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Procurement Choices and Infrastructure Costs

Dejan Makovšek and Adrian Bridge

5.1 Introduction

For many countries around the world, building new infrastructure or repairing existing infrastructure stands near the top of the political agenda. On one hand, countries face the political challenge of securing more funding. On the other, potentially large efficiency gains could be achieved spending the funds that are available. One area for possible efficiency gains involves how we choose to procure projects—the procurement strategy.

In the past decades, contract theory yielded several Nobel laureates (such as Oliver Williamson and Oliver Hart). Their insights led to significant advances in various aspects of how we contract. In the case of infrastructure delivery, however, our understanding of the outcomes of different contractual models is very limited despite decades of use. There is a general lack of empirical data to test whether our theoretical comprehension is complete.

Available evidence from testing contract and auction theory propositions allows us to explain the performance of the most common and simplest

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procurement formats (a design-bid-build contract with a cost-plus payment mechanism, procured in an auction) relatively well.

This is not the case for other procurement formats or larger projects. For instance, in dimensions other than speed of delivery, it is still not fully clear whether contracts that bundle the design-and-build phase outperform the traditional design-bid-build contract, where the two phases are procured separately. Similarly, the implications of using high-powered incentives that lead to greater time and cost certainty in major projects are unclear. Any judgment on other dimensions is even more challenging. In the absence of evidence, industry perceptions need not match reality.

Furthermore, the fact that data on some dimensions of project performance are available and publicly observable can create a bias in procurement and contracting choices against those that are not. For example, cost overruns bear serious reputational concerns and are relatively easy to measure. It is far more difficult to determine whether a project was relatively "expensive." By implication, public clients today procure billions of US dollars of transport and other infrastructure around the world without a full view of the trade-offs between different project performance objectives.

To inform the process of procurement, contract and auction theory offered broad predictions with regard to three key procurement choices: bidder selection, delivery model, incentive power. Combined, the predictions suggest that, for example, a lump-sum contract that combines the phases of design and construction (or also operations and maintenance) procured through a negotiated process should outperform a cost-plus contract in which the design and construction were procured separately and the winning bidder was selected through an auction.

In this chapter, we find that the available evidence does not match the predictions well, especially when it comes to larger, more complex projects. Negotiation and bundling do not clearly lead to less renegotiation per se. An important cause for this result is the inability of the public clients to specify their full needs in advance. An investigation into the root causes behind this result is beyond the scope of this chapter.

We also show that high-powered incentives, requiring high certainty of on-budget and on-time delivery, carry a disproportionate cost premium even in the absence of renegotiations (complete contracts). We argue that this mismatch between predictions and evidence is best explained by the underappreciated role of uncertainty. Currently, uncertainty in contract theory is mainly recognized as a driver of postcontract renegotiations. Uncertainty, however, has an equally important role as a driver of risk contingencies, when bidders need to price the contract in the bidder selection phase.

As a result, efficiency gains in high-powered contracts may be more than offset by contingencies in the private supply chain, driven by uncertainties implicit to complex major infrastructure. The same consideration would apply to high-powered and long-term contracts such as road public-private partnerships (PPPs).[1]

The research and decision-making challenges listed here are a symptom of a larger issue: empirically we know relatively little about how procurement choices affect contract outcomes in (infrastructure) procurement. To make progress on this front we need to introduce systematic infrastructure cost and performance benchmarking, which will also include procurement choices as an explanatory variable. This point, however, is not yet recognized by policy makers. A consequence of this state of affairs is that the current approaches governments use to inform procurement strategies of projects leave a wide margin for further improvement.

Looking toward the future, we conclude the chapter by acknowledging that resolving the issues of bidder selection, project phase bundling, and incentive power still does not represent a comprehensive procurement strategy. The reason is that two essential choices precede these decisions. First is the make-or-buy question: Which capabilities should a procurement entity procure from the market and which should it build in-house? Second, aside from the question of bundling project phases, there is a question whether a project be procured through one or several parallel contracts and where the boundaries between them should lie. Both choices will importantly predetermine the competitive response, well before we start planning the bidder selection process. Both choices also require stepping outside of the purview of auction and contract theory, taking lessons from other new institutional economics theories and beyond.

In reviewing evidence, this chapter specifically focuses on the most advanced economies with competent public clients and institutions. Two reasons merit this choice. The first is that the availability of evidence for advanced economies is much greater. The second is that we can more easily focus on the interaction between procurement practices and project outcomes, without serious white noise from the issues of systematic corruption and underdeveloped institutions; these will have a far lesser significance in advanced economies than in the developing world. A great majority of the available evidence concerns road infrastructure.

Section 5.2 of the chapter begins with a brief historical overview of procurement and contracting, from Roman times until today. This overview serves to introduce basic infrastructure procurement or contracting concepts and reveals that many fundamental procurement problems remain relevant to this day.

1. In road PPPs, for example, both the construction and the maintenance aspects have very strict on-budget requirements—that is, they have to be almost fully priced ex ante. There are no ex post corrections resulting from competitive pressure or incentive regulation. In the case of seaport PPPs however, competition could be present for the same catchment area, providing persistent incentives for efficiency and eroding abnormal rents.

Section 5.3 takes the basic concepts introduced in the historical overview and explains in greater detail the main infrastructure procurement choices: bidder selection, delivery model, and incentive power. As most of the available evidence on our topics concerns road infrastructure, we outline the dominant options used in that market.

Section 5.4 captures what parts of economic theory relate to infrastructure procurement. The auction theory focuses on the bidder selection process and considers the choice of the delivery model or incentive power as a given. Contract theory takes the reverse view and considers the bidder selection choice as a given. Key predictions of auction and contract theory with regard to the main infrastructure procurement choices are distilled.

Section 5.5 lays out what empirical evidence is available to assess the accuracy of theoretical predictions. Predictions that can be assessed are selected. In terms of infrastructure most available evidence comes from transport infrastructure or road projects. To the extent possible, large sample quantitative research will be captured. Sections 5.6 through 5.8 then assess the match between three key theoretical predictions and available evidence.

In section 5.9 we outline how advanced economies approach the procurement of major transport infrastructure. The most developed aspect here is the process of bidder selection, where the rules are enshrined in legislation. Choices with regard to the delivery model and incentive power are left to operational guidance. Recent developments in the UK and Australia are also presented.

Concluding the chapter, section 5.10 highlights where the theoretical predictions and empirical evidence do not meet and stresses the importance for international infrastructure benchmarking to advance the theory and practice of procurement. Recent advances also suggest that an expanded concept of what a procurement strategy should entail is needed.

5.2 History and Procurement Choices

Today most, if not all, public infrastructure managers in advanced economies contract parts or all of design, construction, and maintenance activities to the market. Exceptions in advanced economies, however, existed until recently.[2] The beginnings of public works contracting are ancient. For example, the Roman Empire dealt with the make-or-buy question by having the first roads designed and built by the army with the aid of civilian or slave labor. Over time, these activities were contracted out to contractors—master builders (Adkins and Adkins 2014). The works were given away through a tender, and it is assumed that the lowest price was the winning criteria (Du Plessis 2004).

2. Prior to reforms that ended in 2003 the Norwegian Public Roads Administration planned and built 60 percent of the main roads itself (40 percent was subject to competitive tendering) (Odeck 2014).

The master builder was an all-in-one profile, responsible for the design and delivery of the project. It was not until the Middle Ages, when increasing complexity of projects and the broader availability of paper (used to make preconstruction plans) led to the establishment of a specialized profession, that a different person became responsible for the design of the project (the "designer" or architect), separating design from the function of the builder (Kostof 2000). By implication, the builder now got involved later in the project development process, when the design was (or should have been) already worked out in detail. This was also the birth of the oldest and to date dominant delivery model, called design-bid-build (DBB).

