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Delivery methods, risk sharing, standards and performance for construction, operations, and management: The TEXpress managed lanes system, Dallas-Ft. Worth, Texas

Jonathan L. Gifford^{a,*}, Shanjiang Zhu^b, Daniel Grimaldi^c^a Center for Transportation Public-Private Partnership Policy, Schar School of Policy and Government, George Mason University, 3351 Fairfax Dr., MS 3B1, Arlington, VA 22201, USA^b Department of Civil, Environmental and Infrastructure Engineering, George Mason University, 4400 University Dr., MS 6C1, Fairfax, VA 22030, USA^c Schar School of Policy and Government, George Mason University, 3351 Fairfax Dr., MS 3B1, Arlington, VA 22201, USA

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ABSTRACT

Dynamically tolled managed lanes and public-private partnership (P3) infrastructure delivery approaches can provide decision makers with innovative solutions for addressing traffic congestion challenges. These diverse delivery methods entail very different allocations of risks, costs, and benefits. Thus, evaluating managed toll road performance under different delivery methods can offer valuable insights. To that end, this study evaluates primary documents from the Dallas-Fort Worth, Texas, region's TEXpress managed lanes system to explore its risk allocations, construction standards, and operations and maintenance standards. Texas employed P3 delivery approaches for 5 of the system's 6 major development projects, with the more complex, multi-stage contracts sharing and/or transferring more risk with/to the private sector. The three DBFOM contracts were more than three times larger (average size \$2.08 billion) than the DBB, DBM and DBOM projects (average size \$656 million). The state also imposed more varied and complex construction requirements via the P3 contracts, including penalties for poor performance. The three DBFOM P3 projects delivered their facilities early; the other three projects delivered their facilities late. One DBFOM P3 project had no change orders; the other four projects had 207, 28, 13 and 8 change orders valued at 6.6%, 4.1%, -1.2%, and 0.35% of project cost, respectively. Despite differing delivery methods, few substantial differences appeared among the projects' operations and maintenance standards.

1. Introduction

U.S. public-sector agencies face increasing difficulty in meeting the rising demand for surface transportation facilities. Government funds have become scarcer. Construction costs have also increased (Geddes, 2011; Parry, 2009) and maintenance costs have risen as facilities have aged (Casady and Geddes, 2020). The U.S. Congressional Budget Office projects that the gap between dedicated surface transportation revenues and spending from the federal Highway Trust Fund will average roughly \$18 billion annually between FY2021 and FY2026 out of an annual commitment of around \$60 billion (Kirk and Mallett, 2020, p. 3). This expanding gap could seriously constrain future highway capital investment. However, travel demand keeps on growing despite temporary stalls during recessions (U.S. Department of Transportation, Federal

Highway Administration, Office of Highway Policy Information, 2017) and the Covid-19 pandemic (Casady & Baxter, 2020).

Urban traffic congestion has become a persistent problem because of this imbalance between road capacity and demand growth (Schrank, Eisele, and Lomax, 2019).¹ This imbalance is a global issue and the issue of urban congestion is growing according to the TomTom Traffic Index, which monitors traffic speed in 416 global cities using longitudinal location data (TomTom, n.d.).

Such congestion can produce wide-ranging negative effects for the environment (Daniel and Bekka, 2000), public health (Currie and Walker, 2011; Tonne et al., 2008), and economic growth (Sweet, 2011; Weisbrod, Vary, and Treyz, 2003). Schrank et al. (2019) estimated that the value of time and fuel wasted due to urban congestion has increased from \$47 billion in 1994 to \$179 billion in 2017 (normalized to 2017

* Corresponding author.

E-mail addresses: jgifford@gmu.edu (J.L. Gifford), szhu3@gmu.edu (S. Zhu), dgrimald@gmu.edu (D. Grimaldi).¹ See the latest Urban Mobility Report here: <https://mobility.tamu.edu/umr/>.<https://doi.org/10.1016/j.cstp.2023.101016>

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dollars).

Managed lanes with dynamic toll strategies offer a long-term solution to congestion mitigation that incentivizes better use of road capacity through travel demand management and offers all users a faster and more reliable travel option if and when they need it (Gomez-Ibanez et al., 2018; Schwimmer, Gómez-Ibáñez, and Casady, 2019; Casady et al., 2020b). Additionally, when coupled with public-private partnerships (P3s), managed lanes help attract private capital into the road infrastructure market, overcome public budget limitations, and accelerate the implementation of capacity expansion projects (Bolaños et al., 2019b; Gifford, 2020; Grimsey and Lewis, 2005). Managed lanes may also generate funds for other transportation projects and services. The winning proposal on a recent Virginia project included a \$500 million up-front payment to the state for use on other transportation projects, as well as ongoing funding for the life of the concession for public transit (Virginia Department of Transportation, 2023). Managed lane projects in Dallas-Ft. Worth include operations and maintenance of the adjacent general-purpose lanes and frontage roads.

An analysis of federal Highway Trust Fund shortfalls by the Congressional Research Service identifies toll financing of federal-aid system highways and P3s as two potential remedies for the issue (Kirk and Mallett, 2020, pp. 16–20). There is also evidence that P3 arrangements are preferred by some policymakers in cases of complex and expensive construction projects (Daito and Gifford, 2014). In contrast to traditional design-bid-build approaches, P3s shift many project risks from public-sector owners to private-sector concessionaires via long-term contracts (Gifford, 2020; Iossa and Martimort, 2008; Casady et al., 2019) and create both a mechanism and incentives for both parties to accelerate project delivery, introduce innovation, improve risk management, and improve customer experiences (Bolaños et al., 2017; Ormijana and Rubio, 2015a). Such innovations may arise from many different sources. For example, P3 concessionaires may change the original design to improve connections between managed lanes and the existing network, thus attracting and serving more users (Ormijana and Rubio, 2015a). P3 concessionaires may also provide support to transit services along the corridor (VDOT Office of Public-Private Partnerships, 2020). These advantages could help P3 companies deliver more projects in a shorter period (van Verweij et al., 2022a; see also van Verweij et al., 2022b; Casady et al., 2022), better serve users by giving more opportunities to use express toll roads, and expand network effects at a faster pace.

