Internal Dynamics and Duration of Public Works' Procedures

Yumi Koh*

Singapore Management University

December 8, 2016

Abstract

Public works often require authorization from various agencies before they can be implemented. As agencies' interests differ, the internal dynamics in the decision-making process can affect the length of a procedure. I study the heterogeneous procedural lengths observed across public works to quantify the extent to which the features of agencies affect duration. I estimate the Cox hazard model to study the length of time between legislative authorization for funds and planning agencies' replacement of deteriorated bridges in Pennsylvania. I find that bridges with greater needs tend to have shorter waiting periods, but the effects of the political features are unclear. Bridges with favorable political features may end up with a longer waiting period because planning agencies do not consider them a priority. Having an attribute that is commonly valued by different agencies, however, can shorten the procedural duration. As a bridge project in Pennsylvania is a typical example of a public work, the finding in this paper suggests that the internal dynamics among decision makers have significant effects on the process.

Keywords: Duration analysis, Legislature, Public works, Infrastructures
JEL Classification: C41, D72, H41, H54

*School of Economics, Singapore Management University, 90 Stamford Road Singapore 178903 (Tel:+65 6828 0087, Fax: +65 6828 0833, e-mail:ymkoh@smu.edu.sg).

1 Introduction

Public works often must be authorized by various agencies before they can be implemented. As this process shapes the outcomes of public works, its features and requirements matter. For instance, who the decision-making agencies are and what their interests or constraints are will ultimately affect the outcomes of public works. This suggests that the process of implementing public works is not determined in a political vacuum. Although public works may eventually be implemented, the underlying process that they go through can vary dramatically. Thus, the duration of the process can be informative of the internal dynamics between decision-making agencies. By analyzing the length of a procedure to implement public works, we can investigate the factors that affect the duration of the procedure.

The two main questions that I analyze in this paper are as follows. First, what accounts for the heterogeneous lengths of the process observed across public works? Second, to what extent do the features of decision-making agencies affect the duration? In the empirical application, I estimate the Cox proportional hazard model (Cox 1975) to analyze the duration length for obtaining approval to replace deteriorated bridges in Pennsylvania. The duration is defined as the length of the period between the state legislature's political authorization of funds and the planning agencies' project implementation. The estimation of 644 bridge projects shows that the length of the process is shorter for bridges more in need of replacement. I find that the features of decision-making agencies have significant effects on the duration. Bridges with favorable political attributes can have a longer process, as earlier legislative authorization does not necessarily lead to a sooner implementation. At the same time, I find that bridges with an attribute that is commonly valued by both decision-making agencies tend to have a shorter procedural duration.

Studies in the literature have analyzed the timing and duration of public works. However, the focus has been mostly on the delays that arise in the execution stage, such as the duration between the deadline agreed upon in the contract and the actual time of completion. These studies often analyze the length of delays to study the implications for cost overruns or the efficiency of a government (Guccio, Pignataro, and Rizzo 2004; Lewis and Bajari 2011). In this paper, I focus on the duration in the procedural stage to study the internal dynamics between decision-making agencies. This is closely related to studies in the political science literature that investigate the duration of endorsements. For instance, studies have analyzed the amount of time it takes for the Senate to confirm the President's nominations for judicial or executive branch positions (Binder and Maltzman 2002; Shipan and Shannon 2003; McCarty and Razaghian 1999). They find that although nominees are usually confirmed eventually, the ideological distance between the President and the Senate and periods of divided government can result in significant confirmation delays. Similarly, I analyze the duration of the period between decision-making agencies, but in the context of public works.

In terms of methodology, a large body of literature estimates hazard functions to study how the variables of interest affect the duration of an outcome. Some examples include studying the influence of interest groups on the timing of bureaucratic decisions (Ando 1999), the effect of administrative deadlines on an agency's decisions (Carpenter et al. 2012), the effect of regulatory delay on the timing of product innovation (Prieger 2007), the effect of political fractionalization on the delay of fiscal stabilizations (Grier, Lin, and Ye 2015), and the effect of terrorism on cabinet duration (Gassebner, Jong-A-Pin, and Mierau 2011).

The remainder of this paper is organized as follows. The next section gives an overview of the procedural requirements for replacing deteriorated local bridges in Pennsylvania.

Section 3 discusses the timing of decisions and the empirical strategy used in the estimation. Section 4 describes the data set. Section 5 discusses the estimation results and section 6 concludes.

2 Background of Local Bridge Project Process in PA

In the U.S., Pennsylvania has the second largest stock of deteriorated bridges, followed by Iowa. As Table 1 shows, 4,783 of the 22,783 bridges in Pennsylvania were classified as structurally deficient by the Federal Highway Agency in 2015. A bridge is classified as structurally deficient if it has elements that need to be monitored and repaired.[1] The national average of the structural deficiency rate is around 9.61%, whereas it is 20.99% for Pennsylvania.

