NEW MEXICO DEPARTMENT OF TRANSPORTATION

RESEARCH BUREAU

Innovation in Transportation

Road Lifecycle Innovative Financing (Road LIFE) 2010

Prepared by:
Department of Civil Engineering
The University of New Mexico
Albuquerque, NM 87131

Prepared for:
New Mexico Department of Transportation
Research Bureau
7500B Pan American Freeway NE
Albuquerque, NM 87109

In Cooperation with:
The US Department of Transportation
Federal Highway Administration

Report NM08ADM-01

JULY 2010

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NM08ADM-01		

4. Title and Subtitle	5. Report Date
Road Lifecycle Innovative Financing Evaluation (RoadLIFE)	July 2010
	6. Performing Organization Code 456A
7. Author J. Hall, G. Migliaccio, R. Tarefder, S. Ghorai	8. Performing Organization Report No. 456-02
9. Performing Organization Name and Address Department of Civil Engineering MSC01 1070, University of New Mexico Albuquerque, NM 87131	10. Work Unit No. (TRAIS) 11. Contract No.
12. Sponsoring Agency Name and Address Research Bureau NM Department of Transportation 7500B Pan American Freeway Albuquerque, NM 87199-4690	13. Report Type and Period Covered Final Report February 2008-March 2010 14. Sponsoring Agency Code

15. Supplementary Notes None.

16. Abstract

This report is organized into five sections and nine chapters, and includes a set of appendices containing supporting information and the results of data collection and analysis. The second section of the report summarizes the state of practice of some disciplines related to the RoadLIFE study: project delivery, project financing, and life cycle cost analysis for highway projects. The third section summarizes the consequences of the US 550 reconstruction, specifically an analysis of the impact of innovative procedures on project performance, an evaluation of the road user benefits of the US 550 improvements in terms of travel time savings, vehicle operating costs, and highway safety, and an assessment of the economic development in the Four Corners area that may be attributable to the reconstructed four-lane highway. The fourth section provides instruction on how to use the research products developed in this project. The supplements to this report include a CD containing the warrant tracking software and a PowerPoint presentation describing the research procedure and findings.

17. Key Words	18. Distribution Statement
Alternative project delivery, Economic development impact, Innovative financing, Life cycle cost analysis, Road user benefits	Available from the NMDOT Research Bureau.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	97	

Form DOT F 1700.7

PREFACE

The research reported herein reviews information related to the US 550 project to provide an assessment of the innovations used in this project that could be used for providing guidance for future warranty projects.

NOTICE

The United States government and the State of New Mexico do not endorse products or manufacturers. Trade or manufactures' names appear herein solely because they are considered essential to the object of this report. This information is available in alternative accessible formats. To obtain an alternative format, contact the NMDOT Research Bureau, 7500B Pan American Freeway NE, PO Box 94690, Albuquerque, NM 87199-4690, (505)-841-9145

DISCLAIMER

This report presents the results of research conducted by the authors and does not necessarily reflect the views of the New Mexico Department of Transportation. This report does not constitute a standard or specification.

EXECUTIVE SUMMARY

US 550 in New Mexico, between mileposts 24 and 142 (formerly NM 44), was reconstructed from a two-lane highway to a four-lane roadway with a median during the three-year period 1999-2001. The project, which incorporated innovative funding and contracting methods, also included warranties on the pavement and structures. The expected benefits of completing this project in a timely manner were reduction in travel time, improved highway safety, and enhanced economic development in the Four Corners area of northwest New Mexico. This research project evaluated the funding and contracting methods, assessed the project's benefits, and developed a tool for tracking the warranties.

The US 550 project was delivered with an innovative delivery method. Under the selected approach, a single private entity contracted to deliver design services (including bid package preparation), construction management services, and quality assurance services. In addition, this entity extended its control through the operation and maintenance of the roadway with warranties on pavements and structures. Because most of the individuals involved with project delivery were not affiliated with or have left the NMDOT, the research team relied on voluntary participation by the individuals contacted during the study. Although the response was low, a comparison of US 550's project delivery approach and current industry practices highlighted issues with this new approach. The project's uniqueness made it impossible to find comparable projects. However, individual US 550 innovations were analyzed and compared with current industry practice. This evaluation found that the approach followed in some of the US 550 innovations is contrary to the recommendations on warranty contracting and quality management of innovative contracting projects. These recommendations, published in TRB reports, could benefit the NMDOT if similar innovations are considered for future projects.

A motorist driving the 116 miles of reconstructed US 550 at the currently posted speed limit of 70 mph would save 0.27 h, or about 16 miles, versus the pre-construction conditions. In 2007, reported traffic volume along the corridor ranged from a low of 2,700 vpd near milepost 86 to 13,900 near milepost 124. The weighted average volume for the entire route was 6,234 vpd. Three categories of road users were used to calculate a monetary unit value of time saved. The annual travel time benefit for 2007 is estimated to be $9.4 million. The smoother speed of operation facilitated by a four-lane roadway is counterbalanced by the extra fuel consumption associated with higher travel speeds; as a result, the vehicle operating cost benefit is expected to be negligible. Average annual crash experience along the corridor increased from 85 in the *before* period to 116 in the *after* period. However, due to the growth in annual travel, the crash rate has decreased. If there had been a growth in traffic without an improvement to US 550, it is likely that the crash rate would have actually increased. On the positive side, the portion of crashes involving fatalities and injuries decreased in the *after* period. The expected cost of a crash decreased by approximately 15% after the reconstruction.

One of the primary justifications for improving US 550 was the potential for economic development in the Four Corners area. San Juan County is the fourth most populous county in New Mexico. Among the state's twelve most populous counties, San Juan was the only one that was not connected to the rest of the state by either an Interstate highway or four-lane roadway. Since 1970, the population in San Juan County has grown at a faster rate than the rest of New

Mexico; the growth was particularly evident in the years immediately following the opening of US 550 in December 2001. Employment in the Farmington-Aztec-Bloomfield area has grown at a rate of 2.6% per year since the roadway was completed. The area's 2008 unemployment rate was 3.7%, certainly a favorable rate considering the economy. Average salaries in the county were also good, reflecting the decent paying jobs in the mining and oil/gas sectors. The San Juan Economic Development Service reports that the number of business establishments in the area increased between 2001 and 2004. The Dillion Industrial Park in Aztec is one success story; it has added four significant employers with a total of 350 new jobs. Heavy commercial truck traffic, as reflected by the annual number of Class 9 Equivalent Single Axle Loads (ESALs), had an increasing trend over the period 2003-2008; however, the reported number of Class 9 ESALs dropped further in 2009, with the result that the trend for 2003 to 2009 is negative.

Cost data provided by the NMDOT were used to develop US 550 Warranty Tracking Software, which is provided on a CD as a project deliverable. This US 550-specific application allows NMDOT staff to track warranty transactions. In addition, the application includes a Life Cycle Cost Analysis module, which can calculate the current Net Present Value (NPV) and compare it with the NPV predicted before construction. This project also provides a users guide for using this application. Actual US 550 costs are compared with the predicted costs in the tracking software.

TABLE OF CONTENTS

SECTION I: STUDY BACKGROUND

CHAPTER 1: INTRODUCTION

1.1 Overview

The Road Lifecycle Innovative Financing Evaluation (Road LIFE) study aims at evaluating the benefits of the innovations implemented in the NM44/US550 highway project. Under an agreement between state and federal officials, the New Mexico Department of Transportation (NMDOT) contracted with the University of New Mexico to conduct research on some of the innovative features used on the project, including (1) the purchase of warranties, (2) the procurement of management services of the contractor, (3) the use of an innovative financing approach, and (4) the consolidation of the project in four segments. These US 550 innovative features can be differentiated under innovations in Project Delivery (innovations 1 & 2) and innovations in Project Financing (innovations 3 & 4).

US 550 is a 118-mile road that was upgraded from a two-lane highway to a four-lane highway over a period of three years from 1999 to 2001. In this project, NMDOT has contracted out several services that they would have traditionally self-performed: design (and design management), construction management and long-term pavement management. These services were procured for the project by an external entity, Mesa PDC, which has contributed to both the delivery of the project and the management of maintenance by operating under a set of contracts (i.e., professional services, pavement warranty, and structure warranty). While construction bid packages were also prepared by Mesa PDC, procurement of construction was done separately under the traditional low-bid system administered by the NMDOT.

By using a professional services contract to contract out design and construction management, the NMDOT tried to gain many of the efficiencies found in design-build projects – flexibility, quicker construction, cost savings, and streamlined decision making. Mesa PDC in turn subcontracted the design component to CH2M Hill and the construction management and construction quality assurance services to Flatiron Structures. The flexibility in design and construction management granted to Mesa PDC was balanced by a requirement in the professional services contract that Mesa PDC guarantee the quality of the pavement condition over time. All warranties are listed in Section 12 (PDC Warranties) of the contract. As mentioned in Section 3.1 of the agreement, the PDC shall provide Professional Services as mentioned in Exhibit “A” duly meeting the performance criteria and the guarantee provisions documented in Exhibit E (Pavement Warranty) and Exhibit F (Structures Warranty) of the contract. This guarantee took the form of a 20-year, long-term, fixed price performance-based rehabilitation and reconstruction agreement covered by a $114-million ($110 million for pavement and $4 million for structures) performance bond to the warranty as mentioned in Section 11.7.2 (Warranty Price Payment).

This report is organized into five sections and nine chapters and includes a set of appendices containing supporting information and results of data collection and analysis.

- Section I includes **Chapter 1** as introduction to the report.

- Section II includes three chapters that summarize the state of practice of some of the disciplines related to the Road LIFE study: **Chapter 2** provides a review of the state of practice in Project Delivery; **Chapter 3** provides a review of the state of practice in Project Financing; **Chapter 4** reviews previous applications of Life Cycle Cost Analysis (LCCA) for highway projects.
- Section III includes three chapters that summarize salient information on the US 550 project: **Chapter 5** provides background information on the US 550 project and evaluates the impact of innovative procedures on the project performance; **Chapter 6** evaluates benefits of US 550 road improvements in terms of safety, vehicle operating costs, travel time and maintenance; **Chapter 7** evaluates economic and development impacts resulting from improving access to the communities along US 550.
- Section IV includes instructions on how to use the research products that are included on the enclosed CD: **Chapter 8** includes instructions for using the Warranty Computer Model; **Chapter 9** includes instructions for using the LCCA model.

1.2 Background

Pavement warranty is an innovative contracting procedure intended to protect agencies' investment in transportation infrastructures. A warranty is an assurance that a roadway will serve its useful life; if it does not, the warranty provider will fix the problems and pay to return it to its proper condition. Instead of highway agencies, the warranty providers (usually contractors) guarantee the post-construction performance of the pavement and related structures. The shifting of post-construction performance risk from the state highway agency to the warranty provider is perceived to reduce premature pavement failures, reduce costs, and increase pavement quality. The contractors assume both construction and post-construction performance risk. In return, they charge additional warranty cost for the projects, enjoy more freedom to select materials and construction methods, and use their knowledge and experience without the restrictions inherent in methods-based specifications and innovations. The highway agencies such as state DOTs may benefit from reducing the amount of DOT resources required on a highway project, shifting performance risk, encouraging contractor innovation, improving the quality of constructed products, and ultimately reducing the life-cycle cost of highway projects. However, the cost of highway construction warranties has emerged as an issue with the implementation of this contracting method (*1*).

To date, only a limited number of warranty contracts have been implemented by DOTs in the United States. There are several reasons for that. For example, if a claim happens and the warranty cost cannot cover the liability, the contractors would have a serious financial problem. Alternatively, overestimation of warranty cost could make the bid less competitive. Some states that use pavement warranties have reported a reduction in costs and an improvement in quality, while others have not. Evaluating the warranty is difficult due to factors such as uncertainty in potential cost, pavement deterioration process, performance failures, rehabilitation cost, data availability and systematic evaluation. There is a need for research to examine the use of pavement warranties by state highway agencies in order to understand the impact of pavement warranties and develop guidelines to assist state highway agencies in determining when to use warranties and how to apply them efficiently. It is within these contexts that the study proposed herein will evaluate the US 550 warranty project in New Mexico (*1*).

1.3 Research Objectives

Objective 1: Develop Decision Model to Analyze US 550 Innovations

Develop a decision model to analyze the various innovative procedures (i.e., purchase of a pavement warranty, consolidation of the project in four segments, and procurement of project management services from contractors) that were used by NMDOT in completing US 550. Determine the impacts of these procedures on the project performance (i.e., cost, schedule and quality) to facilitate the decision to include some of these procedures on future projects.

Synopsis of Objective 1 Results The initial plan to achieve this objective has been changed to adapt for research challenges. As described in various quarterly reports, the research team was unsuccessful in securing the collaboration by project parties. While a list of potential participants was identified early on in collaboration with the NMDOT project panel, most of these individuals are not associated with the project anymore. Contact information was obtained only for few individuals and some of them declined the invitation to participate. A copy of the invitation is included in the Appendices. To provide an evaluation of the US 550 innovative features, the research team in agreement with the NMDOT panel decided to use the information from the two interviews jointly with an extensive literature review assessing the state of practice. Therefore, US 550 innovations are compared against the current state of practice. Chapters 2 & 3 summarize the state of practice whereas the analysis of the information collected is provided in Chapter 5.

Objective 2: Evaluate US 550 Benefits

Evaluate benefits of US 550 road improvements in terms of safety, vehicle operating costs, travel time and maintenance. Focus on evaluating costs and benefits for widening the road to four lanes.

Synopsis of Objective 2 Results Results and recommendations are provided at the end of Chapter 5.

Objective 3: Evaluate US 550 Economic and Development Impact

Evaluate economic and development impacts resulting from improving access to the communities along US 550. Identify who benefits from these impacts.

Synopsis of Objective 3 Results Findings, results and recommendations are provided at the end of Chapter 6.

Objective 4: Develop US 550 LCCA Model

Develop a life cycle cost analysis (LCCA) model of the US 550 project. Develop an LCCA model that can be used to input data on cost and benefits for the remainder of the warranty.

Synopsis of Objective 4 Results An LCCA model has been developed and included as a module for a Microsoft Access application that is designed to track warranty transactions. While the model does not contain all the data necessary to run a complete analysis, it is ready to be used as soon as the NMDOT is able to obtain data of various types (e.g., user daily cost).

1.4 Overview of the Research Methodology

In this section, we explain how the research plan meets the objectives stated above by addressing each task. The four tasks are grouped in two phases as follows:

- Phase No.1: Development of Life Cycle Cost Analysis elements
- Phase No.2: Compilation of components into LCCA model

1.5 List of Tasks by Phase

Phase I: Development of Life Cycle Cost Analysis Elements

This phase includes three tasks to be carried out during the initial twelve months of the expected contract time of eighteen months. The outcomes of this initial phase will be a warranty computer model, an evaluation of the US 550 road improvement, and an assessment of economic and development impacts resulting from improving access to the communities along US 550. These studies will be tied into the LCCA model.

- Task 1: Warranty Study and Innovation Assessment
- Task 2: Travel Benefit Evaluation
- Task 3: Economic Development Impact

Phase II: Compilation of components into LCCA model

- Task 4: Life Cycle Cost Analysis Model

SECTION II: STATE OF PRACTICE

An extensive literature review has been performed by the research team to identify all the potentially applicable knowledge and to provide an accurate snapshot of the current state of practice. This section includes the literature review, which is divided in three themes. Each theme is explored in a separate chapter.

Chapter 2 (Project Delivery in Highway Projects) summarizes the state of practice of project delivery in the highway sector. This chapter provides background information for comparing the delivery of US 550 with the state of practice. In addition, a section of this chapter summarizes innovative delivery in other sectors (e.g., building, industrial, etc.). Two innovations implemented in the US 550 delivery relate to the content of this chapter: (i) Procurement of Construction Management (CM) services, and (ii) Procurement of a long-term warranty on pavement and structures. The research team is aware that NMDOT believed that these innovations were unique to the US highway sector. However, a comparison of the US 550 delivery approach with the advance of knowledge on alternative project delivery will be used to make recommendations for the delivery of future projects by the NMDOT.

Chapter 3 (Financing in Highway Projects) summarizes the state of practice of project financing in the highway sector. This chapter provides background information for comparing the financing of US 550 with the state of practice. Two innovations implemented in the US 550 financing relate to the content of this chapter: (i) Use of Grant Anticipation Revenue Vehicles (GARVEE), and (ii) Consolidation of project construction into four segments.

Chapter 4 (Life Cycle Cost Analysis) summarizes previous uses of LCCA for highway projects.

CHAPTER 2: DELIVERY OF HIGHWAY PROJECTS

2.1 Traditional Project Delivery

Design-Bid-Build (DBB) is the method traditionally used for delivering highway projects. Here the owner enters into separate contracts with the providers of design and the construction services. At first, the project is designed by qualified engineer (architect for building and landscaping projects) and the project cost is estimated on a unit price basis. After the design is reviewed by the owner, the project is bid out in the market and request for proposals from prospective contractors are solicited on a lump sum or unit price basis. This is followed by bid appraisal and handing over the project to the contractor with lowest responsive bid (*2*).

In this traditional system the contractors are allocated a lesser amount of risk, as they have to build the project according to the plans and specifications that are "certified" by the owner. The owner on the other hand, can fund the project with a favorable price as the competition among the contractors produces the lowest possible cost for the project (*3*).

Despite the conventional nature of the traditional project delivery, there are many limitations. As the construction process cannot start before the completion of the design, the whole system becomes slow and thus is not suitable for expedited delivery projects. In addition, the "over-the-wall" contractual framework hinders the implementation of advanced Life Cycle Cost Analysis concepts. As the specifications are already stipulated by the owner, there is not much scope for innovation, as the contractor does not have any risk related to quality, performance or maintenance on them. Contractors' input being hardly present in the design phase sometimes results in unrealistic design and gives rise to change order issues (*2*). Besides, the traditional system requires sufficient provision of in-house resources, which is difficult during the period of economic recession, job cuts and hiring freezes. Over the last decades, the highway industry has realized the need to overcome these drawbacks. As a result, several alternative project delivery (APD) approaches have been tried throughout the U.S. The US 550 project is one of these projects that experimented with unusual ways to deliver a project.

2.2 Alternative Project Delivery in Highway Projects

Any project delivery other than traditional contracting methods can be termed as an Alternative Project Delivery (APD). In the following sections, APD concepts will be described, and a state of practice in APD will be offered. First, an analysis of trends in the delivery of U.S. infrastructure projects is provided. Later, specific APD methods will be discussed within the context of highway projects.

Note: While the majority of APD methods can be classified under the category of integrated delivery methods (i.e., delivery of multiple services grouped under fewer contracts), the APD term is used throughout this report to broaden the concepts under analysis.

Trends in the Delivery of U.S. Infrastructure Projects (Adapted from 4)

While APD methods were used for centuries to delivery projects, their use was limited and almost abolished in the initial part of the last century to facilitate the use of the design-bid-build approach. Several studies analyzed the reasons underlying the institutionalization of DBB to become the "traditional" and preferred approach for delivering facilities in the U.S. and Europe.

In the United States, the infrastructure sector, which includes roads, bridges, mass transit, airports, electric power generation, water supply and wastewater management facilities, has experienced a number of shifts in the preferred project delivery approach over the last century. This sector of the construction industry includes several owners that are currently changing project delivery strategy by broadening their delivery options. Therefore, opportunities to investigate implementation of a change in project delivery strategy are available.

Until the end of the 19th century, integrated delivery of design, construction, and long-term operations was mandated and facilitated largely by state statutes. As most important instances of projects using integrated delivery, one reference cited the development of the transcontinental railroad and telegraph, the construction of power generation plants, and the Brooklyn Bridge delivery. Moreover, the fact that design professionals were not organized in strong professional organizations allowed for an environment in which designers were subordinate to constructors (*5*). These factors, among others, led to a wide application of integrated delivery methods.

By the end of the 19th century, however, certain historical developments produced a push to segregate design and construction activities. First, design-oriented professionals organized themselves into professional societies, such as the American Society of Civil Engineers and the American Institute of Architects. These groups' interests were supported by growing public concern over the quality of construction-directed design activities. As a result, de-coupling the procurement of design and construction services was first allowed by the U.S. Congress in 1893; however, the infrastructure sector's use of this split delivery method was not fully assumed until passage of the Federal Aid Road Act in 1916 (*5*, *6*). With the passage ten years later of the Public Buildings Act, the federal government required for the first time that design and construction services be procured separately.

Subsequently, the Great Depression "eclipsed [both] the private funding of public projects and the use of the combined project delivery methods" (*5*, p.428). Thus, the government's preference for using segmented approaches to delivering projects increased through World War II. This shift was later reaffirmed in both the 1956 Federal Aid Highway Act (*6*) and the 1972 Brooks Act, each furthering the separation of design and construction procurement activities (*5*). As a result of this sequence of events, governmental agencies developed their project delivery strategies around the low-bid procurement approach of a single delivery method, the Design-Bid-Build (DBB) method. In the transportation sector, after decades of continuous use, this method has become the institutionalized standard for delivering public infrastructure projects.

The infrastructure sector is recently reencountering the issues surrounding delivery strategy change; the sector-wide standard for delivering projects, the DBB method, is experiencing a deinstitutionalization. According to Oliver (*7*), "deinstitutionalization refers to the delegitimation of an established organizational practice … as a result of organizational challenges to or the failure of organizations to reproduce previously legitimated or taken-for-granted organizational actions" (p.564). In response to both an increasing demand for new capacity and for minimizing the impact of construction on motorists, the transportation sector has been questioning the ability of a project delivery strategy that is based solely on one delivery method. Several studies have shown the poor performance of this method in terms of schedule (i.e., overall duration and schedule certainty) when compared with other methods (*8*-*12*). Over recent years, these concerns have generated a reduction of legal, regulatory, and practical impediments to integrated delivery methods for delivering new infrastructure projects (*13-14*).

As a result of this deregulation, the transportation project sector is observing an increased usage of alternative project delivery methods. Among the many emerging delivery method options, the Design-Build (DB) approach has become one of the most popular alternatives. In 1990, the Federal Highway Administration (FHWA) initiated a special experimental program (SEP-14—Innovative Contracting) to enable DOTs to test and evaluate this delivery method along with a few others. The purpose of this program was to identify alternatives to the DBB delivery method that "provided the potential to expedite highway projects in a more cost-effective manner, without jeopardizing product quality or contractor profitability" (*12*, pp. I-2). Recently, FHWA published a report summarizing the findings and lessons learned from the SEP-14 program. This report not only acknowledged the effectiveness of the DB method in shortening project delivery time, but it also concluded that agencies could pursue alternative financing paths as a direct result of this schedule benefit (*12*).

Reintroduction of Alternative Project Delivery for Delivering U.S. Highway Projects

One of the major reasons for using APD is to guarantee a faster completion of projects, especially in areas having heavy traffic congestion. Thus, APD can help in reducing the cost overruns due to schedule delay and change orders. In addition, APD potentially encourages contractor-induced innovation. In fact, under APD, contractors have more freedom for selecting materials and methods. Therefore, contractors are able to introduce modern technology and techniques to improve the quality of the project, and/or to deliver the project in less time. All these factors together contribute to the benefits of the public by enhancing the quality of living (*3*).

European countries first reintroduced APD in the infrastructure sector. This has been facilitated by the business and institutional environment that allows public-private partnerships to develop, deliver, and operate infrastructure projects. Only in the mid 1980s, FHWA started to study European practices for implementing APD in public funded projects. The initial efforts focused on the formation of research teams and the conduction of information tours for construction industry representatives (*3*). For example, task forces visited several countries in Europe in 1993 for a quality enhancement study by understanding the European Contract Administration Techniques. Several other tours were conducted by the asphalt concrete pavement specialists in 1990s to get exposure to the advanced technology used (*2*). In 1990, after a decade-long discussion, the FHWA decided to experiment with four APDs through "Special Experiment Projects" (SEP). There were two SEPs authorized by the US Department of Transportation (USDOT) i.e. SEP-14 and SEP-15. SEP-14 focused on the implementation of innovative contracting approaches and SEP-15 dealt with Public/Private Partnership (PPP). The APD methods used in the SEP-14 projects were "Design-Build", "Cost-Plus Time (A+B) bidding," "Warranty," and "Lane Rental" (*15*).

Design Build

In Design Build (DB) delivery, the public agency has a single contract with the company that is in charge of both design and construction. There are various types of DB contracts such as Design-Build-Operate-Maintain, Design-Build-Finance-Operate, Design-Build-Operate-Transfer, and Design-Build-Operate-Maintain-Warrant (*16*).

The Utah T2 Center has further categorized the DB projects depending on the scope and extent of the project. They are Low-End DB Projects (LEDB), Mid-Level DB Projects (MLDB) and Mega DB Projects (MDBP). LEDB are small projects that have time constrains and strict deadlines. The scope generally involves routine construction or reconstruction. As the project is small, there are fewer chances for innovation; but the DB option can be very useful for project acceleration as well as attaining the provisions of warranty after construction. MLDB are projects where the owners do not have sufficient in-house ability to implement advanced techniques and new technology. Thus, they hand it over to a single entity, often as a turnkey contract to utilize the expertise from the private sector. A warranty option is generally present in MLDB projects, so that the contractors are really serious in implementing innovations for their own benefit. The Design-Builder (i.e., DB contractor) is usually selected using a procurement method based on Best Value. Contract documents are really important for these types of projects. If not written properly, the contracts may give rise to dispute which cost both money and time. MLDB projects generally consist of bridge reconstruction and projects involving high inducement for innovative design and construction. MDBP are the projects which due to scope and budget and time constraints cannot be executed using traditional project delivery. The projects are generally large, extensive, and complex and have certain time limitations (*73*).

Advantages of Design Build In DB delivery, the major benefit is that the designer and the contractor can work together. Thus, the contractor can participate during the design phase and can monitor and rule out anything in design that may not be possible or convenient to build. In other words, the constructor can communicate their point of view efficiently to the designer, thus considerably reducing the chances of change orders. Here, construction and design phases can overlap and construction can commence even when design is only 50% complete. This facilitates the shortening of project schedule. Moreover, the owner only has a single point of responsibility and has fewer headaches (*15*).

Disadvantages of Design Build Some of the major barriers to DB are the legal restrictions and statutory policies for implementing the DB method in public projects in many states. For example, projects were previously required to go through the National Environmental Policy Act (NEPA) process prior to preliminary engineering and handing over the project. This considerably slowed down the process and defeated the purpose of implementing DB. Later in mid 2006, this act was amended and DB projects can commence before the completion of NEPA formalities (*15*). Another potential drawback may be the decrease of the owner’s control over the project. Chances of compromising the quality, in order to keep pace with the short project schedule, cannot be ruled out (*17*).

Cost-Plus-Time (A+B Bidding)

Using a Cost-Plus-Time approach when selecting a contractor for a project means that the agency will use as criteria for the decision both the initial cost of construction and the time required for completing the project. The time involved is converted into its corresponding dollar value by calculating the user cost, which is obtained by multiplying the user cost rate per day with the number of days of construction. Thus, this type of contract is often referred to as A+B Bidding or multi-parameter bidding. If the agency wants to encourage an early completion, A+B bidding is often used together with an incentive/disincentive (I/D) option. I/Ds are generally levied for projects having heavy moving traffic, lane closures and traffic restrictions where the user delay cost (UDC) may accrue with the time of construction (*18*). A+ B Bidding with I/D is, therefore, used for rehabilitation and reconstruction of projects already in use, to enhance safety on the construction site and to reduce the effect of construction on the community (ICBPG).

Advantages of A+B Bidding One of the obvious advantages is a reduction of project execution time, which can be augmented by the presence of the I/D option. This may lead to enhancement of quality due to the innovative techniques used by the contractor to meet the deadline (3).

Disadvantages of A+B Bidding Many contractors may drop out of the bidding procedure because they may not have sufficient resources to speed up the project schedule. Moreover, the state agency has to provide inspection and testing personnel for additional hours of work performed by the construction company (*3*).

Lane Rental

In this type of contract the contractor is charged according to the time spent for construction activities in the traffic lanes. This is mainly intended to accelerate the construction in places where traffic volume is high. The rates depend on the specific time and the amount of traffic volume in the place. The amount to be charged can be calculated from the UDC, which is affected considerably by the extent of impact on the public. Some of the common types of lane rentals used are lane-by-lane rental, continuous site rental and bonus/rental charge method. The lane-by-lane rental charges the contractor on the basis of the number of lanes occupied at a time for construction. Continuous site rental charges the contractor on a day to day basis. Bonus/rental charge considers the cost of construction as well as the cost of time for which the contractor occupies the lane or shoulder. These types of contracts are useful where the traffic cannot be stopped completely and diversions may not be economical (*3*).

Advantages of Lane Rental Lane rental helps in reducing the project time and in minimizing the impact on public, by allowing the contractor to work during suitable hours of traffic. On the other hand the contractors have to be really efficient in performing work, as the time available is restricted. Thus, lane rental facilitates the overall growth of economy (*3*).

Disadvantages of Lane Rental The only disadvantage may be the lack of knowledge and experience of a majority of the contractors about this particular delivery method (*3*).

The legal framework of the state where the transportation project is being considered significantly affects the choice of PDS. Traditional design-bid-build is the only choice for many states where ADP is not allowed. Even if they are allowed, their level of authorization may vary such as (1) fully authorized, (2) authorized but needs extra approvals, and (*3*) authorized for a pilot program and/or with some limitation (*17*).

