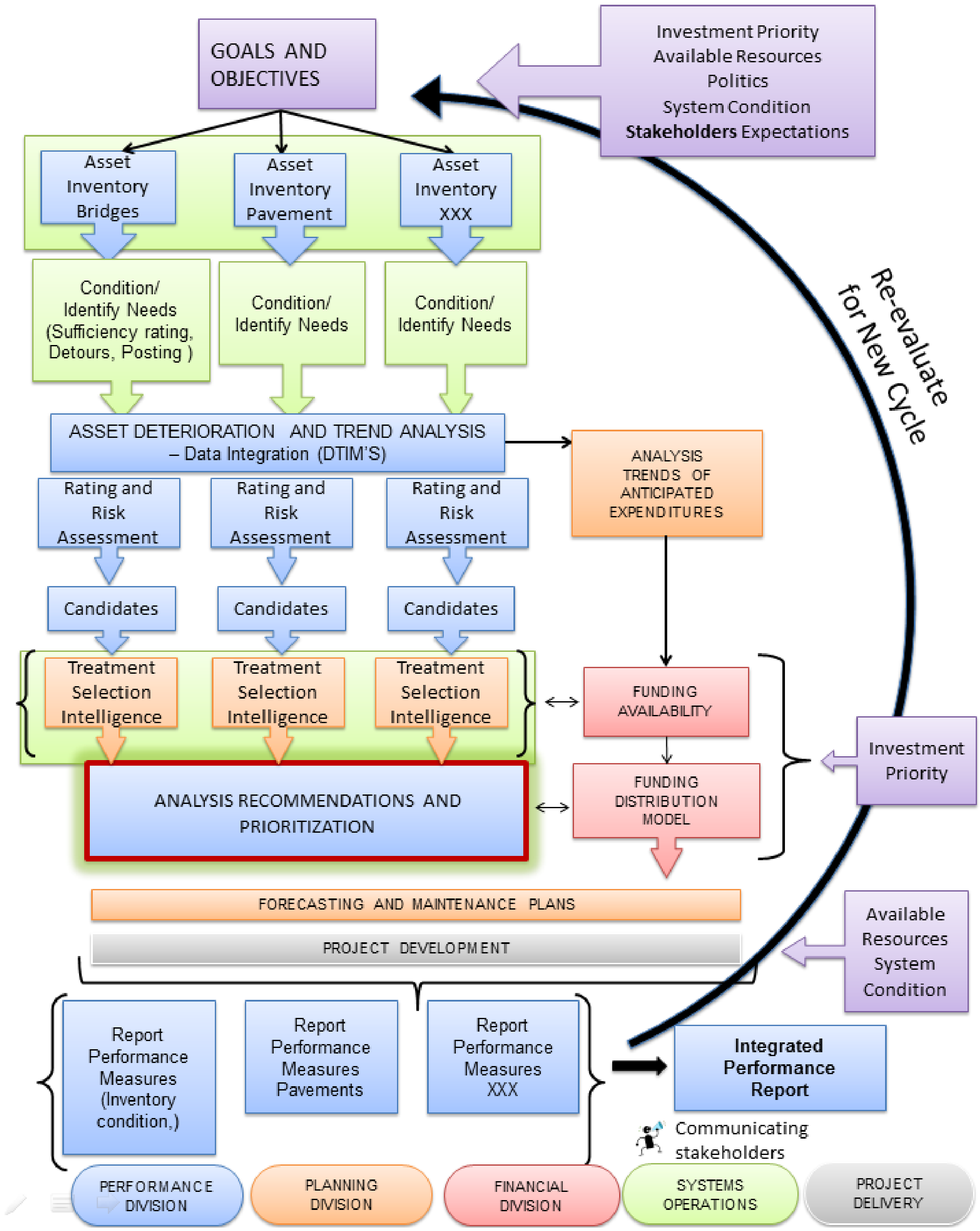

Figure 5-2 TAM Framework with Optional SROI Application

The following four alternatives in which the SROI could be applied to the asset management resource allocation process are proposed:

- SROI-1: As a weighted factor along with DTIMS

The SROI could be used as an additional metric in combination with the DTIMS (Figure 5-2) to understand the condition, and identify the needs of each asset. In this case, each key performance indicator (KPI) will get an assigned weight factor according to the goals and objectives of each state

- SROI-2: As a Parallel indicator

  The SROI could be evaluated at an earlier stage similar to Option 1. However, instead of merging it into a combined score, it can stay parallel to the current rating scores.

- SROI-3: As a last indicator for prioritization

  The SROI could be added later in the process to the selected candidates for the analysis and prioritization. In this case not every asset would have an SROI analysis, and it would be added only to the selected candidates to prioritize resource allocation. The disadvantage of integrating the SROI at a later stage is that some assets with high social needs could get overlooked.

- SROI-4: As a reporting tool

  In conjunction to adding the SROI as a KPI according to the model that better fits the transportation agencies, the SROI could be used when the Report Performance Measurement occurs to summarize and create reports for stakeholders. The SROI Primer states that measuring the SROI improves the organization's impact whether seeking new funding or simply wanting to ensure that the day-to-day activities connect to the objectives. "SROI can help you understand, manage and quantify the value you are creating" (NEF 2004).

In 2012, a survey of non-profit, charity, social enterprise, and social purpose businesses, as well as municipal and provincial representatives, was conducted to determine if social metrics like SROI are able to convey important information needed by public agencies and non-profit organizations. This study showed that:

- Over 70% of the people interviewed agreed that doing an SROI analysis provides a greater ability to communicate that value to key audiences.
- Over 60% agreed that the SROI provides a clear picture of the value of the outcomes they enable clients to experience (S. Robertson 2012).

Adding the SROI to the TAM decision-making process will not only provide a more objective distribution of the resources, but it may also assist in better communication to the stakeholders on the "why and how" of the decisions that are made, stimulating their support and trust.

Globalization and Application outside the U.S.

Unstable economies and climate change have been a burden on the agricultural industry around the world, speeding up the deterioration rate of the agricultural roads due to lack of maintenance or environmental factors. The 2014 Executive Report of the World Road Associations highlights the importance of road maintenance, indicating that: "for OECD countries [Organisation for Economic Co-operation and Development], the ratio of maintenance to overall expenditure on roads was 33% in 2005 but had declined to 27% in 2011 while the age of the stock increases" (WRA 2014). On the other hand, countries like Russia and Colombia have recognized the impact of climate change on their transportation infrastructure, especially on rural roads (Safonov and Safonova 2013; Pinzon 2010).

While the deficient transportation infrastructure on rural roads is struggling to keep up with current demands, international organization such as the World Bank and the Food and Agriculture Organization of the United Nations (FAO) have shown their concerns due to the increasing demand of agricultural products to meet the food demands on growing populations. The FAO projects that food and feed production will need to increase by 70% by 2050 to meet the world's food needs (Hofstrand 2014).

A study done on the road infrastructure in agricultural zones of the Democratic Republic of Congo shows that the conflict of allocating transportation funds between rural and urban zones is not only an issue in the U.S. This report shows that greater attention has been associated to the access to the cities and neglects the impact of the access to ports and connectivity road from agricultural zones. As expressed by Ulimwengu (2009):

> The areas with the highest agricultural potential, such as North and South Kivu are ignored by the proposed investments, even though these regions are a potential breadbasket. If adequate political stability can be achieved in these eastern provinces, road infrastructure there could open up 38 considerable new opportunities for agricultural trade, especially with the relatively proximate mining regions of the south-east, which currently import considerable quantities of food from Zambia.

The same methodology used to evaluate the impact of agricultural bridges in Iowa could be applied to agricultural countries around the world as a tool to prioritize and allocate maintenance resources. In this way, agricultural roads could fairly compete for funding against heavily urbanized zones. Even though this methodology is very flexible, it requires calibration and evaluation of the stakeholders based on the specific social and geographical circumstances where this methodology is intended to be used.

Conclusions

One of the objectives of MAP-21 is to support regional economic growth including a number of provisions designed to improve freight movement in support of national goals (FHWA-5 2012). Agricultural products are a big part of the country's economy, and the U.S. provides nearly half of the world's grain exports (USDA 2013). To get to market, these products must first be transported on the rural transportation infrastructure to reach main highways. Despite the importance of the agricultural sector to the nation's economic growth, rural roads and bridges have difficulty competing for scarce maintenance and construction funding due to low traffic volumes.

Current TAM programs primarily focus on the physical condition of the assets. Most asset managers have no metric other than ADT and percentage of heavy vehicles to quantify the impact on asset users. This defines a gap in the body of knowledge. Dependence on total AADT in asset management decision-making makes it difficult for agricultural states like Iowa to justify spending on low-volume rural road assets. However, this study has shown the potential for using the SROI to calculate the socioeconomic impact and use it as a KPI to provide a more accurate view of the costs and benefits of rural maintenance and rehabilitation projects. The SROI can be applied in different modalities to allow flexibility and continuity of the current prioritization process of each state agency to meet the specific needs of different stakeholders.

The study found that gravel roads represent a higher RUC to users than paved roads. The same is true for heavy trucks' RUC when compared to lighter vehicles. The case study analysis demonstrated that the net effect on RUC for a bridge located on a low-volume gravel road in an agricultural zone where heavy trucks constitute the majority of the traffic has a greater socioeconomic impact than a bridge with higher traffic volume but lower heavy vehicle traffic as quantified using the SROI. In other words, funding the lower volume bridge's repair to restore it to its design capacity creates a greater socioeconomic return on the investment of the maintenance or construction funding.

The fact that the average age of American bridges is 42 out of 50 years (generally bridges are built to stand for 50 years without significant maintenance) and 63.5% of rural bridges are structurally deficient (Davis, et al. 2013) leads to a final recommendation that involves including low-volume bridges in the prioritization process for all TAM plans. Doing so will ensure that the state's economy does not suffer a negative impact unintentionally.

CHAPTER 6 APPLYING SROI TO RISK-BASED TRANSPORTATION ASSET MANAGEMENT PLANS IN LOW VOLUME BRIDGES

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Abstract

State DOTs implement risk-based TAM systems to standardize risk-oriented procedures and assist decision-makers to allocate available funds. These procedures aim to lead agencies to the making of effective decisions to allocate funding to repair, replace, or maintain its assets that provide the highest overall value to all stakeholders. Since reliable tools to measure and compare the socioeconomic impact of different resource distribution alternatives of bridge maintenance funds are lacking, decisions are driven by the AADT and the experience of decision-makers. While AADT certainly measures the number of users that would benefit if funding is allocated for a given bridge project, it fails to account for the impact that a given bridge has on the state or regional economic growth. Relying on AADT puts low-volume bridges on farm-to-market roads at a distinct disadvantage when competing for scarce funding as shown by the large number of structurally deficient low-volume bridges located in croplands of Iowa, a state whose economy is based on agriculture. This paper proposes a methodology to integrate the

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socioeconomic impact of funds allocated to maintenance/repair with AADT and consider the consequences of this decision. The authors demonstrate the use of a stochastic two-way sensitivity analysis on the SROI as the primary metric on two typical Iowa bridges and found that adding SROI to the decision-making process provides a mechanism to more efficiently allocate available resources.

Introduction

According to the FHWA, developing risk-based TAM plans are a high priority objective for most state DOTs. For the purposes of this paper, risk management is defined as a set of procedures, practices, and systems with the objective of "the effective management of potential opportunities and threats" (FHWA-1 2012). Threats refer not only to those factors that represent a physical impact, but also those that may hinder the achievement of organizational objectives (FHWA-1 2012). One of the objectives at the federal and state level is to support regional economic growth as shown on the MAP 21 provisions as well as DOTs' annual strategic plans (FHWA-5 2012; IADOT-4 2012).

This study is focuses on using risk management processes to identify and analyze risk factors that impact regional economic activity. More specifically, it focuses on the process for prioritizing fund allocation to low-volume bridges for maintenance or rehabilitation. The lack of reliable tools to measure and compare the socioeconomic impact of different resource distribution alternatives of bridge maintenance funds has resulted in TAM programs that underestimate the value of low-volume bridges. For instance, bridge maintenance fund allocation practices in Iowa, a state with an agricultural economy, rely on the AADT as the primary metric in decision-making (IADOT-3 2013), ignoring the economic impact of rural bridges, which typically have low AADTs. While AADT is a relevant indicator, it assumes that each vehicle that crosses a bridge has the same impact on the community. Thus, a passenger car with a single occupant carries the same weight as a heavy truck carrying fertilizer to the fields or crops to market. As a result, the disproportionate value of the two vehicles is neglected and potential benefits to the state's larger economy are not considered in the fund allocation decision.

Risk is measured in this paper by the impact of what could happen if no funds are assigned to a given deteriorated bridge. Current indicators used to prioritize assets involve a great variety of factors such as the physical condition of the assets, life cycle analysis of the different treatments available along deterioration trends, safety issues, and users' impacts (AASHTO 2011). However, this paper only presents a socioeconomic analysis to determine the impact that the fund allocation decision has on different types of users.

The authors propose a stochastic system that provides decision-makers with an overall view of the socioeconomic impact to the users of failing to allocate maintenance or repair funds to a given bridge. The analysis furnishes DOTs with an additional indicator to compare the effects of different resource allocation alternatives. The proposed system consists of a two-way sensitivity analysis which illustrates a range of possible SROI values. It is demonstrated for two low-volume bridges in Hamilton

County, Iowa and two different case scenarios: load posting and complete closing. In the example, SROI values are obtained by considering multiple factors such as the type of users, RUC, total LCC for each bridge, detour distance, expected number of vehicles forced to take the detour under each case scenario, and probabilistic distributions of the AADT in both locations.

Background

State transportation agencies have different strategies to evaluate and allocate resources on bridges. While some DOTs have taken the lead to evaluate and prioritize all bridges across the state allowing a visualization of the overall condition of the system, others have chosen to delegate the prioritization process to the county engineers. In states like Iowa, municipalities may request to add a bridge to the Iowa DOT City Bridge Candidate List at any time, and then the Office of Local Systems selects bridges based on their ranking and available funding. In contrast, county bridge projects are selected by the county engineer in cooperation with the county Board of Supervisors without the Office of Local Systems involvement (IADOT-3 2013).

Currently the Sufficiency Rating is one of the indices used to prioritize bridges. This index is essentially an overall rating of a bridge's serviceability, including fields that describe its Structural Evaluation, Functional Obsolescence, and its Essentiality to the Public (NB 2014). In some cases the essentiality to the public is calculated by the AADT and detour distances (NYDOT 2006). On the other hand, some decision-makers, such as county engineers in Iowa, rely on their professional judgment to identify the essentiality to the public to allocate funds along their bridge inventories based on the location and type of users.

The effects of ignoring low-volume bridges has been publicized in studies done by organizations such as Transportation for America, which found that agricultural states, with vast rural areas, have a large number of deficient bridges. For instance, Iowa is ranked third nationwide among states based on the percentage of structurally deficient bridges. The Soy Transportation Coalition describes the effects the aging U.S. transportation infrastructure in the local agriculture as follows: “Decaying roads, bridges, railroads and transit systems cost the U.S. economy $129 billion annually” (Informa 2012).

Social Return on Investment and Risk Management

The stochastic sensitivity analysis proposed in this paper is based on SROI, a methodology developed in 2008 in the United Kingdom. The SROI’s framework is based on “social generally accepted accounting principles” that can be used to quantify and understand the social, economic, and environmental outcomes. This methodology has been used by both governmental and nongovernmental organizations to forecast the value created if the development projects attain their intended outcome (Network 2012). The framework for SROI is based on seven principles as shown in Figure 6-1.