Table 1: National Rankings and State Data

State	Rank	Total Number of Bridges	Number of Structurally Deficient Bridges	% of Total
Iowa	1	24,242	5,025	20.73%
Pennsylvania	2	22,783	4,783	20.99%
Oklahoma	3	23,049	3,776	16.38%
Missouri	4	24,398	3,222	13.21%
Nebraska	5	15,341	2,474	16.13%
National Totals		611,845	58,791	9.61%

Source: U.S. Department of Transportation, Federal Highway Administration, 2015 (http://www.fhwa.dot.gov/bridge/deficient.cfm)

Around 67% of bridges in Pennsylvania are owned by the State Highway Agency, while the rest are local bridges, most of which are owned by the County Highway Agency, the

[1] More formally, a bridge is structurally deficient if it satisfies the following conditions: 1) the deck, the superstructure, the substructure, or the culvert and retaining walls are rated in condition 4 or less out of 9 and 2) the bridge has an appraisal rating of 2 or less out of 9 for the structural condition or for the waterway adequacy (See https://www.fhwa.dot.gov/bridge/0650dsup.cfm).

Town/Township Highway Agency, or the City/Municipal Highway Agency. In general, state bridges are much larger in size, usually crossing highways and rivers. Moreover, they tend to have large spillovers, as their average daily traffic is much higher.[2] As local bridges have concentrated benefits and shared costs, the interests and priorities of decision makers can vary greatly. I therefore focus on local bridges as they can provide more interesting findings regarding the effects of internal dynamics on duration. Nevertheless, the analysis will remain analogous with state bridges.

Public works typically require approval from various agencies, and local bridge projects in Pennsylvania require approval from the state legislature, the Pennsylvania Department of Transportation (Penn DOT), county officials, and local planning organizations to be implemented. An overview of the major requirements to replace or reconstruct a local bridge in Pennsylvania is as follows.[3] First, funds must be authorized for the project by the state legislature in a bill called the "Bridge Bill Capital Budget (BBCB)." In 1982, the state legislature passed the first BBCB to authorize grants for the replacement and rehabilitation of bridges in Pennsylvania. As more bridges deteriorated, the state legislature passed amendments and supplements to authorize funds for more bridges. If a local bridge project involves any state or federal fund participation, it must be included in the BBCB. Table 2 shows a summary of the enacted BBCBs.

Each bill itemizes the bridges that are authorized for funds. For each bridge, the bill stipulates its location, the type of project, and the amount authorized. The aggregate amount authorized by the bill is quite large, so the BBCB is also referred to as the Billion Dollar Bridge Bill. For the five amendment acts passed in the 1980s after the first bill,

[2]The average structural length is around 39.5m for a state bridge and around 20.7m for a local bridge. The average daily traffic is 5,331 vehicles for a state bridge and 985 vehicles for a local bridge (Source: National Bridge Inventory).

[3]For more detailed reading on the procedural requirements, refer to "Overview of Penn DOT Local Project Processes: A Guide to Getting Started on a Local Project with Penn DOT."

Table 2: Bridge Bill Capital Budget

Legislature	Bill Number	Act Number	Type	Amount Authorized
1981-1982	SB 831	Act 235	First bill	$979,196,000
1983-1984	HB 1631	Act 161	Amendment	$1,075,378,950
1985-1986	HB 385	Act 100	Amendment	$2,099,572,950
1987-1988	SB 515	Act 23	Amendment	$2,591,691,950
1989-1990	HB 756	Act 56	Amendment	$3,750,960,950
1989-1990	HB 235	Act 200	Amendment	$4,228,748,950
1991-1992	HB 1959	Act 143	Supplement	$1,725,750,000
1993-1994	HB 2676	Act 147	Supplement	$1,282,553,000
1999-2000	SB 504	Act 53	Supplement	$3,720,209,000
2001-2002	HB 2741	Act 223	Supplement	$1,563,530,000
2003-2004	HB 2745	Act 145	Supplement	$1,399,803,000
2005-2006	SB 874	Act 103	Supplement	$2,103,688,000
2007-2008	SB 1503	Act 98	Supplement	$1,966,906,000

Source: Pennsylvania General Assembly website
(http://www.legis.state.pa.us/cfdocs/legis/home/bills/)

the amounts are cumulative of previous bills because the amendment acts added projects to the itemized list of the first bill in 1982. However, the supplement acts passed since the 1990s only contain newly added projects, so the aggregate amount is no longer cumulative. The BBCB includes both state and local bridges, so the authorized amount reported in Table 2 is inclusive of the funds allocated to state bridges.

