FHWA/IN/JTRP-2008/27

Final Report

**CONSTRUCTION COSTS - USING FEDERAL VS.
LOCAL FUNDS**

***IDENTIFYING FACTORS AFFECTING HIGHWAY
CONSTRUCTION COSTS WHEN SOURCES OF
FUNDING VARY: A CASE STUDY***

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CONSTRUCTION COSTS – USING FEDERAL VS. LOCAL FUNDS

Identifying Factors Affecting Highway Construction Costs

When Sources of Funding Vary: A Case Study

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ABSTRACT

Costs of highway construction projects have been increasing with rising prices of construction materials such as asphalt, concrete and steel. Identifying cost saving strategies is one of the ways for the efficient utilization of available funds (federal and local) by the state Department of Transportation (DOTs) and Local Public Agencies (LPAs). A case study comprising of a sample pair of projects (a federal-aid project and a 100% locally funded project) constructed in Elkhart County, Indiana was undertaken to compare construction costs when sources of funding vary. Based on analysis of cost details from these two projects and discussions with the general contractor involved with these projects and other contractors in Indiana, possible reasons of cost differences between the projects were identified. Pavement evaluation tests were conducted to compare the pavement conditions of the road sections built under the two sample projects. The report presents some observations regarding cost differentials between federally funded projects vs. 100% locally funded projects, and provides some suggestions for future investigation and study.

CHAPTER 1. INTRODUCTION

The Federal Highway Administration's (FHWA) Office of Infrastructure Research and Development (R&D) has identified the delivery of "safe, environmentally-friendly, long-lasting, disaster-resilient, and cost-effective highway infrastructure" as its major goal for the 21st century (*Highways of the future – A strategic plan for highway infrastructure research and development, 2008*). However, with a 49% increase in producer price index (PPI) for highway construction in the US since December 2003 (*AGC Construction Inflation Alert, 2007*), cost-savings is now a challenge for the FHWA, state Departments of Transportation (DOTs) and the local public agencies (LPAs). The FHWA issued guidance to its divisions administering the federal-aid program in all the states on recommended steps for helping state DOTs deal with the increase in cost and decrease in availability of various construction materials (*AGC Highway Facts Bulletin, July 2008*). The guidance indicates that factors responsible for cost increase include: decreased supply and rise in prices of asphalt cement, polymer modified asphalt cement, fabricated structural and reinforced steel; and it requires FHWA division offices to work with state DOTs in making adjustments in contracting considerations for current and future contracts, and for the appropriate use of price adjustment clauses on future contracts on a case-to-case basis.

Cost saving strategies holds the key to striking a balance between federal funds received by the DOTs and planned projects waiting for execution. At the same time, the quality of construction has to be ensured to prevent disasters such as the I-35W bridge collapse in Minneapolis in 2007. Hence, instead of a tradeoff between cost and quality, initiatives are required from the DOTs to build more economical yet durable roads through approaches such as value engineering, promoting performance-based specifications, use of recycled materials, increased contracting efficiencies, price adjustments and risk sharing.

The Indiana Department of Transportation (INDOT) invests approximately \$500 million annually to preserve the existing state highway system (*INDOT Efficiency Task Team Report of the General Government Sub-committee of the Government Efficiency Commission, 2004*). This

includes projects such as highway resurfacing, road reconstruction and bridge rehabilitation. Also, over \$200 million each year is spent on new construction, such as added travel lanes, bridge construction and interchange modifications. In May 2005, INDOT announced a \$2.1 billion funding gap for new highway construction projects over the next 10 years. The Association of General Contractors (AGC) forecasts a yearly producer price index (PPI) increase of 6 – 8% for highway construction material, which adds to the already existing deficit (AGC *SmartBrief*, 2008). Similar to most of the state DOTs, INDOT faces the challenge of keeping pace with new highway construction and limited funding; thus greater initiatives towards construction cost savings on existing and future road construction are required.

1.1. Project Objectives

This study investigates factors related to different work practices such as construction engineering, material testing, inspection etc., which may impact project costs for road construction in the State of Indiana. The primary objective of this study was to extend the Indiana Local Technician Program's (LTAP) compilation of bridge replacement costs to include costs related to roadways and highways, in order to determine: (a) the factors which affect the costs of locally and federally funded projects in Indiana, and (b) the impact of differing sources on projects. Indiana LTAP provides technical assistance and training to the highway, road and street departments of all 92 counties, 117 cities, and over 456 towns in Indiana. Technical assistance is provided through training programs conducted at Purdue University; topical workshops and seminars on subjects pertaining to roads and streets; regular newsletters; and periodic publications. It provides necessary information to help the local units of government find the latest tools to analyze their highway and road problems and to help them perform their responsibilities correctly and efficiently. Indiana LTAP also provides assistance via the telephone and web site (<http://rebar.ecn.purdue.edu/LTAP/home>).

The secondary objectives of the study were to: (a) differentiate regulatory restrictions, design and specification requirements of federally funded and locally funded projects, and (b) compare project cost components of two sample road construction projects, including an evaluation of performance of road sections belonging to each sample project.

Since the focus of the study was on a pair of sample projects, funded by different sources, but conducted by the same contractor in the same area, the study is not exhaustive, and hence the statements in this report are observations and should not construed as findings of a robust and more analytical study. Nonetheless, the observations provide a good platform for future investigation into cost differences of highway construction projects when funding sources are different, and to identify methods to decrease project life-cycle costs without impacting durability and performance.

1.2. Research Methodology

To meet the aforementioned objectives, a multi-step approach was followed. It involved: (a) literature review of factors associated with highway construction costs and funding strategies of INDOT; (b) interviews with highway construction contractors in Indiana, personnel from INDOT and the neighboring Illinois Department of Transportation (IDOT) for their views on reasons for cost differentials between federal-aid and local projects; and (c) comparison of construction costs, specifications and performance of two sample projects proposed for the study based on cost data received from the contractor, Niblock Excavating Inc., and pavement evaluation tests conducted by Elkhart County Highway Division.

Figure 1.1 shows the steps of the research methodology. Steps 1 through 3 involve comparing the sample pair of projects on the basis of cost of items of work, comparing their pavement performance evaluation and identifying differences in requirements such as environmental compliance, disadvantaged business enterprise (DBE) goals and standard specifications, when federal funds are utilized. Steps 4 through 6 involve identification of general differences between federal-aid highway project and 100% locally funded project. Results from interviews (Step 5a) were analyzed to develop a list of probable factors responsible for cost differences between federal-aid highway projects and locally funded projects in Indiana. Finally, suggestions for cost savings were developed for possible use by INDOT on future projects.

Figure 1.1 Steps involved in the research methodology

1.3. Organization of the Report

The report contains six chapters. Chapter 2 discusses the existing literature on construction costs of highway projects; price trends for material, labor and equipment; and funding strategies for highway construction and maintenance projects in the State of Indiana. Chapter 3 discusses the possible factors responsible for cost differences between federally funded and locally funded projects. In Chapter 4, the two sample projects referenced above are analyzed based on the scale and scope of work, cost of items of work and material specifications. Chapter 5 provides the results of performance evaluation of the two sample projects. This evaluation is based on the analysis of pavement tests for surface distress, deflection and roughness. Chapter 6 discusses the conclusions of the study and provides recommendations for cost saving initiatives that can be utilized by INDOT on future projects.

CHAPTER 2. REVIEW OF PRIOR WORK

This study is geared towards identifying factors that can influence costs of construction projects with differing funding sources. A description of the funding sources, the eligibility criteria for projects to receive federal aids and the difference between federal, state and local requirements in areas such as environmental compliance, disadvantaged business enterprise (DBE) programs, material testing, etc., are the first steps towards a systematic literature review. Since a preliminary literature review did not indicate any published work assessing the causes of cost differentials, trends in national average costs of highway projects and their components such as material, labor and equipment were analyzed. Other issues such as the level of competition among contractors, construction material availability, rising fuel prices, etc., are also discussed since they may have a direct influence of bid prices of projects.

In particular, two existing research studies were analyzed: (a) a highway construction cost comparison survey, conducted by Washington DOT (WSDOT) in 2002, and (b) a bridge replacement cost estimation study conducted by the Indiana Local Technician Program (LTAP) in 2005. The former study identified variations in costs of project components such as construction environmental compliance, preliminary engineering, right-of-acquisition, construction engineering, etc. among various state DOTs for a “representative project that would be universal in all states” (*Construction Cost Comparison Survey Report, WSDOT 2002*). The latter study provided a regression based method to estimate the effect differing funding sources (federal vs. local) have on the cost of a bridge replacement project in Indiana.

2.1. Funding for highway construction projects in Indiana

Each year Indiana receives an allocation of federal funds from FHWA under the Surface Transportation Program (STP). INDOT shares a portion of these funds with the LPAs. It receives

75% of the allocated funds while the remaining 25% are received by local agencies including the Metropolitan Planning Organizations (MPOs). Of the 25%, some funds are reserved by federal law for urbanized areas, namely cities with populations at or above 50,000. The rest is for counties and smaller cities and towns in the state (*Program Development Process, INDOT, 2004*). On federal-aid highway projects (state or LPA project), 80% of the costs are covered by federal funds and 20% by non-federal funds i.e., either a state match or a local match. Another important aspect of this funding split is that except for transportation enhancement (TE) funds, it is INDOT's policy that all funds are available for only the construction and construction engineering phases of work. Federal aids will not be approved for preliminary engineering (PE) or right of way acquisition (ROW). Expenses for these phases are required to be covered with funds from other federal, state or local sources. The local federal aid office at INDOT distributes federal funds among the various Local Public Agencies (LPAs) from cities, counties, towns, etc., once projects are proposed and requests for funding are made. There are also 100% state funded and 100% locally funded projects constructed in Indiana that involve no federal funding. The 100% locally funded projects do not require the supervision of INDOT. Such projects do not utilize federal aids and their successful construction is the responsibility of County Highway Divisions. No federal requirements such as federal wage law (Davis-Bacon Act), environmental documentation, DBE goals, CAP certification, etc., are enforceable on projects that do not include a federal dollar.

2.2. Highway construction cost trends for highway projects

With increasing demand for construction materials such as steel and asphalt in developing nations, that has been triggered by increasing fuel prices, most state DOTs have witnessed an increase in construction costs of highway projects. Figure 2.1 shows escalation in the two major national indices of highway construction and maintenance costs: the Federal Highway Administration Bid Price Index (FHWA BPI), and the Bureau of Labor Statistics (BLS) bridge and highway construction producer price index (BHWY PPI). The unfortunate impact of these price increases may be the deferral or cancellation of projects in a contracting agency's long-term construction program (FHWA, 2007). It can also lead to shortage of funds for on-going and

future highway projects. Figure 2.2 shows a trend in the total value of construction on highway and bridge projects in the US. The rise in spending on highway and bridge projects has decreased since 2007. The American Road & Transportation Builders Association (ARTBA) projects the value of construction work involved in highway and bridge projects will be \$80.2 billion in 2009, a mere 1.5 percent increase over \$79 billion expected to be expended in 2008.