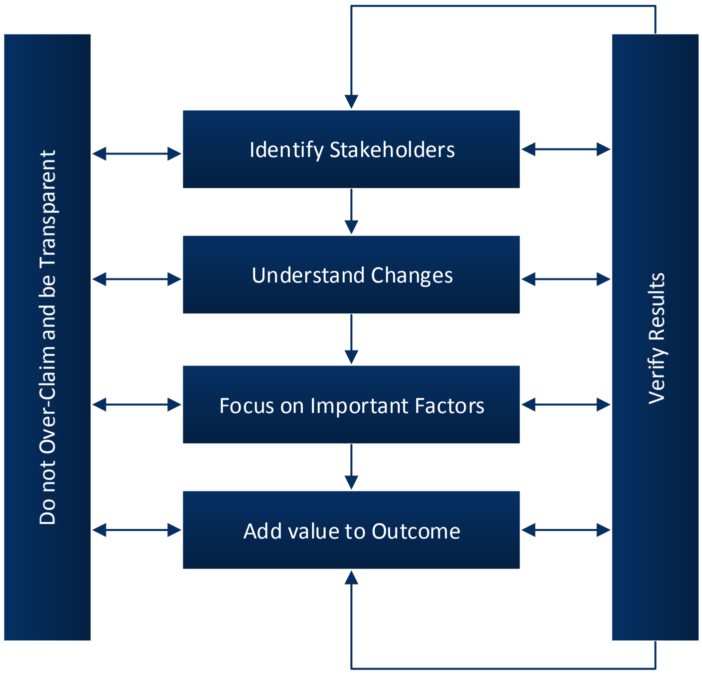

Figure 6-1 SROI Framework (adapted from **(Network 2012)**)

The International Organization for Standardization (ISO) Risk Management Framework described in the FHWA Risk-based TAM report establishes the steps to identify and mitigate risk as shown in Figure 6-2. For the risk assessment in a TAM plan, the decision to not allocate resources to a bridge presents two possible scenarios. The bridge would have to be either restricted in capacity or completely closed to all users, which are the two case scenarios considered in this study.

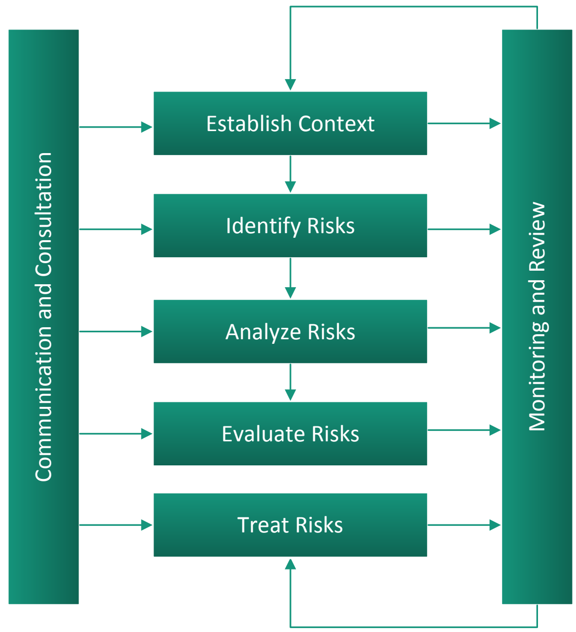

Figure 6-2 ISO Risk Management Framework (FHWA-1 2012)

Case Study Methodology

The following sections of this paper present a stochastic sensitivity analysis applied on two strategically selected case study bridges. These bridges are located on 360th St. and Tollman Ave. In spite of the fact that both bridges are located in rural areas in Hamilton County, Iowa, they differ in total AADT, as well as on the type of road and detour distance. To simplify the exercise it was assumed that the physical condition of the bridges is similar, permitting the utilization of the same LCCA in both bridges.

Case Study Context

This case study analysis assumes the county engineer only has sufficient funding to execute one maintenance project on one of the two structures. Thus, the stochastic sensitivity analysis works as a tool to facilitate this decision by determining the socioeconomic impact of load posting or closing either of the two bridges.

To conduct this analysis, it was first necessary to identify the stakeholders for each bridge. This study only considered the bridge's users as stakeholders since these are the most impacted by this decision. Users were classified in two categories based on the different economic impact: light to medium vehicles and heavy vehicles. Likewise, it was assumed that light and medium vehicles will not be forced to take the detour in case of load posting the bridges. Therefore, this type of users would not be negatively impacted by this type of decision, which would only increase the RUC on heavy vehicles.

Describing the users of low-volume bridges is often directly related to the type of economy that occurs in rural areas, as well as the effect of the seasons on these economic activities. In this case, low-volume bridges in rural areas of Iowa are primarily serving the production of corn and soybeans, as Iowa ranks first in the nation in production of these grains (SCA 2010). Furthermore, the U.S. provides nearly half of the world's grain exports (USDA 2013).

Bridges in this study are described as Bridge A, to refer to the bridge located on 360th St., and Bridge B, for the one located on Tollman Ave. The selected bridges are similar in length and design. For purposes of illustration, the two bridges are assumed to have similar structural conditions, giving them similar LCCs. Each bridge has the following characteristics:

- Bridge A is located on gravel road and has a total AADT of 80 with a rate of 2.5 trucks per medium to light vehicle
- Bridge B is located on a paved road and has a total AADT of 260 with a rate of 0.2 trucks per medium to light vehicle.

The case study bridges were selected and analyzed to illustrate the stochastic system proposed in this paper. Therefore, the principal objective of the example is to clearly present this system for its potential implementation by state DOTs. Where necessary, assumptions were made using known information from previous years or similar bridges in similar locations. Table 5-2 Roads Parameters, presents the characteristics of each road as used in this study.

Stochastic Sensitivity Analysis

The stochastic sensitivity analysis presented in this paper was conducted considering two potential case scenarios: the load posting of both bridges and the complete closure of both bridges. In other words, the first case scenario assumes that either bridge would be load posted if no funds are assigned for its rehabilitation. In this case, it is assumed that only heavy vehicles are required to take the detour. Therefore, the total benefits obtained by rehabilitating one of these bridges (calculated in the form of SROI values) are represented in the money saved by the heavy vehicles that would not have to take the detour given that maintenance/repair work is conducted on one of these bridges. The total benefits for the second case scenario are calculated in a similar way; however, in this case, both bridges would have to be closed if no maintenance funds are assigned. Therefore, all types of vehicles would have to take the detour. In real life, there are an infinite number of different case scenarios that may provide a context for this type of decision. This system provides great flexibility to adapt to the amount of data available. Thus, the stochastic model may be run considering different consequences for each bridge if no maintenance funds are assigned and considering different sources of risk and uncertainty.

For the purposes of this stochastic model, the authors assumed a fixed value for some parameters used to determine the SROI (e.g. detour distance, RUC per type of vehicle per mile, and total LCC) allocating the uncertainty in the AADT, whose probability distribution was estimated by using historical data provided by the IADOT. However, when implemented by transportation agencies to make a real decision, this model may include uncertainty in other parameters in accordance with the data available for decision-makers. For example, if there is enough information to determine a probability distribution for RUC per mile for all or some types of vehicles it may be included when running the model.

The list bellow corresponds to the steps to follow in order to conduct the stochastic sensitivity analysis, which are further described in the following sections. These steps should be followed for each case scenario. As mentioned in the previous paragraph, some of the parameters or metrics listed below may be calculated as a fixed number or may be included in the model as a probability distribution, depending on the quality and amount of data available, and in accordance with the identified sources of uncertainty:

1. Identify and Classify stakeholders (users).
2. Determine the expected number of vehicles forced to take the detour.
3. Determine detour distance.
4. Determine RUC per mile for each type of vehicle.
5. Determine total annual RUC due to detours.
6. Determine total PV of benefits.
7. Determine value of investments.
8. Determine all possible SROI values for each bridge.
9. Conduct a two-way sensitivity analysis.

Case Study Development and Analysis

The case study development and analysis is presented step by step in the following sections. This stochastic sensitivity analysis was conducted for a funding decision to be made in 2013.

1. Identification and Classification of Stakeholders (Users)

Users were classified following the FHWA vehicle classification system (FHWA 2011) and the IADOT's classification system for its historical data. This agency considers heavy vehicles to be those within classes 8 through 13 of the FHWA classification scheme. These include vehicles with single trailers of three or more axles, as well as multiple trailers with five or more axles. Therefore, light and medium vehicles include vehicles classified between 1 and 7, which include motorcycles, passenger cars, two axle/4 and 6-tire unit, buses, three or more axle single units.

This step also includes the determination of the AADT for each bridge for each type of vehicle. For this study, there was some uncertainty in this factor. Therefore, it was determined a probability distribution would be used for each AADT value using IADOT's historical data for a similar road between 2009 and 2012. A triangular probability distribution was assumed and estimated for each AADT value for 2012. The characteristics of each distribution were determined by using AADT known variations during the last few years and AADT values for 2012 as the most likely values (see Table 5-2 Roads Parameters). Table 6-1 Average Annual Daily Traffic and Total Annual Traffic presents the minimum, maximum, and most likely AADT value for each type of vehicle and bridge.

Table 6-1 Average Annual Daily Traffic and Total Annual Traffic

Bridge	AADT			Total Annual Traffic	
	Total	**Light and Medium**	**Heavy**	**Light and Medium**	**Heavy**
Bridge A					
Most Likely	260	210	50	76,602	18,298
Minimum	250	202	48	73,705	17,626
Maximum	269	217	52	79,157	19,020
Bridge B					
Most Likely	80	23	57	8,292	20,908
Minimum	77	22	55	7,979	20,139
Maximum	83	23	60	8,569	21,732

2. Determine Expected Number of Vehicles Forced to Take the Detour

As mentioned before, the first case scenario consists of load posting both bridges forcing all heavy vehicles to take the detour (see Table 6-1). On the other hand, the second case scenario consists of closing both bridges, forcing all vehicles to take the detour (see Table 6-1). It is important to remember that all these values correspond to a probabilistic distribution.

3. Detour Distance

Detour distance was determined by measuring the shortest possible distance that any vehicle would have to take in order to avoid the bridge and continue on the same road. It is possible that decision-makers determine a probabilistic distribution for this parameter when having appropriate data that allow them to predict different detour alternatives used by different types of vehicles. However, for this study it was assumed to be a fixed value for both Bridges A and B; 3.75 and 5.5 miles, respectively.

4. RUC per Mile for Each Type of Vehicle

RUC were used as a metric to understand and monetize the impact that having to detour represents for the users. This parameter is known to be sensitive to a variety of factors such as type of road, type of vehicle, type of user, and inflation (incorporated in step 5); therefore, this study calculates RUC considering the following factors:

- RUC of trucks on gravel roads
- RUC of trucks on pavement/concrete roads
- RUC of light vehicles on gravel surfaced roads
- RUC of light vehicles on pavement/concrete roads
- Rate of heavy trucks versus light vehicles on gravel roads in agricultural zones
- Rate of heavy trucks versus light vehicles on paved roads that are not located in agricultural zones.

The RUC was calculated using The World Bank's HDM-4 Road User Costs Model. This model, unlike others, is designed to differentiate between gravel and paved roads. It calculates RUC using algorithms with input variables such as speed, travel time, and emissions among others (WB 2013). RUC, shown in Figure 5-1, were obtained by using the HDM-4 Road User Costs Model and road characteristics presented in Table 5-2. The terms "Medium Car" and "Articulate Truck" refer to light and medium vehicles and heavy vehicles, respectively.

5. SROI Values for Each Bridge

In order to calculate the SROI value, it was necessary to determine the total PV of benefits and the value of investments (Network 2012). To calculate the value of investing in a given infrastructure project, one must first calculate percentages for peripheral impacts. In this study only the impact of bridges were computed. Network (2012) defines Deadweight, Attributions, and Drop-off as follows:

- Deadweight: The percentage of the outcome that would have happened even if the project had not been built. For example, users seeking out more cost efficient routes or vehicles could have reduced the RUC and the CO_2 emissions.
- Attributions: The percentage of the outcome that was caused by other organizations or departments. An example would be a county making an improvement on another infrastructure along the route.
- Drop-off: A factor used to account for loss of asset serviceability due to normal aging. This is also calculated as a fixed percentage of the remaining level of outcome at the end of each year.

Since no changes to the types of vehicles that will use the road are foreseen and no improvements are planned for these roads other than the maintenance of the bridge itself, the values of deadweight and attributions can be reliably assumed to be zero for both bridges. In the same way, the drop-off is also not considered because routine maintenance is accounted for in the LCCA (presented later in this section), and no further loss of serviceability should occur if the bridge is repaired and restored to its original design capacity. Thus, the only parameter used in this study to determine the total impact of potential investments is the Outcome (see equation 1) which is represented by the total annual RUC due to detours.

In order to determine the total PV of benefits in equation 3, the authors assumed a 4% discount rate since this is commonly used by state DOTs for discounting highway investments (FHWA-4 2003). Likewise, given the physical similarities between both case study bridges, the same value of investment (see equation. 4) for both structures was assumed, which corresponds to a LCC estimated by the FHWA for a similar cast-in-place deck bridge. This value is $662,756 for a 120-year life span (FHWA-3 2013).

Equation 4 was used to determine possible SROI values for each bridge under both scenarios. These values are illustrated in Figure 6-3 and were calculated by using @Risk (Monte Carlo simulation software) to simulate possible numbers for vehicles forced to take the detour based on the probability distributions described in Table 6-1.

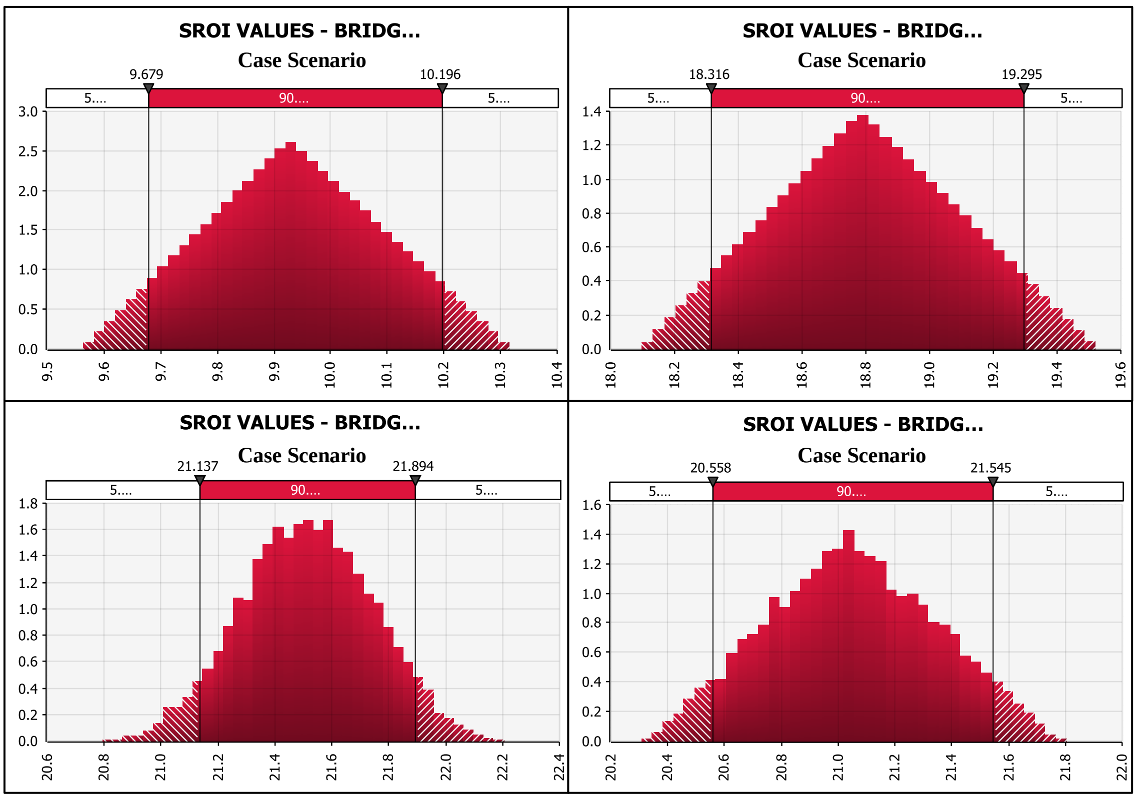

Figure 6-3 Possible SROI values by Case Scenario and Bridge

6. <u>Two-way Sensitivity Analysis</u>

This section describes the last step of this risk-based asset management methodology. It corresponds to a stochastic two-way sensitivity analysis, which consists of combining the probability distribution of for both case study bridges into a single 2-D graph for each case scenario. This graph is intended to assist decision-makers with the allocation of maintenance/repair funds by illustrating all possible SROI values for both investment projects under different confidence intervals.