Aside from the delivery model, there are other contract dimensions that define performance incentives for the contractor. The earliest documented considerations of risk allocation and incentives in contracts go back to Roman Empire times. In his 10 books on Roman construction practices, Caesar Julius's chief engineer, Vitruvius, acknowledged the importance of construction risk allocation. In terms of incentives to the builders, for example, he proposed to Caesar Augustus the reintroduction of a practice from ancient Greece (Morgan 1960):

> When a [master builder] accepts the charge of a public work, he has to promise what the cost of it will be. His estimate is handed to the magistrate, and his property is pledged as security until the work is done. When it is finished, if the outlay agrees with his statement, he is complimented by decrees and marks of honour. If no more than a fourth has been added to his estimate, it is furnished by the treasury, and no penalty is inflicted. But when more than one-fourth has been spent in addition on the work, the money required to furnish it is taken from his property.[3]

This is an example of an early payment mechanism to incentivize performance that has some similarities with today's pain- and gain-sharing in contracts. The basic payment mechanisms widely used today were also documented around medieval times. Construction contracts from the Spanish city of Girona in the fourteenth century were observed to be applying three different formats, including unit price and lump-sum (Chamorro et al. 2018). Unit price (also known as admeasurement or bill of quantities) contracts define rates per unit of work.[4] Estimates of quantities are provided at the beginning, and a correction is applied at the end given the actually executed quantities. A lump-sum (or fixed-price) contract, on the other hand, would determine the cost of the contract in advance without a detailed cost breakdown.

Expert discussions on the performance of the two payment mechanisms

3. The oldest construction codes go back to Hammurabi, when the principle of an eye for an eye was observed. For example, for a collapsed building that killed its owner, the builder was to be put to death as well.

4. Another term used for this payment mechanism in economics is "scaling auctions."

were documented already between 1800 and1830 when the UK, exhausted by war with the French, wanted to be more careful about spending public money. The proponents of the lump-sum contract argued that this was the only way of keeping within cost estimates (Port 1967, 97):

> An architect before he can make a [lump-sum] contract must make a specification, in which he must set down everything that can possibly occur. . . Before a [lump-sum] estimate can be made he must digest his plan, and every part of it must be made out, and he must put down on paper every detail that will possibly happen; and therefore you are sure that the architect must do his duty in the first instance.

Against a much more varied procurement context, the same issues highlighted here are still of interest today. Our methods may have improved over time, but so has the complexity of what we are building. As we shall see in the review of theoretical and empirical work, many of the old dilemmas remain unresolved.

The history of procurement history has been dominated by the idea that competitive bidding yields the best results, inhibiting alternatives. Negotiations were allowed only when competition was not possible. In the US, for example, the construction of the federal Interstate Highway System began with the Federal-Aid Highway Act of 1956. Until the 1990s, this program was almost exclusively procured through competitive bidding based on the lowest price, using a design-bid-build delivery model. The primary payment mechanism was the bill of quantities approach, still dominant today (Federal Highway Administration 2016). The domination of competitive bidding was enshrined through legislation that favored competitive bidding (23 U.S. Code § 112, Pub. L. 85–767). Other methods were allowed only on a declarative level—that is, they could be considered only provided they "are effective in securing competition." Effectively, methods based on negotiation were not desirable.

In the twentieth century the projects became more complex, more expensive (Brooks and Liscow 2019), and larger (Flyvbjerg 2014). In recent decades, particularly for larger projects, procurement models in which negotiations need to play a stronger role are achieving greater penetration.

The next section broadly explains the general characteristics of the main procurement options that exist today and sets the scene for the review of theory and empirical evidence.

5.3 Broad Characteristics of (Infrastructure) Procurement Choices

After a public client makes a make-or-buy decision—that is, decides to procure from the market—our brief historical introduction highlights three key dimensions of procurement choices: selecting the contractor, determining the scope of work the contractor is hired to do, and deciding on what basis to compensate the contractor. Building on Kennedy et al. (2018), we define these choices in the following subsections.

5.3.1 Selecting the Contractor

Bidder selection concerns the process between the moment a call for proposals is published to the moment the contract is signed with the preferred contractor. Multiple options exist between a lowest price auction and a negotiation with a single bidder. Negotiations facilitate the exchange of pre-contract information that reduces uncertainty at the expense of competition. Negotiations also imply greater discretion in bidder selection.

Table 5.1 illustrates the procurement procedures described here as defined in European Union directives (European Union 2014a, 2014b). These pro-

Table 5.1 **Procurement procedures in the EU**

Procedure	Description
Open procedure (Article 45)	In an open procedure, any business may submit a tender. The minimum time limit for submission of tenders is 35 days from the publication date of the contract notice. If a prior information notice was published, this time limit can be reduced to 15 days.
Restricted procedure (Article 46)	Any business may ask to participate in a restricted procedure, but only those that are preselected will be invited to submit a tender. The time limit to request participation is 37 days from the publication of the contract notice. The public authority then selects at least five candidates with the required capabilities, which then have 40 days to submit a tender from the date when the invitation was sent. This time limit can be reduced to 36 days, if a prior information notice has been published
Negotiated procedure with prior call for competition (Article 47)	In a negotiated procedure the public authority invites at least three businesses with which it will negotiate the terms of the contract. Most contracting authorities can use this procedure only in a limited number of cases—for example, for supplies intended exclusively for research or testing purposes. The contracting authorities in sectors such as water, energy, transport, and postal services may use it as a standard procedure. The time limit to receive requests to participate is 37 days from the publication of the contract notice. This can be reduced to 15 days in extremely urgent cases, or 10 days if the notice is sent electronically.
Competitive dialogue (Article 48)	This procedure is often used for complex contracts such as large infrastructure projects where the public authority cannot define the technical specifications at the start. After the publication of the contract notice, interested businesses have 37 days to request participation. The public authority must invite at least three candidates to a dialogue in which the final technical, legal, and economic aspects are defined. After this dialogue, candidates submit their final tenders.

Source: European Union directives (2014/24/EU; 2014/25/EU).

Table 5.2 **Frequency of basic bidder selection options in US road infrastructure procurement**

Procurement procedure	DBB (n = 134)	CM/GC (n = 34)	DB/LB (n = 39)	DB/BV (n = 77)
Low bid	80%	0%	100%	0%
A+B (cost + time)	13%	0%	0%	18%
Best value	1%	47%	0%	61%
Qualifications-based	1%	41%	0%	0%
Other or not classified	5%	12%	0%	21%

Source: Federal Highway Administration (2016).

cedures have counterparts in the US and other advanced economies that serve the same purpose.

Another aspect of the procurement procedure is to define the criteria based on which the bidders will be selected. Three common options are (1) the lowest price, (2) the economically most advantageous offer (a weighted combination of price and nonprice criteria), and (3) a nonprice or qualification-based competition.[5] Table 5.2 provides a snapshot of how frequently particular bidder selection criteria are used in US highway procurement across four main delivery models (these are outlined further later).

5.3.2 The Contractor's Scope of Work

The delivery model defines the stage of the project development (design maturity) at which a contractor is engaged and for what scope of work or services (for example, build-only, design and build, related risk allocation). Table 5.3 outlines common delivery models in use in advanced economies.

5.3.3 Compensating the Contractor

Incentive (or contract) power relates to the effectiveness of risk transfer and how strong the rewards or penalties are to manage performance metrics such as cost/time. The payment method is a key element of incentive power. Two polar opposites in this regard are cost-plus a fee or the lump-sum approaches. Table 5.4 outlines the common payment mechanisms in use. The frequency of different payment methods in US highway procurement is illustrated in table 5.5.

This overview illustrates a wealth of options procuring entities have in their arsenals today. In practice the combinations between the options in the three dimensions are not random.

The available literature shows that the workhorse of transport infrastructure procurement remains the design-bid-build model, procured through a low bid auction and a cost-plus (bill of quantities) payment mechanism (for

5. The criteria are defined based on measures of the bidders past performance or references. Qualifications could also be part of a two-stage process with preselection or included as one of the factors in the economically most advantageous offer.