Figure 2.1 Escalation in highway bid prices (FHWA) and construction material prices (BLS)

Figure 2.2 Value of construction on highway and bridge projects since 2001 (ARTBA, 2008)

2.2.1. Construction material price trends

The cost of highway and street construction materials was up 11.8 percent in January 2008 compared to the same month during the previous year. Between 2002 and 2007, the price of highway and street construction materials rose 46 percent (ARTBA, 2008). Figure 2.3 shows the price trend for a few highway construction materials between 2001 and 2006. A significant jump of 19% was recorded in the price of construction materials between June 2007 and June 2008. Table 2.1 shows a percentage increase in prices of highway construction materials such as iron and steel scrap, diesel fuel, asphalt, cement, etc., since June 2007. Steel scrap is the primary input to the production of steel used in highway projects. Growth in international demand for steel has resulted in prices for common scrap nearly doubling since 2003. Higher gasoline prices and growing international demand for middle distillates, such as diesel fuels, has resulted in a decrease in the production and an increase in the price of asphalt. The price of cement tracks the growth in oil prices since the production of cement is a highly fuel-intensive process (*Growth in Highway Construction and Maintenance Costs*, FHWA, 2007)

Figure 2.3 Price trends of construction materials from 2001 to 2005 in the US (Construction trends for federal-aid highway projects, FHWA)

Table 2.1 Percentage yearly increase in price of construction material (ARTBA, 2008)

<i>Construction material</i>	<i>Percentage increase in price (June 2007 to June 2008)</i>
Iron and steel scrap	97
Diesel fuel	85
Asphalt paving and block manufacturing	14
Sand, gravel and crushed stone	7
Ready-mix concrete	3
Concrete block and brick	3
Cement	1

2.2.2. Construction labor and equipment cost trends

Labor accounts for roughly half the cost of a construction project. Employment in highway and bridge construction fell by 2.9 percent in January 2008 compared to the same month a year ago. Figure 2.4 shows the trend for average hourly wage of construction workers since 2002. Equipment costs had been rising at 5-6 percent rate for the 2006-2008 time frame (*AGC's Construction Inflation Alert, 2008*). Even though global demand for equipment machinery is rising due to increased construction occurring in developing nations such as China and India, the overall demand in the US declined by 1.9 percent in 2007 (Association of Equipment Manufacturers, 2007). A decline in demand of earth moving equipments, bituminous pavers, rollers and soil stabilizers, heavy-duty trucks and compactors was also forecasted for 2008. This could be attributed to a decline of 5% - 7% in the volume of highway and bridge construction in the US (*ARTBA 2009 Economic Forecast, 2008*).

Figure 2.4 Average Hourly wage of construction workers since 2002 (ARTBA, 2008)

2.2.3. Level of competition among contractors

The average number of bids received for a highway project establishes the level of competition among contractors. However, the number of bids received for federal-aid highway projects in the State of Indiana has been decreasing, as shown in Table 2.2. The three major reasons for a decrease in average number of bids per project are: (a) increased work with same number of contractors; (b) project delays caused by material shortages, with no corresponding contract time extension which discourages contractors from bidding for similar projects in future; and (c) consolidation of contractors into a single company to share risk and profits. A decrease in number of bids can be a sign of decline in competitive bidding on federal-aid projects, resulting in a higher average bid price.

Table 2.2 Average number of bids per project in Indiana (AASHTO / FHWA Survey on Construction Cost Increases and Competition, April 2006)

Year	2001	2002	2003	2004	2005
<i>Number of bids</i>	4.17	3.87	3.76	3.56	3.56

2.3. Comparing cost of highway construction among different US States

Highway project costs can differ across US states for a number of reasons. For example, highways are more expensive to build in mountainous areas than in flat areas. Projects in urban areas are more expensive than those in rural areas. Projects with bridges cost more than similar projects that do not require bridges. Compared with smaller projects, it is anticipated that large projects may result in lower unit costs because of economies of scale. However, if the project continues beyond one season, it is likely that efficiencies due to such economies of scale may not be realized. More complicated projects, such as those with a large number of interchanges or complicated engineering problems, can cost more than less complicated projects, due to the higher level of risk involved. Other factors that may affect cost are the degree of competition for contracts (local contractors are also competitive when bidding on smaller projects, and hence there may be more competition among bidders for locally funding projects) and different state design standards.

In 2002, WSDOT analyzed reasons for cost difference in highway construction projects among different states by conducting a national survey that involved 25 US states. After reviewing over fifty potential interchange projects, WSDOT chose a 1.02 mile long interchange project on SE 192nd Avenue interchange on SR 14 as a “representative project” for the survey. The quantities for the 1.02 mile portion of the project used in the survey were calculated and grouped into major bid items. Figure 2.5 shows an aerial photo of the representative project. Table 2.3 lists the major bid items under categories of work such as structures, grading, other construction, and mobilization/contingencies. The drawings and bid items of the project were provided in a survey form. This form was sent to the members of American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Design. The participants were asked to provide unit costs for the major bid items in their respective states, and percentage of cost distributed among categories such as mobilization, preliminary engineering, and construction engineering. They were also asked to provide range of project costs in their state for right-of-way acquisition, environmental documentation and compliance and mitigation associated with the construction; and whether the state had a prevailing wage act in addition to the federal prevailing wage law. The project cost calculated after addition of bid items ranged from \$4.0 million to

\$26.7 million. The data was used to calculate the cost of constructing a single lane mile of the selected project. The national average single lane mile cost was found to be \$2.3 million. Figure 2.6 shows lane mile costs from each of the 25 states that responded to the survey.

Figure 2.5 Aerial photo of the representative project chosen for WSDOT's survey of Highway Construction Cost Comparison, 2002

Table 2.3 Major bid items of the 1 mile long “representative project”

Cost Estimate:		Quantity	Unit
STRUCTURES			
Bridge		7.371	SF
Walls (Retaining)		5,751	SF
GRADING			
Roadway Exc.		933,527	YD 3
Structure Exc. Cl	'B'	14,194	YD 3
Clear/Grub/ Shrubs/Grass		30.00	Acre
OTHER CONSTRUCTION			
Guardrail (w/anchors & terminals)		4,416	LF
Concrete Barrier - Single Slope, Cast in place		5,000	LF
Striping		139,900	LF
Asphalt Concrete Paving		31,089	Ton
Surfacing - Crushed Surfacing		27,575	Ton

Figure 2.6 Highway lane mile cost comparison (WSDOT, 2002)

The study also established variability ranges of costs of preliminary engineering, construction engineering, right of way, environmental compliance and documentation, and mitigation. The survey form consisted of a section where the state DOT was asked to provide the best estimate of the range of variability of percentage of project cost for the aforementioned categories. Table 2.4 shows the variability in the responses of all the 25 state DOTs who participated in the survey. Costs of engineering, both preliminary and construction ranged from 4 to 20 percent. The variability rates for right-of-way acquisition ranged from 10 percent or less to over 30 percent of project cost. The rates for environmental documentation (State Environmental Policy Act (SEPA) and National Environmental Policy Act (NEPA) permits) ranged from 10 percent or less to as much as 20 percent in three of the reporting states. The rates for construction environmental compliance and mitigation ranged from 10 percent or less to nearly 20 percent reported by four states.

Table 2.4 Variability in cost of construction and other cost categories (WSDOT 2002)

State Name	Construction Cost	Right Of Way Variability	Environmental Documentation Variability	Environmental Mitigation Variability	State Prevailing Wage Law	PE %	CE %	Mob. %
Mississippi	\$1,033,576	11 - 20%	0 - 10%	0 - 10%	No	-	5%	5%
Montana	\$1,118,827	0 - 10%	0 - 10%	0 - 10%	Yes	<10%	10%	8%
Wyoming	\$1,261,046	11 - 20%	0 - 10%	0 - 10%	Yes	10%	12%	8%
Arizona	\$1,295,908	>30%	11 - 20%	11 - 20%	No	8%	15%	10%
Ohio	\$1,330,176	11 - 20%	0 - 10%	0 - 10%	Yes	10%	8%	3%
Washington	\$1,445,662	0 - 10%	0 - 10%	11 - 20%	Yes	15%	15%	10%
Illinois	\$1,398,314	0 - 10%	0 - 10%	0 - 10%	Yes	10%	12%	3%
Michigan	\$1,454,462	>30%	11 - 20%	11 - 20%	Yes	8%	0 - 15%	5%
New Mexico	\$1,526,631	> 30%	0 - 10%	0 - 10%	Yes	8 - 10%	15 - 20%	10%
Oklahoma	\$1,510,910	11 - 20%	0 - 10%	0 - 10%	No	5%	9%	3%
South Dakota	\$1,616,581	0 - 10%	0 - 10%	0 - 10%	Yes	4%	10%	10%
North Carolina	\$1,590,182	> 30%	0 - 10%	0 - 10%	Yes	10%	10%	5%
West Virginia	\$1,572,946	11 - 20%	0 - 10%	0 - 10%	Yes	15%	18%	1%
Kansas	\$1,914,917	11 - 20%	0 - 10%	0 - 10%	No	7%	10%	6%
Oregon	\$2,112,486	11 - 20%	0 - 10%	0 - 10%	Yes	12%	-	10%
Idaho	\$2,178,689	> 30%	0 - 10%	0 - 10%	No	10%	10%	10%
California	\$2,213,519	0 - 10%	0 - 10%	0 - 10%	Yes	20%	15%	10%
Arkansas	\$2,257,449	11 - 20%	0 - 10%	0 - 10%	Yes	10%	10%	10%
Massachusetts	\$3,069,336	Varies	0 - 10%	0 - 10%	Yes	10%	10%	0%
Maine	\$3,594,823	0 - 10%	0 - 10%	0 - 10%	No	9%	10%	8%
Hawaii	\$5,942,278	11 - 20%	11 - 20%	0 - 10%	Yes	10%	15%	10%
New Jersey	\$4,787,288	11 - 20%	0 - 10%	0 - 10%	Yes	15%	10%	10%
New York	\$8,461,288	No Data	No Data	No Data	Yes	5%	10%	4%
Colorado	\$1,602,251	No Data	0-10%	11-20%	No	11%	11%	5%

2.4. Comparing highway construction costs on federal and local projects

There is a lack of existing research that discusses the causes for cost differences between federal-aid projects and 100% locally funded projects. However, a study by Indiana LTAP to estimate cost of replacing county bridges indicated that costs tend to be higher when federal aid funding is used for bridge replacement. As a follow-up to a report by INDOT in 2005 that stated that nearly 30% of the total county bridges in Indiana were deficient and needed replacement, LTAP completed a study titled “Indiana County Highway Departments Bridge Replacement Cost Estimation Procedures” to estimate bridge replacement costs in Indiana. The estimation procedure was based on regression of cost data on bridges constructed between 1997 and 2005. Variables such as: average daily traffic (ADT), bridge deck area and old bridge length were used to create expressions for total bridge cost along with preliminary engineering costs and inspection costs. The equation for total bridge cost was given by

$$\textbf{Federal: } [555.61*(\text{DECK AREA})^{0.8673}]$$

$$\textbf{Local: } [126*(\text{DECK AREA})^{1.0002}],$$

Figure 2.7 shows a plot of total bridge cost against deck area in square feet. It was found that bridges with federal funding had larger deck area as compared to 100% locally funded bridges, hence bridge replacement costs were higher. Similarly expressions for preliminary engineering cost as a percent of total costs and construction inspection cost as a percent of total costs were also established. It was found that preliminary engineering costs for locally funded bridge replacement projects were less than those of federally funded projects as shown in Figure 2.8. The design for local bridges “is reused and adapted to another location. Consultants often offer discounts to counties that design a bridge for use in multiple locations...Federally funded projects are often larger, and take more time, and the preliminary engineering costs reflect this” (*Indiana County Highway Departments Bridge Replacement Cost Estimation Procedures, LTAP 2005*). However, as shown in Figure 2.9, the inspection costs for locally funded projects increases as the size of the bridge deck increases (reflected in the costs of the project), while the inspection costs of federally funded bridge projects decreases as the bridge deck decreases (LTAP 2005). No reasons were cited in the LTAP report for the positive slope of the construction inspection cost line for locally funded projects. These observations provide proof to the existence of cost

differentials between local and federal funding in bridge replacement projects and give rise to the possibility of cost differentials for other highway projects in Indiana.