As shown in Figure 6-3, taking no maintenance or repair actions on any of these two bridges implies load posting the bridge (case scenario 1), Bridge B would always be the most advantageous investment for the IADOT from a socioeconomic perspective. In other words, SROI values for Bridge B in case scenario 1 are always higher than those from Bridge A for all possible AADT values on these roads. However, Figure 6-3 shows an overlap of SROI probability distributions for both bridges in case scenario 2. It means that in spite of the fact that Bridge A presents a higher average SROI, it is still possible that Bridge B represents a better investment for the IADOT in case that one of these bridges has to be completely closed due to the lack of enough funding (case scenario 2).

Although it is evident that under different possible AADT values for these roads either of these two bridges may present the highest SROI for case scenario 2, Figure 6-3 does not provide clear information to facilitate an investment decision. Here is where the stochastic two-way sensitivity analysis methodology proposed in this paper, and illustrated in Figure 6-3, plays a valuable role. Using this figure, the IADOT may support its investment decision under different confidence levels. The diagonal line with a slope value of 1 in Figure 6-4, hereafter referred to as neutral line, corresponds to those points at which the SROI is equal for both bridges. Thus, the area above the neutral line represents larger SROI values for Bridge B while all points below it correspond to larger SROI indices for Bridge A.

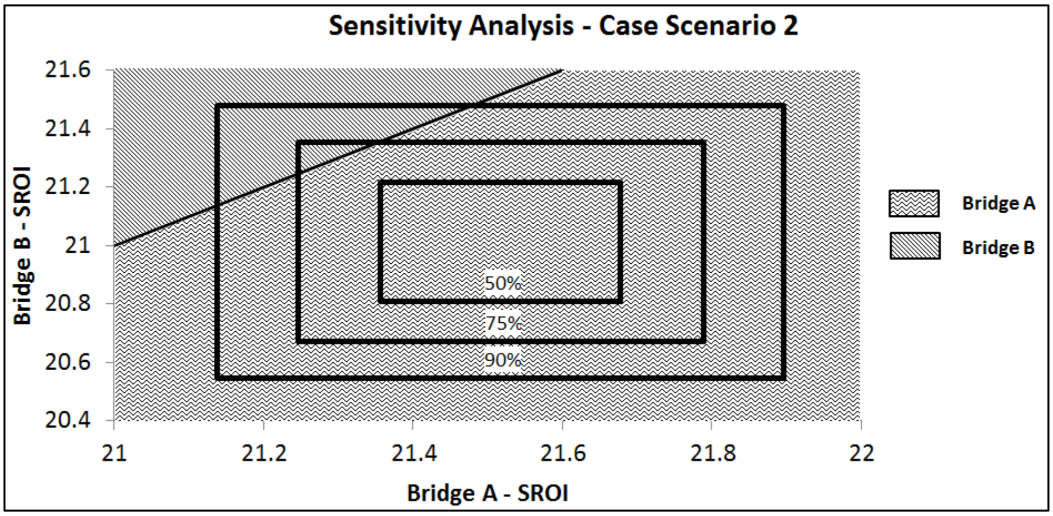

Figure 6-4 Stochastic two-way sensitivity analysis – Case Scenario 2

For instance, under a 90% confidence level, the IADOT will find an 11% probability for Bridge B to present a higher SROI than Bridge A. This percentage corresponds to the portion above the neutral line contained by a 90% confidence interval. Likewise, decision-makers will notice that as the SROI for Bridge A decreases below 21.54, the probability for Bridge B to represent the most advantageous investment decision increases.

A similar approach as the one presented in Figure 6-4 may be used to illustrate the variation of SROI indices for both case study bridges in accordance with their AADT values. Figure 6-5 shows stochastic two-way sensitivity analyzes varying the number of heavy vehicles (a) and the number of light/medium vehicles (b) for each bridge. Moreover, this figure contains a sensitivity analysis between these bridges varying the number of light/medium vehicles in Bridge A and heavy vehicles in Bridge B (c), and the number of heavy vehicles in Bridge A and light/medium vehicles in Bridge B (d). The confidence intervals in Figure 6-5 were established according to the probability distributions for different types of vehicles presented in Table 6-1 Average Annual Daily Traffic and Total Annual Traffic.

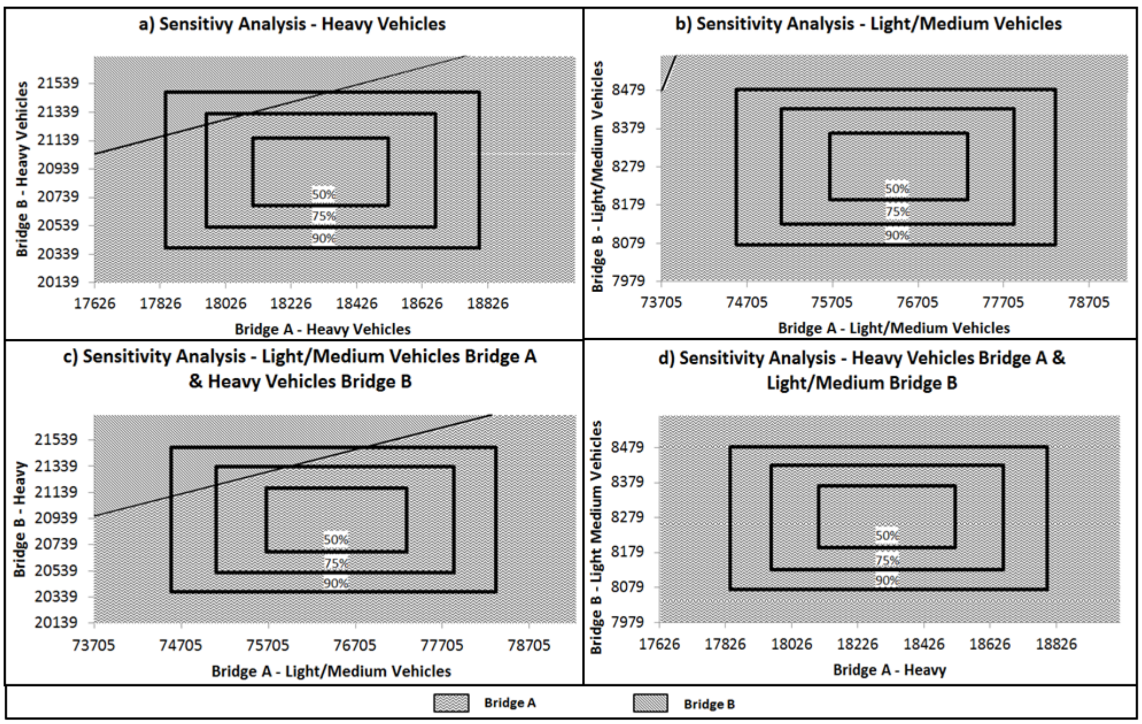

Figure 6-5 Stochastic two-way Sensitivity Analysis – AADT Variation

All four graphs in Figure 6-5 work in similar manner as described above for Figure 6-4. This figure may be used by the IADOT to better understand how different uncertainty sources impact the investment decision. For instance, if the IADOT desires to improve its decision by conducting further research to decrease the uncertainty related to the AADT for these two roads, this agency could simplify this research by ignoring the number light/medium vehicles using Bridge B since this factor does not seem relevant enough to change the decision made based on the SROI indices.

Although it is relatively easy to identify from the case study bridges presented in this paper the investment alternative with the lowest socioeconomic impact on the region, this is just an example of the application of this method. This methodology might be applied on more than two alternatives with more similar impacts on their users and considering more uncertainty in sources. However, when conducting the sensitivity analysis (step 6), it must be performed by varying two factors each time. For example, in Figure 6-5, those variable values not involved in each graph were assumed to have their most likely values.

Conclusions and Recommendations

Including risk assessment based on SROI into the prioritization process for low-volume bridges allows the analyst to quantify the socioeconomic impact of asset management decisions on low-volume agricultural bridges. This is done by adding the SROI value to the user impact which provides a performance indicator to rate the essentiality to the public.

The impact to the users of low-volume bridges in agricultural zones must differentiate between the impact produced to the small/medium size vehicles and the heavy vehicles which are recognized as essential for the region's economic growth. As shown in the case study, it is important to identify all different scenarios and the break-even point where the RUC of the trucks is surpassed by the RUC of small vehicles based on the traffic count of each of these two groups.

The decision to allocate resources between bridges could also vary if the decision of not selecting specific projects involves posting versus closing the bridge. As shown in the case study, comparing the SROI of the two bridges in the prioritization process can change the decision made by including the economic impact on all users by the total closing of the bridge versus a partial restriction where the impact only accounts for impacts to heavy trucks.

Acknowledgement

This work is based on research supported by the IADOT, with a special acknowledgment to their county, city, and traffic engineers.

CHAPTER 7 MEASURING USERS' IMPACT TO SUPPORT ECONOMIC GROWTH THROUGH TRANSPORTATION ASSET MANAGEMENT PLANNING

Submitted for publication in the Public Works Management and Polices Journal

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Abstract

The MAP-21 Act was created, within other objectives, to support the economic growth of regions. With this in mind, the methodologies and policies used to allocate construction and maintenance funds for infrastructural rehabilitation provide a way for state DOTs to spur economic growth. Economic downturns have opened the eyes of decision-makers highlighting the importance of a transparent and cost-effective allocation of resources. This study proposes adding social and economic components to the current prioritization method for low-volume, rural bridges in Iowa and evaluates the potential change in the distribution of funding among the state's structurally deficient bridges. The proposed method identifies stakeholders and value added of infrastructural projects to the state's agricultural economy, concluding that the addition of socioeconomic factors to the current decision method could increase the net benefit of the investments to the community.

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Background

Throughout history, bridges have always been a symbol of economy growth allowing the trading of commercial products between regions (Harrison 1992). This is valid today at an interstate level, as well as a rural level where farmers must move their products from the fields to the distribution centers on the farm-to-market road network. According to the 2013 Report Card for America's Infrastructure, over 35% of the nation's bridges were classified as structurally deficient or functionally obsolete (ASCE 2013). The report mentions that the nation needs to remain focused on aging bridges and work to decrease the total number of deficient bridges to below 15% over the next decade. Additionally, the report states that 74% of these bridges are located in rural areas. The report goes on to recommend that the highest priority be placed on repairing or replacing large-scale bridges in urban areas to reduce congestion. Unfortunately, the report overlooks the problem in states with a strong agriculture economy, such as Iowa, and fails to recognize that these states have the highest percentages of obsolete or deficient bridges, with over 22% of the total rural bridges in deficient condition (TRIP 2014) including some with less than 70 ADT (IADOT 2014). The intent of this research is not to create a method to make rural bridges more competitive than high-volume bridges and shift the share of available funds. The objective is to question the current methods for prioritizing resource allocation to the existing rural road network and improve the manner in which funding is allocated from the current share of rural road improvement money and provide a potential tool to help prioritize bridges with lower-volume traffic based on their impact on the state's economy rather than the number of vehicles that cross them each day.

To illustrate the motivation of this study, it is important to start with the current transportation condition of the state with a primary focus on bridges. Iowa is currently facing an annual transportation funding shortfall of $215 million in order to meet the state's most critical public roadway needs (TRIP 2013). Scott Neubauer, an IADOT bridge engineer, noted that with $200 million over the next five years, 50 more state bridges will be repaired or replaced leaving more than 5,000 county bridges in poor condition (McIntosh 2013) . Polk County engineer Kurt Baileys said "That is not enough to keep up with inflation, let alone the cost of construction that we are seeing. We are basically flat in road use tax, and it is tough to keep the system up as costs increase every year" (McIntosh 2013).

The 2013 Report Card also mentions that the FHWA calculates that more than 30% of existing bridges have exceeded their 50-year design life. To understand Iowa's background, it is important look at its history and identify the reasons behind the condition of the current transportation system in the rural areas. At the beginning of the 19th century, dirt roads acted as section boundaries, and traditional families lived on parcels that could be worked with family labor and horse power (Friedberger 1989). The building of the county road system was based on a section of land, or one square mile (640 acres) (Informa 2013). In addition to this, between 1939 and 1940, over $43 million in funds were allocated to the farm-to-market roads; however, some of these projects were suspended as a consequence of World War II. In 1944, the Postwar Highway Act authorized the expenditure of $500,000,000 per year for three years, and permission was granted to expand the Federal-aid Secondary (FAS) road system. The FAS road system had also been expanded to the farm-to-market system. (Johnson 2002). Unfortunately, the interest in maintaining the farm-to-market system has not persisted through the years, and the state of Iowa changed their percentage of road-use taxes allocated to the farm-to-market system from 15% in 1949 down to the current 8% (Johnson 2002) jeopardizing the sustainability of these roads.

The modernization of the agricultural industry in the last century has had an impact on the size and production of the cropland used for corn and soybeans, adding new exigencies to the transportation infrastructure in rural zones. The average acreage per farm under crop production went from 56 acres in 1954 to 276 acres in 2007. Furthermore, the number of farms has declined by 55%, but many acres have been rented to active farmers (Informa 2013). Additionally, the production of corn has increased from 54.7 bushels per acre in 1960 to 158.8 in 2013 (USDA 2013) . As expressed by the Informa Economic's report to the Soy Transportation Coalition, with these changes, today's farmers would benefit from a county road system that could handle properly configured 97,000-pound trucks, even if this represents the reduction of the total infrastructure system by focusing on improving the roads with higher impact, or reducing the current grid from 1 square mile to 2 square miles, decreasing at the same time the liability of the state and local government (Informa 2013).

Today's challenge lies in the fast growth of the transportation demands followed by an unstable economy that has challenged its sustainability. However, the actual responsibility of public agencies is to consider the needs of the users for whom the infrastructure is providing essential services. Therefore, the current modernization in the agricultural industry is a vital input that must be included in the decision- and policy-making processes used today for the nation's transportation infrastructure.

Problem Statement and Scope of Work

This study uses the framework in Figure 7-1 to establish the needs and uses of the proposed methodology. In order to analyze polices and procedure within an organization, it is imperative to first recognize their goals and mission in order to comprehend the purpose of the decision making.