Another requirement for a bridge project is that it be included in long-run and short-run programs, the "Twelve Year Transportation Program (TYP)" and the "Transportation Improvement Program (TIP)," respectively. The TYP is a fiscally constrained program of transportation improvement projects that includes highways, bridges, transit, rail, and aviation. The time frame of the plan is 12 years divided into three 4-year periods. The TYP is developed and approved by the State Transportation Commission, whose membership includes the Secretary of Transportation, the chairs of the House and Senate Transportation Committees, ranking minority members of the House and Senate Transportation Committees, and ten appointed members.

Table 3: Planning Partner Regions

Name of MPO/RPO	Counties
Adams County RPO	Adams
Altoona MPO	Blair
Centre County MPO	Centre
Delaware Valley Regional Planning Commission	Bucks, Montgomery, Philadelphia, Chester, Delaware
Erie MPO	Erie
Franklin County Planning Commission	Franklin
Harrisburg Area MPO	Dauphin, Perry, Cumberland
Johnstown Area MPO	Cambria
Lackawanna/Luzerne MPO	Lackawanna, Luzerne
Lancaster MPO	Lancaster
Lebanon MPO	Lebanon
Lehigh Valley MPO	Lehigh, Northampton
North Central RPO	McKean, Potter, Elk, Cameron, Jefferson, Clearfield
Northeastern Pennsylvania Alliance RPO	Wayne, Pike, Monroe, Carbon, Schuylkill
Northern Tier RPO	Tioga, Bradford, Sullivan, Susquehanna, Wyoming
Northwest RPO	Crawford, Warren, Forest, Venango, Clarion
Reading Area MPO	Berks
SEDA-COG RPO	Clinton, Columbia, Montour, Union, Northumberland, Snyder, Mifflin, Juniata
Shenango Valley MPO	Mercer
Southern Alleghenies RPO	Somerset, Bedford, Fulton, Huntingdon
Southwestern Pennsylvania Commission	Lawrence, Butler, Armstrong, Indiana, Beaver, Allegheny, Westmoreland, Washington, Greene, Fayette
Williamsport Area MPO	Lycoming
York Area MPO	York

Source: Pennsylvania Planning Partner Profiles
(`http://www.dot.state.pa.us/public/Bureaus/Cpdm/PA%20Plan%20Profile/PA%20Planning%20Partner%20Profile.pdf`)

The TIP is a fiscally balanced plan with a span of 4 years. The projects included in TIP match the first four years of the TYP. The list is developed by Metropolitan Planning Organizations (MPO) and Rural Planning Organizations (RPO), which represent the urban and rural areas of Pennsylvania, respectively. Table 3 shows a list of MPOs and RPOs in Pennsylvania, along with a list of counties which constitutes an MPO or RPO. The decision makers for these organizations include local elected officials, Penn DOT, and other transportation stakeholders. Any local bridge project that involves federal or state funds must be included in the TYP and the TIP. Although there are rare exceptions, inclusion by the TIP usually ends up being implemented within the planned schedule. Note that as the BBCB is not fiscally constrained, inclusion by the bill does not guarantee a spot in the TYP or TIP.

3 Timing of Decisions

In this paper, I analyze the duration between two events for local bridges that are to be replaced or reconstructed. The first event is the legislature's authorization of funds by the BBCB. The second event is the timing of a bridge's replacement or reconstruction.[4] In Table 4, I show the summary of outcomes for 644 local bridges authorized by the BBCB that passed in 1992. The data show that there is a large variation in the waiting periods until implementation even though these bridges were authorized by the legislature at the same time. Among 644 local bridge projects, 211 projects were implemented by 2015, and

[4] Alternatively, one can focus on other events, such as the timing of inclusion by the TYP or TIP, with additional collection of data. However, because almost all projects are implemented within the given schedule by the TYP and TIP, these findings would not differ substantially from those obtained using the timing of implementation. When the reconstruction or replacement of a bridge takes multiple years, I use the initial year of implementation rather than the completion year. This is to focus on the duration of procedure, rather than the duration of execution.

the data for the remaining 433 projects are right-censored. That is, most of these projects have yet to be implemented.

Table 4: Heterogeneous Procedural Duration

Number of Years	Number of Bridges
Within 3 years	39
Between 4 and 6 years	42
Between 7 and 9 years	30
Between 10 and 12 years	35
Between 13 and 15 years	33
Between 16 and 18 years	22
Between 19 and 21 years	10
Censored	433
Total	644

Source: National Bridge Inventory and Act 143.

One possible explanation for the heterogeneous durations is the budget constraint. As the BBCB authorizes more funds for bridges than are available in the budget, bridge projects would have to be implemented over multiple years. However, the data show that this factor cannot solely explain the variation in duration. If this were the case, bridge projects would be implemented in order of legislative authorization. For instance, if the planning agencies have aligned preferences with the legislature and the budget constraint is the only constraint that differs, projects authorized in earlier bills would be implemented first. However, the data show that this is not necessarily true. The planning agencies do not seem to follow the ordering of legislative authorization, and many projects authorized by earlier bills wait much longer before they are implemented.

