

FHWA/IN/JTRP-2009/25

Final Report

**AN ASSESSMENT OF DELIVERY RISKS IN
TRANSPORTATION PROJECTS**

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January 2010



INDOT Research

TECHNICAL *Summary*

Technology Transfer and Project Implementation Information

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January 2010
Final Report

An Assessment of Delivery Risks in Transportation Projects

Introduction

Highway projects that surpass their programmed letting date are delayed delivery projects. The delayed delivery of state highway projects (1) impairs the efficient use of allotted federal and state highway funds, (2) shifts current and future project programming, (3) upsets the letting schedule for construction bidding, (4) DOT and other agency resources are unable to accommodate projects spilling over into current schedules due to programming shifts, (5) users incur increased costs in reference to traffic, route change, increased travel time, (6) and defective highways place user safety at risk.

The inaccuracy of letting schedules can cause disruption of fiscal planning by both overestimated and underestimated project costs and planning schedules. Projects that are not let at the expected time usually incur either additional expenses causing a deficit in allotted funds or inhibit the

programming of additional projects, possibly causing available resources to remain unspent. Occurrences during the development and planning of state highway projects can be segmented into those that are (1) within the control of state agencies for mitigation or (2) outside of the control of state agencies. Issues that could have been mitigated earlier through (a) more frequent contacts that keep parties informed on project challenges or (b) contingency plans for delayed property acquisition or utility challenges, are all within control of state transportation agencies. State agencies need not only address delayed project delivery issues but also must scrutinize the types of delayed projects that hinder efficient programming. In an effort to address these issues, an understanding of the characteristics of projects correlating with the problems causing delay, can permit state agencies to increase the accuracy of project delivery.

Findings

The study was based on 366 state highway projects in Indiana with proposed dates spanning between 1970 and 2006. It investigated the sources of delivery variability (risk factors) that occur in the period between project proposal dates and the letting dates.

The study results proved that the highway work category significantly impacted the expected letting duration of projects. Pavement work required the least amount of development time and posed the least risk to programming and fiscal schedules. Pavement project letting durations increased as proposed costs increased, projects

exceeding \$5 million experienced significantly longer letting durations. The Vincennes and Seymour districts had longer development durations than the remaining four districts. Non-interstate district pavement projects experienced shorter letting durations. Bridge rehabilitation work proved to experience the least amount of letting time amongst bridge projects. The Fort Wayne district was found to significantly decrease the amount of letting time for both pavement and bridge projects. Road/Interchange projects posed the largest risk to project delivery, the probability of letting a project after a given letting duration proved to be very low in comparison to bridge

projects. Road/Interchange projects have 20% probability of exceeding 16 years whereas bridge projects have a 10% probability of exceeding 11 years. New interchange work and interchange modification work significantly increased the

letting duration; projects comprised of four or more contracts experienced longer letting delays also. Road/Interchange work on interstates experienced shorter letting times.

Implementation

Analyses modeling the duration factors for the *actual project* development dates and the changes in the *scheduled* project development dates can be formulated into performance measures. These performance measures may include: (1) project phase costs, (2) actual project phase duration, (3) scheduled project phase duration, (4) the number of design changes in a phase, (5) productivity measurements (i.e. volume of work vs. unit cost).

These performance measures would provide more insight for the assessment of the highway project delivery process. Individual case studies of past projects should be undertaken to further examine the risk factors identified in the study. Probabilities of project delivery risks can be incorporated in the projection selection and programming process.

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INDOT Research Project Implementation Plan

Date: 1/28/10

Research Project Number: SPR-3112

Project Title: An Assessment of Delivery Risks in Transportation Projects

Principal Investigator (PI): Kumares Sinha

Project Advisor (PA): Samy Noureldin Signature: _____

Principal Implementor (PIM): J. Weaver Signature: _____

INDOT Strategic Goal Impact Areas (select all that the implementation of this project will impact):

- Mobility Safety Economic Development Customer Service
 Resource Management Training

Summary of Implementation Plan: The procedure is to be used in analyzing Management Information Portal (MIP) data for improved estimation of highway letting dates. The results are to be used to develop a monitoring program for projects with high risks.

Note: If more than one implementor recommended, please fill in the information on each implementor's implementation items:

Name of Implementor/User: John Weaver Signature: _____

Responsible for Implementing: Incorporation of the results in the analysis of the MIP data and utilization of modeling approach for periodic monitoring of MIP data

Help or resources needed for implementation (e.g., help from PI, funding, equipment, etc.):

Name of Implementor/User: Signature: _____

Responsible for Implementing:

Help or resources needed for implementation (e.g., help from PI, funding, equipment, etc.):

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Responsible for Implementing:

Help or resources needed for implementation (e.g., help from PI, funding, equipment, etc.):

Signatures of SAC members: _____

Final Report

FHWA/IN/JTRP-2009/25

AN ASSESSMENT OF DELIVERY RISKS IN TRANSPORTATION PROJECTS

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Indiana Department of Transportation and
The U.S. Department of Transportation
Federal Highway Administration

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration and the Indiana Department of Transportation. This report does not constitute a standard, specification or regulation.

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LIST OF COMMONLY USED ACRONYMS

CMAQ	Congestion Mitigation and Air Quality
FHWA	Federal Highway Administration
FTA	Federal Transit Authority
INDOT	Indiana Department of Transportation
IPOC	Indiana Planning and Oversight Committee
ITS	Intelligent Transportation Systems
KN	Kin projects
MIP	Management Information Portal
NCHRP	National Cooperative Highway Research Program
RFC	Ready for Contract Date
ROW	Right of Way
SA	Stand Alone Projects
SDOT	State Department of Transportations
STIP	State Transportation Improvement Plan
VE	Value Added Engineering

ABSTRACT

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A large number of uncertainties exist in the delivery of highway projects, and it is important to describe the extent so that budgeting and programming can be carried out in a manner that duly accounts for such uncertainties. The study investigates the sources of delivery variability (risk factors) that occur in the period between project proposed date and the letting date. Data on 366 highway projects were collected from the Indiana Department of Transportation Management Information Portal. Using statistical and econometric techniques, the data was analyzed to identify the potential risk factors and to determine the magnitude and direction of the influence of these risk factors. The study estimated the delivery variability inherent with each project type, providing a basis for rating highway projects in terms of their delivery risks and for incorporating probabilistic concepts in budgeting and programming.

CHAPTER 1. INTRODUCTION

1.1. Background and Problem Statement

Highway projects that surpass their programmed letting date are delayed delivery projects. The delayed delivery of state highway projects (1) impairs the efficient use of allotted federal and state highway funds, (2) shifts current and future project programming, (3) upsets the letting schedule for construction bidding, (4) DOT and other agency resources are unable to accommodate projects spilling over into current schedules due to programming shifts, (5) users incur increased costs in reference to traffic, route change, increased travel time, (6) and defective highways place user safety at risk.

This is only a few of the adverse effects caused by sluggish project delivery. Projects are programmed based on annual letting costs. The inaccuracy of letting schedules can cause disruption of fiscal planning by both overestimated and underestimated project costs and planning schedules. Projects that are not let at the expected time usually incur either additional expenses causing a deficit in allotted funds or inhibit the programming of additional projects, possibly causing available resources to remain unspent. Occurrences during the development and planning of state highway projects can be segmented into those that are (1) within the control of state agencies for mitigation or (2) outside of the control of state agencies. Issues that could have been mitigated earlier through (a) more frequent contacts that keep parties informed on project challenges or (b) contingency plans for delayed property acquisition or utility challenges, are all within control of state transportation agencies. State agencies need not only address delayed project delivery issues but also must scrutinize the types of delayed projects that hinder efficient programming. In an effort to address these issues,

an understanding of the characteristics of projects correlating with the problems causing delay, can permit state agencies to increase the accuracy of project delivery.

The Federal Highway Administration (FHWA) has sought to improve the oversight of highway programming by assessing the performance of each transportation agency. In an effort to do so, the state department of transportation (SDOTs) sign a contract with the FHWA outlining categories of highway programs to be overseen and the type of oversight to be provided. Section 1305 of the Transportation Equity Act for the 21st Century (TEA-21) of 1998 amends Section 106 of Title 23 - United States Code (U.S.C.), Project Approval and Oversight, and this section revises provisions for project oversight of federal-aid highway projects and eliminates the Certification Acceptance (CA) Program (MoDOT, 2005).

SDOTs are obligated to preserve data pertaining to each highway program. For example, the Missouri Department of Transportation (MoDOT) signed the *Federal Aid Project Oversight Agreement* with the FHWA. MoDOT outlines in the oversight agreement that projects exceeding \$1 million dollars, major bridge projects, and major Intelligent Transportation System projects (ITS), will receive full oversight and approval by the FHWA (MoDOT, 2005). Unfortunately, state transportation agencies have very little consistent and accurate scheduling milestones data for the highway programming process. This is due to undocumented schedule changes that leave many SDOT's programming inventory systems riveted with inaccurate time data. An effort must be made to document the initial programmed time and the actual time each milestone is conducted in the programming process. The FHWA is aware of these inventory issues and is progressively addressing them; however, the administration still maintains responsibility for the assessment and moderation of state programming processes (GAO, 2005).

The FHWA set the first measuring rubric for the evaluation of programming costs and schedules in 2004 (GAO, 2005). The objective of programming assessment is to maintain the efficient use of federal funds to minimize excessive costs and ensure punctual highway program delivery. The United States Government Accountability Office (GAO) stated that "some" programming oversight goals had been created but

were not successfully implemented (GAO, 2005). The FHWA was found using information that was relatively late in programming development as the base for cost fluctuation and scheduling duration measurements. This could be the result of incorrect selection of data and/or attributed to the inaccuracies in the inventory databases mentioned previously. Nonetheless, the need for further evaluation utilizing the available highway programming process data is vital for program delivery improvement (GAO, 2005).

The present study provides a methodology to identify transportation projects that are likely to incur letting delays in an effort to minimize risks associated with project delivery. Statistical models are used to evaluate significant dynamics that influence the time length of the letting program in the Indiana Department of Transportation (INDOT) programming process. The letting program begins with the FHWA authorization of the highway project to become a program and concludes when the project is let for contract bids; the period is referred to as the letting program (NCHRP, 2004). Once projects are authorized they are moved from the long-range Transportation Improvement Plan (TIP) into the short-range State Transportation Improvement Plan (STIP). The project authorization date marks the initiation of the letting program and will be referenced to as the proposed date. The final date in the letting program is indicated to as the letting date.

For comprehension, an overall understanding can be outlined schematically as presented in Figure 1.1, Planning, Programming, and Construction. The Programming phase is the interest for this study. In the Planning phase, all highway transportation ventures are known as projects. Once highway projects are authorized and enter the Programming phase they are in development. According to the FHWA, all approved projects under development, regardless of time frame, are known as “the program” (FHWA, 2004). Highway programs continue with this label until the completion of the Construction phase.

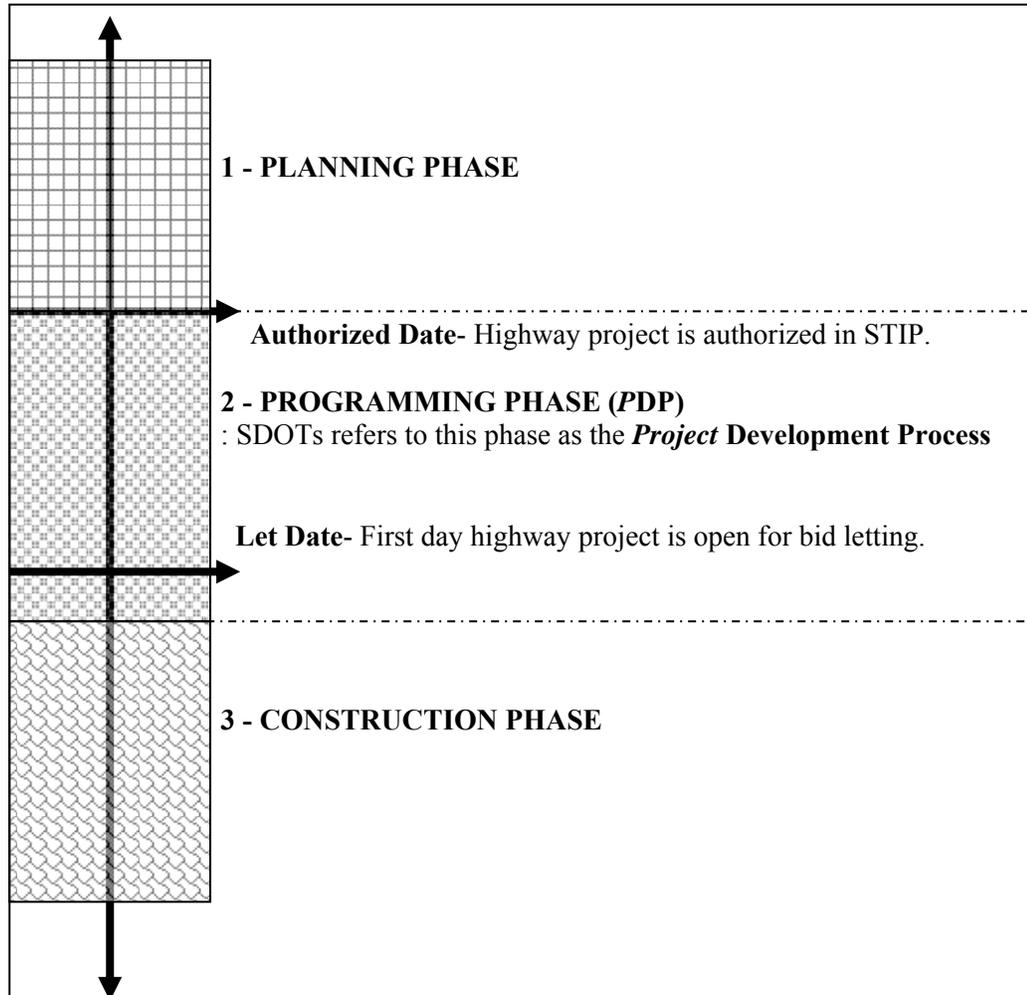


Figure 1.1 Highway Development Process

Table 1.1 Description of Highway Development

Stages of Project Development Process	Typical Activities
Programming	Environmental determination, schematic development, public hearings, Right of Way plan, and project funding authorization.
Advanced Planning/Preliminary Design	Right of way development, environmental clearance, design criteria and parameters, surveys/utility locations/drainage, preliminary schematics such as alternative selections, geometric alignments, and bridge layouts.
Final Design	Right of way acquisition, Plans, Specifications, & Estimates development – pavement and bridge design, traffic control plans, utility drawings, hydraulic studies/drainage design, and final cost estimates.
Letting	Prepare contract documents, advertise for bid, pre-bid conference, and receive and analyze bids
Award	Determine lowest responsive bidder, initiate contract

The steps included in the programming phase are also referred to as the project development phase as indicated in Table 1.1. The specific steps vary from state to state and Table 1.1 presents the generally accepted steps (Fisher and Anderson, 1999; Sinha and Labi, 2007).

Each step in the PDP requires elaborate cooperation from local, state, and federal agencies to provide development and funding services. The FHWA Office of Program Administration continually modifies the PDP to improve regulation and assessment of all stages pertaining to highway transportation programming (FHWA, 2007). Improvement to the development and management of state highway letting programs is a critical component for successful project delivery. Successful project delivery will support achievement of local, state, and national transportation goals (NCHRP, 2004).

1.2. Study Objectives

Given the previous explanation of the letting program time period, the purpose of the study is to analyze components of highway programs that significantly impact letting program delivery in INDOT. The Indiana Administrative Code (IAC) defines highways as “any roadway (a) under the jurisdiction of the department, or (b) where an improvement project is planned.” The findings in this study will identify types of at-risk letting programs in INDOT and provide direction for correction and further investigation of letting program delivery. There is a need to moderate highway letting programs in an effort to enhance INDOT’s ability to manage costs and program scheduling to limit risks in letting program delivery.

1.3. Scope of Study

For this study, a database consisting of a total of 366 highway projects was developed from the INDOT’s Management Information Portal (MIP) between the months of July and September 2008. The projects were segmented into two categories: KIN (KN), projects that consisted of two or more contracts, 118 observations; Stand Alone (SA), projects that consisted of one contract, 248 observations. Project proposed dates span between the years 1970 to 2004 for KN projects and 1980 to 2005 for SA projects, the corresponding letting date ranges were 1994 to 2004 (KN) and 1995 to 2006 (SA). The separation of projects was necessary due to vast differences in variable values. All projects have equal or greater proposed costs of \$1 million; the costs peak at \$11.64 million (SA) and \$34.167 million (KN). Every project selected for analysis was completed prior to the collection of data. This criterion was necessary for the assurance that all dates collected in the system were final and not subject to change.

1.4. Overview of Study Approach

The first step of this study was to clearly establish the objective, which is stated in the previous section. Once a clear objective was outlined, data was collected from the MIP at INDOT. The data was then scrutinized for consistency, as improper scheduling data was often encountered. After a quality data set was compiled, assuring correct analysis, the existing literature was reviewed. There was a limited amount of letting program and scheduling literature available. The bulk of the review consisted of several transportation journals, federal and state publications, and other programming management literature. Literature was collected beginning with the top of the policy chain, from federal agencies and other federal establishments, FHWA, USDOT, and GAO. Upon comprehension of the federal PDP goals, regulations, and systems was achieved, a review of PDPs from state transportation agencies followed. The federal guidelines provide the framework of the PDP, but each state has a unique description of the steps utilized to complete a successful program. The observation of INDOT's elaborate thirteen step Project Development Process (PDP) carefully outlined each step of highway programming. This information was absolutely vital to interpret the corresponding scheduling data from INDOT. The data was analyzed to investigate the factors associated with project delivery risks. Statistical models were developed to accomplish the task.

1.5. Organization of Report

This report is comprised of five chapters. Chapter 1 is the introduction and provides information to the background and motivation for the study. Chapter 2 is the literature review and provides information on current practices at federal and state agencies. Chapter 3 describes the origin, selection, and organization of letting program data. The chapter also describes the analysis methodology of the study. Chapter 4 provides descriptive statistics of the collected data as well as the results of the study. The implications of the results are discussed in this chapter drawing information from the

literature review and the statistical modeling methods discussed in Chapters 2 and 3. Chapter 5 summarizes the conclusions of the study, identifies sources of error, and provides suggestions for further study.

CHAPTER 2. LITERATURE REVIEW

2.1. Introduction

This section provides insight to relevant studies and government manuals that influence the project letting process described in Chapter 1. While there is an abundance of literature on programming policies and project varieties, there is very limited information presenting numerical figures concerning time duration for the project development phase and the program delivery concerns.

An overview of the incurred investment risks due to delayed program delivery indicates the importance of assessing letting programs. The scope of impact for successful program delivery surpasses the obvious objective of program completion by state transportation agencies. State Departments of Transportations (SDOTs) are responsible for providing the construction, reconstruction, rehabilitation, and expansions of highways to facilitate safe and efficient transport of goods and people. SDOTs must provide these services in timely manner to maintain quality transportation services and optimize the use of public funds. A summarized description of the FHWA Project Development Process is provided prior to the explanation of subsequent programming processes.

2.2. Reducing Project Delivery Duration

A need for improved highway delivery time management has drawn the attention of highway associations, societies, and federal, state, and local agencies over the years. The FHWA Value Added Engineering (VE) methods were first launched approximately thirty years ago (FHWA, 2004). The techniques center on increasing the value of highway projects by locating risks, developing alternate approaches, weighing the effects on project value, and choosing the best alternative to add value to the project. The projects selected for VE assessment were initially very large, costing approximately \$25 million or more. But recently Washington DOT (WSDOT) reported including smaller projects, just over \$2 million and a new risk analysis process that scrutinizes project schedules and budgets. The fundamental credence for expanding the scope of the VE methods to include project schedules is, “If we can deliver a project on time or sooner, for example, that definitely adds value (FHWA, 2004).” In 2003, WSDOT reportedly saved \$60 million utilizing the VE techniques and expects to increase savings with the addition of schedule analysis.

Findings in a report written by the American Association of State Highway and Transportation Officials (AASHTO) stated that project development processes needed to be shortened by approximately 50 percent (AASHTO, 2007). According to the study, the average highway project takes 10 to 15 years to complete, gauging from the STIP to the end of construction, but can be shortened between 5 to 7 years. Results also described durations as long as (9) nine years for planning to construction finish and a maximum at 6 years for environmental procedures. The report also outlined essential topics that impact the timely delivery of federal-aid transportation projects. These issues particularly with respect to FHWA responsibility have been compiled in Table 2.1.