Figure 2.7 Plot of total bridge cost (local and federal) against deck area (LTAP 2005)

Figure 2.8 Preliminary engineering cost as a percentage of construction cost (LTAP 2005)

Figure 2.9 Construction inspection costs as a percentage of construction cost (LTAP 2005)

2.5. Chapter Summary

The cost of constructing highway projects has been rising mainly due to the increase in prices of construction materials such as asphalt, steel, cement, diesel fuel, labor and equipment. However, the level of impact of these price increases varies across the different states in the US. This could be attributed to the existing material market conditions in the state, the availability of skilled labor, policies of the state DOTs, etc. Highway projects in most of the states have to fulfill federal requirements such as meeting DBE goals, following standard specifications for design and materials, environmental compliance documentation, etc., in order to receive federal funding. But for 100% locally funded projects, such federal requirements may not be applicable. This could result in differences in costs between federal aid projects and locally funded projects. By identifying factors responsible for the cost differences, initiatives for cost savings on federal-aid projects could be made. Local practices related to construction techniques, material testing, local buying and stockpiling, etc., could be replicated on federal-aid projects if they do not impact the quality and performance of the constructed structure. More economical alternative materials that have been used on previous local projects and that have matched the performance and durability of roads and bridges built using federal specifications in the same region, could be used on a trial basis on future federal-aid projects. Also, if large projects would be ‘broken’ down in to smaller sub-projects, the use of local products and local contractors could be enhanced, leading to lower costs.

CHAPTER 3. GENERAL FACTORS RESPONSIBLE FOR COST DIFFERENCES BETWEEN FEDERAL-AID PROJECTS AND 100% LOCALLY FUNDED PROJECT IN INDIANA

Between May 2008 and October 2008 interviews were conducted with highway construction contractors working on both INDOT and local jobs, to identify possible factors that could impact cost differences between federal-aid projects and 100% locally funded projects. Based on available information from FHWA and INDOT, issues such as (a) scale and scope of work; (b) FHWA standards with respect to design, environmental compliance, material certification and testing, and DBE requirements; and (c) material availability and restrictions on the use of recycled materials; were analyzed. The following sections discuss each of these issues and their possible impact (direct or indirect) on construction costs.

3.1 Scale and scope of work

INDOT estimates that the gross level of funds available in 2008, 2009, 2010 and 2011 will be approximately \$1,810,660,000 annually (*Indiana Statewide Transportation Improvement Program* (INSTIP)). INDOT shares a portion of these funds with local public agencies (LPAs). There are three principal types of projects, that can be funded under this program: (a) Bridge projects listed on the National Bridge Inventory (NBI) selection list at FHWA; (b) Roadway projects with routes on the federal highway system; and (c) Hazard elimination/safety projects for improvement of safety and reduction of severity of crashes through installation of signals, correcting sight distance problems, etc. (*INDOT/Local Federal-aid Sharing Arrangement*, 2007). Increasingly, federal-aid programs and projects are being undertaken by LPAs (*Surface Transportation Environment and Planning Cooperative Research Program* (STEP) 2008).

Highway projects tend to larger in scale, scope and cost due to factors such as: (a) higher number of grade crossings and access ramps (i.e., over water, railroad or highway); (b) additional right-of-way acquisition; (c) environmentally sensitive areas requiring extensive time consuming study and remediation; (d) larger project size and complexity requiring additional stabilizing structures,

and (e) methods of construction delivery (*Sinha and Labi, 2000*). Hence, it is often difficult for a county to raise 100% of the desired project cost. This leads regional LPA requests for federal funds to contribute to the costs of highway and bridge projects. As discussed in Section 2.1, the LPAs have to match the federal participation on an 80/20 basis. The LPA is responsible for 100% for all project costs that exceed the approved amount of federal participation.

Group III, IV and Local Bridge Projects are selected by rules promulgated by INDOT and approved by FHWA. A project selection committee is part of that process. It is composed of the following voting members:

1. Director of the Local Programs Division (Chair)
2. Manager of the Local Program Assistance Office (vice Chair)
3. Crawfordsville District representative
4. Fort Wayne district representative
5. Greenfield District representative
6. LaPorte District representative
7. Seymour District representative
8. Vincennes District representative

A minimum of five votes is required for approval.

For each program (Group III, IV and Local Bridge) the Local Programs Division will set a date for submission and issue a “call for projects” to all the eligible LPAs within each district. Prior to the formal selection meeting, which is open to the public, each District is required to complete a “district Verification of Project Eligibility” form for each proposed project, either existing or new.

Once the project selections have been made, each INDOT District Local Programs Coordinator schedules an early coordination meeting with the successful LPAs to discuss the following:

1. Consultant selection procedures required to qualify for federal funding participation for PE
2. The LPA's anticipated method of funding each project phase (100% local or credits for up-front PE & R/W).
3. The INDOT/LPA Project Coordination contract (copy for execution to be provided to LPA) which will specify the federal funds allocated to the project, the time frame to complete the project (window of opportunity) and the consequences of not meeting the project schedule.
4. The LPA's obligation to file quarterly project status reports (copy of report form provided to LPA)

The LPA must fund the preliminary engineering (PE), (e.g., survey, environmental, design, geotechnical) and right-of-way (e.g., property, damages to property, abstracting, appraising, buying) phases with 100% local up-front funds. After a construction contract is awarded, the calculation of the amount of matching funds the LPA must remit to INDOT is reduced by the amount of allowable "credits" accrued during the PE and R/W phases. These "credits" are 80% of the allowable up-front LPA incurred costs. The credits are limited to 50% of the local portion of federally eligible construction and construction inspection costs. Note that the credits can only be utilized if there is sufficient room under the CAP (federal allocation) after the federal portion of construction and construction inspection is utilized.

As always, the LPA must have complied with all federal and INDOT regulations for selection of consultants, procurement of right-of-way and authorization for credits. In addition there are regulations for DBE goals, environmental compliance, standard specification of materials, etc. Figure 3.1 shows an example of a flow chart of the various steps involved in construction of a federal-aid highway project once approved for federal participation.

Apart from using federal funds, county highway departments also utilize local funds to construct and maintain highways, county roads, streets and bridges. The source of local funds available to counties include: the Motor Vehicle Highway fund, the Local Road and Street fund, and the Cumulative Bridge fund. The County Council that meets regularly approves the allocation of

these funds for these projects and for maintenance projects. The decision to use 100% local funds instead of requesting federal aid depends on factors such as initial cost estimates, availability of local funds, urgency of completion, etc. Discussions with John Bowers, Engineering Supervisor, Elkhart County Highway Division indicated that cost estimates using federal specifications were generally higher as compared to estimates prepared using the county's standards and specifications available on the Elkhart County Highway Division's website.

Figure 3.1 Project flow-chart for local federal-aid projects (Local Public Agency Manual, Missouri DOT 2007)

3.2 Performance-based vs. prescriptive specifications

When the future performance of a product/structure is projected using construction tests and measurements linked to design via modeling, the specifications are commonly known as performance-related or performance-based specifications. When the final product is described in terms of component materials, dimensions, tolerances, weights, and required construction methodology-equipment type, size, speed, etc., the specifications are commonly described as method or prescriptive specifications. Currently, prescriptive specifications are more prevalent in highway construction (*Publication on Performance Specifications Strategic Road Map, FHWA 2004*).

However, there appears to be an increasing interest in understanding the value of performance-related or performance-based specifications. At the FHWA's Performance Related Specification (PRS) Technical Working Group (TWG) meeting in November 2002, it was observed that engineers have long sought relationships between a material characteristic and its impact on product performance. If clear relationships could be determined and properly translated into specification language, the benefits could be significant. Agencies could better understand quality and performance and more accurately translate design intent into construction requirements. Agencies also could target and economize inspection programs, and more rationally develop incentives and disincentives. Contractors could use materials and methods in which they have experience and confidence.

At the local agency level, the performance of a construction material that is locally available is typically evaluated by its performance on previous local projects. The use of an alternate material could be encouraged if the durability of the constructed highway or bridge built using the alternate material, is comparable to a similar project built using prescriptive specifications. The FHWA uses the Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects (FP-03) for construction projects. These specifications are available to the contractors on both the FHWA website and INDOT website. Within the standard specifications, separate sections exist for major work items such as general provisions, earthwork, bases, bituminous paving, rigid pavements, structures, traffic control devices, lighting and material details. Depending on the average daily traffic (ADT), load capacity for the local road and bridge

section and local weather conditions, a "practical design" philosophy (similar to that of the Missouri DOT (MoDOT)) of "doing what is required rather than what is desired" can be promoted. MoDOT has been making changes to its standard specification handbook since 2001 in an effort to completely shift to performance based specifications. Their objective is “to encourage innovative thinking, to promote new construction technologies and techniques, and to permit greater opportunities for contractors to showcase their quality workmanship with minimal restrictions placed on them by state government.” (*Missouri Standard Specification Book for Highway Construction*, MoDOT) A set of nine questions are addressed during the process of revising the standard specifications. They are:

- Is the existing specification essential for safety?
- Is the specification mandated by Federal or state laws or statutes, local laws, codes, ordinances, orders, decrees or regulations?
- Is the existing specification essential for convenience to MoDOT, the contractor, the public or the property owner?
- Is the existing specification essential for providing instruction to achieve the desired results?
- Is the existing specification essential for quality assurance?
- Is acceptance based on certification a viable option?
- Is it possible to measure the needed properties or performance of the finished product?
- Is it possible to measure long-term performance immediately after construction?
- Will the performance measurement or testing be reasonable and not cost prohibitive?

Efforts for a more “practical” approach to design and specification on a regional basis can help reduce construction costs. Projects on non-National Highway Systems (NHS) are not required to meet the requirements contained in Title 23 of the United States Code (USC). However these regulations provide considerable flexibility to individual States and FHWA Division offices in reaching agreement on "responsibilities" for design, plans, specifications, estimates, contract awards, and inspection of Federal-aid highway projects (*Sample Memorandum of Agreement, State DOT and FHWA*). Non-federal-aid projects are not required to follow FHWA’s standards and specifications. This provides the local agencies a chance to experiment with alternative

designs and materials that are comparable in performance with other federal-aid projects in the region.

3.3 FHWA's design standards, environmental compliance, material certification, testing and DBE requirements

Federal-aid highway projects are required to undergo a project development process that includes a number of steps starting from project planning through post construction review. The process is divided into five main types of tasks: design, technical service branch (TSB), environmental, acquisition and construction. There are also a set of milestones that need to be met as a part of the project development process. Review of design at preliminary (30% complete), intermediate (50% complete), Plans in Hand (PIH) (70% complete), final (95% complete) and Plan, Specification and Estimate (PS&E) sign off (100% complete) stage, are also mandated to confirm that the design selected by the Pavement Selection Team (PST) meets QC/QA requirements, National Environmental Policy Act (NEPA) requirements, and that to ensure that the design integrates environmental mitigation (*Project Development Process Flow Chart, Federal Lands Highway Division, FHWA 2007*).

However, 100% locally funded projects are exempt from the aforementioned project development process. The local agencies may have their own set of review stages until the project is ready for letting. They can set their own design standards or refer to existing standards of the state DOT. While projects that use only local funding do not fall under the National Environmental Policy Act (NEPA), all other applicable laws must still be obeyed, including but not limited to:

- The Endangered Species Act (ESA).
- The Clean Water Act (CWA).
- The Clean Air Act as Amended (CAAA).
- Resource Conservation and Recovery Act (RCRA).
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

- The Indiana Cemetery Law
- Accidental Discovery of Human Remains regulations (*Procedural Manual for Preparing Environmental Documents*, INDOT 2007).