This suggests that factors other than the budget constraint affect internal dynamics in the decision-making process. To investigate these factors and to quantify their effects, I use the Cox proportional hazard model to estimate the length of waiting time until implementation. The duration begins for a bridge once it is authorized by the legislature, and the hazard rate is the “risk” of being reconstructed or replaced. The hazard rate for the Cox proportional hazard model is written as

$$h(t|X_t, \beta) = h_0(t) exp(X_t \beta) \tag{1}$$

where $h_0(t)$ is the unspecified baseline hazard function, X_t is the vector of covariates for a bridge, and β is a vector of parameters to be estimated. The baseline hazard function $h_0(t)$, which is common across all observations, refers to the hazard rate when all explanatory variables are set to zero. The hazard rate $h(t|X_t, \beta)$ shows the likelihood that a bridge project will be implemented at time t conditional that it has not been at time $t-1$. Cox proportional models are widely used as they do not impose restrictive parametric assumptions. Moreover, they are suitable for treating right-censored data because they avoid the selection bias.

The covariates that enter into X_t can be classified into three categories: (1) technical attributes of a bridge; (2) factors affecting the timing of legislative authorization; and (3) factors affecting the timing of final implementation.

Attributes of a bridge The bridge characteristics differ in multiple dimensions, such as usage level, deterioration rating, operating status, network importance, and safety status. These characteristics vary over time and capture the needs of each bridge. For instance, a bridge may deteriorate rapidly, making it urgent to replace as quickly as possible. Therefore, I control for multiple dimensions of bridge attributes that vary across time.

Factors affecting political authorization Political incentives or representation in the legislature can influence fund authorization decisions via the BBCB. Previous studies show that politicians allocate resources to maximize their vote outcomes (Strömberg 2008) and that politicians with relevant committee memberships, majority party affiliations, or greater seniority are able to produce more favorable outcomes for their districts (Atlas et al. 1995, Berry et al. 2010, Knight 2008). Political interests and representation can affect not only the timing of legislative authorization but also the duration of the process that comes afterward. For instance, suppose that a bridge has not severely deteriorated but was authorized for funds because of its favorable political attributes. If the planning agencies do not consider this project a priority, earlier approval by the legislature can actually lead to a longer procedural duration. Therefore, I include political features related to the legislature's authorization decision in the duration analysis.

Factors affecting final implementation As the timing of a project's implementation marks the end of the waiting period, the features of the planning agencies and their constraints also affect the duration. For instance, if a planning agency has a large stock of deteriorated bridges in its district, a bridge may have to wait longer to be replaced because of budget limitations. Therefore, I capture the tightness of the resource constraint using the size and quality of the bridges in need of replacement. To take into account the features of planning agencies, I use the districts of MPOs and RPOs.

4 Data Sets

I construct a data set by combining data from three sources: (1) the 1992 BBCB; (2) the National Bridge Inventory (NBI); and (3) the Pennsylvania Manual.

BBCB of 1992 The data on BBCB are available from the legislative archive of the Pennsylvania General Assembly website.[5] Among the many BBCBs passed throughout different years, I focus on the 1992 bill. Theoretically, any bill can be chosen for the analysis. However, the other data set that contains the technical attributes of individual bridges is only available from 1992, so I chose the bill that can maximize the availability of other data sets. The 1992 bill authorized around $1.72 million in aggregate for the replacement and rehabilitation of 1,181 state bridges and 873 local bridges. Among these, I focus on local bridges; the duration for all of them begins in 1992.

National Bridge Inventory (NBI) Given the authorized set of local bridges, I track their status using a data set called the National Bridge Inventory (NBI). These data are available on the Federal Highway Administration of the U.S. Department of Transportation website.[6] NBI includes bridge-level data for all public bridges in the U.S. and has been annually reported since 1992. Around 116 variables are reported for each bridge, including a description, usage measures, technical ratings, operating status, and the year of replacement or reconstruction. Thus, the NBI provides time-varying characteristics of bridges by year and the year of replacement or reconstruction, which marks the end of the waiting period. One feature of this empirical application is that the data on the objective measures of needs are available. For public works that do not yet exist and are to be newly built, data on time-varying needs are likely to be unavailable. However, the NBI data provide the necessary information in this context, so this empirical setting does not face this issue.