Table 2.1 Areas for Minimizing Highway Project Delivery Time (AASHTO, 2007)

Areas for Modification	Reasoning
1. Make clear the principal function to be executed by FHWA.	The primary responsibility of the FHWA and the U.S. DOT is to improve mobility for the American people in the most expeditious way possible.
2. When requested to do so by state or local government project sponsors, U.S. DOT should establish a goal to complete the NEPA process for major projects in 24 months.	60 months is the current average time to complete National Environmental Policy Act (NEPA) reviews on major transportation projects.
3. Some recent Federal actions will hinder, rather than expedite, project delivery.	i.e. SAFETEA-LU authorized states to assume delegations of FHWA's environmental role. Most states have chosen not to seek delegation authority because of FHWA's interpretation that if they do so they must give up the option of advanced right-of-way acquisition and final design paid for with non-Federal funds
4. Create Partnerships between Resource Agencies and Transportation Agencies.	Transportation agencies and environmental resource agencies all would benefit from a closer working relationship.
5. The Commission should call for the Council on Environmental Quality (CEQ) to clarify the parameters for indirect and cumulative impact analysis and mitigation.	States must assess the indirect and cumulative impacts of transportation projects sometimes required for non-transportation activities. Some Federal agencies have used this authority to extract dollars from transportation agencies well beyond reason, because the transportation agencies have deep pockets, or to drive the cost of projects high enough to be cancelled.
6. Reform or eliminate Clean Air Act conformity regulations because of the progress being made through cleaner fuels and cleaner engines.	The Commission should recommend that Congress take a close look at the Clean Air Act conformity requirements, to determine whether they will have a meaningful effect in the future, given how effective EPA's engine and fuel requirements have been in lowering vehicle emissions to a fraction of 1960 levels.
7. Change federal policies so corridors for the future can be identified and preserved. (U.S. growth is expected to be 140 million people in 50 years.)	Current federal environmental restrictions make it extremely difficult to identify and preserve transportation corridors for the future. It will be almost impossible to reacquire corridors once urban areas are developed.

The AASHTO report (2007) highlighted a selection of successful highway projects where rapid actions were taken once SDOTs experienced emergency situations and/or exceedingly high traffic problems. California's Department of Transportation (CALTRANS) was challenged when the I-580 overpass leading to the San Francisco-Oakland Bay Bridge was completely destroyed by an earthquake and damaged the I-880 below in April 2007. The reconstruction of the overpass and inspection of I-880 was expected to take (50) fifty days but was delivered in just (26) twenty-six days. In Webbers Falls, Oklahoma in 2002, a runaway barge ran into the I-40 Bridge support columns. The bridge closing was estimated to cost the neighboring economy \$430,000 per day and estimated to take 3 months to complete. The bridge was finished within (67) sixty-seven days; cutting the expected delivery time and economic costs down by roughly 33 percent. INDOT has also been recognized for its expeditious repair of the Indianapolis intersection between Interstates 65 and 70 within the I-465 loop. The estimated time for delivery using standard methods was 6 months, but an incentive contract dropped the estimated completion time to 85 days and actual completion time was 55 days (AASHTO, 2007).

Although the present study is focused on project delivery in terms of the time taken to develop a project, design, and prepare letting documents after a project is programmed, the cases discussed above proved that a speedy highway project delivery is always possible, but the current efforts are limited to those projects deemed an urgent situation based on the magnitude of functional displacement. The responsibility lies on the FHWA as well as state transportation agencies to reinforce the fact that highway projects should always be developed and delivered in the shortest duration possible regardless of urgency.

2.3. Investment Risks and Program Delivery Overview

Highway projects are largely financed by federal funds. Investment risks can occur when project spending surpasses the estimated amount or program development is extended beyond the schedule, causing an increase in spending, occupying resources

reserved to administer other projects, economic losses to the local area, traffic congestion, etc. USDOT Project Oversight regulations permit the FHWA to mitigate these issues by providing guidance, formalities, and dialogue between all participating entities during the planning, development, and construction of select projects. While this program has aided in great advancements in the highway development process, there are still opportunities to improve the effectiveness of the program to decrease program delivery time.

2.3.1. Project Oversight

Projects that receive funding are required to be overseen by the FHWA, including management of the planning and programming processes. Project oversight is mandated for particular, high-cost, federal aid highway programs in an effort to ensure the efficient use of federal funds. Though these projects are observed more closely, *full* oversight is not definite and the consistency in the amount of oversight specified for each project fluctuates. Those projects that receive *full* oversight are given the following for planning and programming processes (GAO, 2005):

1. prescribed design and construction standards,
2. approved design plans and estimates,
3. approval of the selection of the contract award,
4. periodic inspections of the progress of construction, and
5. final acceptance of projects when they are completed.

The category of programs receiving FHWA oversight for design and construction in 2002 are given in Table 2.2, along with the correlating percent of federal funding obligated to those program types. As seen in Table 2.3, only Interstate System projects exclusively received oversight from the FHWA. Interstate federal funds account for merely 12 percent of the total obligated federal funds. The remaining 42 percent (Federal-aid highways off the National Highway System) are left to the control of

SDOTs, and 45 percent (National Highway System Non-Interstate Routes) have the possibility of being overseen by either.

Table 2.2 Types of Projects Receiving FHWA Oversight versus State Oversight
(GAO, 2005)

Type of project	Mileage	Percent of federal highway funds obligated in 2002	Design and construction oversight	Exceptions
Interstate System	47,00	12	FHWA oversight	Certain types of projects, or projects below a dollar threshold where FHWA and state determine state oversight is appropriate
National Highway System, non-Interstate routes	115,00	45	State may assume oversight	State or FHWA determines state oversight is not appropriate
Federal-aid highways off	798,00	42	State shall assume oversight	State determines state oversight is not appropriate

While federal oversight is reserved for high-cost projects, there are two policies that add to the challenges to oversee highway programming by the FHWA. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and TEA-21 both have given a great amount of control to the SDOTs causing difficulties for the FHWA to moderate highway programming. The issue is being resolved with each SDOT drawing up an agreement contract with FHWA for a unique project oversight program (MoDOT, 2005). The oversight program agreement is useful tool to manage program letting schedules.

In reference to the present study of INDOT's letting program, the Indiana Design Manual, Section 40-7.0, Item 3 clearly states the boundaries for federal or INDOT project oversight responsibility. The FHWA is given oversight responsibility based on the (3) three factors: the highway system, project scope of work, and project cost as shown below (Uremovich, 2004):

1. Highway System: Interstate projects,

2. Project Scope of Work: New Interstate Construction/Reconstruction,
3. Project Cost: Interstate Projects greater than \$1million.

The Stewardship and Oversight Agreement permits FHWA oversight to review all stages in the federal aid program. However, those projects under the supervision of the Indiana Planning Oversight Committee (IPOC) exclude the FHWA from involvement in “day-to-day project activities.” The projects under the IPOC are still permissible to the FHWA Program and Process Review (Uremovich, 2004). Table 2.3 defines projects under the IPOC or FHWA Oversight umbrella.

Table 2.3 FHWA Oversight and INDOT Oversight Segmentation (Uremovich, 2004)

Project Category	Highway System		
	Interstate	Non - Interstate NHS	Non-NHS
New Construction, Reconstruction, or Partial Reconstruction (4R) \geq \$1,000,000	FHWA Oversight	INDOT Oversight	INDOT Oversight
New Construction or Reconstruction (4R) $<$ \$1,000,000	INDOT Oversight	INDOT Oversight	INDOT Oversight
Resurfacing (3R) Project	INDOT Oversight	INDOT Oversight	INDOT Oversight
Design Build Project	FHWA Oversight	FHWA Oversight	INDOT Oversight
Rest Area or Weigh Station \geq \$1,000,000	FHWA Oversight	INDOT Oversight	INDOT Oversight
Intelligent Transportation System (ITS) Features	FHWA Oversight	FHWA Oversight	INDOT Oversight

According to INDOT, a Major Projects is transportation improvement where the anticipated result of the improvement is expected to involve one or more of these instances (INDOT, 2007):

1. Has a substantial impact to public access, level of service, traffic flow, or mobility patterns.
2. Require substantial right-of-way acquisition.
3. Has substantial public controversy.

4. Have significant environmental impacts.
5. Additionally, this classification applies to each roadway transportation improvement that will require a substantial financial investment to complete all aspects of project development. This type of project typically involves one or more of these situations:
 6. Making substantial alterations to the existing roadway (e.g., lane addition).
 7. Relocating a major portion of a roadway (e.g., major change to horizontal and/or vertical alignment).
 8. Developing a new roadway alignment (e.g., bypass).
 9. Constructing a new or major modification to an existing interchange.

The INDOT definition of a Minor Project is given as a transportation improvement that generally is located on an existing alignment (INDOT, 2007).

1. Small adjustments to the existing alignment to improve geometric conditions.
2. Minor alterations of a non-Interstate roadway that does not result in significant environmental impacts.
3. If environmental impacts are present, they can be analyzed and approved through the EA or Categorical Exclusion process.

The categories of projects under the IPOC are greater than those overseen by the FHWA. For the purpose of the present study the issue is not based on the need for more federal or more state supervision, but what type of oversight combination can provide for the swift delivery of highway transportation programs.

The IPOC oversight annual course of action has length of roughly one year, as shown in Table 2.4. After the completion of the final step, funds are allotted and the project is authorized. In 2005, the projects under the IPOC accounted for approximately 30 percent of construction projects.

Table 2.4 IPOC Sequence (INDOT, 2005)

September 15:	INDOT's Division of Planning issues call to INDOT districts and other responsible parties to submit project nominations for major new capacity projects to the IPOC.
October - November 20	District offices hold early coordination meetings with local units of governments and MPOs in development of these proposals. Process to update the Indiana Statewide Transportation Improvement Program (INSTIP) begins.
November 20 - Jan 1:	Draft list of projects developed. Draft Preliminary Major New Construction Program published and released for public comment, legislature and MPO review no later than January 15. Draft INSTIP compiled.
January 15 - March 1	: Districts and MPO's hold public meetings on projects under their jurisdiction to be included in the INSTIP and the 10 year Major New Construction Program.
April 1	Draft constrained list of projects published for public comment.
May 1:	Updated ten year funded Major New Capacity Program published by IPOC to coincide with the INSTIP which will include all categories of projects, with the Major New Capacity program as one component.
June 1:	INSTIP, of which the Major New Capacity Program is a subset, is submitted to FHWA for review and approval. FHWA approval is sought by July 1 to coincide with INDOT fiscal year.

2.3.2. Effects of Scheduling Changes on Project Costs

The increase of project delivery time is almost synonymous with an increase of transportation costs, due to a growth in inflation and project overhead. Scheduling changes can cause all agencies and entities involved in the project development process to encounter an increase in overhead costs. As a result of these cost increases, the timing of expenditures may need amending and have adverse effects on the planned annual budgets. The purpose of on-time project delivery is to prevent SDOTs from (1)

employing their scheduling delay contingency plans in attempt to thwart the waste of public monies (2) and the hassle of shifting programmed projects (NCHRP, 2007).

2.3.3. Investment Risks and INDOT Program Delivery

INDOT has recently taken a huge step to fund state transportation investments from 2005 to 2015. The 75 year lease of the Indiana Toll Road (ITR) to Cintra, a Spanish-Australian consortium, for an upfront payment of \$3.85 billion is a major source of non-federal funding for the state of Indiana. An elaborate plan titled “Major Moves” outlines the funding and scheduling of projects throughout the state of Indiana.

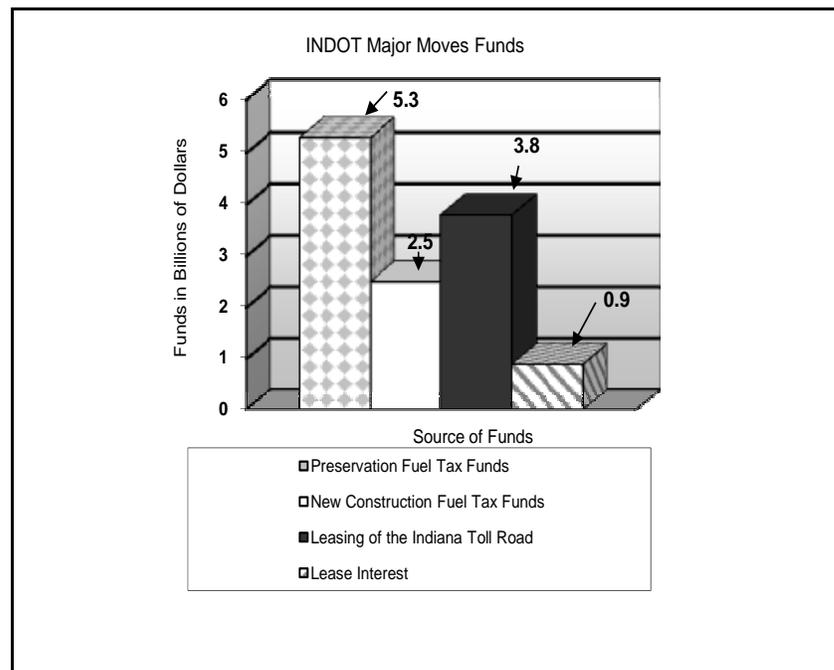


Figure 2.1 INDOT Major Moves Funds (INDOT, 2006a)

In Figure 2.1, sources for funding of Major Moves projects include: preservation fuel tax funds (\$5.3 billion), new construction fuel tax funds (\$2.5 billion), and leasing money from the leasing of the Indiana toll road (\$3.8 billion) plus lease interest (\$0.9 billion). The state would have encountered a \$1.8 billion gap in transportation funding if actions were not taken to keep the state’s transportations systems running smoothly.

Now that INDOT has such a relatively large amount of money, the motivation is strong to minimize risks and assure on-time program scheduling for the proper use of these accounts to avoid cost inflation and other problems.

2.4. Transportation Planning

The previous sections discussed: (1) the need for punctual program delivery, (2) current works reducing project delivery time and (3) connecting investment risks with program schedule delays.

Highway transportation projects are planned years in advance and are segmented into the proper funding categories during the early planning phase, Long Range Transportation Improvement Plan (TIP), before the Program Delivery Process. A brief summary of the TIP is illustrated as it is not directly involved with the duration area of interest for this study. Projects are first brought for approval in the TIP by SDOTs to the USDOT's FHWA. The TIP is a living, documented directory of potential transportation projects that is continually modified by transportation agencies, stake holders, and members of the communities. INDOT has created two committees, the Policy Oversight Committee and the Technical Coordination Committee; both control the expansion of potential projects in the TIP.

“The *Policy Oversight Committee* has authority over the entire range of transportation planning activities carried out by INDOT and provides the coordination necessary to develop the department's Long-Range Transportation Plan. The Policy Oversight Committee approves major Long-Range Transportation Plan elements and new project recommendations. A *Technical Coordination Committee* was established to provide for the involvement of a number of different sections from the Division of Environment, Planning and Engineering, the Multimodal Division and the Program Development Division. These include the long-range transportation planning section, the programming section, the relinquishment section, the traffic statistics section, the rail section, the public transportation section and the aviation section... upon the review

and recommendation of the Technical Coordination Committee candidate projects are passed to the *Policy Oversight Committee* for approval (INDOT, 2007).”

An (8) eight step procedure completes the planning process and approves projects to be entered into the State Transportation Improvement Plan (STIP), as shown in Figure 2.2.

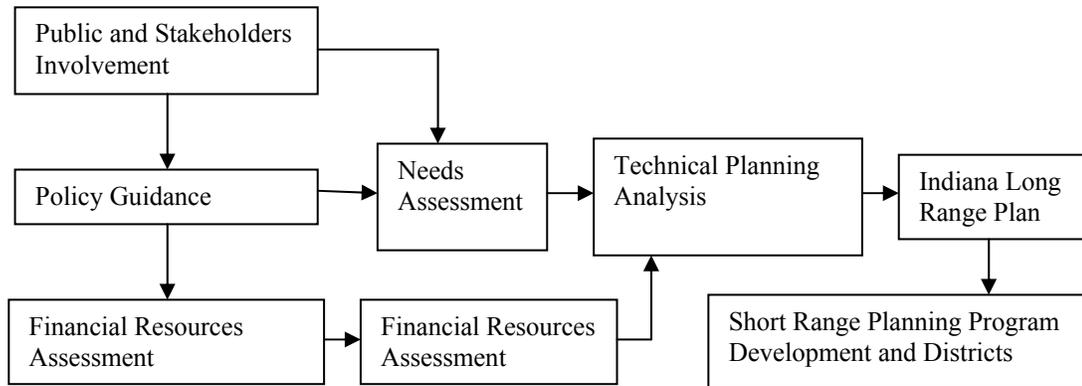


Figure 2.2 INDOT Planning Procedures (INDOT, 2007)

In a recent study of the Metropolitan Planning Authority (MPO) for the San Francisco Bay area, the Metropolitan Transportation Commission (MTC) expressed concern to increase the efficiency of project delivery by collecting scheduling data from sponsor and monitoring progress (Murray and Birner, 1999). The first step was to meet with all entities involved in funding a transportation project and concluding the session with a signed contract stipulating if: (1) *all* STP funds and (2) all Congestion Mitigation and Air Quality Improvement Program (CMAQ) funds were not ready at the selected date, the project would not enter the STIP and be removed from the TIP. The ultimatum of punctuality or project termination was a huge incentive for all parties to be prompt.

Next a database was created to update all parties of the progress on each project. The software highlighted tasks behind schedule throughout the development of the project and maintained schedule awareness. The electronic monitoring database easily kept entities on schedule and an agreement with the FHWA and Federal Transit

Administration (FTA) was made to streamline the review process. Projects that were found behind schedule were discussed in oversight committee meetings and given the proper assistance to get back on schedule. Each of the agencies monitored the progress of TIPs to be authorized STIP projects using the scheduling software. In the end, the efforts of the oversight committee to authorize projects more quickly were a success. Extended work to the database was done to expand its abilities to accommodate more TIP programs, but there was still room for improvement. TIP projects had different identifiers in the TIP database than in the potential STIP; “a danger in using multiple software packages for the same database is that one can wind up with two versions of the same database” (Murray and Birner, 1999). Agencies could potentially have outdated information regarding specifications, funding, quality documents, project identifiers, etc, causing double work on tasks that had already been completed or progress using false outdated information.

The predicament was alleviated by (1) creating a unique identifier for each project that could be recognized in both the TIP and potential STIP databases and (2) linking current information between the two systems. A similar quandary is faced by Indiana Department of Transportation (INDOT) as there are two databases, the Management Information Portal (MIP) and the Scheduling/Project Management System (SPMS). The projects can be readily identified in both systems but do not always contain the same information pertaining to the stages of the development process. This issue was recognized while collecting data for the present study.

2.4.1. Program Prioritization

“...The costs of programmed projects usually exceed available funds, the prioritization of projects is especially important for this time period (STIP)” (FHWA, 2004). Program prioritization is the final step in the planning process, each state has unique calculation methods that involve evaluations from stake holders, Metropolitan Planning Organizations, and other participating agencies. The Vermont DOT’s selection of specific proposed transportation projects requires that (1) the agency verify

the selection of transportation projects for stake holders and the public, (2) the most significant projects are placed at the head of development agenda, (3) projects selected minimize long-term costs, and (4) focus on maintenance and rehabilitation rather than new construction (Virginia DOT, 2008).

The prioritization process includes rankings that weigh deciding factors and measure the magnitude of each factor. Indiana's Major New Capacity Program which caters to projects on a larger scale is regulated by the IOPC. The IOPC states for these projects: 50 percent of scoring is allotted to transportation enhancement or preservation; projects that improve safety are allotted 25 percent, and the creation/retention of jobs and investment in Indiana's economy along with customer input earns the remaining 25 percent of the total project score (INDOT, 2005). If accepted, the IOPC has multiple funding combinations for projects (INDOT, 2005):

- (1) Agree to fund a project for construction during the following ten-year period.
- (2) Agree to share funding of a project with another entity.
- (3) Agree to fund some phase of project development, such as preliminary engineering, design or right of way acquisition to prepare it for construction funding in a later year.
- (4) Ask the staff to provide a more in-depth feasibility analysis to clarify the potential cost and benefits of a project if few project details are certain.
- (5) Ask the project sponsor to scale back the project and re-submit the project in a lesser form.
- (6) Reject the request for funding.

INDOT also recently implemented the Major Moves Program, stated earlier, which prioritizes highway development projects using an 11 criterion analysis spanning the years 2006-2015. Projects included in this program include new construction or major preservation.

The prioritization of relatively large projects and small projects have some differences, but the purpose of prioritization to select the best projects that will benefit

the economic development, safety, and efficiency of transport for the city and surrounding communities remains the same regardless of size.

2.5. Project Delivery Process

The steps in the STIP PDP are imperative to the study of highway project letting delivery improvement. Section 2.4 provided background for the long-term transportation improvement plan as preface to the stages of the STIP Project Delivery Process. The purpose of the present study is to outline the factors increase the time duration of the letting program in the PDP. Once these factors are identified for the letting program, the PDP steps will be analyzed for areas of mitigating extended letting program delivery duration.

2.5.1. STIP Planning

The State Transportation Improvement Plan (STIP) is comprised of projects that have been selected from the federally approved Long Term Transportation Improvement Plan (TIP). Projects selected for the STIP are brought into fruition in roughly 3 years.