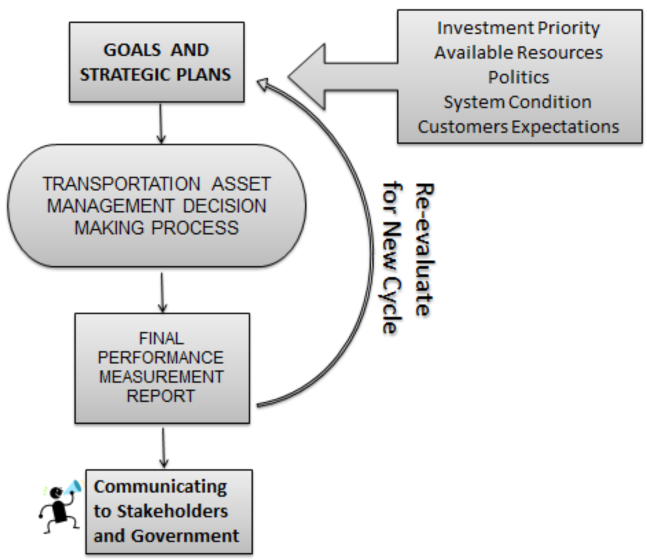

Figure 7-1 Summary of TAM Framework

This study was developed to target the following goals set by MAP-21, the FHWA's TAM initiative, and IADOT mission:

MAP-21's goal: To support regional economic growth (FHWA-5 2012).

TAM's goal: Deliver to an agency's customers the best value (Cambridge 2002).

IADOT's Mission: Delivering a modern transportation system that provides pathways for the social and economic vitality of Iowa, increases safety, and maximizes the customer's satisfaction (IADOT-4 2012).

The above goals share a common interest in economic growth and the wellbeing of the road network's users. Furthermore, these goals must allow the organization to transparently measure their performance for self-evaluation as well as to serve as a communication tool to taxpayers and legislators to help increase the institution's credibility and support. The economy has reached to a point where public institutions such as the DOTs are forced to look closely at how the money is being spent to ensure that the resources are allocated in the most cost-effective ways ensuring the sustainability of the transportation system.

From the economic perspective, the U.S. provides nearly half of all the world's grain exports, and Iowa ranks first among the states in production of corn and soybeans (USDA 2013). The state and federal governments are required to support the local economy through transportation infrastructure. Therefore, this research analyzes the condition deficit of rural bridges located in agricultural zones of Iowa by studying the current prioritization methods used to allocate funds to these bridges and comparing that result to the outcome of one proposed method that includes using SROI as an indicator.

Social Return on Investment

SROI was developed by the SROI Network formed in 2008 in the United Kingdom with the purpose of promoting the use and development of their methodology internationally. SROI is a framework based on "social generally accepted accounting principles" that can be used to quantify and understand the social, economic, and environmental outcomes. This methodology has been used by both governmental and nongovernmental organizations to forecast the value created if the selected projects attain their intended outcome. The outcome is a metric that can be used to compare different prospective projects and make resource allocation decisions. (Network 2012). In essence, SROI analyzes the stakeholders' interests and the social, economic, and environmental impacts generated from the allocation of resources to specific bridges. The analysis also prevents from inflating the impact by identifying and isolating the users that have a deceptive impact that does not exist due to specific circumstances of the impact.

Local bridges are prioritized by the IADOT using a point system where each indicator receives a point on a scale of 0 to 10. Those points are later added together to obtain a total priority score used for prioritization in a descending order of importance. Parallel to this, the proposed method uses the same point system where the SROI ratings also assign points on a scale of 0 to 10, and the points are added. These indicators are shown in Table 7-1. As can be seen in the table, the estimated AADT and the detour distance from the current method have been merged and now form the SROI indicator.

Table 7-1 Prioritization Methods Indicators

Weight	Current	Proposed	Weight
25%	Sufficient Rating	Sufficient Rating	25%
25%	Estimated AADT	SROI	50%
25%	By, Pass, Detour		
25%	Bridge Posting	Bridge Posting	25%
100%	Total Score	Total Score	100%

Both the current and the proposed SROI methods provide a prioritized list of bridge candidates for funding as their final output. Comparing the two lists will answer the question of whether the implementation of the SROI-based method would produce a different output than the current method on the priority by which resources are allocated to maintain, rehabilitate, or replace structurally deficient low-volume bridges. In other words, will including the SROI parameter actually provide a higher benefit-cost ratio to the maintenance funds, helping support the local farmers and, consequently, the economy of the region? The new candidates list also helps solve the question of what, if any, is the impact to the users of structures located in urban versus rural zones. Table 7-1 shows the different indicators used by each of the two prioritization methods, and how the total scores were calculated for each candidate bridge by adding the points of each of those variables with their specific weighted score.

Subsequently, the authors analyzed the implementation of the SROI as a key performance indicator (KPI) applied to the TAM as an integrated system that helps reduce the “worst-first” scenario, where the city and county engineers wait until there is a red flag on the structure to include them in a prioritization list instead of looking at the entire system as a whole.

Research Methodology

There were 97 bridges on the IADOT 2014 State-City Bridge Candidates List. Any highway bridge within the corporate limits, whether in whole or in part, may be submitted for consideration to the list, including bridges on farm-to-market extensions within the city limits of cities with populations less than 500 (IADOT-2 2014).

Social Return on Investment

The first step in this research was to use the SROI framework to identify the stakeholders and their impact. SROI provides the tools for the decision-making process by requiring the user to analyze the effect based on where the actual impact occurs (Figure 6-1). This could also be interpreted as identifying the risk of doing nothing, or in other words, what would happen if no maintenance is done. Because of the great diversity of economies in the U.S., each state must first understand the demographics of their stakeholders and how they experience a positive impact from transportation infrastructure projects.

Measuring the impact will allow state DOTs to measure their performance based on the outcomes instead of the inputs and/or outputs. To better explain the difference between inputs, outputs, and outcome, assume the input is the amount of money that is allocated every year to maintain bridges, and the outcome is the number of bridges that are able to get maintenance with that money. It would be misleading if the amount of money invested in maintenance was used as a performance indicator to prove the interest of the institution for the wellbeing of the bridges and the community. The reason for this is that the increase in money needed for maintenance can be the cause of a severe deterioration of the infrastructure which requires a higher investment. On the other hand, a small amount of resources allocated for maintenance does not necessary imply a better infrastructure since it could easily mean a procrastination of their responsibilities. Similar to the interpretation of the money/inputs, the number of bridges maintained could be misused as an indicator of performance. Therefore, this study highlights the importance of focusing on the actual impact those inputs and outputs have on the stakeholder in order to measure the actual outcome and draw accurate conclusions about the performance of the organization.

After developing the SROI framework, the researchers next focused on the impact that the local bridges have on the agricultural industry. Stakeholders were classified in four groups, recognizing that each group has a different impact based on RUC (see Figure 5-1 RUC $/Mile by Vehicle Type and Road Surface). The RUC was calculated using the World Bank's HDM-4 Road User Costs Model (WB 2013). This model, unlike others, is designed to differentiate between gravel and paved roads. It calculates road user costs using algorithms with input variables such as speed, travel time, and emissions among others. (WB 2013). Also, users were classified in two major groups based on the FHWA's 13-vehicle classification (FHWA 2011) system shown in Figure 2-2. The first category includes vehicles with single trailers of three or more axles, as well as multiple trailers with five or more axles representing the vehicles that carry fertilizer, seed, and machinery to the farm and the ones that haul the produce to market after harvest. The second category includes vehicles classified between 1 and 7, which includes motorcycles, passenger cars, two axle/4 and 6-tire units, buses, and three or more axle single units.

Computing Rural Bridge SROI and LCCs

The PV of the total impact throughout the life cycle of the asset is calculated based on the annual total impact using RUC as the financial proxy and the detour distances as the multiplier, the type of vehicle, and type of road using Equations 2 and 3 (Network 2012). Finally, the SROI index is calculated based on the LCC of the asset and the PV of the total impact (Equation 4).

There are three steps in calculating the SROI index:

1. Projecting into the future :

$$\text{Total Impact} = \sum_{t=1}^{(\text{life span})} \text{Impact at end of year } 1\left(1 - \text{deterioration rate}\right)^{t-1} \quad \text{(Equation 2)}$$

Note: This equation was simplified assuming that there would be a maintenance allowance throughout the life cycle to prevent deterioration. Since deterioration equals zero, the total annual impact equals the annual RUC.

2. Calculating the NPV:

$$\text{PV} = \sum_{t=0}^{(\text{life span}-1)} \left(\frac{\text{Impact at end of year}}{(1+r)^{t+1}}\right) \quad \text{(Equation 3)}$$

3. Calculating the ratio

SROI Index = $\frac{\textbf{Total PV of benefits}}{\textbf{Value of investments}}$ (Equation 4)

One of the challenges of this research was the limited information available in the literature and at the county engineer's offices detailing the LCC of small bridges. Therefore, the conceptual LCC was calculated using a top-down stochastic method that is based on the cost per square foot of a concrete slab, concrete T-beam, concrete I-beam, and steel bridges as shown in Table 7-2 (Anand and Gransberg 2014).

Table 7-2 Bridges LCC/SF

Type of Bridge	LCC Cost/sq. ft.
Concrete Slab bridge	$362.65
Concrete T-beam bridge	$354.97
Concrete I-beam bridge	$344.55
Concrete box beam bridge	$340.20
Steel bridge	$328.48

The second challenge was the limited traffic count data available. The IADOT does not have the resources to conduct comprehensive traffic counts by vehicle classification on all local roads across the state; however, this information is necessary to calculate the SROI. In this study, the socioeconomic benefit will be primarily from impact to heavy trucks essential to agriculture rather than lighter passenger vehicles.

Estimating Rural Bridge Traffic Characteristics

To calculate the AADT of heavy trucks and lighter vehicles at each of the candidate bridges, daily traffic data was collected from 12 of the 57 continuous traffic recorded locations that are differentiated by the FHWA's 13 vehicle classes. These traffic stations were classified by Rural Primary, Municipal Primary, Rural Secondary, and

Municipal Streets. The average percentage of truck traffic and the average percentage of lighter vehicle traffic were calculated for each of the four road types as shown in Table 7-3 and were used along with the estimated AADT calculated by the DOT for each of the candidate bridges.

Table 7-3 Actual AADT and Trucks %

	Total AADT	% of Trucks	% of Lighter Vehicles
Rural Primary			
Site 276	2979	22.69%	77.31%
Site 257	3368	21.77%	78.23%
Site 267	4209	11.20%	88.80%
Average	**3519**	**18.55%**	**81.45%**
Rural Secondary			
Site 300	260	6.47%	93.53%
Site 301	986	5.65%	94.35%
Site 307	877	6.11%	93.89%
Site 312	1077	8.06%	91.94%
Average	**800**	**6.57%**	**93.43%**
Municipal Primary			
Site 804	3085	10.35%	89.65%
Site 830	2531	8.79%	91.21%
Average	**2808**	**9.57%**	**90.43%**
Municipal Street			
Site 902	20486	0.22%	99.78%
Site 912	3535	0.79%	99.21%
Site 901	6018	0.17%	99.83%
Average	**10013**	**0.39%**	**99.61%**

The final step was to create a Bridge Priority Score by assigning numbers to each bridge from 1 to 97 based on the total priority points. Since several bridges result in the same amount of points, a modification to break the ties was made by employing Hansen's (2008) pairwise comparison method, termed the "Scoring Additive Multi-attribute Value Model Using Pairwise Rankings of Alternatives" (Paul Hansen 2008).

Results of the Analysis

In 2014, the IADOT used its current prioritization process to identify 46 out of the 97 bridges for funding in the annual program. The total number of bridges was limited on the total amount of available funding for that fiscal year. The total cost to rehabilitate the 46 bridges on the 2014 list was estimated to be $87,758,303. The SROI index was calculated for each of those bridges, and the average SROI was calculated to be 46. Then the total impact and the total LCC of these 46 bridges were added to calculate the total SROI for the annual fiscal year which gives an index of 24.

In comparison, the proposed SROI-based prioritization method using the same amount of available funding reprioritized the list and recommended 66 bridges to be rehabilitated. This is an addition of 22 bridges to the budget while cutting 2 bridges from the actual 2014 list. The average SROI index of the 66 bridges was 50, and the total SROI for the total year was calculated to be 28. Table 7-4 summarizes the results and compares the two methodologies.

Table 7-4 Summary of Results and Comparison of Methodologies

	Methodology	
	Current	**Proposed**
Number of Bridges Funded	46	66
Average SROI per bridge	46	50
Total Impact	$2,111,612,173	$2,514,868,485
Total LCC	$89,577,190	$89,433,955
Total SROI	24	28

In Table 7-5, the total of the 22 new bridges were also compared to the total of the 2 displaced bridges originally in the funding. Not only were 22 more bridges able to be funded, but also there was a significant increase in the total impact resulting in a higher SROI index, indicating a net improvement in the overall impact to the rural bridge network for virtually the same investment.

Table 7-5 Bridges added vs. Bridges displaced

	Investment	Impact	Life Cycle	SROI
New Bridges Added	$13,670,523	$1,032,800,880	$13,422,713	77
Bridges Left out	$13,556,872	$629,544,568	$13,565,948	46

Integrating SROI as a Key Performance Indicator in the TAM Framework

As mentioned before, the current method used to allocate the resources to the local bridges is done based on the number of candidates that are nominated by local engineers. Because this filter has been established, the SROI has only been considered on bridges that have already shown some kind of distress.

Figure 7-2 represents a proposed TAM framework and two proposed stages when the SROI could be added as a key performance indicator (KPI). Based on the data collected and resource allocation method used by the IADOT, this study applied the SROI to the latest stage after the candidates had already been identified. However, if the final goal of the TAM is to support an infrastructural system that is sustainable and that helps allocate the money to extend the life cycle of the structures, resulting in the most cost-efficient investment of the resources, then it becomes necessary to start looking at the condition, life cycle, finances, and user's impact of the entire inventory. The authors are aware that to implement SROI at an earlier stage as shown in the framework, represents a significant effort and commitment for the state DOTs to maintain an updated inventory of all structures including local and county bridges. This ideal application promises the possibility to identify and focus on the transportation systems that truly matters to the users.