Among the 873 local bridges authorized by the BBCB, 644 are successfully tracked in

[5] http://www.legis.state.pa.us/cfdocs/legis/home/bills/
[6] http://www.fhwa.dot.gov/bridge/nbi/ascii.cfm

the NBI data. The two data sets do not share a common unique identifier for bridges, so I link the bridges in the bill to the NBI data using the following information: (1) county code; (2) place code (township, borough, city); (3) facility carried by bridge (SR/PA/US/TR number or road name); (4) feature crossed (creek, river, lake, railroad); and (5) segment number or other additional location description, if mentioned. The matching fails to be perfect, as descriptions in the bill are sometimes not sufficient to uniquely identify bridges or the bill sometimes lacks necessary information. The matched data give 10,777 observations of 644 bridges from 1992 to either 2015 or the year of replacement: 211 local bridges were reconstructed or replaced before 2015, while the outcomes for the rest of the bridges are right-censored.

Pennsylvania Manual Finally, I refer to the Pennsylvania Manual, which is a comprehensive guide to Pennsylvania's government. This book is published biennially by the Department of General Services for the Commonwealth. I collect information on the political environment of the legislature at the time of bill passage, including the members and chairman of the relevant committees in the referral process of the BBCB. I also collect information on the politicians' residential addresses to match with bridges' locations.

Table 5 gives a summary of the statistics for the 644 bridges at the time of the legislature's authorization in 1992. The first set of variables includes bridges' political attributes related to the legislature. Three committees are involved in the BBCB referral process: (1) the Transportation Committee; (2) the Appropriations Committee; and (3) the Rules & Executive Nominations Committee. A large proportion of authorized bridges are located in counties represented by politicians on these relevant committees. Moreover, I compare bridge locations with the reported residential addresses of all politicians in both

Table 5: Descriptive Statistics of Bridges in the 1992 BBCB

Variable	Value
Share of bridges with Transportation Committee member(s)	60.87%
Share of bridges with Appropriations Committee member(s)	80.59%
Share of bridges with Rules & Nominations Committee member(s)	50.93%
Share of bridges with politicians residing within their county subdivision	6.52%
Share of bridges with chair(s)	27.64%
Average sufficiency rating (out of rating 100)	45.42
Average age	68.45 years
Average daily traffic volume	779.51 vehicles
Average length of bridge structure	216.58m
Average detour length	14.62km
Share of bridges that are closed to traffic	3.57%
Share of bridges that are posted for load or other restrictions for usage	63.66%
Average amount authorized for a bridge	$451,437

Source: National Bridge Inventory and Act 143.

chambers. Around 6.52% of the authorized bridges are located in a county subdivision in which at least one politician resides.[7] In the second set of variables, the technical attributes of bridges are shown at the time of authorization. In general, bridges tend to be deteriorated, as indicated by low sufficiency ratings and restrictions imposed on their usage. On average, around $450,000 was authorized for replacing a local bridge.

Table 6 summarizes the bridges' various political attributes along with their usage status. For example, the first two rows compare the percentage of bridges whose usage is restricted depending on whether they are located in areas represented by relevant committee members in the Senate. The statistics show that bridges with relevant committee members in the Senate have a lower rate of usage restrictions. Similarly, analysis using other dimensions of political factors show that bridges with favorable political attributes tend to have a lower rate of usage restrictions. This may suggest that given technical

[7] The area of county subdivisions is quite small. For instance, Adams County is 1,352km^2 and is divided into 34 subdivisions. Therefore, matching the location of a bridge with politicians' residences at the county subdivision level is a relatively strict requirement.

attributes, bridges with favorable political attributes were authorized earlier. However, further analysis of duration is needed to determine whether these bridges are implemented sooner or end up waiting longer. This result is discussed in the next section.

Table 6: Descriptive Statistics of Bridges in the 1992 BBCB

		% of Bridges with restricted usage	Number of observations
Relevant committees in the Senate	Yes	59.62%	416
	No	71.05%	228
Relevant committees in the House	Yes	59.91%	439
	No	71.71%	205
Chair(s) in the Senate	Yes	47.10%	155
	No	68.92%	489
Chair(s) in the House	Yes	54.64%	97
	No	62.53%	547
Politicians' residence	Yes	35.71%	42
	No	65.61%	602

Source: National Bridge Inventory and Act 143

5 Estimation Results

Table 7 shows the estimation results of the duration analysis. Note that some of the covariates are interacted with the log of time. This is because the Cox proportional model makes the proportionality assumption—hazard functions of two observations with different values of a covariate differ only by a factor of proportionality. If the assumption is not valid, this can give biased estimates (Box-Steffensmeier and Zorn 2001, Box-Steffensmeier and Jones 2004). To address this issue, I test the proportionality assumption of the Cox model and allow the covariates that show evidence of non-proportionality to be time varying.[8]

[8]The stphtest routine in Stata 14.0 was used in the analysis.