P3 projects that combine design, construction (i.e., “building”), financing, operations, and maintenance phases (DBFOM projects) provide the opportunity for a holistic approach to asset lifecycle management (Casady and Geddes, 2019). Transferring all risks to a single developer allows the developer to have a holistic approach in comparison to design-build (DB) construction, where one company builds while another provides operations and maintenance (O&M). The O&M contractor, in this case, cannot generally influence the design or other characteristics of the projects to improve lifecycle performance. The DBFOM’s holistic approach allows innovation across all stages of the project, enabling design, construction, operation, maintenance, and revenue optimization (Casady and Geddes, 2016).

However, the P3 mechanism varies from project to project due to variable regulatory environments, specific project conditions, and local attitudes (Casady et al., 2020a, Casady et al., 2020b; Casady 2021; Casady 2023). In addition, the public sector always has the option to deliver the managed toll road projects through conventional project delivery mechanisms, most commonly design-bid-build (DBB) or design-build (DB). These diverse project delivery methods entail very different allocations of risks, costs, and benefits. Evaluating the performance of managed toll road projects under different delivery methods would be very helpful for the improvement of such methods, and for informing future debates about P3 policies and policy learning in road concession programs more broadly (Casady and Parra, 2021).

The Texas TEXpress Lanes system in the Dallas-Fort Worth (DFW)

area offers an opportunity for such a study. The facilities are co-located in the same region, which avoids confounding comparisons due to differences in factors such as regulatory environment, level of congestion, and acceptance of tolls among local travelers. The TEXpress Lanes System in DFW, delivered by the Texas Department of Transportation (TxDOT), has employed a range of procurement approaches. As the performance of a project in both the construction and operation phases would be affected by many details (see Casady et al., 2020b), the authors first evaluated project delivery methods to establish comparability across different projects in the DFW region. Because this research seeks to be comprehensive, it includes the comparison of a wide range of performance measures among projects delivered through different methods. However, it is restricted by the amount of data available at this stage. Longitudinal performance data such as traffic volume, speed, accident rate, incident response time, and pavement quality over time for all projects remain largely unavailable. Therefore, this analysis focuses on comparing the projects’ risk-sharing profiles, construction standards and results, and operations and maintenance (O&M) standards, thereby setting the stage for more comprehensive performance comparisons in the future.

The documents that were reviewed for this research include Comprehensive Development Agreements (CDAs),² Capital Maintenance Agreements (CMAs),³ TxDOT fact sheets, and registries from meetings during the bidding processes associated with each project. Additionally, information regarding change orders and other project characteristics were obtained directly from TxDOT through open records mechanisms.⁴

2. The TEXpress system

The TEXpress Lanes System (TEXpress System) connects the Dallas-Fort Worth region through a network of nine express corridors, all of which provide managed lanes with dynamic toll strategies as an alternative travel option running parallel with general-purpose lanes (i.e., lanes open to all vehicles and where no tolls are charged).⁵ The system’s managed lanes did not replace general-purpose lane capacity but rather reflect overall capacity expansion financed, at least in part, by the expected toll revenues. The capacity expansion included both managed and general-purpose lanes in several cases.

Table 1 presents an overview of all DFW projects evaluated in this project; Appendix A provides additional information on each facility. The nine corridors were built through six major development projects: 1) I-30; 2) I-35-E; 3) Midtown Express, including SH 114, Loop 12, and SH 183; 4) I-635 (LBJ); 5) North Tarrant Express (phase 2), including Northeast Loop 820, Airport Freeway (phase 2), and 6) I-35W.

The system’s dynamic tolling approach adjusts toll rates every five minutes based on real-time traffic conditions to guarantee a minimum speed of 50 miles per hour. Tolls are collected by the North Texas Toll Authority (NTTA), which distributes revenues to each concessionaire/agency. The actual algorithm for price adjustment may vary according to concessionaire/agency, but these overall features are the same: the per-mile toll rate is usually a function of the traffic density of the managed lane and the actual toll charged is the product of the toll rate and the mileage covered by each toll gantry. The expected tolls (usually for the next two or three segments) are displayed before the managed

² CDAs serve as the contract between the private contractor and public agency for performing different tasks in transportation projects. These agreements typically combine elements such as design, development, finance, and construction.

³ CMAs serve as the contract to provide capital maintenance services for a project for a prespecified period of time, unless terminated.

⁴ https://www.txdot.gov/apps-cg/contact_us/form/openrecords.htm.

⁵ A tenth corridor (I-635E) is currently being converted from HOV/Express to a TEXpress lane.

Table 1
General Characteristics of the TEXpress System.

Project	Corridors	Delivery Method	Concession Length or Maintenance Option	Number of Managed Lanes (Maximum), Excludes General Purpose Lanes & Frontage Roads	Design and Construction Costs, excluding right of way (US\$ million, 2017 dollars)	Annual Average Daily Traffic (AADT), 2018	Centerline Length (Miles)	Contract Award Year	Opening Year
I-30 TEXpress	I-30	DBB	None	2 (reversible)	67.90	128,957	12	2013	2016
I-35E TEXpress	I-35E	DBM	Up to 3 5-year renewal options	2 (reversible)	910.83	101,000	18	2013	2017
Midtown Express Project	SH 114 – TEXpress Lanes	DBOM	25-year concession	2 (each direction)	989.42	102,700	14.5	2014	2018
	Loop 12 – TEXpress Lanes	DBOM	25-year concession	1 (each direction)		212,159	2.5		2018
	SH 183 – TEXpress Lanes	DBOM	25-year concession	1 (each direction)		20,916	13.7		2018
LBJ TEXpress Lanes	I-635 / I-35E	DBFOM	52-year concession	3 (each direction)	2,469.67	180,782	13.3	2009	2015
North Tarrant Express (NTE) TEXpress Lanes 1&2	Northeast Loop 820 Airport Freeway	DBFOM	52-year concession	2 (each direction)	2,399.44	110,264	6.4	2009	2014
NTE TEXpress Lanes (Phase 3)	I-35W	DBFOM	52-year concession	3 (each direction)		125,580	6.9		2014
			45-year concession	2 (each direction)	1,373.26	141,876	9.8	2013	2018