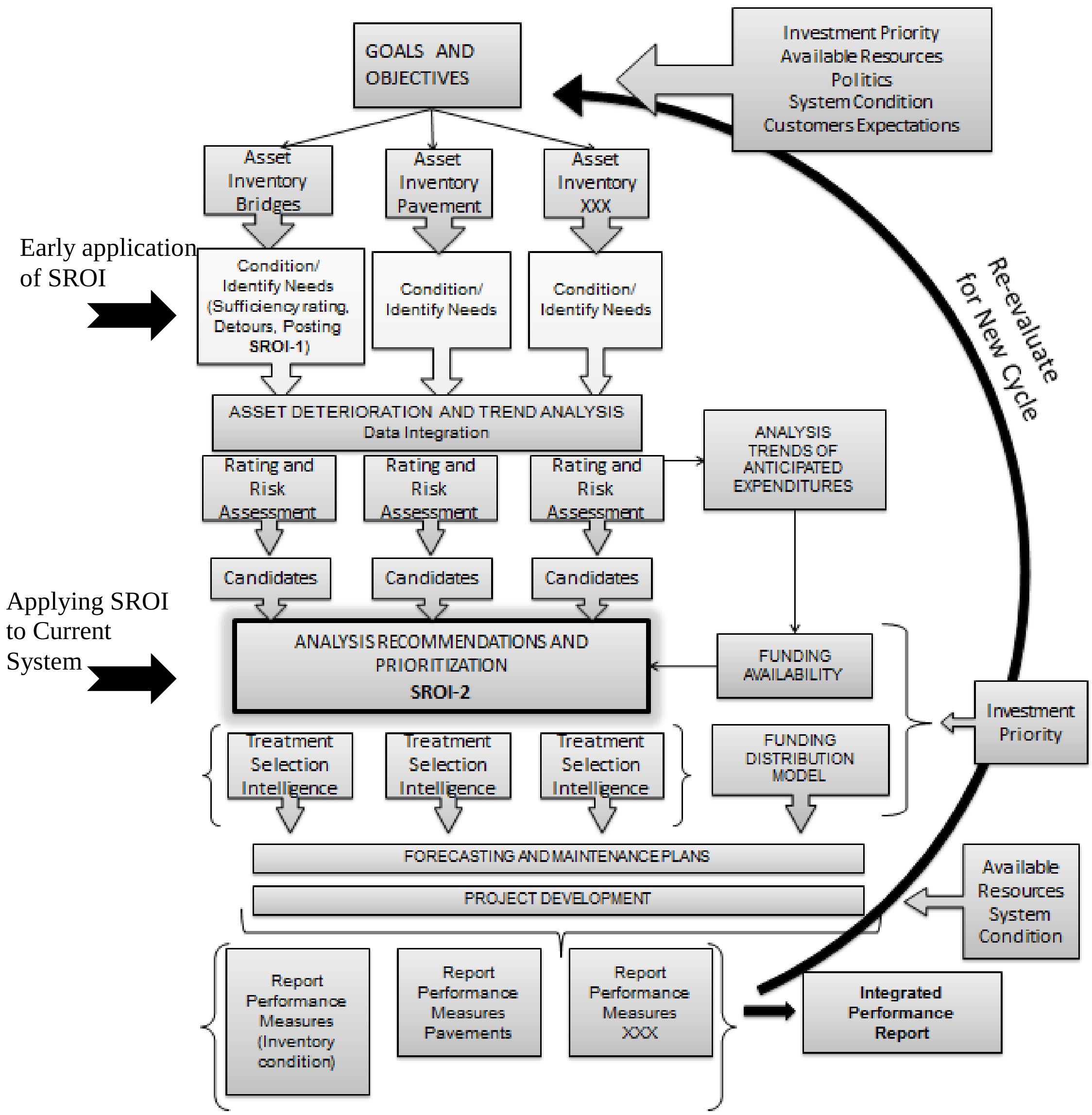

Figure 7-2 TAM Framework

In order to maintain a sustainable infrastructure system, the framework integrates the analysis of trends and anticipated expenditures, which come from an updated inventory, as well as the life cycle of the assets so that the DOT can ensure that those bridges will continue getting the required attention. In order to secure the maintenance cost over the years, the institutions must set realistic goals based on the forecasted revenue generated. This could lead to unpopular decisions that require the elimination of assets that have simply been ignored over the years. In the case of Iowa, several of these bridges in rural areas have been closed to traffic, which has not only added to the liability of the state, but also could provide a false overall condition of the state's bridges that does not reflect the service offered to its stakeholders.

Although this study does not analyze the bridges with the lowest impact in the state, it could potentially help in the decision-making process, as well as in the justification and communication of these decisions to the stakeholders about the need to eliminate bridges from the state's inventory without causing a negative impact to their users. This is explained by the evolution of the agroindustry which has indirectly shaped the transportation system over the years, even though the actual transportation grid has not been re-evaluated or designed to keep up with today's requirements.

Conclusions

After studying the goals and strategic plans of the IADOT and comparing them with the overall condition of the bridges, a disconnect was found between the desire to improve the response to the users' needs and support the economic growth of the region with the way the decision to allocate maintenance and rehabilitation resources has been made for the city and rural bridges. Even though agriculture is an important part of Iowa's economy, the majority of the bridges in structurally deficient condition are located in rural areas where heavy agricultural equipment and heavily loaded trucks frequently transit.

This study addressed this issue by introducing a new KPI that focuses on the social and economic impact of the users. The inclusion of SROI to the prioritization process of local bridges in Iowa can provide a way to allocate the state's resources enhancing the impact on Iowa's most important industry. This proposed methodology not only demonstrated an increased in the impact generated to the users of the bridges by 24% with the same amount of funding, but also reduced the percentage of bridges that will remain on the candidate list as structurally deficient condition from 52% to 32%.

The inclusion of the SROI as a KPI was the result of analyzing stakeholder impact, which directs attention to the impact generated by heavy traffic in rural areas, driving the decision of whether or not to maintain rural bridges. This research shows how changes in the policies and procedures could divert resources and benefit specific parts of the population; therefore, including the impacts on stakeholders is an important step in the development of strategies that achieve the desired outcome. In that same way, the SROI could be applied to different geographic zones and governmental departments by focusing on the goals and the interests of their stakeholders.

Acknowledgement

The authors would like to acknowledge the IADOT, which funded this project, as well as their urban and county engineers for their support during the process.

CHAPTER 8 CONSOLIDATED CONCLUSIONS AND LIMITATIONS

The first step before embracing the development of regulations and polices is to clearly understand what results are expected once the new strategy gets implemented. This was the case of the IADOT which was required by the FHWA to develop and implement a transportation asset management plan that fulfilled a number of goals in order to provide better services to the users, increase economic support, and improve their infrastructure.

After studying the current condition of the state's infrastructure and the needs of the users located in regions where the economy of the state takes place, it was clear that this project needed to focus on the rural areas, more specifically on the bridges that serve the agroindustry.

Several methodologies were exanimated but two were found to be the best fit for the needs. The proposed methodology was based on an integration of SROI with HDM-4 used by the World Bank to measure the impact of their projects. This methodology integrates the social, economic, and environmental impacts as well as differentiates between type of users' vehicles, type of roads, and the risk of not providing the require funding to the structures.

After testing the proposed methodology it was found that higher AADT did not necessarily represented a higher impact. There were several other variables that play an important role and therefore the stakeholders were divided in two categories based on the size of their vehicles. This way only the impact of the vehicles affected by the posting or closing of a bridge could be discriminated, and the impact of a maintenance or rehabilitation project was not inflated.

Therefore, considering the scenarios where the bridge would be posted, i.e. reducing the weight allowed to cross over the bridge, versus a complete closure drove the attention to bridges located in zones with a greater volume of heavy traffic, which indeed represents the rural zones with greater productivity. If these bridges were to be posted, the heavy trucks would be forced to detour while smaller vehicles will still be able to cross.

Moreover, classifying the users in these two groups also helped to distinguish the different impacts based on the vehicle operation cost, which as expected, heavy commercial vehicles had greater RUC. This indicator was helpful in the case of bridges that could be closed to help identify how many more small vehicles will represent a higher impact compared with a bridge with lower AADT but greater percentage of heavy trucks.

The proposed methodology was designed to be used as an additional indicator for funding needs of individual assets; furthermore, it is an excellent tool to help measure and communicate the performance of the DOT as a summary of the fiscal year, providing a clear and objective explanation of the allocation of the resources and how these impact the community. Nevertheless, this methodology is not static, and it should be considered dynamic. The proposed TAM framework can be updated every year based on a given year's final performance report or based on changing inputs from stakeholders. This permits the agency to reevaluate stakeholder needs and changing economic interests. Therefore, if a decrease on serviceability is observed on other sectors of the transportation system, such as emergency/evacuation routes that result from changes in population and land use, as well as accelerated deterioration of the assets under analysis, the model can be adjusted to address the changes as they occur. This adjustment will provide a greater measure of equity to stakeholders and permit funds to be disbursed in the coming fiscal year that positively impact the growth sector. After comparing the allocation of annual budget for 2014 within the candidate bridges using the current system with the recommended distribution of the resources provided by the proposed methodology, it was found that if the allocation of the resources would have been done including SROI, not just the IADOT method, it would have increased the impact generated by 24%. Moreover, out of the total local bridge candidate list, it reduced the percentage of bridges that will remain as structurally deficient condition from 52% to 32%.

Some of the limited accuracy on the final result is the result of the limited information available on the LCC of bridges as well as traffic counts and vehicle classification. If more accurate results are desired, the DOT would be required to expand the resource needed to understand the traffic on low-volume roads, as well as better record keeping of the maintenance provided to the structures throughout their life cycle.

Using SROI in a TAM plan must be seen as a valuable KPI that should be used in conjunction with the other traditional indicators. SROI alone does not supplant the current prioritization systems, instead it supports and enhances them as part of the process of continually improving the way decision-making is done. SROI is not a deterministic indicator that could be used alone to prioritize assets. Some of the limitations are based on scenarios were the SROI cannot be calculated due to the lack of one of the variables. Such cases include where the bridge is the only access to a specific location, such as agricultural, recreational facilities, or any other in services valued by the community. In this case the SROI index is not available, but the impact is great.

Eventually, this methodology could be applied to other geographic zones as well as to other assets. However, this study was completed based on the needs and requirements of the state of Iowa, the DOT, and the users; therefore, the implementation of this methodology on a different context would require a calibration of the system based on the specific requirements of the region and stakeholders.

CHAPTER 9 CONTRIBUTIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Chapter 9 discusses and highlights the importance of the findings and contributions drawn during the research completed for this thesis. Furthermore, this chapter presents some recommendations for future research, which are intended to improve the decision-making process for funding allocation on TAM plans. Likewise, these recommendations are aimed to take SROI on TAM systems to a higher level, where it can involve other indicators as well as other type of assets.

Contributions

Since classic asset prioritization methodologies are primarily based on traffic volume plus asset condition for capital project decision-making, low-volume assets are at disadvantage, and high economic impact activities (HEIA) such as the agricultural industries located on low-volume assets suffer a negative impact.

Adding SROI to the TAM plan as a KPI adds new value to the body of knowledge providing rational justification for allocating resources to low-volume assets that service HEIA and improve communication and transparency, enhancing the credibility of the users and legislation toward decision-makers.

Integrating the social impact to the evaluation of infrastructural projects is a current need that promises a tremendous impact on different areas of the decision-making process for maintenance and new construction fund allocation. Not only does this ensure that the current tax dollars are spent in the most cost-effective way possible, but it also ensures an infrastructural network that is socially responsible and sustainable for current and new generations.

The Institute for Sustainable Infrastructure (ISI) has developed Envision™, a holistic framework for rating the community, environmental and economic benefits of all types and sizes of infrastructure projects. It evaluates, grades, and gives recognition to infrastructure projects that use transformational, collaborative approaches to assess the sustainability indicators over the course of the project's life cycle. Current sustainability rating systems for infrastructure in the U.S., such as LEED and Greenroads are sector specific. No U.S. system covers all aspects of civil infrastructure, so the Envision™ rating system was designed to fill that gap. Envision™ covers the roads, bridges, pipelines, railways, airports, dams, levees, landfills, and water treatment systems.

One of the areas of evaluation questions whether the developers have considered the needs of the surrounding community and asked not just if the project is done right but also if it is the right project (ISI 2012). SROI provides the tools needed so developers can answer this question and engineers can design and build infrastructural projects that respond to social, economic, and environmental needs.

Recommendations for Future Research

This thesis was focused on developing a mechanism that helps integrate low-volume bridges into the candidates for maintenance and rehabilitation funds, even though the algorism was developed including the key indicators, there are some external variables that were not covered in this study that are recommended to be analyzed in future studies.

- This study included only the positive impact generated to the users by the execution of maintenance projects. Accepting the fact that there are not sufficient resources to maintain all bridges, some will be exposed to posting or even closure. The negative impact caused by detouring traffic that these bridges will generate to adjacent roads and bridges as well as the community was not calculated, and it would be necessary to compare the breaking point between the positive impacts versus the negative for better decision making.

- Better understanding of the bridges' life cycle and the way different maintenance treatments could extend their life cycle or reduce the overall maintenance cost of the structures will provide the opportunity to include this variable into the decision-making process. This will help answer the question of whether some of the big bridges that were left off of the funding list could cost more to maintain in the future if no maintenance is done now. At this point, the prioritization has been based on rehabilitation of the bridges more than on preventive maintenance, and there are no records of how this preventive treatment plays a role in the decision-making process.

- In the calculation of the PV for the LCC and benefits of the assets, this study used 4% as the discount rate based on recommendations from the FHWA (FHWA-4 2003). However, it would be important to study the sensitivity of this rate, and the reason behind it. For instance, the 4% suggested for transportation projects may not be appropriate for a social and economic setting outside of transportation. Factors such as type of discount rate and nominal versus real could affect the selection of the rate and how it affects the decision-making process. In the case that inflation were to be considered as part of the discount rate, it may be necessary to consider inflation rates calculated using the consumer's price index for social aspects and the construction cost index for transportation projects. Similarly, previous studies done on the LCCA of pavement treatments have shown that a low discount rate may favor higher cost and a longer-lived alternative (Gransberg, et al. 2010).

- Different methods could also be analyzed in the selection of the discount rate. The FHWA Guidelines for LCCA Report mentions that "estimating the discount rate is not a straightforward matter. Furthermore, there is no consensus on how to value the real earning capacity of these public funds. The choice of the discount rate is one of the most debatable topics in public project evaluation" (Ozbay, et al. 2003). It suggested four different philosophies that could be evaluated in the selection of the discount rate including Opportunity Cost of Capital, Societal rate of time preference, Zero Interest Rate, and Cost of Borrowing Funds.

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APPENDIX A REPORTS OF INFORMAL INTERVIEWS WITH IOWA COUNTY ENGINEERS

Marion County – Brian Hatch, Engineer

The meeting with the Marion County Engineer Mr. Brian Hatch was held on July 9 2013 at the Marion County Office in Knoxville.

When introduced to a TAM plan, Mr. Hatch noted that no information had been communicated from the state agency to the county engineers about the needs and advantages of this plan. The prioritization process at Marion County is still done based on the “worse-first” scenarios, as well as the availability of the resources. For instance, there is a $4 million bridge that requires rehabilitation, but the county does not count that bridge with the 20% required by the state to match available funds. This means that not only do the worst bridges get funded, but also only the smallest projects.

There is also a judgmental influence on the decision-making. If an engineer does not consider a bridge to be important for the community, it will not be included in the potential candidates. Marion County Engineers do not have a standardize method to measure the importance of those structures.

By January 2013, Marion County had 7 closed bridges, 3 bridges posted under 7 tons, 6 bridges with capacities between 8 and 15 tons, 9 bridges with capacities between 16 and 22 tons, 12 bridges with capacities between 23 and 29 tons, and 4 bridges with capacities between 30 and 40 tons. From 2002 to 2012, 68 bridge projects have been completed with an average cost of $150,927. The costliest projects were executed in 2002 for $1,671,822 while the least costly projects involve repairs for $3,741 in 2006.