In column 1, I provide the result when only the technical attributes of bridges are included in the estimation. All of the coefficients have the expected sign and all but one are statistically significant at 1%. If a covariate has a positive coefficient, its characteristics are associated with a greater conditional probability of a bridge being replaced. The estimated parameters show that a higher sufficiency rating, which implies a better overall condition, results in further delay. Bridges with closed operating status or with more lanes underneath the structure or with a larger proportion of length to be improved have shorter waiting periods. However, bridges with a longer span length have a longer duration, which suggests that costlier projects may take longer to implement. Finally, the detour length of a bridge, which captures the additional travel distance if a bridge were to be shut down, turned out to be insignificant.[9]

In column 2, I show the result when political attributes in the legislature are also included in the estimation. These are the political attributes that remain constant at the 1992 values. The variables House chair and Senate chair each refer to the number of chair members in the county in which a bridge is located. Chair includes the chair of the chamber and the chairs of the three relevant committees involved in the referral process of the bill. There are also two indicator variables to capture whether at least one senator or House member live in the county subdivision in which a bridge is located. Finally, there are two indicator variables that capture whether there is at least one Transportation Committee member representing the county of a bridge's location in each chamber. These two variables are interacted with the log of time. The results show that the variables related

[9]The technical attributes of a bridge vary in each year throughout the duration period. For instance, a sufficiency rating usually worsens as a bridge deteriorates. The underlying assumption is that the agencies' authorizations do not change the stochastic deterioration process of bridges in any fundamental way. This is a reasonable assumption given that bridges are not operated or treated differently because of legislative authorization or procedural duration. Therefore, these covariates are assumed to be exogenous in the estimation.

Table 7: Estimation Results for the Cox Model

Variable	(1)	(2)	(3)	(4)
Sufficiency rating	-0.0278***	-0.0267***	-0.0283***	-0.0271***
	(0.0037)	(0.0038)	(0.0037)	(0.0038)
Closed	1.1003***	1.1455***	1.1121***	1.1766***
	(0.2106)	(0.2117)	(0.2139)	(0.2148)
No. of lanes under the structure	0.2671***	0.3287***	0.2665***	0.3127***
	(0.0964)	(0.1081)	(0.0957)	(0.1067)
Maximum span length	-0.0784***	-0.0783***	-0.0795***	-0.0802***
	(0.0219)	(0.0231)	(0.0221)	(0.0237)
Square root of detour length	0.0048	0.0017	0.0067	0.0055
	(0.0222)	(0.0225)	(0.0218)	(0.0219)
Length of structure improvement × $log(time)$	0.0287***	0.0330***	0.0291***	0.0340***
	(0.0095)	(0.0111)	(0.0096)	(0.0113)
Senate chair		-0.4488***		-0.5126***
		(0.1727)		(0.1824)
House chair		0.3300		0.4730
		(0.2275)		(0.3094)
I(Senators' residence)		-1.0778*		-1.1065*
		(0.6400)		(0.6254)
I(House members' residence)		0.2177		0.2102
		(0.3982)		(0.4011)
I(Senate Transp. Committee) × $log(time)$		0.0984		0.1697*
		(0.0841)		(0.0960)
I(House Transp. committee) × $log(time)$		-0.0001		0.0038
		(0.0869)		(0.0869)
Average sufficiency rating in regional district			0.0125	0.0192
			(0.0117)	(0.0119)
No. of bridges to replace in regional district			-0.0001	-0.0003
			(0.0005)	(0.0008)
Log-likelihood	-1171.90	-1166.98	-1171.17	-1165.15
χ^2	126.30	133.15	127.05	135.17
Observations	10,116	10,116	10,116	10,116

Notes: The unit of observation is an individual bridge in a year. Robust standard errors, clustered by bridge, are in brackets. */**/*** indicate significance at 10/5/1% level. The Efron approximation is used to handle tied failures in the Cox model.

to the Senate have significant negative effects on the hazard rate. For instance, bridges located in areas represented by chairman in the Senate or in areas that coincide with senators' residences have longer waiting periods. As shown in Table 6, bridges with favorable political representation were shown to have lower rates of restrictions imposed on their usage compared to other bridges. In line with this, the finding suggests that bridges with favorable representation in the Senate may have been authorized early, but this does not necessarily lead to preferential treatment in the latter stage. As a result, such bridges may end up with a longer waiting period.

Column 3 shows the estimation result when covariates that affect the timing of project implementation are included. One major constraint that the Penn DOT and local planning agencies face is the budget constraint. Therefore, I include two variables to proxy for the tightness of this constraint —the average sufficiency rating of bridge stock and the number of bridges that need to be replaced in each year. The idea is to see whether a bridge's waiting duration lengthens when the overall quality and quantity of the stock is worse and larger in a regional district in which a bridge is located. For the regional districts, I take TIP into consideration and define a bridge stock according to the districts of planning agencies, as shown in Table 3. The coefficients have the expected sign, as a better quality of bridge stock and a larger stock of bridges have positive and negative effects on the hazard rate, respectively. However, they are not statistically significant at standard levels.