Much of the documentation costs and design development costs do not apply to local projects that do not utilize federal funds. This can decrease the preliminary engineering and construction engineering costs for 100% locally funded projects. Similarly, the material certification and testing procedures established by the FHWA and followed by state DOTs are enforceable only on federal-aid projects. FHWA established material specifications are available for contractors as a part of the set of standard drawings and specification on most DOT websites including the INDOT website along with test methods for construction material which are updated annually. The Materials and Tests Division at INDOT works to develop, inspect and test materials used to construct and maintains highways. For example, INDOT has established a Quality Control/Quality Assurance (QC/QA) program for aggregates for the purpose of properly assigning the responsibility of manufacturing and overall improvement of the consistency of aggregates. The QC/QA program for aggregates requires that only a Certified Aggregate Producer may supply aggregates to INDOT. The Certified Aggregate Producer Program (CAPP) is a program whereby a qualified mineral aggregate producer requesting to supply material to INDOT assumes all of the plant site controls while INDOT monitors the producer's production, sampling, and testing procedures (*Certified Aggregate Technician Program Manual*, INDOT 2007). Replacement of these testing procedures by less extensive testing methods on local projects may decrease the total project cost.

State DOTs are required to submit an annual DBE goal to the FHWA for review and approval. In accordance with 49 CFR § 26.45, the annual DBE goal must reflect the projected level of DBE participation on DOT federal aid contracts in the absence of discrimination and is calculated based on the most recent, complete, and accurate data available. INDOT's overall DBE goal for federal fiscal year 2009 is 9.42%. INDOT estimates that 3.72% of its annual goal will be met through race-neutral participation and 5.33% will be met through race-conscious (the inclusion of contract goals) measures. INDOT's DBE program is administered by INDOT's Economic Opportunity Division and applies to only federal-aid INDOT and LPA contracts. The DBE

program should not be confused with the State of Indiana's Minority Business Enterprises (MBE) and Women's Business Enterprises (WBE) program that is governed by Indiana law and administered by the Indiana Department of Administration. INDOT is required to apply those MBE/WBE goals, set annually by the Governor's Commission on Minority and Women Business Enterprises Commission, on 100% state funded contracts. Projects that are 100% locally funded are not subject to either the DBE or MBE/WBE program.

3.4 Material availability and use of recycled materials

Producers of construction materials such as aggregates, gravel, sand and stone, hot mix asphalt, geotextiles, concrete products, traffic signals, markers, etc., who have been pre-approved and tested by INDOT, and who meet INDOT's specifications for use on INDOT contracts have increased material costs as compared to local producers who are not INDOT certified. This could be attributed to the cost associated with carrying regular tests on samples of materials for confirming compliance with INDOT's QC/QA specifications. Also, since such pre-qualified material producers are limited in number in Indiana, the procurement of materials in a timely and economic manner may pose some difficulties. Hauling materials from non-local producers adds increased transportation expenses to the procurement of materials. In case of 100% locally funded projects, a major cost saving strategy is the use of alternate materials that have performed well on past projects. A certain level of risk is attached with the use of new materials and this risk is borne by the contractor who is responsible for providing guarantees. Thus, availability and hauling of material tend to be non-critical factors on local funded projects and can be an important factor in cost differentials between federal-aid projects and 100% locally funded projects.

Concrete and asphalt recycling has been a practice of INDOT for the past 15 to 20 years. Each year INDOT reuses approximately one million tons of reclaimed material for road construction projects in the State of Indiana (<http://www.in.gov/indot/6733.htm>). Typical concrete contains 60-70% aggregate by volume. Construction costs may be reduced for concrete projects using Recycled Concrete as Aggregate (RCA). Also, an increased use of RCA reduces the mining and

use of virgin aggregate proportionately, demonstrating good land and resource stewardship while minimizing the rising cost of aggregate. INDOT allows restricted use of Reclaimed Asphalt Paving (RAP) on federal-aid and state projects. Recycled materials may be used as a substitute for a portion of the new materials required to produce Hot Mix Asphalt (HMA) mixtures. When only RAP is used in the mixture, it shall not exceed 25% by weight (mass) of the total mixture. Mixtures containing 15% or less RAP shall use the same grade of binder as specified (*INDOT's Standards Committee Meeting, 2008*). The use of recycled materials such as RCA and RAP on 100% locally funded is allowed.

3.5 Cost differences between federal-aid and 100% local projects in Illinois

A telephone interview was conducted with Jerry Cameron, Construction Cost Manager, Illinois DOT (IDOT) to determine the factors responsible for cost differences between federal-aid projects and 100% locally funded projects in Illinois. The possible factors suggested by Mr. Cameron were as follows:

- (a) The scale and scope of local projects are smaller as compared to federal-aid projects
- (b) Because local projects are typically of shorter duration and require less traffic control, contractors may submit lower bids. However, in some districts such as Springfield, IL, a merger of contractors has led to decreased competitive bidding and has resulted in higher bid prices.
- (c) Availability of materials can affect project costs. For example, in a 60 -70 mile radius around Chicago, limestone is found very close to the surface resulting in lower costs for quarrying. In the remaining 2/3 of the state, however, limestone is difficult to find, resulting in higher costs. Close proximity to stone quarries and asphalt production plants, decreases transportation costs and results in lower prices. Producers of precast concrete structures are scattered all over the state, leading to varying price tags for precast concrete structure.

Mr. Cameron also provided an approximate breakdown of costs on a federal-aid project, as shown in Table 3.2. However, cost data for 100% locally funded projects in Illinois could not be

found. IDOT also encourages the use of local and recycled construction materials on highway projects. For example, the use of crushed concrete as aggregates was allowed on the Dan Ryan Expressway project. However, they are required to pass the durability tests established by IDOT.

Table 3.1 Approximate distribution of project cost on federal-aid highway projects in Illinois (Jerry Cameron, IDOT)

<i>Cost component</i>	<i>Percentage of project cost (%)</i>
Preliminary Engineering 1 (PE1) including environmental compliance, soil analysis, geometric and hydraulic design etc.	8 – 10%
Preliminary Engineering 2 (PE2) including putting together drawings- plans and sections, material estimates	7 – 10%
Construction Engineering including inspection, material testing, etc	Around 8%
Right of way acquisition	Highly variable

3.6 Chapter Summary

The chapter discussed four major factors that could lead to differences in costs between federal-aid projects and 100% locally funded projects. Interviews with Indiana contractors revealed that an increased level of risk may contribute to higher costs for federal-aid contracts. From the contractors' perspective, the level of risk involved is lower for LPA jobs for the following reasons: (a) lower investments are at stake; (b) decision-making is faster due to quick access to projects resulting in expedient decision-making by county highway personnel; (c) the permitted use of more economic and readily available materials, resulting in the optimization of local funds for the purchase of materials, provided they do not compromise the quality and performance of the constructed product/structure; and (d) material testing requirements for local projects are not as extensive as those for federal-aid projects. A combination of all these factors can result in a lower construction cost for 100% locally funded projects.

CHAPTER 4. ASSESSMENT OF SAMPLE PROJECTS

The chapter introduces the primary features of a pair of sample highway projects in Indiana: the first is a 100% locally funded and the second is a project using federal funds with a 20% local match. These two projects were selected to compare costs and explore possible factors responsible for existing differences in their project costs. Both the projects were constructed in Elkhart County, Indiana by the same contractor, Niblock Excavating Inc. A comparison is made of the major items of work such as common excavation, subgrade treatment, hot mix asphalt (HMA), installation of drainage pipes, etc., and common unit priced and lump sum items that are present in the estimates of both projects. The drawings for the two projects are also compared to determine whether differences in pavement designs, if present, could have an impact on the cost differences.

4.1. Introduction of projects

The 100% locally funded project is the County Road 17 from CR4 North to the Michigan state line. The project was a 1.76 mile long new alignment of 4-lane highway completed in 2002 with a project duration of 10 months. The project using federal aid funds is the County Road 17 Phase 1A project from CR18 South. This project was a multi-year project that started in March 2003 and was completed in May 2005. It consisted of 2.8 miles of new alignment of 4-lane highway with a concrete median wall separation and a bridge. The estimated Annual Average Daily Traffic (AADT) value was 24,300 vehicles per day (VPD). Both the projects were constructed by Niblock Excavating Inc., Bristol, Indiana.

Figure 4.1 and Figure 4.2 show the locations of the two road sections with (A) and (B) as the beginning and end stations, respectively. The choice of sample projects was made with the assumption that similar type of work performed by the same contractor would assure comparable workmanship and quality of construction. The difference would then lie in the designs, costs of items of work and material specifications.

Figure 4.1 CR17 N to Michigan state line (Locally funded) A= Beginning station and B= End Station (Google maps)

Figure 4.2 CR17 Phase 1A from CR18 S (Federally funded) A= Beginning station and B= End Station (Google maps)

4.2. Comparison of pavement designs

The pavement designs for both projects had similarities in lane width, average lane slopes, shoulder width, dimensions of under-drain, depth of subgrade treatment, thickness of HMA layers, etc. The major difference was the existence of a concrete barrier on the federal-aid project. Also, there were two intersections on the federal project as CR17 crossed CR20 and CR26 before ending at CR28. The design consultant for the locally funded project was Lawson–Fischer Associates P.C., South Bend; and for the federal-aid project, the design consultant was American Structurepoint Inc., Indianapolis. Table 4.1 compares the design factors of the two projects based on the drawings available for both the projects. It can be seen that the design documents for the local project did not include detailed data regarding traffic, erosion control and traffic maintenance plans. Typically, traffic and design data includes the AADT values, the directional distribution of traffic and the design speeds. The traffic maintenance plan includes the layout of construction signs, temporary pavement markings, barricades, etc. Erosion control details include layout for temporary silt fencing, sediment traps, slope drains, etc. along the road section to be constructed. The aforementioned details were not explicitly shown on the drawings for the locally funded project. However, traffic control/maintenance of traffic is inherent on all county projects. In the event a specific line item is not provided in the itemized bid sheets, the cost is included in other items. Erosion control is also included in all county projects and the costs for erosion control would be handled through similar means. Hence, on the local project, standard traffic control and erosion control practices were used.

Figure 4.4 shows the difference in QC/QA specifications for HMA used on the federal-aid project and the HMA specification used on the locally funded projects. The QC/QA sampling and testing of the HMA includes measuring the temperature of the mixture at the paver, the density of the mixture, the coring procedure, and the procedure for measuring the smoothness (*INDOT Quality Control Procedures, Chapter 12, 2008*).

Table 4.1 Comparing design documents of both sample projects

<i>Design factors</i>	<i>CR17 (CR18 to CR28) federal-aid</i>	<i>CR17 (CR4 to Michigan State line) 100% local funds</i>
Traffic and design data	Present	Not present in the drawings
Traffic maintenance plan	Present	Not present in the drawings
Erosion control details	Present	Not present in the drawings
Lane width	12 ft (approximate)	12 ft (approximate)
Shoulder width	10 ft approximate)	10 ft (approximate)
HMA (base, intermediate and surface)	QC/QA	Non QC/QA, however depth of fills are same

4.3. Cost comparison of sample projects

The comparison of project costs of the two projects was performed by considering the major bid items and the common unit-price work items. Table 4.2 compares the costs of major items of work for the two projects. It is observed that the federally funded project was larger in scope as compared to the locally funded project due to additional items of work such as median barrier, bridge and box structures. No DBE goals were required for the locally funded project because there were no federal funds involved.

Table 4.2 Comparison of cost components of the sample projects (Bid tabulations provided by Niblock Excavating Inc.)