Hamilton County – Dan Waid, Engineer

The meeting with the Hamilton County Engineer, Mr. Dan Waid, was held on February 25, 2014 at the Hamilton County Office. Mr. Waid is an experienced engineer and has been the County Engineer of Hamilton County for over 7 years. He has an excellent knowledge of the county, the bridges, and technicalities and these attributes help him make excellent decisions with regards to the transportation assets of Hamilton County. Hamilton County also hires the same bridge consultants as Boone County to conduct the inspection of their bridges. The reports submitted by the consultant contain all the details required to make decisions for the bridges in the county. The county engineer prioritizes the needs for funds for the bridges based on factors such as the ADT, traffic flow, and businesses around the area, political aspects, detour length, and other physical aspects. The two bridges on the first case study belong to this county. The conclusions of the case study were presented and compared with the way he arrived at the decisions regarding the bridges. Through the discussion, it could be concluded that the county engineer had arrived at the same decisions as the study through his own logical analysis of the situation. There was not a standardized process or methodology followed to arrive at this conclusion. The discussions from the meeting were in alignment with the study and proved as an external validation for the study.

Boone County –Robert J. Kieffer, Engineer

The meeting with the Boone County Engineer, Mr. Robert J. Kieffer, was held on March 17, 2014 at the Boone County Office.

According to Mr. Kieffer, Boone County currently has 200 miles of paved roads and 800 miles of gravel roads which contain the majority of the bridges in the county. Out of the total 105 bridges in the county, 18 bridges are posted. These contain some bridges that are too narrow for trucks and larger vehicles.

Boone County hires a bridge consultant to conduct inspections on the bridges in the county every 2 years and makes its decisions regarding the management of assets based on the reports submitted by the consultant. This report also contains the estimated remaining life of any bridge structure.

Some major indicators that are considered while making decisions are the traffic pattern, traffic flow (count), prospective businesses that would be affected, classification of the gravel roads such as farm-to-market, detour length, and user costs. Emphasis is given to those with lesser useful life remaining. Another important factor influencing the decision-making process is the political aspect. The decisions are discussed with the Board and also communicated to the farmers every year at the meetings with the Farm Bureau. Farmers are also encouraged to communicate through emails or letters or walk in anytime and discuss their views with the County Engineer. Some of the maintenance work done on paved bridges include sealing of the bridge decks every 5 years, removal of debris of the piers, and erosion.

Boone County generally considers low volume bridges any bridge with and ADT of around 20 vehicles /day or lower. For a typical bridge on a gravel road, the construction costs would be around $400,000. The main problems faced in the construction or replacement of bridges in this county is the acquisition of the Right of Way (ROW) for the bridge.

An interesting example stated in the meeting was the Wagon Wheel Bridge in the west side of the county across the Des Moines River. It has been closed for almost 4 years now. Though it had a high ADT and people have to take a detour around the bridge now, it has not been possible to replace the bridge since the cost would be around $4 million. It would not be practical to justify spending the limited funds on just one bridge. Another interesting factor that was discussed in the meeting was that Boone County does not follow any specific methodology to forecast the ADT through its bridges.

Story County – Darren Moon, Engineer

The meeting with the Story County Engineer Mr. Darren Moon was held on May 22, 2014 at the Story County Office in Nevada, IA. Story County has 200 bridges longer than 20 feet and another 76 bridges less than 20 feet. These bridges range from 13 feet to 410 feet long. Out of these 276 bridges, 50 have a sufficiency rating below 50, and 80 bridges are posted with load or width restrictions. It includes 74 bridges listed as "structurally deficient" or "functionally obsolete". According to the County Engineer, the Federal Bridge Funding received is $330,000 per year.

Major indicators such as bridge posting, sufficiency rating, total ADT are used to prioritize budget allocation for the bridges of Story County. Detour length, when considered, is generally not greater than 4 miles. As observed in other counties, political issues influence the decision-making process greatly. The county keeps track of any major maintenance work done on the bridges through its life span. In general, temporary replacement work is done on bridges with the intention of extending its service life by a few more years.

The decisions made by the county engineer regarding the roads and bridges in the county are based on expert knowledge of the area and the surroundings. No specific or systematic method is followed for this. The standard "worst-first" procedure is followed for replacement and other major works.

The decisions are discussed with the Board and also with the farmers at the meetings with the Farm Bureau. So far there have been no major obstacles in communicating the decisions to the Board.

APPENDIX B IADOT'S CITY BRIDGE PRIORITY POINT RATING WORKSHEET

This appendix contains the points-based prioritization rating used by the IADOT to identify the bridges with greater needs in order to allocate state and federal funds.

Attachment A to I.M. 2.020
July 18, 2011

City Bridge Priority Point Rating Worksheet

FHWA Structure Number: ____________________ City: ______________________

Inspection date used: __________________ Estimated improvement cost: ____________

Sufficiency Rating: **Priority Points**

81 - 100	=	0 points	35 - 42	=	6 points
75 - 80	=	1	27 - 34	=	7
67 - 74	=	2	19 - 26	=	8
59 - 66	=	3	11 - 18	=	9
51 - 58	=	4	≤ 10	=	10
43 - 50	=	5			

Sufficiency Rating: _______ = ________________

Estimated Average Daily Traffic:

< 25	=	0 points	3001 - 4000	=	6
25 - 250	=	1	4001 - 6000	=	7
251 - 500	=	2	6001 - 8000	=	8
501 - 1000	=	3	8001 - 10,000	=	9
1001 - 2000	=	4	> 10,000	=	10
2001 - 3000	=	5			

Est. ADT: _______ = ________________

Bypass, Detour Length (Out-of-distance Travel) (miles):

< 1	=	0 points	≥ 3 < 4	=	8
≥ 1 < 2	=	4	≥ 4	=	10
≥ 2 < 3	=	6			

Detour: _______ (miles) = ________________

Bridge Posting (SI&A Item 70 value):

5	=	0 points	2	=	6
4	=	2	1	=	8
3	=	4	0	=	10

Bridge Posting: _______ (SI&A Item 70 value) = ________________

Total Points = ________________

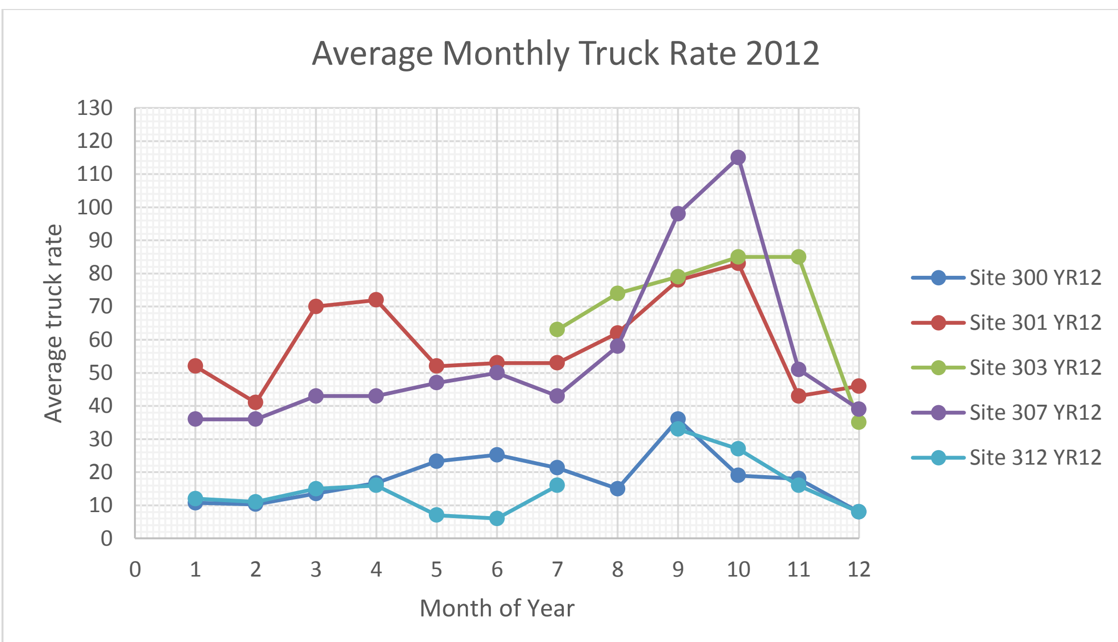
(40 points maximum)

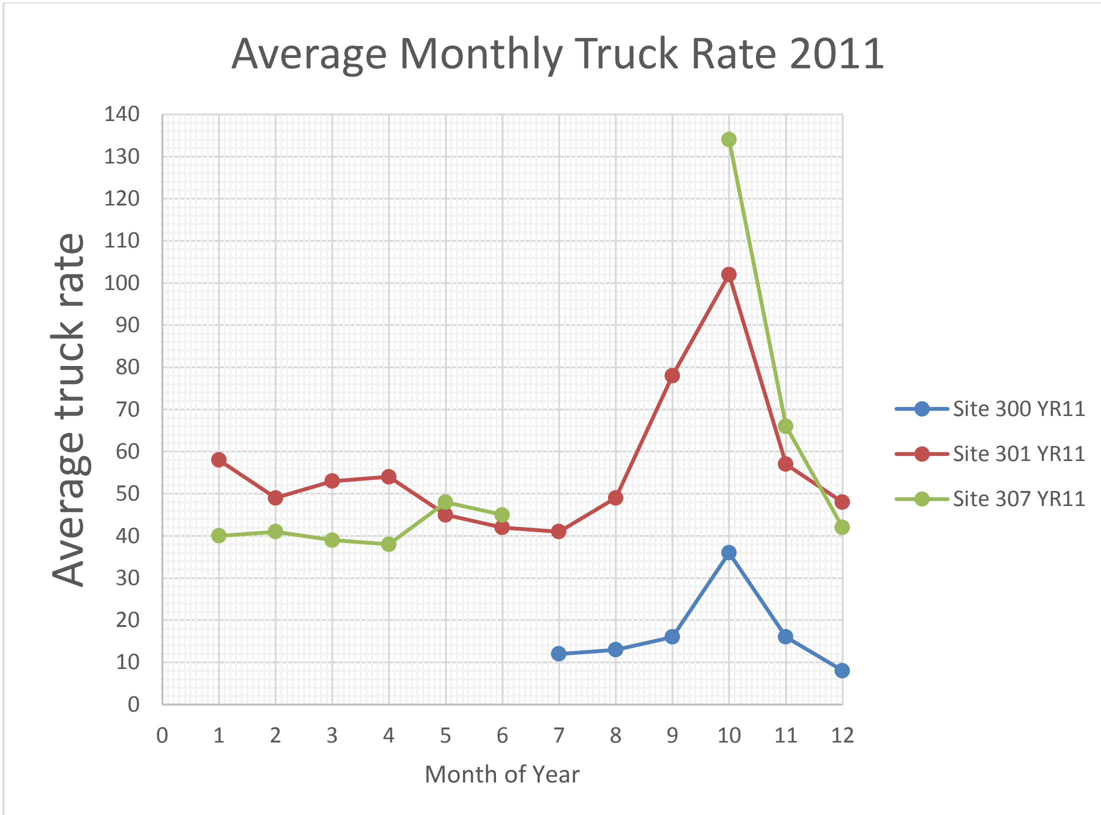
APPENDIX C ANNUAL TRUCK TRAFFIC FOR RURAL SECONDARY ROADS IN IOWA

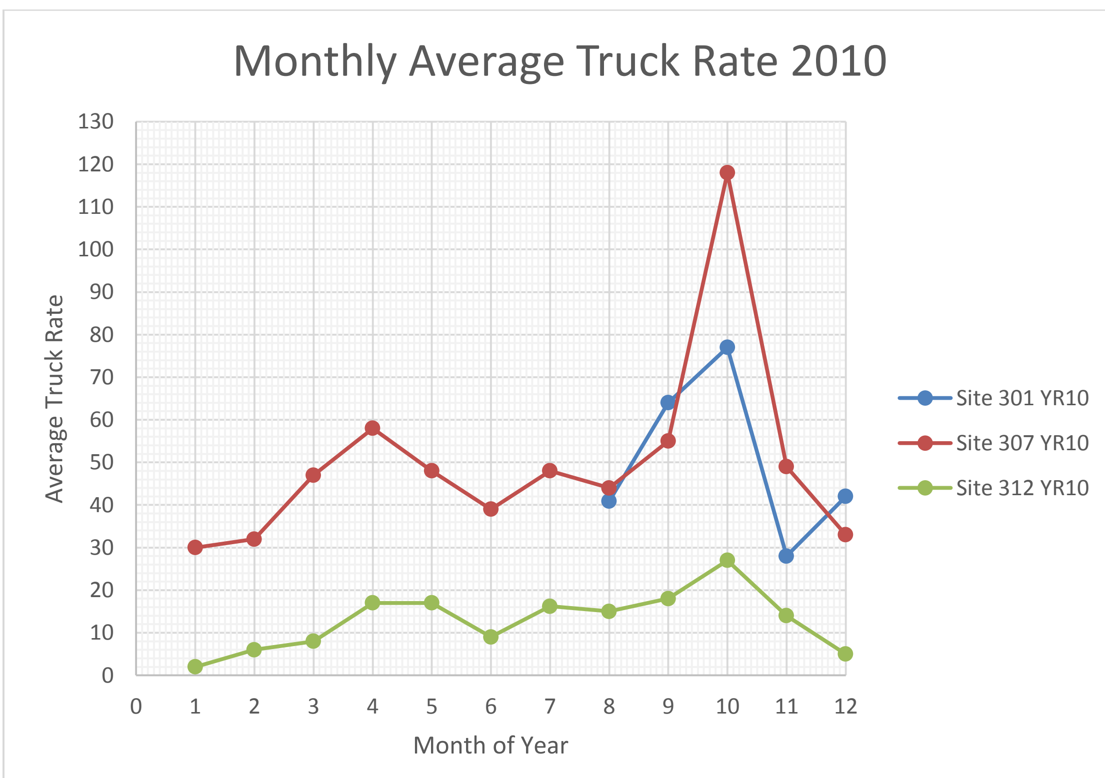
The table and graphics included in this appendix show only the actual monthly average of daily of trucks for stations 300, 301, 303, 307 and 312. Some months and years are missing information due to system failure or weather conditions.