Table 5.3 Commonly used delivery models

Delivery model type	Broad structure
DBB (design-bid-build) ("traditional delivery")	Design and construction separately and sequentially tendered to the private sector. Design either undertaken in-house or outsourced (for larger projects). Contractors engaged on basis of complete design (input-specified), with clients providing a design warranty. Contracts predominantly rely on bill of quantities payment mechanism. Lump-sum tends to be used only in smaller/simple contracts.
DB (design and build)	Design and construction are procured together from the private sector. At the time a request for proposal is issued, the design is developed up to an outline design level and the results are defined through an output specification (defines performance/end result) or a prescriptive specification (defines method and material). Contracts are predominantly fixed-price/lump-sum.
EPC (engineering-procurement-construction)	This option is similar to the DB variant with the two distinctions. Generally, there is no outline design available, only a specification of the functions the asset needs to perform. The contractual penalties for nonperformance (e.g. delay) can also be more severe than in a DB contracts. In PPPs, the project company (the SPV) contracts the design and construction through an EPC contract (and an operations and maintenance contract).
ECI (early contractor involvement)	Typically involves a two-stage process, with clients engaging a limited pool of contractors to work alongside designers, followed by a competed DB stage (with designers integrated into the contractor). Mostly used when conditions are highly uncertain or considerable innovation is required.
Construction manager/general contractor (CM/GC)	The client procures professional services on a qualifications or best-value basis from a construction manager. During the design phase, the contractor acts as a consultant to the client to offer suggestions on innovations, cost and schedule savings, and constructability issues. Upon completion of the design or individual design packages, the contractor and client negotiate a price for the construction contract, and then the construction manager acts as a general contractor to complete construction. The contract can employ a guaranteed maximum price administered on a cost-reimbursable basis, unit price, or lump-sum contract (Federal Highway Administration 2016). This approach is gaining prominence in the US and is similar to ECI.
Alliancing	Clients and selected contractors jointly prepare project scope and target cost and agree on a shared risk/reward mechanism (cost incentive). Parties are bound by open-book accounting, no blame/no dispute policy, and unanimous decision-making. Project functions—transcending planning, design, and construction—are integrated through a joint project management board. Mostly used when conditions are highly uncertain and/or complex.

Source: Kennedy et al. (2018), adapted by the author.

Table 5.4 Commonly used payment mechanisms

Payment mechanism	Broad structure
Remeasurement (also known as bill of quantities; unit price)	Using the remeasurement method (the measured or unit price contract), the works actually done are measured based on the individual rates and prices offered by the contractor in the bid in the bill of quantities (prepared by the employer). The bill of quantities contains particular items and gives a description of the work and quantity. Every individual item and the respective rate or price must beproperly contemplated and its content clearly understood to avoid disputes. The contractor will evaluate the rates and prices in the bill of quantities while keeping in mind prices for the materials, products, labor, equipment, plants, and so on (e.g., per cubic meter cost of the pit to be excavated). This process is called estimating and affords a means for the employer of comparing tenders received once they have been priced.
Cost-plus a fee (also known as cost reimbursable)	Under the cost-plus method, the contractor receives from the employer not only the payment for reasonable and properly incurred cost, but also a fee for overhead and profit. This method is more appropriate for high-risk projects where a lump-sum price (which takes all contingencies into account) would be too high. To encourage the contractor to perform the works for the lowest possibleprice, some additional mechanisms can be used—for example, the maximum guaranteed price or target price, described below. Under this arrangement, contractors are usually obliged to maintain comprehensive and contemporary cost records, and the employer usually reserves the right to audit the claimed costs to ensure they have been reasonably and properly incurred. The profit and overhead surcharge will be subject to competition in the tender period. This method is rarely used and is prohibited in some jurisdictions (Federal Transit Administration 2016).
Lump-sum (fixed-price)	Under the lump-sum method, a preagreed sum (regardless of actual cost incurred) is paid by the employer and the works actually done are not measured but paid against the schedule of payments, mostly once the predetermined sections (or milestones) are finished or when the project is fully completed. The lump-sum price is also influenced by claims, variations, and adjustments based on the particular contractual risk allocation, claims options, and variation (and adjustments) procedure.
Guaranteed maximum price	Employers sometimes want to cap the total contract price using the guaranteed maximum price to allocate all risks of potential price increases to the contractor. This approach is used and accepted, for example, in the United States using the construction management at risk delivery method. The main drawback of such a system is that it must be perfectly thought out in respect of risk allocation, insurance, securities, and financial reserves (or risk surcharges). Such a setup is not appropriate for projects in which numerous hazards with major risks are pending and it is not possible to price such risks transparently.
Target price contract	Under this regime, during the work two things happen in parallel. The contractor is generally paid actual costs plus a fee on a regular basis. The initial target price is adjusted during the work in accordance with claims and variations (compensation events) and their estimated cost. On completion, these two elements are compared. If there is a saving or a cost increase as against the target, thenthe parties share such savings or cost increases in the agreed proportions set out when the contract was agreed. A target price contract relies heavily on the ability of the procurement authority to competently engage with the private party in a collaborative fashion. It also assumes open-book principles—that is, the procuring authority should be able to monitor progress and actual costs incurred by the contract effectively.

Source: Klee (2018).

Table 5.5 **Use of payment mechanisms in US highway procurement**

Payment method	Design-bid-build (n = 134)	Construction manager/ general contractor (n = 34)	Design and build (low bid) (n = 39)	Design and build (best value) (n = 77)
Lump-sum	2%	3%	85%	91%
Cost-plus fee*	2%	0%	0%	0%
Remeasurement*	93%	38%	5%	0%
Guaranteed maximum price	0%	56%	0%	4%
Other or not classified	3%	3%	10%	5%

Note: Contract value ranged from $69,000 to $358 million with a mean of $27 million. *Description adjusted: cost-plus fee was originally "cost reimbursable" and remeasurement was originally "unit price."
Source: Federal Highway Administration (2016).

example, Federal Highway Administration 2016; Minchin et al. 2013).[6] This is true regardless of the project size. This procurement format is considered to be low-powered. Risk transfer to the contractor is minimal.

For major projects, ranging from several million to hundreds of millions of US dollars, other alternative contracting approaches have slowly started increasing in use since the 1990 in some advanced economies like the US, UK, Australia, Sweden, Netherlands (for example, for the US, see Federal Highway Administration 2016).

In US road infrastructure procurement, the introduction of alternative contracting approaches began more systematically with the initiation of the Federal Highway Administration's Special Experimental Project 14 (SEP-14) in 1990. Once cleared by the Federal Highway Administration (FHWA), the new approaches are no longer considered experimental; hence the state road agencies can use them on federal-aid projects without FHWA's approval. In 2004, the FHWA initiated SEP-15, which allowed contracting agencies to explore innovative approaches that address all phases of project development, such as PPPs.

The scope of this chapter does not extend beyond design-build (DB) and its close relative, the engineering-procurement-construction (EPC) contract, which is the default option for PPPs. Both alternatives are typically procured through negotiated procedures and rely on the lump-sum payment mechanism.[7]

6. The economics literature distinguishes between cost-plus and fixed-price contracts, whereas in construction contract law several formats could qualify. The cost-plus contract captures both the remeasurement and "cost-plus fee" payment mechanisms, while fixed-price contracts use the lump-sum payment mechanism. We note that cost-plus fee contracts are almost never used in infrastructure procurement and are prohibited in some jurisdictions (for example, the US; Federal Transit Administration 2016).

7. In the US, competitive bidding is used to secure a low bid or a best-value proposal (Federal Highway Administration 2016). That said, the Code of Federal Regulations (CFR; 23 CFR

A key distinction among the three delivery models involves at what point in the project development the contractor (that is, the winning bidder) is expected to price the project. A design-bid-build contractor would bid at a stage when the design is fully developed. In design-build, only an outline design will be available, where the engineering is typically 10–20 percent complete. An output specification will be available, though, describing what functions the asset should perform. For an EPC contract bidder there will be no outline design and only the output specification will be available. The DB and EPC bidders are expected to develop and price their solutions during the bidding process.[8]

Because the two alternatives also transfer design risk and ask for high cost certainty through the lump-sum payment mechanism and additional incentive mechanisms (such as liquidated damages for delays), these alternatives are considered to be high-powered procurement formats, with very high risk transfer.

In the next section, we look at the key predictions economic theory has made with regard to the three procurement choices. We do not deal with the make-or-buy question, as that topic deserves a separate paper, and instead focus on the three procurement choices just outlined.