Construction Warranty (APD during post – completion phase):

The post-completion phase of any project consists of repair and maintenance of several categories of assets (e.g., pavement, bridge, drainage structures). Repairs can be scheduled or unscheduled. In the latter case, repair activities are generally treated as emergencies. To concentrate their in-house personnel on management and planning, state agencies are shifting more design and construction responsibilities to outside entities. The contract turns out to be more interesting when risks are also shifted along with responsibilities. These approaches are often identified as innovative contracting, with warranty contracting being one of these approaches. These contracts require different types of contract specifications that are more focused on performance than on prescribed construction methods. Under a warranty contract, any repair, maintenance or deficiency is the contractors' responsibility, with contractors responsible for maintaining the integrity of the asset under warranty. This trend toward post-completion clauses aims at decreasing the cost and duration of the highway projects while retaining high quality performance. This trend is motivated by the necessity to meet an increasing demand for projects while dealing with a continuous reduction of an agency's personnel. As a result, there is a tendency to identify contractors as the best party to handle the risks associated with quality and performance of the project (*19*).

However, warranty contracts are not free from challenges, including higher costs, early failures, and reduction or even elimination of small contractors from the bidding process (*20*). Therefore, researchers have identified criteria that should be met before a warranty option is used. As warranty option is comparatively new in the highway industry, projects should be carefully selected for its implementation and the best practices should be thoroughly studied before implementation. Figure 1 explains a warranty implementation guideline (*19*).

Warranty Practices in the United States of America and Europe Warranty provisions were first used in North Carolina in 1987. About 240 warranty projects were completed in the USA by 1999. Michigan Department of Transportation (MDOT) conducted 390 warranty projects by 2001. Warranty provision was selected in 70% of the MDOT projects for preventive maintenance and applications. Ohio DOT's first warranty project was in 1998 for the surfacing of I-480. Wisconsin DOT's effort to involve the contractor in the warranty provision decision making process produces excellent results for contractor service records and quality of installation. Indiana DOT has five year warranty provisions for labor and materials on hot-mix asphalt pavement projects (*20*). The state of New Mexico opted for a 20 year warranty for upgrading the 118-mile two-lane NM 44 to the four-lane US 550. The warranty cost amounted to $62 million and was supposed to save $89 million on future maintenance and repair. The Warranty Interim Final Rule published April 19, 1996, states that warranty provisions should only be applied to the items that are under the best control of the contractors. Routine maintenance and third party damages should be the responsibility of the DOTs (*21*).

In Europe, highway contracts are awarded after pre-qualification and using best value procurement process. Design, innovation, environmental impact, safety considerations and extended warranty are the important criteria in the best value process. Most European countries need a security bond equal to or less than 5% of the bid, which is typically not enough for covering the major failure repair cost. Hence, trust is a major issue. US contractors need to provide a warranty bond which may go up to 30% of the contract price to cover the worst case scenario (*20*).

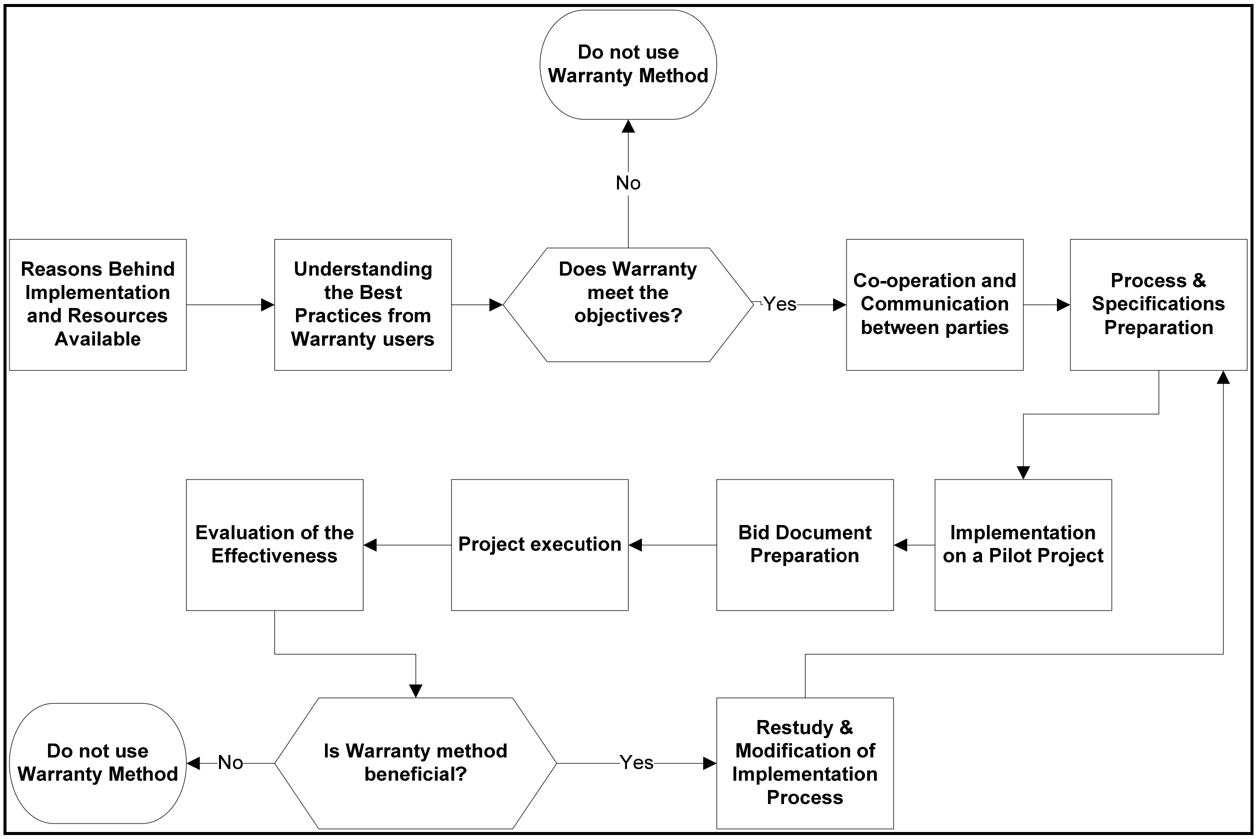


FIGURE 1 Warranty Implementation Guideline (Thompson et al, 2002)

Construction Management/Quality Assurance/Quality Control (CM/QA/QC) in Warranty

The warranty contract provides the contractor with more freedom to select materials such as mix design, methods and techniques of construction, payment method, and incentives option, than on a project using traditional method where the State Highway Agency (SHA) decides most of the things. It is the responsibility of the contractor to perform both quality controls of the materials, and quality assurance testing of the constructed products. The SHA does not need to perform a formal quality assurance program, but it may decide to collect samples of materials. All costs related to project management and construction should be recorded by SHA for future reference to analyze the benefits of the warranty projects over traditional projects. The agency may sometimes spell out the minimum specifications for materials and quality-control plans. The common thing in both the options is that the product should perform in compliance with the pre-defined performance criteria (*19*).

The work site quality control is an important aspect used to analyze the amount of work completed, productivity and the quality of the completed work. In addition, given that construction work is risky, precautions should be taken to keep people safe from potential dangers in the construction site. All repair works are conducted according to the standard practices unless any performance standards are developed. Monitoring the budget is another major element which affects QC/QA. This is mainly done to monitor the expenditure so that that the expenses can be restricted within the budget limit and also allocation of funds can be done for appropriate purposes depending on the requirement and on the information obtained from budget monitor. While interruptions in the construction process due to weather conditions are quite common, delays due to these interruptions should not be ignored as usually happens because these delays tend to add up and then affect the overall schedule later. Therefore, the schedule should be updated accurately and any change in the schedule should be realistic (*22*).

Evaluation of Warranty Provisions Warranty provisions, when applied to any project, are expected to have some effect on project objectives like cost, quality, schedule, legal assessment and bonding issues.

Cost of warranty projects The major issues concerning the cost of warranty projects are changes of bid price, the impact of warranty duration on the project cost, and small contractors losing out on warranty projects. Research shows an up to 15% average increase in bid prices due to warranty provisions. Although warranty provisions are expected to yield savings in project delivery and maintenance cost, research did not confirm such optimistic results and contradicted the view that warranties reduce lifecycle costs by spreading the initial cost over the entire warranty period (*21*). A study on cost effectiveness of warranty projects in Indiana reveals that the warranty contracts are 27-30 % less cost effective than other traditional contracts in the initial five years. However, these contracts tend to be 70-90% more cost effective in the long run. When both service life and pavement conditions are taken into account, warranty contracts turned out to be 58-65% more cost effective (*23*).

The warranty duration considerably affects the contract cost, which is to be optimized for a particular project. Because implementation of warranty provisions is quite new in the market, long-term effects on project cost are not understood properly yet. Therefore, procedures for calculating the accurate cost of warranty provisions are still limited. The performance cost of various warranted projects in various states can be compared from the cost data documented by each state, although there may be some challenges in accumulating all the data at the same place. The data, if available, can predict the future trend of the warranty program. Presently, different states have mixed experience with warranties; for example, warranted pavements in Wisconsin have about 10% less life cycle cost (i.e. bid price + maintenance cost) than regularly contracted pavements, while Florida had contrasting results with warranted pavement costing more than regularly contracted pavements. Warranty specifications can only be refined with experience in this field, which can result in providing better quality pavements in a most cost effective manner (*24*).

If a warranty bond is required to participate in the bid, adoption of long warranty clauses may exclude small contractors from the competition because of the difficulty in obtaining such a guarantee for these contractors. On the other hand, contractors experienced with warranty contracting would take advantage of their lower bonding fees to be ahead of newcomers. This aspect has some benefits because it guarantees that experienced contractors are competitive because of their experience independently from their price offer (*25*).

Quality of Warranty Projects The warranty provisions have a significant impact on the project quality. This encourages the contractor to try different innovations. In addition, these provisions produce several changes in the way the agency performs site inspection and keeps record. To avoid or minimize future warranty repairs and maintenance, the contractor should perform better during the construction phase. Conversely, contractors are often not confident about innovations and hesitate to implement changes due to the risk associated with the adoption of innovative technologies and methods, new equipment and different materials. When these concerns triumph, the goal of achieving a better quality product is defeated (*20*).

Before the introduction of warranty provisions, contractors were not concerned about the post-construction pavement performance. Now, warranty contracts force contractors to plan and execute their work while keeping long term performance in mind. On the other hand, under contracts including a warranty option, contractors are relieved from the pressure of prescriptive specifications, and are able to start and stop the project anytime they want. The contracting industry often claim that they understand quality better than the agency and, therefore, they can produce better results if left alone (*25*).

A survey of 13 DOTs revealed that the requirement of the inspection and record keeping during the construction and the warranty phase decreases according to the majority of the contractors, making the process more efficient (*20*).

Another issue with the warranty is the optimization between cost and quality. It has to be seen that the quality achieved is really worth the extra money spent on warranty for the extra risk associated, additional documentation and cost of the bond. In many cases the contractor has to be pushed to provide a better performance, even if they are under warranty. This may cost the DOT even more (*20*).

Again, most of the DOTs now treat warranty as an insurance option against the unexpected rather than the original theory of warranty contracting, i.e., innovations incorporated by the contractor, considerable enhancement of quality, and reduction in the duration and life cycle costs of the construction. One of the ways to encourage contractors to improve the quality of the project may be incentive or disincentive (I/D) option (*20*).

Duration of Warranty Projects Bayraktar *et al.* found that contractors involved in a warranty project believed that warranty provisions do not have much effect on reducing the project duration. On the contrary, it may increase the duration in some cases. If the I/D option is included, contractors may consume more time to meet the quality requirements. According to the study, there are few cases where the project duration is reduced (*20*).

Legal Assessment Framework for Warranty Contracting Although alternative project delivery may provide many lucrative benefits, one of the major concerns for implementing them is the legal environment of the state. For this purpose the researchers in Alabama DOT (ALDOT) have developed a legal assessment framework (LAF), after reviewing the statutes in several states which have incorporated warranty contracts. The research team figured out three elements that are crucial for a successful program and may face legal problems. They are design-build contracting, bidding laws allowing innovation and feasible bonding criteria. The LAF prepared by the ALDOT is shown in Figure 2 (26).

This legal assessment framework was used by the State of Alabama to develop a process for implementing performance based warranties: (1) an implementation plan has to be developed in collaboration with the contractors, people from academics and most importantly surety industry; (2) the agency should consult with the legislature to develop innovative legislation if possible which will allow the use of design-build project delivery and also flexible bidding laws; (3) the agency should pursue the surety industry to develop legislation, which the agency can use to set a smaller bond amount in the projects with warranty; and (4) an overall revision of the specifications should be conducted and suitable modifications be done to increase the possibility of warranty success (*26*).

Bonding of warranty projects Sureties are crucial to this aspect of warranty contracting. Large contractors are advantaged in bonding the project because they have larger working capital to handle any financial problem. Therefore, the surety companies are more comfortable with them rather than smaller contractors. When small contractors are able to secure bonds, they are charged high premium rates. Although extremely apprehensive about the risk present in warranty contracting, sureties often do not refuse to bond smaller contractors as they are the ones who produce the maximum revenue for the company. Sureties involved in warranty projects suggest that DOTs undertaking a warranty project should limit the warranty period to three year. If they decide to consider a warranty period more than three years, the surety should be renewed each year. Sureties also recommend not paying the contractor up front for a warranty (*20*).

Contractual Aspects of Warranty Projects (Disputes) The initial experience with warranty contracting shows that these projects are not different from conventional projects when it comes to litigations. While data do not support this claim, there is a belief among contractors and sureties that warranty contracting has the potential for increasing disputes and litigations. The rational provided relates to the length of the contracts, with contractors involved in the project after construction has been completed and throughout the operations of the project (*20*). Inability to identify the real reason for failures can also trigger disputes independently if these reasons are beyond the control of the contractor. Another major issue relates to the chance that either the contractor or the surety will go out of business during the warranty period. As a result, there is the potential for the surviving party to not honor the warranty bond if a problem takes place (21).

Innovation in Warranty Approach "Similar to Financial Option, Warranty Option is a right but not an obligation to buy a warranty" (*21*). A warranty may not be of much use for a project which is well done, as the warranty is going to end without any major problems and the failure cost will not be more than the warranty cost. Thus, an intelligent decision will be to defer the purchase of the warranty until the end of the construction, as the warranty starts after the construction is completed. In this case, although the warranty amount is mentioned in the bid by the contractor, the state DOT can wait until the completion of the construction before deciding whether to purchase the warranty, depending on the probability of the failure of the project. Hence, the state DOT is not compelled to buy the warranty during the bidding phase, even if it is a traditional low bid. After calculating and comparing the potential failure cost with the warranty cost, the choice of whether to or not to go for warranty option should be made (*21*).

A relative study of conventional warranty and warranty options according to various categories is presented in Table 1.

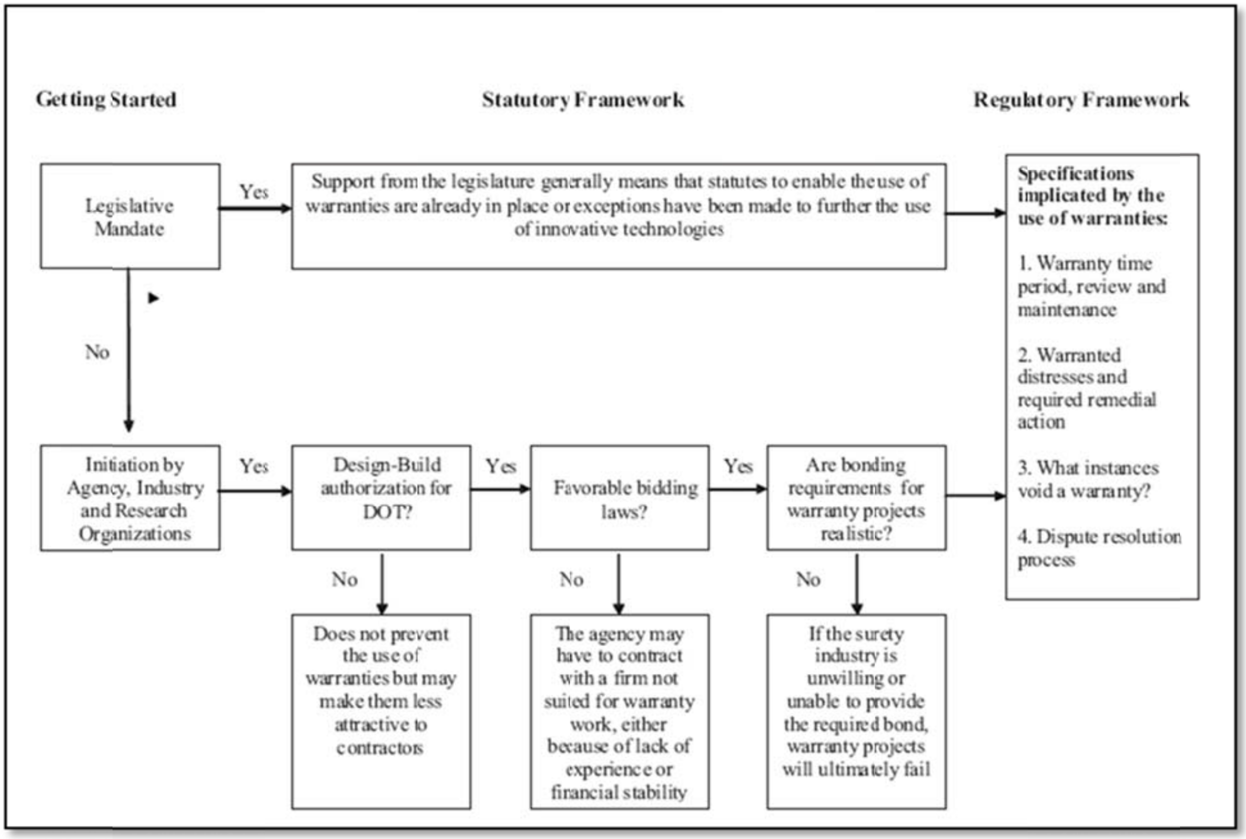


FIGURE 2 Legal Assessment Framework for performance warranties (*26*)

Performance Warranties A performance based contract (PBC) concentrates more on the performance obtained from the end product rather than the procedure to obtain the end product. PBC can encourage the contractor to incorporate innovation in materials and processes used, which sometimes may lead to some undesirable results. In order to obtain a quality project, there should be a balance between the increased opportunity and greater responsibility of the contractor, which is only possible through warranty provision. In other words, warranty can act as a buffer for the agencies to handle the uncertainties related to the performance based contracts (27).

TABLE 1 Comparison of Conventional Warranty versus Warranty Option (*21*)

CATEGORY	CONVENTIONAL WARRANTY	WARRANTY OPTION
Bidding	Warranty has to be purchased when the contract is offered. The total price of the contract is included in the initial bid price and hence higher.	Warranty Purchase decision delayed until the end of construction. Initial Bid Prices will be low. Bids are similar to that of non-warranted contracts.
Flexibility for DOTs	DOTs have no idea about the quality of the project and may have to buy it even if they may not use it depending on the future performance of the project.	Availability of more information after the completion of the project, helping in predicting the future performance more accurately and allowing the state DOT to buy warranties only for the projects having high probability of failure within the warranty period.
Risk for Contractor and surety	The surety company and contractor have the normal risks associated with the warranty contract.	The warranty option lowers the risk for a high-quality contractor but increases the risk for a poor-quality contractor because the state DOT may give up the option if a well-performed project is observed.
Bonding	A long-term warranty puts surety companies in a risky situation if contractors default. Surety companies are not too comfortable with long-term warranty bonds as they put them in a risky situation if contractors fail to pay.	The warranty liability depends on the quality of the work performed. The reduced risk in this option may reduce the price of the bond.
Incentive	Incentive option, if applied, will be high.	In warranty option, the contractor may be encouraged to produce higher quality work through incentives, since the DOT may decide not to purchase the warranty after the completion as many of them have limited bonding capacity.
Warranted Projects	If the state DOT is under tight warranty budget, they will not be able to go for many warranty projects at the same time.	In warranty option, the state DOT can delay the warranty decision until the completion of construction. Thus, state DOTs would be in a position to cover more projects under tight warranty budget.

2.3 Alternative Project Delivery (APD) in Other Industry Sectors

Building Sector

The American Institute of Architects (AIA) uses the term Integrated Project Delivery (IPD) for the alternative contracting procedure in the building sector. “Integrated Project Delivery is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction” (*28*). The reason behind finding such an innovative delivery method is to overcome the limitations present in the traditional methods such as lack of communication between the architect and construction manager, legal restrictions, participation of the construction manager long after the start of the project, putting more importance on value engineering rather than value management and lack of participation and interest of the contractor before the issue of final bid documents. Thus, sometimes there is a considerable difference between the design and construction which in turn gives rise to disputes and adversarial relationship between the participants (*30*).

In IPD, efforts are being made to bring together facility managers, end users, contractors and suppliers right from the beginning of the design process. Designers should be fully aware of the impact of their decision on the project. All the processes are supposed to be prepared keeping in mind the desired outcome, not just the cost aspect. Communication between the project participants is given significant importance and focus should be on clarity and transparency. The revenues earned and the risk associated with the project should be distributed proportionally among the participant throughout the project life. For this purpose, the owner, designer, construction manager and contractors should sign a rational contract and they should have mutual respect and trust for each other (*30*).

IPD, if carried out properly, should benefit all team members i.e., owner, designer and contractor. Here, owners can communicate their objectives to the rest of the members more effectively and thus issues of cost overrun, schedule delay, unimpressive lifecycle cost and un-sustainability can be avoided. Contractors can provide their opinion in design and thus can contribute to pre-planning strategies. This helps the contractor to picture the whole project beforehand and solve the issues that otherwise would have risen during construction. Designers on the other hand can utilize the contractors’ know-how during the design phase and can provide accurate cost estimates. All these factors together enhance the chances of project success (*28*). Based on the information obtained from “Integrated Project Delivery: A Guide” by AIA, the research team has framed an IPD structure, which is shown in Figure 3.

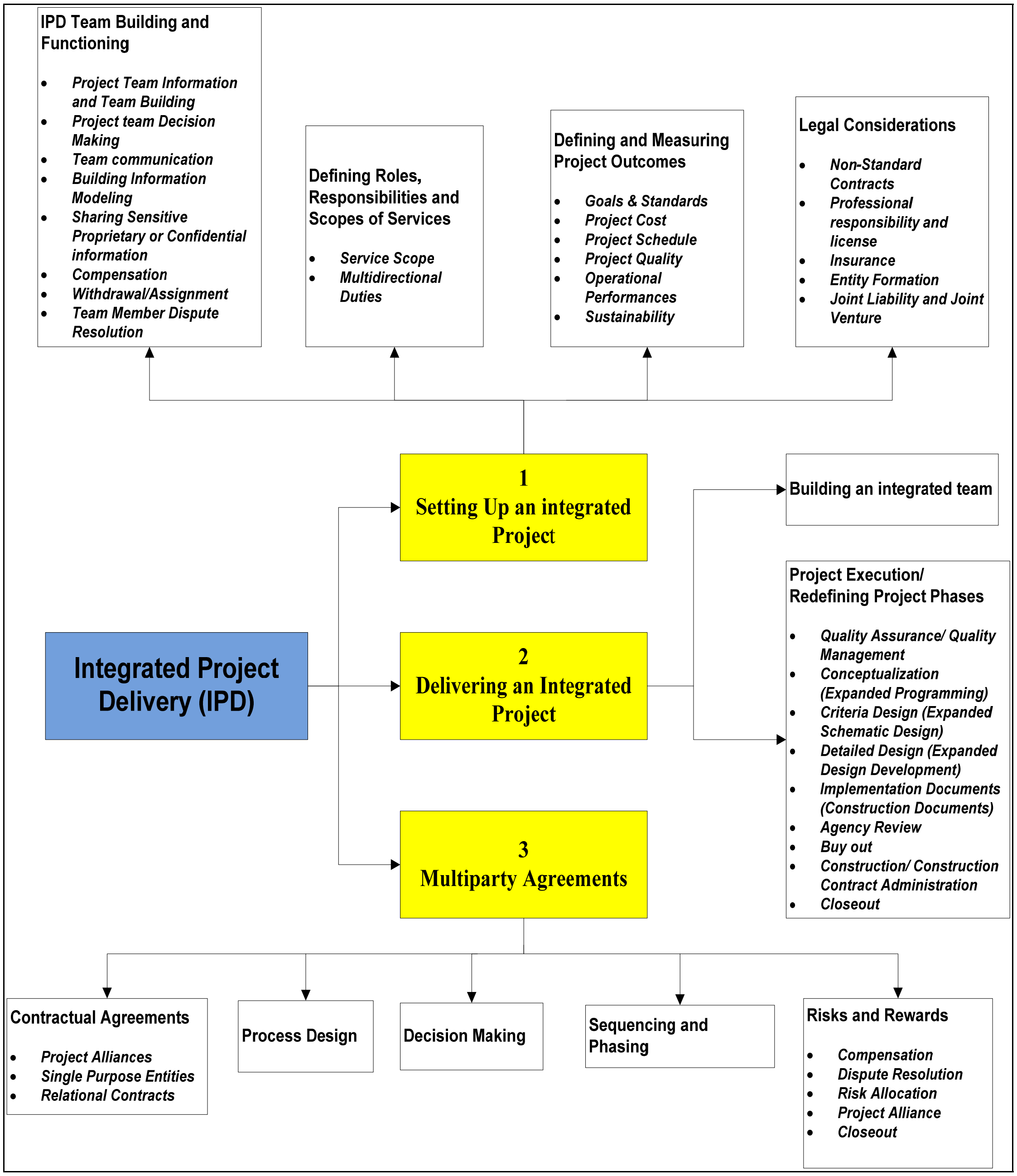


FIGURE 3 Integrated Project Delivery Framework (AIA, 2007)

Industrial Sector

The alternative project delivery methods generally used in the industrial sector are Design-Build and Construction Management at Risk (CMR). Like projects in any other sector, industrial projects should also perform well in meeting the cost and schedule targets and should satisfy customers by providing them with a high-quality facility which meets their objectives. But at the same time, the risk has to be optimized because industrial projects often tend to get overwhelming in terms of scope and budget (*29*).

In CMR, the construction manager (CM) is brought in during the design process to assist designers in pre-project planning. The owner has different contracts with designer and CM. Selection of the contractors is generally done by Best Value and Qualification Based procurement methods. Low Bid can also be opted if sufficient pre-construction services are provided by the CM. Specialty contractors if needed can also be hired early. In CMR, the contract is generally guaranteed maximum price (GMP) and the CM guarantees cost and schedule (*31*). Lump sum contracts were found to be a hindrance for potential architects when the competition is high due to elevated cost of the bid (*32*).

The Construction Industry Institute (CII) research reveals that design and construction cost can be best controlled by DB delivery closely followed by CMR. Cost control of some less complex industrial facilities like postal facilities, warehouses, distribution facilities, parking and groceries can be best done by CMR. This is probably because the simplicity of the project may encourage the owner to select local contractors who can still work under capable CMs. In the projects delivered by DB, the cost growth is almost half that in the projects delivered by traditional methods. The schedule delay can almost be negated in the project using DB and CMR, unlike in most of the projects using DBB. Moreover, the projects can be accelerated considerably and are very useful for facilities needing to be constructed on a tight schedule without knowing the overall budget. This is possible due to the involvement of the constructors early during the design and planning phase. DB takes the responsibility of assuring the design away from the owner. Companies having DB experience are a big bonus for the projects they are undertaking. Study also reveals that success rates for complex projects are higher for the ones using the alternative delivery and they achieve significantly high quality in this case (*32*).

CHAPTER 3: FINANCING OF HIGHWAY PROJECTS

3.1 Traditional Project Financing

Usually, State Highway Agencies (SHA) tend to adopt the traditional "pay-as-you-go" form of financing, where the SHA, after analyzing the total funds available from federal and state sources, tries to allocate appropriate amount of money for future projects. Under this mechanism, the state usually is provided funding on an installment basis over several years. As a result, the agency may expand the duration of the project and/or complete it by parts to match the delivery speed with the funding flow. The gas taxes collected by both the state ($0.202 per gallon) and the federal governments ($0.184 per gallon) make important contributions in funding highway projects (*33*). In recent years, the state can no longer depend upon the revenue collected from the gas tax. In fact, the increasing fuel efficiency of vehicles does not "refill" the Highway Trust Fund (HTF) at the same speed as required repairs, making this mechanism inadequate for funding new highway projects. As a result, agencies have been relying more on bonds, which are basically a form of debt to finance future projects (*34*).

3.2 Innovative Project Financing

In transportation "Innovative Financing" can be defined as a supplementary highway financing method that incorporates a set of nonconventional techniques, meant to benefit the funding aspect of the project. This type of financing option is quite new to transportation, unlike the other sectors of construction (*35*). The economic recession has a significant impact on state DOTs' budgets, making them insufficient to meet the increasing requirements of highway facilities. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Transportation Equity Act for the 21st Century (TEA-21) have provided the transportation decision makers an opportunity to make use of the new financial strategies and to manage both federal and state funds to provide additional money for future projects. Most funding options help in accelerating the project, which in turn saves significant amounts of money by negating the price rise due to inflation. The user benefits can also be realized earlier due to shorter project duration (*36*).

The funding options available in the market can be categorized into three sections: Financing of Debt, Public/Private Partnership (PPP) and Project Consolidation in Segments.

3.3 Financing of Debt

In this provision, the SHA finances its transportation program by borrowing money from the municipal bond market. The states are affected greatly by the interest rates levied on these debts. As the amount of debt ranges among hundreds of dollars, slight changes in interest rate will have considerable impact on the tax payers. Thus, various options having unique strategies have been prepared by the FHWA to lower the interest rate on the borrowed money. Some of the major options are Grant Anticipation Revenue Vehicles (GARVEE), Section 129 loans, State Infrastructure Banks (SIB), and Transportation Finance and Innovation Act (TIFIA) (*37*).