Sources: Project documents, including comprehensive development agreements (CDAs) and capital maintenance agreements (CMAs). **Notes:** Construction costs include not only managed lane implementation but also improvements and expansions to the general-purpose lanes and frontage roads adjacent to the TEXpress corridors. However, it is very challenging to allocate total costs to different elements at the project level based on the public documents. They are kept as a lump sum in this analysis, but future research may further divide them based on new information. Construction costs do not include expenditures related to operations and maintenance activities. Design and Construction costs are normalized to 2017 prices (using the consumer price index). The AADT values represented in this table reflect the highest trafficked segment within each corridor, as measured in 2018 (TxDOT Traffic Count Database System, TCDS).

lane entrances. The toll setting algorithms are usually proprietary and are not disclosed to the public even for the express lanes operated by the public sector. However, a single public entity, the NTTA, collects tolls for all facilities. The public sector (TxDOT) manages toll setting and equipment for the I-30, I-35E, and Midtown Express facilities; P3 companies manage these functions for the LBJ and North Tarrant Express facilities.

3. Delivery methods & risk sharing

TxDOT employed four methods when delivering the six TEXpress system projects between 2009 and 2014: design-bid-build (DBB) for I-30; design-build-maintain (DBM) for I-35E; design-build-operate-maintain (DBOM) for Midtown Express; and design-build-finance-operate-maintain (DBFOM) for LBJ and North Tarrant Express phases 1 and 2, and I-35W (see Table 1).

3.1. Risk allocation

In the literature, researchers have argued that one major advantage of P3 procurement compared to conventional project delivery is its ability to foster innovations and improved project management through risk allocations that are better aligned with the capabilities of the different parties involved (Gifford, 2020; FHWA, 2012). These risk-sharing mechanisms are usually defined in the concession agreements and the details may vary even between projects of the same delivery method. Understanding such details is very important for assessing the incentives and costs for different parties at different stages of the projects, and thus setting the stage for an “all-in” performance comparison to be conducted fairly and scientifically. Therefore, this paper first reviews the risk-sharing mechanism.

There are many risks associated with a complex highway project such as those considered here. These risks may arise at different stages of the project and may be associated with different aspects: design,

construction, and operations and maintenance. Many risks arise well before the project reaches financial close, including political risks, regulatory risks, site risks, permitting risks, planning, and NEPA process risks, and procurement risks (FHWA, 2012). Although these risks embedded in the project development phase are significant and may affect the success of a P3 project, many of these risk components are only considered in the internal deliberations from the private or the public side and are not well captured by the public documents we assembled. Therefore, this project only considers risk allocations after a CDA is signed. This research groups these risks into five different categories: design, construction, operation and maintenance, finance, and demand. For each category, the risk is further divided and allocated in different ways. An additional risk is associated with lifecycle costs and handing back the project in a good state of repair at the end of the concession. This is addressed in Section 5.

Design risk relates to which party is responsible for the design phase of a construction project. The risk is the cost associated with a design that has errors or omissions that will need to be fixed later. Such costs might be large, especially if those deficiencies are discovered after construction has commenced. This risk also includes the potential delays and costs if the P3 concessionaire tries to introduce design innovations that may require additional regulatory reviews such as environmental reevaluation. Engaging the private sector earlier in the project development process might stimulate innovation and reduce such risks later in the process. Conversely, excluding the private sector involvement early in the project planning process may significantly limit innovative solutions (Bolaños et al., 2019b; Grimsey and Lewis, 2005; Ormijana and Rubio, 2015a). Still, some projects might have restricted room for design adjustments, and thus private-sector involvement may not necessarily lead to the adoption of innovative solutions (Rangel and Galende, 2010).

Construction risks relate to cost and schedule. Cost risks arise from conditions not anticipated in the contracted construction cost. Such increases might be caused, for example, by the discovery of site conditions that are different from those originally expected that may force the

developer to change the basic design of the project or take additional mitigation measures. For instance, the discovery of historical remains might delay construction or force the developer to change the alignment of the roadway. Some projects also require the builder to maintain traffic while the project is in development, which entails another dimension of risk.

The other dimension of construction risk relates to schedule. Essentially all contracts, P3 or otherwise, contain completion deadlines and may include late completion penalties and early completion incentive payments. The literature suggests that the late-completion penalties or early-completion rewards are not the only incentives for P3 projects to explore construction innovations. Early completion would allow P3 projects to start generating toll revenues ahead of schedule, which could provide a stronger incentive (Bolaños et al., 2017; Gifford, 2020).

Demand-risk DBFOM P3s like LBJ and NTE sometimes include schedule incentives above and beyond those embodied in the comprehensive agreement between the P3 and the owner. Such projects may pass on to the design-builder not only the late penalty imposed by the owner through the comprehensive agreement but also all the debt service requirements between the concessionaire and its lenders. Thus, the financial incentives for on-time completion for the design-builder are very strong.

Operations and maintenance risks are associated with the cost variations for preserving a previously defined performance for the project after final acceptance. These costs could be affected by the initial building standards, the construction quality, the level of usage, the weather, and the maintenance strategy (e.g., type and frequency of major rehabilitations). Operational risks are associated with cost variations for conducting routine activities that aim to sustain the overall capacity of the facilities daily, such as traffic incident detection and weather responses.

Finance risks are associated with the costs of securing the funding for the design, construction, maintenance, and operation of the highways. For example, P3 projects may apply for federal aid (e.g., Transportation Infrastructure Finance & Innovation Act, TIFIA) or credit assistance, which are subject to federal review and approval. P3 projects may also need to issue bonds in the market. All these activities involve some risks that may introduce additional costs or even jeopardize the successful delivery of a P3 project. Although demand risks may affect the revenues of a P3 project, thus contributing to the financing risks, they are so fundamental to a P3 project, particularly under the revenue-risk model, that they are usually laid out separately.