5.4 Economic Theory Applications to Infrastructure or Construction Procurement

Two streams of economic theory deal with the basic procurement choices outlined earlier: auction theory and contract theory. Auction and contract theory have different focuses. Auction theory focuses on the bidder selection process and considers the project delivery model and incentive power as a given. Auction theory does not consider delivery models or incentive power. It does, however, yield insights or consequences for their application. Conversely, the main focus of contract theory has been the delivery model selection and incentive power. The results of the bidder selection process, i.e., the level of competition and price achieved are in this case a consequence of incentive power choices.

In both theories there is also a basic distinction between two types of contracts: complete and incomplete contracts. In complete contracts there are no ex post renegotiations. The winning bid fully reveals the bidder's revenue expectations ex ante. This could be the case for smaller and simpler contracts in infrastructure delivery.

§ 636) allows significant two-way information exchange activities between the proposal submission and bidder selection to reduce uncertainties or errors in the proposals. Recent research confirms this to be the case (Calahorra, Torres-Machi, and Molenaar 2019). For this reason, in economics this approach to bidder selection would qualify as "negotiations." The US variant of competitive dialogue—competitive negotiations—is applied in PPP procurement.

8. In practice these default options represent what is common, but they may not be always observed. For example, the level of outline design that the procuring entity makes available could vary.

In an incomplete contract, the bids no longer fully reveal the bidders' revenue expectations. Contracts are incomplete because writing comprehensive contracts is costly (Coase 1937; Klein, Crawford, and Alchian 1978; Williamson 1975, 1985), the project is too complex or the mere uncertainty of the future makes a complete contract impossible. The contractual incompleteness creates incentives for ex post bargaining and for good- and bad-faith renegotiation (Grossman and Hart 1986; Hart 1995; Hart and Moore 1990; Williamson 1979). The first is necessary because of unforeseen events, and the second is the result of strategic behavior to extract additional rents. The need to absorb changes leads to adaptation cost and what is more easily observable, cost overruns.[9]

5.4.1 Bidder Selection and Auction Theory Propositions

The traditional auction theory view has been that the benefits of competition always outweigh any other auction mechanism that involves fewer bidders (Bulow and Klemperer 1996). A key assumption behind this finding is that of complete contracts—that is, that the object of the auction can be well defined, which means the (lowest) price becomes the key determinant of the optimal result.

The more complex the object of procurement however, the less complete the contract. Therefore, auction theory adopted two main alternatives to auctions: negotiations and relational contracting. Both imply a trade-off with reduced completive pressure.

Goldberg (1977) suggested that competition for the contract stifles communication between the principal and the agent, which may lead to a sub-optimal specification of the project. He argued that the bidders might have important information about construction practices, prices, or other aspects that might allow the client to prepare a better informed tender, reducing ex post adaptation cost. So far, theoretical has work tried to formalize the trade-off between ex ante information exchange (in negotiations) and ex post renegotiation in auctions (Herweg and Schmidt 2017).

In cases when the public clients repeatedly contract with a pool of the same firms, the issue of incomplete contracts could also be managed by long-term relations, or relational contracting—that is, through the use of reputational mechanisms (Spagnolo 2012).

Reliance on mechanisms other than competition at the same time implies greater discretion in bidder selection on the side of the procuring entity. As a result, there is greater scope for corruption, favoritism, or other practices that do not necessarily lead to best procurement results. Both adjustments to the traditional view, which prefers auctions, focus on contractibility and by implication uncertainty as a source of renegotiations and adaptation cost.

In a limited stream of auction theory literature (Goeree and Offerman 2003;

9. These two terms are not equivalent; the distinction is explained later in the chapter.

Milgrom and Weber 1982), uncertainty affects the bidders' ability to price the subject of the tender (or risk) efficiently rather than enable renegotiations. Specifically, bidders can lack information about the true cost of the object that is being tendered.[10] When this is so, bidders will also not be able to accurately assess potential ex post changes and in consequence additional ex post revenue opportunities. If bidders are risk averse, the perceived risk variance and the resulting risk premiums at a given level of competition will be higher.

Goeree and Offerman (2003) identify two effects of more information and lower uncertainty. First, if more information is made publicly available to the bidders, risk premiums will get lower, and bidding will become more aggressive.[11] Second, more public information may reduce the entry barriers for less experienced firms, increasing the number of competitors, which has a knock-on effect on the aggressiveness of the bidding again.

What this all implies is that contracts could be complete, a good level of competition could be present, and the most efficient bidder could win, but the procurement of a project would still be inefficiently expensive if the bidders did not have sufficient information about the true cost of the object procured. The theoretical prediction in this case does not explicitly extend to the question of when we can use bundled or high-powered contracts. Implicitly, though, it can be deduced that, especially in these cases, the exchange of precontract information will be a key requirement.

5.4.2 The Choice of the Delivery Model and Contract Theory Propositions

Contract theory consists of two streams, the principal-agent theory and the property rights theory. It is the latter that proposes it is possible to solve

10. As Goeree and Offerman (2003) explain, in private value auctions, bidders know their own value for the commodity but are unsure about others' valuations. In contrast, common value auctions pertain to situations in which the object for sale is worth the same to everyone, but bidders have different private information about its true value. The standard textbook example for a private value auction is the sale of a painting. A well-known example for a common value auction is the sale of oil drilling rights, which, to a first approximation, are worth the same to all competitors. In the real world, most auctions involve a mixture of both. If, for example, the competitors for the oil drilling rights used different technologies (so that their cost structures would be different), their private valuations of the rights would be different. Hence, if the common value of the object is uncertain, a bidder with a moderate private value and an overly optimistic estimate of the common value may outbid a rival with a superior private value but more realistic conjectures about the common value. If the common value were less uncertain, then bidders with superior private values (the most efficient bidders) would consistently prevail, leading potentially to an even higher auction result. Goeree and Offerman's (2003) proposition is similar but distinct from the principal-agent theory problem of adverse selection driven by information asymmetry between principal and agent and cannot be solved by a menu of contracts.

11. The same result in conventional financial economics would be attributed to improved risk pricing efficiency (Makovšek and Moszoro 2018) through a mechanism more straightforward than that of Goeree and Offerman (2003). This mechanism implies that risk premiums do not only arise as a result of reduced risk diversification possibilities. They also result from the inability to accurately assess risk. As investors are risk averse, disproportionate markups are added to accommodate the lack of information about risk.

the incomplete contract problem by bundling the contract phases (Hart 1995, 2003; Iossa and Martimort 2015).

In property rights theory, the appropriate assignment of ownership or residual control rights gives the owner of the asset bargaining power in situations beyond those defined in the contract. The logic of this approach is manifest in the design-and-build contract, in which any issues with incomplete design are internalized within a single contract. Going one step further, in PPP, the residual control rights are transferred to a private party.

In a stereotypical PPP, a dedicated project company (a special purpose vehicle) enters the contractual relationship with the public sector. The agreement between them defines an output specification—that is, what the project is meant to achieve, as opposed to what the project is (the input). The PPP is the bundling of project phases, from design to operations, in one long-term contract (for example, a design-build-finance-operate-maintain [DBFOM] contract).[12] The project company finances the project and recovers its investment either through a service-level agreement with the public client or by being granted the right to charge the users of the infrastructure (Engel, Fischer, and Galetovic 2014). The project company does not itself execute the project but organizes the execution through a network of contracts, passing the technical risks onto its suppliers (for example, construction risk to the construction contractor).

In such an arrangement the issues of incomplete contracts are internalized through two key incentives:

1. The output specification approach implies that the private sector partner obtains the residual control (ownership) rights to the infrastructure asset—that is, chooses the solutions to meet the predefined service standards. This approach is supposed to reduce contractual incompleteness issues, compared with the traditional approach, in which the input is defined by the public client.[13] The output specification also implies a full transfer of design, construction, and operations risk—a lump-sum/fixed-date contract.
2. The bundling of asset construction together with operation and maintenance into one single contract also incentivizes the private partner to invest in quality at the construction phase if such investments lower the project's life-cycle operating and maintenance cost.

12. While this is a common term to describe the broad contract arrangement in a PPP, the phase of design and build is contracted as the engineering-procurement-construction contract. As laid out in section 5.3, this format also bundles the design and build phases, but is generally tendered against an output specification. No outline design is made available.