Grant Anticipation Revenue Vehicle (GARVEE)

The uncertainty related to the funds being borrowed and the interest rate charged are considerably reduced if the repayment money comes from a guaranteed source. GARVEE can be defined as a financial tool where the federal agency repays the principal as well as the interest for any political subdivision using it (*38*). The states, therefore, can make use of GARVEE to fund their projects right away, rather than waiting for other traditional forms of funding. Thus, states expecting funding in the future can start their projects immediately, even if the DOTs do not have money allocated for them (*34*).

Types of GARVEE There are many types of GARVEEs available. A specific type of GARVEE is selected for a particular project, depending on its nature. The types are:

- Short-Term GARVEE – Here the federal reauthorization period is not exceeded by the bond term and the state has the support of the already authorized federal funds. Primary risks, therefore, are often considered appropriation risks in case of short-term notes.
- Long-Term GARVEE – Here the bond terms exceed the reauthorization period and thus hold more risk than the previous type. The risk associated is called the authorization risk, as the federal highway program (FHP) has to be reauthorized by Congress. Although there are hardly any cases of rejection of reauthorization of FHP, authorization is not certain. Thus, most of the long-term GARVEEs are provided by "backstop" security.
- Backstopped GARVEE – Here the GARVEE has the backing of alternative revenue sources such as vehicle registration revenue, gas tax or toll revenue, to repay the debt if the federal funds dry up before the full repayment. Thus the risk involved is comparatively less.
- Naked GARVEE – The GARVEE devoid of any support from the backstops is called naked GARVEE and is solely dependent on future federal funds. The only backing obtained can be through the purchase of bond insurance.
- Direct GARVEE – This type of GARVEE is applicable for the projects listed in the state's State Transportation Improvement Plan (STIP) and needing funding for more than three years. The projects are referred to as Advanced Construction Projects and they get prior approval from the FHWA to get their debt repaid directly by the federal source.
- Indirect GARVEE – These can be used for any transportation project (e.g., state DOT projects) and can be repaid from the funds of other projects. They are much more flexible and, as there is no federal requirement, federal approval is not needed (*34*).

Benefits of GARVEE GARVEEs are of great help for the states under tight budget conditions and they have obvious benefits. One of the main objectives of a GARVEE is to speed up the project delivery. The data available in the industry show that highway projects can be accelerated by as much as 25 years (Mayer, 1999). Acceleration of the project, on the other hand, produces cost savings by reducing the inflation effect on the real estate price, materials, and right-of-way, but also by reducing the user delay cost in case of rehabilitation projects (*34*).

The construction of large projects can now be funded upfront by a GARVEE, which otherwise would have been very difficult for the DOTs to execute using the traditional "pay-as-you-go" approach. Besides, a GARVEE does not add to the state debts and thus is not a problem for the legal debt limits. In other words, a GARVEE can be treated as future revenues which can be received from the federal agencies. But at the same time the amount of GARVEE funds that a state can accrue may not be unlimited. A GARVEE is free from the involvement of any state legislature and public consent, thus saving a lot of time and effort associated with complex bureaucracy (*34*).

Disadvantages of GARVEE Like everything, GARVEEs have drawbacks and are criticized by some administrative and political personalities. They do not favor the accumulation of debts that do not produce any revenue. The only revenue source for a GARVEE is funding from unrelated projects listed in the capital program. This in turn may affect the overall federal budget adversely and may cut short funding for other projects. Some states may be considered in the reimbursement list, which may lead to the shortfall of the debts in those states, thus, defeating the main objective of GARVEEs. Again, as GARVEEs can be issued only by states, other organizations like Metropolitan Planning Organizations are deprived of this option (*34*).

The authorization of the FHP by Congress, as mentioned earlier, is not guaranteed and if by any chance the highway funds are not offered, the state will be accountable for repaying the debt. The increase of GARVEE debt as transportation revenue may also trigger the increase of gas taxes in order to raise the transportation resources (*34*).

Unfortunately, there are some controversial projects associated with GARVEEs. Thus, project planning should be given due consideration, as GARVEEs are meant to put on track useful projects important for society. A GARVEE should not be thought anything more than a financial mechanism (*34*).

Section 129 Loans

Loans under Section 129(a) (7) of Title 23 in the National Highway System (NHS) act are termed as Section 129 loans. This allows the state agencies to utilize the federal-aid highway fund in an innovative way. The state DOT can lend out the federal funds received for other projects and then collect revenues from them, which can boost their own resources to some extent. Although the projects for which the money can be lent were previously limited to toll projects, later the scope was broadened. The formation of the Section 129 loan has major contributions from the amendment of Section 1012 of ISTEA and Section 313 (b) of the NHS Act (*35*).

Advantages of Section 129 Loans Section 129 Loans have provided the states an opportunity to produce some extra revenue from their regular federal supply and invest it back in building their infrastructure. It is also useful for the party borrowing from the state agency, as the interest rate is much lower than the normal market rates (*35*).

Disadvantages of Section 129 Loans One disadvantage may be that the projects under the Section 129 loans are not eligible for loan guarantees, although they may have some provisions for reimbursement in the Section 129(a) (7) loan program (*36*).

State Infrastructure Bank (SIB)

A State Infrastructure Bank (SIB) provides loans to certain federal-aid projects, with higher present value of repayment (*40*). SIB has helped to augment funding opportunities from both state and federal resources and has supported the execution of many projects that otherwise would have been delayed due to budget limitations. The SIB is benefited by the provision of credit enhancement and also from the revenue collected from loan repayment. The interest rates and the repayment period are set following a variety of methods; for example, using a nationally recognized municipal index for determining the interest rate. Despite the presence of certain requirements for using SIB, the states enjoy some flexibility in utilizing it according to their needs. The repayment period can range from 10 to 30 years, depending on the type of legislation. Each state has a unique structure for SIBs. Projects have to apply formally and the best projects in each state are shortlisted after a proper review process. A project has higher chances of being selected for SIB funds if the program is supported strongly by DOT officials. The project should be able to show sufficient security for a repayment stream and financial feasibility and should have economic benefits for society (*37*).

Advantages of SIB A SIB has some potential benefits. It provides flexibility for project financing and accelerates project completion. It ensures that high priority projects ready to be constructed are not waiting for funding. Thus, the funds are getting recycled, which in turn increases state and local investments, boosting community development. A SIB can also be used to overcome an emergency or disaster repair. Besides, it provides financial access to diverse communities (*37*).

Disadvantages of SIB The capitalization level of a SIB gets increased sometimes due to lack of legislative authority to control their funds. This also restricts the maximum loan amount in a SIB, which again can be restricted additionally by federal and state capitalization. The federal requirements sometimes act as a hindrance to SIB activity and can adversely affect schedule and cost for small projects. Lack of demand for loans in some states has posed challenges in implementing the program. Thus, a SIB needs proper marketing to get more agencies acquainted with it (*37*).

Transportation Finance and Innovation Act (TIFIA)

Enacted in 1998, and a part of the Transportation Equity Act for 21st Century (TEA-21), the Transportation Finance and Innovation Act (TIFIA) assists projects having sufficient project revenue streams by providing credit assistance in the form of direct loans, loan guarantees and lines of credit (*41*). A Secured Loan has a maximum term of 35 years and the repayment should start within 5 years of substantial completion. With Loan Guarantee, the debt repayment is ensured to the non-federal lender. A Line of Credit is a contingent loan available up to 10 years after substantial completion (AASHTO).

TIFIA allows the projects to get started and marketed with the help of flexible credit assistance and repayment policies. Private agencies get interested to invest in the public sector under this act, thus fueling the construction of important projects that would have been delayed or not constructed at all. TIFIA enhances a sense of security, as the credit assistance is provided in a responsible fashion to capital market participants comfortable with repayment (*37*).

Advantages of TIFIA TIFIA helps the project to reach the capital markets, providing them with supporting debt and assisting them in long-term, fixed-cost and upfront financing. It allows flexibility of amortization and no penalty for pre-payment. Interest rates can be committed up front and thus are fixed throughout the pre-payment period. Agencies can borrow their required amount of money. The borrower may not be a big investor (*42*).

Disadvantages of TIFIA One disadvantage is that the state should apply with an application fee and compete for funding categories. TIFIA also charges a substantial processing fee for negotiating the loan agreement (*37*).

3.4 Public/Private Partnerships (PPP)

While Public/Private Partnership (PPP) have been used in the U.S. before, they have been encouraged recently through Special Experimental Program No. 15 (SEP-15). This US DOT program encourages states to adopt PPPs on an experimental basis to enhance the probability of overall project success by trying to negate the adverse effects of financial obstacles, legal issues and environmental restrictions (*63*). A PPP is a concept where private entities invest in the public sector, like highway construction or rehabilitation, in order to benefit from the revenues collected in the future from the project. The private parties entering into the contract try to regain the investment in the post-construction phase and also some overhead if possible. The partnerships can be of many types, depending on the requirements of both the entities and also the scope of the project (*43*). Some of the innovative financing techniques that can come under a PPP are Design-Build-Finance-Operate, Build-Operate-Transfer, and Long-Term Lease Concessions.

1) Design-Build-Finance-Option (DBFO) — The private contractor is partly responsible for financing the project delivery, design and operation of the facility and then is allowed to maintain the facility. The contractor can collect revenues in the form of a toll tax. A better quality project can be expected from this process, as the contractor will not want major repairs during the post construction period. Another advantage is shifting of risk to the contractor during the contract period (*44*).

2) Build-Operate-Transfer (BOT) — The process is quite similar to DBFO. But here the contractor retains ownership for a limited amount of time after construction and then has to transfer it over to the owner (*44*).

3) Long-Term Lease Concession — Under this type of agreement, the private entity pays an upfront lump sum amount to the public party, which in turn provides the former the privilege to collect revenue from the facility over the contract life (*16*).

PPP Advantages

Handing over a project to a private party under this type of financial arrangement is advantageous over borrowing money, as the latter involves several hassles as well as uncertainties associated with interest rate fluctuations. Thus, private agencies interested in entering into a PPP can considerably reduce or completely replace the requirement of public funds (*16*).

PPP Disadvantages

In a PPP, as the private entities are more concerned with the return of investment, the public agency has very little control over the project (*43*). In other words, private bodies are taking over public property and the chances of user fee increase for profit motives rather than public policy objectives cannot be overruled. Moreover, PPP implementation also has several legal issues associated with it (*16*).

3.5 Project Consolidation in Segments

This is a different kind of innovation that can be applied to big projects which need to be completed in a very short period of time. In this type of innovation, the contract is divided into different sections and carried out separately at the same time. The contracts may be handed over to different contractors. This process was used by New Mexico DOT for its 118-mile long US

550 corridor project and allowed a completion within three years. Under the traditional “pay-as-you go” funding approach, the approach of NMDOT to implement the US 550 corridor would have been to subdivide the road into 5-10 mile segments. Each of these segments would have been redesigned and reconstructed as soon as money became available.

Under the traditional financing approach, completing the 118-mile project would have taken up to 27 years. Using GARVEE bonds shortened the US 550 funding cycle, with the project being consolidated into four segments (instead of numerous 5-10 miles stretches). The decision to consolidate the project and to seek four separate construction contracts was motivated by the state’s desire to allow local contractors to compete for the construction component.

CHAPTER 4: LIFE CYCLE COST ANALYSIS (LCCA) OF HIGHWAY PROJECTS

4.1 Overview

The final step of US 550 Road Lifecycle Innovative Financing Evaluation is compiling the information obtained from work done in the previous tasks and preparing a user-friendly computerized Life Cycle Cost Analysis (LCCA) model. In this project the assessment of the innovative decisions is challenging, as it requires the evaluation of both monetary and non-monetary costs and benefits. As stated in the initial proposal, the research team planned to use multi-attribute decision analysis techniques such as the analytical hierarchy process (AHP). However, these techniques could not be used because of the lack of data. Therefore, the research team developed a Microsoft Access application, the US 550 Highway Tracking Software that is discussed in detail in Chapter 9 and included on the accompanying CD. This application allows NMDOT staff to track warranty transactions. In addition, the application includes an LCCA module, which can calculate the current Net Present Value (NPV) and compare it with the NPV predicted before construction. This chapter summarizes the state of practice of LCCA modeling.

4.2 Analytical Hierarchy Process (AHP)

Background and Definition

Making a decision is difficult when both qualitative and quantitative aspects of an alternative are important. Analytical Hierarchy Process (AHP) is a powerful tool designed to simplify the decision making process for such complex situations. The alternative may have different social, political, economic and technical factors. AHP takes into consideration various risks and uncertainties involved with a complex setting and often provides a rational decision (*45*).

Methodology

The rating scale used by AHP contains arbitrary numbers from one to nine. Each number is related to an assumption. The ranking depends considerably on the objectiveness of the decision maker. The AHP value scale prepared by Dr. Thomas Saaty, developer of AHP, is shown in Figure 4. The methodology used for AHP is described briefly in Figure 5.

Value	Interpretation
0.111	Extreme preference/importance B over A
0.143	Very Strong preference/importance B over A
0.2	Strong preference/importance B over A
0.333	Moderate preference/importance B over A
1	Equal preference/importance A and B
3	Moderate preference/importance A over B
5	Strong preference/importance A over B
7	Very Strong preference/importance A over B
9	Extreme preference/importance A over B

FIGURE 4 AHP Value Scale (*45*)

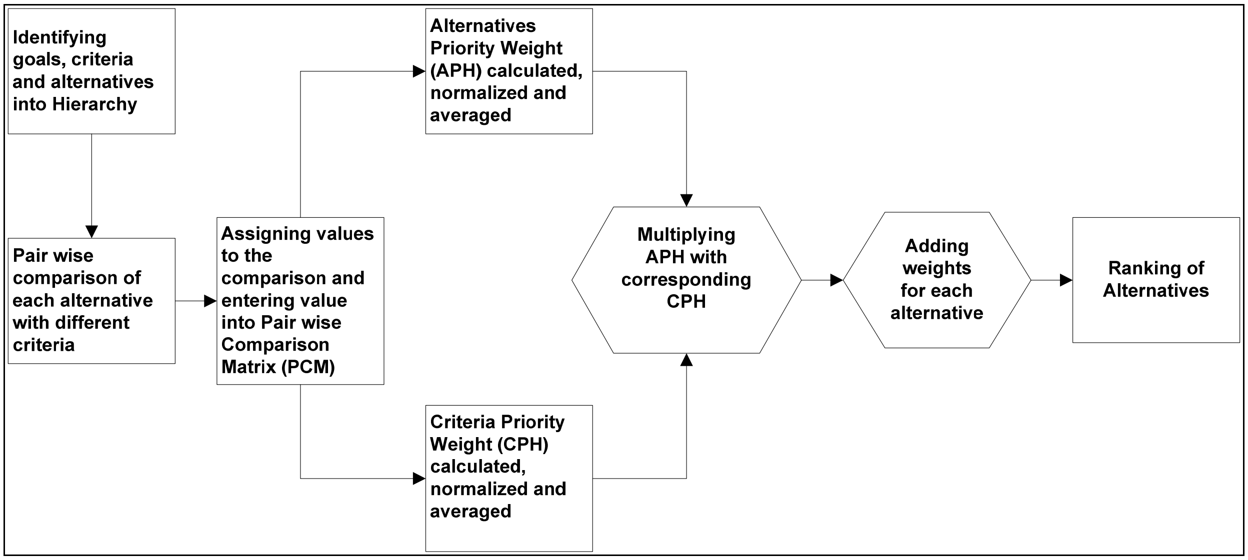


FIGURE 5 AHP Methodology (45)

4.3 Life Cycle Cost Analysis (LCCA)

Life Cycle Cost Analysis can be termed as the economic evaluation of certain project alternatives before making any investment decision. LCCA analyzes all the competing designs or construction approaches, and selects the one with lowest cost. For calculating LCCA, all costs over the life of the project are considered, including user cost, maintenance and repair cost, and agency cost. LCCA can act as a decision-making tool to compare different options for construction, design, management and maintenance that may be applicable to a particular project (*18*).

The steps of the LCCA process are as follows:

- Identification of potential alternatives
- Determination of analysis period
- Estimation of agency and user costs
- Calculation of life cycle cost
- Analysis of the results (*18*)

Step 1: Identifying Potential Alternatives

Implementation of LCCA is more useful when there are more than one ways to design or construct a project. Thus the very first step of the process is to identify all the potential alternatives that can be implemented in the project. Different alternatives may have different types of maintenance and rehabilitation activities associated with them. Thus all the necessary elements of analysis in each alternative are detailed (*18*).

Step 2: Determination of Analysis Period

After recognizing all the elements in the prospective project alternatives, the interval of conducting maintenance and rehabilitation for each alternative is allocated. The service life over which the analysis of the project will be conducted is also decided. A typical transportation facility will undergo a life cycle of design, construction, maintenance, and decommissioning. The timing of the maintenance and rehabilitation, if any, should be predicted as accurately as possible. An idea of the timing can be obtained from the already existing data for similar projects or by consulting the expertise in the field (*18*).

Step 3: Estimation of Agency and User Costs

The financial impact on the highway agency and the users for construction, maintenance, rehabilitation and decommissioning should be considered for the LCCA. Attention should be paid to the cost elements, which vary considerably among the alternatives. All the calculations should be done taking in to account the discount rate and bringing the dollar value to a constant amount. Costs are divided into two major categories — Agency Cost and Road-User Cost (*35*).

Agency cost is the cost over the life of the project for which the owner is responsible. It generally consists of preliminary engineering, contract administration, initial construction, maintenance cost, rehabilitation cost, administrative cost and salvage value. If warranty provisions are present, then the warranty cost also comes under this category. Maintenance costs are regular repair cost incurred, and the rehabilitation costs are generally major expenditures for the resurfacing of the pavement. Salvage value can again be broken down into residual value (i.e., the net present value of the pavement at the end of the analysis period) and serviceable life (i.e., the remaining life of the pavement after the analysis period).

The costs incurred by motorists during the construction, regular use, maintenance, and rehabilitation are termed road-user costs. These are important for LCCA as they vary considerably as a function of the project and often have greater impact than agency cost. These consist of vehicle operating cost, user delay cost and crash cost (*35*).

Step 4: Life Cycle Cost Calculation

The user and agency cost obtained from various alternatives are used to calculate the life cycle cost. Because the dollar’s value is not fixed with time, the cost over the years cannot simply be added. Consequently, all future values should be discounted to the present and then added. Net Present Value is the conversion of anticipated future cost to present amount. The cash flow diagram visualizes the quantity and timing of the transactions projected over the life of the analysis period (*35*). A sample cash flow diagram is shown in Figure 6.

The input variables used in the Deterministic Approach are discrete numbers and can be calculated easily on a spreadsheet. The level of certainty of the results obtained can be enhanced by performing a sensitivity analysis, which is also facilitated with a spreadsheet.

A probabilistic distribution is used when the project alternatives are uncertain and the value of the analysis is determined by a frequency distribution of the possible values obtained. Simulation programming is then used to randomly select a value from the probabilistic distribution and the selected value can be used to calculate a distribution of net present value (*35*).

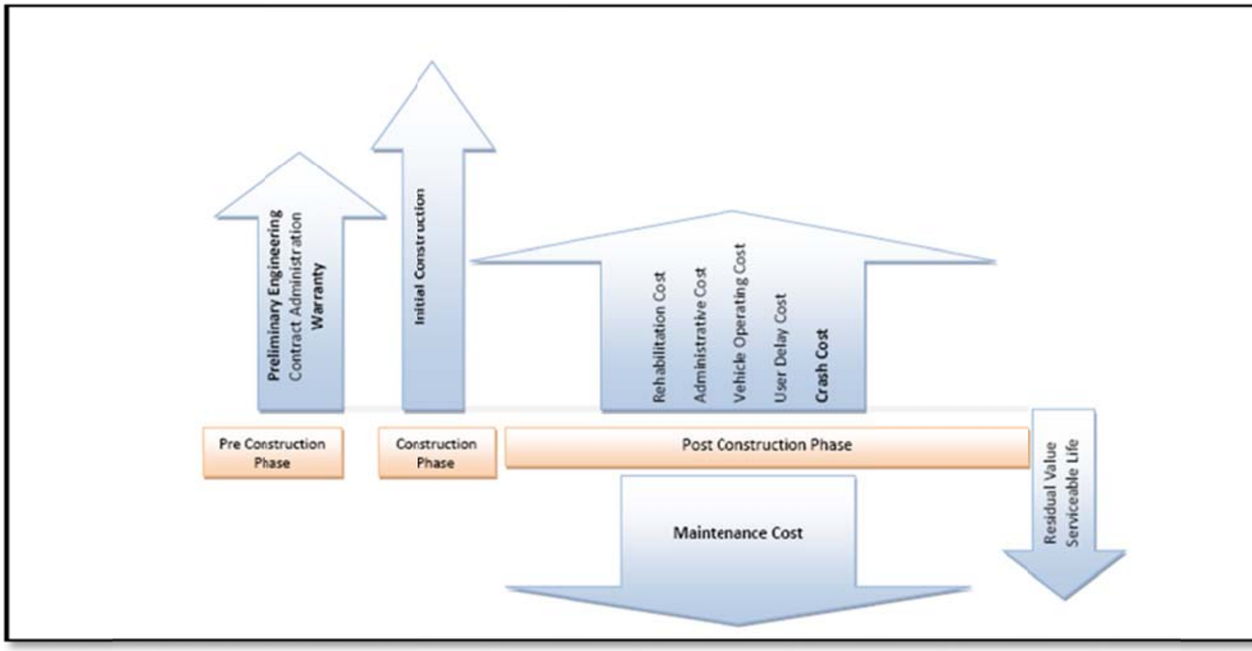


FIGURE 6 Cash Flow Diagram

Step 5: Analysis of the Results

The NPVs calculated for each alternative are then compared. Road-user cost plays a central role in differentiating NPV results, although agency costs can become important if roadway design alternatives differ in initial construction costs. In spite of low agency cost, an alternative can be rejected if the road-user cost is much higher, because the latter contributes significantly to a project's life cycle cost (*36*).

4.4 Benefit Cost Analysis (B/C)

Benefit Cost (B/C) analysis considers both project benefits and costs for selecting the optimal alternative for project execution. Alternative designs can provide different benefits; for example, a bridge replacement project must consider which alternative can accommodate future traffic demand. A decision about whether a project should be undertaken or not is made after reviewing all the project's benefits. A proposed project should not be undertaken if the LCC exceeds its benefits. B/C is very useful for reconstruction and upgrading projects. Some of the benefits taken into account are reduced travel distance or time, lower vehicle operating cost, and improved safety. In other words, LCCA can looked be at as a subset of B/C. A comparison of project elements required for LCCA and B/C are shown in Table 2 (*47*).

TABLE 2 Comparison of Analysis Elements: Life-Cycle Cost Analysis versus Benefit-Cost Analysis

Project Element	**LCCA**	**B/C**
Agency construction, rehabilitation, and maintenance expenditures	Yes	Yes
User costs during construction, rehabilitation, or maintenance	Yes	Yes
User costs during normal operations	Yes	Yes
User benefits resulting from project	No	Yes
Externalities resulting from project	No	Yes

4.5 Existing LCCA Computer Models

RealCost Software

RealCost is a computerized LCCA model prepared by the Federal Highway Administration (FHWA). The software allows investigating the effects of cost, service life, and economic inputs on life-cycle cost and helps in guiding the pavement designers to make pavement investment decisions. To make the software user friendly, a graphical user interface (GUI) was designed. RealCost automates FHWA's LCCA methodology as it applies to pavements. The software calculates life-cycle values for both agency and user costs associated with construction and rehabilitation. Both deterministic and probabilistic modeling of pavement LCCA problems can be performed by the software. Outputs are obtained in the form of tables and graphs. RealCost can also support deterministic sensitivity analyses and probabilistic risk analyses.

Although there is provision for comparing only two alternatives at a time, pavement engineers can use it for an unlimited number of alternatives by saving the inputs and outputs of all the analysis. The user cost calculation method used by FHWA can be automated in the software. Here the traffic demands are compared to the roadway capacity on an hour-by-hour basis and the traffic conditions are visualized. A spreadsheet application is suitable for this calculation-intensive method (*48*).

The analysis output of the software after comparing agency cost and road-user cost does not provide all the information needed to select the best alternative. Other factors including risk, budget, and political and environmental concerns must also be considered (*48*).

RealCost uses a Microsoft Excel 2000/2007 worksheet with additional Visual Basic for Applications (VBA) code. The VBA code provides the ability to perform Monte Carlo simulation in the analysis, and it is used to construct the GUI. Two interface mechanisms, the form and the worksheet, are present in the software.

Form Interface The GUI can be treated as the face or switchboard of the software. There are four components in each form, while some data entry forms may have an additional provision for probability analysis. Figure 7 shows a sample form interface.

Form Name Name used in RealCost to refer to the form
Data Entry Field Area for data input
Data Field Description Phrase used to identify the data entry field
Command Button GUI device that triggers a command or series of commands to the software

Probability Button Specific type of command button that opens a form where probabilistic inputs can be assigned (*48*)

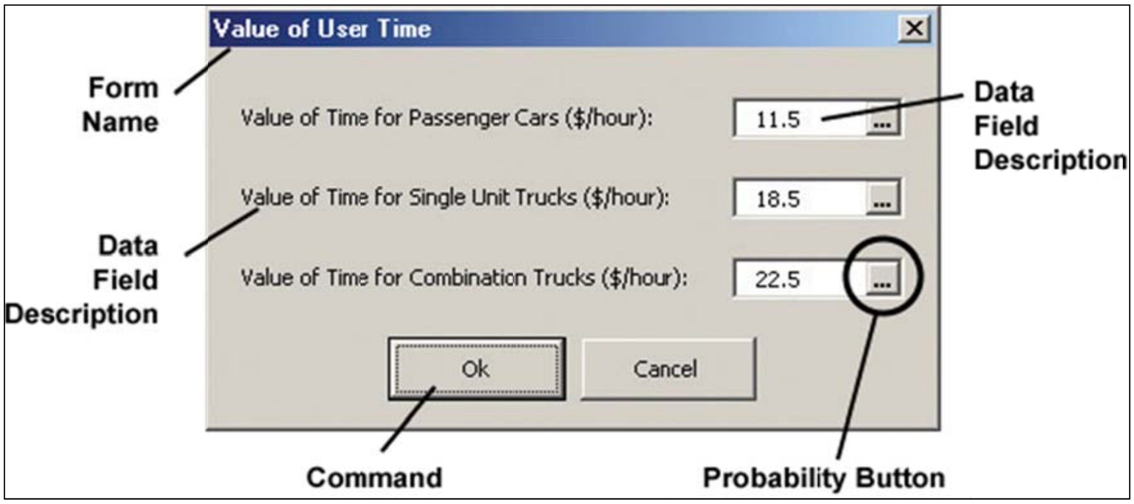


FIGURE 7 An example data entry form, Value of User Time (FHWA)

Worksheet Interface After the form interface is closed, the worksheet interface is available, which can also be used to enter data into the cell having the same level as the corresponding field on the form interface. Both form and worksheet store all the entered data in Excel 2000/2007. But the form interface is required to execute some functions. A sample part of the worksheet shown in Figure 8 contains the data entered in the Value of User Time form in Figure 7 (*48*).