Demand risks are associated with the revenue uncertainty surrounding the future use of the new infrastructure. This risk is intrinsic because of the uncertainties related to population growth, gas prices and taxes, economic growth, construction of new competing facilities, and other unforeseeable events. The 2008–2010 economic recession and 2020 Covid-19 pandemic, both of which have dramatically reduced demand for travel in most U.S. markets, are extreme examples of this kind of risk (Casady and Baxter, 2020). Availability payment projects place no demand risk on the developer, by contrast.

In demand-risk P3 projects, the public sector is largely shielded from such risks (Gifford, 2020). In the most extreme cases, the demand may be so low that the project companies can no longer service their debt and declare bankruptcy. In such cases, the road will still be operated and remain open to the public. For example, Bolaños et al. (2019a) compared U.S. and European bankruptcy policy and concluded that U.S. policy minimized the fiscal impact of bankruptcies on asset owners.

Moving demand risk to the private sector imposes a market test of the government sponsor's traffic projections since developers will have to risk their capital and future dividends on a project traffic forecast. In revenue risk projects such as the P3s in DFW, the equity share of the project is typically higher than those where the government takes the revenue risk because lenders want more equity at stake to protect them in case revenues fall short. Some evidence in the literature shows that the private sector tended to be overly optimistic about the demand for

express toll lanes prior to the financial crisis of 2008 and 2009 (Bain, 2009; Lemp and Kockelman, 2009). As mentioned earlier, bearing demand risk also incentivizes the developer to design the project in such a way as to attract as much traffic as possible (Ormijana and Rubio, 2015a; Rouhani et al., 2015).

This literature review ultimately suggests that risk allocation will shift from the owner to the private sector as the delivery mechanism shifts from traditional delivery to the P3 model (Gibson et al., 2015; see also Rall et al., 2010).

3.2. Risk allocation in the TEXpress system

Risk allocation in the TEXpress system supports the expectation that P3 projects shift greater risk to the private sector. Table 2 summarizes the risk allocation mechanisms for the six projects considered in this study (NTE phases 1 and 2 are combined in this table). Appendix B defines all variables used in Tables 2 and 3. As is evident from Table 2, there is considerable variation in risk allocation. As expected, risk allocated to the private sector increases as the procurement approaches move from the traditional DBB approach to P3 (e.g., DBFOM). Except for the I-30 project, whose DBB approach leads to the least private-sector involvement, design risks remained with the private sector for all projects. In the case of I-30, the builder was responsible for executing a previously defined construction project.

The I-35E and Midtown facilities' respective DBM and DBOM approaches incorporate greater private-sector involvement, bearing most construction risks and shifting routine and major maintenance risks entirely to the private sector. The LBJ and the two phases of North Tarrant Express (NTE) projects' DBFOM delivery approaches give the private sector the most extensive risk portfolios. This is consistent with the fact that managing risk has been one of the main reasons motivating public agencies to engage in P3 projects, coupled with lack of funds (Bolaños et al., 2019b).

In particular, the LBJ and NTE P3 projects have transferred demand risk to the private sector. With traditional delivery, if toll revenue falls short, the government would be responsible for providing the funds to service project expenses, including debt service and O&M. Such funds might otherwise have been available to fund new transportation projects or for government purposes outside the transportation department.

3.3. Hypotheses and research questions

This initial analysis shows that the six projects offer a diverse portfolio of risk allocation mechanisms. The traditionally delivered I-30 project allocates the most risk to the public owner, while the DBFOM approach used for LBJ and NTE phases 1 and 2 shifts the most risk to the private sector, with other projects falling in between. As discussed earlier, these risk allocations may foster innovations in different areas, including design, construction, operations, and maintenance.

Driven by the desire to minimize design and construction risk and to start collecting toll revenue as early as possible, demand-risk DBFOM P3 concessionaires are incentivized to do a better job in project design and construction to ensure speedy project delivery. At the same time, P3 concessionaires are also incentivized to add design innovations to the state's original design concept in order to improve the expected demand for the project. For example, concessionaires may recognize opportunities to provide better and more numerous access points between the existing network and the new facilities than envisioned in the state's original design concept. Such enhancements may enable connections between the existing network and the new facilities that were not possible in the state's original design concept. Or the enhancements may expand capacity at critical points to facilitate connections the state's design concept had anticipated. The expected increase in revenue from such enhancements offsets the increased construction cost and complexity for such connections. Pursuing these two competing objectives may generate complex dynamics during the project design and

Table 2
Risk-share comparison.

Risk Element	Project (Delivery Method)					
	I-30 (DBB)	I-35E (DBM)	Midtown (DBOM)	LBJ (DBFOM)	NTE-1&2 (DBFOM)	I-35W (DBFOM)
Design	P	D	D	D	D	D
Construction – Utilities	P	S	S	D	D	D
Construction - Historical Remains	P	S	S	S	D	D
Construction - Soil Contamination	P	S	S	S	S	S
Construction - Geological Conditions	P	S	S	D	D	D
Construction – Right-of-Way Cost	P	S	S	P	D	D
Construction – Right-of-Way Time	P	D	D	P	D	D
Construction schedule	D	D	D	D	D	D
Construction cost overrun*	P	S	S	S	S	S
Maintenance (routine & major)	P	D	D	D	D	D
Operation	P	P	D	D	D	D
Finance	P	P	P	D	D	D
Demand	P	P	P	D	D	D

Source: Project documents, including comprehensive development agreements (CDAs) and capital maintenance agreements (CMAs).

Notes: *Considering overrun costs due to changes in materials quantities to the execution of the work. Risk held by the private developer (D), the public sector (P), or shared (S).

Table 3
Construction provisions.