13. The transfer of control rights also incentivizes investment into relation-specific assets (sunk with no or limited alternative use)—that is, infrastructure—despite the presence of an incomplete contract. In theory the transfer of control rights would also incentivize innovation.

Iossa and Martimort (2015)[14] formalized these propositions and found that the design-build-operate-maintain bundle provision beats traditional procurement if benefits from bundling are significant.[15] A key proposition that defines Iossa and Martimort's results is the assumption that the life-cycle cost optimization savings offset the (additional) risk premiums of a high-powered (PPP) contract, in which the private party bears the operations risk; hence Iossa and Martimort suggested that bundling and high-powered contracts go hand in hand.[16] An implicit assumption to the conclusion above is also that the bidder selection stage would not be affected by bundling and the high power of the contract.

Hence, the theoretical prediction is that through bundling project phases (that is, the transfer of residual control), we can eliminate or reduce contract incompleteness.

5.4.3 The Choice of Incentive Power and Contract Theory Propositions

In terms of how much risk one should transfer in a contract, the principal-agent theory defined the problem as a trade-off between incentives and insurance. Incentives are provided through transferring risk or making the agent's payoff dependent on the agent's effort. The agent's risk aversion implies there is a cost to risk transfer. Hence, lower risk aversion on the part of the agent allows the principal to provide more incentives by making the agent's payment depend on the agent's effort, while higher risk aversion increases the gains from insuring the agent and reduces the pay-for-performance sensitivity (Holmstrom and Milgrom 1987). In short, risk transfer should be executed at a level at which the risk premium does not offset the gains from increased effort.

On top of this basic relation, the principal-agent theory in a complete contract setting applies the issues of the opportunistic behavior of agents resulting from the information asymmetry between the agent and the principal. Two problems emerge: the adverse selection ex ante and moral hazard ex post contract signature (Laffont and Tirole 1993).

Adverse selection in the bidder selection process can occur because the principal does not know the true efficiency of the agents (the bidders). This makes it difficult for the principal to determine who will exert the most effort

14. In an earlier paper, Iossa and Martimort (2012) included uncertainty in user demand as a factor in the risk premium and noted that the PPP only makes sense if the private party can assess the risk well. Hence, bundled contracts would make sense for less complex contracts. This point was not transferred to the more recent paper or applied in the context of construction risk.

15. An analogous approach could be applied to a design-build contract only, arguing that contract incompleteness resulting from design issues would be internalized in this contract format.

16. They also acknowledge that the long-term nature of this contractual arrangement brings with it additional uncertainty (resulting from exogenous shocks), which may lead to renegotiation of the PPP contract itself (in other words, despite the property rights theory approach, contractual incompleteness remains an issue).

at a given incentive. If contracts are complete, however, the initial bid fully reveals the contractor's revenue expectations up front and there can be no ex post renegotiation. This means that when renegotiations are unlikely, a high-powered incentive—that is, a lump-sum (high-powered) contract—will ensure the best contractor is chosen in the competition (Bajary and Tadelis 2001).

When contracts are incomplete, the initial bid will not fully reveal the contractor's revenue expectations, and renegotiations will occur. Three theoretical solutions have been put forward.

Hart and Holmstrom (1987) sought to address the adverse selection problem in the context of incomplete contracts by offering the (potential) agents a menu of contracts, which allow them to be interested in the trade and reveal their true type.

McAfee and McMillan (1986) combined a bidding model with adverse selection and moral hazard challenges. These authors suggested that neither cost plus nor fixed-price contracts are desirable in an incomplete contract setting. The proposed solution is an incentive contract that makes the payment depend both on the bid and on realized costs: if realized costs exceed the firm's bid, the firm is responsible for some fraction of the cost overrun; if the firm succeeds in holding its costs below its bid, the firm is rewarded by being allowed to keep part of the cost underrun. A caveat to this result is that in McAfee and McMillan's model, cost-plus contracts give the contractor no incentive to bid aggressively; hence these contracts are never optimal.

A third option recommends low-powered incentives (Bajari and Tadelis 2001; Williamson 1985). Low-powered incentives have adaptability advantages. In construction, for example, this would be because cost-plus contracts involve a bill of quantities to which the bidders need to assign unit prices. If the actual quantities differ from the estimated ones the unit prices in the bill of quantities offer a reference price list to evaluate variation claims.[17] The lump-sum contract, on the other hand, involves only a general cost breakdown and it is not usual for it to contain a price/quantity breakdown as in the cost-plus (bill of quantity) contracts. Hence, the lump-sum contract is more rigid and involves greater transaction cost to renegotiate. A key driver behind this thinking is the assumption that the information asymmetry ex ante—the fact that the private party knows more than the public one, causing the adverse selection—is not the main issue. Both parties equally face future uncertainties.

Lastly, the moral hazard post contract signature manifests as quality shading. If the quality of the output is difficult to monitor, the contractor will reduce the quality to cut cost and increase profit margins. In this case

17. The contractor will still try to renegotiate the unit prices for the added work; however, the initial unit prices in the bill of quantities offer a reference point. This "anchor" is not available in the lump-sum arrangement.

high-powered incentives will exacerbate quality shading (Holmstrom and Milgrom 1991). If the quality is observable (at least after the job is finished), we can hold the agent financially accountable for his actions (Laffont and Martimort 2001), for example through performance guarantees.

The theoretical prediction of this part of contract theory is that in complete contracts we should rely on high-powered schemes, assuming ex post quality can be monitored. Thus, if bundling leads to greater contract completeness, bundling and high-powered incentives should go hand in hand.

If contracts are incomplete, several options are put forward. The obvious choice is to prefer low-powered incentives. More sophisticated propositions suggested the use a menu of contracts to ensure effective self-selection of the most efficient bidder. Lastly, McAfee and McMillan (1986) proposed a target price contract. In it, the public and the private party agree on a target in the competition phase and then share the savings or the losses at the end of the project.

5.4.4 What Does Theory Not Yet Address?

No economic theory would reconcile the perspectives of the auction and contract theory in a single model. One aspect that stands out in particular is the underappreciated role of uncertainty in contract theory, where it presently plays three roles:

1. A source of information asymmetry between the principal and the agent that interferes with the precontract identification and selection of the most efficient bidder
2. A source of information asymmetry between the principal and the agent, which ensures stronger incentives actually lead to greater postcontract effort
3. A postcontract source of renegotiations and adaptation cost

Uncertainty in contract theory, however, is not yet acknowledged as a source of less aggressive bidding or excessive contingencies ex ante. In short, it matters how well the bidders know the risks they are taking at the moment they need to price the contract.

A direct extension of this point is that the risk variance during contract execution is not just a question of choosing who will bear it but that of reducing or increasing it. A further unaddressed key question is whether it is more sensible to create the information to reduce the risk variance sooner in the project development cycle or later and who should do it.

Goldberg (1977) illustrated that if the bidders bore the cost of risk identification, it would be absorbed as overhead and included in future bids. Conversely, if the client fully compensated bidding cost, that would equal a cost-plus contract negotiated with a single bidder. In the precontract phase, it would be inefficiently costly, but these costs could well be offset by greater efficiency in the contract execution phase (more aggressive bidding and better contract specification or engineering solutions).

If bidders are to bear the cost of risk identification, is it efficient for all bidders (including the losers) to produce the same information (all detect the same risks separately)? Against the prospect that they might lose, do bidders invest sufficiently in information production? These are major issues for the procurement of complex projects that remain unaddressed in theory.

The next sections look at whether the empirical evidence matches theoretical predictions in the procurement of infrastructure.

5.5 Testing Theoretical Predictions and Available Evidence

Our review of auction and contract theory revealed a range of applications to infrastructure (or construction) procurement. The available empirical evidence allows us to further assess the following predictions, arranged according to three basic procurement choices:

1. Bidder selection
   - In complex projects increased exchange of precontract information should lead to more aggressive bidding and reduce the end cost of the project.
   - Negotiations should be preferred to auctions, because they allow an increased precontract information exchange and thus help reduce the need for costly renegotiations during contract execution.
2. Delivery model
   - Contracts that bundle project phases (for example, design and build) should also help reduce the incidence of renegotiations.
3. Incentive power
   - Fixed-price or lump-sum contracts are to be preferred in contracts in which there is little to no renegotiation—in other words, contracts that are complete. In all other cases cost-plus contracts should be used.