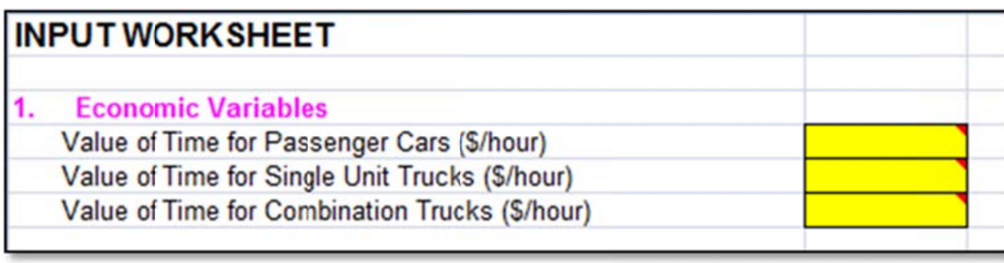


FIGURE 8 Example Worksheet Extract, Value of User Time

Quinbin's LCCA Model

The Quinbin LCCA model is completely a worksheet interface model that is mainly prepared to investigate the benefits of highway warranty. Here the warranty cost is considered as an agency cost. Net present value (NPV) is calculated in the worksheet for an analysis period of 20 years. The NPV is computed in three different worksheets for best, moderate and worst case scenarios. The expenditure over time was estimated from the NPV charts prepared for best, moderate and worst case scenarios. Various charts are prepared for analysis. Some of the important graphs are NPV vs. interest dates, NPV vs. discount rates. The Quinbin LCCA model is not very user friendly. The user must have detailed knowledge about LCCA to operate it. Figures 9, 10, and 11 show the spreadsheet and graphs produced by the software.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	
1	Initial Investment for Warranty Coverage:				($62,000,000)													
2																		
3	Best-Case Scenario																	
4	YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
5	EXPENSES	$0	$46,393	$187,211	$212,046	$1,585,000	$835,000	$85,000	$5,685,000	$85,000	$5,096,950	$85,000	$13,085,000	$85,000	$15,085,000	$85,000	$85,000	$27,0
6																		
7	i, Interest Rate	NPV	NPV	NPV	NPV	NPV	NPV	NPV	NPV	NPV	NPV	NPV	NPV	NPV	NPV	NPV	NPV	N
8	0.010	$0	$45,934	$183,522	$205,810	$1,523,154	$794,474	$80,074	$5,302,502	$78,496	$4,660,344	$76,949	$11,728,396	$75,433	$13,254,625	$73,947	$73,215	$23,0
9	0.011	$0	$45,888	$183,159	$205,200	$1,517,136	$790,552	$79,600	$5,265,897	$77,877	$4,619,021	$76,192	$11,501,416	$74,543	$13,085,198	$72,929	$72,136	$22,7
10	0.012	$0	$45,843	$182,798	$204,592	$1,511,149	$786,654	$79,129	$5,229,581	$77,264	$4,578,105	$75,442	$11,475,935	$73,664	$12,918,100	$71,927	$71,074	$22,3
11	0.013	$0	$45,798	$182,437	$203,987	$1,505,191	$782,779	$78,662	$5,193,550	$76,656	$4,537,591	$74,701	$11,351,933	$72,796	$12,753,299	$70,939	$70,029	$22,0
12	0.014	$0	$45,752	$182,077	$203,384	$1,499,262	$778,927	$78,157	$5,157,803	$76,053	$4,497,475	$73,967	$11,229,391	$71,939	$12,590,759	$69,966	$69,000	$21,6
13	0.015	$0	$45,707	$181,719	$202,783	$1,493,362	$775,097	$77,736	$5,122,337	$75,455	$4,457,753	$73,242	$11,108,291	$71,093	$12,430,448	$69,007	$67,987	$21,3
14	0.016	$0	$45,662	$181,361	$202,185	$1,487,491	$771,290	$77,278	$5,087,150	$74,863	$4,418,420	$72,524	$10,988,615	$70,258	$12,272,332	$68,062	$66,991	$21,0
15	0.017	$0	$45,618	$181,005	$201,589	$1,481,649	$767,506	$76,823	$5,052,238	$74,276	$4,379,472	$71,814	$10,870,343	$69,433	$12,116,381	$67,131	$66,009	$20,6
16	0.018	$0	$45,573	$180,649	$200,996	$1,475,836	$763,744	$76,372	$5,017,600	$73,695	$4,340,906	$71,112	$10,753,459	$68,619	$11,962,562	$66,214	$65,043	$20,3
17	0.019	$0	$45,528	$180,295	$200,405	$1,470,051	$760,003	$75,923	$4,983,233	$73,118	$4,302,716	$70,417	$10,537,944	$67,815	$11,810,844	$65,310	$64,092	$20,0
18	0.020	$0	$45,483	$179,941	$199,816	$1,464,295	$756,285	$75,478	$4,949,135	$72,547	$4,264,900	$69,730	$10,523,782	$67,022	$11,661,196	$64,419	$63,156	$19,7
19	0.021	$0	$45,439	$179,589	$199,229	$1,458,567	$752,589	$75,035	$4,915,303	$71,980	$4,227,452	$69,050	$10,410,955	$66,238	$11,513,588	$63,542	$62,235	$19,4
20	0.022	$0	$45,394	$179,238	$198,645	$1,452,866	$748,914	$74,596	$4,881,735	$71,419	$4,190,369	$68,377	$10,299,446	$65,465	$11,367,990	$62,677	$61,328	$19,1
21	0.023	$0	$45,350	$178,888	$198,063	$1,447,194	$745,261	$74,159	$4,848,429	$70,862	$4,153,648	$67,712	$10,189,239	$64,701	$11,224,373	$61,824	$60,434	$18,8
22	0.024	$0	$45,306	$178,538	$197,483	$1,441,549	$741,629	$73,726	$4,815,382	$70,310	$4,117,283	$67,053	$10,080,317	$63,947	$11,082,708	$60,985	$59,555	$18,5
23	0.025	$0	$45,261	$178,190	$196,906	$1,435,932	$738,018	$73,295	$4,782,593	$69,763	$4,081,272	$66,402	$9,972,664	$63,202	$10,942,966	$60,157	$58,690	$18,2
24	0.026	$0	$45,217	$177,843	$196,331	$1,430,342	$734,429	$72,868	$4,750,058	$69,221	$4,045,611	$65,758	$9,866,265	$62,467	$10,805,121	$59,341	$57,837	$17,9
25	0.027	$0	$45,173	$177,497	$195,758	$1,424,779	$730,860	$72,443	$4,717,777	$68,684	$4,010,296	$65,120	$9,761,102	$61,741	$10,669,143	$58,537	$56,998	$17,6
26	0.028	$0	$45,129	$177,152	$195,187	$1,419,243	$727,312	$72,021	$4,685,745	$68,151	$3,975,322	$64,489	$9,657,161	$61,024	$10,535,007	$57,745	$56,172	$17,4
27	0.029	$0	$45,086	$176,807	$194,618	$1,413,734	$723,785	$71,602	$4,653,962	$67,623	$3,940,688	$63,865	$9,554,426	$60,316	$10,402,685	$56,964	$55,359	$17,1
28	0.030	$0	$45,042	$176,464	$194,052	$1,408,252	$720,278	$71,186	$4,622,425	$67,100	$3,906,388	$63,248	$9,452,882	$59,617	$10,272,151	$56,195	$54,558	$16,8
29	0.031	$0	$44,998	$176,122	$193,488	$1,402,796	$716,792	$70,773	$4,591,132	$66,581	$3,872,419	$62,637	$9,352,515	$58,927	$10,143,379	$55,437	$53,770	$16,6
30	0.032	$0	$44,954	$175,781	$192,926	$1,397,367	$713,326	$70,362	$4,560,081	$66,067	$3,838,779	$62,033	$9,253,309	$58,246	$10,016,344	$54,689	$52,994	$16,3

FIGURE 9 NPV Chart for Best Case Scenario

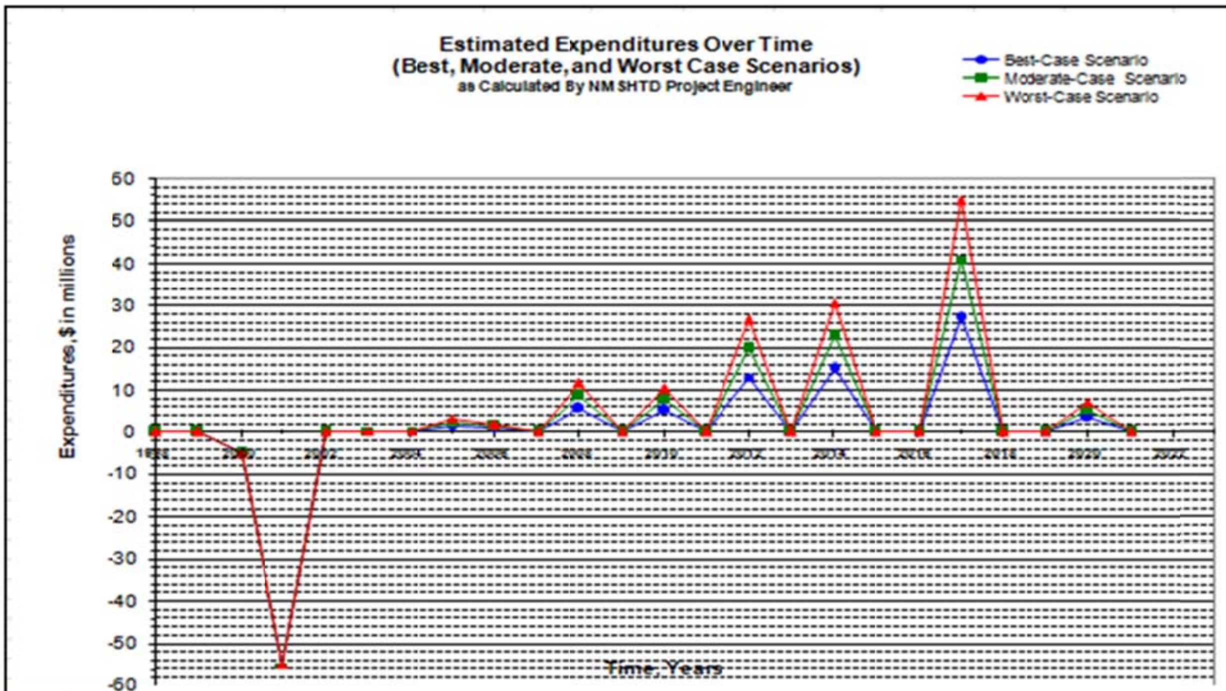


FIGURE 10 Estimated Expenditure over Time

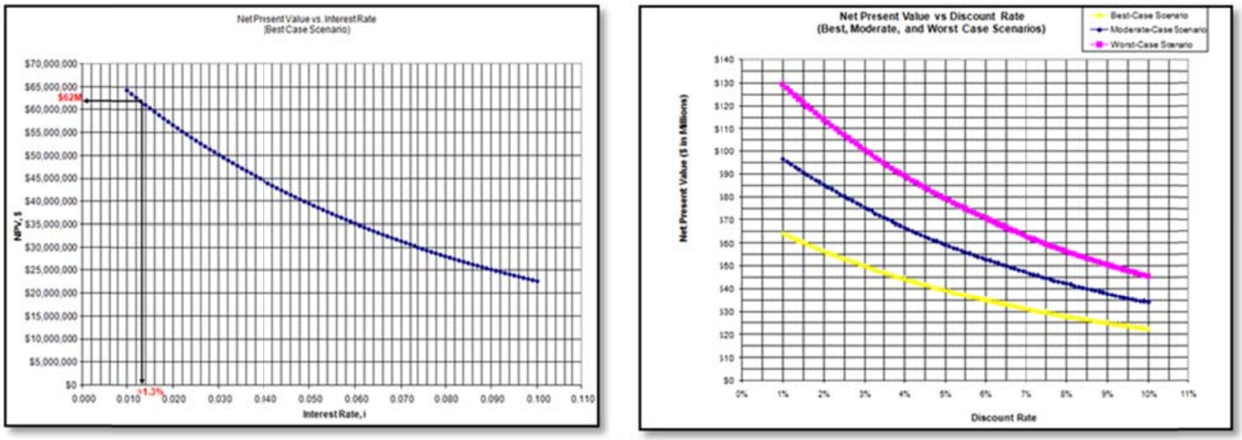


FIGURE 11 NPV vs. Interest Rate and Discount Rate

SECTION III: US 550 PROJECT ANALYSIS

CHAPTER 5: US 550 INNOVATIONS ANALYSIS

5.1 US 550 Case Study

US 550 is the primary trade and tourist route for northwest New Mexico. It leads to the "Four Corners", where Utah, Colorado, Arizona and New Mexico meet at a single point. The route contributes considerably to economic development in northwest New Mexico. The New Mexico State Highway and Transportation Department (NMSHTD) needed to reconstruct and expand the former two-lane highway into four lanes in a reasonable time period within the budget established by the New Mexico legislature and incorporated certain innovations to achieve the goal.

Key Features of US 550 Innovations

The innovative contracting and financing approaches incorporated in the US 550 project have made it a candidate for further evaluation. The following key features are perceived as crucial for defining the US 550 contracting approach. The contractual framework is shown in Figure 12.

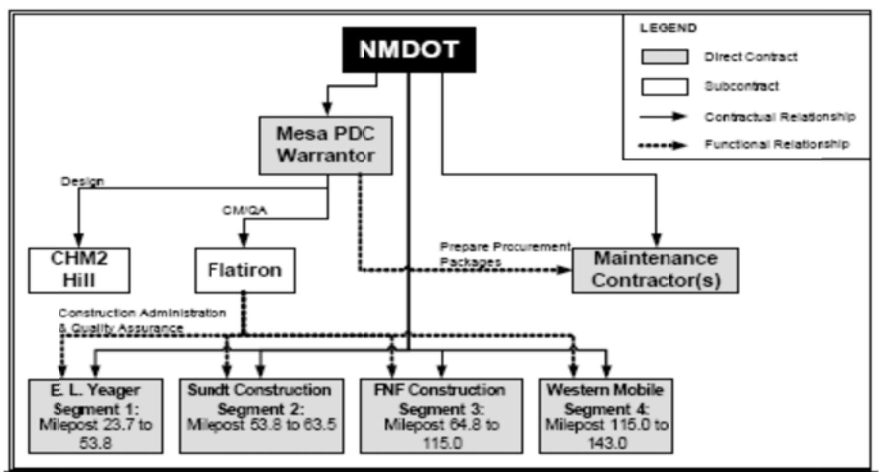


FIGURE 12 US 550 Contractual Framework

- ***Project Financing:*** The strategy used by the NMDOT to secure the funding for US550 through the Federal Highway Administration truly falls under the classification of "innovative financing." For the first time ever, a state issued $295 million of bonds with the sole source of repayment being future federal funds without any state guarantee. The specific bonds utilized are referred to as GARVEE (Grant Anticipation Revenue Vehicles) bonds. The State of New Mexico created a virtually 100% federal-aid project. NMDOT met the requirement to match federal funds through what is called a "soft match." By constructing the southernmost segment of the facility utilizing state funds, the state leveraged those funds to a match for the $295 million project. In addition, the state employed a match waiver that is available where the corridor crosses federal lands.

The financing approach used for the US 550 has been sometimes defined as a Public Private Partnership. This may trigger a question about the effectiveness of public private partnerships. To answer this question, a comprehensive benchmarking evaluation of Public Private Partnership projects is needed. To perform such an evaluation, extensive data for a large number of projects would be needed. This was outside the scope of the RoadLIFE project. Although the US 550 project has sometimes been described as a PPP, this project does not qualify as a PPP project. An recently-published article in the SAGE Journal of Public Works Management and Policy (*49*) provides an explanation. Findings from that study are listed below:

- Only a few PPP projects achieved the expected advantages.
- Most of the PPP projects ended up with higher maintenance cost and poor performance.
- The immaturity of the American PPP market may be one of the reasons for the lack of success.
- It is recommended that when public and private stakeholders come together to deliver a project, "both sectors should play to their strengths, the public as policy maker and standard bearer and the private as an innovator and efficiency expert. The means to this end depend upon balancing the interests of the state, society, industry and market."

Once it is understood that the financing approach for US 550 does not qualify as a public private partnership, other questions may be raised on its effectiveness. The objectives for using this financing approach (i.e., to accelerate budgeting, and therefore project completion and to create a "100% virtual federal-aid project") were achieved for the US 550 project. Therefore, the adopted financing approach can be considered a success. While it was not within the scope of this study, it might be useful to undertake a comprehensive study of how GARVEE bonds affect agencies' budgets in the long term. This is left as a recommendation for future research. Lastly, the financing approach was designed to fund the project up to the completion of construction activities. It looks like there was an assumption that the financing approach would not encompass funding for US 550 maintenance activities and NMDOT matching of warranty expenditures.

- ***Project Consolidation in Segments:*** Under the traditional "pay-as-you go" funding approach, the approach of NMDOT to implement the US 550 corridor would have been to subdivide the road into 5-10 mile segments that would have been redesigned and reconstructed as soon as money became available. Under this approach, completing the 118-mile project would have taken up to 27 years. On the other hand, US 550 was completed in three years thanks to the use of the GARVEE funding mechanism, but also to the consolidation of the road into four segments that were constructed under four separate construction contracts by four different contractors (Sundt Construction Inc., E.L. Yeager Construction, FNF Construction Inc. and Western Mobile). Further, the delivered road would cost about the same to construct in 1999-2000 dollars as a similar highway would have cost in 1997 dollars.

The main goal for selecting this approach was to achieve an early completion of the construction activities. Since the project was completed within a short time frame, this approach can be considered to be successful. As discussed in this report, this innovation was tied with the decision to pursue innovative financing. In the absence of full funding for the project, the Department could not have implemented the consolidation into segments.

- ***Project Delivery System:*** When the US 550 project was conceived, New Mexico State law did not allow the use of design-build contracts. Despite this institutional limitation, delivery of the US 550 project follows an innovative public-private approach based on a Design-Bid-Construction Management-Maintain (DBCMM) model. The US 550 project was able to achieve some of the advantages provided by design-build by being implemented (i.e., opened to traffic) in a short period (three years). Its contractual agreement also includes a long-term warranty – the first of its kind in the United States. Regarding the DBCMM approach, the research team tried to understand if this approach was successful and if a better alternative could be used in the future. These questions are partially answered when discussing NMDOT monitoring requirements in the next section. A more detailed response cannot be provided because of the lack of collaboration by the individuals contacted during the study. Only two individuals (out of more than a dozen invited) agreed to meet with the researchers, and the amount of information collected was not enough to answer the majority of the questions that the researchers intended to ask. For instance, Quality Assurance (QA) was one of the responsibilities allocated to MESA PDC. However, MESA staff was not available for an interview in spite of the schedule flexibility by the researchers. Due to this lack of information, the research team could not know whether the data obtained by MESA were crosschecked with the data obtained by the test conducted (if any) by the DOT. Although a study conducted by the Kentucky DOT reveals that there is not much difference between the contractor-conducted QA data and the DOT-performed QA (*50*), we believe that quality assurance and pavement performance data should be collected by NMDOT, not by the construction contractor or a third party employed by the contractor.

- ***Warranty Program:*** In the warranty agreement, each distress has its own limit and is not combined with any other distress to hide or mask the actual condition of the pavement. The specific types of condition indicators and their corresponding limits include smoothness, cracking, rutting, potholes, and other kinds of surface distress. The condition of the pavement would be assessed on a periodic basis, and an annual maintenance plan would be prepared and submitted for NMDOT review and comment. This annual assessment would give the agency the opportunity to review the condition of the road and the projected pavement management plans. The NMDOT maintenance crews would perform normal non-pavement maintenance along the roadway, such as mowing, snow removal, guardrail replacement and signing. Both preventive and corrective maintenance would be scheduled as necessary for optimum long-term service. As with the initial construction, Mesa would use New Mexico’s normal procurement process to issue bid packages for contractors, who would then perform the maintenance. Corrective maintenance would be performed either by private contractors or in the event of an emergency by state crews. The cost will be reimbursed by Mesa. The NMDOT estimates that the present value of all maintenance costs that it would pay on a conventional highway over a twenty-year period would be approximately $151 million.

Based on this estimate, a savings of $89 million ($151 million less $62 million cost of warranty) is projected by the department over the 20-year warranty period.

Regarding the Warranty Program, several questions have been raised. These questions are proposed below. A response is attempted based on the research team's investigation of common practices around the country.

Should NMDOT consider the use of warranties in the futures? As stated in the NCHRP report on warranty contracting, "warrant[ies] are viable options for contracting of highway construction projects" (*51*, p. iii). The NCHRP guidelines that are summarized in the appendices identified advantages and disadvantages for using warranties. The PIs agree with the NCHRP report on the fact that warranties may be "particularly beneficial in specific situations and, therefore, should be given appropriate consideration in the selection of the contracting method." (*51*)

Do they need to be better monitored? Appropriate quality control and assurance are key issues on every project. Quality processes are highly dependent on the delivery approach. The US 550 project was delivered with a unique and unrepeated delivery method. Under the selected approach, a single private entity was contracted to deliver design services (including bid package preparation), construction management services, and quality assurance services. In addition, this entity is extending its reach throughout the operation and maintenance of the roadway through two warranties (structures and pavement).

While quality processes are well established for traditional design-bid-build projects, there are not established best practices for all the new delivery methods that have been used to deliver highway projects. To address this lack of information for design-build (DB) projects, NCHRP recently published a report that summarizes current practices for managing the quality process on DB projects (*52*). While the US 550 is not a design-build project, some of the information in that report may provide insight on what would be the best way to manage quality on a project that includes warranties. The following paragraphs highlight this information, first in regard to the contract procurement phase, and later, in regard to the project execution phase.

As the report states, quality assurance can start at the procurement phase. DB contracts are usually procured either using a single-step or a two-step procurement process, with the latter being considered best for quality purposes. On the other hand, construction contracts for US 550 were awarded using a low-bid procurement while the US 550 main contract was awarded to the only participant, Mesa PDC. While a comparison is difficult to make between DB and the US 550 delivery, the procurement approaches adopted for US 550 seem in disagreement with the recommendations of the NCHRP report.

During the project execution, the DOT personnel should monitor the delivery of design and construction services. The oversight process by the DOT should be detailed in the procurement documents and repeated in the contractor-provided design and construction quality management plan. While the research team was unable to gain access to a significant number of project participants, information collected from the project panel suggests that the amount of DOT oversight was very limited for this project. The agency strongly relied on Mesa-provided quality assurance with the assumption that Mesa would try to maximize design and construction quality to minimize future warranty expenditures. While this assumption makes sense, the research team suggests that for future projects the agency exercise the right to "over-the-shoulder" reviews. Performing these reviews would allow the agency to provide context-rich (the agency knows NMDOT conditions better than an out-of-state contractor) input to the contractor quality team. Several publications are available that describe the "over-the-shoulder" review process for design-build projects.

Do they perhaps need to include an optional warranty in the contract rather than purchasing it up front? The use of options on services to be delivered after construction completion is a recent subject of discussion within the highway industry. The SH-130 DB project delivered by TxDOT included a maintenance option. For that project, a very complex QA/QC scheme was designed so that risks on design decisions stayed with the design builder while detailed information on the quality of construction was provided to the agency. Using this information, TxDOT could decide to exercise an option that would require the contractor to provide maintenance for 15 years at a pre-established price. While it is too early to reach a conclusion about the effectiveness of this approach, the SH-130 scheme may suggest how construction QA and warranty/maintenance options are interrelated. This relationship has been strongly suggested in a recent NCHRP report (*52*).

The rationale for using a warranty/maintenance option is that a warranty may not provide much value when a project is well done, as the warranty is going to end without any major problems and the failure cost will not be more than the warranty cost. After calculating and comparing the potential failure cost with the warranty cost, the choice of whether or not to choose a warranty option should be made (*21*).

Thus, deferring the decision to purchase a warranty is expected to provide the agency two benefits. First, the agency may base its decision on observed construction quality. Second, a contractor is expected to produce a better quality product if there is a chance that the agency elects the warranty/ maintenance option at a pre-established price.

How can NMDOT improve this process in the future? The US 550 approach was strongly affected by the state statutory procurement approach, which lacked the authority to pursue design-build and public private partnerships. If the state decides to keep pursuing innovative delivery and financing approaches, it is suggested that the state develop a regulatory environment that enables and nurtures innovation. Over the last decade, many states have been pursuing innovative delivery and financing. Therefore, a large number of lessons learned are available for use by the NMDOT. As a matter of fact, the cited NCHRP report on warranty contracting is only one of many research deliverables that are available to transportation staff and decision makers.

- ***Public Outreach:*** As part of the partnering process, the team includes 40 agencies in their regular partnering meetings. These include the cities, towns, villages, tribes and pueblos, county officials, universities, landowners, utility organizations, private organizations, the Associated Contractors of New Mexico, as well as several state and Federal agencies. NMSHTD and Mesa PDC knew agency partnering alone would not be enough for such a huge project. So, they sought ways to actively involve and address the needs of the public and construction communities that would be impacted by the NM 44 project. Two executive-level and three project-level partnering sessions were facilitated during the detailed engineering phase. Two formal value engineering reviews were also conducted. The attendance included FHWA, utilities, a local village mayor, engineering firms, environmental consultants, botanists, US Forest Service, BLM, NM Department of Labor, representatives of the Zia pueblo, the Navajo nation, the Jicarilla Apache, Associated Contractors of New Mexico, University of New Mexico and construction contractor consultants. Throughout all of these events, "creative tension" was a natural outcome, but this has generated many innovative ideas that NMSHTD can carry forward to other projects. All partners had a mutual respect for each other, and all were committed to thinking about the long term and at a global level. Incentives encouraged all parties to co-operate in the project (*53*).

US 550 Cost

The Pavement Warranty expires after:

20 years of service life

4,000,000 equivalent single axle loads (ESAL)

- $110 million total pavement expenditures for the pavement warranty

The Structures Warranty (bridges, culverts, erosion, and sediment control) expires after:

- 10 years of service life
- 2,000,000 equivalent single axle loads (ESAL)
- $4 million total structures expenditures ($2 million NMDOT + $2 million Mesa PDC), for the structures warranty

Evaluation of the effects of the aforementioned key innovations and benefits of the US 550 warranty contract on cost, time, and quality is very important. As mentioned previously, pure performance-based contracting is not widespread in the highway construction industry, including in New Mexico. Indeed, the warranty aspect of the US 550 contract is something new for the NMDOT. Therefore, determination of the lessons learned from this warranty project is crucial for implementation of future warranty projects in New Mexico.

TABLE 3 US 550 Costs

Task	**Party Involved**	**Expenditure (in millions)**
Design/ Construction Management	CH2M HILL/ Flatiron Structures	$ 46.32
Construction	Sundt Construction Inc., E.L. Yeager Construction, FNF Construction Inc. and Western Mobile	$ 215.00
Warranty	Mesa PDC	$ 62.00
	Total	**$ 323.82**

5.2 US 550 Innovation Findings and Recommendations

The two most typical characteristics of the US 550 project are: the warranty period and the warranty cost. The warranty is the first of its kind in the United States. Critics say $62 million seems like a lot of money to maintain a road that was touted for its high quality (*54*). Mesa PDC told the state in its formal proposal in December 1997 that while initial construction costs are high, the improved road would require "minimum maintenance." As warranties are quite new in the U.S., there are not enough data to conclude whether warranties are convenient or not. Among the few examples of long-term warranties for roads within the U.S. (see section 3.1.5.1), the majority have opted for warranties covering five years or less of the operations. Usually, the cost of these warranties was included in the basic bid. Another highly criticized US 550 aspect is the 20-year term. Because they have to cover a longer period, long-term warranties produce a higher initial investment when compared with short-term warranties.

The US 550 approach included an upfront payment of $62 million to Mesa PDC to make sure the pavement is properly maintained for 20 years after completion and the structures are properly maintained for 10 years. In addition, the warranty agreements include two other conditions that may produce an early expiration of the warranty commitment by Mesa PDC. The first condition is related to the amount of traffic, with a traffic ceiling provided in ESAL. The second condition identified a ceiling to the total amount to be spent by the warrantor on each of the two classes of assets (i.e., pavement and structures).

The Warranty Option (see section 3.1.5.4) could have been applied on the US 550 project, as much money has been spent during the construction phase to improve the quality. If the Warranty Option was adopted, the state might have saved $62 million on a warranty after scrutinizing the quality of the project. A Warranty Option would give the state the option to select whether to go or not to go with the warranty contract after construction; or in other words, they could have delayed their decision and would not have to buy the warranty during the bidding phase. However, the state would have needed to control the project quality closer, either using its own personnel (with additional administrative costs) or an independent quality assurance contractor (with additional quality assurance costs).

An interesting finding was that one of the contract provisions may produce another pathway to an early termination of the warranty contract. Basically, Mesa PDC determines when repair work is needed, but the agency is required to initiate the work through the selected maintenance contractors and to advance the cost of these repairs. Later, the agency may submit a request for reimbursement to Mesa PDC. This clause determines an unusual situation where the warrantor can request significant cash advances from the agency regardless of the availability of these funds at that specific time.

Another situation that aggravates the management of the warranty from the agency's side is the fact that Mesa PDC will reimburse only a part of the repair costs. In fact, the warranty contract includes an attachment that was designed to retain the risks associated with material cost escalation to the agency. However, the formula adopted is unique and, unfortunately, adds additional stress to the agency's way of managing the warranty.

US 550 used the GARVEE as a financial option along with project consolidation in four segments, which helped NMDOT complete the project in three years instead of 27 years. From a financial standpoint, the disadvantages of GARVEE persist (see section 3.2.1.1). Some legislators are concerned that a shortfall in future federal highway funds will affect other New

Mexico road projects because the US 550 bonds have first priority on federal money, which accounts for nearly half the state's $608 million highway budget in 2000 (*54*). Only a few states have used this method of borrowing money so far. All the other states (such as Arkansas, Colorado, Massachusetts, Mississippi and Ohio) are funding their road projects with bonds, which require either legislative or voters approval first.

Besides, unlike the other states that have issued the bond, New Mexico has not articulated how it will pay them off if future federal funding falls off. Other states like Mississippi have pledged state revenue if that happens (*54*). If there were chances of generating considerable revenue from US 550, NMDOT could have opted for Transportation Finance and Innovation Act (TIFIA).

Some suggestions to improve the way NMDOT uses warranty contracts were made by one of the interviewees:

NMDOT should be more involved during the design and the construction management and quality assurance process. This suggestion may prove particularly useful if the NMDOT decides to consider warranties under a Warranty Option mechanism (see previous sections).

NMDOT should be ready for immediate maintenance impact. On US 550, there is no set-aside money for the maintenance. This created problems for the contractors involved or for the agency's staff that oversee the maintenance process. For example, the DOT may have allocated only $6 million for maintenance where $10 million is required in a certain year. Hence, money may not be available when it is needed.

When there is any emergency problem, the agency is obligated to undertake appropriate actions. However, the current arrangement on US 550 does not allow the agency to use the ordinary maintenance contractor, as the state contractors are not in the emergency clause. As a result, undertaking emergency repairs takes longer than desired. Therefore, it would be better to have a specific contractor with a single contract dedicated to warranty repairs. This contract could include two separate timelines for repairs — one for standard work and the other for emergency work (e.g., damages due to floods). Another option could be to have the warranty contract designed to have the warrantor in charge of scheduling and managing maintenance operations (i.e., warranty/maintenance contract).