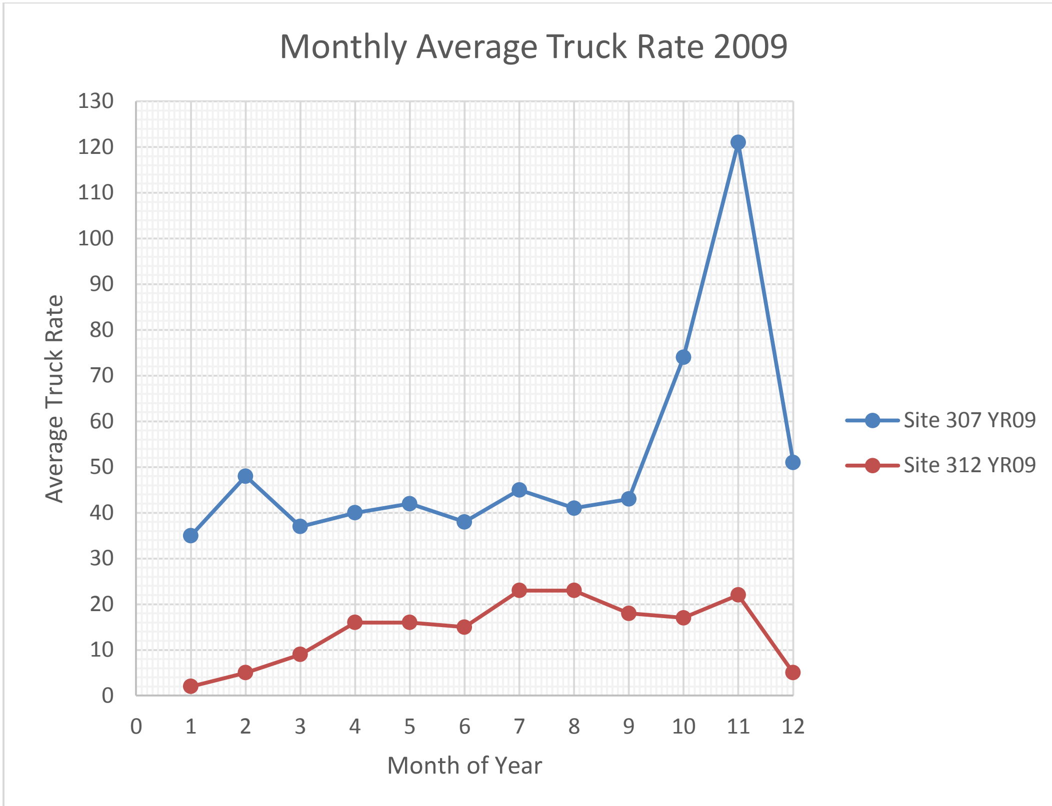
	Site 300	Site 301	Site 303	Site 307	Site 312
1/1/2012	10.71	52		36	12
2/1/2012	10.31	41		36	11
3/1/2012	13.55	70		43	15
4/1/2012	16.73	72		43	16
5/1/2012	23.29	52		47	7
6/1/2012	25.2	53		50	6
7/1/2012	21.29	53	63	43	16
8/1/2012	15	62	74	58	
9/1/2012	36	78	79	98	33
10/1/2012	19	83	85	115	27
11/1/2012	18	43	85	51	16
12/1/2012	8	46	35	39	8
1/1/2011		58		40	
2/1/2011		49		41	
3/1/2011		53		39	9
4/1/2011		54		38	
5/1/2011		45		48	
6/1/2011		42		45	
7/1/2011	12	41			
8/1/2011	13	49			
9/1/2011	16	78			
10/1/2011	36	102		134	
11/1/2011	16	57		66	19
12/1/2011	8	48		42	9
1/1/2010				30	2
2/1/2010				32	6
3/1/2010				47	8
4/1/2010				58	17
5/1/2010				48	17
6/1/2010				39	9

7/1/2010				48	16.225
8/1/2010		40.92		44	15
9/1/2010		64		55	18
10/1/2010		77		118	27
11/1/2010		28		49	14
12/1/2010		42		33	5
1/1/2009				35	2
2/1/2009				48	5
3/1/2009				37	9
4/1/2009				40	16
5/1/2009				42	16
6/1/2009				38	15
7/1/2009				45	23
8/1/2009				41	23
9/1/2009				43	18
10/1/2009				74	17
11/1/2009				121	22
12/1/2009				51	5




Average Monthly Truck Rate 2011
Average truck rate
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
11
12
Month of Year
Site 300 YR11
Site 301 YR11
Site 307 YR11


Monthly Average Truck Rate 2010
Average Truck Rate
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
11
12
Month of Year
Site 301 YR10
Site 307 YR10
Site 312 YR10


Monthly Average Truck Rate 2009
Average Truck Rate
Month of Year
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10 11 12
Site 307 YR09
Site 312 YR09

APPENDIX D ESTIMATED DAILY TRAFFIC USED IN CASE STUDIES

This table presents the actual data for Station 307 used to estimate the daily traffic for the bridges located at 360th Street and Tollman Avenue in Hamilton County, Iowa. The shaded data corresponds to data that has been estimated.

#307 Model			360th St Gravel			Tollman Ave. Paved		
Date	# Trucks	# Cars	Date	# Trucks	# Cars	Date	# Trucks	# Cars
1/1/12	2	527	1/1/11	2	9	1/1/12	2	86
1/2/12	11	644	1/2/11	11	11	1/2/12	10	105
1/3/12	86	1315	1/3/11	89	23	1/3/12	78	215
1/4/12	50	1277	1/4/11	52	23	1/4/12	45	209
1/5/12	104	1352	1/5/11	108	24	1/5/12	95	221
1/6/12	68	1543	1/6/11	71	27	1/6/12	62	252
1/7/12	12	1033	1/7/11	12	18	1/7/12	11	169
1/8/12	9	769	1/8/11	9	14	1/8/12	8	126
1/9/12	50	1280	1/9/11	52	23	1/9/12	45	209
1/10/12	52	1332	1/10/11	54	24	1/10/12	47	218
1/11/12	49	1216	1/11/11	51	22	1/11/12	45	199
1/12/12	28	1060	1/12/11	29	19	1/12/12	25	173
1/13/12	36	1039	1/13/11	38	18	1/13/12	33	170
1/14/12	4	850	1/14/11	4	15	1/14/12	4	139
1/15/12	9	687	1/15/11	9	12	1/15/12	8	112
1/16/12	50	1203	1/16/11	52	21	1/16/12	45	197
1/17/12	26	1059	1/17/11	27	19	1/17/12	24	173
1/18/12	53	1187	1/18/11	55	21	1/18/12	48	194
1/19/12	50	1230	1/19/11	52	22	1/19/12	45	201
1/20/12	28	656	1/20/11	29	12	1/20/12	25	107
1/21/12	8	743	1/21/11	8	13	1/21/12	7	121
1/22/12	4	388	1/22/11	4	7	1/22/12	4	63
1/23/12	19	696	1/23/11	20	12	1/23/12	17	114
1/24/12	33	1027	1/24/11	34	18	1/24/12	30	168
1/25/12	59	1110	1/25/11	61	20	1/25/12	54	181
1/26/12	67	1388	1/26/11	70	25	1/26/12	61	227
1/27/12	43	1275	1/27/11	45	23	1/27/12	39	208
1/28/12	13	1019	1/28/11	14	18	1/28/12	12	166
1/29/12	4	741	1/29/11	4	13	1/29/12	4	121
1/30/12	58	1329	1/30/11	60	24	1/30/12	53	217
1/31/12	36	1245	1/31/11	37	22	1/31/12	33	203

2/1/12	72	1277	2/1/11	75	23	2/1/12	66	209
2/2/12	69	1358	2/2/11	72	24	2/2/12	63	222
2/3/12	50	1501	2/3/11	52	27	2/3/12	45	245
2/4/12	6	850	2/4/11	6	15	2/4/12	5	139
2/5/12	4	730	2/5/11	4	13	2/5/12	4	119
2/6/12	55	1347	2/6/11	57	24	2/6/12	50	220
2/7/12	57	1218	2/7/11	59	22	2/7/12	52	199
2/8/12	66	1202	2/8/11	69	21	2/8/12	60	196
2/9/12	53	1225	2/9/11	55	22	2/9/12	48	200
2/10/12	40	1337	2/10/11	42	24	2/10/12	36	218
2/11/12	10	1040	2/11/11	10	18	2/11/12	9	170
2/12/12	14	807	2/12/11	15	14	2/12/12	13	132
2/13/12	40	975	2/13/11	42	17	2/13/12	36	159
2/14/12	36	1197	2/14/11	37	21	2/14/12	33	196
2/15/12	37	1220	2/15/11	38	22	2/15/12	34	199
2/16/12	30	1219	2/16/11	31	22	2/16/12	27	199
2/17/12	33	1368	2/17/11	34	24	2/17/12	30	224
2/18/12	24	990	2/18/11	25	18	2/18/12	22	162
2/19/12	10	779	2/19/11	10	14	2/19/12	9	127
2/20/12	41	1230	2/20/11	43	22	2/20/12	37	201
2/21/12	49	1071	2/21/11	51	19	2/21/12	45	175
2/22/12	43	1295	2/22/11	45	23	2/22/12	39	212
2/23/12	35	1045	2/23/11	36	18	2/23/12	32	171
2/24/12	20	1174	2/24/11	21	21	2/24/12	18	192
2/25/12	10	916	2/25/11	10	16	2/25/12	9	150
2/26/12	8	781	2/26/11	8	14	2/26/12	7	128
2/27/12	55	1290	2/27/11	57	23	2/27/12	50	211
2/28/12	39	1093	2/28/11	41	19	2/28/12	35	179
2/29/12	25	867	---	26	15	2/29/12	23	142
3/1/12	54	1304	3/1/11	56	23	3/1/12	49	213
3/2/12	39	1374	3/2/11	41	24	3/2/12	35	224
3/3/12	17	980	3/3/11	18	17	3/3/12	15	160
3/4/12	9	618	3/4/11	9	11	3/4/12	8	101
3/5/12	45	1214	3/5/11	47	21	3/5/12	41	198
3/6/12	65	1357	3/6/11	68	24	3/6/12	59	222
3/7/12	54	1387	3/7/11	56	25	3/7/12	49	227
3/8/12	40	1283	3/8/11	42	23	3/8/12	36	210
3/9/12	46	1499	3/9/11	48	27	3/9/12	42	245
3/10/12	14	1049	3/10/11	15	19	3/10/12	13	171
3/11/12	43	1265	3/11/11	45	22	3/11/12	39	207
3/12/12	43	1265	3/12/11	45	22	3/12/12	39	207

3/13/12	34	1366	3/13/11	35	24	3/13/12	31	223
3/14/12	57	1423	3/14/11	59	25	3/14/12	52	232
3/15/12	75	1390	3/15/11	78	25	3/15/12	68	227
3/16/12	64	1514	3/16/11	67	27	3/16/12	58	247
3/17/12	20	1166	3/17/11	21	21	3/17/12	18	191
3/18/12	19	959	3/18/11	20	17	3/18/12	17	157
3/19/12	56	1309	3/19/11	58	23	3/19/12	51	214
3/20/12	38	1368	3/20/11	40	24	3/20/12	35	224
3/21/12	48	1384	3/21/11	50	24	3/21/12	44	226
3/22/12	39	1328	3/22/11	41	23	3/22/12	35	217
3/23/12	43	43	3/23/11	45	1	3/23/12	39	7
3/24/12	15	1119	3/24/11	16	20	3/24/12	14	183
3/25/12	11	852	3/25/11	11	15	3/25/12	10	139
3/26/12	53	1295	3/26/11	55	23	3/26/12	48	212
3/27/12	51	1402	3/27/11	53	25	3/27/12	46	229
3/28/12	67	1406	3/28/11	70	25	3/28/12	61	230
3/29/12	86	1417	3/29/11	89	25	3/29/12	78	232
3/30/12	74	1596	3/30/11	77	28	3/30/12	67	261
3/31/12	16	1072	3/31/11	17	19	3/31/12	15	175
4/1/12	14	898	4/1/11	15	16	4/1/12	13	147
4/2/12	71	1410	4/2/11	74	25	4/2/12	65	230
4/3/12	81	1495	4/3/11	84	26	4/3/12	74	244
4/4/12	61	1480	4/4/11	63	26	4/4/12	56	242
4/5/12	78	1456	4/5/11	81	26	4/5/12	71	238
4/6/12	66	1411	4/6/11	69	25	4/6/12	60	231
4/7/12	23	1014	4/7/11	24	18	4/7/12	21	166
4/8/12	12	993	4/8/11	12	18	4/8/12	11	162
4/9/12	43	1297	4/9/11	44	23	4/9/12	39	212
4/10/12	46	1389	4/10/11	48	25	4/10/12	42	227
4/11/12	49	1457	4/11/11	51	26	4/11/12	45	238
4/12/12	52	1386	4/12/11	54	25	4/12/12	47	226
4/13/12	33	1483	4/13/11	34	26	4/13/12	30	242
4/14/12	8	1059	4/14/11	8	19	4/14/12	7	173
4/15/12	10	883	4/15/11	10	16	4/15/12	9	144
4/16/12	37	1364	4/16/11	38	24	4/16/12	34	223
4/17/12	47	1451	4/17/11	49	26	4/17/12	43	237
4/18/12	42	1448	4/18/11	44	26	4/18/12	38	237
4/19/12	33	1335	4/19/11	34	24	4/19/12	30	218
4/20/12	62	1617	4/20/11	64	29	4/20/12	56	264
4/21/12	27	1089	4/21/11	28	19	4/21/12	25	178
4/22/12	20	890	4/22/11	21	16	4/22/12	18	145

4/23/12	76	1453	4/23/11	79	26	4/23/12	69	237
4/24/12	62	1443	4/24/11	64	26	4/24/12	56	236
4/25/12	60	1459	4/25/11	62	26	4/25/12	55	238
4/26/12	45	1464	4/26/11	47	26	4/26/12	41	239
4/27/12	58	1489	4/27/11	60	26	4/27/12	53	243
4/28/12	14	1068	4/28/11	15	19	4/28/12	13	174
4/29/12	7	844	4/29/11	7	15	4/29/12	6	138
4/30/12	47	1394	4/30/11	49	25	4/30/12	43	228
5/1/12	47	1426	5/1/11	49	25	5/1/12	43	233
5/2/12	62	1426	5/2/11	64	25	5/2/12	56	233
5/3/12	64	1447	5/3/11	67	26	5/3/12	58	236
5/4/12	58	1447	5/4/11	60	26	5/4/12	53	236
5/5/12	25	1192	5/5/11	26	21	5/5/12	23	195
5/6/12	10	848	5/6/11	10	15	5/6/12	9	139
5/7/12	55	1423	5/7/11	57	25	5/7/12	50	232
5/8/12	49	1369	5/8/11	51	24	5/8/12	45	224
5/9/12	90	1483	5/9/11	94	26	5/9/12	82	242
5/10/12	57	1548	5/10/11	59	27	5/10/12	52	253
5/11/12	51	1647	5/11/11	53	29	5/11/12	46	269
5/12/12	34	1376	5/12/11	35	24	5/12/12	31	225
5/13/12	13	1087	5/13/11	14	19	5/13/12	12	178
5/14/12	62	1483	5/14/11	64	26	5/14/12	56	242
5/15/12	39	1506	5/15/11	41	27	5/15/12	35	246
5/16/12	51	1575	5/16/11	53	28	5/16/12	46	257
5/17/12	91	1523	5/17/11	95	27	5/17/12	83	249
5/18/12	59	1704	5/18/11	61	30	5/18/12	54	278
5/19/12	24	1273	5/19/11	25	23	5/19/12	22	208
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5/21/12	63	1518	5/21/11	65	27	5/21/12	57	248
5/22/12	41	1439	5/22/11	43	25	5/22/12	37	235
5/23/12	54	1470	5/23/11	56	26	5/23/12	49	240
5/24/12	68	1543	5/24/11	71	27	5/24/12	62	252
5/25/12	73	1609	5/25/11	76	28	5/25/12	66	263
5/26/12	9	1301	5/26/11	9	23	5/26/12	8	213
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5/28/12	39	1041	5/28/11	41	18	5/28/12	35	170
5/29/12	56	1467	5/29/11	58	26	5/29/12	51	240
5/30/12	59	1610	5/30/11	61	28	5/30/12	54	263
5/31/12	35	1466	5/31/11	36	26	5/31/12	32	240
6/1/12	59	1712	6/1/11	61	30	6/1/12	54	280
6/2/12	22	1211	6/2/11	23	21	6/2/12	20	198