	Project (Delivery Method)					
	I-30 (DBB)	I-35E (DBM)	Midtown (DBOM)	LBJ (DBFOM)	NTE-1&2 (DBFOM)	I-35W (DBFOM)
Bid Type	Quantities			Lump-Sum Fixed Price		
Change Orders						
Number of change orders	207	28	13	0	8*	Not avail.
Value of change orders (% of original construction price)	6.6	4.1	-1.2	0	0.35	Not avail.
Schedule						
Completion Deadline	Yes	Yes	Yes	Yes	Yes	Yes
Penalty for Late Completion	No	Yes	Yes	Yes	Yes	Yes
Min. Daily Penalty for Late Completion – Concessionaire to Owner (US\$)	\$0	\$163,000	\$107,000	\$50,000	\$5,600	\$55,000
Min. Daily Penalty for Late Completion – Contractor to Concessionaire (US\$)	\$0	Not avail.	Not avail.	\$59,000	\$143,333	\$183,118
Project Completed According to Initial Schedule	No	No	No	Yes	Yes	Yes
Construction delay (days)	769	61	30	-221	-246	About 2 months early *
Construction Standards						
Noise Level Requirements	No	Yes	Yes	Yes	Yes	Yes
Vibration Level Requirements	No	Yes	Yes	Yes	No	No
Air Quality Requirements	No	Yes	Yes	Yes	Yes	Yes
Responsibility for Existing Assets	No	Yes	Yes	Yes	Yes	Yes
Insurance Coverage	No	Yes	Yes	Yes	Yes	Yes
Traffic Management during Construction	No	Yes	Yes	Yes	Yes	Yes

Source: Information acquired from TxDOT through the Public Information Act and from project documents, including CDAs and CMAs.

Notes: See Appendix II for variable definitions. *Personal communication, Michael Gage, Alternative Project Delivery Supervisor, TxDOT, 3/21/21.

construction phases, which requires a more detailed investigation. In short, P3 projects involve more design innovations to improve access and throughput, while still meeting the construction schedule.

For O&M, P3 projects are incentivized to minimize service disruptions due to maintenance or incident responses so service time and revenue can be maximized. P3 projects may also take additional measures, such as reconfiguring on-ramps and/or merging points and better coordination with upstream entrance points, to minimize congestion and maximize revenue. Therefore, all else equal, P3-managed lane projects are expected to serve more travelers (i.e., higher volumes at higher speeds) due to revenue incentives.

This paper will first compare the standards or provisions that specify expected services among the six projects. The paper will then investigate the evidence (either quantitative or anecdotal) to test these hypotheses. This project will point out the need for future efforts if the comparison is inconclusive because of significant data gaps.

4. Construction

4.1. Standards based on CDAs

Table 3 compares the construction provisions that are relevant to this analysis for each of the six TEXpress projects. Information about defect rectification periods⁶ is omitted due to a lack of data for four of the six projects.

All projects employed lump-sum fixed prices except for I-30, which stipulated material quantities. All six contracts include specific completion deadlines. Except for I-30, all the projects also include a specific daily penalty in dollars for late completion, ranging from \$5,600 to \$163,000 per day. In addition, the three DBFOM contracts also imposed internal penalties on the design-builder for late delivery, with minimum penalties ranging from \$59,000 to \$183,118 per day. In

⁶ This is a fixed period, starting at the date of practical completion, whereby the contractor must return to site to rectify defects (if any are discovered).

contrast, the I-30 contract did not specify a late completion penalty. I-30's lack of a specific penalty for late completion may make the construction deadline less enforceable and it may deserve further investigation through interviews to see if any alternative enforcement mechanism has been involved in this case.

Except for the I-30 project, all TExpress contracts include specific requirements for environmental practices (noise, vibration, and air quality), maintenance of existing assets, insurance coverage, and traffic management during construction. In general, the contracts require compliance with national (e.g., National Environmental Policy Act, NEPA) and State (Texas Commission on Environmental Quality, TCEQ) regulations. Only the NTE project contained, in its Master Development Plan, provisions of additional measures for dust and particulate control during the construction phase.⁷ These additional provisions may raise the bar for the NTE project and their implications for construction costs deserve further investigation.

4.2. Construction performance

When comparing the construction performance of the six projects, the number of projects evaluated is not large enough to support any robust statistical analysis. Instead, this study focuses on anecdotal evidence and points out directions that should be explored further with a larger pool of projects.

For the projects where change order data is available, the lump sum fixed-price contracts had far fewer change orders and closer adherence to the original budget. The I-30 project had roughly seven times more change orders than any other project. LBJ, by contrast, had zero. The final construction costs of the I-30 project overran the original budget by 6.6%, the highest overrun within our sample. Among the 207 change orders for the I-30 project, 83 were related to the addition of items not initially included in the contract and 124 represented changes in the quantities used. Within this last group of change orders, the average variation in quantities was equivalent to a 40% increase over the initial amount. This huge difference in the number of change orders between I-30 and the other projects supports the expectation that lump sum fixed-price contracts provide greater predictability for owners than the model of bid quantities.

With respect to schedule, for the four P3 projects where data is available, they performed much better than the DBB project. LBJ and NTE phase 1 reached completion 7 and 8 months ahead of schedule, respectively. I-30, in contrast, was more than two years late, although contract amendments avoided late-completion penalties. I-35E and Midtown experienced more modest 61-day and 30-day delays, respectively. In the case of I-35E, the extension of construction time was mainly due to the state exercising several design options on the basic scope of the project, amending the contract to avoid late-completion penalties. The Midtown project did incur penalties for late completion.

LBJ and NTE were the only projects to reach completion substantially ahead of the original schedule. The contracts' late completion penalties in these two P3 projects are smaller (\$50,000 and \$55,000 per day, respectively) in comparison to the I-35E and Midtown projects (\$163,000 and \$107,000 per day, respectively).

Without evidence about why projects were late, it is impossible to determine whether the procurement method was a factor. I-30's lateness and high number of change orders may have been the result of changes prompted by TxDOT after the contract was let, and the absence of penalties is suggestive but not definitive.