<i>Major lump sum items</i>	CR17 N (federal) (2003 \$)	% of construct- ion cost	Quantity	CR17 S (local) (2002 \$)	Quantity	% of construct- ion cost
Construction engineering	75,000	0.89		26000		1.52
Mobilization & Demobilization	248,000	2.93		65000		3.80
Clearing Right of Way	105,000	1.24		35000		2.05
Field office	18,700	0.22		2400		0.14
Structure & obstruction removal	20,500	0.24		6000		0.35
Maintaining traffic	50,000	0.59		15000		0.88
Total	517,200	6.11		149400		8.73%
<i>Major unit-priced items of construction</i>	CR17 N (federal) (2003 \$)	% of construct- ion cost	Quantity	CR17 S (local) (2002 \$)	Quantity	% of construct- ion cost
Excavation, temporary erosion control, backfill etc. (cu. yd.)	1,436,000	16.96	325,867 CY	200000	67,588 CY	11.69
Hot mix asphalt (HMA) aggregate (base, intermediate, surface), asphalt coats etc.	3,157,000	37.28	96,181 TON	1,026,665	25,250 TON	60.00
Concrete median, barrier	450,000	5.31		0		0.00
Reinforced concrete bridge	620,000	7.32		0		0.00
Geotextiles, riprap, seeding, mulching etc.	284,500	3.36	4939 SYS	183,950	233 SYS	10.75
Guardrail	356,000	4.20		0		0.00
Pipes (drainage)	450,000	5.31	84,567 LF	32,000	930 LF	1.87
Precast structures	376,400	4.45		0		0.00
Fence (farm fields)	106,400	1.26	1201 LF	52,725		3.08
Detour markers, barricades, signs, electronic signals etc.	235,300	2.78		21,700		1.27
Stripping, pavement marking etc.	51,300	0.61		17,500		1.02
Total Construction Cost	8,467,283	100.00		1,711,099		100.00

4.3.1. Common unit-price items

The unit-price items present in the bid estimates of both the projects were selected and compared. Due to difference in specification of materials used, common items of work were selected for comparison of the bid estimates of both projects. They were: common excavation, structure backfill, compacted aggregate for base, asphalt milling, drainage pipe installation and markers. Figure 4.3 shows a plot of unit prices of the items. The major difference in unit price was found for asphalt for prime coat, which was found to be \$100.36/ton (2002 dollars). However, the percentage of total cost for this item was very low for both the projects. Since, the two projects were completed a year apart, the effect of inflation could affect the unit prices for common items of work and cost per mile of the projects.

Figure 4.3 Comparing common unit priced items for the two sample projects

4.3.2. Effect of inflation

The effect of inflation on cost per mile of the project was accounted for by using the Annual price trends for Federal-aid Highway Construction Composite Index, FHWA (2002–2003) for Indiana. The index changed from 160.2 in 2002 to 170.76 in 2003. Hence a correction factor of 0.94 has to be multiplied to all the 2003 dollars values to convert them into 2002 dollar values. The cost per mile for the local project was found to be \$1,028,239/mile (2002) and the cost per mile for the federal-aid project was calculated to be \$2,872,438/mile (2002). Similarly, the effect of inflation was adjusted for common excavation. The national index for common excavation changed from 125.7 in 2002 to 212.2 in 2003. Hence, a correction factor of 0.59 was used to convert 2003 dollar values of common excavation to 2002 dollar values. The unit price of common excavation for the local project was \$2.40/cubic yard (2002) and the adjusted unit price of common excavation for the federal project was \$2.96/cubic yard (2002). The cost of the common excavation item was higher for the federal-aid project. However, a limitation in the use of federal-aid highway construction indices is that it may not be representative of the price trends during 2002-03 in the state of Indiana. Also, cost indices for other items of work (structure back fill, asphalt, compacted aggregate) were not available, and hence could not be used to compare unit prices of these items after adjustments for inflation.

4.3.3. Effect of economies of scale

Having accounted for the effect of inflation, a comparison of quantities of work items was essential to investigate any effect of economies of scale on either project, especially because the road section for federal-aid project was longer and required larger quantity of soil, aggregate and HMA. Using the example of common excavation, the percentage share for this item in the respective construction costs of the two projects was calculated, as shown in Table 4.3. The effect of economies of scale can be observed for HMA and pipe installation work items, since the quantity of work was larger on the federally funded project. However, for common excavation work item, the unit price in the case of the federal-aid project was higher than in the case of the locally funded project, although the quantity of the excavation was larger for the federal-aid project.

Table 4.3 Effect of economies of scale on items of work common in both sample projects

Item of work	Federal-aid sample project			100% locally funded sample project		
	Quantity	Unit price (2002)	% total cost	Quantity	Unit price (2002)	% total cost
Common excavation	325,867 CY	\$2.96/CY	14.8	67,588 CY	\$2.40/CY	8.96
Hot mix Asphalt	96,181 TON	\$32.8/TON	37.28	25,250 TON	\$40.26/TON	60
Installation of pipes	84,567 LF	\$0.38/LF	5.32	930 LF	\$34.4/LF	1.87

Note: Transportation cost for hauling materials on the site for both the projects were not provided by Niblock Excavating Inc.

4.4. Comparison of specifications of sample projects

An analysis of the bid estimates for the sample pair of projects revealed that while the federal-aid project followed QC/QA requirements for material specifications, the locally funded project did not. Table 4.4 shows the specifications of hot mix asphalt (HMA) for both the projects. It can be seen that QC/QA –HMA was used for the federal-aid project and therefore increased the number of HMA items. On the other hand, HMA for the locally funded project comprised only three layers: the surface, intermediate and base and therefore the number of items for HMA was reduced. Similarly, the specifications for base preparation vary for both projects as shown in Table 4.5. The specification for the locally funded project does not include subgrade treatments. The aforementioned difference in specifications of HMA and base preparation are examples of the federal requirements that need to be fulfilled on all federal-aid projects. Additional items of work added to the total project cost on the federally funded project.

Table 4.4 Comparison of Hot Mix Asphalt (HMA) pay items/quantities/unit prices of the two sample projects

County Road 17 Phase 1A from CR18 South to CR28, IN (FEDERAL)

Description	Quantity	Unit	Unit price	Bid amount
QC/QA-HMA, 1, 64, Surface, 9.5 mm	3482	metric tons	\$36.90	\$128,485.80
QC/QA-HMA, 2, 76, Surface, 9.5 mm	1549.00	metric tons	\$42.90	\$66,452.10
QC/QA-HMA, 3, 76, Surface, 9.5 mm	6856.00	metric tons	\$42.30	\$290,008.80
QC/QA-HMA, 2, 76, Intermediate, 19 mm	2505.00	metric tons	\$33.90	\$87,970.50
QC/QA-HMA, 3, 76, Intermediate, 19 mm	23023.00	metric tons	\$33.40	\$768,968.20
QC/QA-HMA, 5, 76, Intermediate, 25 mm	13773.00	metric tons	\$33.00	\$454,509.00
QC/QA-HMA, 1, 64, Base, 25 mm	11701.00	metric tons	\$30.00	\$351,030.00
QC/QA-HMA, 2, 76, Base, 25 mm	7378.00	metric tons	\$33.00	\$243,474.00
QC/QA-HMA, 3, 76, Base, 25 mm	24105	metric tons	\$33.00	\$795,465.00
HMA Type A, Surface	460.00	metric tons	\$46.75	\$21,505.00
HMA Type A, Intermediate	737.00	metric tons	\$35.00	\$25,795.00
HMA Type A, Base	560.00	metric tons	\$37.50	\$21,000.00

County Road 17 extension from CR4 in Elkhart County, IN to Michigan State Line (LOCAL)

Description	Quantity	Unit	Unit price	Bid amount
HMA Surface No. 11, HV Mainline, SSB-PG-70-28	5725	metric tons	\$31.50	\$180,337.50
HMA Intermediate No. 8, HV, Mainline	7750	metric tons	\$26.00	\$201,500.00
HMA Base No. 5, HV, Mainline	11825	metric tons	\$24.00	\$283,800.00

Table 4.5 Comparison of base preparation pay items/quantities/unit prices of the two sample projects

COUNTY ROAD 17 PHASE 1A from CR18 to CR28 (FEDERAL)				
Description	Quantity	Unit	Unit price	Bid amount
Subgrade treatment, Type A	32,170	square meters	\$1.75	\$56,297
Subgrade treatment, Type B	3,260	square meters	\$1.75	\$5,705
B Borrow	401	cubic meters	\$18.0	\$7,218
Aggregate for end bent Backfill	38	cubic meters	\$160.0	\$6,080
Structure Backfill	3940	cubic meters	\$15.0	\$59,104
Compacted Aggregate, No. 53, Base	30940	metric tonnes	\$12.0	\$371,691
COUNTY ROAD 17 from CR4 to MICHIGAN STATE LINE (LOCAL)				
Description	Quantity	Unit	Unit price	Bid amount
B Borrow for structure backfill	556	cubic yards	\$8.0	\$4,448
Compacted Aggregate for Base, 53, O Limestone or Slag	24,325	ton	\$12.75	\$310,143
Compacted Aggregate for Base, 73, O Limestone or Slag	272	ton	\$12.75	\$3,468

4.5. Chapter Summary

The comparison of design, cost of work items and specifications for the sample projects indicated that cost differences existed between the federally funded and locally funded projects and that the economies of scale were reversed in case of the federally funded project. These differences could be attributed to changes in the work processes required for federally funded project, and thus warrant further investigation.

The next step in the study (as discussed in Chapter 5) involved interviewing highway contractors in Indiana and personnel from INDOT and Elkhart County Highway Division for identifying possible factors responsible for existence of differences in costs. Pavement tests were also conducted on the two road sections in order to evaluate their performance.

CHAPTER 5. PERFORMANCE EVALUATION OF SAMPLE PROJECTS

A comparison of the performance of the similar road sections, namely, County Road 17 from CR4 North to Michigan state line (100% locally funded) and County Road 17 Phase 1A from CR18 to CR28 (federally funded), was undertaken to determine whether the locally funded project matched the level of performance and durability when compared to the federal-aid project that was built using federal standards and specifications. The tests for pavement evaluation were funded by the Elkhart County Highway Division and performed by MHM Associates Inc., along with a subcontractor, Soil and Material Engineers Inc., South Bend, Indiana. The following sections discuss the types of tests conducted on the road sections built for the federally funded and 100% locally funded projects and provide a comparison of the results obtained.

5.1. Pavement performance tests conducted on road sections

MHM Associates performed roughness testing, deflection testing and visual inspection of surface distress on the following road sections:

- a) County Road 17 from CR4 to Michigan state line (100% locally funded)
- b) County Road 17 from CR18 to CR28 (CR18 to CR20, CR20 to CR26, CR 26 to CR28) (built using federal funds)

Both the sections have two north bound lanes and two south bound lanes and tests were conducted on all lanes. Since the pavement in the road sections is a full depth asphalt pavement, both the sections were assumed to have the same pavement structure. This assumption is valid since the thickness of aggregates and HMA layers was approximately the same for both projects. Table 5.1 shows the average thickness of each individual HMA layer. The total depth of base, intermediate and surface layers was 13.8 inches.

Based on results obtained from the roughness testing and deflection testing and visual inspection of distress, a pavement condition rating (PCR) was awarded to each lane of the two road

sections. There is general agreement that the ability of a pavement to sustain traffic loads in a safe and smooth manner is adversely affected by the occurrence of observable distress. The rating method provides a procedure for uniformly identifying and describing, in terms of severity and extent, pavement distress. This scale generally has a range from 0 to 100 as shown in Figure 5.1. A PCR of 100 represents a perfect pavement with no observable distress and a PCR of 0 represents a pavement with all distress present at their “High” levels of severity and “Extensive” levels of extent. The PCR provided by MHM Associates Inc., for the two sample sections was on a scale of 1 to 10. Both the projects scored 9 and above on all the four lanes as shown in Table 5.3 and 5.4.