Finally, in column 4, I include all of the variables analyzed in columns 1, 2, and 3. The magnitudes of the estimated parameters do not change substantially. The coefficient capturing representation in the Transportation Committee of the Senate now becomes statistically significant. However, the sign is positive, in contrast to the negative signs for chair and for the residence indicator in the Senate. This may be because the Senate

Table 8: Estimation Results for the Weibull Model

Variable	(1)	(2)	(3)	(4)
Sufficiency rating	-0.0278***	-0.0271***	-0.0279***	-0.0273***
	(0.0037)	(0.0039)	(0.0038)	(0.0039)
Closed	0.9772***	1.0144***	0.9799***	1.0253***
	(0.2036)	(0.2054)	(0.2053)	(0.2066)
No. of lanes under the structure	0.2361**	0.3273***	0.2378**	0.3246***
	(0.0943)	(0.1087)	(0.0946)	(0.1078)
Maximum span length	-0.0811***	-0.0839***	-0.0813***	-0.0854***
	(0.0221)	(0.0233)	(0.0223)	(0.0237)
Square root of detour length	0.0048	0.0032	0.0054	0.0047
	(0.0222)	(0.0221)	(0.0222)	(0.0221)
Length of structure improvement $\times$ $log(time)$	0.0286***	0.0339***	0.0285***	0.0342***
	(0.0081)	(0.0662)	(0.0082)	(0.8661)
Senate chair		-0.3768**		-0.3972**
		(0.1746)		(0.1782)
House chair		0.3572		0.3409
		(0.2311)		(0.3019)
I(Senators' residence)		-1.1018*		-1.1066*
		(0.6604)		(0.6539)
I(House members' residence)		0.2276		0.2298
		(0.4004)		(0.4007)
I(Senate Transp. Committee) $\times$ $log(time)$		0.0115		0.0266
		(0.0789)		(0.0861)
I(House Transp. committee) $\times$ $log(time)$		-0.0685		-0.0684
		(0.0790)		(0.0790)
Average sufficiency rating in regional district			0.0046	0.0088
			(0.0125)	(0.0129)
No. of bridges to replace in regional district			-0.0001	0.0001
			(0.0005)	(0.0008)
p	0.9454	0.9488	0.9376	0.9329
Log-likelihood	-529.76	-524.65	-529.65	-524.39
χ^2	126.38	129.60	126.26	129.97
Observations	10,116	10,116	10,116	10,116

Notes: The unit of observation is an individual bridge in a year. Robust standard errors, clustered by bridge, are in brackets. */**/*** indicate significance at 10/5/1% level.

Transportation Committee has further influence outside the legislature, as its members are also part of planning agencies that determine the prioritized list of bridges. Therefore, being linked to Transportation Committee can have further implications for procedural duration. At the same time, all of the variables related to the House remain insignificant.

To examine the robustness of the results, I conduct a sensitivity analysis by estimating the proportional hazard Weibull model. That is, I make a parametric assumption that the baseline hazard has a Weibull distribution and estimate the duration model using the same set of covariates. The Weibull model is specified as the following:

$$h(t|X_t, \beta) = pt^{p-1}exp(X_t\beta) \tag{2}$$

where p is the hazard shape parameter. The estimation results are summarized in Table 8. Overall, I find that the estimated coefficients are quite consistent with those obtained from the Cox model. For variables related to bridge needs, the magnitudes are almost the same and the signs are also consistent with those estimated in the Cox model. As for political features, variables related to the Senate other than the Transportation Committee continue to have negative and statistically significant coefficients. The Senate Transportation Committee variable, which used to be statistically significant at 10% in the Cox model, now becomes insignificant but the sign still remains as positive.

In Table 9, I show the percentage change in the hazard rate for given changes in covariates that were significant. I use the estimated parameters in column 4 of Table 7. The change in the hazard rate is calculated using the following formula:

$$\%\Delta h(t) = \frac{e^{\beta(x_i=X_1)} - e^{\beta(x_i=X_2)}}{e^{\beta(x_i=X_2)}} \times 100 \tag{3}$$

As for discrete covariates, the hazard rate change is calculated by varying the value

Table 9: Magnitude of Effects on the Duration of Project Implementation

Variable	Change in X (from, to)	Change in Hazard Rate
Closed	(open, closed)	214.24%
Senate chair	(0, 1)	-40.11%
I(Senators' residence)	(0, 1)	-66.93%
I(Senate Transp. Committee)	(0, 1)	28.48%
Number of lanes under the structure	(0, 1)	36.71%
Sufficiency rating	(45.42, 70.43)	-49.28%
Maximum span length	(11.25, 14.89)	-25.34%
Length of structure improvement	(5.79, 9.93)	47.11%

of a covariate from 0 to 1. For continuous covariates, the change is set to be the mean value and roughly one standard deviation above. Table 9 shows that the need measures of a bridge have consistent effects on the duration. That is, projects with worse operating ratings, closed status, or a longer length of structure to improve have shorter waiting periods. Moreover, projects with a greater risk if they were to fail, as determined by the number of lanes passing under the bridge structure, have shorter durations. Finally, projects with cheaper costs of implementation as proxied by the structure length have shorter waiting periods.