The early or nearly-on-time delivery of the P3 projects and their low number of change orders is also suggestive but not definitive. It may be that TxDOT chooses P3 delivery where it is settled about a project's scope and expects few if any change orders.

⁷ <https://www.txdot.gov/government/partnerships/current-cda/north-tarrant-express/cda-mdp-1.html>.

4.3. Innovations through alternative technical concepts

One key aspect this research also investigates is whether the P3 arrangements incentivized more innovations through alternative technical concepts during the design and construction process, as the literature suggests. Ormijana and Rubio (2015b, 2015a) describe innovations introduced in the LBJ and NTE phase projects. Ormijana was with Ferrovial Agroman US Corporation and Rubio was with Cintra, both companies that are affiliated with the concessionaires that delivered these projects.

After the CDAs were signed, the LBJ P3 concessionaire did propose an alternative design for the interchange between LBJ and the Dallas North Tollway (DNT), which triggered an environmental reevaluation of the NEPA process under the liability of a private developer. The environmental reevaluation was completed within 13 months and the project was delivered on schedule with the modified design. This modified design was supposedly easier to construct and provides better technical feasibility to build future direct connectors at this interchange, which could boost travel demand by providing better accessibility to the LBJ.

Similarly, in the NTE phase 2 project, the south terminus of I-35W was redesigned to improve connectivity with the existing network after the CDAs were signed. This reconfiguration would have been significant enough to trigger a Supplemental Environmental Impact Statement (SEIS) process if it had been submitted after the NEPA Record of Decision (ROD) was granted. In this case, however, the P3 concessionaire partnered with TxDOT early in the process and the reconfiguration was included as a modification to the draft EIS. The new design was included in the final EIS and ROD, meaning the project schedule was not affected by this change.

For the I-30, I-35E, and the Midtown projects, the authors found no documentation about the implementation of alternate technical concepts (ATCs). However, this does not mean that ATCs were not considered or added in these three cases. Interviews with TxDOT officials who were involved in the project development could help validate or reject this point. Based on the available materials, the revenue-risk P3 arrangement did incentivize innovations in the design and construction process, while no such evidence was found in the projects that lacked revenue risk. On this point, more efforts are needed to move from anecdotal evidence to robust empirical results.

5. Operations and maintenance

5.1. Operations and maintenance standards

Lastly, the operations and maintenance features of the six projects were compared using the O&M standards stipulated in relevant contract documents. Table 4 shows O&M standards for the six TExpress projects. For the five P3 projects, standards were outlined in the contract documents. For I-30, the maintenance contract signed by TxDOT requires only routine maintenance. Thus, several maintenance items that apply to the P3 projects do not have standards for I-30. This is a major difference between the DBB project and the P3s: the only DBB project also has far fewer requirements for O&M.

Table 4 also shows that TxDOT applied similar O&M requirements across the five P3 projects. Requirements for pavement quality (IRI, skid resistance, and concrete joint tolerance), debris clearance time, road sweeping time, air quality, operation noise levels, snow and ice control and clearance, and customer service response were all identical across the projects. Some differences appear in standards for incident response time (stricter for the LBJ project), pavement failure remedy (stricter for Midtown), pavement markings remedy, and concrete joints repair (both laxer for Midtown). No clear trend links these limited variations with the projects' delivery methods.

The three DBFOMs and Midtown projects also contain handback requirements, which ensure that the asset is handed over to TxDOT in a

Table 4
O&M standards comparison.

O&M Standard Element	Project (Delivery Method)					
	I-30 (DBB)	I-35E (DBM)	Midtown (DBOM)	LBJ (DBFOM)	NTE-1&2 (DBFOM)	I-35W (DBFOM)
Incident Response Time - General (hr)	1	1	NA	0.25	1	1
Minimum Response Rime Compliance (%)	–	98	98	98	98	98
Debris Clearance Time (hr)	3	2	NA	2	2	2
Road Sweeping Time (hr)	3	24	NA	24	24	28
Snow and Ice Clearance (hr)	3	2	2	2	2	2
Pavement IRI (inch): Main Lanes/Frontage Roads	–	120/150	120/150	120/150	120/150	120/150
Pavement Failures Remedy (days)	–	28	10	28	28	28
Pavement Skid Resistance (inch)	–	30	30	30	30	30
Pavement Markings Remedy (days)	–	28	60	28	28	28
Concrete Joints Tolerance (inch)	–	0.25	0.25	0.25	0.25	0.25
Concrete Joints Remedy (days)	–	28	30	28	28	28
Operation Noise Levels	–	Yes	Yes	Yes	Yes	Yes
Operation Air Quality	–	Yes	Yes	Yes	Yes	Yes
Snow and Ice Control	–	No	Yes	Yes	Yes	Yes
ITS - Success Rate (%)	–	NA	NA	99.8	99.8	99.8
Customer Service (%)	–	100	100	100	100	100
Handback provisions	–	No	Yes	Yes	Yes	Yes

Source: Project documents, including comprehensive development agreements (CDAs) and capital maintenance agreements (CMAs).

Notes: See Appendix II for variable definitions.

good state of repair at the end of the concession period. The LBJ project, for example, requires the creation of a handback reserve fund five years before the termination of the agreement. Funded by the concessionaire, this fund is designed to correct any deficiencies in the asset’s state of repair prior to termination. This requirement may serve as yet another incentive for a more efficient lifecycle cost management (Gifford, 2020).

5.2. Operations and maintenance performance

The analysis above shows that TxDOT applied relatively uniform standards for operations and maintenance across all five P3-managed lanes in the DFW region, although minor differences did occur for certain criteria. This uniformity establishes a good case for performance comparison among projects of different delivery methods. For revenue-risk projects, the P3 concessionaires are incentivized to minimize disruptions due to incident responses or maintenance. In order to maximize the amount of traffic served, the P3 concessionaires are also incentivized to take different measures to avoid heavy congestion on the managed lanes.