Table 5.1 Assumed thickness of asphalt layers for both projects

Layer	Application Rate	Layer Thickness (in)
HMA Surface	90 kg/m ³	1.5
HMA Intermediate	300 kg/m ³	5
HMA Intermediate	140 kg/m ³	2.3
HMA Base	300 kg/m ³	5
TOTAL		13.8

Figure 5.1 Pavement Condition Rating (PCR) rating scale

5.2. Pavement surface roughness (smoothness) testing

Pavement roughness is generally defined as an expression of irregularities in the pavement surface that adversely affect the ride quality of a vehicle (and thus the user). Roughness is an important pavement characteristic because it affects not only ride quality but also vehicle delay costs, fuel consumption and maintenance costs. The World Bank found road roughness to be a primary factor in the analyses and trade-offs involving road quality vs. user cost (*UMTRI, 1998*). Pavement roughness is measured in terms of the International Roughness Index (IRI) which has the units of inches per mile. The lower the IRI number, smoother the surface and smoother the ride. Figure 5.2 shows IRI roughness scale and the type of surface corresponding to the IRI.

Roughness testing for the two road sections was performed using ARIA profiler model 5006. It is equipped with lasers and accelerometers designed to collect longitudinal profile/roughness data and calculate IRI values in inches/mile. Data was collected continuously at 1000 samples per second while the vehicle was travelling at a speed upto 55 miles per hour and analyzed by related software systems. Mr. Jerry Mohajeri from MHM Associates, indicated that typically the vehicle travel speeds are in the range of 60-65 mph on highways when roughness testing is conducted. (Note: 65 mph was recorded in the report submitted by MHM to Elkhart County Highway Department in November 2008). For this assessment, the speeds ranged from 50-55 mph. However, when testing was done close to bridges, traffic lights, changes in traffic etc., vehicle speeds were further reduced.

Figure 5.3 shows IRI values for a south bound lane on CR17 to the Michigan state line. IRI values for all the four lanes on both road sections can be found in Appendix A. Typically, if the IRI values are in the range of 75-110 inch/mile, the pavement is expected to provide a smooth ride. The average IRI values are lower for the locally funded road section. There is also a higher range in the IRI values, as well as a large number of higher IRI values (IRI greater than 200 inch/mile) for different road sections constructed under the federally funded program. Mr. Mohajeri from MHM Associates indicated that, overall, the road sections CR17 from CR4 to the Michigan State Line, provided a smoother ride than did the road sections on CR 17 from CR 18 to CR 28. The results of these tests indicate that the road section built using 100% local funds is performing better in terms of pavement smoothness than the road section built using federal

funds. It is well documented that pavements with higher initial smoothness last longer (Smith et al. 2002). While the data were collected 5-6 years after the pavements were open for use by motorists, the test results support the claim of higher quality of the locally funded project and indicate that the local project would retain its pavement smoothness longer.

Figure 5.2 IRI Roughness Scale (Sayers and Karamihas 1998)

Figure 5.3 IRI values for a south bound lane on CR17 to MI state line

5.3. Deflection testing

Surface deflection is measured as a pavement surface's vertical deflected distance as a result of an applied (either static or dynamic) load. It is the primary means of evaluating a flexible pavement structure (asphalt paving) and rigid pavement (concrete paving) load transfer. Although other measurements can be made that reflect (to some degree) a pavement's structural condition, surface deflection is an important pavement evaluation method because the magnitude and shape of pavement deflection is a function of traffic (type and volume), pavement structural section, temperature affecting the pavement structure and moisture affecting the pavement structure. All impact load devices deliver a transient impulse load to the pavement surface. The subsequent pavement response (deflection basin) is measured by a series of sensors. The most common type of equipment is the falling weight deflectometer (FWD). The FWD can either be mounted in a vehicle or on a trailer and is equipped with a weight and several velocity transducer sensors. To perform a test, the vehicle is stopped and the loading plate (weight) is positioned over the desired location. The sensors are then lowered to the pavement surface and the weight is

dropped. Multiple tests can be performed on the same location using different weight drop heights (ASTM, 2000).

Non destructive deflection testing of the two road sections was performed using Dynatest Model 8081 FWD. Testing at each location was performed at approximate load levels of 9000, 12000, 18000 lbs. Pavement surface deflections were measured below the load plate at distances of location 8, 12, 18, 24, 36 and 60 inches away from the center of the load. Tests were generally spaced at 1000 ft in each lane. Tests were staggered in each lane to provide an effective spacing of 250 ft along the project length. Table 5.2 lists the average deflection values for all the four lanes on both road sections tested. Appendix B shows deflection data for both the road sections. The deflection data was analyzed to compute the structural number and sub-grade modulus using the procedures outlined in 1993 AASHTO Guide for Design of Pavement Structures. The modulus of asphalt concrete was back calculated by MHM Associates Inc., using the program Modulus developed by the Texas Technical Institute. The structural number (SN) is an abstract number expressing the structural strength of a pavement (*Structural Design Training Module, WSDOT Pavement Guide, Volume 1, 2006*). A higher structural number is indicative of a stiffer asphalt pavement. Subgrade properties are essential pavement design parameters. Materials typically encountered in subgrades are characterized by their strength and their resistance to deformation under load (stiffness). Apart from the deflection values for the road sections, Table 5.2 also shows the structural number, the subgrade modulus and the asphalt concrete modulus for each lane, estimated using the aforementioned program.

It can be seen that for road section built for the federal-aid project, deflection below load is smaller; while the structural numbers, subgrade modulus and asphalt concrete modulus values are higher than that for the locally funded project. The higher subgrade modulus can be attributed to fine-grained, clayey soil structure for the federally funded road section. Higher asphalt modulus values for the federally funded indicated a stiffer HMA mix (QC/QA based). A higher structural number signifies that the pavement can support larger Equivalent Single Axle Loads (ESALs). Hence, the federally funded road section is designed to perform better than the locally funded section when Average Daily Traffic (ADT) values rise.

Table 5.2 Average values of parameters

Location	Lane	Average Values			
		Deflection below Load for a 9000 lb Load (mils)	Estimated Structural Number	Estimated Subgrade Modulus (psi)	Estimated Asphalt Concrete Modulus (ksi)
CR 17 From Stateline to CR 4	1	8.50	3.91	5697	469
	2	7.10	4.00	7395	536
	3	7.25	3.98	7260	515
	4	8.20	3.90	6039	446
CR 17 from CR 18 to 28	1	4.92	5.17	8604	992
	2	4.98	5.14	8713	936
	3	5.29	4.92	8464	857
	4	5.30	5.00	7839	904

5.4. Surface distress

Surface distress is "Any indication of poor or unfavorable pavement performance or signs of impending failure; any unsatisfactory performance of a pavement short of failure" (Highway Research Board, 1970). Surface distress modes can be broadly classified into the following three groups:

1. *Fracture*: This could be in the form of cracking (in flexible and rigid pavements) or spalling resulting from such things as excessive loading, fatigue, thermal changes, moisture damage, slippage or contraction.
2. *Distortion*: This is in the form of deformation (e.g., rutting, corrugation and shoving), which can result from such things as excessive loading, creep, densification, consolidation, swelling, or frost action.
3. *Disintegration*: This is in the form of stripping, raveling or spalling, which can result from such things as loss of bonding, chemical reactivity, traffic abrasion, aggregate degradation, poor consolidation/compaction or binder aging.

Thus, surface distress indirectly is related to roughness (the higher the number and severity of cracks/distortion and disintegration, the rougher the pavement) as well as structural integrity of

the pavement. Distress images of the pavement were collected using 3 CCD high resolution digital video camera focus covering two lanes. Visual analysis and rating of pavement surface were in accordance with PASER Manual developed by University of Wisconsin. The two major types of distress recorded were long cracks and surface flushing or discoloration in wheel path. The surface distress observed for the locally funded section was long cracks on one of the north bound lanes. For the federally funded project, all the lanes (north and south bound) displayed surface distress. Flushing was mainly observed on the part of the section between CR20 and CR26 and CR26 to CR28. Hence, greater surface distress was observed for the federally funded project.

5.5. Chapter Summary

Table 5.3 and 5.4 show the summary of results obtained for the locally funded road section (CR 17 from CR 4 to Michigan state line) and the federally funded road section (CR17 from CR18 to CR28) respectively. The PCR values are slightly higher for the locally funded project. Also, surface distress exists on only one lane on the locally funded project as compared to all the four lanes of the federally funded project. The average IRI values are lower for the locally funded road section. The results of these tests indicate that the road section built using 100% locally funded project may have better pavement performance than the road section built using federal funds.

Table 5.3 Summary of test results for 100% locally funded project

LANE No.	ROAD NAME	START OF SECTION	END OF SECTION	Deflection (mils)	Roughness Index (IRI)	Surface distress	Pavement Condition Rating (PCR)
Lane 1 SB.	County Road 17	MI State Line	CR 4	8.50	92.80		10.0
Lane 2 SB.	County Road 17	MI State Line	CR 4	7.25	85.60		10.0
Lane 3 NB.	County Road 17	CR 4	MI State Line	7.25	70.40		10.0
Lane 4 NB.	County Road 17	CR 4	MI State Line	8.20	103.30	LONG.CRACK	9.0

Table 5.4 Summary of results for federal-aid project

LANE No.	ROAD NAME	START OF SECTION	END OF SECTION	Deflection (mils)	Roughness Index (IRI)	Surface distress	Pavement Condition Rating (PCR)
Lane 1 SB.	County Road 17	CR 18	CR 20	4.92	94.30	LONG. CRACK	9.0
Lane 2 SB.	County Road 17	CR 18	CR 20	4.98	109.00	LONG. CRACK	9.0
Lane 3 NB.	County Road 17	CR 20	CR 18	5.29	79.00	FLUSHING*	9.5
Lane 4 NB.	County Road 17	CR 20	CR 18	5.3	111.00	LONG. CRACK	9.0
Lane 1 SB.	County Road 17	CR 20	CR 26	4.92	111.30	FLUSHING	9.0
Lane 2 SB.	County Road 17	CR 20	CR 26	4.98	110.60	FLUSHING*	9.0
Lane 3 NB.	County Road 17	CR 26	CR 20	5.29	136.00	FLUSHING*	9.0
Lane 4 NB.	County Road 17	CR 26	CR 20	5.3	129.00	LONG. CRACK	9.0
Lane 1 SB.	County Road 17	CR 26	CR 28	4.92	96.40	FLUSHING*	9.0
Lane 2 SB.	County Road 17	CR 26	CR 28	4.98	122.80	FLUSHING*	9.0
Lane 3 NB.	County Road 17	CR 28	CR 26	5.29	85.50	FLUSHING*	9.5
Lane 4 NB.	County Road 17	CR 28	CR 26	5.3	72.80	LONG. CRACK	9.0

CHAPTER 6. SUGGESTIONS FOR COST-SAVINGS ON FEDERAL-AID PROJECTS

The primary objective of this study was to extend the Indiana LTAP's compilation of bridge replacement costs to include roadways and highways, to assess the costs of locally and federally funded projects in Indiana and to determine the factors which affect the costs of projects and their impacts when the funding sources are different. A pair of similar projects both built in Elkhart County but each with a different funding source was selected to compare their design, cost estimates of items of work and material specifications. It was followed by an evaluation of performance of both the projects through pavement evaluation tests. Since the focus of this study was on a pair of sample projects, funded by different sources, but conducted by the same contractor in the same area, the study is not exhaustive, and hence the statements in this report are observations and should not be construed as findings of a robust and more analytical study. Nonetheless, the observations provide a good platform for future investigation into cost differences of highway construction projects when funding sources are different, and to identify methods to decrease project life-cycle costs without impacting durability and performance.