2.5.2. Major and Minor Programs

Once projects are selected from the TIP to enter the state transportation improvement plan they become *authorized* and *programmed* upon funding (INDOT, 2001). Programmed project are then separated in different categories determined by the SDOT. A common segmentation by SDOTs, and also chosen by INDOT, is the separation of project into *minor* and *major* categories. The programming processes for major and minor programs do mainly differ in the beginning stages of the PDP; every program must meet federal and state regulations regardless of size. Major programs have different time specifications and are usually given an extended amount of time for

each procedure in comparison to the minor projects. These are for obvious reasons such as more land to survey for environmental assessments, larger air quality affects, larger economic impact, etc., all aspects are magnified. Due to this, major programs also may have a special committee that is responsible for the development from authorization to letting. The committee may act as a supervising body that assesses each step in the process, as the “supreme court” for critical decisions, and/or liaison to interacting agencies. INDOT has a detailed outline describing the major and minor *PDP*. The *PDP* figures displayed are a combination of the original INDOT *PDP* figures and the Programming Development figure introduced in Chapter 1.

As seen when comparing Figure 2.3 and Figure 2.4, *major* projects have a more detailed Programming stage and a lengthier Advanced Planning/Preliminary Design stage in comparison to *minor* projects. The *minor* projects are allotted 1,531 Days, roughly 51 months (4 years and 3 months), whereas the *major* projects are designated 2,544 Days, about 84.8 months (7 years) (Mroczka and Kicinski, 2006a). Information for Figure 2.3 and Figure 2.4 was compiled from INDOT.

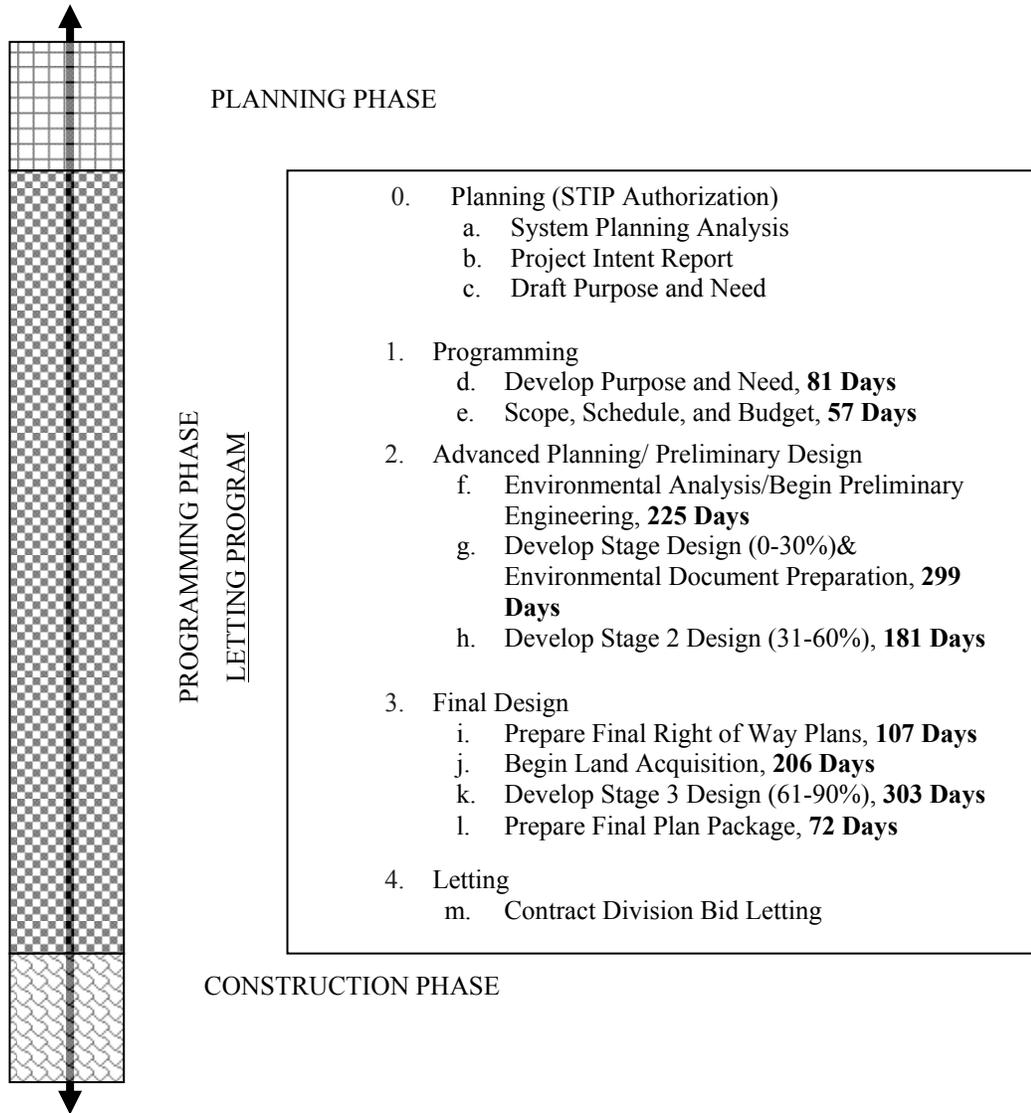


Figure 2.3 Stages in the Project Development Process: Minor Projects (Kicinski and Mroczka, 2006a)

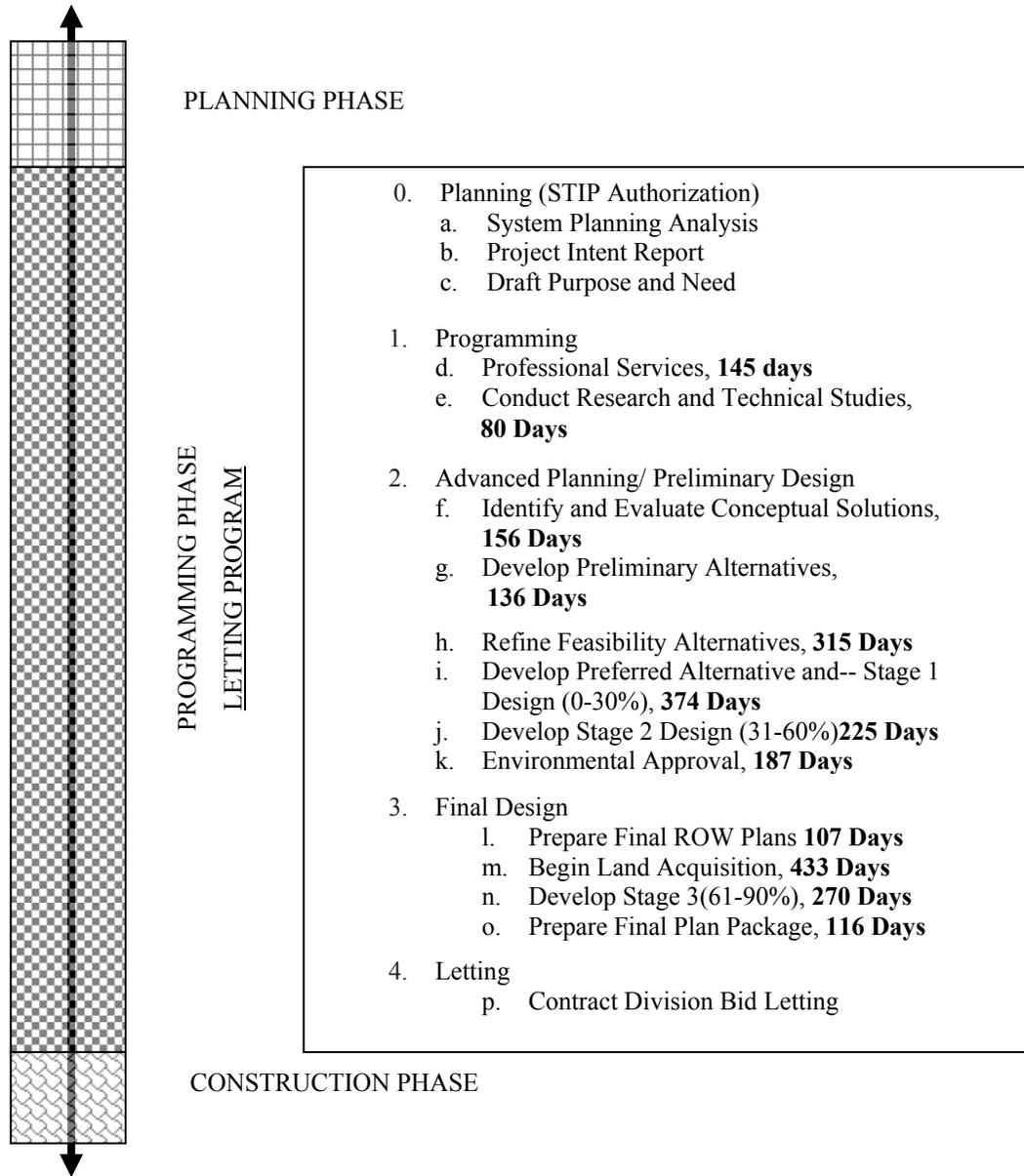


Figure 2.4 Stages in the Project Development Process: Major Projects (Kicinski and Mroczka, 2006a)

2.5.3. Project Authorization

Projects are “approved and authorized for funding” (INDOT, 2001). Upon project selection for the STIP, sources of funding are delegated to officially *authorize* and *program* a project. Each state has an evaluation system that provides sound judgment on the selection of highway transportation projects to authorize into the STIP. The evaluation process may involve analysis of highway systems, a ranking rubric conducted by senior members of the programming process, or any other combination of ways to conclude a sound judgment of the selection of transportation system. INDOT categorizes the projects as major or minor upon selection for authorization. Major projects are the responsibility of the INDOT Planning Oversight Committee (IPOC), a special committee established for making decisions regarding major programs.

Projects are then given identifiers that permit all team members to track the maturing project. Not all project management systems are equally effective in managing the schedules of projects, reports have shown that schedule monitoring systems are not updated at the same rate at which changes in the schedule take place (NCHRP, 2004). INDOT has two tracking systems, the Management Information Portal (MIP) (from which all the data of this study was extracted) and the Scheduling Project Management System (SPMS). Issues affecting the accuracy of project data and the MIP’s ability to track changes are discussed further in the results and conclusion of this report.

As indicated in the 2004 NCHRP study, a vital step in the selection of a highway project is the presentation of ample evidence of a need for the project and its efficacy in accomplishing the federal, state, and local goals. After all the previous steps have taken place in the STIP planning phase, an official *Purpose and Need* Statement is generated to conclude the process.

2.5.4. Programming

The Programming step has the shortest time duration for the entire *PDP*, but the delays of procedures within the step do not pose the greatest risks to the delivery of the project. Inaccurate estimates of traffic studies or other data collected pose the risk of altering the project scope or design and in turn increase the duration to project letting. This step includes technical studies, data collection, traffic studies, and notifies the land owners around the location of the project. After completing studies and notifying all participating parties, the finalized purpose and need statement, project scope, schedule, and budget are developed. The objective of the project schedule is to dictate the timing of procedures to be carried out to attain the programmed letting date. The purpose and need statement are approved by the district for minor projects and the IPOC for major projects.

2.5.5. Advanced Planning/Preliminary Design

The Advance Planning and Preliminary Design step contains the bulk of the project development procedures and is the longest time duration in the *PDP*. As a result, this step provides the most opportunities to decrease and to increase the letting program duration. The environmental analyses, preliminary designs, and the feasibility analyses consume the majority of the time within the step. SDOTs seek to maintain the project development schedule but, the lengthy federal processing and approval of documents are somewhat in opposition. SDOTs that have sought to work closely with federal agencies in an attempt to mitigate the revisions and the risks delaying the project development schedule.

2.5.6. Final Design

This step includes completion of the final (Right of Way) ROW plans, land acquisitions, the third design stage, final plan package, and the program Ready for

Contract (RFC) document. The RFC does not lead to an immediate project letting. There are still formal procedures within each state agency that must be met before projects can be let. The risk of project delays decreases as the development of the project progresses, but late design changes or alterations pose great risks of letting delays. Design changes that are outside of the initial right of way plan can cause major letting delays.

2.5.7. Program Letting

After the completing the RFC paperwork, letting preparation is required before a project is ready for bid letting. Projects in the letting program are to be submitted to a *letting schedule*. Once projects are admitted into the letting schedule they are given a precise letting date. Due to letting management issues such as project delays or crowding in the letting schedule, a project letting date may be changed. The final letting date submitted to INDOT's MIP system concludes the time duration for this study of program letting duration. Project letting continues until all bids are submitted before the deadline and reviewed. Then a bid is selected (usually the lowest bid) for contract award.

2.6. Project Delivery Improvement Opportunities

Along with the many areas of improvement identified earlier within the chapter, there are also more specific improvement areas within the letting program. Many circumstances arise throughout the *PDP* and cause delivery delays. "...One finding, after analyzing the answers, is that none of the SHAs (State Highway Agencies) responding to the questionnaire have a well-defined and comprehensively-documented letting program process (NCHRP, 2004)." This statement implies that the root cause of project delivery lies with the fact that SDOTs must build a clear, fixed, documented programming process. After a strong foundation for project programming is documented and applied, an analysis of areas for improvement will be more useful.

Using these blurry pieces of information about the programming stages, several other factors influencing letting program delivery, and ultimately needing improvement, were established by NCHRP (Table 2.5). Table 2.6 describes the top four factors causing letting schedule changes and the mitigation actions. Each of these factors listed within the table can also be perceived as an area needing improvement in the *PDP*.

Most projects are not submitted to the letting schedule (or removed from the letting schedule) if 3 requirements are not met: (1) Design Advancement, (2) Funding, (3) Other Constraints. The design advancement is obviously based on the maturity of the design including important ROW or land acquisitions, and funding is simply based on existence, are funds present. A more complicated challenge lies in the other remaining project constraints (although these issues are not the top reasons for scheduling changes): (1) seasonal issues (2) number of projects being let in a given period of time (3) type of projects let in a given period of time (4) regions or district location (5) time needed to process addenda (6) cost (7) difficulty (8) duration (9) consistent with the state annual program. Moderation and improvement of obtaining these 3 key requirements in a timely manner may also improve project delivery.

SDOTs hold several letting program meetings to increase awareness of programs that are early, on schedule, or experiencing delays. The frequency of these meetings varies from agency to agency. If issues causing the delay are within the control of the project team, then early recognition may influence earlier action to intervene a lengthy project step caused by issues in Table 2.5 and Table 2.6.

Table 2.5 Typical Factors that Create Change in the Letting Program (NCHRP, 2004)

Factor Area	Times Cited	Typical Factors Cited
Funding and/or Cost	21	Budget shortfall or lack of funds, cash flow uncertainty, changes in state budgets, cost creep, changes in matching funds
Environmental Clearance	14	Obtaining timely permits because of readiness, clearance, new regulations
Right of Way	12	Difficulty in acquiring ROW, delays, readiness
Project Scope	8	Changes in specifications, program changes in TIP/STIP, changes directed by executive office, changes in demographics or traffic patterns in project area, changing site conditions
Utilities	6	Coordination on federal projects, relocation not complete, clearance not acquired
Design Completion	6	Delays in design progress with plans not ready to go, conflicts with ROW and utilities, addenda during bidding, workforce shortages, work overload
Schedule Constraints	6	Slippage as a result of not meeting deadlines, late information, lack of timely and clear PS&Es
Project Priority	5	Shift in priorities from legislature, emergency projects push others out of schedule
Interagency Coordination	4	Agreements not signed, cost too high, impact of third party involvement
Plan Accuracy	3	Mistakes, clarifications, processing errors
Project Status	3	Project not required; clearing non-lets

Notes: ROW = right-of-way; TIP = Transportation Improvement Program; STIP = Statewide Transportation Improvement Program; PS&E = plans, specifications, and estimates.

Table 2.6 Top Four Factors Causing Change in the Letting Program (NCHRP, 2004)

Factor Area	Main Causes	Typical Actions
Funding and/or Cost	Lack of resources to fund projects; overruns of other projects; trying to let too many projects; changes in funding type; lagging schedules shifted funds to other projects; additions/reductions in program allocations; increased spending in congestion relief through transfer of funds; more complete information; poor initial estimates; government bodies such as state legislatures modify funding levels; design changes increasing cost; costs associated with schedule delays; changes dictated by field actions	Reschedule projects (move to next fiscal year or bring projects into current fiscal year); over program to use all available funds; change funding source or obtain additional funds; develop better early estimates of project cost; better manage cash flow to balance dollars; modify project scope by adjusting limits; minimize changes; select from committed projects or projects on reserve; tapering of federal funds, that is, use federal funds first; monitor large projects that may slip; hold lettings to minimum target but maintain contingency
Environmental Clearance	Delay in obtaining federal approval of environmental documents; lack of staff/high workload; process delays or too late in process; lack of training; simply not meeting deadlines; process/coordination takes longer than anticipated; unforeseen problems related to endangered or threatened species, archeology, Native American, historical features	Move effort to earlier in project development process; improve process of obtaining permits; closer coordination with agencies may be through meetings; hire additional staff; place project on hold (move back to pool of projects)
Right-Of-Way	Delay by relocatees; condemnations and legal issues obtaining property; not 100% ready to certify by FHWA representatives; late design changes; schedule delays do not leave adequate time to purchase land; increase cost of ROW; late land surveys; too optimistic in timing of acquiring ROW; lack of permits; lack of trained staff	Reschedule projects; shelve projects; move effort to earlier in project development process; conditional certifications of ROW; restrictive clause to limit contractor access; improve coordination schedule between design and management; closer coordination with agencies; improve project management process and provide new tools
Project Scope	Demographic/traffic pattern changes result in adjustments in design requirements; community input or public process; unforeseen problems such as changed site conditions; changes in specific designs such as pavement or traffic control; design team decision to modify scope; modification to design standards	Reschedule projects; process changes in timely manner; limit late scope changes in final design

Notes: ROW = right-of-way.

2.7. Chapter Summary

This chapter provided a background for the Transportation Improvement Program, State Transportation Improvement Program, Programming Development Process, *Project* Development Process, and letting process. A number of case studies highlighted the need for improvement of highway project delivery programs and the adverse effects of deviation from the programmed delivery of projects on highway users as well as state agencies. The bulk of project delivery literature focused on prioritizing systems, clearly defining the programming process, decreasing the requirements for expected timelines for project delivery, better coordination between participating federal, local, and government agencies, and the oversight role of the federal government and state agencies. While all of these studies are imperative to decreasing project delivery duration, little information was found describing the effects of highway project characteristics as they relate to project delivery. Project characteristics may include the highway type, highway letting cost, highway district location, etc. The “constraints” category was the third filter in the selection or removal of highway projects from the letting schedule. The category identified project characteristics such as location and type as influential areas for scheduling issues, yet little research has been conducted reviewing project types. There is an obvious need to correlate the types of projects and their significant influence on project delivery time. The top factors in Table 2.6 that influence change in scheduling include technical and process issues with ROW, environmental clearance, project scope, and funding. These issues can be combined with project characteristics to provide a better solution to time reduction, such as (1) what *types* of projects cause ROW delay? (2) what *types* of projects incur a lengthy environmental clearance? (3) what *type* projects have funding issues? The factors in Table 2.5 can also be drafted in this manner.

The present study seeks to discover project characteristics that can be identified with longer letting program durations and then suggesting along which steps in the letting programming process should (1) mitigation and (2) contingency plans take place.

CHAPTER 3. DATA

3.1. Introduction

Descriptive data corresponding to each project was collected from the INDOT Management Information Portal (MIP). This chapter discusses the data formatting procedures and the data availability issues. The tables describe the dispersion of highway projects for each characteristic collected from the data management system. The results and discussion of the analysis are presented in Chapter 4.

3.2. Data Availability

The letting duration timeline encompasses what most SDOTs define as the Project Development Process. The common definition of the Project Development Processes comes to an end once a project has finished construction. The present study, however, is interested in the time spent developing the project from authorization to letting for construction. Several studies have addressed the issue of project delivery time by analyzing the structure, planning, and agency interactions throughout the development process. Other studies evaluated the amount of federal and state funds involved in projects and the effects on project delivery. For instance, if a project was financed under a certain federal category and future highway needs expanded under that same category, an originally planned project may be delayed due to financial limitations. No studies were found during the course of this research to have evaluated the duration of the project delivery based on the collection of delivery schedule dates from a given SDOT.

3.2.1. Data Acquisition

Data was collected from the Indiana Department of Transportation Management Information Portal (MIP) between the months of July and September 2008. Each project field had to be extracted individually due to the structure of the information management system. The analysis period was set between the years 1970 to present (2008) for highway projects costing \$1 million or more. The cost limit was implemented to analyze those projects that posed a greater risk to state budgeting and programming if delayed.