Other alternative propositions on how to inform incentive power in incomplete contracts in infrastructure procurement cannot be assessed because of lack of use in practice (the case for menus of contracts) or lack of evidence about the performance of the solution (the case for the target price contract).[18]

18. In practice this option is used in collaborative projects, in which the public and private parties jointly manage the execution. A high level of professional competence on the public side is required. Furthermore, the effectiveness of the method lies in the assumption that the public side can monitor the required cost of the contractor effectively. If that is not the case, the contractor is incentivized to bid with a high target and build on cost, maximizing private rents and essentially transforming this approach into a lump-sum contract.

With regard to the predictions that we can assess, ideally the evidence would allow us to secure a view of comparative statics—namely, how a change in a single procurement choice, keeping all else equal, affects the project outcomes. The outcomes would in their minimum configuration control for the trade-offs between cost certainty (that is, cost overruns), overall cost per physical unit of infrastructure, and quality. Since no piece of evidence meets this ideal, and since project outcomes can depend also on factors other than procurement choices, several explanations with regard to the interpretation of the evidence in this chapter are required.

Geographically, in its review of evidence this chapter specifically focuses on the most advanced economies with competent public clients and institutions. Two reasons merit this choice. The first is that the availability of evidence for advanced economies is much greater. The second is that we can more easily focus on the interaction between procurement practices and project outcomes, without serious white noise from the issues of systematic corruption and the quality of governance. Poor execution of procurement processes or contract management can be a substantial factor affecting project outcomes. For the same reason we do not pursue evidence that concerns regional or local authorities.[19]

We found that that the quality of infrastructure is not explicitly controlled in any of the studies. Fortunately, in general most of the available evidence concerns road infrastructure in advanced economies. Road design standards in this case are well established with a long tradition, and quality supervision by the procuring entities is considered to be effective—that is, quality shading is not considered to be an issue. No available evidence would suggest otherwise. The same assumption is adopted in several large-sample studies (for example, in Bajari, Houghton, and Tadelis [2014] or in Bolotnyy and Vasserman [2019]).

5.6 Does Increased Precontract Information Exchange Increase Bidding Aggressiveness?

Negotiations allow for more space to exchange precontract information than auctions. By definition, a negotiated process reduces the power of competitive pressure, since the number of bidders with which one can simultaneously negotiate and mutual transaction costs will imply participation restrictions. As a consequence, a negotiated process implies a trade-off

19. Evidence on the impact of increased discretion in bidder selection and rare attempts to compare the outcomes of negotiations versus auctions almost in the entirety come from this strata (for example, Baltrunaite et al. 2018; Chabrost 2018; Coviello, Guglielmo, and Spagnolo 2018; Palguta and Pertold 2017), mainly showing a negative impact of increased discretion. A single study of larger projects for road authorities in the US also exhibits a negative impact (Park and Kwak 2017)

between reduced competitive pressure and increased ex ante information exchange.

That said, increased ex ante exchange of information or the reduction of the uncertainties faced by the bidder can also be achieved in auctions. Procurement authorities have the possibility to share risk-related information on the object of procurement, regardless of the bidder selection approach. The theoretical prediction was that making more information available during the tendering phase (that is, reducing uncertainty) can lead to more aggressive bidding and also affect market entry (Goeree and Offerman 2003).

Kosmopoulou and Zhou (2014) show how removing an exogenous risk factor for the contractors reduces the price of the winning bids in road construction. Considerable time may pass between the actual bid submission and contract completion. If input prices (for example, for oil) are volatile, contractors need to be mindful of potential future price variations that affect the cost of their products (for example, asphalt). As contractors cannot do much to control these costs, they are a source of exogenous uncertainty. In the US, multiple institutions have applied pass-through formulas for inputs affected by considerable price variability. The Oklahoma Department of Transport (ODOT) applied such a formula for asphalt mixtures (an oil-related input). If the initial oil price grew by more than 3 percent, an automatic additional payment would be disbursed to the contractor. Between August 2006 and June 2009, ODOT granted a net additional payment to firms equal to 5.05 percent of the value of eligible contracted items, in return achieving an 11.7 percent reduction (on average) in the price of winning bids for the eligible items. The study relied on several empirical methods to confirm its findings, including difference-in-difference and discontinuity regression design.

In the case of De Silva et al. (2008) the procurement authority made additional information available, which led to a reduction in bid prices. The Oklahoma Department of Transport (ODOT) in the past published the bill of quantities without detailed internal estimates of unit prices. ODOT then changed its policy and started revealing its estimate for each component of the project.[20] The study compared the winning bids for asphalt pavements and bridge work. Asphalt paving projects are relatively straightforward as the job descriptions typically specify an area of roadwork to be surfaced, the depth of surfacing required, and the material to be used. In bridge work, there is more uncertainty. Soil conditions at a site may not be fully known until excavation work begins, and repairs may not be fully under-

20. ODOT released "a set of individual cost estimates for each quantity of material used and each important task involved. As a result, this policy change provides detailed information that can reduce substantially the uncertainty related to common components of the cost. For example, in one case, the state can reveal the cost of excavation which depends on soil conditions, and in another, the cost of a specific bridge repair which depends on the extent of the damage" (De Silva, Kosmopoulou, and Lamarche 2009).

stood until some demolition work is undertaken. The analysis included the state of Oklahoma, where the procurement protocol changed, and the state of Texas, where it remained the same (in other words, a difference-in-difference approach was used). In total, more than 13,000 bids submitted by construction firms were analyzed over the period 1998–2003. No change was recorded for asphalt projects, while the average bid for the bridge projects was reduced by 9.6 percent, with the average winning bid reduced by 9 percent. Unfortunately, no information is available on whether contract renegotiations were affected as well.

Using the same data, De Silva, Kosmopoulou, and Lamarche (2009) investigated bidder entry and survival. Entrants are typically less informed than incumbents; hence there is also a difference in efficiency. If an entrant wants to penetrate the market, the entrant must take greater chances in bidding. If the entrant does not become experienced (informed) within a reasonable period, the losses will force the entrant to exit. In this particular sample there were 322 incumbent firms and 109 entrants participating in over 2000 auctions. Using panel data regression, it was found that the information release reduced the bidding differential between entrants and incumbents attributed to information asymmetries. In addition, the median length of entrant presence in the Oklahoma procurement auctions increased by 68 percent.

The available empirical literature discussed here refers to auctions in cost-plus contracts using the design-bid-build delivery model—a detailed design is already available at the bidding stage.[21] The evidence concerns small and by implication simpler projects.[22] Yet even at this level significant and disproportionate impacts of uncertainty have been measured (for example, absorbing a 5 percent input price uncertainty led to an 11 percent reduction in winning bid price). In relation to the theoretical predictions, this section confirmed that reducing uncertainty for the bidders ex ante positively affects the winning bid price and competition. No empirical work investigates larger, more complex projects.

5.7 Do Negotiations and Bundling Lead to Less Renegotiation?

Following the exposition of economic theory, less renegotiation reduces adaptation cost. Bajari, Houghton, and Tadelis (2014), analyzing auction-

21. The delivery model or incentive power are not mentioned explicitly. The mentioning of auctions and the use of the bill of quantities imply however that these were cost-plus design-bid-build contracts.

22. Absolute bid size in US dollars is not mentioned. An approximate contract size can be inferred from Kosmopoulou and Zhou (2014). They reported that eliminating oil price fluctuation generated savings of 5 percent, amounting to US$23 million in over 600 auctions. Kosmopoulou and Zhou further report that these savings concern eligible items (related to oil price) that represent about 40 percent of the project value. These numbers together lead to an average project size of about US$1.5 million.

procured design-bid-build cost-plus road projects in the US with a mean size of US $2 million showed that these can be significant on a sample of 3,661 bids. Several models were used to break down the outcomes into separate effects. The adaptation cost represented 7–14 percent of the winning bid and ranged from 55 cents to two dollars for every dollar of change. The bidders could foresee where adaptation would be necessary, and the private rents are competed away (the average bidder could expect a profit margin of 3.5 percent). This is the case for small projects, however, where the uncertainty the bidders face is limited.