Based on observations from the comparison of the sample projects and interviews of highway construction contractors and personnel from INDOT, IDOT and the Elkhart County Highway Division, the following suggestions for possible cost savings on federal-aid projects are proposed:

- a) General cost reduction strategies that include: (1) standardization and consolidation of aggregate, asphalt and other construction material specifications on a regional basis taking into account the topography, weather conditions and similarities in performance of local materials; and (2) continuing to encourage the increased use of recycled asphalt pavement and recycled concrete at the state level, promoting a "practical design" philosophy of "doing what is required rather than what is desired". Note: INDOT's current standard specifications allow the use of recycled asphalt pavement and rubblized Portland cement concrete pavement (PCCP.)

- b) Providing flexibility in the administration of state and federal requirements: These initiatives include: (1) encouraging INDOT to re-examine and set appropriate DBE goals for various regions in the state; and (2) supporting new aggregate sources, plants, and quarries in the state.
- c) Risk optimization initiatives that include: (1) steps to work with industry to develop appropriate price adjustment clauses and guidelines for their use especially when materials prices vary significantly in short durations; (2) bringing together representatives from LPAs, material producers, local contractors to: (i) meet with FHWA planners and follow the Context Sensitive Solutions (CSS) Policy, and (ii) to revise specifications to share the risk associated with contingencies in weather-related delays (acts of God, severely unusual weather) or financial crisis. Context Sensitive Solutions incorporate accepted effective design practices and allows transportation officials with inputs from community stakeholders as a step towards providing safe, cost effective and efficient highway facilities, in a timely and conflict-free manner.
- c) Dividing federal-aid projects into smaller, non multi-year projects on which 100% local funding can be used, thus allowing: (i) more competitive bids by local contractors; and (ii) exemption from federal requirements that can add to the total project cost.
- d) Developing a catalog of alternate standards/combinations for using the new Mechanistic-Empirical Design for Pavements, based on level of importance of project, material options and design options.
- e) Collaborating with local agencies to identify creative methods for constructing and maintaining highway projects, economically and effectively. The LPA initiative approved by INDOT in 2009 is a significant step towards improving the process and reducing development time for local federal-aid construction projects. Also, as LPAs continue to participate in a diverse range of projects from simple sidewalks to complex interchanges and bridges, they can be assisted by the FHWA as well as INDOT to administer such projects more effectively.

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APPENDICES

APPENDIX A. IRI values recorded from the pavement evaluation tests conducted on the
sample road sections

CR 17-MI STATE LINE TO CR 4-LANE1 SB

Location (ft)	IRI (inches/mile)
264.4828 to 521.8845	113.47
533.5684 to 2275.1890	100.79
2278.7300 to 2282.9790	80.24
2302.4520 to 5275.1400	93.11
5285.7620 to 6835.4820	90.27
6839.0230 to 6840.4390	80.03
6922.9350 to 6951.2600	80.23
6955.1540 to 7015.6990	82.35
7187.0640 to 7443.0490	85.66
7465.7090 to 7746.4790	88.01
7778.6980 to 7782.9470	80.23
7788.9660 to 7894.1220	80.51
8088.1460 to 8852.2080	151.47
Average IRI	92.80

CR 17-MI STATE LINE TO CR 4-LANE2 SB

Location (ft)	IRI (inches/mile)
3771.3310 to 3772.4010	70.02
3801.6560 to 3803.7960	70.03
3996.0910 to 4001.0860	70.16
3174.8250 to 3426.3420	73.13
4298.6250 to 4829.8440	74.81
3536.5820 to 3630.7670	74.89
7777.0550 to 7832.3530	75.55
8084.2270 to 8706.7760	78.37
6231.9180 to 6821.2890	132.48
5348.9330 to 6039.9800	136.24
Average IRI	85.57

CR 17-CR 4- TO MI STATE LINE-LANE3 NB

Location (ft)	IRI (inches/mile)
264.3946 to 1048.4870	95.64
1290.6970 to 1431.0770	67.30
1513.2680 to 1727.8390	65.06
1739.8400 to 1792.5740	60.72
1840.9430 to 6323.2870	77.11
6341.1070 to 6344.3800	60.14
6350.5630 to 6356.3810	60.45
6625.8680 to 6900.8090	62.17
6973.1810 to 6981.1820	60.15
7120.8340 to 7175.0230	62.56
7195.0250 to 7812.1880	81.84
7818.0070 to 7824.1900	60.66
7864.5580 to 8852.3110	101.57
Average IRI	70.41

CR 17-CR 4- TO MI STATE LINE- LANE4 NB

Location (ft)	IRI (inches/mile)
264.5403 to 541.4283	96.05
820.9355 to 1610.8150	122.46
1717.4540 to 1848.4150	84.4
1865.2520 to 1874.9810	80.32
1877.2260 to 1882.0900	80.39
2346.8130 to 3576.3450	116.17
3784.3850 to 4391.2940	100.9
4453.7810 to 7071.4950	121.06
7174.0190 to 8405.7960	128.66
8451.0710 to 8852.1850	103.4
Average IRI	103.381

CR 17-CR 18 TO CR20- LANE 1 SB

Location (ft)	IRI (inches/mile)
263.0088 to 954.2455	91.85
1083.8080 to 1107.4610	70.37
1116.6400 to 1122.2890	70.25
1126.1720 to 1177.0090	73.19
1219.3730 to 1378.5900	73.18
1433.6630 to 4538.9320	77.29
4561.5260 to 4805.8250	83.64
4946.3310 to 4986.2240	70.66
5063.8910 to 5092.4860	71.84
5223.8140 to 7246.6880	261.19
Average IRI	94.346

CR 17-CR 18 TO CR20-LANE2 SB

Location (ft)	IRI (inches/mile)
264.4643 to 2623.9070	230.95
2698.8750 to 2723.4400	75.58
2810.8500 to 2829.3530	75.46
2846.8990 to 2855.8310	76.11
2862.5310 to 3654.3280	111.19
3746.8430 to 7245.1720	87.01
Average IRI	109.38

CR 17-FROM CR20 TO CR18-LANE3 NB

Location (ft)	IRI (inches/mile)
262.8366 to 3525.7861	208.84
3530.8690 to 3535.221	60.05
3570.4390 to 3613.271	61.90
3733.8050 to 3742.151	60.36
3747.6000 to 4981.551	81.89
5140.5620 to 5147.091	60.31
5326.0720 to 5436.071	63.10
5476.0050 to 5478.901	60.11
5508.6780 to 5511.941	60.10
5526.4670 to 5530.821	60.17
5899.3030 to 7246.881	99.99
Average IRI	79.71

CR 17-FROM CR20 TO CR18-LANE4 NB

Location (ft)	IRI (inches/mile)
262.6951 to 738.2374	181.08
800.3179 to 924.4788	89.53
935.4881 to 2500.0381	117.44
2558.4480 to 3539.8051	111.99
3738.2830 to 3763.3611	86.41
3796.0820 to 3800.3611	85.32
3804.0330 to 3850.2111	85.84
3891.4960 to 3896.3811	85.17
3899.4470 to 3906.4811	85.05
3914.1260 to 4524.8311	101.96
4809.8580 to 7160.9611	193.07
Average IRI	111.17

CR 17-CR 20 TO CR26-LANE 1 SB

Location (ft)	IRI (inches/mile)
264.3342 to 1065.9780	148.70
1306.7460 to 1327.9550	101.06
1399.0470 to 1519.2340	104.47
1596.6100 to 1659.0600	104.36
1667.7010 to 1681.8410	100.70
1691.6600 to 1702.2650	101.00
1708.9420 to 1718.3690	100.05
1932.4280 to 1944.6040	101.15
1948.5320 to 2129.5990	112.20
2208.5460 to 2535.3300	114.30
2628.4170 to 5082.4440	136.42
Average IRI	111.31

CR 17-FROM CR20 TO CR26-LANE2 SB

Location (ft)	IRI (inches/mile)
280.6036 to 446.5762	107.74
594.1434 to 619.0070	100.10
622.8818 to 641.2874	100.36
648.3912 to 726.2111	102.55
838.9045 to 1371.6960	132.47
1983.5990 to 1988.4430	100.16
1994.2550 to 1998.1300	100.31
2001.3590 to 5082.1860	141.21
average IRI	110.61

CR 17-FROM CR26 TO CR20-LANE3 NB

Location (ft)	IRI (inches/mile)
519.7067 to 3057.0780	189.98
3172.4920 to 4634.1670	133.64
4893.3290 to 4990.4290	130.96
4998.0310 to 5014.9630	125.86
5030.8580 to 5031.8950	125.02
5035.6960 to 5062.6490	126.00
5066.1040 to 5082.3450	125.61
average IRI	136.72

CR 17-FROM CR26 TO CR 20-LANE4 NB

Location (ft)	IRI (inches/mile)
613.2651 to 4347.2180	159.00
4385.5910 to 4388.0790	115.08
4397.6720 to 4406.9100	115.92
4431.7820 to 4442.0850	115.53
4446.3490 to 5082.3540	139.82
average IRI	129.07

APPENDIX B. Deflection data recorded from the pavement evaluation tests conducted on
the sample road sections

COUNTY ROAD 17: FROM STATELINE TO COUNTY ROAD 4

Distance (Feet) (Note 1)	Lane	Deflection (mils) for 9000 lb Load at							Estimated Structural Number	Estimated Subgrade Modulus (psi)	Estimated Asphalt Modulus (ksi)
		0"	8"	12"	18"	24"	36"	60"			
0	1	6.7	6.1	5.5	4.9	4.3	3.2	1.9	4.45	6,187	683
0	2	6.5	5.7	5.1	4.4	3.8	2.7	1.8	4.14	7,816	681
250	4	7.7	6.9	6.3	5.4	4.7	3.3	1.9	3.97	6,319	498
500	2	6.2	5.4	4.7	4.0	3.3	2.2	1.3	4.05	9,000	512
750	3	6.2	5.3	4.7	4.0	3.4	2.3	1.4	4.10	8,735	568
1000	1	7.5	6.6	6.0	5.1	4.4	3.0	1.7	3.95	6,750	467
1249	4	8.1	7.1	6.4	5.4	4.5	3.0	1.7	3.77	6,600	392
1500	2	6.7	6.0	5.4	4.6	4.0	2.8	1.8	4.13	7,425	623
1750	3	5.7	5.1	4.6	4.0	3.5	2.5	1.6	4.41	8,486	784
2000	1	6.9	6.2	5.7	5.0	4.4	3.1	1.8	4.29	6,387	593
2251	4	7.3	6.6	6.0	5.3	4.6	3.3	1.9	4.22	6,000	559
2500	2	6.7	6.0	5.4	4.8	4.2	3.0	1.8	4.20	7,071	639
2750	3	6.6	5.9	5.3	4.6	4.0	2.9	1.7	4.17	7,425	620
3000	1	8.7	7.7	6.9	6.0	5.1	3.6	2.1	3.75	5,824	433
3250	4	9.1	8.1	7.3	6.3	5.4	3.7	2.2	3.72	5,500	408
3500	2	7.5	6.5	5.8	5.0	4.3	3.1	1.9	3.91	6,907	545
3749	3	7.4	6.4	5.6	4.7	4.0	2.7	1.6	3.84	7,425	452
4000	1	9.0	8.0	7.1	6.0	5.2	3.5	1.9	3.70	5,712	360
4251	4	7.7	6.8	6.1	5.2	4.4	2.9	1.5	3.88	6,750	386
4500	2	9.7	8.4	7.3	6.0	4.9	3.1	1.7	3.43	6,061	269
4749	3	8.6	7.7	6.8	5.8	4.9	3.2	1.7	3.73	6,061	346
5000	1	8.2	7.3	6.6	5.7	5.0	3.5	2.2	3.89	5,940	516
5250	4	7.0	6.1	5.5	4.8	4.1	2.8	1.7	4.04	7,244	541
5500	2	6.5	5.6	5.0	4.2	3.6	2.5	1.6	4.05	8,250	594
5750	3	6.5	5.7	5.1	4.3	3.7	2.5	1.5	4.10	8,027	545
6001	1	9.1	8.1	7.5	6.5	5.8	4.1	2.4	3.92	4,829	460
6251	4	7.9	7.1	6.3	5.5	4.7	3.2	1.8	3.90	6,319	442
6500	2	7.3	6.4	5.6	4.8	4.1	2.7	1.5	3.92	7,244	432
6750	3	7.1	6.2	5.5	4.7	4.1	2.8	1.7	4.00	7,244	528
7000	1	8.9	8.0	7.3	6.3	5.5	3.9	2.2	3.80	5,400	433
7250	4	8.4	7.5	6.8	5.9	5.1	3.5	2.1	3.85	5,824	459
7500	2	7.0	6.2	5.5	4.7	4.0	2.7	1.6	4.00	7,425	499
7750	3	7.6	6.6	5.7	4.7	4.0	2.6	1.6	3.78	7,425	416
8000	1	8.7	7.7	7.0	6.1	5.2	3.6	2.0	3.79	5,712	410
8250	4	10.0	8.8	7.9	6.7	5.8	3.9	2.2	3.57	5,121	339
8500	2	7.0	6.3	5.7	5.0	4.4	3.0	1.8	4.15	6,750	568
8749	3	8.6	7.6	6.9	6.0	5.2	3.7	2.1	3.82	5,712	450
9000	1	7.7	6.9	6.3	5.6	5.0	3.6	2.1	4.20	5,500	571
9000	4	9.1	8.3	7.6	6.7	5.9	4.2	2.3	3.96	4,714	432
9223	3	8.2	7.2	6.5	5.6	4.9	3.4	1.9	3.86	6,061	446
9224	1	12.1	10.7	9.5	8.0	6.7	4.4	2.3	3.29	4,433	238