However, collecting performance data remains challenging. The authors have contacted stakeholders in the region to collect O&M data, including travel speed, traffic volume, incident responses time, and road maintenance performance. This initial data collection effort found that little data is available. For example, operators may rely on third-party data providers such as INRIX to monitor travel speed along the corridor. However, the INRIX data did not date back to the period before 2012 in the region, which prevents a before-and-after comparison. Also, the traffic volume data along the managed lanes and the parallel general-purpose lanes and frontage roads are not systemically documented for some facilities maintained by TxDOT. The authors have collected one-month incident response data from the region. However, the period is too short to conduct a robust statistical analysis. Future research on comparative performance would thus be valuable.

In theory, it would also be possible to compare the accumulation of non-compliance points across the five P3 projects. However, this data is not readily available. Yet, such data could provide a useful basis for comparison in future research.

6. Summary, conclusions, and future research

The authors reviewed contracts, agreements, and other related documents associated with six express toll lane projects (nine corridors) in the DFW area. These projects were delivered using different methods,

ranging from conventional DBB to complex P3 provisions that cover design, construction, operations and management, finance, and eventual handback.

Risk allocation for these six projects aligns with theoretical expectations that P3 projects shift greater risk to the private sector than traditional delivery. Depending on the project delivery mechanism, the risks at each stage of the project are allocated differently between the private sector and the public sector. For the three DBFOM projects, LBJ, NTE, and I-35W, most risks are shifted to the private sector, creating both incentives and opportunities for the private sector to innovate to improve efficiency at different stages of the project.

Additionally, TxDOT imposed a high degree of uniformity across the TEXpress system’s construction, operation, and maintenance requirements, independent of varying delivery methods. The three DBFOM projects performed the best in meeting their original project completion schedules and involved the least change orders. The I-30 project, which differs from the other five projects, involved many more change orders. The results within this limited sample seem to corroborate that P3 arrangements transfer more risk to the private sector, reduce uncertainty about construction costs, and accelerate project delivery (Bolaños et al., 2019b; Gifford, 2020).

Taken together, the risk allocation demonstrated in this analysis of contract provisions and construction outcomes suggests that the use of the DBFOM model shifted risks successfully, resulting in better on-time delivery and fewer change orders. This finding is consistent with the theoretical rationales behind the use of P3s.

However, did TxDOT simply use DBFOMs for its simpler and less complex projects? This research did not examine what was behind TxDOT’s selection of procurement approaches. Yet, the three DBFOM projects were by far the largest of the DFW-managed lane projects. Their overall construction costs, \$1.4 billion, \$2.4 billion, and \$2.5 billion, greatly exceed the project values of \$68 million, \$911 million, and \$989 million for the DBB, DBM, and DBOM projects. To the extent project cost is an indicator of project complexity, it appears the DBFOM projects were more complex than the others. Indeed, these cases are consistent with TxDOT using DBFOM for its more complex projects.

The high degree of uniformity across the TEXpress system’s construction, operation, and maintenance requirements, regardless of the project delivery mechanism, also suggests that the performance of different projects during the construction and operations and management phases could be compared in a reasonable way. For example, even though TxDOT imposed very similar O&M requirements across the TEXpress System, concessionaires may vary in their performance in

meeting those requirements. Future research could explore how the public sector goes about monitoring project performance and compare performance outcomes with project delivery approaches.

This research also found that two of the revenue-risk projects, LBJ and NTE phase 2, included alternate technical concepts (ATCs). This finding is consistent with the notion that P3s incentivize ATCs, although it does not demonstrate causality.

Future research should evaluate whether the P3-delivered TEXpress facilities maximize throughput, mitigate congestion on both the express and general-purpose lanes, and provide more reliable services along the corridor through O&M innovations and efficiency improvement. These comparisons could help test theories about the incentives and opportunities for innovations created by P3 arrangements. For instance, private concessionaires that depend on toll revenues to remain profitable might respond to incidents more quickly to avoid revenue losses from prolonged disruptions. Similarly, the managed lanes' operational efficiencies could influence how congestion pricing schemes affect traffic speeds on both the managed and general-purpose lanes. More broadly, using DBFOM P3s for larger projects would presumably allow them to produce greater social benefits—i.e., more users should equate to more benefits. This might suggest, theoretically, that a welfare-maximizing procurement policy by a state would prioritize using DBFOM P3s for large and complex projects. Given that O&M requirements are similar

enough for both P3 and conventional projects, we hope to test more of these theories and hypotheses in the next phase of this project.

CRediT authorship contribution statement

Jonathan L. Gifford: Conceptualization, Writing – review & editing. **Shanjiang Zhu:** Conceptualization, Writing – review & editing. **Daniel Grimaldi:** Conceptualization, Data curation, Investigation, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. . Case descriptions

I-30 TEXpress.

The I-30 TEXpress facility is a 12-mile highway corridor in Dallas County consisting of two reversible managed lanes.⁸ The facility opened in August of 2016 with dynamic operations commencing six months later. Consistent with the other TEXpress System facilities, the I-30 facility offers a 50% toll rate discount to high occupancy vehicles (HOV) during rush hour periods. The facility was delivered through a traditional design-bid-build contract (DBB) with TXDOT taking responsibility for facility tolling, operations, and maintenance. TXDOT then hired a private company to manage the reversible lanes' maintenance and operations.

I-35E TEXpress.

Connecting Denton and Dallas counties, the I-35E express corridor comprises two reversible managed lanes, approximately 18 miles in length. The project cost \$845 million to construct over a period of roughly four years. In addition to the managed lanes' construction, the works included improvements to adjacent facilities and the creation of one extra general-purpose lane. TXDOT delivered the project using a design-build-maintenance (DBM) contract, transferring responsibility for managed- and general-purpose lane maintenance to the private concessionaire for up to three 5-years periods. The capital maintenance agreement specifies overall quality requirements for the facility's pavements, bridges, drainage structures, noise walls, and other features. The State oversees the fulfillment of these standards.

Midtown Express Project.