However, the effect of political attributes on the duration suggests that having political representation could either shorten or lengthen the duration. The main difference seems to stem from whether a political factor under consideration also has the potential to exert influence in a later stage outside the legislature. This seems to drive different features of the Senate variables to have contrasting effects on the hazard rate.

6 Conclusion

In this paper, I estimate the Cox hazard model to quantify the effects of project attributes and decision makers' interests on the procedural lengths of public works. In particular, I focus on the length of time between the legislative authorization for funds and the replacement of deteriorated local bridges in Pennsylvania. As there is great heterogeneity in this duration, I explain what accounts for this difference observed across bridge projects. In general, bridges with greater needs for replacement have shorter durations. At the same time, I find that the factors considered by the legislature and planning agencies also have significant effects. In particular, the analysis shows that projects with favorable political attributes in the legislature may actually have longer waiting periods, as their political advantages are not necessarily valued by planning agencies. However, being affiliated with the Senate Transportation Committee, which is involved in both stages of the procedure, reduces the duration. A bridge project in Pennsylvania is a typical example of a public work that involves various decision-making agencies. Although the numerical estimates may not be directly applicable to other empirical settings, the finding in this paper suggests that the internal dynamics among decision makers have significant effects on the process.

References

[1] *The Pennsylvania Manual (Volume 110).* Dept. of General Services for the Commonwealth of Pennsylvania, 1991.

[2] Ando, A. W. Waiting to be protected under the endangered species act: The political economy of regulatory delay. *The Journal of Law and Economics 42*, 1 (1999), 29–60.

[3] Atlas, C. M., Gilligan, T. W., Hendershott, R. J., and Zupan, M. A. Slicing the federal government net spending pie: Who wins, who loses, and why. *The American Economic Review 85*, 3 (June 1995), 624–629.

[4] Berry, C. R., Burden, B. C., and Howell, W. G. The president and the distribution of federal spending. *American Political Science Review 104*, 04 (2010), 783–799.

[5] Binder, S. A., and Maltzman, F. Senatorial delay in confirming federal judges, 1947-1998. *American Journal of Political Science 46*, 1 (2002), 190–199.

[6] Box-Steffensmeier, J. M., and Jones, B. S. *Event History Modeling: A Guide for Social Scientists.* Cambridge University Press, 2004.

[7] Box-Steffensmeier, J. M., and Zorn, C. J. W. Duration models and proportional hazards in political science. *American Journal of Political Science 45*, 4 (2001), 972–988.

[8] Carpenter, D., Chattopadhyay, J., Moffitt, S., and Nall, C. The complications of controlling agency time discretion: Fda review deadlines and postmarket drug safety. *American Journal of Political Science 56*, 1 (2012), 98–114.

[9] Cox, D. R. Partial likelihood. *Biometrika 62*, 2 (1975), 269–276.

[10] Gassebner, M., Jong-A-Pin, R., and Mierau, J. O. Terrorism and cabinet duration. *International Economic Review 52*, 4 (2011), 1253–1270.

[11] Grier, K., Lin, S., and Ye, H. Political fractionalization and delay in fiscal stabilizations: a duration analysis. *Public Choice 164*, 1 (2015), 157–175.

[12] Guccio, C., Pignataro, G., and Rizzo, I. Do local governments do it better? analysis of time performance in the execution of public works. *European Journal of Political Economy 34* (2014), 237 – 252.

[13] Knight, B. Legislative representation, bargaining power and the distribution of federal funds: Evidence from the us congress. *The Economic Journal 118*, 532 (2008), 1785–1803.

[14] Lewis, G., and Bajari, P. Procurement contracting with time incentives: Theory and evidence. *The Quarterly Journal of Economics 126*, 3 (2011), 1173–1211.

[15] McCarty, N., and Razaghian, R. Advice and consent: Senate responses to executive branch nominations 1885- 1996. *American Journal of Political Science 43*, 4 (1999), 1122–1143.

[16] Prieger, J. E. Regulatory delay and the timing of product innovation. *International Journal of Industrial Organization 25*, 2 (2007), 219 – 236.

[17] Shipan, C. R., and Shannon, M. L. Delaying justice(s): A duration analysis of supreme court confirmations. *American Journal of Political Science 47*, 4 (2003), 654–668.

[18] Stromberg, D. How the electoral college influences campaigns and policy: The probability of being florida. *The American Economic Review 98*, 3 (June 2008), 769–807.