TABLE 4 US 550 Innovations Matrix

	Project Financing (GARVEE)	**Project Consolidation**	**Project Delivery System (Design – Bid – Construction Management - Maintain)**	**Warranty**
Advantages	• Useful for states under tight budget condition (*55*) • Speeds up Project delivery (*55*) • Reduces effect of inflation on project cost (*5*) • Instant funding of construction projects (*5*) • Does not add to state debts, thus not affecting legal limit (*5*) • Not interfered by State Legislature and Public Consent (*5*)	• Useful for big project to be completed in short time • Involvement of more than one contractor • Opportunity for local contractors	• Probability of achieving best value • More professional relationship with the constructor • Constructability input from the Construction Manager(CM) during the design phase • Transfer of QA/QC responsibility from owner to CM Company	• Compatibility with the low bid system • Saving in use of owners resources • Probability of achieving higher quality projects • Shifting of post-construction responsibilities and risk from agency to the contractor • Chances of contractor's innovation to achieve project objectives in less time (*4*)
Disadvantages	• Accumulation of debt without producing revenue • May affect overall federal budget adversely • Risk of Federal Highway Program (FHP) not being approved by Congress May trigger raise in gas tax (*5*)	• More than one point of contract	• Multiple points of responsibility • Clients must manage more contracts • Slower than Design – Build	• Not favorable for small contractors, thus affecting open competition • Extensive use of resources upfront for training and implementation (*4*)
Implementation Steps	1) Selection of project recommended by FHWA and regional transportation planning agency 2) Testing the	1) Assessment of the extent of the project 2) Estimation of the time taken to complete the project, if executed by	1) Through study of the project objective and the circumstances under which it is to be constructed 2) Identifying	1) Identifying implementation objective and availability of resources for implementation 2) Investigation of the best practices 3) Decision of whether

	Project Financing (GARVEE)	**Project Consolidation**	**Project Delivery System (Design – Bid – Construction Management - Maintain)**	**Warranty**
	project design for environmental clearance 3) Contractual paperwork to provide the state with the funding 4) Depending on the nature of GARVEE plan selected, the payment plan is determined as described in section 3.3 (*5*)	single contractor 3) Calculation of the time in which the project is desired to completed 4) If the time calculated in step 4 is much smaller than step 3, the number of sections in which the project is to be split is determined. 5) Then each section is designed and bid out separately. 6) Each segment is handed over to a different contractor	factors affecting Project Delivery i.e. owner characteristics, project characteristics, design characteristics, regulatory circumstances, contractor characteristics, risk associated and probability of claims and dispute 3) Use of survey results and multi-criteria decision making to determine the proper project delivery method	to go for warranty or not 4) If no, stopping warranty contracting process 5) If yes, co-operation and communication with the parties involved 6) Preparation of specification 7) Implementation on a pilot project 8) Bid document Preparation 9) Project execution 10) Evaluation of effectiveness 11) Evaluation of the process to understand whether it is beneficial 12) If no, suspension of warranty contracting for future projects. 13) If yes, modification of the existing process to perfection. (*4*)
US 550 Goals	• To accelerate budgeting, and therefore project completion • To create a "100 % virtual federal – aid project"	• To accelerate project completion	• To accelerate project completion • To minimize agency oversight during delivery	• To transfer risks associated with pavement and structure quality to private party to increase the probability of achieving a high quality project • To save "$89 million … on maintenance over a warranty period of 20 years"
Analysis	The two above mentioned goals were achieved.	The above mentioned goal was achieved.	The two above mentioned goals were achieved. However, the decision of outsourcing QA services may have produced some of the issues reported	To date about $24 million has been spent for performing maintenance activity on US 550. Only about $16 million has been reimbursed by MESA. "Review MESA proposal with projection cost."

	Project Financing (GARVEE)	Project Consolidation	Project Delivery System (Design – Bid – Construction Management - Maintain)	Warranty
			after completion. While it was not possible to obtain detailed information on the QA management, it seems that DOT personnel were scarcely involved in these activities. The literature review pointed out that different approaches are more successful in guaranteeing long-term quality results.	

CHAPTER 6: BENEFITS OF US 550 ROAD IMPROVEMENTS

6.1 Travel Benefit Evaluation

The benefits associated with the construction of a new highway or the reconstruction of an existing highway are the difference in road-user costs between the former road condition and those that exist after the facility is improved. These benefits may be evaluated using the techniques of engineering economy, which Winfrey (*56*) defines "as that phase of engineering which has to do with the analysis of proposed engineering works, equipment, and processes to determine the relative worth of the net economic gains to be expected from the proposals in relation to the net economic costs required to produce the gains." Furthermore, Winfrey notes that "the analysis for economy is *wholly money based*; therefore, the factors that are priceable on the market are separated from those non-market factors that cannot be market-priced." What this means is that factors such as social consequences, despite their importance, are omitted from the calculations. For example, motorist comfort and convenience, pollution reduction, and aesthetic improvements, which do not have market values, are not incorporated. This does not mean, however, that the redesign of a highway should ignore any or all of these factors.

The primary road-user benefits associated with the reconstruction of US 550 are:

- A reduction in travel time for those driving in the corridor
- A potential decrease in motor vehicle operating costs
- A decrease in the number and/or severity of motor vehicle crashes

6.2 Travel Time Benefits

The reduction in travel time occurs on the rural portions of US 550, specifically the 116 miles outside of Cuba, NM. A motorist traveling on the reconstructed road at 70 mph would require 1.66 h to travel the 116 miles. Because the road now has four lanes, it's logical to believe that a motorist could easily travel at 70 mph. On the old road, a motorist traveling at 60 mph would require 1.93 h to travel the same distance. Because the former roadway only had one lane in each direction, however, it is possible that a motorist might encounter a slower-moving vehicle and be forced to reduce speed until it was safe to overtake the lead vehicle. Based on the foregoing calculations, a motorist on the reconstructed roadway would save 0.27 h, or about 16 minutes in one direction.

Additional factors in the calculation of the travel time benefit are the amount of traffic, vehicle occupancy, and the monetary value of time. Traffic volumes were obtained from the NMDOT's Planning Bureau. In 2007, the two-directional traffic volume on US 550 ranged from a low of 2,698 between mileposts 85.49 and 102.77 to a high of 13,889 between mileposts 123.47 and 143.00. Clearly, many trips along US 550 do not travel the entire route. However, motorists will enjoy a portion of the travel time reduction even if they travel only part of the route.

Because the traffic volumes vary along the route, an average traffic volume was calculated in the following manner. First, the daily travel along the route was calculated by summing the products of the section lengths and the daily traffic volumes; this result was multiplied by 365 to determine the annual travel, which is used later in the accident rate calculations. The average traffic volume was obtained by dividing the annual vehicle-miles of travel by the product of 116 miles and 365 days per year. The results for 1993 through 2007, excluding the three construction years, are plotted in the accompanying figure. The daily traffic volume grew from 2,772 in 1993 to 6,234 in 2007, corresponding to a compounded annual growth rate of 6%. The least-squares regression line (r=0.91) for the relationship between year and traffic volume is given in Figure 13.

Traffic Volume = -345,172 + 174.67*Year

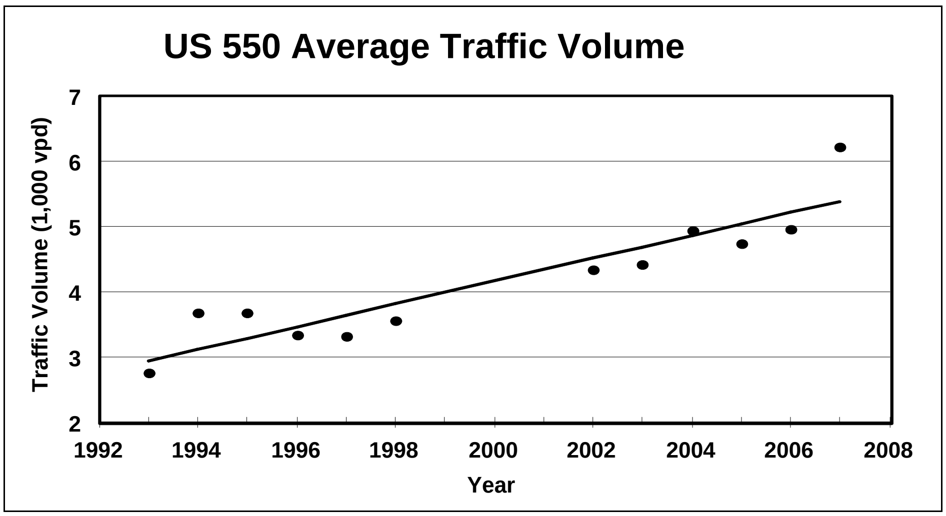


FIGURE 13 US 550 Average Traffic Volumes

A second relevant factor is the monetary value of time. This value certainly varies from one person to another, and could vary for any individual from one time to another. For example, a motorist who is driving while employed (e.g., a truck driver) would have one value, while the same person traveling on a vacation to the Four Corners area would likely have a lower value. Because the exact characteristics of the travelers are unknown, and they certainly vary by season, it was assumed that motorists could be subdivided into three groups:

- Professionals, 5%
- Truck drivers, 20%
- Casual travelers, 75%

Professional travelers would be those traveling while employed. The web site salary.com (*56*) was reviewed to determine the median salaries of eight professions: physician ($148,342), pharmacist ($106,764), project manager III ($96,742), attorney ($89,453), registered nurse ($62,089), engineer ($58,238), architect ($56,637), accountant I ($41,560). These values average to $82,500/year, or $39.65/h. For the purpose of this analysis, it will be assumed that professionals traveling on US 550 are alone in their vehicles.

Truck drivers, who also typically drive alone, earn a wage (or, in some cases, a mileage-based rate) while driving. They may drive large tractor-trailers, single-unit trucks (such as UPS trucks or concrete mixers), or in some cases, heavy-duty pickup trucks. The website payscale.com (*37*) reports on median hourly rate for heavy truck drivers by years of experience. The median rate for drivers with 10-19 years of experience is $15-21/h; the middle point of $18/h was used in this analysis.

The largest category of motorists falls into the casual traveler category. These individuals include farm/ranch workers, homemakers, vacationers, and even some youngsters. Although some may travel alone, many will travel in vehicles with multiple occupants. This is especially true for vacationers and shoppers visiting Albuquerque, the Four Corners area, and even Cuba. Some may have a very low monetary value of time, while others might be closer to the lower end of the rate for truck drivers. To avoid overestimating the monetary value of time for these travelers, the researchers elected to use the current New Mexico minimum wage rate (*58*) of $7.50/h. By recognizing that an individual vehicle may contain just a single driver or a family of several, this analysis assumed that the average vehicle occupancy was 1.75 occupants per vehicle.

Using the foregoing percentage distributions of travelers, hourly values of time, and vehicle occupancies, the weighted average value of time for a vehicle on US 550 is given by the sum of the products of the share of travel, vehicle occupancy, and the monetary value of time:

Value = 0.05*1*$39.65 + 0.20*1*$18.00 + 0.75*1.75*$7.50

= $15.43/h

The daily travel time benefit per vehicle on the reconstructed US 550 is the product of this value and the average daily traffic on the route; the annual benefit is calculated by multiplying this value by 365 days/yr. In 2007, this would be:

Annual Travel Time Benefit = 0.27h*$15.43/h*6,234veh/day*365days/year

= $9.4 million/yr

6.3 Vehicle Operating Cost Benefits

Many early highways were economically justified in part because they reduced vehicle operating costs. Smoother highways produced less wear and tear on vehicles and helped to reduce fuel consumption. Redesigns that reduce stop-and-go driving also reduce brake wear. Tire wear and balance can also be reduced by eliminating potholes. However, in the case of the reconstruction of US 550, the most obvious vehicle operating cost affected is fuel consumption. One source (*59*) reports that "tests have shown that most cars use about 20% less fuel driving at 90 km/h (56 mph) than at 110 km/h (68 mph)." The primary reason for this is that the air resistance of the vehicle increases with the square of the vehicle's speed. The same article notes that using cruise control on the highway reduces fuel consumption by 15-30%. The use of cruise control for extended distances is more feasible on the new four-lane road than on the old two-lane road. Considering the increased fuel consumption associated with higher operating speeds and the decreased fuel consumption associated with using cruise control, it is reasonable to conclude that the net effect of the reconstructed US 550 on fuel consumption is negligible.

6.4 Safety Consequences

One of the justifications for the reconstruction of US 550 was the perceived lack of safety on the old road. Indeed, several safety issues were considered in the redesign of the roadway. The safety features introduced on the reconstructed road include:

- Four lanes, reducing the need for passing maneuvers in the opposing lane
- Rumble strips on the shoulder and median to reduce encroachment
- Left-turn lanes at intersections to remove turning vehicles from the through lane
- Clearer roadsides to minimize the consequences of encroachment
- Judicious use of guardrail designed to modern standards

Using US 550 crash data for 1996-1998 (*before*) and 2002-2008 (*after*) furnished by the University of New Mexico's Division of Government Research, the crashes on the route between mileposts 24 and 142 were evaluated. Overall, the crash experience increased from 85 per year in the *before* period to 116 per year in the after period, an overall increase of 36 percent. The number of crashes by year is shown in the accompanying figure. Figure 14 also shows the best-fit linear regression line, which depicts an annual increase of four crashes per year over the eleven year study period.

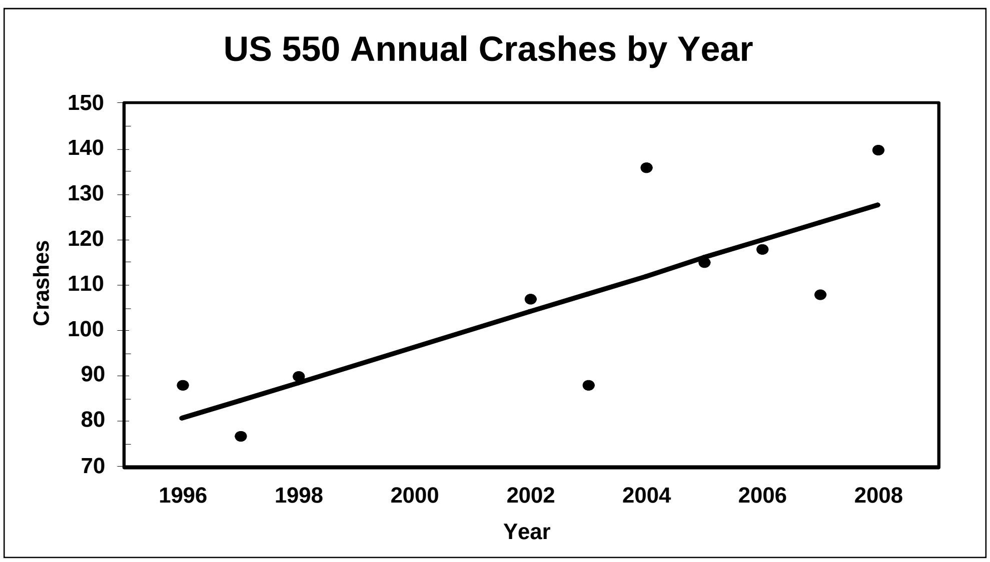


FIGURE 14 US 550 Annual Crashes by Year

The increase is not unexpected given the substantial increase in average traffic volumes shown in an earlier figure. The situation certainly would have been worse if the road had remained in its former two-lane configuration. In an effort to develop a better understanding of the crashes on US 550 before and after the reconstruction, comparisons were conducted of selected crash characteristics, specifically severity, day of the week, and crash class. The results are presented in the following tables. Table 4 shows the number per year and percentage of crashes by severity in the *before* and *after* periods. Despite the increase in the number of crashes, the severity of crashes decreased in the *after* period, as reflected by the fact that the percentage of property damage only crashes increased, while the percentage of injury and fatal crashes decreased.

TABLE 4 US 550 Crash Severities

	Before		*After*	
Severity	Number/yr	Percent	Number/yr	Percent
Fatal	3.3	3.9	3.6	3.1
Injury	32.3	38.0	37.4	32.3
Property Damage Only	49.3	58.0	75.0	64.7

Table 5 shows the distribution of number of crashes per year and the percentage of crashes by day of the week. As indicated by the table, the percentage of crashes occurring on Monday, Wednesday, and Saturday decreased in the *after* period, while the percentage increased on the other four days of the week. The most significant changes include a five percent increase on Sunday and a five percent decrease on Saturday. These changes might be due to variations in traffic volumes on these days or possibly some days with inclement weather.

TABLE 5 US 550 Crashes by Day of the Week

	Before		*After*	
Day of the Week	**Number/yr**	**Percent**	**Number/yr**	**Percent**
Sunday	9.7	11.4	18.9	16.3
Monday	13.0	15.3	16.7	14.4
Tuesday	11.7	13.7	16.9	14.5
Wednesday	11.0	12.9	13.0	11.9
Thursday	12.0	14.1	17.9	15.4
Friday	12.7	14.9	17.9	15.4
Saturday	15.0	17.6	14.0	12.1

The relatively small increase in the percentage of overturning crashes, most of which occur off the roadway and which should be ameliorated by the shoulder rumble strips, is likely due to the increase in speed limit, which permits less room for driver error; however, crashes in this class are quite survivable for occupants restrained by safety belts. The more substantial increase in the proportion of fixed object accidents is, at first glance, surprising. On further consideration, the roadway was redesigned within a restricted right-of-way, resulting in more retaining walls in cut sections and more guardrail on fill sections, thus providing more opportunities for fixed object impacts.

TABLE 6 US 550 Accident Classifications

	Before		*After*	
Class	Number/yr	Percent	Number/yr	Percent
Overturn	17.3	20.4	25.0	21.6
Other non-collision	4.3	5.1	5.0	4.3
Pedestrian	0.7	0.8	0.9	0.7
Other vehicle	23.3	27.5	25.4	21.9
Vehicle on other roadway	0.0	0.0	0.3	0.2
Parked vehicle	2.3	2.7	1.0	0.9
Animal	20.3	23.9	28.1	24.3
Fixed object	15.7	18.4	28.7	24.8
Other Object	1.0	1.2	1.6	1.4

Numerous factors can affect the number and severity of crashes. At the simplest level, increases in traffic volume may increase crash frequency. Some, such as roadway design and pavement friction, are under the control of the engineer. Others, such as weather, level of enforcement, and driver-related factors, are not. Two simple examples emphasize this point. A decision by the New Mexico State Police to focus on speed limit, safety belt usage, or impaired driver enforcement should enhance highway safety. On the other hand, a winter with an unusual amount of snowy roads or a monsoon season with an unusual amount of rain can increase crash occurrence. To help account for the traffic volume variations, comparisons can be based on crash rates. However, the most realistic way to account for factors such as weather or enforcement, which the highway engineer cannot control, is to incorporate in the analysis comparison routes that were not altered during the study period. Although there is no guarantee that a comparison route will experience identical enforcement and weather conditions as those that existed on US 550, the selection and use of appropriate comparison sites should help to place the observed changes in the proper context. Former UNM graduate student Monica Jaramillo consulted with NMDOT engineers in 2007 and they jointly identified three potential comparison sites, which were two-lane rural state highways in both the *before* and *after* periods. These routes are:

- US 60, Milepost 78 to 138
- US 64, Milepost 376 to 421
- US 491, Milepost 8 to 94

The University of New Mexico's Division of Government Research provided the researchers with crash data for these three route segments for the periods 1996-1998 and 2002-2008. The NMDOT's Planning Bureau provided two-directional traffic volumes for these segments for the same time periods. The crash experience on all three of these comparison routes decreased between the *before* to the *after* period: on US 60 from 20.7 crashes per year to 11.9 (-42%), on US 64 from 31.7 crashes per year to 30.0 (-5%), and on US 491 from 115.0 crashes per year to

80.6 (-30%). Table 7 compares the percentage distribution of crashes by severity in the *before* and *after* periods for US 550 and these three comparison routes; the *after* percentages are shown in parentheses. As shown in the table, the proportion of crashes that resulted in a fatality increased during the *after* period on both US 60 and US 491. However, this finding must be viewed carefully; given that the total number of annual crashes on both these routes decreased substantially in the *after* period, the absolute number of fatal crashes actually decreased on both routes. The figure on the following page shows the annual variation in crashes on each route in the *after* period in comparison with their values in the 1996-1998 *before* period. Overall, crashes on US 64 decreased by a small amount while those on US 60 and US 491 decreased by larger amounts.

TABLE 7 Crash Severity Distributions

Route	US 550	US 60	US 64	US 491
Fatal	3.9 (3.1)	3.2 (4.8)	4.2 (3.8)	4.9 (5.9)
Injury	38.0 (32.3)	48.4 (41.0)	41.1 (41.9)	44.1 (45.2)
Property Damage Only	58.0 (64.7)	48.4 (54.2)	54.7 (54.3)	51.0 (48.9)

Using the traffic volume data by roadway segment, vehicle-miles of travel during each year from 1993 through 1998 and for each year from 2002 through 2007 were computed for US 550 and for each of the three comparison routes. Travel varies widely among the routes, so to portray that change from year to year, each route's travel was normalized to 1993. The results are plotted in Figure 16.

Using the annual travel data, crash rates were calculated for the period 1996-1998, and for each year in the *after* period. Table 8 shows the calculated crash rates for the routes in the three- year *before* period and for each year in the *after* period.

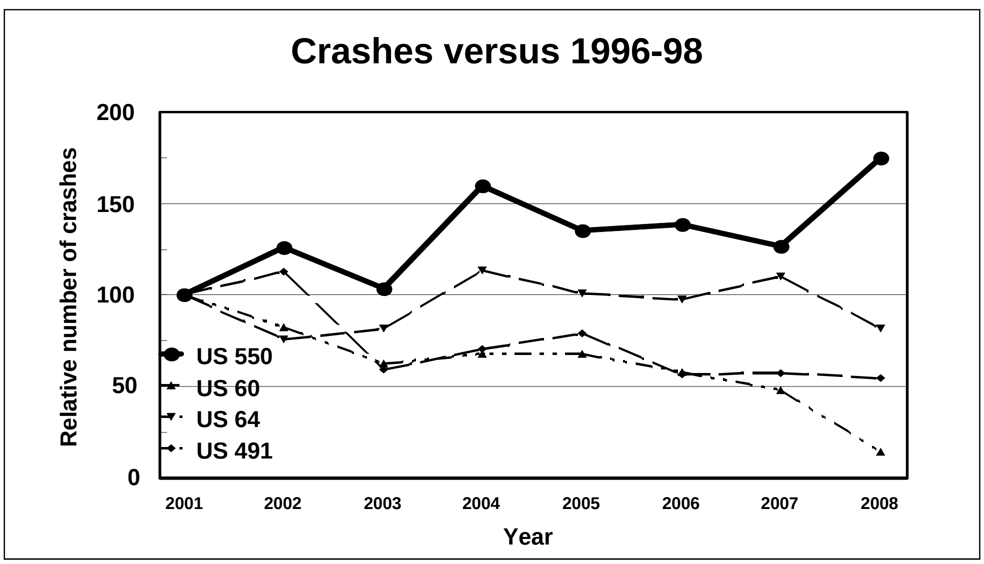


FIGURE 15 Crashes versus 1996-98

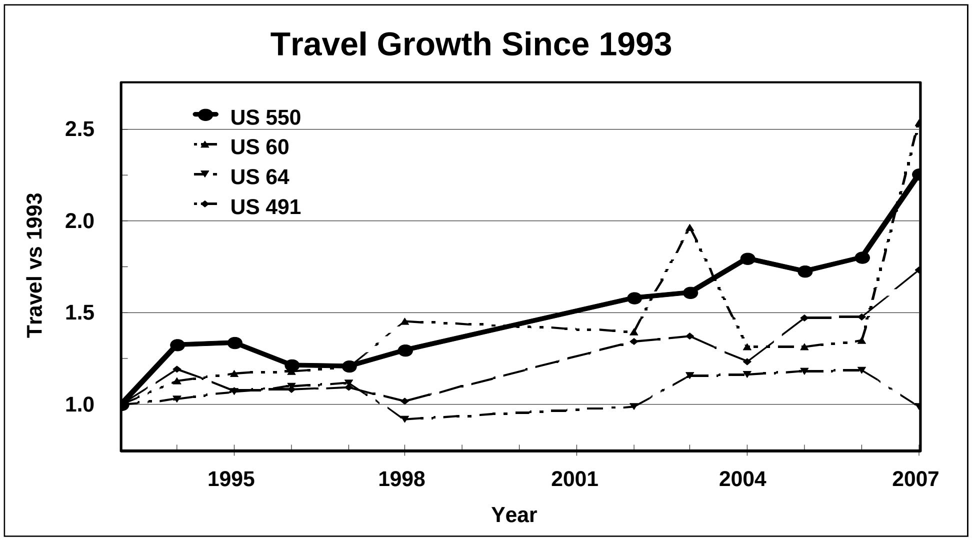


FIGURE 16 Travel Growth since 1993

TABLE 8 Crash Rates per million vehicle-miles (mvm)

Route	*Before*	2002	2003	2004	2005	2006	2007	2008
US 550	0.59	0.58	0.47	0.65	0.57	0.46	0.41	0.55
US 60	0.74	0.56	0.30	0.49	0.49	0.41	0.18	0.05
US 64	0.67	0.54	0.50	0.69	0.60	0.58	0.78	0.56
US 491	0.84	0.75	0.39	0.51	0.48	0.34	0.30	0.27

As shown in the figure, travel on US 64 was little changed over this 14 year period, while it grew by 75% on US 491 and by 150% on US 60. On US 550, it grew by 125%. Table 5 indicates that, with the exception of 2004 and 2005, crash rates on US 550 and the comparison routes have trended downward. The most dramatic decreases in crash rates occurred on US 60 and US 491. With the exception of 2007, the crash rates on US 64 closely parallel those on US 550. All of the crash rate results must be viewed cautiously, because valid crash rates require both reliable traffic volume data and complete and accurate reporting of crashes.

Table 6 provided a general overview of the crash classification on US 550. A more refined examination using the parameter "Accident Analysis," or simply Analysis, provides a better picture of the types of collision. During the *before* period, the most common crashes were overturning on the road or roadside (17.3/year), deer/elk/game animal (15.3), opposite direction sideswipe (6.0), guardrail (5.7), same direction rear-end (4.3), and opposite direction head-on (4.0). During the *after* period, the most common crashes were overturning on the road or roadside (25.0/year), deer/elk (23.3), guardrail (13.3), same direction rear-end (6.6), same direction sideswipe (5.7), and opposite direction sideswipe (4.6). Perhaps the best finding in the *after* period is that the opposite direction head-on collisions were cut in half to 1.9/year despite the increase in travel documented in the Figure 16 on the previous page.

6.5 Cost of Crashes

The principal investigator previously developed a model (*60*) for calculating the expected cost of a traffic accident based on the manner of collision and the route characteristics (urban or rural). The methodology, based on the injury outcomes of over 250,000 New Mexico traffic accidents during the period 1992-96, provides a rational method for estimating crash costs. The expected costs per crash on rural and urban NMDOT-administered roads are shown in Table 9.

These costs were applied to the US 550 crashes in the *before* and *after* periods. For example, during 1996-98, US 550 had one angle collision at an intersection involving a left-turning vehicle; in the seven year *after* period, there were nine of these crashes. In other words, these crashes increased from an average of 0.3 per year in the *before* period to 1.3 per year in the *after* period. Using the $162,000 per rural intersection angle left-turning crash shown below, the expected annual cost of these crashes on US 550 jumped from $54,000 to $208,000, an increase of 286%. Similar calculations were performed for the other crash types that occurred on US 550 during the *before* and *after* periods; several of the larger increases and decreases in annual expected cost are shown in Table 10.

Some of these changes are quite logical. The dramatic increase in guardrail crashes, for example, is due to the fact that reconstructed US 550's steep embankments required more use of guardrail. The increase in overturning crashes may be due to increased travel speed, but it may also reflect the increased travel on US 550. At the same time, the installation of channelized left-turn lanes at intersections removes left-turning vehicles from the through lanes, thus lessening the opportunity of same direction left-turn crashes at intersections. In addition, the provision of wide shoulders and flat roadside on many sections of road reduces that likelihood of an impact with a parked vehicle.

Overall, the annual cost of all traffic accidents on US 550 increased from $12.8 million in the *before* period to $14.9 million in the *after* period. There is good news, however; because the average annual number of crashes increased from 85 to 115.9, the expected cost of a crash dropped from $150,000 in the *before* period to $128,000 in the *after* period.

TABLE 9 Expected Cost per Crash, $

Collision Type	Rural	Urban
Pedestrian	1,101,000	507,000
Pedal cyclist	303,000	114,000
Overturning	247,000	166,000
Intersection, ≥2 vehicle	*125,000*	*45,000*
Angle, Straight	177,000	68,000
Angle, 1 l Left-turn	162,000	51,000
Same Direction, Rear End	61,000	30,000
Same Direction, 1 Left-turn	97,000	25,000
Opposite Direction, Left-turn	178,000	75,000
Other	72,000	23,000
Non-Intersection, ≥2 vehicles	*168,000*	*37,000*
Opposite Direction	435,000	168,000
Same Direction	86,000	33,000
Other	118,000	39,000
Fixed Object	*70,000*	*40,000*
Embankment	131,000	75,000
Tree	120,000	91,000
Abutment, Utility Pole	104,000	65,000
Culvert, Ditch	80,000	38,000
Guardrail	79,000	67,000
Other	40,000	30,000
Driveway-related	86,000	36,000
Parked Vehicle	114,000	27,000
Animal	11,000	10,000
Other Accidents	18,000	32,000
All Collisions	138,000	48,000

TABLE 10 Crash Costs for Selected Crash Types

Crash Type	Crashes/yr		Expected Cost, $1000		% Increase
	Before	***After***	***Before***	***After***	
Intersection, Angle, 1 LT	0.3	1.3	54	208	286
Guardrail	6.0	13.3	474	1,050	121
Non-Intersection Same Direction	5.7	12.3	487	1,057	117
Embankment	1.0	2.0	141	282	100
Other Fixed Objects	6.0	11.6	240	463	93
Overturning	17.3	25.0	4,281	6,175	44
Enter/Leave Driveway	2.0	1.0	172	86	-50
Parked Vehicle	2.3	1.0	266	114	-57
Intersection, Same Direction	0.7	0.3	48	21	-57
Intersection, Same Direction, 1 LT	0.7	0.1	65	14	-79

CHAPTER 7: US 550 ECONOMIC DEVELOPMENT IMPACT

The on-line files of the San Juan Economic Development Service (*61*) were reviewed in an effort to determine the economic development impact of the reconstructed US 550. Farmington-Aztec-Bloomfield is one of 363 metropolitan areas in the United States. According to the SJEDS, the area ranks about 300th from the top on many economic development indicators. However, it ranks 160th in average wages, possibly due to a large number of decent paying jobs in the mining and oil/gas sectors. Over the period 2001 through 2006, employment in the area grew by 10 to 15 percent in retail, mining, health, construction, wholesale, and other services. Over the same period, employment in local government, administration, professional services, and restaurants/hotels remained virtually unchanged.