Note 1: Reference station (Distance = 0) is at the north edge of the intersection of CR17 and Stateline Road

COUNTY ROAD 17, FROM COUNTY ROAD 18 to COUNTY ROAD 28

Distance (Feet) (Note 2)	Lane	Deflection (mils) for 9000 lb Load at							Estimated Structural Number	Estimated Subgrade Modulus (psi)	Asphalt Concrete Modulus (ksi)
		0"	8"	12"	18"	24"	36"	60"			
0	1	4.1	3.7	3.4	3.2	2.9	2.3	1.5	5.83	8,609	1200
0	2	4.7	4.3	4.0	3.7	3.4	2.7	1.8	5.63	7,333	1200
250	4	7.3	6.4	5.8	5.2	4.5	3.2	1.8	4.31	6,187	541
500	2	5.9	5.1	4.8	4.5	4.1	3.3	2.1	5.16	6,000	1167
751	3	6.0	5.1	4.7	4.3	3.9	3.0	1.8	4.87	6,600	900
1000	1	5.0	4.4	4.1	3.7	3.5	2.7	1.8	5.35	7,333	1200
1249	4	6.5	5.6	5.2	4.8	4.3	3.3	2.0	4.77	6,000	838
1500	2	5.3	4.7	4.3	3.9	3.4	2.6	1.7	5.02	7,615	1037
1750	3	5.7	5.0	4.5	4.1	3.6	2.7	1.6	4.83	7,333	828
2000	1	5.8	5.1	4.8	4.3	3.9	3.0	1.9	5.01	6,600	995
2249	4	5.7	5.0	4.6	4.2	3.8	2.9	1.8	4.99	6,828	972
2500	2	5.9	5.1	4.7	4.2	3.7	2.7	1.6	4.71	7,333	764
2750	3	5.8	5.0	4.6	4.1	3.7	2.7	1.6	4.77	7,333	803
3000	1	5.9	5.2	4.8	4.3	3.9	3.0	1.7	4.93	6,600	832
3250	4	6.1	5.4	5.0	4.4	4.0	2.9	1.7	4.73	6,828	749
3501	2	5.0	4.3	3.9	3.4	2.9	2.0	1.1	4.65	10,241	696
3751	3	4.8	4.1	3.8	3.3	2.9	2.1	1.1	4.95	9,429	781
4000	1	4.5	3.9	3.6	3.1	2.9	2.1	1.2	5.20	9,429	993
4250	4	5.2	4.4	4.0	3.6	3.1	2.2	1.2	4.63	9,581	728
4501	2	5.8	5.1	4.7	4.1	3.6	2.6	1.5	4.70	7,615	717
4750	3	5.9	5.2	4.7	4.2	3.8	2.8	1.6	4.78	7,071	765
5000	1	5.3	4.7	4.4	4.0	3.6	2.8	1.7	5.20	7,071	1054
5250	4	5.3	4.7	4.4	3.9	3.5	2.6	1.4	5.02	7,615	810
5500	2	4.7	4.1	3.8	3.3	3.0	2.2	1.3	5.13	9,000	981
5750	3	5.7	5.0	4.6	4.1	3.6	2.6	1.4	4.75	7,615	695
6000	1	4.4	3.9	3.6	3.2	2.9	2.2	1.3	5.40	9,000	1137
6251	4	6.3	5.7	5.2	4.7	4.2	3.0	1.6	4.69	6,600	637
6500	2	4.0	3.4	3.1	2.8	2.6	2.0	1.1	5.57	9,900	1200
6750	3	5.8	5.2	4.7	4.3	3.9	2.9	1.7	4.93	6,828	845
7000	1	6.1	5.4	4.9	4.5	4.0	2.9	1.6	4.73	6,828	702
7250	4	7.6	6.9	6.3	5.8	5.2	3.8	2.1	4.50	5,211	587
7500	2	5.7	5.0	4.6	4.1	3.6	2.6	1.5	4.75	7,615	749
7750	3	5.2	4.6	4.3	3.9	3.5	2.7	1.6	5.19	7,333	1014
8001	1	3.5	2.9	2.6	2.4	2.1	1.6	1.0	5.31	14,143	1200
8250	4	4.6	4.1	3.7	3.3	3.0	2.1	1.1	5.12	9,429	829
8500	2	4.9	4.4	4.1	3.6	3.3	2.4	1.2	5.17	8,250	797
8749	3	4.9	4.3	4.0	3.6	3.2	2.3	1.2	5.06	8,609	805
9000	1	5.0	4.5	4.1	3.7	3.3	2.5	1.4	5.17	7,920	922
9250	4	4.1	3.6	3.4	3.1	2.7	2.0	1.1	5.47	9,900	1065
9500	2	5.2	4.6	4.2	3.7	3.3	2.3	1.2	4.84	8,609	702
9750	3	6.3	5.7	5.3	4.8	4.3	3.2	1.8	4.82	6,187	737
10000	1	5.9	5.4	5.0	4.6	4.1	3.1	1.8	5.01	6,387	848
10250	4	5.1	4.6	4.2	3.8	3.4	2.4	1.3	5.01	8,250	790
10499	2	5.7	5.2	4.8	4.4	4.0	3.0	1.7	5.07	6,600	861
10750	3	4.6	4.0	3.6	3.3	2.9	2.1	1.2	5.12	9,429	939
11000	1	4.5	3.9	3.6	3.3	2.9	2.1	1.2	5.20	9,429	978
11251	4	4.8	4.3	3.9	3.6	3.2	2.5	1.4	5.34	7,920	1030
11500	2	5.5	4.8	4.4	3.9	3.5	2.5	1.4	4.81	7,920	755

COUNTY ROAD 17, FROM COUNTY ROAD 18 to COUNTY ROAD 28

Distance (Feet) (Note 2)	Lane	Deflection (mils) for 9000 lb Load at							Estimated Structural Number	Estimated Subgrade Modulus (psi)	Asphalt Concrete Modulus (ksi)
		0"	8"	12"	18"	24"	36"	60"			
11750	3	6.3	5.6	5.1	4.6	4.1	3.0	1.5	4.69	6,600	609
12000	1	6.1	5.5	5.1	4.7	4.3	3.2	1.8	4.95	6,187	802
12250	4	5.0	4.5	4.2	3.8	3.5	2.8	1.6	5.45	7,071	1117
12500	2	6.2	5.6	5.3	4.8	4.3	3.2	1.8	4.89	6,187	760
12750	3	7.3	6.6	6.0	5.3	4.7	3.3	1.6	4.36	6,000	467
13000	1	5.0	4.5	4.0	3.6	3.2	2.3	1.1	4.99	8,609	698
13249	4	4.3	3.8	3.5	3.2	2.8	2.1	1.2	5.39	9,429	1073
13500	2	2.4	2.0	1.8	1.7	1.6	1.3	1.0	6.84	15,231	1200
13749	3	3.7	3.0	2.7	2.5	2.2	1.6	1.0	5.19	13,500	1200
13999	1	3.6	3.1	2.8	2.5	2.3	1.8	1.1	5.76	11,000	1200
14250	4	4.2	3.7	3.3	3.0	2.7	2.0	1.2	5.37	9,900	1152
14499	2	4.1	3.6	3.2	2.9	2.6	2.0	1.2	5.47	9,900	1200
14750	3	4.5	3.8	3.4	3.0	2.7	1.9	1.1	4.87	11,000	909
15000	1	4.2	3.5	3.1	2.8	2.4	1.7	1.0	4.89	12,375	946
15250	4	5.3	4.6	4.1	3.6	3.2	2.3	1.3	4.77	8,609	759
15499	2	4.6	3.8	3.4	3.0	2.7	1.8	1.0	4.79	11,000	782
15750	3	4.6	3.9	3.5	3.2	2.8	2.0	1.1	5.01	9,900	866
15934	1	4.8	4.2	3.9	3.5	3.2	2.5	1.5	5.34	7,920	1153
15844	4	5.1	4.4	4.0	3.6	3.3	2.5	1.4	5.10	7,920	932
16644	1	5.7	4.8	4.4	4.0	3.7	2.9	1.7	4.99	6,828	967
16721	2	3.9	3.4	3.1	2.7	2.5	1.8	1.1	5.43	11,000	1200
16750	3	4.9	4.1	3.7	3.2	2.9	2.1	1.2	4.71	10,241	852
16835	4	4.6	4.0	3.7	3.3	3.0	2.3	1.3	5.32	8,609	1054
16890	1	5.0	4.4	4.0	3.6	3.2	2.4	1.4	5.08	8,250	938
17174	1	5.7	5.0	4.5	4.0	3.5	2.5	1.4	4.68	7,920	694
17250	4	4.7	4.1	3.7	3.4	3.0	2.3	1.3	5.24	8,609	1004
17500	2	4.6	4.0	3.6	3.3	3.0	2.3	1.3	5.32	8,609	1069
17750	3	4.7	4.0	3.6	3.2	2.8	2.0	1.1	4.79	10,607	821
17999	1	3.8	3.4	3.1	2.8	2.5	1.9	1.1	5.68	10,421	1200
18250	4	5.2	4.6	4.3	3.9	3.6	2.8	1.8	5.29	7,071	1200
18500	2	4.3	3.7	3.3	3.0	2.6	1.9	1.1	5.15	10,421	990
18751	3	4.8	4.3	3.9	3.5	3.2	2.4	1.5	5.24	8,250	1113
19000	1	4.4	3.7	3.3	2.9	2.6	1.9	1.1	4.88	11,423	972
19250	4	5.3	4.8	4.4	4.0	3.6	2.8	1.8	5.20	7,071	1121
19500	2	6.1	5.3	4.9	4.4	3.9	3.0	1.8	4.81	6,600	835
19750	1	4.8	4.4	4.1	3.8	3.4	2.6	1.6	5.43	7,615	1174
19750	3	4.2	3.7	3.4	3.1	2.8	2.1	1.4	5.48	9,429	1200

Note 1: Reference station (Distance = 0) is at the south edge of the intersection of CR17 and CR 18