The theoretical prediction is that negotiations might facilitate increased precontract exchange of information and reduce the need for renegotiations. The more complex the project, the stronger the case.

Lessons from the private sector (Bajari, McMillan, and Tadelis 2009) show that in residential construction industry (private-private transactions), negotiated projects prevail and are generally awarded to more efficient or more experienced contractors. There is no analysis, however, that would test the impact on procurement outcomes. Caution is also necessary when trying to draw lessons from private-private contract relationships and transpose them to public-private relationships. Spiller (2009) proposed that third-party and governmental opportunism increase the incentives of public managers and private investors to raise contractual rigidity. In consequence public contracts are created with less flexibility than purely private contracts. Recent evidence confirms this is indeed the case (Beuve, Moszoro, and Saussier 2019). By implication, public managers in a negotiated process may be less flexible than private ones.

For infrastructure procurement, however, there is no evidence that would test the impact of the introduction of negotiations, keeping all else equal—for example in design-bid-build projects.[23] The use of negotiations in design-bid-build contracts has a limited function, since the solution to the engineering challenge is already defined (through a detailed design). What is left to be negotiated in public sector procurements is the interpretation of the specifications and the price. This means negotiations or competitive dialogue would have the greatest value in delivery models, where the bidders can also inform the solution—specifically, in our case, in design-build and engineering-procurement-construction contracts. Evidence is available that allows us to assess whether renegotiations in these cases are less significant than in auction-procured design-bid-build projects. To do so, we look at cost overruns on road projects.

Cost overrun evidence is spread over small and large projects, which may exhibit different levels of complexity and ultimately interfere with our inter-

23. A few studies exist that try to capture negotiation effects, but these studies do not do so in terms of procurement outcomes, or they refer to lower levels of the government, or both (for example, Baltrunaite et al. 2018; Chever and Moore 2017).

pretation of the evidence. Hence our first task is to get a view of how cost overruns develop with project size.

5.7.1 Cost Overruns in the Design-Bid-Build Delivery Model and Project Size

Cost overruns are not the same as adaptation cost. If cost overruns are high, however, adaptation cost will be high as well. Cost overruns represent the total value of changes to the initial contract. As explained in Bajari, Houghton, and Tadelis (2014), the first part of cost overruns comes directly from the additional work that was not anticipated (by the client). Adaptation cost (the second part) come in addition as the result of disruption to the normal workflow and the resulting haggling, disputes, and opportunistic behavior during renegotiations.[24] Put simply, it is the difference between the unit price for an item in the initial contract and the elevated unit price for the extra piece of work after renegotiation.

The number one direct reason for cost overruns that consistently appears in the construction management literature on transport infrastructure is scope creep, followed by errors and omissions in the design of the project (Makovšek 2013).[25]

Cost overruns are typically calculated as the difference between the total ex post cost of a contract and its initial reference value. In this section and in table 5.6, we are looking at the literature that measured cost overruns versus the award price. Most studies capture entire populations of projects over a select time period.

Table 5.6 does not show a stark difference between projects below US$5 million and projects that are tens of millions of dollars in size. Overall, the systematic cost overruns reach at most 9 percent.

Research on smaller project sizes showed that cost overruns do increase with project size.[26] Gkritza and Labi (2008), on a sample with an average project size of US$1 million, show a 1.55 percent growth in cost overrun for each 1 percent growth in contract award value. They acknowledge, however, that the relationship is nonlinear. This rate of growth does not extend to larger projects—at several US$10 million the systematic cost overruns would quickly exceed 50 percent or more. Very large projects of several US$100 million would have systematic cost overruns of several 100 percent.

24. As seen from Bajari, Houghton, and Tadelis (2014) and from Bolotnyy and Vasserman (2019), contractors can predict changes in simple contracts. These are included in their bids together with the expected earnings, which are then competed away (in their case) and represent a small part of the actual cost overrun. This is also why the cost overrun reported by Bajari, Houghton, and Tadelis (2014) is substantially lower (5.7 percent) than the adaptation cost.

25. The root cause of direct reasons is a different question. For example, the dominant explanation could be optimism bias or deliberate misrepresentation by the project's promoters, or more mundane reasons could be at work, such as inadequate risk management or ex post stakeholder pressure that could not be foreseen and managed ex ante.

26. The same has been determined for Navy construction projects (Jahren and Ashe 1990).

Table 5.6 Cost overruns in design-bid-build projects measured against contract value (at award) as the reference estimate

Source	Project type	Time period*	N	Project size (mean in millions)	Average cost overrun (%)	Standard deviation (in %)	Geography
Ellis et al. (2007)	Roads and bridges	1998–2006	1908	US$2.8	9.36	n/a	US, Florida
Bordat et al. (2004)*	Roads	1996–2001	599	Not directly reported (small)	5.6	n/a	US, Indiana
Bordat et al. (2004)*	Bridge	1996–2001	621	Not directly reported (small)	8.1	n/a	US, Indiana
Bhargava et al. (2010)	Roads	1995–2001	1862	US$0.9	6.1	24.4	US, Indiana
Hintze and Selestead (1991)*	Roads	1985–1989	110	Not directly reported (small)	9.2	1.22	US, Washington
Bajari, Houghton, and Tadelis (2014)**	Roads	1999–2005	819	US$2.7	5.7	11.8	US, California
Love et al. (2019)[a]	Roads	1999–2017	18	US$197	5.7	12	Hong Kong
International Transport Forum (2018a)***	Roads and bridges	2008–2017	28	€75	9.3	8.1	Slovakia
Federal Highway Administration (2016)	Roads	2004–2015	134	US$21.6	4.1	9.1	US

Note: *Eighty-nine percent of projects were below US$2.5 million. **The authors do not report on cost overruns versus the winning bid but versus the in-house prebid estimate. Since the mean winning bid is 5.4 percent lower than the mean prebid estimate, the actual cost overruns measured against the winning bid in their sample would be marginally higher. ***The entire motorway program in the stated period.

[a] Shared by authors based on original data.

This is not confirmed in table 5.6 or by the Federal Highway Administration (2016), which found no relation between project size and cost overrun for larger projects in the size range up to US$357 million.[27] This is not to say, however, that for very large, mega projects above this range, cost overruns will not be substantially larger on average.

Based on this evidence, we cannot conclude that with the design-bid-build model larger contracts are more incomplete than smaller ones in ranges up to a few hundred million dollars.

5.7.1.1 Further Evidence on Cost Overruns in Large Projects

In addition to the studies in table 5.1, a body of evidence exists that measures cost overruns against the formal decision to build.[28] This evidence further corroborates the point that cost overruns (and by implication adaptation cost in contracts) in large projects are not disproportionately larger than in smaller ones.

As the formal decision to build occurs earlier in the project development, the estimates are less accurate, since the design documentation is not yet fully developed. The textbook example in figure 5.1 illustrates this point.

The evidence for road projects does not fully correspond to the textbook exposition. A consistent systematic cost overrun of around 20 percent ranging from several tens to several hundreds of million dollars has been shown. This is the case for advanced economies of the world (for example, Cantarelli et al. [2012] for the Netherlands; Flyvbjerg, Holm, and Buhl [2003] for Western Europe; Makovšek, Tominc, and Logožar [2012] for Slovenia).[29]

The early estimates are thus less accurate in terms of their dispersion

27. This analysis was not included in the original report and was confirmed by subsequent analysis of the data by the authors (personal communication with authors and Keith Molenaar).

28. This body of evidence is concerned with the presence of systematic errors in the cost (or benefit) estimates at the time, when a decision is formally made to proceed with the project development. If costs are systematically underestimated (or benefits systematically overestimated), then project appraisal may be affected. The formal decision to build is normally taken long before the project is mature enough to reach tendering. The studies do not observe contracts specifically, and a project may consist of many different contracts. The studies also do not report on any procurement dimension used in the contracts. Further review of available work in this domain is available in International Transport Forum (2018b) or Cantarelli et al. (2012).