Other indicators of economic impacts come from occasional newspaper stories. For example, an article in the January 2, 2010, edition of the Albuquerque Journal reported on the development of the Dillion Industrial Park in Aztec. The park, started in 2005, initially attracted a drilling company, which currently employs 180. Since then, Pepsi Bottling Company opened a 60,000-square-foot plant that brought in 75 jobs. NalCo, an oil and gas service company, is building a $2 million facility in the park, where it will employ 50. Federal Express built a $3 million facility that also employs 50. Although the additional jobs are certainly a positive sign, especially in the tight economy, it is not possible to directly attribute the park development or the additional employment to the reconstruction of US 550. Part of the initial justification for the reconstruction of 118 miles of US 550 under an innovative scheme for its design and construction was to achieve the road-user benefits of an improved, 4-lane roadway in a short period rather than over an extended period of time that would have been required if the reconstruction was done serially in 5-mile segments. But there is a complementary set of benefits that may occur to others along the corridor in their roles as employers, employees, and communities seeking to attract businesses. These benefits come in the form of increased economic activity along and at the ends of the corridor.

When companies seek to locate or expand a business or industry, they typically consider a number of factors about the area, including the availability and skills of the local workforce, area amenities, and the willingness of the community to accept them. A critical concern for many businesses is the availability of good transportation access. In this regard, a lengthy 2-lane road, such as the former NM 44 connecting central New Mexico to the Four Corners area, was *not good transportation access*. In the mid-1990s, the Farmington-Aztec-Bloomfield-Shiprock area was the most populous region in New Mexico without access provided by either an Interstate highway or a divided 4-lane road. This is reflected by the following table, which shows the 12 most populous counties in New Mexico; prior to 2001, San Juan County was the only one without access to other parts of the state via an Interstate or other 4-lane roadway.

TABLE 11 Ranking of New Mexico Counties by Population

Rank	County	Access
1	Bernalillo	I-25 & I-40
2	Dona Ana	I-10 & I-25
3	Santa Fe	I-25 & 4
4	San Juan	2
5	Sandoval	I-25 & 4
6	McKinley	I-40
7	Valencia	I-25 & 4
8	Otero	4 US 54 & 70
9	Chavez	4 US 70 & 285
10	Lea	4 US 62/180
11	Eddy	4 US 62 & 285
12	Curry	4 US 70

The reconstruction of NM44/US 550 was intended to correct this problem and make Farmington and the Four Corners area much more attractive to business, industry, and tourists. When this project began, the researchers believed that the following parameters might be indicators of the success of NM 44's reconstruction in enhancing economic activity along the corridor:

- population growth
- employment growth
- unemployment rate
- per capita income
- gross receipts tax growth
- measures of construction activity
- new or expanded business and industry

Information on some of these economic indicators was available through UNM's Bureau of Business and Economic Research (*61*). Additional information was available from New Mexico's Economic Development Department. While working on this project, the researchers found that the on-line files of the San Juan Economic Development provided some useful, but limited, data on local improvement (*61*). Most of the SJEDS annual information can be characterized as *lagging indicators*, because they do not become available until 12-18 months after the end of the year.

The reconstructed US 550 crosses Sandoval and San Juan Counties, and the southwest corner of Rio Arriba County. Because of the dominance of Rio Rancho, and to a lesser extent, Bernalillo, in Sandoval County, it was not possible to separate the economic impact on Sandoval County into the Rio Rancho/Bernalillo component and that occurring in the northwestern portion of the county where US 550 was reconstructed. It was not possible to determine the effect in Rio Arriba County because only nine miles of US 550 are in this county. Rio Arriba's only connection to US 550 is via NM 537, a low-volume road (less than 300 vpd) that connects through the Jicarilla Apache Indian Reservation to Dulce, 67 miles to the north. Consequently, San Juan County was the primary beneficiary of any economic development resulting from US 550's reconstruction.

On-line files of the SJEDS were reviewed to determine the economic development impact of the reconstructed US 550. Farmington-Aztec-Bloomfield is one of 363 metropolitan areas in the United States. According to the SJEDS, the county’s average weekly wages in mining were $1,258, followed by $852 in transportation and warehouse, and $784 in construction. Over the period 2001 through 2006, employment in the area grew by 10 to 15 percent in retail, mining, health, construction, wholesale, and other services.

The researchers examined several potential indicators of changes in economic activity in San Juan County that might be attributed to the reconstruction of NM 44/US 550. Based on data from the US Bureau of Census and UNM’s Bureau of Business and Economic Research (UNM BBER), the population of San Juan County dropped slightly in the 1960s. However, population grew through the 1970s (4.5% per year, compounded), at a slower rate in the 1980s (1.2%/yr); the rate nearly doubled in the 1990s to 2.2%/yr. The corresponding increases in the rest of New Mexico during these three decades were 2.4%, 1.5%, and 1.8%, respectively. As shown in Figure 17, the population growth in San Juan County since the completion of US 550's reconstruction in December 2001 has been 0.6%/yr while the corresponding growth in the rest of New Mexico has been 1.2%. These recent statistics must be viewed cautiously because various state-sponsored programs, such as credits for film production, may have attracted population and employment to other parts of New Mexico. The SJEDS projects the following populations in the years to come: 2010, 128,592; 2020, 145,072; and 2030, 154,403.

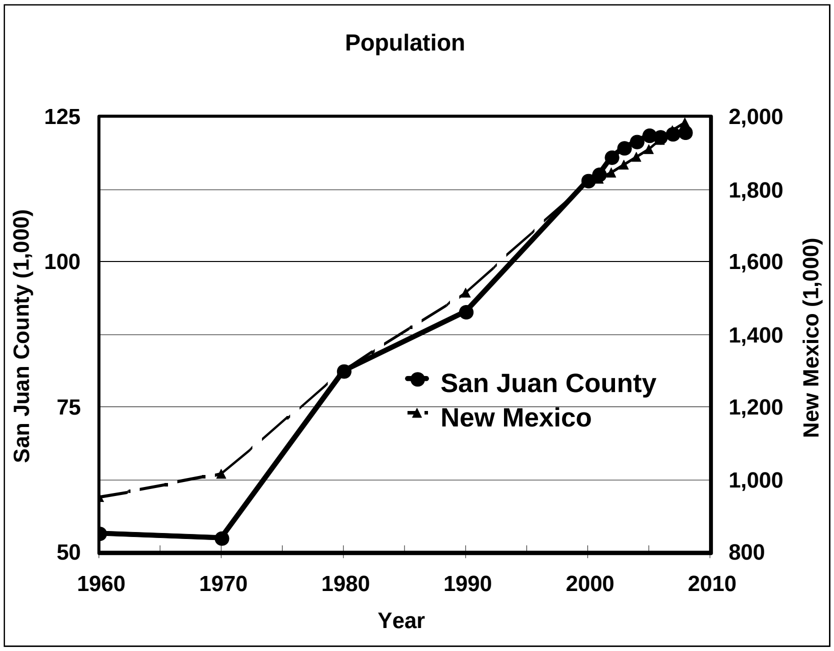


FIGURE 17 Population Growth in San Juan County

UNM's BBER also provides information on employment on the Farmington Metropolitan Statistical Area, which is essentially San Juan County. Based on these statistics, employment grew from 35,465 in 1990 to 48,116 in 2001; this corresponds to a compounded rate of 2.8% per year, modestly higher than the population growth for this time period. Following the reconstruction of US 550 in December 2001, employment in San Juan County grew to 55,834, an annual increase of 2.6%. However, this apparent decrease in the employment growth rate must be judged in terms of another employment statistic, the rate of unemployment in San Juan County. Data from UNM's BBER show that the unemployment rate in the county was 8.9% in 1990, peaking at 12.1% in 1996. Despite recent economic challenges to the US economy, San Juan County's unemployment rate decreased to 3.2% in 2007, increasing slightly to 3.7% in 2008. The recent changes in San Juan County's employment and unemployment rates are depicted in the Figure 18.

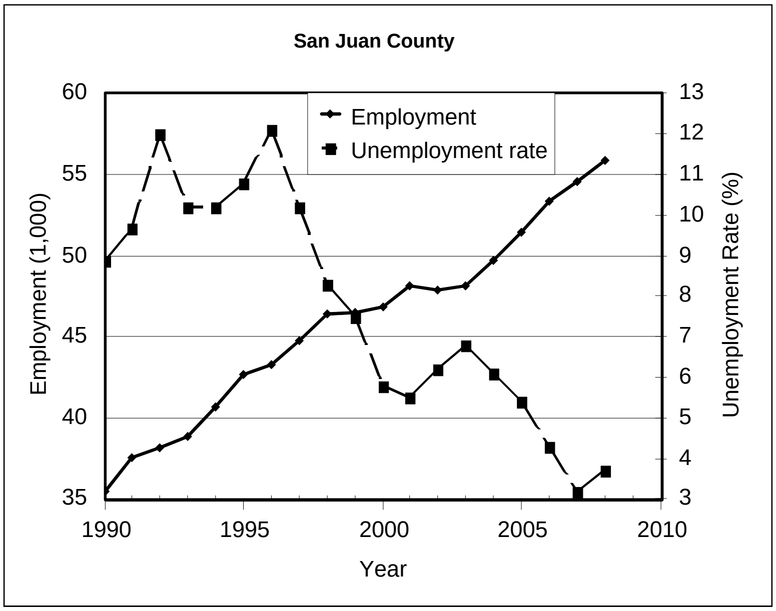


FIGURE 18 Employment & Unemployment Rate in San Juan County

The SJEDS was created in 1989 to assist companies seeking to expand their services and to help recruit new business to the community. A decade later, shortly before the completion of the US 550 reconstruction, San Juan College opened a Small Business Development Center. The cooperative efforts of these two organizations have helped create jobs in Farmington, Aztec, Bloomfield, and the Four Corners area. Certainly some of the employment growth described above is due to the work of these agencies. SJEDS reports that the number of business establishments in the county increased from 2,558 in 2001 to 2,657 in 2004, the latest year for which data are reported. The top ten private sector employers in San Juan County for 2008 (the latest year for which data are available) are shown below; most require an efficient highway transportation system for their business success. As one sign of economic growth, Raytheon Missile Systems, number 6 on the list, and Dawn Trucking, number 8, were not on the top-ten list just two years earlier.

San Juan County's largest employers in the public sector in 2008 were San Juan Regional Medical Center (1,600), Farmington Public Schools (1,197), Central Consolidated Schools (1,157), City of Farmington (821), San Juan County (685), and San Juan College (532). The reconstruction of US 550 likely had no direct effect on employment in these agencies. However, most of these employers rely on good highway transportation and most specifically benefit from the 4-lane US 550. Indirectly, if US 550 increased private sector employment, it would have increased employment in the government sector.

According the UNM's BBER, in 2008 the primary employment categories in San Juan County were retail trade (12.3%), mining (11.5%), construction (10.1%), health care and social assistance (10.1%), and accommodation and food services (8.0%).

TABLE 12 Largest Private Sector Employers in San Juan County, 2008

Company	Product/Service	Full Time Employees
BHP Hilton	Mining/Coal	1,035
Aztec Well Servicing	Oil & Gas	700
Conoco Phillips	Oil & Gas	600
Arizona Public Service	Power Plant	599
PNM San Juan Generating Station	Power Plant	380
Raytheon Missile Systems	Mfg: Electronics	320
Enterprise Products Operating LP	Natural Gas	275
Dawn Trucking	Oil & Gas	270
TurboCare Generator Services	Mfg: Coil Rewinding	270
Exterran	Oil & Gas	260

Overall, San Juan County ranks fourth in population, trailing only Bernalillo, Dona Ana, and Santa Fe Counties; it may be surpassed in 2009 by fast-growing Sandoval County. However, the total taxable gross receipts in San Juan County for 2007 trailed only Bernalillo County. As shown in Figure 20 from the BBER, San Juan County's taxable gross receipts were $4.4 million, slightly more than Santa Fe County and considerably more than Dona Ana County. The BBER attributes the high level of gross receipts tax in San Juan County to *pull factors*, which compare the local ratio of gross receipts tax to personal income to that for other areas in New Mexico. The statewide average is 1. However, San Juan County's pull factors for several important industries, including gasoline stations (3.0), mobile home dealers (2.4), automobile dealers (2.0), and retail food (1.2) had factors greater than one. These high factors indicate that San Juan County is attracting customers from outside the county, including northeast Arizona, southeast Utah, and southwest Colorado, as well as from McKinley, Rio Arriba, and Sandoval Counties. The very high pull factor for gasoline stations likely reflects tourist attractions to the Four Corners area, obviously facilitated by the US 550 road project.

The researchers sought economic data for Roswell and Chaves County in an attempt to provide a comparison with the economic growth in the Four Corners area following the completion of US 550. Access to Roswell is provided by US 70 and US 285, both of which are 4-lane divided highways. However, for reasons that are not clear, the economic data available for Roswell/Chaves County are not as extensive as the data that are readily available for Farmington/San Juan County.

Commercial Truck Traffic on US 550

Another potential indicator of US 550's reconstruction effect on the economic development in the Four Corners area is the amount of large commercial traffic using the reconstructed roadway. The ideal indicator would be the volume of WB-50 trucks, commonly referred to as 18-wheelers. In the absence of this information, a reasonable surrogate is the annual number of Class 9 ESALs (equivalent single-axle loads), where Class 9 refers to the weigh-in-motion truck classification for a five-axle tractor-trailer combination; by far, the most common Class 9 configuration in New Mexico is a 3-axle tractor pulling a 2-axle semi-trailer. Figure 19 shows the annual, two-directional, Class 9 ESALs on US 550 since completion of the reconstruction. The dashed line, depicting the best-fit linear regression relationship over the period 2003 through 2009, shows a downward trend, but is heavily influenced by the exceptionally low ESAL total in 2009. This decrease is probably due to the nation's economic downturn from late 2008 through 2009. The solid line, which shows the best-fit linear regression over the period 2003 through 2008, shows a positive trend prior to the national economic problems cited above. However, ESAL counts on US 550 vary substantially from year to year, increasing through 2005 and decreasing thereafter. Statistical testing at the 95% level of confidence confirmed that neither line's slope (-4,065 ESALs/yr for 2003-2009, +5,436 for 2003-2008) is significantly different from zero. In other words, there has not been a significant increase or decrease in Class 9 ESALs in the after period. Unfortunately, corresponding data are not available for the before period. Although US 550 has positively affected economic development, national economic trends can be more significant.

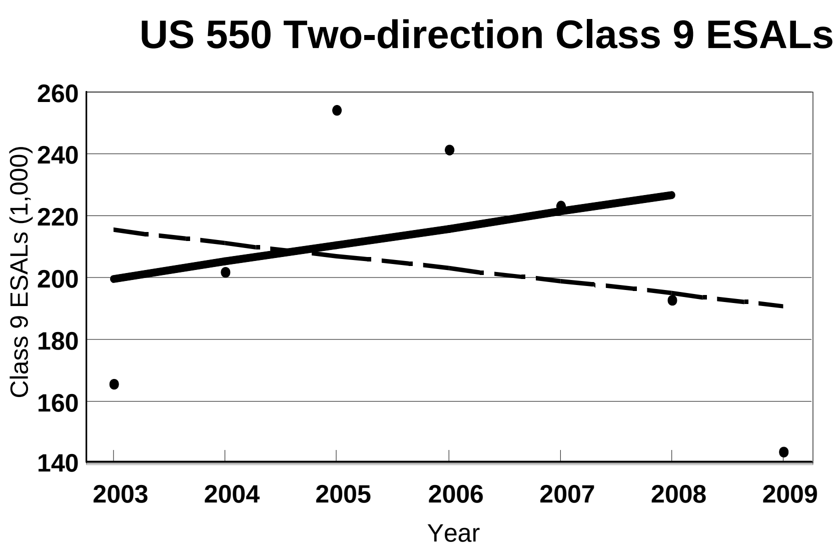


FIGURE 19 US 550 Two-direction Class 9 ESALs

Summary

For the years 2002 through 2007, immediately following the completion of US 550 reconstruction, San Juan County enjoyed growth in population and employment, along with a decrease in the unemployment rate. This performance met or exceeded that of New Mexico as a whole. The situation deteriorated a bit in 2008 (and likely in 2009, although data are not yet available) due to the downturn in the country's economic situation.

The creation and expansion of the Dillon Industrial Park on the southern edge of Aztec was noted earlier. The Animas Industrial Park on a 78-acre area parcel on US 550 north of Bloomfield became San Juan County's third industrial park when it opened in the fall 2007. The 120-acre San Juan County Industrial Park, located 16 miles north of Farmington on NM 170, is located on a former BHP mine site. The TLS Industrial Park, located east of Farmington, is currently home to a well service company. This is an impressive level of industrial park activity in a rural county.

It is clear that San Juan County has fared well since the completion of NM44/US 550's reconstruction. If the NMDOT had pursued its more typical program of roadway improvement by staging a series of 5- to 8-mile reconstruction projects, San Juan County would have received delayed growth in population and employment, and the motorists traveling the route would have been subjected to travel delays over an extended time period. Because multiple factors influence the growth of jobs and the attraction of new businesses, it is not possible to draw a firm conclusion. The foregoing analysis strongly suggests that San Juan County experienced benefits in the form of increased population, business growth, and employment.

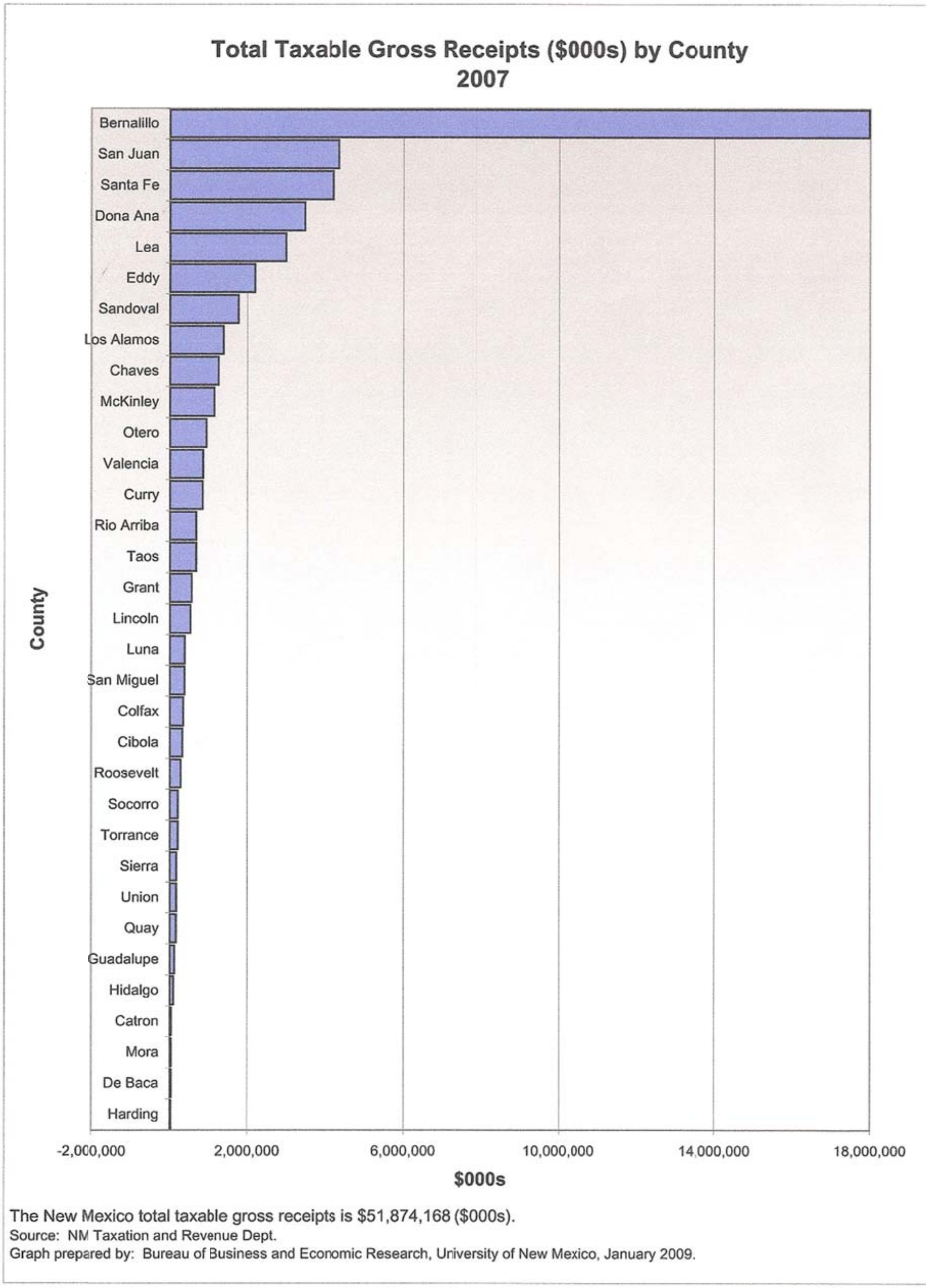


FIGURE 20 Total Taxable Gross Receipts by County 2007

SECTION IV: ROADLIFE RESEARCH PRODUCTS

CHAPTER 8: PAVEMENT COMPUTER MODEL

In this study, a pavement computer model, called DBViewer, is developed to give a quick view of pavement warranty conditions and expenditures. DBViewer is a simple DataBase parser and data monitoring software designed using Microsoft .NET technology. It has been designed to parse an MS Access database prepared for tracking the NMDOT's US 550 Warranty Expenditures and Pavement Conditions. It assumes a pre-specified format for data tables inside the MS Access database, and in this sense, is not a general database parser. In case the MS access file (*.mdb) needs to be modified, the format of the tables is required to remain the same.

Upon starting, the software searches for a database file named Reimbursement Spreadsheet.mdb in the root partition (C:\Reimbursement Spreadsheet.mdb). In case the file is not found in this location, an error message (including the OS exception information) is shown to the user. Note that the exception information, provided by the .NET framework, usually includes useful information about the cause of software failures. As a result, we passed all the exception messages to the user. If the MS Access file is found successfully, the software starts to check the compatibility of the database tables. If the format of the tables does not match the pre-specified format, an exception will occur and an error message will be shown to the user. Otherwise the software parses all the data tables and shows the results in three Data Grids and several charts. For the sake of compatibility, we followed the style previously used in the provided MS Excel file by NMDOT (Jeff Lowry NMDOT). Some of the example data tables are given below:

TABLE 13 Reimbursement Spreadsheet Data

Tables	**Description**
Emergency Repairs	Emergency Repairs Expenditures with details
Structures Warranty	Structures Warranty Expenditures with details
Pavement Warranty	Pavement Warranty Expenditures with details
Summary	Summary of the three tables
Expended Chart	Warranty Expenditures To Date Chart
Category Chart	Warranty Expenditures Chart by Category
Reimbursed Chart	Reimbursements to NMDOT from Mesa per Fiscal Year
Future Expend	Estimated Warranty Expenditures 2010 - 2012
BAR To Date	Budget Adjustments Requests (BARs) To Date - Reimbursements to NMDOT from Mesa PDC

CHAPTER 9: LCCA MODEL

9.1 Data Required for LCCA Analysis (Adapted from Pavement Interactive Consortium)

The following sections list information necessary for performing an LCCA analysis of pavement projects. Without the availability of any of these data, a complete LCCA for projects cannot be done.

Agency Costs

Agency costs are all those costs incurred by the owning agency over the life of the project.

Preliminary Engineering These are costs associated with preliminary items such as feasibility studies of designs, permitting, engineering design and consultation.

Availability Data on these costs are available and were included in the Proposal and LCC Prepared by Mesa PDC.

Contract Administration These are costs associated with contract administration.

Availability Data on these costs are not available.

Initial Construction These are costs associated with construction activities. For instance, different roadway sections and material quantities should be accounted for in the analysis.

Availability Data on these costs are available and were included in LCC Prepared by Mesa PDC.

Maintenance Costs These are costs associated with maintaining the pavement surface at some acceptable level.

Availability Data on these costs are available and were provided by Mesa PDC.

Rehabilitation Costs These are costs associated with each rehabilitation (typically they are resurfacing costs). They are computed in a manner consistent with the initial construction costs.

Availability Data on these costs are not available because, according to the NMDOT, no rehabilitation efforts have been needed.

Administrative Costs These are other administrative or overhead costs.

Availability Data are not available.

Salvage Value: Residual Value This is net value from recycling the pavement. The differential residual value between pavement design strategies is generally not very large, and, when discounted over long periods of time (e.g., 35 years), tends to have little effect on LCCA results.

Availability Data on these costs are not available.

Salvage Value: Serviceable Life This is the remaining life in a pavement at the end of the analysis period.

Availability Data are not available.

User Costs

User costs are those costs that are accrued by the user of the facility during the construction, maintenance and/or rehabilitation and everyday use of a roadway section. User costs should be included in an LCCA because they tend to be several orders of magnitude larger than agency costs and can often be the major driving force in life-cycle cost.

Vehicle operating costs (VOC) These costs include all costs associated with operating a vehicle including fuel, oil, part replacement, upkeep and maintenance. Vehicle operating costs will vary depending upon roadway condition. For US 550, although the travel time has decreased by approximately 30 minutes, there is not much change in VOC, because vehicular speed has increased, resulting in greater fuel consumption.

Availability Data are not available.

User Delay Costs These are costs associated with highway users' time. User delay costs help quantify costs associated with slowdowns due to construction and maintenance activities and denial-of-use. Some of the data required for calculating user delay costs are percent of daily traffic delayed, amount of daily traffic, percent of trucks and percent of cars, cost of delay per hour, and time of delay in hours. The process of calculating UDC is specified in FHWA's "LCCA in Pavement Design" (*18*).

Availability Data are not available.

Crash Costs These are costs associated with highway accidents. Generally crash costs are related to the expected severity of the different crash types.

Availability Data are available and were included in Section 6.4.

Equivalent Single Axle Load (ESAL) These are data on the traffic volume on the highway.

Availability Data are available and were provided by NMDOT.

Externalities Data These are data related to the noise and air pollution that can affect the environment around the project.

Availability Data are not available.

9.2 LCCA PROPOSED ARCHITECTURE VS. DATA AVAILABILITY

As stated in the initial proposal, the research team planned to use multi-attribute decision analysis techniques such as the analytical hierarchy process (AHP). However, these techniques could not be used because of the lack of data. In addition, data requirements for the potential modules to be included in the LCCA model were verified and are reported in Table 14.

TABLE 14 Proposed Modules of LCCA Model

Modules	Data Required	Availability	Possible?
Net Present Value	Preliminary Engineering	Yes	No
	Contract administration	No	
	Initial construction	Yes	
	Maintenance costs	Yes	
	Rehabilitation costs	NA	
	Administrative costs	No	
	Salvage value	No	
	Vehicle operating costs (VOC)	No	
	User delay costs	No	
	Crash costs	Yes	
Benefit Cost Analysis	Preliminary Engineering	Yes	No
	Contract administration	No	
	Initial construction	Yes	
	Maintenance costs	Yes	
	Rehabilitation costs	NA	
	Administrative costs	No	
	Salvage value	No	
	Vehicle operating costs (VOC)	No	
	User delay costs	No	
	Crash costs	Yes	
	Equivalent Single Axle Load (ESAL)	Yes	
	Externalities Data	No	
Return on Investment	Preliminary Engineering	Yes	No
	Contract administration	No	
	Initial construction	Yes	
	Maintenance costs	Yes	
	Rehabilitation costs	NA	
	Administrative costs	No	
	Salvage value	No	
	Vehicle operating costs (VOC)	No	
	User delay costs	No	
	Crash costs	Yes	
	Equivalent Single Axle Load (ESAL)	Yes	
	Externalities Data	No	

9.3 US 550 WARRANTY TRACKING SOFTWARE (US550-WTS)

Because the unavailability of data hindered the opportunity to conduct a complete LCCA analysis, the research team developed a Microsoft Access application, the US 550 Warranty Tracking Software that is included on the accompanying CD. This application is designed to allow NMDOT staff to track warranty transactions. In addition, the application includes an LCCA module, which can calculate the current Net Present Value (NPV) and compare it with the NPV predicted before construction. The following section of this chapter includes a user guide for using this application.