3.2.2. Project Identification

Projects that met the search requirements were collected and identified by the designation number (DES#) in the MIP. The DES# is “an INDOT assigned number to identify the project in the INDOT scheduling system (INDOT, 2009).” Highway projects are composed of contracts which are given DES#s. As a result a single project could have multiple contracts identified by DES# in the MIP. Projects with multiple contracts were grouped together in Microsoft Excel and given a single identifier for the analysis. Table 3.1 illustrates a highway project with (7) seven contracts grouped together with a single identifier (0050). Projects with single contract were identified using the original DES#. Multiple contract projects will be identified as Kin (KN) and single contract projects will be identified as Stand Alone (SA) simplicity.

Table 3.1 KN DES Numbers Illustration

KN Identifier (Provides a common identifier for KN contracts)	Designation Number
0050	9244245
0050	9304960
0050	9304970
0050	954424A
0050	964424X
0050	9831650
0050	9832420

3.2.3. Dates

There are 6 project development dates recorded sequentially in the MIP: (1) Proposed Date (2) Authorized Date (3) Design Date (4) Ready for Contract Date (RFC) (5) Letting Date (6) Finished Date. The (2) Authorization Date and the (5) Letting Date were collected to measure the letting duration. As stated earlier, the project Authorization Date marks the approval and *funding* of a project and the Letting Date is defined as the date when the department opens bids for an improvement project. The (3) Design Date and the (4) RFC Date represent internal benchmarks within the letting duration timeline. The RFC Date was defined as the date established by the department when all materials will be available for the preparation of contract documents for a project. These internal letting duration dates were collected with the notion to analyze the duration between the (2) Letting Date and (3) Design Date, the (3) Design Date and (4) RFC Date, and the (4) RFC Date and (5) Letting Date. The use of these internal letting duration dates were thought to provide a more isolated analysis of letting duration issues and the development procedures within each time duration analysis.

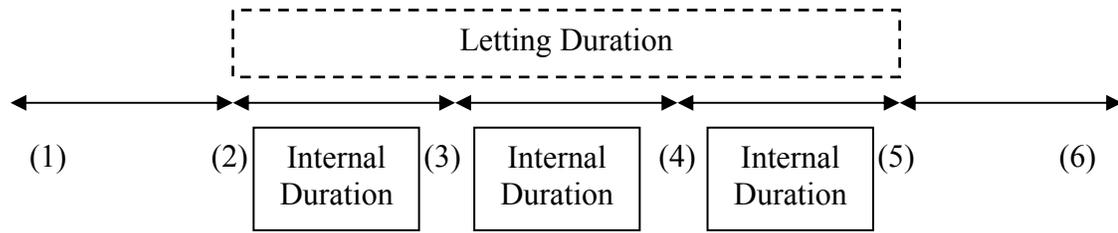


Figure 3.1 Internal Letting Duration Dates

Upon extracting the dates, two factors were found inhibiting the proposed phase to phase duration comparison: (a) the Design Date and the RFC Date were often recorded as the same date or with 2 to 3 days difference and (b) the Design Date was in such close proximity to the letting date that it was inadequate for duration analysis. Subsequently, the intermediate dates were of no benefit to the analysis and were excluded. The only time duration analyzed was that between the Authorization Date and the Letting Date.

3.2.4. Organization of KN Characteristics

SA project characteristics were collected easily and recorded. However, KN projects are comprised of an assortment of contracts and therefore have multiple descriptions for each characteristic. The characteristics of KN projects were aggregated into a single description for the analysis. Table 3.2 provides an example of a KN project with one contract under a different work classification and functional class. The figure also presents the proposed cost of each contract within the project. Aggregated classifications of KN projects were justified by (2) two observations: (a) the ratio of the contract cost in relation to the entire project cost and (b) the contract classification majority. Refer to the example; (6) six out of the (7) seven Base Work classifications were identified as “Major Pavement Project (Interstate)” and the same ratio was given the Functional Class characteristic of “Urban Interstate.” In addition, the ratio of the proposed costs of similar categories (\$14.707 million) in relation to the total project proposed cost of \$14.774 million was significantly high at 99.9% of the project costs. All characteristics for KN projects were compiled in this manner. Figure 3.2 provides

the distribution of KN and SA projects; KN projects account for roughly one –third of the population.

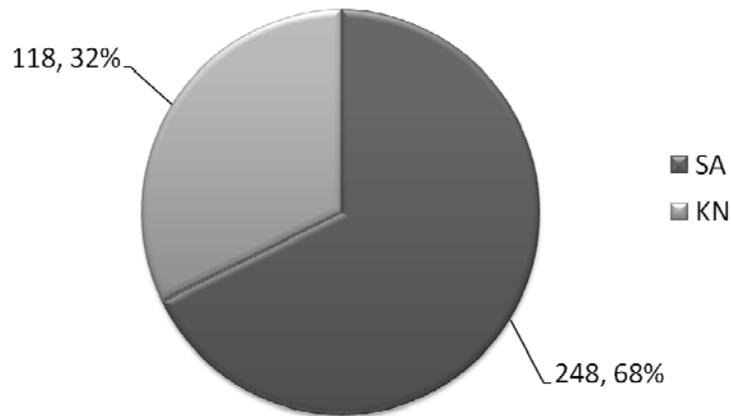


Figure 3.2 Distribution of KN and SA Projects

Table 3.2 KN Project Example

KN	Proposed Cost	Base Work	Functional Class
0050	\$11,549,000	Major Pavement Project (Interstate)	Urban Interstate
0050	\$1,058,000	Major Pavement Project (Interstate)	Urban Interstate
0050	\$1,512,000	Major Pavement Project (Interstate)	Urban Interstate
0050	\$257,000	Major Pavement Project (Interstate)	Urban Interstate
0050	\$237,000	Major Pavement Project (Interstate)	Urban Interstate
0050	\$67,000	District Maintenance Work Project (Traffic)	Urban Other Principal Arterial
0050	\$94,000	Major Pavement Project (Interstate)	Urban Interstate
Aggregated Classification	\$14,774,000	Major Pavement Project (Interstate)	Urban Interstate

3.2.5. Aggregation of KN Dates

Each KN contract was sorted for the first authorized contract and the last authorized contract. As displayed in Table 3.3, the first contract Authorization Date for this KN project was January 1, 1992 and the last contract was January 1, 1998. The first contract Authorization Date is used as the overall project Authorization Date for

the letting duration. The duration between the first and last contract varies for each project, in this example the difference is six (6) years. Measuring the letting duration from the last authorization dater or even the median authorization date would significantly reduce the amount of letting time and inaccurately represent the letting duration. The first authorized contract usually has the largest cost as seen in Table 3.2 and accounts for the majority of the project work. Measuring the letting duration from the last contract would provide a time estimate for a contract costing a fraction of the total KN project cost, \$94,000 versus \$14.7 million. This could potentially create a letting duration bias between KN and SA projects. All contracts are let on the same date because highway projects are let after all contracts are complete. Therefore, the letting duration of this project was measured between January 1, 1992 and December 15, 1998. Each SA project consists of only (1) one contract and therefore has one authorization date.

Table 3.3 Configuration of KN Dates

KN	Project Authorized	Letting Start
0050	1/1/1992	12/15/1998
0050	1/1/1993	12/15/1998
0050	1/1/1993	12/15/1998
0050	1/1/1995	12/15/1998
0050	1/1/1996	12/15/1998
0050	1/1/1998	12/15/1998
0050	1/1/1998	12/15/1998
Last Contract Date	1/1/1998	12/15/1998
First Contract Date	1/1/1992	12/15/1998

3.3. Data Description

The total population of highway projects (366) were segmented into the following work categories for duration modeling: (a) Pavement (210, 57%), (b) Bridge (94, 26%) and, (c) Road/Interchange (62, 17%).

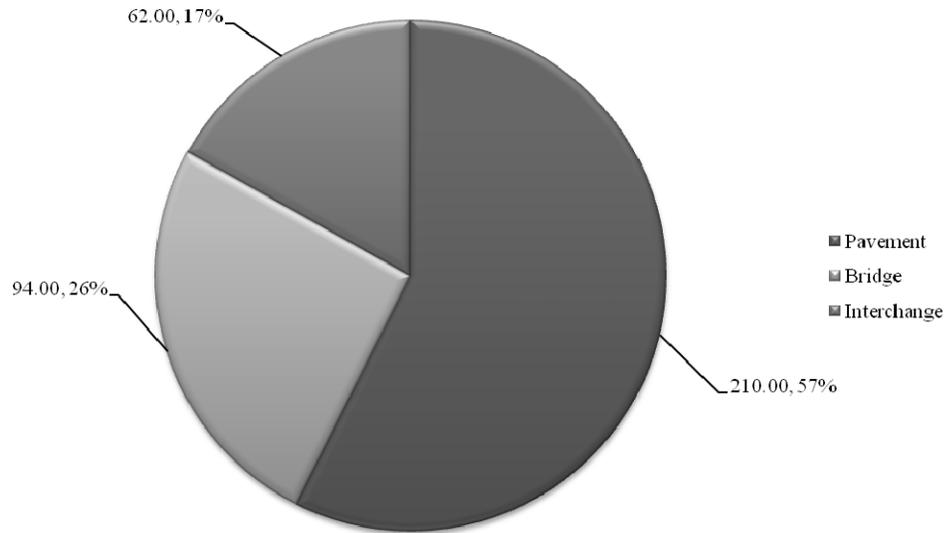


Figure 3.3 Work Category

3.3.1. Selection of Project Sample

Only completed projects were selected for the study. As stated earlier, letting dates are scheduled in the system in advance but are subject to change due to many project development issues discussed previously in the literature review. In this respect, the completed projects were chosen to eliminate the possibility of shifting letting dates, changes in letting costs, or any other unexpected changes to the project information provided in the MIP. Each category was modeled separately to identify parameters affecting project duration.

3.3.2. District Segmentation

The work category representation in the six (6) Indiana districts can be used to validate the duration results in Chapter 4. Road/Interchange projects have the longest letting duration overall, a district with a large number of these projects in a given time period could be more likely to experience letting delays. The duration modeling results can use this table to either validate or disprove these notions. Although INDOT segments the districts to provide the most efficient services, but some districts have a (a) greater extent of roadway systems (b) larger population size adding to traffic growth (c) greater wear-and-tear of highways, and as a result encounter more highway projects relative to other districts. Awareness of work category representation in districts is important to moderate district boundaries.

Table 3.4 Work Category Representation in INDOT Districts

District	Number of Projects				
	SA	KN	Pavement	Bridge	Road/Interchange
Crawfordsville	14	46	44	12	4
Fort Wayne	14	43	38	8	11
Greenfield	25	38	38	12	13
Laporte	26	38	16	31	17
Seymour	15	47	39	18	5
Vincennes	24	36	35	13	12
TOTAL	118	248	210	94	62

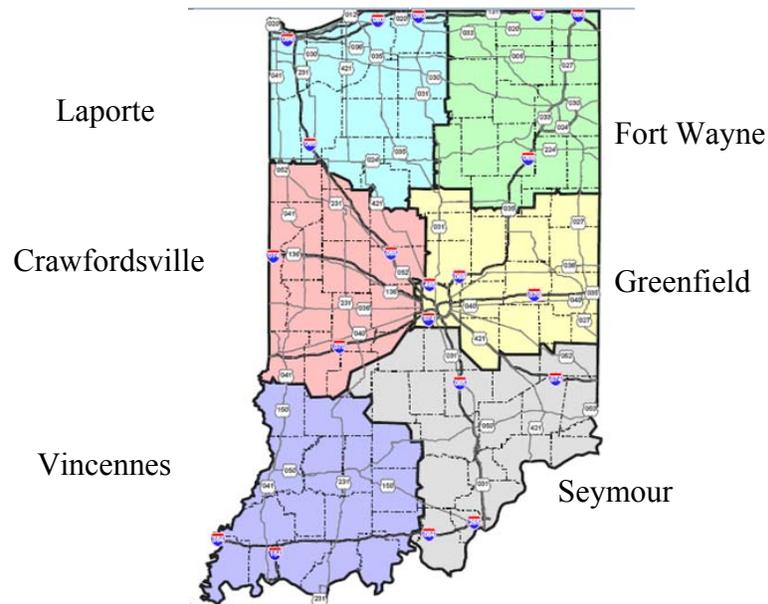


Figure 3.4 Indiana District Map (INDOT, 2008)

3.3.3. Classification

State highways can be placed into several categories that define their roles in providing service or their jurisdiction. The most prevalent classification system is that of Functional Classes. Functional Classes determine the (a) mobility and (b) land access involvement of a roadway and the results to the statewide transportation system (1) connection to border state transportation systems (2) spacing of roadways and (3) trip length. Functional Class is utilized to outline (a) financial planning (b) responsible districts (c) design regulations leading to (d) improvement requirements (INDOT, 2007).

Table 3.5 Functional Class Representation within Work Categories

Functional Class	Frequency				
	SA	KN	Pavement	Bridge	Road/ Interchange
Rural Interstate	15	12	13	12	2
Rural Principal Arterial	50	30	43	18	19
Rural Minor Arterial	44	4	34	14	-
Rural Major Collector	81	8	71	16	2
Rural Minor Collector + Rural Local Road	-	1	-	-	1
Urban Interstate	11	23	14	6	14
Urban Freeways and Expressways	5	5	-	9	1
Urban Other Principal Arterial	40	32	33	18	21
Urban Minor Arterial Street	2	3	2	1	2
Urban Collector Street	-	-	-	-	-
Rural Interstate	-	-	-	-	-
TOTAL	248	118	210	94	62

The Table 3.6 below lists the distribution of urban and rural highway projects based on the work category descriptions. A large majority of pavement and bridge work were found to be in rural areas, but road/interchange projects were not as prevalent.

Table 3.6 Work Class in Urban and Rural Areas

Area	Frequency				
	SA	KN	Pavement	Bridge	Road/Interchange
Urban	58	63	49	34	38
Rural	190	55	161	60	24
TOTAL	248	118	210	94	62

3.3.4. Program Class

Another classification system used to categorize highway projects is the program class. The program class describes the number of projects in a specific INDOT program, for example, the Major Moves program. As mentioned in the literature review, MM projects are funded by a specific pool of funding and meet the needs specified in the MM proposal. The Major Moves (MM) projects are in a

relatively newer program and many were not selected for the study pool. The data set contained mostly *normal programs* and *no categorization programs*.

Table 3.7 Highway Sample Program Class

Program Class	Frequency				
	SA	KN	Pavement	Bridge	Road/Interchange
None	34	1	35	-	-
Normal Project	208	56	162	94	1
Priority 1 Project	-	-	-	-	-
Mega Ace Project	-	1	-	-	1
Crossroads Project	5	56	10	-	51
Major Moves Project	1	-	1	-	-
High Profile Ace Project	-	4	2	-	2
TOTAL	248	118	210	94	62

3.3.5. Base Work

The Base Work category is the subdivision of the three Work Class Categories. The Base Work isolates the exact work conducted with the Pavement, Bridge, and Road/Interchange categories (Table 3.8).

Table 3.8 Base Work

Base Work	Frequency				
	SA	KN	Pavement	Bridge	Road/ Interchange
Added Travel Lanes Project	3	24	-	-	27
New Road Construction Project	4	24	-	-	21
Road Construction	-	-	-	-	-
Interchange Modification Project	-	-	-	-	14
New Interchange Project	1	13	-	-	-
Bridge Rehabilitation – Historic	-	-	-	-	-
Bridge Replacement – Historic	20	4	-	24	-
District Bridge Project (Rehabilitation)	19	5	-	24	-
District Bridge Project (Removal)	16	7	-	23	-
District Bridge Project (Replacement)	16	4	-	20	-
Major Bridge Project (New Bridge/ Grade Separation)	1	1	-	2	-
District Pavement Project (Non-I)	1	-	145	1	-
Major Pavement Project (Interstate)	142	3	27	-	-
Major Pavement Project (NHS)	9	18	3	-	-
Major Pavement Project (Non-NHS)	2	1	28	-	-
Road Reconstruction	14	14	7	-	-
TOTAL	248	118	210	94	62

3.3.6. Transportation System

The Transportation System identification outlined those projects listed as a member of the National Highway System (NHS) (comprised of NHS roadways that are not included in the interstate system), Interstate on Federal Aid, Off Federal Aid, Primary, or Secondary. The placement of a highway into one of the given categories is somewhat complex and there exceptions in each category. The category of “On Federal Aid” refers to those projects that are on federal aid but not a part of the NHS. The

category “Off Federal Aid” refers to projects not a part of the NHS and not receiving federal aid.

Table 3.9 Highway Sample Transportation Systems

Transportation System	Frequency				
	SA	KN	Pavement	Bridge	Road/Interchange
Interstate	26	35	27	18.00	16.00
NHS	55	42	44	26.00	27.00
On Federal Aid	163	37	138	48.00	14.00
Off Federal Aid	1	-	-	-	1.00
Primary	3	4	1	2.00	4.00
Secondary	-	-	-	-	-
TOTAL	248	118	210	94	62

Table 3.10 Highway Routes

Routes	Frequency				
	SA	KN	Pavement	Bridge	Road/Interchange
Interstate	26	36	27	18	17
US Road	82	37	57	41	21
State Road	140	45	126	35	24
TOTAL	248	118	210	94	65

3.3.7. KN Project Description

A vast majority of KN projects had only two (2) contracts; the number of contracts within a KN project ranged upward of sixteen (16). The distribution of the contracts can be viewed in the Table 3.11 below. Intuitively, all else being equal, greater number of contracts comprising a KN project is expected to lead to increased likelihood of lengthy letting time duration.

Table 3.11 Number of Contracts within KN Project

Number of Contracts Within a KN Project	Frequency of KN Projects
2.00	44
3.00	13
4.00	18
5.00	16
6.00	5
7.00	9
8.00	6
9.00	2
10.00	2
11.00	1
12.00	-
13.00	-
14.00	1
15.00	-
16.00	1
TOTAL	118

Table 3.12 describes the *unique* project proposed dates for KN projects. Unique project proposed dates consist of those KN projects that have contract proposed on different dates. For example, KN projects depicted with 1 unique proposed date means all contracts were proposed on the same date. Those projects that are listed having 2 unique proposed dates mean that all contracts were proposed on one of the two dates. This must be understood that 2 unique contracts does not mean only 2 contracts were in the project. A project with 4 contracts can have 2 unique proposed dates. Three (3) contracts can be proposed on one date and the fourth contract can be proposed on another. Eighty-six (86) projects had contracts proposed on more than one date: (2) two unique dates [43], (3) three unique dates [18], (4) four unique date [16], (5) five unique dates [6], (6) six unique dates [1], and seven (7) unique dates [2].

Table 3.12 KN Contract Unique Proposed Dates

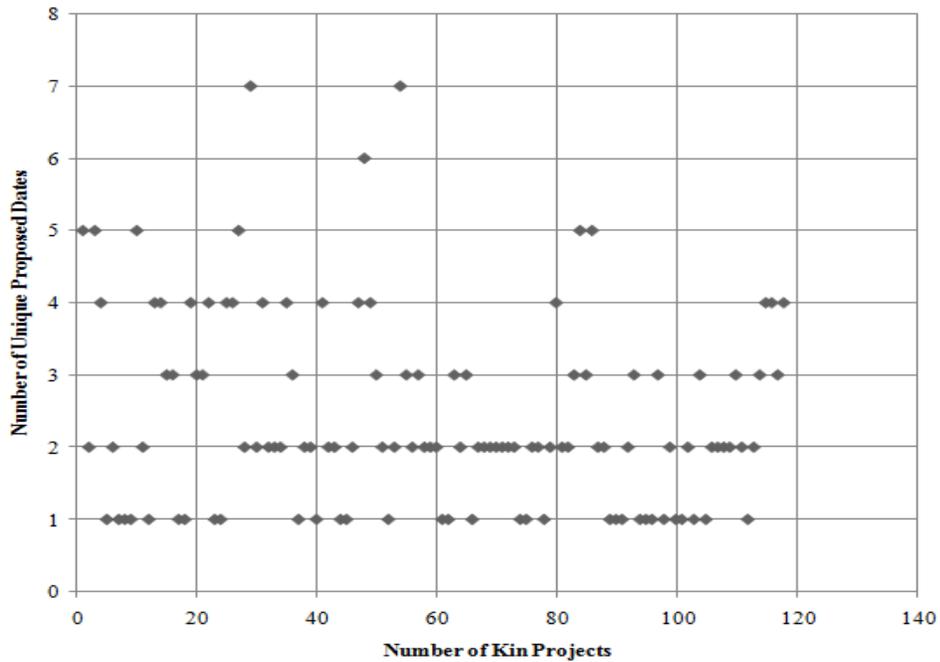


Table 3.12 KN Contract Unique Proposed Dates describes the number of unique KN proposed dates between the range of 1 and 7. The data set had a large population of KN projects: 2 contracts (44), 3 contracts (13), 4 contracts (18), 5 contracts (16), 6 contracts (5), 7 contracts (9), 8 contracts (6), 9 contracts (2), 10 contracts (2), 11 contracts (1), 14 contracts (1), 16 contracts (1).