The Midtown Express Project includes three TEXpress corridors: SH-114, Loop-12, and SH-183. The SH-114 corridor has a total length of 14.5 miles and operates with one or two managed lanes in each direction, depending on the section, connecting Euless, in Tarrant County, to Irving, in Dallas County. The SH-183 TEXpress corridor is 13.7 miles long, connecting Irving and Grapevine. The smaller, 2.5 miles Loop-12 corridor operates in Dallas' northwest region. Both SH-183 and Loop-12 operate with one managed lane in each direction.

Delivered through a design-build-operate-maintain (DBOM) approach, the project's construction phase cost \$847 million and lasted roughly three years – from 2015 to 2018. The private concessionaire then took responsibility for operating and maintaining the corridors for a 25-year term, starting from the time of substantial completion. TXDOT remains responsible for dynamic tolling operations and for observing the concessionaire's O&M standards compliance.

LBJ TEXpress Lanes.

Operating within Dallas County, the LBJ TEXpress lanes comprise two interconnected corridors – I-635 and I-35 – totaling 13.3 miles (centerline). Both operate with up to three managed lanes in each direction depending on the section. TXDOT delivered the facility using a design-build-finance-operation-maintain (DBFOM) approach. The private concessionaire assumed the project's demand risk. Although the project employed \$445 million in public funds and \$790 million in TIFIA loans, it also received \$395 million from private bonds and \$683 million from private equity. Facility revenues derive from tolls charged over a 52-year concession.

Construction took four years, costing an estimated \$2.1 billion. The concession contract also included improvements and expansions to the existing general-purpose and frontage lanes, as well as their operations and maintenance for the concession term.

NTE TEXpress Lanes (Phases 1 and 2).

In June of 2009, TXDOT signed two DBFOM comprehensive development agreements for the North Tarrant Express project. The first agreement covered the delivery of a two-part, 13.3-mile segment in Tarrant County connecting I-35W to Bedford: Northeast Loop 820 and Airport Freeway. Construction began in 2010 with four managed lanes (two in each direction) opening to the public in 2014. The second agreement encompassed the design of a master development plan for additional three segments connecting between Fort Worth and Haslet to the Dallas Fort Worth Airport. As a

⁸ An additional, roughly six-mile portion reaching into Tarrant County remains under construction. The expansion is expected to open in 2021.

part of this plan, another agreement was signed in 2013 to deliver a 9.8-mile express corridor along I-35W. Construction for these additional managed lanes (two in each direction) concluded in 2018.

In addition to constructing the managed lanes, the same concessionaire assumed responsibility for improving, expanding, operating, and maintaining the existing general-purpose lanes. The concession terms equaled 52 years for the first phase, and 45 years for the second. The project received public funds and TIFIA loans, but a substantial share of the cost came from the private sector. As of this writing, the project’s private bonds and equity total \$1.5 billion.

Appendix B. . Project characteristics, variables, and definitions

Risk sharing	Design	Which party undertakes responsibility by the design of the project?	
	Construction – Utilities	Which party undertakes the increase in costs caused by utility adjustments?	
	Construction - Historical Remains	Which party undertakes the increase in costs caused by the discovery of historical remains within the construction site?	
	Construction - Soil Contamination	Which party undertakes the increase in costs caused by the discovery of contaminated soil within the construction site?	
	Construction - Geological Conditions	Which party undertakes the increase in costs caused by the discovery of contaminated soil within the construction site?	
	Construction – Right-of-Way Cost	Which party undertakes the increase in costs caused by changes in the ROW cost?	
	Construction – Right-of-Way Time	Which party undertakes the increase in costs caused by changes in the ROW cost?	
	Maintenance	Which party is responsible for general maintenance after the construction?	
	Construction Standards	Bid Type	L – Lump-sum fixed price Q – Bid on quantities
		Number of change orders	The number of executed change orders
Value of change orders (% of construction price)		The sum of all executed change orders divided by the original construction price.	
Construction Cost		Measured in millions U.S. \$	
Completion Deadline		Whether a commitment with a completion deadline	
Completion Penalty		Whether a penalty is imposed for late completion	
Completion Penalty Size		Maximum daily value paid as a penalty for late completion	
Completed According to Initial Schedule		Whether construction work met originally established deadlines	
Construction delay (days)		The difference (in days) between the day of work completion and the date originally predicted for the work completion.	
Noise Level Requirements		Whether specific provision for controlling construction noise levels	
Vibration Level Requirements		Whether if specific provision for controlling construction vibration levels	
Air Quality Requirements		Whether specific provision for controlling air quality during construction	
Existing Asset Maintenance		Whether concessionaire is responsible for preserving existing assets affected by construction	
Insurance Coverage		Whether concessionaire is required to acquire insurance coverage	
Traffic Management		Whether concessionaire is responsible for traffic control during construction	
Operations & Maintenance (O&M) Standards	Defect Rectification Period	Measured in years	
	Incident Response Time	General – time to respond to incidents (hours)	
	Minimum Response Compliance	Share of incidents that meet required incident response times (%)	
	Hazard Mitigation Time	Debris Clearance Time - time to clear roadway from obstructions and debris (hours) Road Sweeping Time - time required to sweep clean roadway areas (hours) Snow and Ice Clearance – total time, from loading point, to remove ice and snow (hours)	
	Pavement International Roughness Index (IRI)	Required Quality (inch)	
	Permanent Remedy Time	Pavement Failures – required time to remedy pavement failures (days) Pavement Markings Remedy – time to remedy sections that do not meet minimum requirements (days) Concrete Joint Repair – time to repair defects on concrete joints (days)	
	Pavement Skid Resistance	The minimum skid resistance acceptable without triggering obligation for remedial actions (inch)	
	Concrete Joints Tolerance	Maximum size tolerated for unsealed joints (inch)	
	Operation Noise Levels	Whether if specific mention regarding noise control levels	
	Operation Air Quality	Whether if specific mention about air quality control levels	
	Snow and Ice Control	Whether if specific mention of snow and ice control obligations	
	Intelligent Transportation System (ITS)	Success rate (%)	
	Customer Service	Inquires responded to in 10 days (%)	

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