9.4 US 550 WARRANTY TRACKING SOFTWARE (US550-WTS) USER GUIDE

Background and Need

The state of practice on LCCA software has been discussed in Chapter 4 of this report. During the review of the literature, the research team identified several software packages that can be used to analyze and determine the Life Cycle Cost (LCC) of different project options during the pre-completion phase. However, existing models did not include a model to track the LCC of a completed project throughout its lifecycle to include the post completion phase. Moreover, there are few computerized models able to determine the accuracy of the LCC predicted for a particular alternative during the selection process, with respect to the current LCC. Thus there was a need for a computer program which can integrate regular expenditures and LCC elements of a highway project and can provide the employee with an interactive and user friendly database to record, calculate and track the project information data. The developed US 550-WTS application has been designed to facilitate the task of tracking economic transactions for NMDOT projects that include a warranty provision covering all or a certain amount of maintenance and repair expenditure.

Scope

The US 550 Warranty Tracking Software can track expenditures related to repair and maintenance, and can track the Life Cycle Cost (LCC) of the project by calculating the Net Present Value of all the expenditures combined together. The software was prepared using the Microsoft Access 2007 database with the help of Visual Basics and Structured Query Language (SQL) programming. New Mexico Department of Transportation (NMDOT) categorizes repair activities for US 550 into two categories: 1) Pavement and 2) Bridge, Drainage and Erosion. Depending on the nature of the repair, they can be classified into normal and emergency. The functions of the software are listed:

- Documentation of project details (e.g., Project ID, Location, milepost)
- Documentation of warranty activities for both the Structural Warranty and the Pavement Warranty through two separate modules
- Documentation of warranty details (e.g., warranty amount, warranty duration, warranty starting date)
- Documentation of warranty expiration conditions (i.e., Maximum Equivalent Single Axle Load – ESAL, Maximum Expenditure covered, Warranty Duration)

- Recording and storage of new transaction data for repair (e.g., type of repair, repair date, contractor involved, repair expenditure)
- Querying of specific transaction data by key word
- Documentation and reporting of total expenditure to date
- Comparison between total current expenditure and expenditure covered by the warranty (i.e., tracking of the expiration of the warranty)
- Entering of User Delay Cost (UDC), Vehicle Operating Cost (VOC) and Crash Cost (CC)
- Calculation of the Net Present Value (NPV)
- Comparison between the actual NPV and the NPV predicted during the design phase
- Reporting of any particular type of transaction with the total amount
- Reporting of transaction with a particular contractor
- Reporting of total transaction report
- Creation of NPV reports and display of the comparison between the predicted NPV and the current NPV

Note: Although the current version of the US550-WTS application is designed for US 550 warranties, it would be able to manage more than one project if required in the future.

System Design Approach

To create an application able to perform the above-mentioned functions, a data flow diagram was prepared. The diagram, shown in Figure 21, provides an overview of how the software will request, calculate and present data.

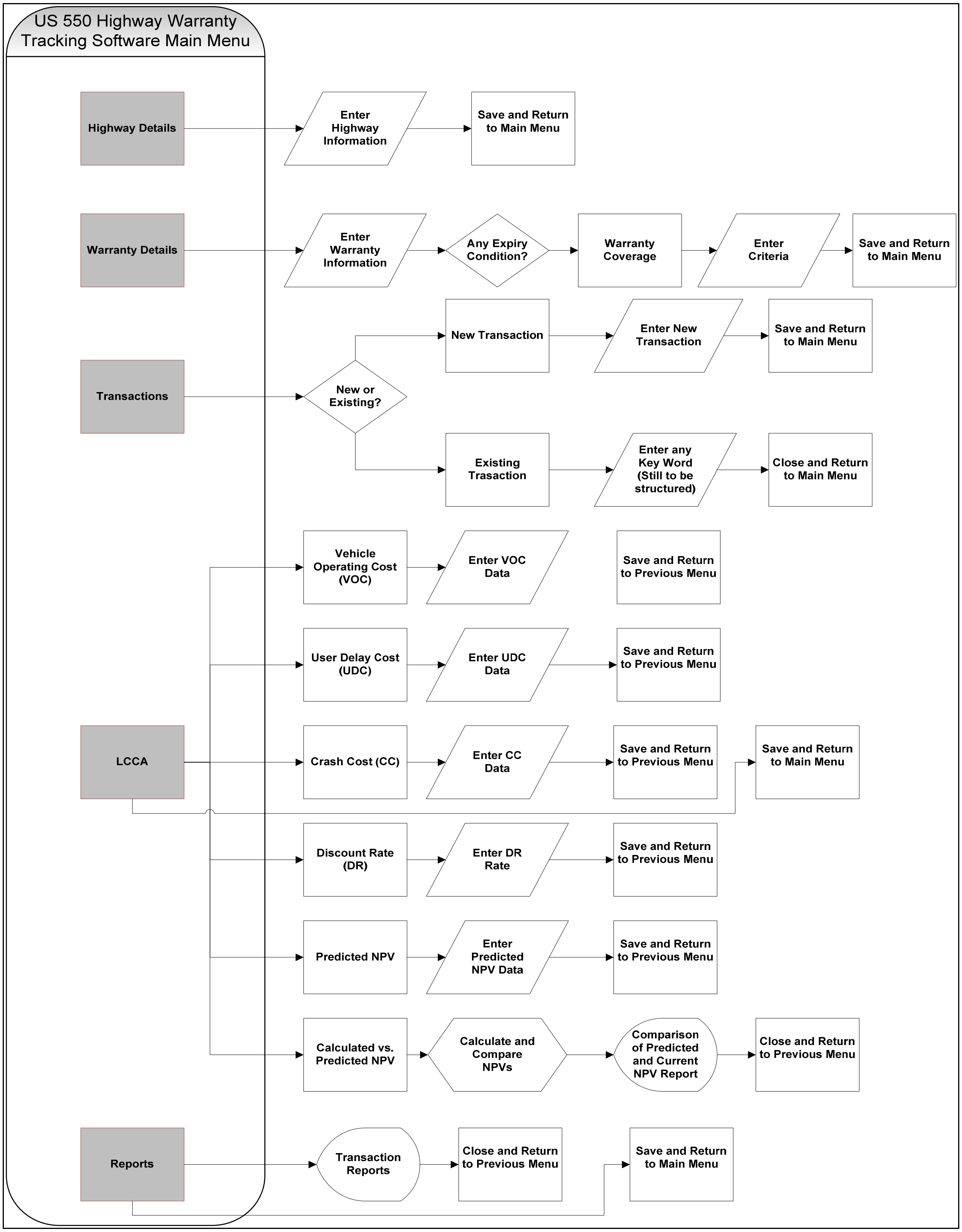


FIGURE 21 Data Flow Diagram

Entity Relationship Diagram

The entity relationship, shown in Figure 22, was created during the conceptual phase of the design. The diagram represents graphically the relationship of the entities in the database structure. The relationship is the backbone of the database application, which relates all the tables, calculation and codes to each other.

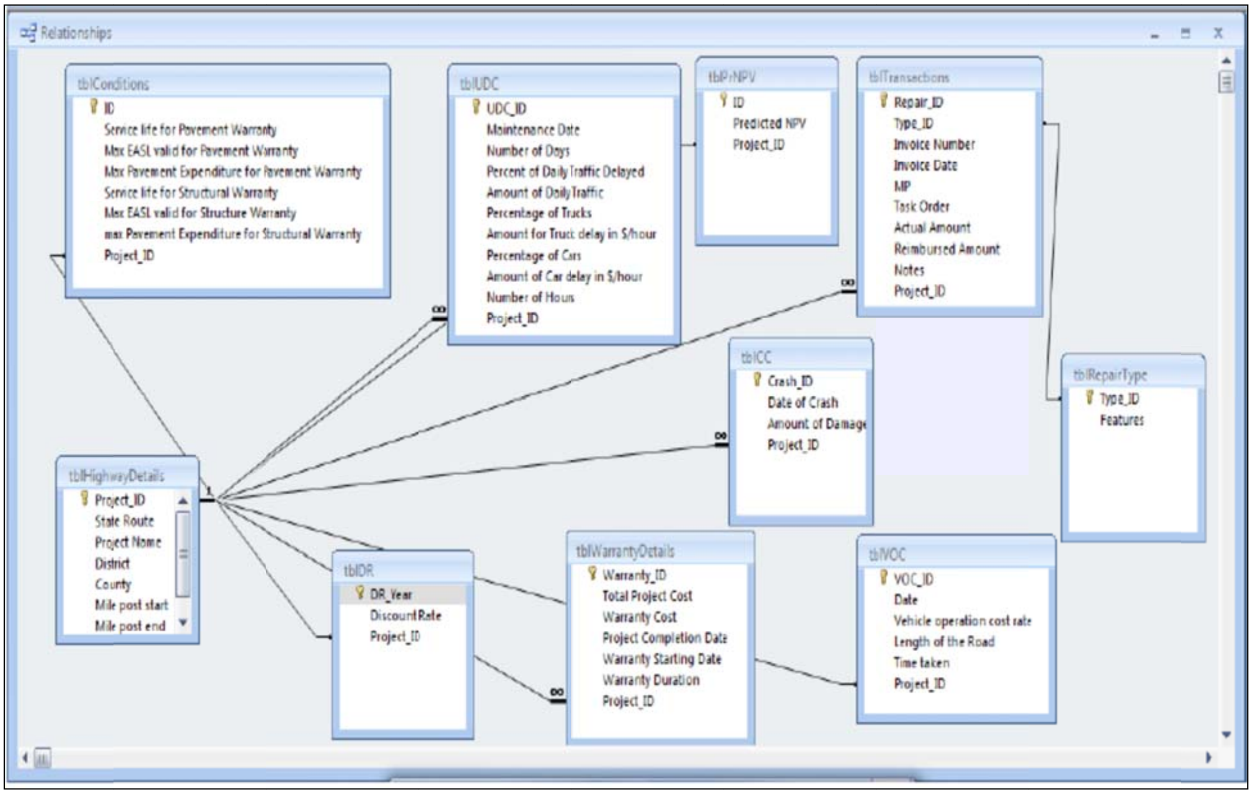


FIGURE 22 Entity Relationship Diagram

Brief Description of the Software

The database provides a form interface to the user which makes the data entry process much easier. The interface consists of many switches or tabs, which the user can press to navigate through the software. When opened, the software will display the main switchboard, as show in Figure 23.

FIGURE 23 US 550–WTS Main Menu

As the application contains several macros, the user will need to modify the security settings in her/his computer. When the "Option" tab, that comes up on the left side of the database (see Figure 24) is pressed, the "Microsoft Office Security Option" dialog box opens, where "Enable this content" option should be selected (see Figure 25).

All the details regarding the highway project can be entered into the form (see Figure 26) that opens up when the "Highway Details" tab is selected. The form contains the fields Project ID, State Route, Project Name, District, County, Mile Post Start, Mile Post End and Comments regarding the project. All the data entered can be saved by pushing the "Save" button.

The "Warranty Details" tab (see Figure 27) can be used to enter the information related to the warranty such as Warranty ID, Total Project Cost, Warranty Cost, Project Completion Date, Warranty Duration and Warranty Starting Time. It also has an option, "Warranty Coverage Condition," where the criteria governing the validity of the warranty can be specified. The criteria are service life, Maximum ESAL, and Expenditure Covered. The warranty tab, shown in Figure 28, can be subcategorized into structural warranty and pavement warranty.

Once all the details regarding the project are entered, the software is ready to track the transactions going on in the maintenance period. The "Transactions" button, when pushed, provides the user with the option of entering a new transaction (New Transaction) or viewing the existing transactions (Existing Transactions) in a spreadsheet format, as shown in Figure 29.

Similarly, the LCCA module consists of various tabs such as Vehicle Operating Cost, User Delay Cost, Crash Cost, Discount Rate for calculating NPV, Current Calculated NPV, and Predicted NPV. The Current vs. Predicted NPV tab shows the comparison between them (Figure 30). A user can jump back to the Main Form anytime by pressing the “Return to Main Menu” tab. The LCCA module is shown in Figure 30.

Finally, the Warranty Tracking Software can produce reports of the transaction. The reports can be specific to the type of the repair, or they may be a report for overall expenditure. Reports can also be obtained for all the transactions pertaining to a particular contractor. A sample report of the BD&E transaction is shown in Figure 32.

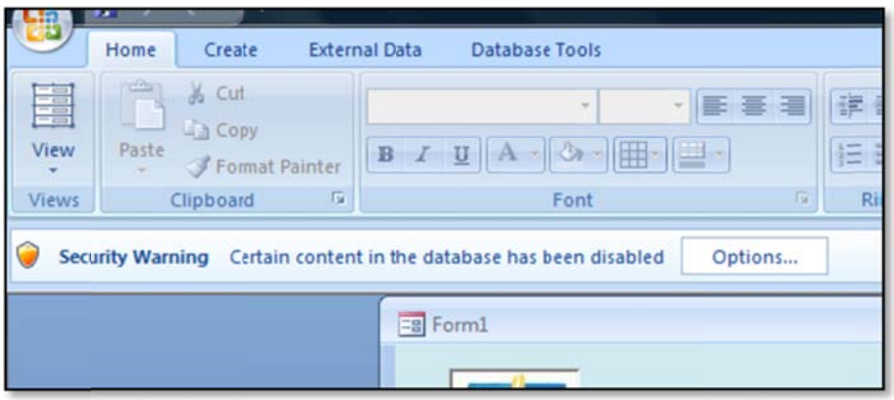


FIGURE 24 Security Warning Option

FIGURE 25 Microsoft Office Security Options

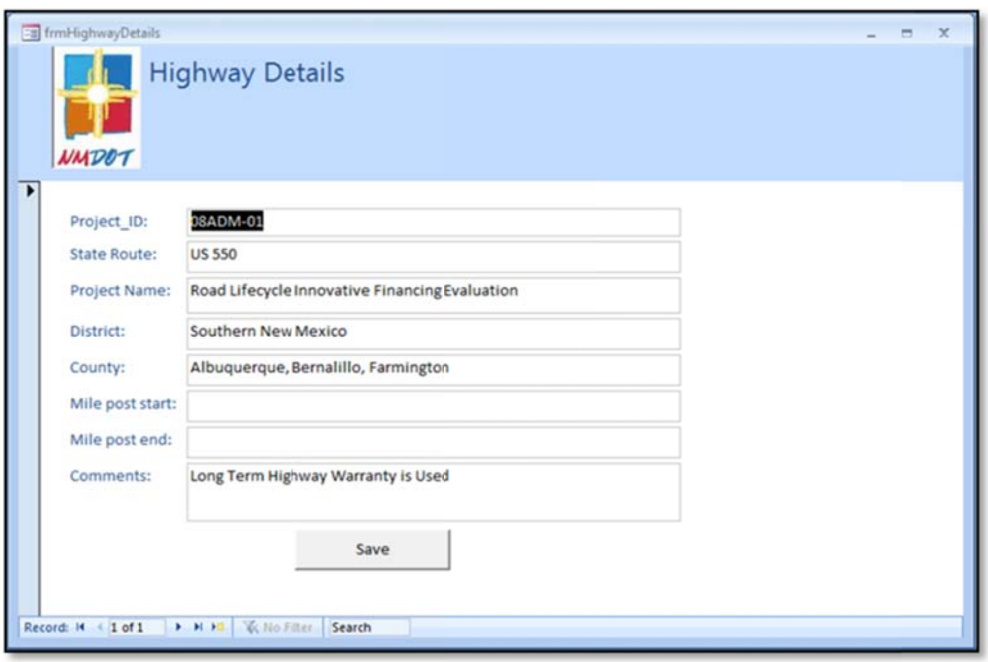


FIGURE 26 US 550-WTS Highway Details Form

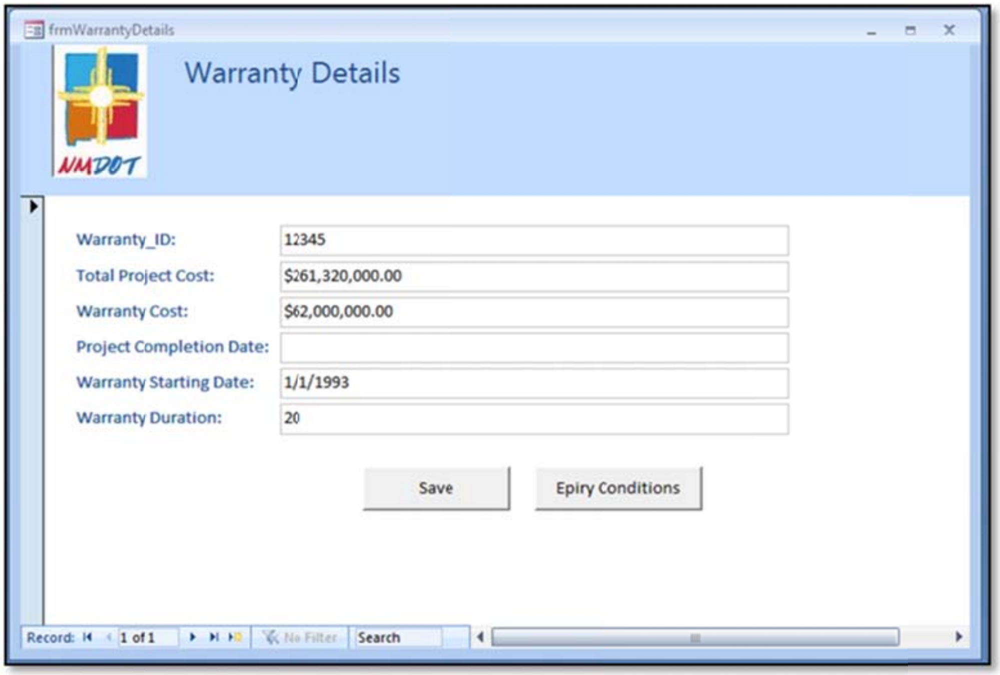


FIGURE 27 US 550-WTS Warranty Details Form

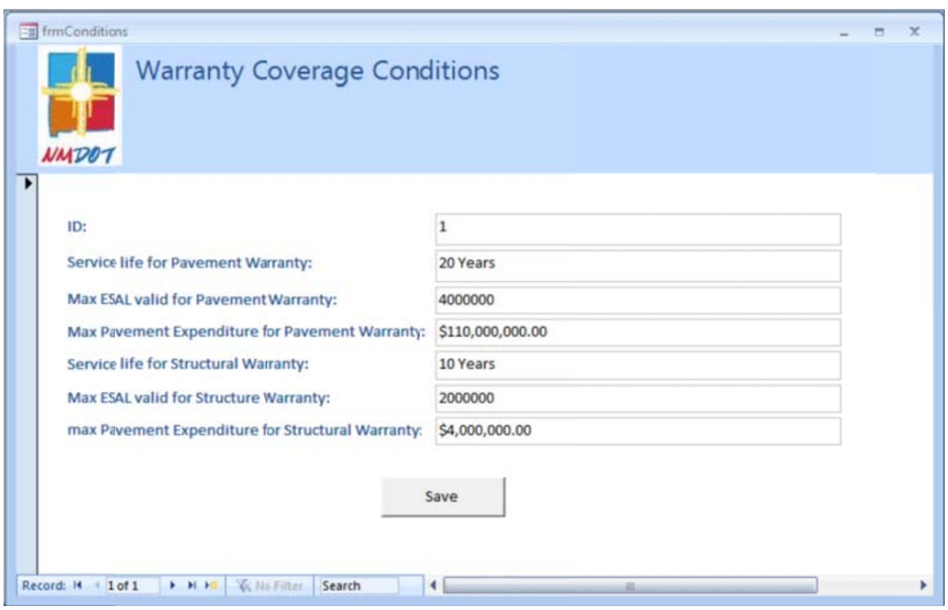
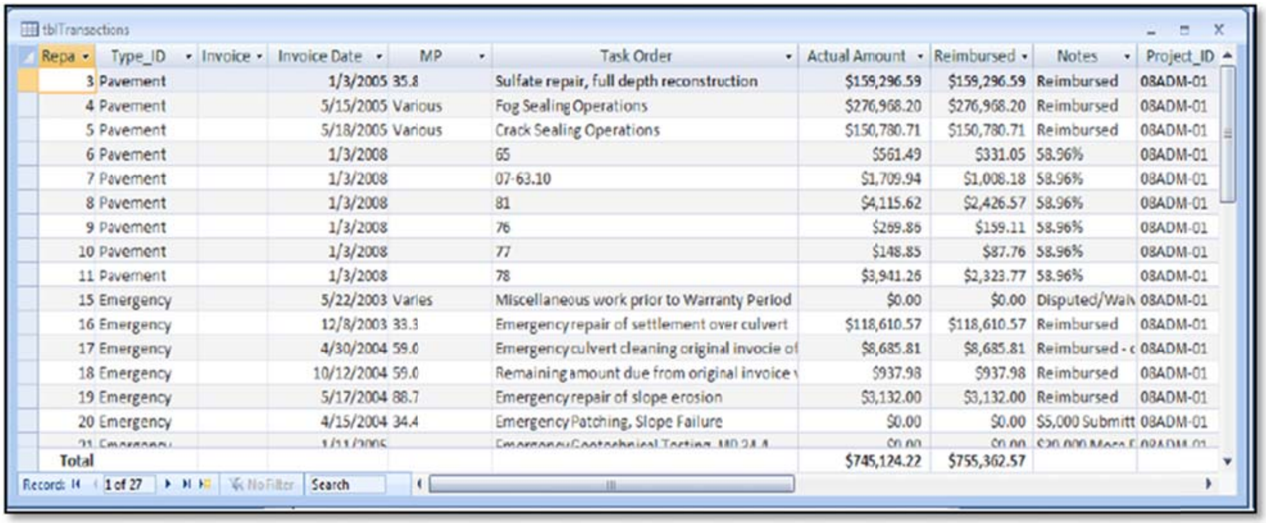


FIGURE 28 US 550-WTS Warranty Coverage Conditions Form



tblTransactions

Repa	Type_ID	Invoice	Invoice Date	MP	Task Order	Actual Amount	Reimbursed	Notes	Project_ID
3	Pavement		1/3/2005	35.8	Sulfate repair, full depth reconstruction	$159,296.59	$159,296.59	Reimbursed	08ADM-01
4	Pavement		5/15/2005	Various	Fog Sealing Operations	$276,968.20	$276,968.20	Reimbursed	08ADM-01
5	Pavement		5/18/2005	Various	Crack Sealing Operations	$150,780.71	$150,780.71	Reimbursed	08ADM-01
6	Pavement		1/3/2008		65	$561.49	$331.05	58.96%	08ADM-01
7	Pavement		1/3/2008		07-63.10	$1,709.94	$1,008.18	58.96%	08ADM-01
8	Pavement		1/3/2008		81	$4,115.62	$2,426.57	58.96%	08ADM-01
9	Pavement		1/3/2008		76	$269.86	$159.11	58.96%	08ADM-01
10	Pavement		1/3/2008		77	$148.85	$87.76	58.96%	08ADM-01
11	Pavement		1/3/2008		78	$3,941.26	$2,323.77	58.96%	08ADM-01
15	Emergency		5/22/2003	Varies	Miscellaneous work prior to Warranty Period	$0.00	$0.00	Disputed/Waiv	08ADM-01
16	Emergency		12/8/2003	33.3	Emergency repair of settlement over culvert	$118,610.57	$118,610.57	Reimbursed	08ADM-01
17	Emergency		4/30/2004	59.0	Emergency culvert cleaning original invocie of	$8,685.81	$8,685.81	Reimbursed - c	08ADM-01
18	Emergency		10/12/2004	59.0	Remaining amount due from original invoice	$937.98	$937.98	Reimbursed	08ADM-01
19	Emergency		5/17/2004	88.7	Emergency repair of slope erosion	$3,132.00	$3,132.00	Reimbursed	08ADM-01
20	Emergency		4/15/2004	34.4	Emergency Patching, Slope Failure	$0.00	$0.00	$5,000 Submitt	08ADM-01
Total						$745,124.22	$755,362.57		

Record: 1 of 27 No Filter Search

FIGURE 29 US 550-WTS Existing Transaction Output

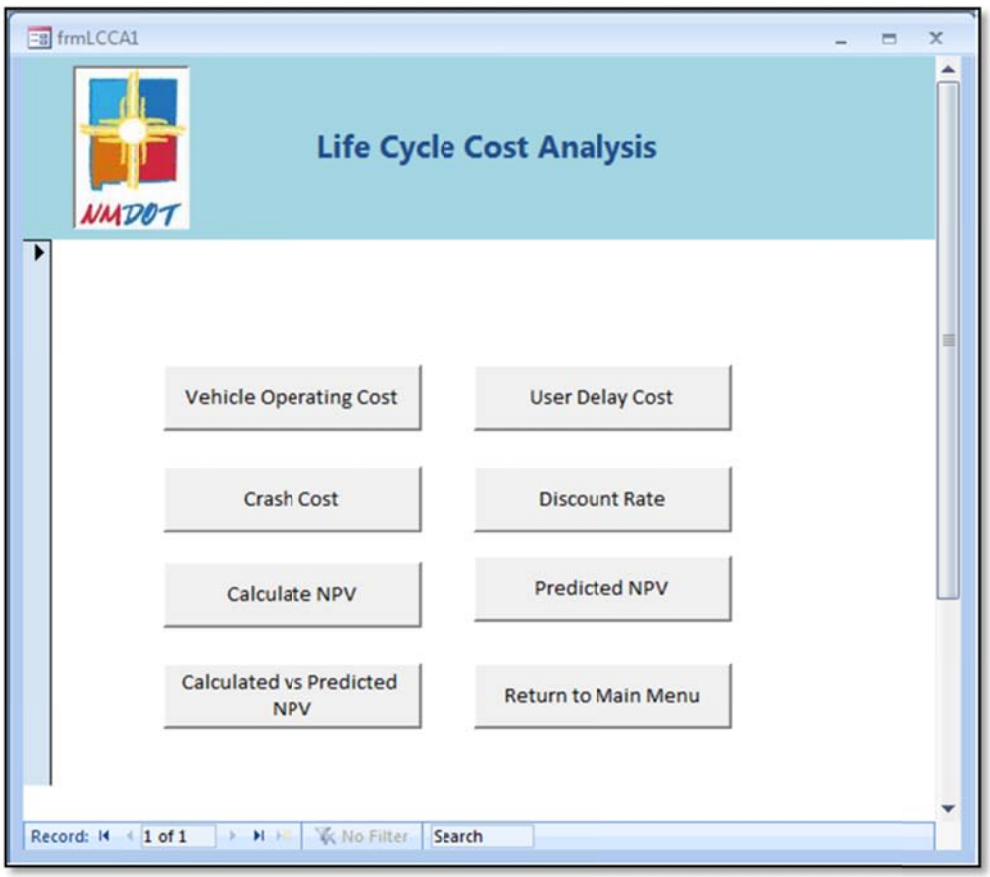
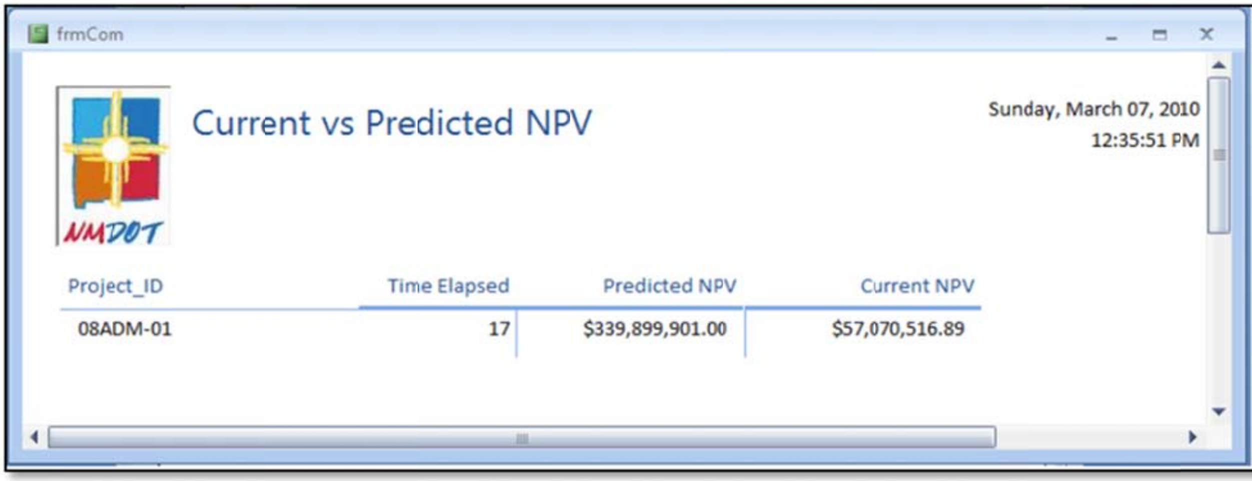