The majority (73.8%, 183 projects) of SA projects were proposed and let within 60 months (5 Years). The remaining 26.8% spanned upward of 250 months (about 20 Years). The duration for KN projects commenced upon the first date a contract in the project was proposed. The duration of KN projects were significantly longer than the SA projects. Only 26 of the KN projects were let under 5 years and only 67 under 10 years. KN projects in this sample clearly take a substantially longer time to let in comparison to SA. Proposed costs for the entire data set ranged from \$1 million to just over \$30 million. SA projects were mostly under or around \$3 million and KN project had a larger range, as high as around \$30 million plus

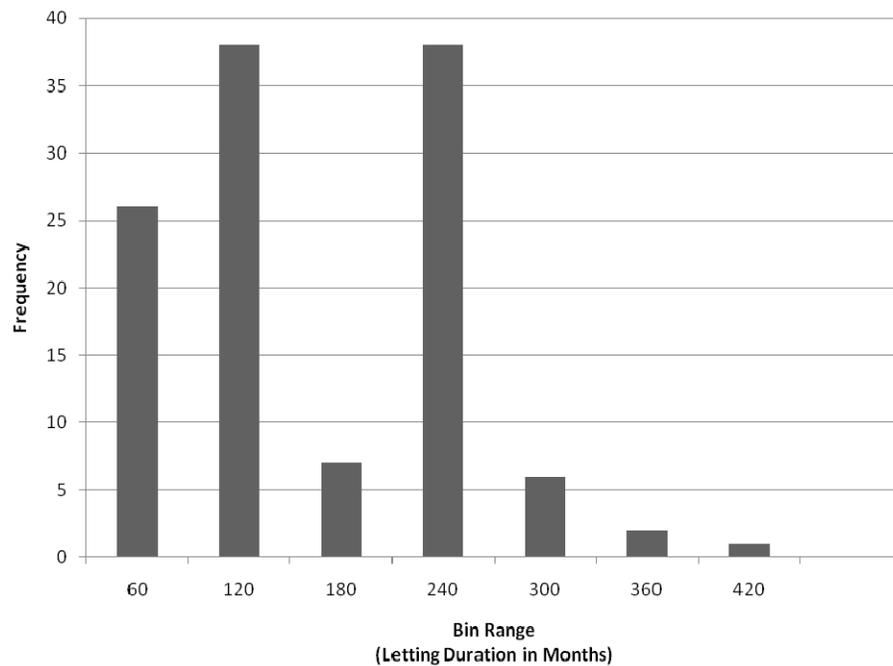


Figure 3.5 KN Project Proposed Date to Letting Date Duration

The bin ranges are: (in months) 0-60, 61-120, 121-180, 181-240, 241-300, 301-360, and 361-420. There is an obvious split between projects let under 10 years and project let between 15-20 years. Few projects are let between 10-15 years. This observation could suggest that those KN development processes that exceed 10 years are less likely to be let soon and more likely to be let after reaching the fifteenth year.

3.4. Proposed and Letting Duration Description of Projects

The figures and tables below describe the annual dispersion of projects throughout the data set. The proposed year for the total (366) study population ranged from 1970 to 2005. The Pavement projects spanned from 1972 to 2005, Bridge projects from 1980 to 2000, and Road/Interchange projects from 1970 to 2004. The bulk of the SA projects after the year 1992 for KN projects.

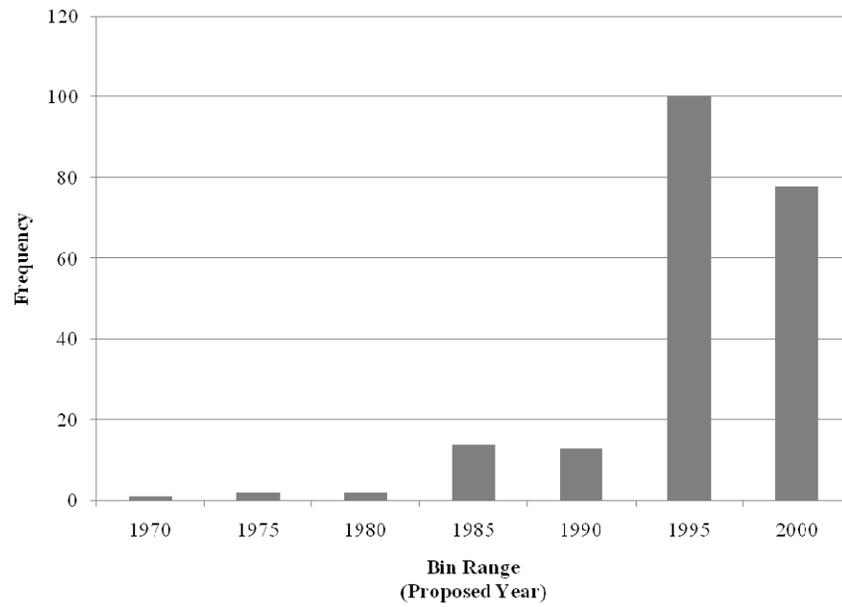


Figure 3.6 Pavement Project Proposed Year Histogram

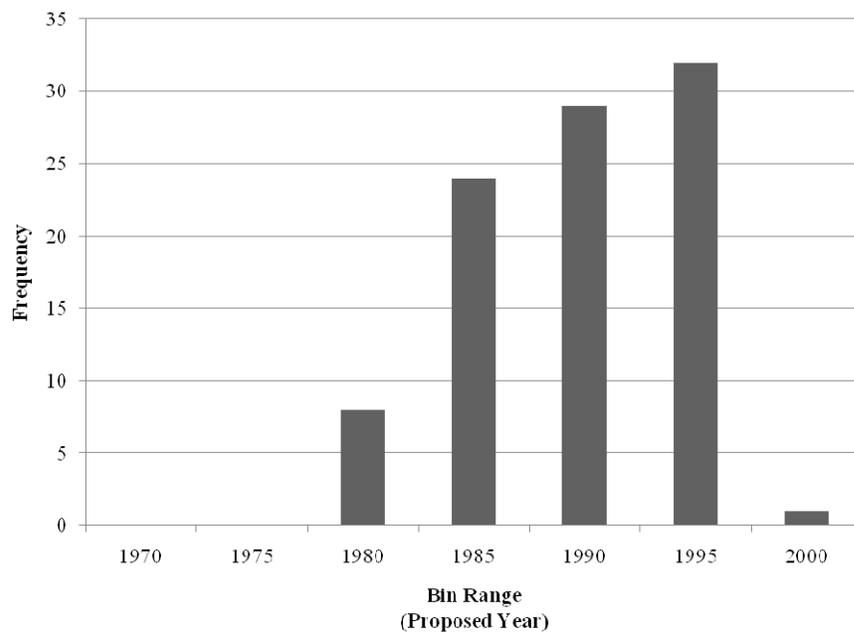


Figure 3.7 Bridge Project Proposed Year Histogram

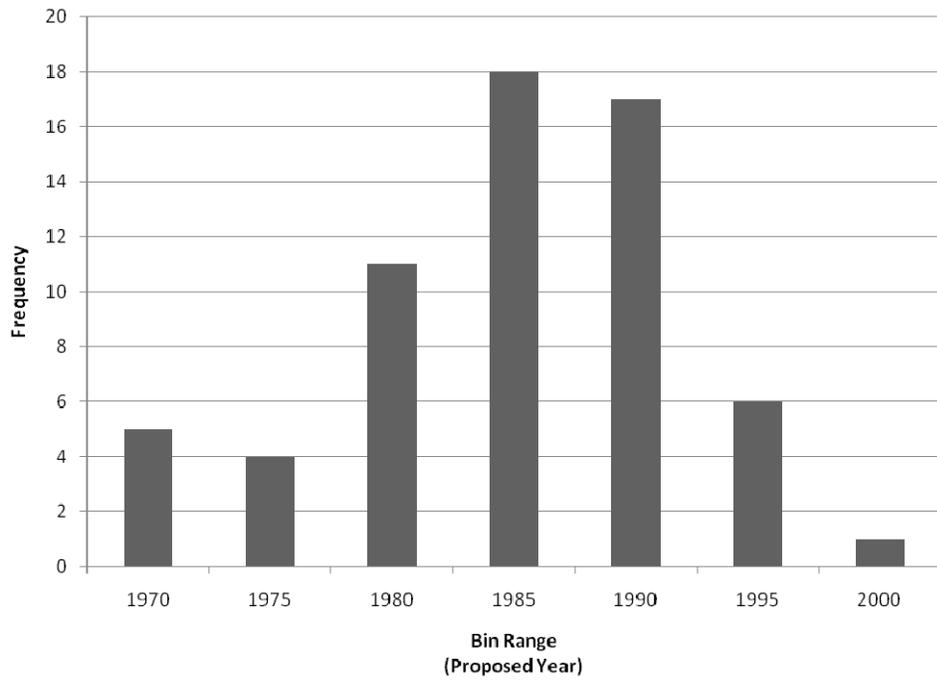


Figure 3.8 Road/Interchange Proposed Year Histogram

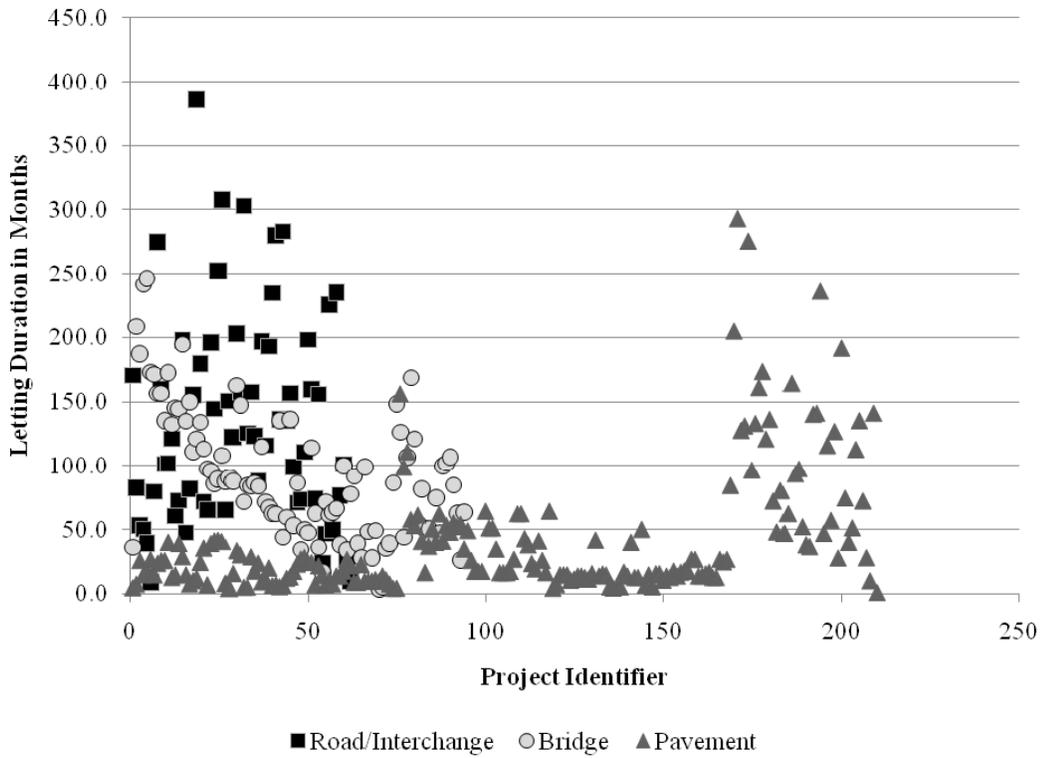


Figure 3.9 Bridge, Road/Interchange, and Pavement Project Letting Durations

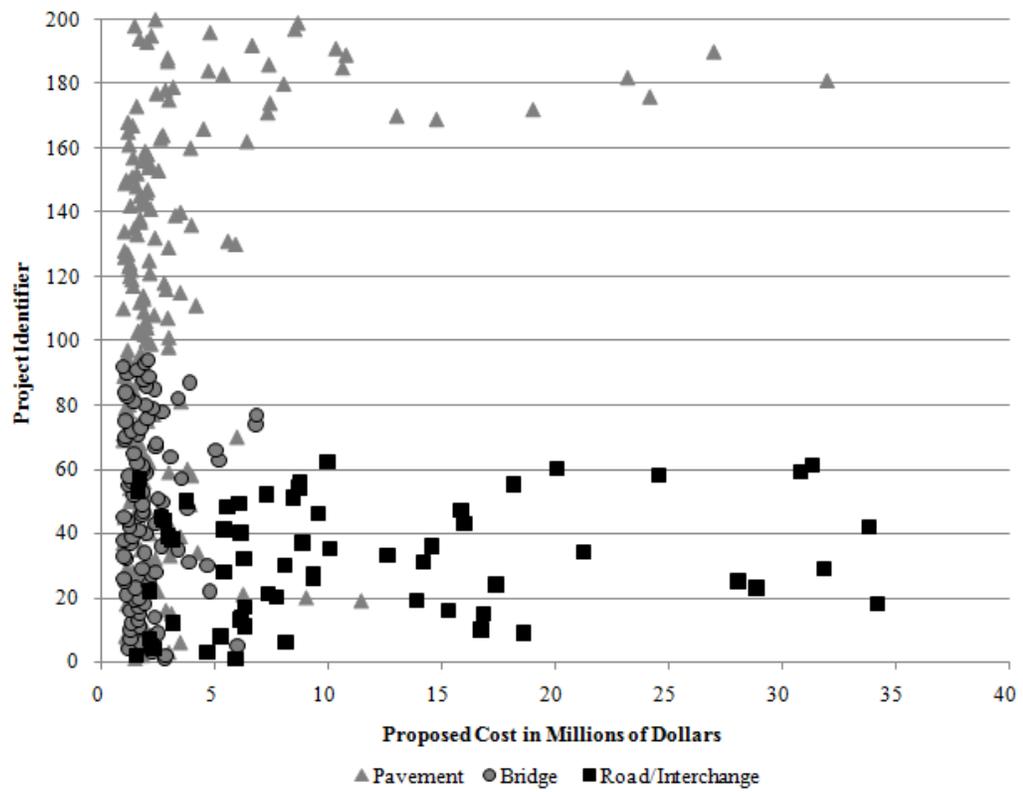
3.5. Financial Description of Projects

Figure 3.10 Pavement, Bridge, and Road/Interchange Proposed Costs

3.6. Chapter Summary

The chapter described the procedures taken to collect and format data for letting duration assessment. The data for the study was collected from the INDOT Management Information Portal. Multiple contract projects were formatted by aggregating the characteristics. Aggregated characteristics were determined by the ratio of the contract cost to total project cost and the most common characteristic observed. KN project letting duration were measured from the first authorized contract date to project letting date. All contracts are let on the same date because partial projects are not admitted for bid letting. The data was described in tabular format for KN, SA, road/interchange, bridge, and pavement projects. KN and SA descriptions are not mutually exclusive from the three (3) work categories. The separation of single and multi-contract projects is different from the separation of work categories.

CHAPTER 4. DATA MODELING AND RESULTS

4.1. Introduction

Several continuous data models were taken into account to analyze important factors contributing to the time duration between the letting date and proposed date for the 366 Indiana projects. The selected models were used to determine the probability of a project being let soon after a given amount of time has passed using the identified parameters that strongly influenced the letting duration. A review of the statistical concepts used to conduct the letting duration analysis is also provided in the chapter. The chapter concludes with the results and explanation of the analysis.

4.2. Duration Models

The letting observations typify that of continuous data, in which observations can represent any infinite value within a finite or infinite interval. There are several types of statistical models that can accommodate continuous data. A standard least squares regression model and several duration models were considered. All of these models satisfy the need for a multivariate analysis, which observes and analyzes for many factors affecting the letting duration time. However, duration models are preferred over regression models to study duration effects. Duration effects examine the increase or decrease in likelihood of a highway project to end soon the longer the project is in process. The regression model and a simple descriptive analysis

are incapable of examining these effects, but duration models can by observing the shape of the hazard function. Hazard-based duration models are utilized to estimate the probability that an event will occur at a specific time given that a certain amount of time has already passed. The notion behind these models is that the probability of an event occurring changes over the lifetime of the subject. In respect to the analysis of highway letting time duration, these concepts translate to the probability of a highway project being let given a certain amount of time has already transpired. The characteristics (model variables) are used to describe those highway projects that experience longer letting durations. Transportation agencies can use this information in the planning stages.

There are two types of hazard-based statistical models used to determine the duration of events, (1) semiparametric and (2) fully parametric. In fully parametric models, the parameter has a finite constituent to model the time duration, whereas in semiparametric models the parameter has a finite and infinite dimension constituent. For the study of letting time duration, a parametric model utilizing a finite parameter was selected as the best choice because of the finite nature of the data. Fully parametric models include the: Weibull Model, Weibull with Gamma Heterogeneity, and the Log-Logistic Model. These models assume a parametric functional form of the influence on the covariates and distribution on duration times. The functional form of the covariate influence is $\text{EXP}(\beta X)$, where β is the covariate and X (letting duration variable) is the vector. A covariate affects the relationship between the dependent variable and the response variable (letting duration).

The mathematical expressions for the duration models are defined as such: where $S(t)$ = project survival time, the probability of the project letting duration after a given amount of time has passed, and $h(t)$ = the hazard function, the increased or decrease likelihood of a project to be let soon over a given period of time. P = probability that a letting duration time of, T , will be less than or equal to a specified letting time, t . Gamma, λ has the dimension of a reciprocal of time and can be interpreted as a rate, where β is the estimated covariate (letting duration effect) of the

highway duration variable, X . The weibull with heterogeneity model includes an additional variable θ , for unobserved heterogeneity (unobserved letting duration variations in the data) (Washington, S., et al., 2003).

1. Weibull

$$h(t) = (\lambda P)(\lambda t)^{P-1}, \lambda = \text{EXP}(\beta X)$$

$$S(t) = \text{EXP}(-\lambda t^P)$$

2. Weibull with Gamma Heterogeneity

$$h(t) = [(\lambda P)(\lambda t)^{P-1}] / [1 + \theta(\lambda t)^P], \lambda = \text{EXP}(\beta X)$$

$$S(t) = 1 / [1 + \theta(\lambda t)^P]$$

3. Log Logistic

$$h(t) = [(\lambda P)(\lambda t)^{P-1}] / [1 + (\lambda t)^P], \lambda = \text{EXP}(\beta X)$$

$$S(t) = 1 / [1 + (\lambda t)^P]$$

- a. For, $P = 1$, the λ has a value of $(\lambda(0) = \lambda)$ and is monotone decreasing as t , decreases
- b. For, $0 < P < 1$, the hazard is still monotone decreasing
- c. For, $P > 1$ it increased from 0 to a maximum achieved at, $t = (p-1)^{(1/p)}/\lambda$ and then decreased toward 0.

The hazard function describes the rate at which event durations are ending at a given time. The software used models the parameter vector β with a negative $(-\beta)$, such that the affect on the covariate is $\text{EXP}(-\beta X)$. Therefore, the hazard, $h(t)$, is increased, increasing the rate at which event durations are ending at a given time and subsequently decreasing the letting duration. Consequently, the positive or negative value on the t -statistic correlates with the duration and not the hazard. A negative t -statistic suggests a decreased letting duration and a positive t -statistic suggests an increased letting duration. The correlating survivor function provides the probability of a duration being greater than or equal to some specified time.

4.2.1. Comparison of Fully Parametric Models

The statistical software, LIMDEP, was used to run the duration models and analyze the data. The entire data sample was modeled utilizing all (3) three parametric approaches as seen in Table 4.1. The results were then observed to determine the best approach.

Table 4.1 Weibull, Weibull with Gamma Heterogeneity, and Log-Logistic

Dependent Variable	Weibull LL = -514.65		Weibull with Gamma Heterogeneity LL = -503.05		Log-Logistic LL = -504.17	
	Parameter Estimate	T-stat	Parameter Estimate	T-stat	Parameter Estimate	T-stat
	5.75	50.86	5.55	48.72	5.50	53.79
DISF	-0.56	-4.22	-0.79	-5.39	-0.80	-5.44
DISTS	-0.07	-0.64	-0.39	-3.08	-0.42	-3.38
DISTV	0.23	1.31	0.44	2.67	0.46	2.87
PCOST	4.74E-5	4.68	-0.46	4.45	4.00E-5	4.51
FC2	-0.30	-2.35	-0.66	-3.42	-0.47	-3.53
FC3	-0.45	-3.16	-0.66	-4.30	-0.67	-4.35
FC4	-0.38	-2.96	0.83	3.79	-0.67	-4.91

Dependent Variable – letting duration; DISF – Fort Wayne District; DISTS – Seymour District; DISTV – Vincennes District; PCOST – project proposed cost; FC2 – functional class rural principal arterial; FC3 – functional class rural minor arterial; FC4 – functional class rural major collector

The weibull model proves to be the most inappropriate with the smallest log-likelihood value of -514.6545 and the loss of significance for (2) two variables (DISTS and DISTV) with t-statistics less than 1.7. However, the weibull with gamma heterogeneity and the log-logistic have very similar log-likelihoods of -503.9449 and -504.1655 respectively and maintained significance of all variables. A decision could not be made at this point to select between the weibull with gamma heterogeneity and the log-logistic model. After a log-likelihood ratio test proved that the sample should be separated into (3) work categories or KN and SA projects, a second comparison of the weibull with gamma heterogeneity and the log-logistic model was performed.