6/3/12	19	919	6/3/11	20	16	6/3/12	17	150
6/4/12	61	1511	6/4/11	63	27	6/4/12	56	247
6/5/12	60	1525	6/5/11	62	27	6/5/12	55	249
6/6/12	72	1567	6/6/11	75	28	6/6/12	66	256
6/7/12	55	1471	6/7/11	57	26	6/7/12	50	240
6/8/12	66	1690	6/8/11	69	30	6/8/12	60	276
6/9/12	22	1319	6/9/11	23	23	6/9/12	20	215
6/10/12	15	1033	6/10/11	16	18	6/10/12	14	169
6/11/12	44	1474	6/11/11	46	26	6/11/12	40	241
6/12/12	44	1418	6/12/11	46	25	6/12/12	40	232
6/13/12	72	1563	6/13/11	75	28	6/13/12	66	255
6/14/12	61	1536	6/14/11	63	27	6/14/12	56	251
6/15/12	75	1578	6/15/11	78	28	6/15/12	68	258
6/16/12	31	1103	6/16/11	32	20	6/16/12	28	180
6/17/12	23	952	6/17/11	24	17	6/17/12	21	156
6/18/12	66	1515	6/18/11	69	27	6/18/12	60	248
6/19/12	60	1534	6/19/11	62	27	6/19/12	55	251
6/20/12	65	1535	6/20/11	68	27	6/20/12	59	251
6/21/12	56	1526	6/21/11	58	27	6/21/12	51	249
6/22/12	95	1626	6/22/11	99	29	6/22/12	86	266
6/23/12	24	1166	6/23/11	25	21	6/23/12	22	191
6/24/12	29	1030	6/24/11	30	18	6/24/12	26	168
6/25/12	74	1598	6/25/11	77	28	6/25/12	67	261
6/26/12	59	1543	6/26/11	61	27	6/26/12	54	252
6/27/12	42	1577	6/27/11	44	28	6/27/12	38	258
6/28/12	62	1589	6/28/11	64	28	6/28/12	56	260
6/29/12	52	1523	6/29/11	54	27	6/29/12	47	249
6/30/12	15	1085	6/30/11	16	19	6/30/12	14	177
7/1/12	21	942	7/1/11	22	17	7/1/12	19	154
7/2/12	40	1398	7/2/11	42	25	7/2/12	36	228
7/3/12	68	1538	7/3/11	71	27	7/3/12	62	251
7/4/12	16	863	7/4/11	17	15	7/4/12	15	141
7/5/12	56	1466	7/5/11	58	26	7/5/12	51	240
7/6/12	38	1477	7/6/11	40	26	7/6/12	35	241
7/7/12	23	1261	7/7/11	24	22	7/7/12	21	206
7/8/12	18	1049	7/8/11	19	19	7/8/12	16	171
7/9/12	61	1415	7/9/11	63	25	7/9/12	56	231
7/10/12	51	1528	7/10/11	53	27	7/10/12	46	250
7/11/12	66	1567	7/11/11	69	28	7/11/12	60	256
7/12/12	51	1565	7/12/11	53	28	7/12/12	46	256
7/13/12	62	1538	7/13/11	64	27	7/13/12	56	251

7/14/12	12	1226	7/14/11	12	22	7/14/12	11	200
7/15/12	24	1021	7/15/11	25	18	7/15/12	22	167
7/16/12	61	1482	7/16/11	63	26	7/16/12	56	242
7/17/12	52	1405	7/17/11	54	25	7/17/12	47	230
7/18/12	43	1321	7/18/11	45	23	7/18/12	39	216
7/19/12	47	1452	7/19/11	49	26	7/19/12	43	237
7/20/12	54	1488	7/20/11	56	26	7/20/12	49	243
7/21/12	12	1192	7/21/11	12	21	7/21/12	11	195
7/22/12	22	958	7/22/11	23	17	7/22/12	20	157
7/23/12	74	1452	7/23/11	77	26	7/23/12	67	237
7/24/12	42	1369	7/24/11	44	24	7/24/12	38	224
7/25/12	52	1446	7/25/11	54	26	7/25/12	47	236
7/26/12	48	1500	7/26/11	50	27	7/26/12	44	245
7/27/12	77	1500	7/27/11	80	27	7/27/12	70	245
7/28/12	20	980	7/28/11	21	17	7/28/12	18	160
7/29/12	23	822	7/29/11	24	15	7/29/12	21	134
7/30/12	47	1288	7/30/11	49	23	7/30/12	43	210
7/31/12	54	1441	7/31/11	56	25	7/31/12	49	235
8/1/12	59	1414	8/1/11	61	25	8/1/12	54	231
8/2/12	61	1393	8/2/11	63	25	8/2/12	56	228
8/3/12	90	1474	8/3/11	94	26	8/3/12	82	241
8/4/12	17	1087	8/4/11	18	19	8/4/12	15	178
8/5/12	21	998	8/5/11	22	18	8/5/12	19	163
8/6/12	92	1435	8/6/11	96	25	8/6/12	84	234
8/7/12	97	1424	8/7/11	101	25	8/7/12	88	233
8/8/12	71	1387	8/8/11	74	25	8/8/12	65	227
8/9/12	116	1395	8/9/11	121	25	8/9/12	106	228
8/10/12	71	1556	8/10/11	74	28	8/10/12	65	254
8/11/12	28	1270	8/11/11	29	22	8/11/12	25	207
8/12/12	22	824	8/12/11	23	15	8/12/12	20	135
8/13/12	50	1525	8/13/11	52	27	8/13/12	45	249
8/14/12	74	1554	8/14/11	77	27	8/14/12	67	254
8/15/12	57	1507	8/15/11	59	27	8/15/12	52	246
8/16/12	66	1459	8/16/11	69	26	8/16/12	60	238
8/17/12	63	1596	8/17/11	65	28	8/17/12	57	261
8/18/12	22	1181	8/18/11	23	21	8/18/12	20	193
8/19/12	23	938	8/19/11	24	17	8/19/12	21	153
8/20/12	63	1449	8/20/11	65	26	8/20/12	57	237
8/21/12	57	1364	8/21/11	59	24	8/21/12	52	223
8/22/12	51	1499	8/22/11	53	27	8/22/12	46	245
8/23/12	60	1339	8/23/11	62	24	8/23/12	55	219

8/24/12	76	1517	8/24/11	79	27	8/24/12	69	248
8/25/12	21	1103	8/25/11	22	20	8/25/12	19	180
8/26/12	28	927	8/26/11	29	16	8/26/12	25	151
8/27/12	51	1375	8/27/11	53	24	8/27/12	46	225
8/28/12	64	1522	8/28/11	67	27	8/28/12	58	249
8/29/12	73	1503	8/29/11	76	27	8/29/12	66	246
8/30/12	58	1445	8/30/11	60	26	8/30/12	53	236
8/31/12	101	1725	8/31/11	105	31	8/31/12	92	282
9/1/12	24	1204	9/1/11	25	21	9/1/12	22	197
9/2/12	17	956	9/2/11	18	17	9/2/12	15	156
9/3/12	11	856	9/3/11	11	15	9/3/12	10	140
9/4/12	46	1499	9/4/11	48	27	9/4/12	42	245
9/5/12	62	1511	9/5/11	64	27	9/5/12	56	247
9/6/12	94	1396	9/6/11	98	25	9/6/12	86	228
9/7/12	75	1627	9/7/11	78	29	9/7/12	68	266
9/8/12	52	1067	9/8/11	54	19	9/8/12	47	174
9/9/12	24	909	9/9/11	25	16	9/9/12	22	149
9/10/12	73	1483	9/10/11	76	26	9/10/12	66	242
9/11/12	79	1538	9/11/11	82	27	9/11/12	72	251
9/12/12	79	1470	9/12/11	82	26	9/12/12	72	240
9/13/12	46	1490	9/13/11	48	26	9/13/12	42	243
9/14/12	123	1591	9/14/11	128	28	9/14/12	112	260
9/15/12	94	1202	9/15/11	98	21	9/15/12	86	196
9/16/12	66	1002	9/16/11	69	18	9/16/12	60	164
9/17/12	86	1414	9/17/11	89	25	9/17/12	78	231
9/18/12	145	1491	9/18/11	151	26	9/18/12	132	244
9/19/12	175	1577	9/19/11	182	28	9/19/12	159	258
9/20/12	164	1684	9/20/11	171	30	9/20/12	149	275
9/21/12	201	1589	9/21/11	209	28	9/21/12	183	260
9/22/12	144	1193	9/22/11	150	21	9/22/12	131	195
9/23/12	42	982	9/23/11	44	17	9/23/12	38	160
9/24/12	157	1615	9/24/11	163	29	9/24/12	143	264
9/25/12	178	1527	9/25/11	185	27	9/25/12	162	249
9/26/12	234	1584	9/26/11	243	28	9/26/12	213	259
9/27/12	163	1561	9/27/11	169	28	9/27/12	148	255
9/28/12	149	1759	9/28/11	155	31	9/28/12	136	287
9/29/12	86	1264	9/29/11	89	22	9/29/12	78	207
9/30/12	45	1012	9/30/11	47	18	9/30/12	41	165
10/1/12	173	1489	10/1/11	180	26	10/1/12	157	243
10/2/12	127	1520	10/2/11	132	27	10/2/12	116	248
10/3/12	123	1582	10/3/11	128	28	10/3/12	112	258

10/4/12	117	1405	10/4/11	122	25	10/4/12	106	230
10/5/12	97	1549	10/5/11	101	27	10/5/12	88	253
10/6/12	57	1198	10/6/11	59	21	10/6/12	52	196
10/7/12	46	898	10/7/11	48	16	10/7/12	42	147
10/8/12	97	1466	10/8/11	101	26	10/8/12	88	240
10/9/12	74	1498	10/9/11	77	26	10/9/12	67	245
10/10/12	165	1527	10/10/11	172	27	10/10/12	150	249
10/11/12	69	1511	10/11/11	72	27	10/11/12	63	247
10/12/12	115	1557	10/12/11	120	28	10/12/12	105	254
10/13/12	15	1003	10/13/11	16	18	10/13/12	14	164
10/14/12	10	850	10/14/11	10	15	10/14/12	9	139
10/15/12	184	1459	10/15/11	191	26	10/15/12	167	238
10/16/12	197	1443	10/16/11	205	26	10/16/12	179	236
10/17/12	200	1492	10/17/11	208	26	10/17/12	182	244
10/18/12	188	1396	10/18/11	195	25	10/18/12	171	228
10/19/12	178	1671	10/19/11	185	30	10/19/12	162	273
10/20/12	16	1029	10/20/11	17	18	10/20/12	15	168
10/21/12	15	882	10/21/11	16	16	10/21/12	14	144
10/22/12	206	1472	10/22/11	214	26	10/22/12	187	240
10/23/12	178	1377	10/23/11	185	24	10/23/12	162	225
10/24/12	232	1386	10/24/11	241	25	10/24/12	211	226
10/25/12	155	1392	10/25/11	161	25	10/25/12	141	227
10/26/12	179	1578	10/26/11	186	28	10/26/12	163	258
10/27/12	13	1115	10/27/11	14	20	10/27/12	12	182
10/28/12	11	954	10/28/11	11	17	10/28/12	10	156
10/29/12	188	1454	10/29/11	195	26	10/29/12	171	238
10/30/12	60	1503	10/30/11	62	27	10/30/12	55	246
10/31/12	71	1501	10/31/11	74	27	10/31/12	65	245
11/1/12	71	1488	11/1/11	74	26	11/1/12	65	243
11/2/12	94	1649	11/2/11	98	29	11/2/12	86	269
11/3/12	25	1143	11/3/11	26	20	11/3/12	23	187
11/4/12	51	1314	11/4/11	53	23	11/4/12	46	215
11/5/12	92	1411	11/5/11	96	25	11/5/12	84	231
11/6/12	67	1349	11/6/11	70	24	11/6/12	61	220
11/7/12	102	1502	11/7/11	106	27	11/7/12	93	245
11/8/12	87	1542	11/8/11	90	27	11/8/12	79	252
11/9/12	68	1624	11/9/11	71	29	11/9/12	62	265
11/10/12	44	1155	11/10/11	46	20	11/10/12	40	189
11/11/12	10	769	11/11/11	10	14	11/11/12	9	126
11/12/12	47	1244	11/12/11	49	22	11/12/12	43	203
11/13/12	78	1435	11/13/11	81	25	11/13/12	71	234

11/14/12	70	1469	11/14/11	73	26	11/14/12	64	240
11/15/12	38	1426	11/15/11	40	25	11/15/12	35	233
11/16/12	52	1559	11/16/11	54	28	11/16/12	47	255
11/17/12	12	1014	11/17/11	12	18	11/17/12	11	166
11/18/12	13	840	11/18/11	14	15	11/18/12	12	137
11/19/12	61	1371	11/19/11	63	24	11/19/12	56	224
11/20/12	55	1453	11/20/11	57	26	11/20/12	50	237
11/21/12	62	1536	11/21/11	64	27	11/21/12	56	251
11/22/12	9	1001	11/22/11	9	18	11/22/12	8	164
11/23/12	22	1117	11/23/11	23	20	11/23/12	20	182
11/24/12	18	1040	11/24/11	19	18	11/24/12	16	170
11/25/12	6	895	11/25/11	6	16	11/25/12	5	146
11/26/12	70	1325	11/26/11	73	23	11/26/12	64	216
11/27/12	47	1307	11/27/11	49	23	11/27/12	43	214
11/28/12	45	1424	11/28/11	47	25	11/28/12	41	233
11/29/12	67	1486	11/29/11	70	26	11/29/12	61	243
11/30/12	50	1541	11/30/11	52	27	11/30/12	45	252
12/1/12	15	1057	12/1/11	16	19	12/1/12	14	173
12/2/12	19	880	12/2/11	20	16	12/2/12	17	144
12/3/12	48	1412	12/3/11	50	25	12/3/12	44	231
12/4/12	49	1389	12/4/11	51	25	12/4/12	45	227
12/5/12	78	1456	12/5/11	81	26	12/5/12	71	238
12/6/12	52	1454	12/6/11	54	26	12/6/12	47	238
12/7/12	50	1672	12/7/11	52	30	12/7/12	45	273
12/8/12	19	1083	12/8/11	20	19	12/8/12	17	177
12/9/12	8	751	12/9/11	8	13	12/9/12	7	123
12/10/12	40	1304	12/10/11	42	23	12/10/12	36	213
12/11/12	59	1419	12/11/11	61	25	12/11/12	54	232
12/12/12	71	1539	12/12/11	74	27	12/12/12	65	251
12/13/12	60	1456	12/13/11	62	26	12/13/12	55	238
12/14/12	95	1582	12/14/11	99	28	12/14/12	86	258
12/15/12	11	1076	12/15/11	11	19	12/15/12	10	176
12/16/12	10	792	12/16/11	10	14	12/16/12	9	129
12/17/12	80	1347	12/17/11	83	24	12/17/12	73	220
12/18/12	85	1332	12/18/11	88	24	12/18/12	77	218
12/19/12	79	1385	12/19/11	82	24	12/19/12	72	226
12/20/12	3	280	12/20/11	3	5	12/20/12	3	46
12/21/12	33	1112	12/21/11	34	20	12/21/12	30	182
12/22/12	6	1024	12/22/11	6	18	12/22/12	5	167
12/23/12	5	807	12/23/11	5	14	12/23/12	5	132
12/24/12	13	946	12/24/11	14	17	12/24/12	12	155

12/25/12	5	698	12/25/11	5	12	12/25/12	5	114
12/26/12	61	1269	12/26/11	63	22	12/26/12	56	207
12/27/12	69	1235	12/27/11	72	22	12/27/12	63	202
12/28/12	39	1235	12/28/11	41	22	12/28/12	35	202
12/29/12	15	911	12/29/11	16	16	12/29/12	14	149
12/30/12	6	780	12/30/11	6	14	12/30/12	5	127
12/31/12	28	1141	12/31/11	29	20	12/31/12	25	186
Total	20110	468855		20908	8292	29200	18298	76602