FIGURE 30 US 550-WTS LCCA Module



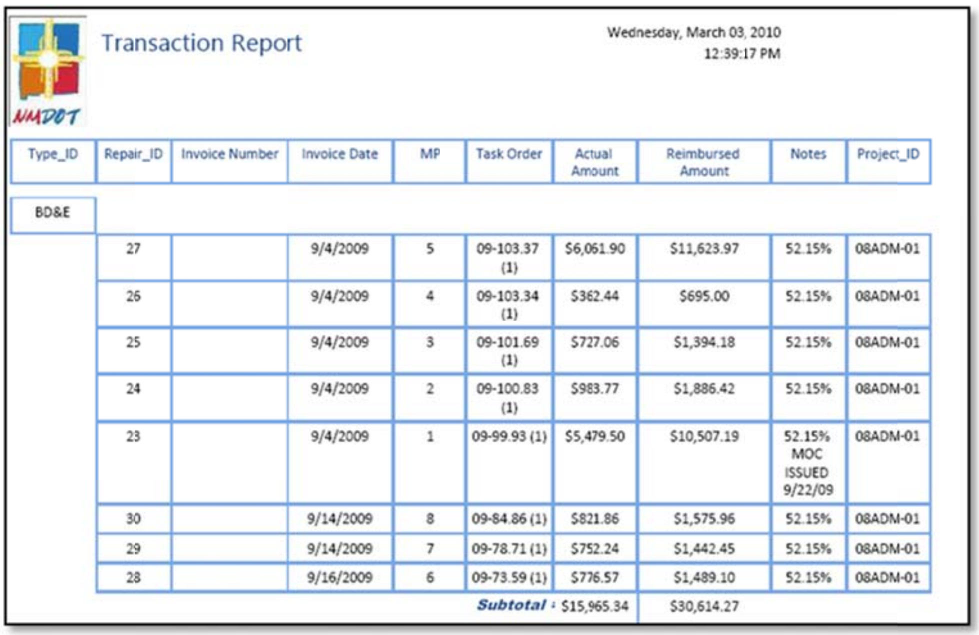
frmCom

Current vs Predicted NPV

Sunday, March 07, 2010
12:35:51 PM

Project_ID	Time Elapsed	Predicted NPV	Current NPV
08ADM-01	17	$339,899,901.00	$57,070,516.89

FIGURE 31 US 550-WTS NPV Comparison Report



Transaction Report

Wednesday, March 03, 2010
12:39:17 PM

Type_ID	Repair_ID	Invoice Number	Invoice Date	MP	Task Order	Actual Amount	Reimbursed Amount	Notes	Project_ID
BD&E									
	27		9/4/2009	5	09-103.37 (1)	$6,061.90	$11,623.97	52.15%	08ADM-01
	26		9/4/2009	4	09-103.34 (1)	$362.44	$695.00	52.15%	08ADM-01
	25		9/4/2009	3	09-101.69 (1)	$727.06	$1,394.18	52.15%	08ADM-01
	24		9/4/2009	2	09-100.83 (1)	$983.77	$1,886.42	52.15%	08ADM-01
	23		9/4/2009	1	09-99.93 (1)	$5,479.50	$10,507.19	52.15% MOC ISSUED 9/22/09	08ADM-01
	30		9/14/2009	8	09-84.86 (1)	$821.86	$1,575.96	52.15%	08ADM-01
	29		9/14/2009	7	09-78.71 (1)	$752.24	$1,442.45	52.15%	08ADM-01
	28		9/16/2009	6	09-73.59 (1)	$776.57	$1,489.10	52.15%	08ADM-01
					Subtotal :	$15,965.34	$30,614.27		

FIGURE 32 US 550-WTS Sample Transaction Report

SECTION V: APPENDICES

APPENDIX A: LIST OF REFERENCES

1. Federal Highway Administration (2010, March), Background for Pavement Warranties, Retrieved March 4, 2010 from FHWA website: http://www.fhwa.dot.gov/pavement/warranty/backgrnd.cfm .
2. Hancher, D. E. (1999, November). Contracting Methods for Highway Construction, *Journal of Transportation Research Board*, 1-7.
3. Carpenter, B., Fekpe, E., Gopalakrishna, D. (2003, February). Performance-Based Contracting for the Highway Construction Industry. Koch Industries Inc, Washington D.C.
4. Migliaccio, G.C. (2007). Planning for Strategic Change in the Project Delivery Strategy. Doctoral dissertation, University of Texas at Austin.
5. Pietroforte, R., & Miller, J. B. (2002). Procurement Methods for US Infrastructure: Historical Perspectives and Recent Trends. Building Research & Information, 30(6), 425.
6. Rein, C., Gold, M., & Calpin, J. (2004). The Evolving Role of the Private Sector in the U.S. Toll Road Market. *Journal of Structured & Project Finance*, 9(4), 27-33.
7. Oliver, C. (1992). The Antecedents of Deinstitutionalization. Organization Studies, 13(4), 563.
8. Ibbs, C. W., Kwak, Y. H., Ng, T., & Odabasi, A. M. (2003). Project Delivery Systems and Project Change: Quantitative Analysis. *Journal of Construction Engineering and Management*, 129(4), 382.
9. Sanvido, V. E., & Konchar, M. D. (1997). Project Delivery Systems: CM at Risk, Design-Build, and Design-Bid-Build (Research Report No. 133-1). Austin, Texas: The Construction Industry Institute.
10. Shrestha, P. P., Migliaccio, G. C., O'Connor, J. T., & Gibson Jr, G. E. (2007a). Benchmarking of Mega Design/Build Highway Projects: One-To-One Comparison and Comparison with DBB Projects. Transportation Research Record 1994, December 2007.
11. Shrestha, P. P., Migliaccio, G. C., O'Connor, J. T., & Gibson Jr, G. E. (2007b, May). Comparison Between Design-Build and Design-Bid-Build Transportation Projects Using Lane Mile Data. Paper presented at the Proceedings of the 2007 ASCE Construction Research Congress, Nassau, Grand Bahamas.
12. U.S. Department of Transportation (USDOT) – Federal Highway Administration (FHWA). (2006). Design-Build Effectiveness Study. Retrieved April 2, 2007, from http://www.fhwa.dot.gov/reports/designbuild/designbuild.pdf .
13. Kennedy, M., Hurley, L., & Pritchett, L. (2006). The Fully Integrated Design-Builder. Design-Build Dateline, 13(4), 34-38.

14. Papernik, B., & Davis, B. (2006). Innovation in Highway Delivery: Survey of SEP-14/SEP-15 Projects. Design-Build Dateline, 13(4), 8-11.

15. AASHTO (2007, August), Accelerating Project Delivery. Washington DC: American Association of State Highway and Transportation Officials.

16. Fishman, E., (2009, January). Legal Research Digest 51. Transportation Research Board, National Academics. Retrieved from http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_lrd_51.pdf .

17. Ghavamifar, K., Touran, A. (2008, January). Alternative Project Delivery Systems: Applications and Legal Limits in Transportation Projects. *Journal of Professional Issues in Engineering Education and Practice*, 134(1), 106-111.

18. Federal Highway Administration. (1998, September). Life Cycle Cost Analysis in Pavement Design. (Publication FHWA-SA-98-079). Washington, DC: Office of Asset Management.

19. Thomson, B. P., Anderson, S. D., Russell, J. S., Hanna, A. S. (2002, July). Guidelines for Warranty Contracting for Highway Construction. *Journal of Management in Engineering* 18(3), 129-137.

20. Bayraktar, M. E., Cui, Q., Hastak, M., Minkarah, I. (2005, December). An Evaluation of Warranty Contracting in the United States of America. *Canadian Journal of Civil Engineering* 33, 1 – 9.

21. Cui, Q., Bayraktar, M. E., Hastak, M., Minkarah, I. (2004, July). Use of Warranties on Highway Projects: A Real Option Perspective. *Journal of Management in Engineering* 20(3), 118-125.

22. AASHTO (2007), *Maintenance Manual for Roadways and Bridges*. Washington DC: American Association of State Highway and Transportation Officials.

23. Singh, P., McCullouch, B.,G., Labi, S., Sinha, K. C. (2005, February). An Evaluation of the Cost-Effectiveness of Warranty Contracts in Indiana. Joint Transportation Research Program (Project No. C-36-67SS), West Lafayette, Indiana.

24. Wang, L. B., Park, J. Y., Hill, S. H. (2005). Use of Pavement Management System Data to Monitor Performance of Pavements under Warranty. *Journal of the Transportation Research Board 1940*, 21-31.

25. Shober, S.F., Whited, G. C., McMullen, K. W. (1996). Wisconsin Department of Transportation's Asphaltic Pavement Warranties. *Journal of the Transportation Research Board 1543*, 113 - 119.

26. Sees, E., Cui, Q., Johnson, P. (2009, July). Legal Environment for Warranty Contracting. Journal of Management in Engineering 25(3), 115-121.

27. Ozbek, M., Garza, J. M. (2007). Development of Performance Warranties for Performance- Based Road Maintenance Contracts. In K. R. Molenaar & G. Yakowenko (Eds), Alternative Project Delivery Procurement, and Contracting Methods for Highways (pp. 20-36). Washington DC: American Society of Civil Engineers.

28. American Institute of Architects (AIA). (2007). Integrated Project Delivery: A Guide. Retrieved from http://www.aia.org/contractdocs/AIAS077630.

29. Construction Industry Institute (CII). (2001, June). Owner's Tool for Project Delivery and Contract Strategy Selection. (Research Summary 165-1). Austin, TX.

30. Goser, C., Freese, J. (2009, March). Lessons Learned from a Fully Integrated Project that is Utilizing a Six Party Agreement. Associate General Contractors of America National Convention.

31. Gould, F., Joyce, N. (2008). *Construction Project Management*. New Jersey: Pearson Prentice Hall.

32. Construction Industry Institute (CII). (1997, December). Project Delivery Systems: CM at Risk, Design-Build, Design-Bid-Build. (Research Summary 133-1). Austin, TX.

33. Puentes, R., Prince, R. (2005). Fueling Transportation Finance: A Primer on the Gas Tax. The Brookings Institute Series on Transportation Reform.

34. Puentes, R., Warren, D. (2005, March). Today's Road with tomorrow's Dollars: Using GARVEE Bonds to Finance Transportation Projects. The Brookings Institute Series on Transportation Reform.

35. Federal Highway Administration (2002, April). Innovative Financing Primer (Publication FHWA-AD-02-004). U.S. Department of Transportation. Retrieved December 5, 2009 from FHWA website: http://www.fhwa.dot.gov/innovativefinance/ifp/index.htm .

36. Federal Highway Administration. Guidance on Section 313(b) of the NHS Act: Loan Provisions under Section 129(a)(7) of Title 23. May 1996. http://www.fhwa.dot.gov/innovativefinance/ifg.htm .

37. Federal Highway Administration (2002, February). State Infrastructure Bank Review. (Publication FHWA-AD-02-003). U.S. Department of Transportation. Retrieved December 5, 2009 from FHWA website: http://www.fhwa.dot.gov/innovativeFinance/sibreview/index.htm .

38. Mayer, J., R. (2002, October). Tools in the Toolbox: Strategies for Effective Application. Federal Highway Administration, U.S. Department of Transportation.

39. Mayer, J. R. (1999). GARVEE Roundup. FHWA's Innovative Finance Quarterly 5(2), 3.

40. Wisniewski, K. (1999). SIB Update. FHWA's Innovative Finance Quarterly 5(2), 4-5.

41. Inman, M. (1999). Federal Credit Program. FHWA's Innovative Finance Quarterly 5(2), 1-2.

42. American Association of Port Authorities (2006, May). Transportation Infrastructure Finance. 2006 Finance Seminar. Retrieved December 4, 2009 from AAPA website: http://www.aapa-ports.org/files/SeminarPresentations/06_Finance_Sullivan.pdf .

43. Grimsey, D., Lewis, M., K. (2002). Evaluating the Risks of Public Private Partnerships for Infrastructure Projects. *International Journal of Project Management*, 20(2), 107 – 118.

44. USDOT, (2007, January). 2006 Status of the Nation's Highways, Bridges, and Transit Conditions and Performance, Report to Congress. 357. Retrieved from http://www.fhwa.dot.gov/policy/2006cpr/pdfs/cp2006.pdf .

45. Smith, J. T., Tighe, S. L., (2006, August).The Analytical Hierarchy Process as a Tool for Infrastructure Management, Paper presented in 1st Annual Inter-university Symposium on Infrastructure Management.

46. Federal Highway Administration. (2002, August). Life Cycle Cost Analysis Primer. (Publication FHWA IF-02-047). Washington, DC: Office of Asset Management.

47. Chasey A. D., Garza, J. M., Drew, D. R. (2002), Using Simulation to Understand the Impact of Deferred Maintenance, *Computer Aided Civil and Infrastructure Engineering*, 17, 269-179.

48. Federal Highway Administration (2004, May), Asset Management: RealCost Software User Manual, U.S. Department of Transportation, Retrieved September 6, 2009 from FHWA website: http://www.fhwa.dot.gov/infrastructure/asstmgmt/rc210704.pdf .

49. Garvin, M. J., Wooldridge, S. C., Miller, J. B., McGlynn, M.J. (2000). Capital Planning System Applied to Municipal Infrastructure. *Journal of Management in Engineering*, 16(5), 41 – 50.

50. Mahboub, K., Hancher, D., Wang, Y., Contractor-Performed Quality Control: Is the Fox Guarding the Henhouse? *J. Profil. Issues in Engr. Educ. And Pract.* 130, 255 (2004), DOI:10.1061/(ASCE) 1052-3928 (2004) 130:4(255).

51. National Cooperative Highway Research Program (2001). Guidelines for Warranty, Multi-Parameter, and Best value Contracting, NCHRP Report # 451.

52. Gransberg, D., Datin, J., Molenaar, K., Quality Assurance in Design-Build Projects, NCHRP Synthesis 376, 2008.

53. Mesa, PDC, & LLC. (2000). A Summary of the New Mexico State Route 44 Project.

54. Albuquerque Journal (1999, December). Four Lane Politics. A Journal Special Report Reprint.

55. Life Cycle Cost Analysis, The Pavement Interactive. Retrieved on March 4, 2010 from http://pavementinteractive.org/index.php?title=Life-Cycle_Cost_Analysis .

56. *Economic Analysis for Highways*, Robley Winfrey, International Textbook Company, 1969.

57. Salary.com, http://swz.salary.com/salarywizard/layouthtmls/swzl_salarycenter.html .

58. Labor Law Center, State Minimum Wage, http://www.laborlawcenter.com/t-State-Minimum-Wage-Rates.aspx?gc...

59. "Primer on Vehicle Fuel Efficiency and Emissions, Executive Summary," CAA, http://www.scribd.com/doc/23006668/Executive-Summary-of-the-Primer-on-Automobile-Fuel-Efficiency-and-Emissions .

60. Hall, J., "Economic Benefit of Accident Reductions," 68th Annual Institute of Transportation Engineers Meeting, Toronto, 1998.

61. San Juan Economic Development Service, http://www.sanjuaneds.com/ .

62. UNM Bureau of Business and Economic Research, http://bber.unm.edu/ .

63. AASHTO Center for Excellence in Project, Transportation Funding and Financing. Retrieved December 7, 2009 from AASTHO website: http://www.transportation-finance.org/funding_financing/financing/credit_assistance/tifia.aspx .

64. Cui, Q., Life Cycle Cost Analysis Model, Highway Warranty Workshop. (2006). University Transportation Center of Alabama.

65. Fraser, N., I. Bernhardt, E.M. Jewkes, and M. Tajima. *Engineering Economics in Canada*, 2nd Edition, Prentice Hall Canada Inc., Scarborough, 2000.

66. Gibson, G.E., Connor, J. T., Migliaccio, G., Waleski, J. (2007). Key Implementation Issues and Lessons Learned with Design-Build Projects. In K. R. Molenaar & G. Yakowenko (Eds), Alternative Project Delivery Procurement, and Contracting Methods for Highways (pp. 1-18). Washington DC: American Society of Civil Engineers.

67. Kleinburd,R.,(2009, December). Innovative Financing for Highway Projects. O.R.Colan Associates.

68. Kobayashi, K. , Ejiri, R., Myungsik, D., (2008, June). Pavement Management Accounting System. *Journal of Infrastructure Systems*, 14 (2), 159-168.

69. Martinez, Martin PM Consultants, Personal Communication, September 29th, 2009.

70. Michin, R. E., Smith, G. R. (2007). Guidelines for Quality -Based Contractor Qualification. In K. R. Molenaar & G. Yakowenko (Eds), Alternative Project Delivery Procurement, and Contracting Methods for Highways (pp. 98 - 112). Washington DC: American Society of Civil Engineers.

71. Miller, J. B. (1997). Engineering Systems Integration for Civil Infrastructure Projects. *Journal of Management in Engineering*, 13(5), 61.

72. Saaty, T.L. *Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process*, RWS Publications, Pittsburgh, PA, 1994.

73. Utah T2 Center, Innovative Contracting Best Practice Guide, University of Utah. Retrieved on February 25, 2009 from http://www.ic.usu.edu/index.php .

APPENDIX B: INTERVIEW DOCUMENTS

Invitation to Participate in Study

To: <Name of the Invitee>

From: Jerome W. Hall, Ph.D., Giovanni C. Migliaccio, Ph.D, Rafiqul Tarefder, Ph.D. Department of Civil Engineering, University of New Mexico.

Subject: NM44/US550 Road Lifecycle Innovative Financing Evaluation.

Reference: Invitation for a Phone Interview.

Dear <Invitee>:

In accord with several agreements between state and federal officials, the New Mexico Department of Transportation (NMDOT) has requested the University of New Mexico to conduct an objective and impartial study of the benefits of the NM44/US550 reconstruction project that was completed in 2001.

On this roadway project, long term warranties were included in the scope of the work. To date, only a limited number of warranty contracts have been implemented by Department of Transportation in the United States. Therefore, there is a need for research to examine the use of pavement and bridge warranties and to develop guidelines to assist state highway agencies in determining when to use warranties and how to apply them efficiently. A research team at the University of New Mexico is evaluating the NM44/US550 warranty project in New Mexico.

You have been identified by the NMDOT as a potential source of information for this study; your cooperation in assisting us with compiling this information is greatly appreciated. We believe that your participation in this study will prove to be interesting and rewarding. We expect that a dozen key representatives from federal and state transportation agencies, and consulting firms involved in the project will participate in this study. We will, of course, provide you with feedback from the results as the project is completed. Any information you provide as part of this study will remain anonymous. We look forward to your participation and request that you indicate your willingness to participate, by answering to the attached invitation letter by mail, phone or fax. If you have any further questions, please contact Dr. Migliaccio at gcm@unm.edu or (505) 277-1948

Sincerely,

Jerome W. Hall, Ph.D., P.E.
Giovanni C. Migliaccio, Ph.D.
Rafiqul Tarefder, Ph.D.
Department of Civil Engineering, MSC 01 1070
University of New Mexico
Albuquerque, NM 87131
Fax (505) 277-1988

Invitation Letter

Under agreements between state and federal officials, the NMDOT has asked the Department of Civil Engineering, University of New Mexico to conduct an objective and impartial study of the benefits of the NM44/US550 reconstruction project, completed in December 2001. You have been identified as a potential source of information and your cooperation in assisting us with compiling this information is greatly appreciated.

Project Summary:

The purpose of our research is to improve understanding of the innovations implemented in the NM44/US550 highway project (i.e., use of innovative financing approach, purchase of a pavement and bridge warranties, consolidation of the project in four segments, and procurement of project management services from contractors). The objectives pursued in this research are:

1. Developing a decision model to analyze the various innovative procedures that were used by NMDOT in completing NM44/US550 and determining the impacts of these procedures on the project performance (i.e., cost, schedule and quality). This will facilitate the decision to include some of these procedures on future projects.
2. Evaluating benefits of NM44/US550 road improvements, in terms of safety, vehicle operating costs, travel time and maintenance. Focus on evaluating costs and benefits for widening the road to four lanes.
3. Evaluating economic and development impact resulting from improving access to the communities along US 550 and identifying the party benefiting from these impacts.
4. Assessing a life cycle cost analysis (LCCA) of the NM44/US550 project and developing a LCCA model that can be used to input data on cost and benefits for the remainder of the warranty.

Statement of Privacy:

The following conditions will be maintained during the study:

- The information collected during the survey will be kept anonymous.
- The responses will not be placed in any permanent record, and will be destroyed when no longer needed by the researchers.
- The identity of the respondent will remain anonymous; all information obtained will not be linked in any way to the participant.
- In addition, no personal information will be made public at any time during or after this project.

<u>YOUR PARTICIPATION IS VOLUNTARY AND YOU MAY DECIDE TO WITHDRAW FROM THE STUDY AT ANY TIME.</u>

Instructions:

We appreciate your participation in this study. We'd like to schedule a face-to-face interview or a phone-interview, in order to conduct the survey. If it is not possible to arrange an interview we would like to send you a questionnaire.

If you have any question please don't hesitate to contact Dr. Migliaccio at gcm@unm.edu. If you agree to be contacted as a participant to this study, please provide your contact information below and return this form to the address provided below by <date>.

Name: ____

Preferred Method of Contact (phone/mail/email): ___________________________________

Jerome W. Hall, Ph.D., P.E.
Giovanni C. Migliaccio, Ph.D.
Rafiqul Tarefder, Ph.D.
Department of Civil Engineering, MSC 01 1070
University of New Mexico
Albuquerque, NM 87131

APPENDIX C: WARRANTY IMPLEMENTATION GUIDELINES

Detailed guidelines for implementing warranty contracting (WC) in the highway industry have been developed by National Cooperative Highway Research Program (NCHRP). The implementation process was divided into several sections such as "conceptual planning," "program planning," "bidding," "contract award," "construction," "maintenance," "evaluation of performance," "pilot project evaluation," and "organizational program evaluation." The NCHRP report includes a flow chart representing the whole process in pages 8-10. The following sections summarize steps to be considered for a particular project depending upon the experience of the State Highway Agency (SHA) in using WC in its previous projects. The NCHRP research team has defined the experience level of the SHAs in the following manner:

- No Experience: First time user of highway WC
- Lower–to–Moderate Level of Experience: Having up to five WC projects
- High Level Experience: Having more than five WC projects

Conceptual Planning Phase

1) Level of Experience of SHA: This phase identifies the experience level of the SHA considering exercising a warranty. If the SHA falls under the "No Experience" category, then it should start with identifying the amount of motivation it has for implementing SHA. If the SHA is lower to moderately experienced, then it can begin by reviewing and understanding the warranty contracting best practices. A highly experienced SHA can directly commence with preparing warranty specifications.
2) Motivation for Implementing Warranties: The SHA must figure out the valid reasons for implementing a WC before any other step. After carefully evaluating its scope and objective to be achieved by the warranty provision, the SHA needs to decide whether or not to opt for this contracting option.
3) Review of Best Practices for Warranty Contracting: The highway agency should review the previously conducted highway warranty projects and study the information available from their execution to integrate and put into practice the best methods possible in WC implementation.

Program Planning Phase

4) WC Decision: The decision of considering warranty contracting should depend on a comparison of results from the previous two steps. After reviewing WC best practices and comparing these results (Step 3) with the agency's reasons for considering WC (Step 2), the agency should have enough basis for making the decision. A critical aspect of this decision is the expected level of management support.
5) Rejection of WC: If the agency is not so confident, then it should stop the process at this time. On the other hand, if the previous analysis has produced results that support the use of WC, the agency should go to the next step, which is identifying the elements to be considered for the warranty.
6) Identifying End Products for Warranty Implementation: End products are the constituents on which WC has to be applied. For instance, asphalt pavement and structures were the end products for the US 550 warranty.

7) Establishment of Cooperation and Communication among project participants: All project stakeholders should be involved in the WC development process. This involvement should begin in the early stages. The parties are also required to be informed about the relevant information regarding a warranty, such as respective roles and responsibilities, risk transfer, identifying problems and additional requirements. Thus, it is vital for the parties to be in good relationship, as cooperation of all the parties throughout the process is needed for a WC project to be successful.
8) Preparation of Warranty Specification: Warranty specifications can be prepared following the AASHTO Guide Specifications for Highway Construction (1998 Edition). WC specifications should include a set of key elements that are listed in Table 4 at page 15 of the NCHRP Report.
9) Final review of the specification before use: draft specifications should be thoroughly reviewed by the agency so that the specification language would be free from vagueness that may give rise to disputes. Project stakeholders should participate in the review process. This review should be open to all potential participants to the procurement of the warranty contract (potential proposers).
10) Selection of Pilot Project: After the specification is finalized, SHA should select a suitable project on which the warranty provision can be tested to obtain detailed information about the process and also to understand the best way to implement it. The projects suitable for this purpose are probably low budget projects having low complexity.
11) Bid Documents Preparation: The warranty program should be explained in the bid document, especially for pilot projects. The SHA may perform quality control testing for informational purposes.

Bidding, Contract Award, and Construction Phases

12) Pre-Bid Conference: A Pre-bid conference should be conducted by the agency to make sure that all the parties are comfortable with the warranty program and have understood the specific terms and conditions.
13) Bidding out: After a satisfactory bid document is prepared, the SHA will bid out the project. Bidding would be done similarly to traditional projects.
14) Selection of Lowest Responsible Bidder: This may also be similar to traditional projects. More detail is provided in the NCHRP report.
15) Preconstruction Conference: The SHA should conduct a preconstruction conference to address the questions of the selected warranty contractor and to make sure that WC terms and conditions are understood and quality aspects are commonly agreed upon. At this time, the contractor should also be encouraged to disseminate information to the field personnel. Finally, this is the time to form the conflict resolution team.
16) Construction Phase: the contractor is usually provided the liberty of selecting any material, methods and techniques that the contractor thinks will meet the established performance criteria, as it is the responsibility of the contractor to maintain the facility during the warranty period. As mentioned earlier, the SHA can collect samples to conduct quality testing only for informational purposes.

Maintenance and Evaluation of Performance Phase

17) Initiation of the Warranty Period: The warranty period can start at the end of substantial completion, or just after accepting the project, or during the opening of the traffic. Again the

warranty can start for only a section of the project if other parts of the project are still under construction.

18) Collections of Performance Data by SHA: Performance data as mentioned in the warranty specification are collected by agency staff to check whether the end product has met the performance criteria. Surveys should be conducted by the SHA, 1 month after the completion date on the sections which may be both predetermined and random. All the costs incurred by the SHA for periodic distress survey should be recorded.
19) Analysis of Performance Data by SHA to determine the need of Remedial Action: If the end product does not meet the performance criteria, then the SHA should adopt remedial actions, which are generally specified for different distresses in the warranty document such as rehabilitation.
20) Remedial Actions: If the analysis reveals the need of remedial action, then the SHA needs to inform the contractor about the remedial measures required to be taken.
21) Notification to the Contractor about the remedial action: The SHA should notify the contractor about the problem and need of remedial action, in writing, within a certain interval of time after the survey is being conducted.
22) Contractor's action on remedial issue: The contractor needs to respond to the notice within a stipulated amount of time with a plan for fixing the problem. The contractor can begin work after the plan is reviewed and accepted by the owner. If the contractor fails to comply with the plan or is not willing to carry out any work for the remedy, the case is handed over to the conflict resolution team.
23) Employment of "Conflict Resolution Team (CRT)": The CRT plays a vital role to resolve disputes when there is a misunderstanding in the acceptance of responsibility by either party. The CRT should be able to resolve the conflict in 30 days. If the contractor refuses to pay, then the contractor's surety company is asked to pay on behalf the contractor, as it is in "default of obligations under the warranty bond." If this does not work, the SHA should go for litigation to make the claim.
24) Status of the Conflict: If the issue is resolved, then the SHA should move forward or should notify the surety about the contractor default.
25) Warranty period: If the warranty is not over before the dispute resolution, the previous steps starting from the performance data collection are to be conducted every year until the completion of the warranty period. This should be followed by final inspection and warranty termination.
26) Notification to Surety of Contractor Default: This is just an intermediate step to be conducted if the contractor refuses to pay for the maintenance cost incurred by the SHA.
27) Need of Maintenance: The need of maintenance can be identified by either party. The responsibility for the maintenance has to be figured out clearly and documented in the agreement.
28) Classification of Maintenance: Maintenance can be categorized into Routine, Preventive, Remedial Action and Emergency. Routine maintenance should generally be conducted by the SHA; this includes signage maintenance, snow removal, salting/sanding, mowing, and replacement of guardrails. Preventive maintenance is the precautionary measure that should be taken by the contractor to prevent remedial action. Remedial action is needed when the distress exceeds the threshold limit and requires replacement or repair in compliance with the warranty specification. Emergency repairs are required for the failure or distresses which need

immediate attention. These are supposed to be performed by the contractor, but in unfavorable conditions, the owner may have to fix it and later charge the contractor for the costs.

29) Completion of Warranty Period: If the warranty period is not complete, then the need of maintenance is to be performed until the end of the period. At the end, the SHA should go over to the next step, i.e., warranty termination.

Pilot Project and Organizational Program Evaluation Phases

30) Final Inspection/ Warranty Termination: SHA should run a final scrutiny of the project at least one month before the end date. Repair work, if needed, should be performed by the contractor within one month. If everything meets the performance criteria at the end of the warranty period, the SHA should terminate the warranty at that time.

31) Warranty Evaluation: The evaluation of the whole process is really important to assess the extent to which the objective defined before undertaking the project is achieved. Some of the aspects to be evaluated are long term performance, amount and quality of resources used, transfer of risk and liabilities on participants, claims and litigation and also cost and schedule overgrowth, if any. The lifecycle cost (LCC) thus calculated can be compared with the LCC if the project was executed using the traditional method. All the parties involved in the project should be aware of the results obtained from the evaluation.

32) Whether to implement warranty in future projects: If the results obtained from the evaluation are not too satisfactory, then the SHA may opt not to implement warranty any more. But if the results show that the pilot project has fulfilled the expectations desired from the warranty contracting, then it may carry out some more studies and apply changes if required to the warranty program.

33) Discontinuing the use of Warranty Program: As mentioned earlier, the warranty provision, if not successful in achieving the project objective, should not be considered for future projects.

34) Recommendation and Modification: The lessons learned from the pilot project should be used to make necessary modifications to any aspect of the warranty that has created any problem during the process, to obtain a perfect warranty implementation procedure.

35) Refinement of Warranty program: The information obtained from the project should be documented and used to refine the warranty program by revising the warranty specification prepared. Also the projects most suitable for warranty contracting should be identified.

36) Continuation and Expansion of Warranty Implementation: Once the modifications are made, the new specifications should be used for future projects, and each project should be evaluated to obtain the cost and performance data to better understand the use of warranties.