Table 4.2 Comparison of Log-Logistic and Weibull with Gamma Heterogeneity in the Pavement Work Category

	Log-Logistic LL = -245.14		Weibull with Gamma Heterogeneity LL = -243.48	
	Parameter Estimate	T-stat	Parameter Estimate	T-stat
Dependent Variable	4.78	41.73	4.50	32.97
DISTF	-0.65	-3.76	-0.56	-3.29
DISTS	-0.42	-3.18	-0.46	-3.61
DISTV	0.79	4.82	0.84	5.42
PCOST	5.94E-5	4.88	6.26E-5	6.02
FC2	-0.39	-2.61	-0.26	-1.80
FC3	-0.52	-2.97	-0.36	-2.20
FC4	-0.33	-2.45	-0.17	-1.24

Dependent Variable – letting duration; DISF – Fort Wayne District; DISTS – Seymour District; DISTV – Vincennes District; PCOST – project proposed cost; FC2 – functional class rural principal arterial; FC3 – functional class rural minor arterial; FC4 – functional class rural major collector

When analyzing data, the likeliness of the individual studies must be taken into account such that combined estimates provide a valuable depiction of the studies. Both the log-logistic and the weibull with gamma heterogeneity account for the variations between the studies due to randomization, heterogeneity. Unlike the log-logistic model, the weibull with gamma heterogeneity provides an additional variable to account for excessive heterogeneity. The result in Table 4.2 depict that the weibull with gamma heterogeneity model had a slightly lower log-likelihood at -243.479, but also lost a significant variable with a t-statistic of -1.24 (significant variables were chosen with a t-statistic magnitude of 1.7 or greater). This suggests that additional heterogeneity is not significant and the weibull with gamma heterogeneity model is inappropriate for the data set. This proved to be the case for Bridge and Road/Interchange work category models also, therefore the log-logistic model was chosen for the study.

4.2.2. Likelihood Ratio Test

The likelihood ratio test is a mechanism used to determine the likeness of variables between the entire data set and the suggested segmentation of the data set. Two likelihood ratio tests were performed analyzing the work categories and the KN and SA projects. The work categories were observed separately due to their high significance in the model; the KN and SA projects were selected for the test based on the obvious difference of multiple contract projects versus single contract projects. The chi squared value compares the log-likelihoods of the segmented models and the complete model:

$$\begin{aligned} \text{chi-squared} &= -2[\text{LL}\beta_{\text{TOTAL}} - \text{LL}\beta_{\text{PAVEMENT}} - \text{LL}\beta_{\text{BRIDGE}} - \text{LL}\beta_{\text{ROAD/INTERCHANGE}}] \\ \text{chi-squared} &= -2[-504.1655 - (-245.1467) - (-86.64366) - (-66.65810)] = 211.43 \end{aligned}$$

$$\begin{aligned} \text{chi-squared} &= -2[\text{LL}\beta_{\text{TOTAL}} - \text{LL}\beta_{\text{KN}} - \text{LL}\beta_{\text{SA}}] \\ \text{chi-squared} &= -2[-453.9051 - (-124.5302) - (-313.9501)] = 30.8 \end{aligned}$$

The degrees of freedom (DF) is the number of variables free to vary in each model. The DF is calculated by taking the sum of the variables for all segmented models and subtracting the number of variables for complete model:

$$\text{DF}_{\text{Work Categories}} = (7 + 7 + 7 - 7) = 14 \text{ and } \text{DF}_{\text{KN and SA}} = (6 + 6 - 6) = 6.$$

The chi-squared and DF are then used to calculate the probability value (p-value). The p-value is the smallest value of significance used to reject the null hypothesis (Washington, et al., 2003). In this case the null hypothesis is that the segmented models and complete model variables (project characteristics effecting letting durations) are similar.

The resulting p-value for both segmentation options was near zero (0.00E-6) for both log-likelihood tests. This indicates that there is a near 0% probability that variables for the segmented work categories and the segmented KN and SA projects are the same. This means that the characteristics (variables) used to analyze the letting duration of highway projects differ for each work category and also differ between single and multi-contract projects. The importance of this finding is that project

characteristics impact the letting duration differently based upon the work category or number of contracts. For example, may have significant influence on bridge contracts but be of no significance for road/interchange projects. Table 4.3 indicates the likelihood test descriptions.

Table 4.3 Work Categories Likelihood Test Description

	Log Likelihood	Observations	Variables
Pavement	-245.1467	210	7
Bridge	-86.64366	94	7
Road/Interchange	-66.65810	62	7
All Data Model	-504.1655	366	7
KN	-124.5302	248	6
SA	-313.9501	118	6
All Data Model	-453.9051	366	6

4.3. Duration Model Development

Four separate duration models were created for pavement, bridge, road/interchange, and KN projects. These models were created by selecting variables with significant t-statistics, having an important influence on letting time duration, and were interpreted to explain the duration of highway projects. The t-statistic is used to determine whether you can reject the null hypothesis that the coefficient estimate is equal to zero. The null hypothesis in this case is that the variable is not significant in project letting duration. The p-values are used in combination with the t-statistics to observe the significance of the variable. The confidence level at which the null hypothesis can be rejected is calculated by subtracting the p-value from 1. For example, a p-value of 0.06 rejects the null hypothesis (that the coefficient estimate is 0 indicating the variable is not significant in project letting duration) with 94% confidence; the lower the p-value, the more confident the rejection of the null hypothesis. None of the p-values can reject the null hypothesis with a 100% confidence level but they can be very close. The resulting p-values for each of the model variables were low, indicating a high confidence that the selected variables significantly impact the project letting duration.

4.3.1. Road/Interchange Project Results

The road/interchange letting duration model indicated three (3) project characteristics that may significantly influence the letting time, interchange modification/new interchange projects, projects on the interstate system, and KN projects with (4) four or more contracts. Table 4.4 provides information about the dependent variable (letting duration) and independent variables (project characteristics). The parameter estimates (covariate, β), standard errors, t-statistics, and p-values describe the influence of the variable (project characteristic) on the letting duration. The parameter estimates indicate the estimated magnitude and direction of the covariate. Recall that the software estimates negative covariates, $-\beta$, which means that a negative parameter estimate increases the hazard (increases the likelihood of a project being let soon) and a positive parameter estimate decreases the hazard (decreases the likelihood of a project being let soon). The relative values of the three variable parameter estimates indicate the influence of the variable on the letting duration. This means that a variable with a positive parameter estimate increases the risk of a longer letting duration that can potentially upset state programming and fiscal plans; the magnitude of the parameter describes relatively how much risk.

The standard error shows how much the parameter estimate deviates from the sample mean, how much the estimated influence of the characteristic differs from the average influence; this indicates the usefulness of the parameter estimate. If the standard deviation is high, this means that the estimated influence and direction of the road/interchange characteristic varies a lot across projects and the estimated influence of the parameter on the letting duration time is of no use. The t-statistic combines these two important descriptions and is used to determine if the project characteristic poses risk to the letting duration. The t-statistic is calculated by dividing the parameter covariate (magnitude and direction of influence) by the standard error (the deviation of the influence from the average influence of the sample). Positive t-statistic indicate that the associated variable causes the letting duration to increase and negative t-statistics indicate the opposite. Recall that the p-value is the smallest value of

significance used to reject the null hypothesis; the null hypothesis in this case is that the selected variables do not influence the project letting duration. Therefore the low p-values indicated in Table 4.4 mean that there is an estimated 97% to nearly 100% probability that the selected variables influence the letting duration as described by the t-statistic. As a result, the probability of the correlating delivery risk described by the t-statistic on is also high.

The transportation system (1 = Interstate, 0 = non-Interstate) have the most significant t-statistic at a value of -2.65, and this variable was found to have the greatest probability of impacting road/interchange project letting durations (approximately 99.99% probability). This suggests that the project development procedures for road/interchange projects on interstate highways allow for a significantly faster delivery. New interchanges and interchange modification projects had 97% probability of increasing the letting duration as indicated by the 2.17 t-statistic. KN projects with four (4) or more contracts had a 94% probability of increasing the delivery with a t-statistic of 1.91. The explanation of the impact of each variable is given in Table 4.7.

Table 4.5 depicts the minimum and maximum value for each variable, the standard deviation, and the mean. The standard deviation and the mean were used to calculate the standard error described earlier. The characteristics of/road interchange projects were modeled with an observation of one 1, for yes, and 0, for no, therefore the maximum and minimum values for the observations are one and zero. Table 4.6 describes the sigma (inverse of the p-value to determine model significance), p-value, log likelihood, hazard model inflection point in months and years (point in time in which the likelihood of the project being let soon decreases with time), and the number of data observations. The sigma and p-value in Table 4.6 were not of significance and were not used to measure the usefulness of the model. The greater log likelihood of -62.22 reinforces better fit of the separated models.

Table 4.4 Logistic Hazard Model Variables Impact on Road/Interchange Project Duration from Proposal to Letting in the State of Indiana

LOGISTIC HAZARD MODEL VARIABLES				
Variable	Parameter Estimate	Standard Error	T-stat	P-Value
Constant (Letting Duration, Dependent Variable):	4.01	0.21	19.39	0E-6
Base-Work, Interchange Modification, New Interchange Project (1=yes, 0=no)	0.58	0.27	2.17	0.03
Transportation System, Interstate (1=yes, 0=no)	-0.63	0.24	-2.65	0E-6
Projects with 4 or more contracts (1=yes, 0=no)	0.32	0.17	1.91	0.06

Table 4.5 Logistic Hazard Descriptive Statistics of Variables Impacting Road/Interchange Project Duration from Proposal to Letting in the State of Indiana

DESCRIPTIVE STATISTICS OF VARIABLES				
Variable	Mean	Standard Deviation	Minimum	Maximum
Constant (Letting Duration in months, Dependent Variable):	92.49	51.00	3.22	246.44
Base-Work, Interchange Modification, New Interchange Project (1=yes, 0=no)	0.23	0.42	0	1
Transportation System, Interstate (1=yes, 0=no)	0.47	0.50	0	1
Projects with 4 or more contracts (1=yes, 0=no)	0.26	0.44	0	1

Table 4.6 Logistic Hazard Model Descriptions for Road/Interchange Project Duration in the State of Indiana

Model Description	
Sigma	0.36
P-Value	2.74
Log-Likelihood	-62.22
Inflection Point (in months)	168.41
Inflection Point (in years)	14.03
Number of Observations	64

Table 4.7 Discussion of Variable Effects on Road/Interchange Project Letting Durations

DISCUSSION OF VARIABLES	
Variable	
Base-Work, Interchange Modification, New Interchange Project (1=yes, 0=no)	The variable increased letting duration probability. If you recall from Table 3.8, there were several base work categories within road/interchange projects. Of those categories interchange modification and new interchange projects were found to significantly increase the duration of project letting. In comparison to the latter base work categories, “construction” and “added travel lanes”, the modeled significance of interchange work is sensible. The longer letting duration times can be attributed to the design and planning for an above grade crossing of multiple roadways. Planning and designing for an interchange project is not as simple as at grade intersections. The planning must account for the complexities of modifying the interchange while maintaining the integrity of the structure.
Transportation System, Interstate (1=yes, 0=no)	The variable decreased letting duration probability and the most significant variable. The shorter duration time period can be attributed to the following: (1) the interstate projects usually receive a very large amount of federal funding, sources estimate around 90%, and therefore are quickly financed, leading to quick planning and design (2) the majority of interstate work is routine maintenance and accounts for corresponding base work categories “added travel lanes” or “constructions”.
Projects with 4 or more contracts (1=yes, 0=no)	The variable increased letting duration probability. KN projects compiled of 4 or more individual contract increased the letting duration. In reference to contract proposed costs, the majority of KN projects consist of one (1) major contract accompanied by several smaller contracts; in Table 3.2 the major contract accounted for 99.9% of the total proposed project costs. It can be hypothesized that as the number of contracts increases, the dispersion of proposed costs indicates the loss of a single major contract entitled to the majority of letting preparation. Multiple contracts also increase the number of agency formalities and paperwork to be processed, which intern may increase the letting duration. Of the 62 road/interchange contracts 29 were comprised with 4 or more contracts (46.8%). This indicates that although nearly half of the population has 4 or more contracts, the implication of added contracts to road/interchange project significantly increases the duration. This also reveals that projects with (3) or less contracts decrease the letting duration time.

4.3.1.1. Hazard Function and Survival Function for Road/Interchange Projects

The hazard function indicates the likelihood of a road/interchange project to be let. The point of inflection marks when road/interchange projects are most likely to be let. In Figure 4.1, the inflection point for the hazard function is depicted at 168.41 months, about 14 years as shown in Table 4.6. This means that before 14.03 years, a road/interchange project is more likely to be let and the likelihood of being let increases with time. After about 14 years the project is less likely to be let and the likelihood decreases with time. In summary, the risk of late delivery of road/interchange projects increases with time after 14 years.

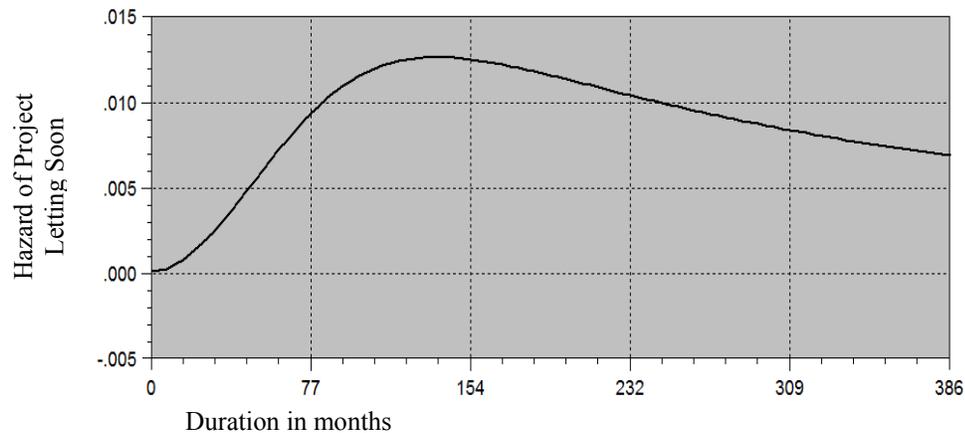


Figure 4.1 Road/Interchange Hazard Function

In Figure 4.2, the survival function indicates the probability (y-axis) of a road/interchange project's letting duration exceeding a given time (the x-axis). Intuitively, as project development progresses the probability of letting increases. However, the rate at which the probability of letting increases determines the delivery risk. Note that in the first 77 months (approximately 6.5 years) the 100% (1.0) probability of a letting duration exceeding a given time period drops to 75% (0.75). However, in the second 77 months (77-154 months) the probability of exceeding a given time period drops from 75% to 30%. This means that the rate of the letting probability increased significantly between 6.5 to 14 years. The rate at approximately

14 years decreases substantially, which coincides with the findings of the hazard function in Figure 4.1. This means that risk of incurring letting delays largely increases after 14 years for road/interchange projects although the probability of letting has increased to 80%. The survival function also indicates the minimum project development time before a project be let; at 25-30 months (a little over 2 years) the be probability is equivalent to 1.0 (100%), this means that all road/interchange projects will take a minimum of approximately 2 years to developed and let.

This information can be used to determine if the expected probabilities match project development goals for road/interchange project letting. If road/interchange projects are desired to have a letting probability greater than 75% after 6.5 years, appropriate changes need to be made in project development process.

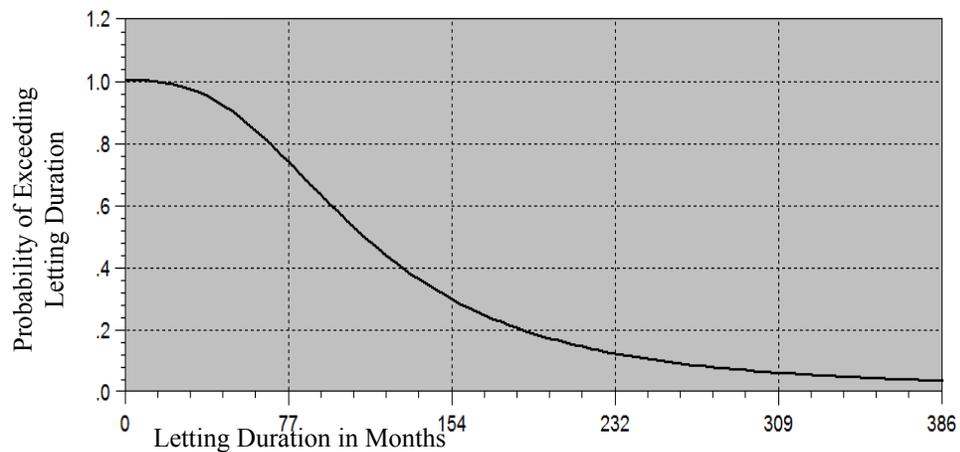


Figure 4.2 Road/Interchange Survival Function

4.3.2. Bridge Project Results

Three significant bridge project characteristics were found to influence the letting duration, district bridge rehabilitation projects, historic bridge rehabilitation, and bridge projects located in the Fort Wayne District. The t-statistic values indicated that all variables were significant and the negative sign for the parameter estimate meant the variables were associated with a decrease in the letting duration time, as shown in Table 4.8. Unlike road/interchange projects, bridge project parameter estimate signs and t-

statistic values showed that the magnitude of influence of each significant variable was very different. District bridge rehabilitation projects experienced letting durations that were nearly 1.8 times less than historic bridge rehabilitation projects and nearly 6 times shorter than projects located in the Fort Wayne District. Table 4.9 indicates the mean, standard deviation, minimum, and maximum values for each variable. Table 4.10 describes the inflection point for bridge projects to be at 108.05 months (9 years) for a sample of 94 bridge project observations. The log likelihood of the model is -119.8 and justifies the separation of the work categories.

The remaining work categories were bridge removal, replacement, and major bridge projects (new bridge/grade separation). These work categories were not found to significantly increase the letting duration. These can be suggested for several reasons. According to the sample of observations, district bridge replacement projects and major bridge projects did not occur often and therefore did not significantly impact the letting duration. These projects are probably programmed considerably apart and do not pose much risk to programming or fiscal schedules. Historic bridge replacement projects and district bridge removal projects do occur often throughout the data set and generally have longer letting durations, but the letting durations may vary sufficiently to have a significant impact on project delivery. Figure 4.3 depicts the letting duration for each bridge work category. The p-values for both rehabilitation categories indicated a 99.99% probability of decreasing the bridge letting duration; Fort Wayne district was associated with a 91% probability of decreasing letting duration. The role of each of the variables is summarized in Table 4.11.

Table 4.8 Logistic Hazard Model Variables Impact on Bridge Project Duration from Proposal to Letting in the state of Indiana

LOGISTIC HAZARD MODEL VARIABLES				
Variable	Parameter Estimate	Standard Error	T-stat	P-value
Constant (Letting Duration, Dependent Variable):	4.76	62.5	20.93	0E-6
Base-Work, District Bridge Rehabilitation (1=yes, 0=no)	-0.87	0.13	-6.78	0E-6
Base Work, Bridge Rehabilitation - Historic (1=yes, 0=no)	-0.54	0.14	-3.82	0E-6
Forty Wayne District (1=yes, 0=no)	-0.30	0.17	-1.71	0.09

Table 4.9 Logistic Hazard Descriptive Statistics of Variables Impacting Bridge Project Duration from Proposal to Letting in the State of Indiana

DESCRIPTIVE STATISTICS OF VARIABLES				
Variable	Mean	Standard Deviation	Minimum	Maximum
Constant (Letting Duration, Dependent Variable):	135.72	82.38	8.373	386.17
Base-Work, District Bridge Rehabilitation (1=yes, 0=no)	0.24	0.43	0	1
Base Work, Bridge Rehabilitation - Historic (1=yes, 0=no)	0.25	0.44	0	1
Forty Wayne District (1=yes, 0=no)	0.09	0.28	0	1

Table 4.10 Logistic Hazard Model Descriptions for Bridge Project Duration in the State of Indiana

Model Description	
Sigma	0.27
P-Value	3.70
Log-Likelihood	-119.8
Inflection Point (in months)	108.05
Inflection Point (in years)	9.00
Number of Observations	94

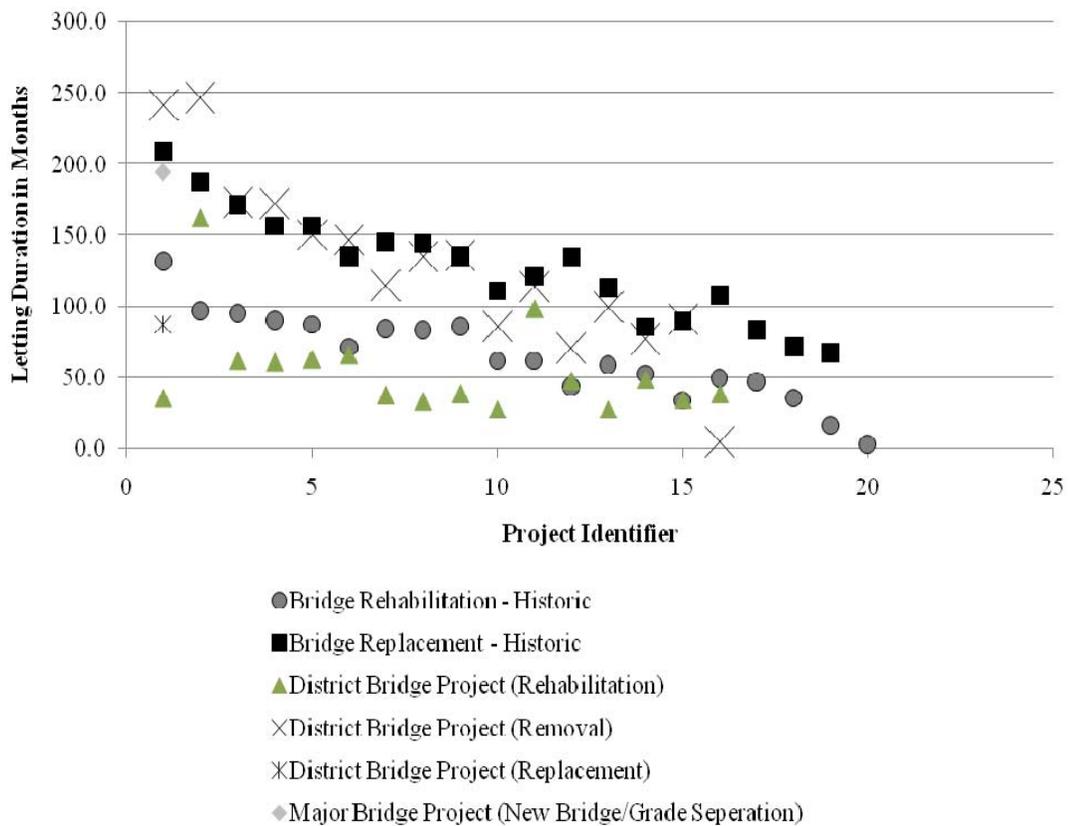


Figure 4.3 Bridge Projects Base Work vs. Letting Duration

Table 4.11 Discussion of Effects of Variables on Bridge Project Letting Durations

DISCUSSION OF VARIABLES	
Variable	
Base-Work, District Bridge Rehabilitation (1-yes, 0-no)	The variable decreased the letting duration probability and is the most significant variable, being 1.8 times as significant as bridge-rehabilitation – historical and nearly 6 times as significant as the Fort Wayne District variable. Approximately 24% of the sample is within this category. Rehabilitation is a much shorter procedure than those other bridge categories such as “removal”, “replacement”, or “new bridge.” In relation to funding, the majority of district bridge rehabilitation projects also cost less than the other bridge projects, including historical bridge rehabilitation.
Base Work, Bridge Rehabilitation – Historical (1-yes, 0-no)	The variable decreased the letting duration probability and accounts for 26% of the sample. Historical bridges are much older than those in the district bridge category and hypothetically would require approval from the public, interest groups, and authorization within the department for environmental and other concerns. Whatever significant attribute(s) deemed the bridge historical may require more detailed planning and design preparation, and may explain the difference in significance between the historical bridge and district bridge rehabilitation projects. Rehabilitation is a much shorter procedure than those other bridge categories such as “removal”, “replacement”, or “new bridge.”
Forty Wayne District (1-yes, 0-no)	The variable decreased the letting duration probability. Fort Wayne has the least number of bridges out of Indiana’s (6) six districts. The relatively small number of bridges perhaps provides an advantage for the Fort Wayne district to let projects earlier.

4.3.2.1. Hazard Function and Survival Function for Bridge Projects

The hazard function describes the likelihood of a bridge project to be let over time. Figure 4.4 depicts the inflection point of the hazard function to be at 108.05 months (9 years), also shown in Table 4.10. This means that the likelihood of a bridge project to be let increases over time before 9 years and decreases over time afterwards. The risk of incurring project delivery issues increases with time after 9 years. This suggests that bridge projects approaching development durations of 9 years should be observed carefully for issues that may cause delays in scheduled tasks.

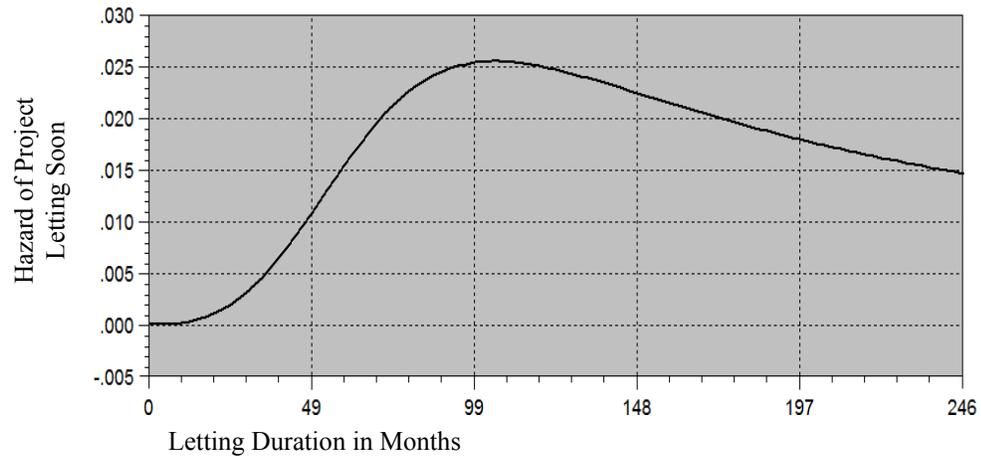


Figure 4.4 Bridge Hazard Function

Figure 4.5 depicts the bridge survival function, which describes the probability (y-axis) of a bridge project to exceed a given duration (x-axis). The probability of a bridge project exceeding a letting duration of 25 – 30 months (a little over 2 years) is 1.0 (100%). This means that all bridge projects will take 25-30 months to develop and let, similar to the minimum development durations for road/interchange projects. The probability that the letting duration is more than 140 months (11.6 years) is 0.1 (10%). Ninety percent (90%) of bridge projects in the sample were let before 11.6 years. The associated risk is therefore lower than the road/interchange projects. Road/Interchange projects pose a significantly higher risk of having longer letting durations than bridge projects. The rate at which the probability decreases is also substantially faster for bridge projects than road/interchange projects, indicating a less delivery risks

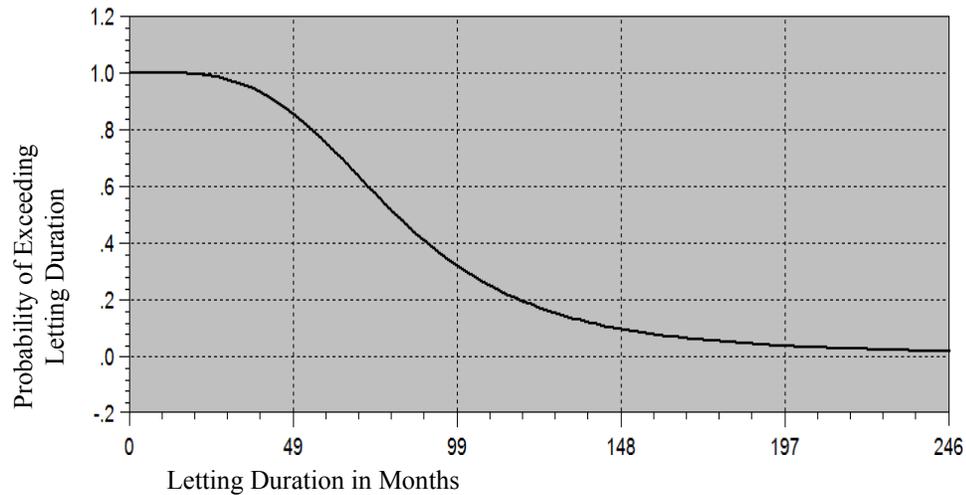


Figure 4.5 Bridge Survival Function

4.3.3. Pavement Project Results

The pavement project model found five variables that significantly influenced the letting duration, as shown in Table 4.12. The parameter estimate signs and t-statistic values reveal that district pavement projects not located on the interstate system significantly decrease the letting duration. Unlike the previous work categories, several district locations significantly impacts the letting duration of pavement projects. The Fort Wayne and Seymour Districts were associated with decrease in the letting duration, whereas pavement work in Vincennes District increased the letting duration. All three t-statistics describing the influence of districts were found to have nearly 100% probability of influencing letting duration. The model described the Vincennes District to increase the risk of pavement project delivery delays the most with a t-statistic value of 5.8. The letting procedures conducted in this district should be observed closely for improvement opportunities. As pavement project proposed costs increased the letting duration increased, this means that the projects with higher proposed costs experience longer letting durations than those with relatively smaller costs. Table 4.13 describes the mean, standard deviation, minimum, and maximum values for each variable. Table 4.14 describes the values of the inflection point (time at which letting durations risk

begin to increase) to be 38.43 months (3.19 years), and 94 observations. The log likelihood is also justifies the separation of work categories.

Figure 4.6 depicts the cost of pavement projects and the correlating letting duration; the figure depicts the significance indicated by the proposed t-statistic. The cluster of point indicates that projects exceeding \$5 million tend to have longer letting durations than those pavement projects between \$1 million to \$5 million. Figure 4.7 depicts the duration of pavement projects across the districts and further describes the model findings. Figure 4.8 depicts that non-interstate district pavement projects have decreased letting durations. Each of the variables is discussed further in Table 4.15.

Table 4.12 Logistic Hazard Model Variables Impact on Pavement Project Duration from Proposal to Letting in the state of Indiana

LOGISTIC HAZARD MODEL VARIABLES				
Variable	Parameter	Standard Error	T-stat	P-value
Constant (Letting Duration, Dependent Variable):	3.78	0.12	32.15	0E-6
Fort Wayne District (1=yes, 0=no)	-0.64	0.148	-4.47	0E-6
Seymour District (1=yes, 0=no)	-0.50	0.133	-3.95	0E-6
Vincennes District (1=yes, 0=no)	0.76	0.15	5.08	0E-6
Base Work - District Pavement Project (Non-Interstate) (1 –yes, 0- no)	0.87	0.11	-8.03	0E-6
Proposed Cost	0.2E-4	0.13E-4	1.93	0.05

Table 4.13 Logistic Hazard Descriptive Statistics of Variables Impacting Pavement Project Duration from Proposal to Letting in the State of Indiana

DESCRIPTIVE STATISTICS OF VARIABLES				
Variable	Mean	Standard Deviation	Minimum	Maximum
Constant (Letting Duration, Dependent Variable):	40.62	48.31	0.99	293.211
Fort Wayne District (1=yes, 0=no)	0.18	0.43	0	1
Seymour District (1=yes, 0=no)	0.19	0.44	0	1
Vincennes District (1=yes, 0=no)	0.17	0.28	0	1
Base Work - District Pavement Project (Non-Interstate) (1 –yes, 0- no)	0.69	0.46	0	1
Proposed Cost (in thousands of dollars)	3.03E4	4.23E4	1E4	31.96E5

Table 4.14 Logistic Hazard Model Descriptions for Pavement Project Duration in the State of Indiana

Model Description	
Sigma	0.41
P-Value	2.44
Log-Likelihood	-230.02
Inflection Point (in months)	38.43
Inflection Point (in years)	3.19
Number of Observations	210

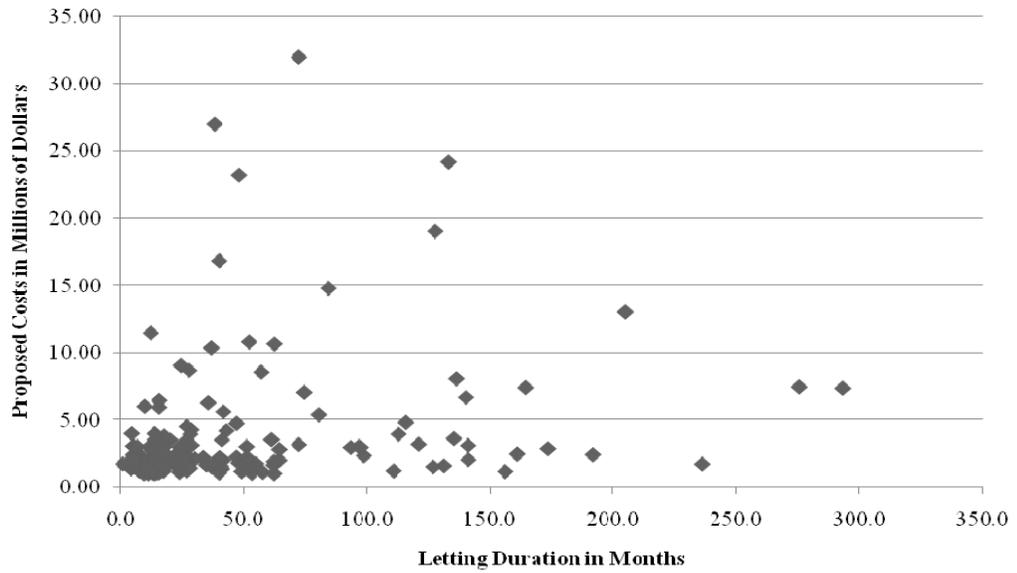
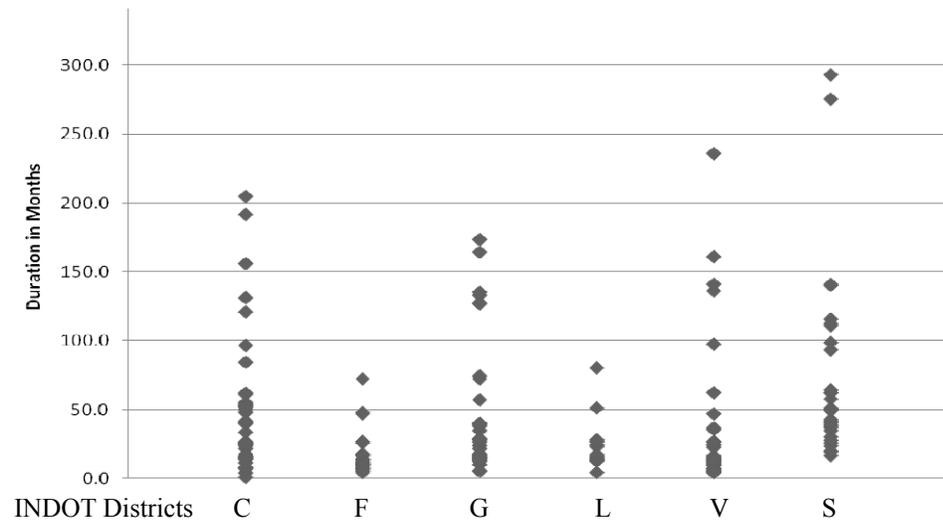


Figure 4.6 Pavement Projects Letting Duration vs. Proposed Costs



C – Crawfordsville, F – Fort Wayne, G – Greensfield, L – Laporte,
V – Vincennes, and S – Seymour

Figure 4.7 Pavement Projects per INDOT District versus Letting Duration

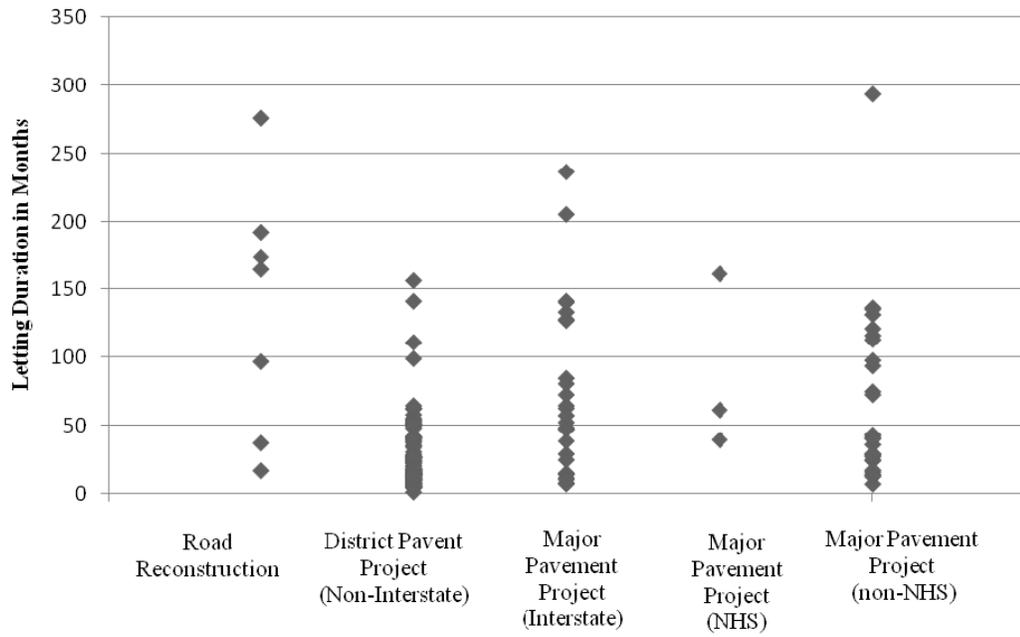


Figure 4.8 Pavement Project Base Work vs. Letting Duration

Table 4.15 Discussion of Effects of Variables on Pavement Project Letting Durations

DISCUSSION OF VARIABLES	
Variable	
Fort Wayne District (1=yes, 0=no)	The variable decreased the letting duration probability. Fort Wayne was also found to decrease the letting duration for pavement projects. With respect to this model, Fort Wayne has roughly the same number of pavement projects as the remainder of the districts; however, since the district does have the smallest number of bridge projects in this sample, time that most districts spend working on the bridge projects are put forth into pavement projects.
Seymour District (1=yes, 0=no)	The variable decreased the letting duration probability. Although 3 major intersections interstate crossings border Seymour district, pavement projects are handled in a timely fashion.
Vincennes District (1=yes, 0=no)	The variable increased the letting duration probability. Vincennes had 13 bridge projects and 18 road/interchange projects going on during the timed duration of this study. The programming may have had several projects needing to be let and the pavement projects were not priority.
Base Work - District Pavement Project (Non-Interstate) (1 –yes, 0- no)	The variable decreased the letting duration probability. This base work pavement category is the only one that is not labeled as a “Major” pavement project. This was also inferred in the proposed cost variable description. In the state of Indiana, the harsh winters cause plenty of damage to the roadways with the freeze-thaw effect, therefore district pavement projects are common throughout the year to repair the damages caused by the extreme weather. The majority of this work is routine and does not requiring lengthy letting duration times.
Proposed Cost	The variable increased the letting duration probability. As the proposed cost increases the letting duration also increases. This model is the only one in the study with the proposed cost as a significant variable. With this in mind, the proposed costs most likely coincide with the amount of engineering, design, and planning time. Also, 58 of the 210 projects are categorized as “Major Pavement”, which accounts for 28% of the population. The proposed costs for 11 of the 58 projects are greater than \$10 million and another 13 are between \$5 and \$10 million dollars. These 23 major pavement projects may be responsible for the proposed cost significance.

4.3.3.1. Hazard Function and Survival Function for Pavement Projects

As stated earlier, the hazard function can be used to determine the likeness of a project to be completed after a given amount of time has passed. Figure 4.9 shows the hazard function inflection point for pavement projects letting durations to be 38.43months (approximately 3 years), also recorded in Table 4.15. This means that highway pavement projects are more likely to let before 3 years and less likely to be let thereafter. Pavement projects have a significantly shorter letting duration than road/interchange and bridge projects and pose very little risk to project delivery.

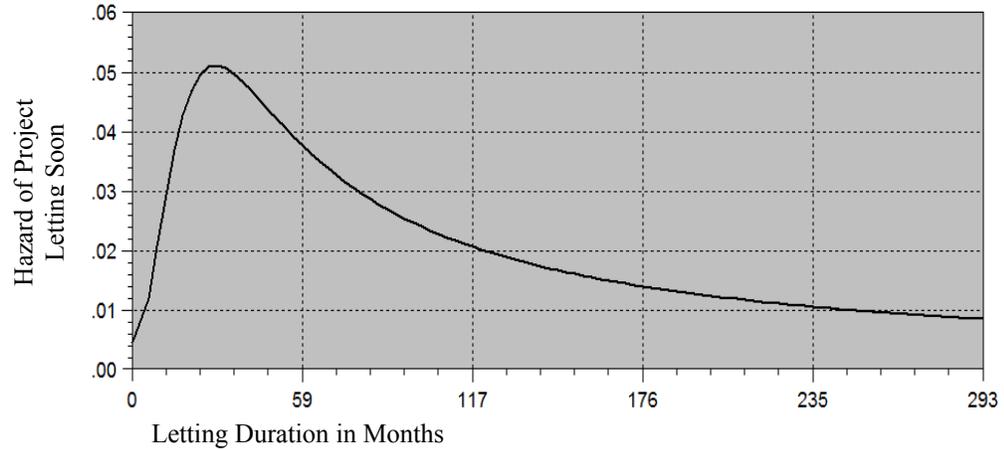


Figure 4.9 Pavement Hazard Function

Figure 4.10 depicts survival function, the probability (y-axis) of a project exceeding a given period of time (x-axis). The probability that a pavement project will experience a letting duration exceeding 5 months is (100%). This is significantly lower than the minimum letting duration of approximately 2 years for road/interchange and bridge projects. This means that pavement project can be let almost 18 months earlier than the minimum letting duration for bridge and road/interchange projects. The probability that the letting duration will be more than 45-50 months (around 4 years) is 0.2 (20%) and more than 137 months (11.5 years) is 0 (0%). Pavement projects pose little risk to project delivery.

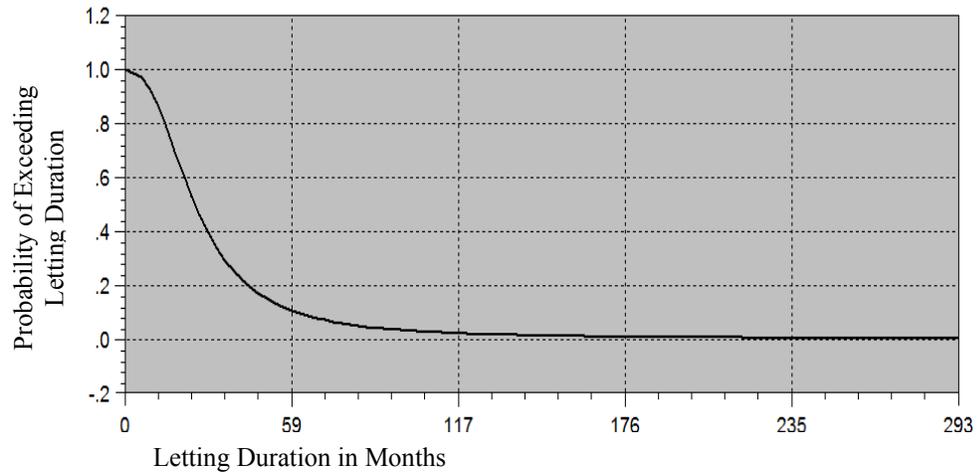


Figure 4.10 Pavement Survival Function

4.3.4. KN Project Results

KN projects are not mutually exclusive from the previously observed work categories. The model t-statistics in Table 4.16 indicate the highway work that increased the letting duration for KN projects were all associated with the road/interchange work category. This means that KN contracts within these work areas experience longer letting durations. KN projects that had all contracts authorized on the same date or on two (2) dates significantly decreased KN project letting time. This suggests that multiple contract projects should propose contracts on the same date to begin the development process. The p-values are low and have similar significance to those models described earlier. Table 4.17 describes the mean, standard deviation, minimum, and maximum values for each variable. Table 4.18 describes the inflection point to be 149.47 months (12.45 years), and 118 KN project observations. The log likelihood indicates the segmentation of the data is better than the compiled data, however, after discovering the large letting duration differences between each work category, the data best separated by the project work. Table 4.19 describes the effects of each variable on KN projects.

Table 4.16 Logistic Hazard Model Variables Impact on KN Project Duration from Proposal to Letting in the state of Indiana

LOGISTIC HAZARD MODEL VARIABLES				
Variable	Parameter Estimate	Standard Error	T-stat	P-value
Constant (Letting Duration, Dependent Variable):	4.70	0.13	36.43	0E-6
Base Work, Added Travel Lanes Project (1=yes, 0=no)	2.8	0.158	1.82	0.07
Base Work, New Road Construction Project, Road Construction Project (1=yes, 0=no)	0.70	0.17	3.87	0E-6
Base Work, Interchange Modification Project, New Interchange Project (1=yes, 0=no)	0.50	0.20	2.50	0.01
One unique project proposed Date (1 –yes, 0- no)	-0.44	0.16	-2.70	0.01
Two unique project proposed Dates (1=yes, 0 –no)	-0.34	0.15	-2.32	0.02
Functional Class, Rural Principal Arterial (1=yes, 0=no)	-0.32	0.15	-2.11	0.03

Table 4.17 Logistic Hazard Descriptive Statistics of Variables Impacting KN Project Duration from Proposal to Letting in the State of Indiana

DESCRIPTIVE STATISTICS OF VARIABLES				
Variable	Mean	Standard Deviation	Minimum	Maximum
Constant (Letting Duration, Dependent Variable):	200.00	74.42	1.00	386.17
Base Work, Added Travel Lanes Project (1=yes, 0=no)	0.20	0.40	0	1
Base Work, New Road Construction Project, Road Construction Project (1=yes, 0=no)	0.20	0.40	0	1
Base Work, Interchange Modification Project, New Interchange Project (1=yes, 0=no)	0.11	0.31	0	1
One unique project proposed Date (1 –yes, 0- no)	0.27	0.45	0	1
Two unique project proposed Dates (1=yes, 0 –no)	0.36	0.48	0	1
Functional Class, Rural Principal Arterial (1=yes, 0-no)	0.25	0.44	0	1

Table 4.18 Logistic Hazard Model Descriptions for KN Project Duration in the State of Indiana

Model Description	
Sigma	0.35
P-Value	2.86
Log-Likelihood	-115.81
Inflection Point (in months)	149.47
Inflection Point (in years)	12.45
Number of Observations	118

Table 4.19 Discussion of Effects of Variables on KN Project Letting Durations

DISCUSSION OF VARIABLES	
Variable	
Base Work, Added Travel Lanes Project (1-yes, 0-no)	The variable increased the letting duration probability. With respect to KN projects, adding travel lanes projects can increase the letting duration time due to the multiple tasks described by each contract. For example adding travel lanes on a bridge may also be accompanied by a bridge deck reconstruction and widening.
Base Work, New Road Construction Project, Road Construction Project (1-yes, 0-no)	The variable increased the letting duration probability. The design and planning steps required construct a new road can easily incur longer letting duration due to land acquisition, ROW, utilities, public hearings, and interest groups highly oppose new items in their communities at times. Twenty-four (24) of the 28 “new road construction/road construction” projects are KN projects; this makes sense because if a new roadway is being belt, most likely several contracts will be used to let the project.
Base Work, Interchange Modification Project, New Interchange Project (1-yes, 0-no)	The variable increased the letting duration probability. The variable was identified earlier as being significant within the “road/interchange model.” The longer letting duration times can be attributed to the design and planning for an above grade crossing of multiple roadways. Planning and designing for an interchange project is not as simple as at grade intersections. The planning must account for the complexities of modifying the interchange while maintaining the integrity of the structure.
One unique project proposed Date (1 –yes, 0- no)	The variable decreased the letting duration probability. Thirty-two (32) projects have one unique proposed date. This means that all contracts within a KN project were authorized on the same date and decreased the time letting. A single authorization date allows KN contracts to go through the letting process during the same time period.
Two unique project proposed Dates (1-yes, 0 –no)	The variable decreased the letting duration probability. Forty-three (43) projects were found to have two unique contract dates. That means all of the contracts were authorized on two dates and decreased the time to letting. Two authorization dates suggests that the all contracts were going through the letting duration at the same time decreasing the letting duration time.
Functional Class, Rural Principal Arterial (1-yes, 0-no)	The variable decreased the letting duration probability. Seven (7) of the rural principal arterial (RPA) roads were found to have one unique contract date and ten (10) of the projects were found to have two unique contract dates. Based on the significance of unique proposed dates and the decreased impact on letting time duration, the RPA may have been influenced by the number of unique contracts within the project sample. The RPA does provide travel to highly populated areas but the result of the location of the highway is still mostly rural and may incur longer letting durations due to simplified formalities based on the region of the road.

4.3.4.1. Hazard Function and Survival Function for KN Projects

Figure 4.11 shows hazard function for KN projects. The inflection point for KN projects is 149.47 months (12.45 years) as recorded in Table 4.18. This means KN projects are more likely to be let before this point and less likely to be let afterwards. However, the work category hazard models described the large difference in base work categories; the work category segmentation provided a better explanation of the letting durations.

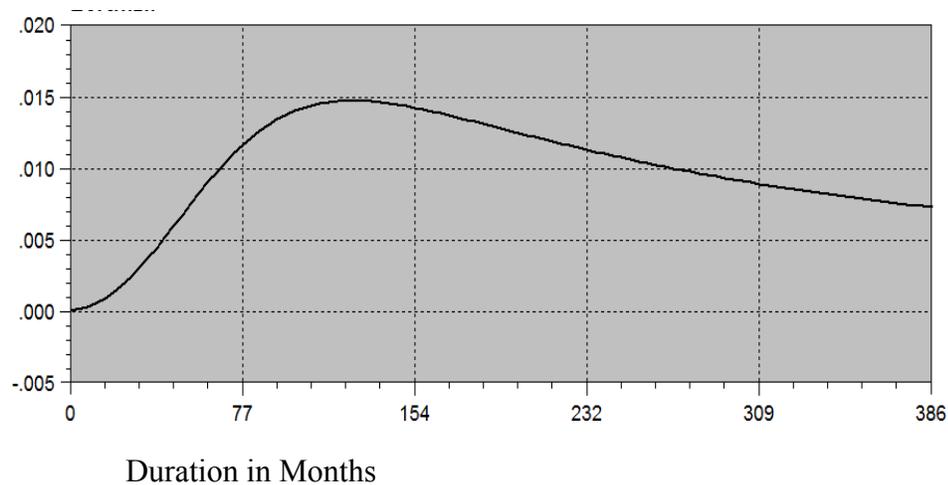


Figure 4.11 KN Hazard Function

Figure 4.12 depicts the survival function for KN projects. The probability of the letting duration to be more than 20-21 months is 1 (100%). This probability of a longer letting duration drops to about 0.2 (20%) after 160 months (13.3 years). The minimum development duration indicated by the KN model is significantly lower than the road/interchange and bridge categories and higher than the pavement categories. This is another show the need for the work category segmentation to explain the risks in project delivery more accurately.

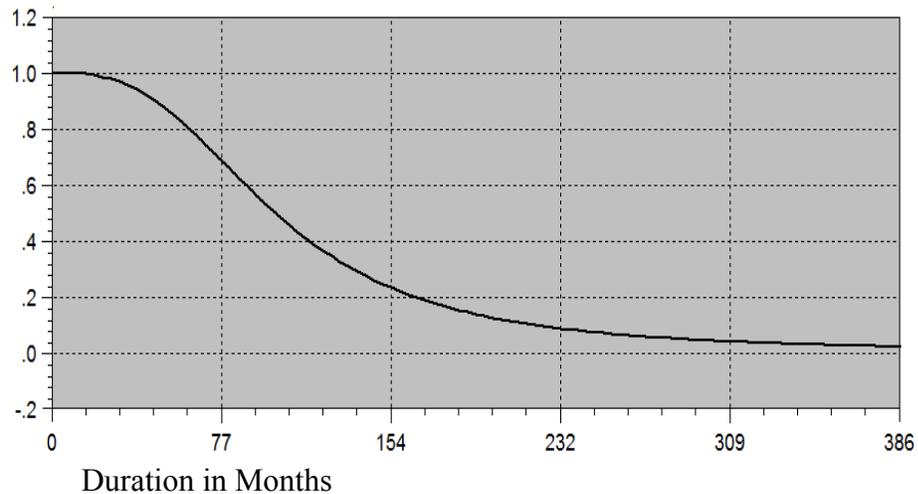


Figure 4.12 KN Survival Function

4.4. Chapter Summary

The chapter explained how duration models can be used to analyze the letting duration effects of state highway projects over a period of time. For the study data set, pavement, bridge, and road/interchange work categories were found to be significant factors of letting duration. A likelihood test was used to determine the similarity of model parameters of the total study population and the three separate work categories. The test results suggest that the parameters for each work category are not similar and thus separate tests need to be conducted. Results of the likelihood test also suggests that SA and KN project types should be modeled separately.

The hazard functions indicated the point in time (inflection point) at which projects are more likely to be let and when they are less likely to let. The survival functions described the minimal development duration before a project can be let and the probability of project letting after a duration of time has passed. Variables for each model were observed for their (1) effect on letting duration (2) and the risks they imposed on the project. The model parameters indicated that (a) road/interchange work had a 20% probability of exceeding a letting duration of 16 years, (b) bridge work had a 10% probability of exceeding a letting duration of 11 years, (c) pavement work had a

10% probability exceeding a letting duration of 5 years (d) and KN projects had 20% probability exceeding a letting duration of 13 years.

Road/Interchange work with 4 or more contracts (KN projects) or new/modified interchange work increased letting time durations as opposed to road construction and adding travel lanes. Bridge projects consisting of district bridge rehabilitation and historic rehabilitation were found to decrease the letting duration. Pavement projects that were non-interstate district pavement projects decreased the letting time duration and letting durations increased with increasing project proposed cost. The letting duration for pavement projects were the only work category significantly impacted by the monetary size of the project. KN projects in which all contracts were authorized on the same date or two (2) dates decreased the letting duration; single authorization date projects had a greater significance in decreasing letting duration. The vast majority of KN contracts, 43%, were road/interchange projects. Each of the road/interchange base work categories, road construction/new road construction, new interchange/interchange modification, and added travel lanes, all increased the letting duration for KN projects.

The risk in project delivery lies in the probability of long letting duration that could potentially upset state programming and/or fiscal schedules. Pavement projects did not pose a large risk; they had the greatest probability of having development work finishing early and required a development period of only 5 months before a project could be let. Interchange/Road projects and bridge projects posed a significant risk to project delivery; interchange/road work posing the greater risk.

The delivery risk for road/interchange projects can be minimized by combining less than four contracts for each project and by planning and managing tasks more accurately for interchange modification projects and new interchange projects. Interchange modification projects and new interchange projects require extensive planning and environmental studies and can be greatly affected by environmental and other community concerns described in the literature review. The planning and designing formalities should be scrutinized as road/interchange projects pose the largest risk to the programming schedule. The development of bridge removal projects, bridge replacement projects, and new bridge projects require the most preparation amongst

bridge projects. The development procedures should be scrutinized for common tasks where delays occurred amongst these work categories.

CHAPTER 5. CONCLUSION

5.1. Overview

The study results indicated that the highway work category significantly impacted the expected letting duration of projects. Pavement work required the least amount of development time and posed the least risk to programming and fiscal schedules. Pavement project letting durations increased as proposed costs increased, projects exceeding \$5 million experienced significantly longer letting durations. The Vincennes and Seymour districts had longer development durations than the remaining four districts. Non-interstate district pavement projects experienced shorter letting durations. Bridge rehabilitation work proved to experience the least amount of letting time amongst bridge projects. The Fort Wayne district was found to significantly decrease the amount of letting time for both pavement and bridge projects. Road/Interchange projects posed the largest risk to project delivery, the probability of letting a project after a given letting duration proved to be very low in comparison to bridge projects. Road/Interchange projects have 20% probability of exceeding 16 years whereas bridge projects have a 10% probability of exceeding 11 years. New interchange work and interchange modification work significantly increased the letting duration; projects comprised of four or more contracts experienced longer letting delays also. Road/Interchange work on interstates experienced shorter letting times.

The delivery risk can be minimized by carefully managing the interchange projects in a given fiscal period, as they pose the largest risk to upsetting the letting schedule. The letting duration for interchange projects should be estimated conservatively and the number of contracts within a single project should be kept below four. New interchange projects and modification projects require a more developed method for

completing designs and meeting federal requirements. Bridge removal, replacement, or the development of a new bridge must be programmed in a manner that they will not adversely affect the letting duration for other highway projects. The Fort Wayne district may be observed as a prototype for decreasing the letting duration of bridges. INDOT should further review the planning, design, and environmental stages of the past bridge and interchange projects that caused delays within the letting schedule. The lesson learned will provide insight as to what steps can be taken to minimize the letting duration for road/interchange and bridge projects.

5.2. Summary of Study

The objective of this study was to assess the letting duration risks by modeling characteristics of Indiana highway projects that influenced the duration from proposed to letting, utilizing data maintained by the INDOT information management system, Management Information Portal (MIP). Data was extracted from the portal between the months of July and September 2008. Upon accessing the portal, each project characteristic required manual mining. A great amount of time was attributed to the collection of scheduling data. Sorting through the collected data led to several purges and collection of new data due to date inconsistencies commonly found. The models identified programmed highway projects that may incur a lengthy project development period. Mitigating delays in project delivery can be achieved with a combination of experience and technical analysis. While this study describes the types of projects most likely to incur a project delivery delay, specific initiatives to minimize delivery risk will require detailed evaluation of past projects and their development process.

5.3. Modeling Concerns

Numerous issues were encountered throughout the development of this study causing concerns in the analysis of project letting duration. Many of these problems could be resolved once an agency strives to maintain more accurate project

development data. There is an obvious need for more informative data monitoring the time duration of the development of state highway projects. Variables described the project types, contracts, costs, etc. However, a record of the influential factors outside of the physical attributes would provide a better analysis of letting durations as discussed in the literature review. More information regarding data about the structure of the development process would prove helpful, such as: (1) the transportation agencies involved with the project, (2) recorded information and time duration regarding critical steps such as the (a) environmental evaluation (b) air quality evaluation (c) land acquisition (d) accurate dates of each developmental stage (e) design phases (3) number of staff allotted to the project (4) categorized challenges or feedback from the project staff. In order to attempt to have this type of accurate information on-hand, a highway agency must have easily accessible monitoring systems that can enable supervision and promote the importance and impact of such information to the delivery of highway projects.

5.3.1. Information Systems

There are two project management systems utilized by INDOT, (SPMS) and the (MIP). Only the MIP was used for data collection to maintain consistency and accuracy of data. Also the two management systems had numerous discrepancies with date information.

5.3.2. Project Development Dates

Several dates related to the project development process are available in the MIP: (1) Proposed Date, (2) Authorized Date, (3) Design Date, (4) Ready for Contract Date, (5) Project Let Date, and (6) Project Finished Date. Unfortunately many of the dates recorded for the development of a project are the same. For example, it is not uncommon for the Design Date, and RFC Date to be recorded on the exact same day. Four of the dates stated (2, 3, 4, and 5) are all within the interest of this study, but the

finding of inconsistency minimized the extent of the project analysis drastically. A logistic hazard model of the time duration for each phase, between the listed dates could have permitted (1) an individual phase analysis and (2) comparison of phase duration. Furthermore, allocating the phase with the longest time duration would lead to a more precise assessment of the tasks and procedures conducted within a phase. For example if the time duration between the Design Date and the Ready for Contract Date was observed to be the longest for a Bridge Replacement project, then the procedures carried out during that phase of the project can be scrutinized. With these issues in mind, only the Authorization Date and the Letting Date were used in the study analysis.

It is recognized that *scheduled* project development plan dates and the *actual* project development plan dates are not always the same. However, the data management system does not reflect two dates, the system records one date, that date being the *actual* date tasks were carried out.

5.3.3. Access to State Data

Receiving authorization for project data outside of Indiana was not achieved. A study comparing letting durations across states would be beneficial.

5.3.4. Selection of Models

Many of the characteristics collected had a very small population and could not be used in the logistic hazard model. In an effort to mitigate this problem descriptive characteristics with similarities were aggregated to form a variable with a large enough analysis pool in the duration of letting time.

5.4. Further Studies

Throughout the study, ample opportunities for advanced and/or additional risk assessment of highway letting durations have come to the forefront. While conducting the literature review, most studies brought awareness to the lack of clear matrices describing the (1) project development structure, (2) agency involvement of each project, and (3) policies active during the development of a project. Exploration in these areas accompanied by the cooperation of agencies to record a clear understanding of the project development process, would act as an excellent foundation for the study of efficient project delivery scheduling. Studies collaborating with state transportation agencies are imperative to the compilation and establishment of useful letting duration data. Such data would include *scheduled* and *actual* project development dates signifying the initiation and ending of development milestones. Analyses modeling the duration factors for the *actual project* development dates *and* the changes in the *scheduled* project development dates can be formulated into performance measures. These performance measures may include: (1) project phase costs, (2) actual project phase duration, (3) scheduled project phase duration, (4) the number of design changes in a phase, (5) productivity measurements (i.e. volume of work vs. unit cost) (Labi & Sinha, 2007). These performance measures would provide more insight for the assessment of the work highway project delivery process. Individual case studies of real past projects would provide the missing information that was unaccounted for in this study. In order to accomplish this task, INDOT (or the participating agency) needs to have consistent information within the project information management system. The case studies then can be scrutinized alongside this present study and provide better explanation for the variability in letting duration.

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