29. Identification of the root cause of cost overruns measured against the decision to build (or the award price) is subject to ongoing work; the root cause is likely not the same for mega projects, which capture substantial political attention and so on. The explanations range from optimism bias or deliberate misrepresentation by the project's promoters (Flyvbjerg, Holm, and Buhl 2002) to technical explanations (Börjesson, Eliasson, and Lundberg 2014; Eliasson and Fosgerau 2013; Makovšek 2014) where the methods used to create inputs for project selection were imperfect, while the users had no ex post information to correct for errors. What is clear is that when projects get very large, the key determinant of cost overruns becomes the length of the project gestation period—the amount of time spent on project development before it reaches the tendering phase (Cantarelli et al. 2012; Flyvbjerg, Holm, and Buhl 2003). Hence, if a project requires a large number of years or decades to reach a decision to build, it is more likely to experience higher cost overruns. Very large projects are a case in point.

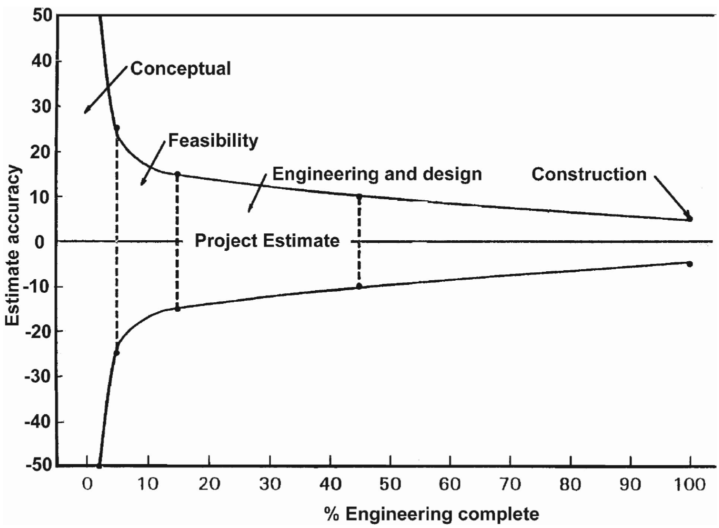

Fig. 5.1 Cost estimation accuracy over the life of the project
Source: Schexnayder, Weber, and Fiori (2003).

around the mean. The less developed the project design, the more costs are systematically underestimated. As the level of engineering becomes more complete, cost underestimation will decrease. The formal decision to build in the studies cited here is typically made at an outline design stage (10–20 percent of engineering complete).

For a design-bid-build (or any) contract to achieve a 20 percent cost growth against the award price, the winning bid on average would have to be made at a cost level that corresponds to a project's estimate very early in its development, and then the contract would need to consistently lead to a 20 percent cost overrun. This, however, is not what the evidence for larger project sizes in table 5.1 suggests.

In summary, the evidence discussed here further corroborates that design-bid-build road projects, ranging from 10 million to several hundred million dollars, experience average cost overruns well below 20 percent. An important stylized feature of cost overrun distributions measured against the contract award price or the decision-to-build estimate throughout almost all studies is a distribution asymmetric to the left with a tail to the right.

5.7.2 Do Bundled Delivery Models Lead to Less Renegotiation?

More complete contracts imply greater pressure on the bidders to express their revenue expectations ex ante and stress the importance of precontract information exchange. In transport infrastructure, bundled delivery models are commonly applied in large projects and in conjunction with high-powered incentives—the lump-sum payment mechanism.

5.7.2.1 Design-Build Contracts

The design-build model bundles design and construction phase in a single contract. Bidders in this case are commonly selected based on best value through a negotiated procedure.[30] The level of design provided to the bidders can range from 0 to 50 percent (Molenaar, Songer, and Barash 1999) of engineering but is commonly concentrated on the low end of the range. The payment mechanism applied is lump-sum (Chen et al. 2016; Federal Highway Administration 2016).

A rare example of a study that tried to control for complexity, bidder selection process, delivery model, and payment mechanism (but not cost per physical unit) was conducted by the Federal Highway Administration (2016).[31] Data for 291 projects were collected with a large share of bigger projects (mean US$27 million, standard deviation = 41 million); however, the results were statistically insignificant.[32] That said, the difference in cost overruns measured for design-bid-build and design-build projects was also very small.[33]

One of the key challenges for researchers of this topic was that the introduction of design-build delivery model is a relatively recent event, starting in the 1990s. As a result, most other studies faced the issues of small, unrepresentative samples, statistical significance issues, difference in project size magnitudes and therefore complexity, and so on (Federal Highway Administration 2006; Minchin et al. 2013; Park and Kwak 2017; Shrestha et al. 2007; Shrestha, O'Connor, and Gibson 2012; Warne 2005).

In summary, the evidence does not show that the design-build delivery model, in which the negotiated procedure is more commonly used, leads to greater contract completeness than auction-procured design-bid-build delivery model. How renegotiations can occur in the design-build model, however, is different from design-bid-build contracts. In the latter case a detailed design is made available to the contractor. This leaves the responsibility for design errors and omissions with the public client but at the same time also gives the public client control with regard to what exactly

30. In this case, the price is only one of the criteria for bidder selection, and bidders are not (primarily) selected on a lowest-bid basis.

31. One of the most cited studies on private sector vertical construction (residential or commercial/industrial buildings) contract performance (Konchar and Sanvido 1998, 102) also controlled for project complexity. The sample included 155 design-build projects and 116 design-bid-build projects. Facilities built were divided in six types. However, in multivariate linear regression neither the cost overrun differences nor the cost per physical unit (US dollars per square meter) for the two delivery models were statistically significantly different.

32. This is also a rare example of a study that included data on payment mechanism and procurement process.

33. DBB (bidder selection by lowest bid criterion) = 4.1 percent; DB (bidder selection by lowest bid criterion) = 2.8 percent; DB (bidder selection by best value criterion) = 4.0 percent. A similar result was found for 117 civil infrastructure DB projects (which included road projects) by Chen et al. (2016), who measured a systematic cost overrun of 5.8 percent.

the engineering solution is. In the design-build contract, an outline design is made available during bidding. In consequence most of the responsibility for design errors and omissions needs to be internalized by the contractor, leaving a much smaller scope for him to claim design error or omission. The public client no longer defines a detailed solution but provides a functional (output) specification, to which the asset needs to perform.

A logical conclusion would be that the cost overruns in design-build contracts are not smaller because the public client was not able to fully define ex ante what functions the public client wants the asset to perform. In consequence, changes are still required during construction. This point finds support in a study of 45 major design-build road projects in the Netherlands (Verweij, van Meerkerk, and Korthagen 2015),[34] with a mean project value of €190 million. The authors found that on average 50 percent of the cost growth could still be attributed to scope changes.[35] The root causes for this phenomenon are beyond the scope of this chapter, although the project management literature does offer some ideas, starting with Flyvbjerg, Holm, and Buhl's (2002) optimism bias or strategic misrepresentation.

5.7.2.2 Engineering-Procurement-Construction Contracts

In the design-build contract, an outline design is commonly made available during the bidding. This is not the case in the engineering-procurement-construction contract. The public client has even less control over what exactly the solution will be and defines expectations exclusively through an output specification. The lump-sum payment mechanism is the default option for this delivery model.

In transport infrastructure such contracts are primarily used because of the application of public-private partnerships (PPPs or P3 in the US).[36] A PPP is a project finance arrangement in which private debt and equity are used to finance the project and are paid back from the cash flow generated by the project. As lenders have no other recourse, they try to insure against risk that they cannot manage well or that is not part of their core business. Construction risk is transferred to the construction contractor through an engineering-procurement-construction contract alongside a range of incentives against nonperformance.[37] The bidders are normally selected through the negotiated process.

34. Thirty-eight of these were road projects. The study did not report the cost overrun against the contract award value. In addition, some projects were still in execution.

35. Of the rest, 12 percent could be directly attributed to incomplete contracts (incomplete, incorrect, conflicting contract terms); 35 percent of changes were due to technical necessities (for example, ground conditions turned out to be different from what was expected); 3 percent were due to changes in laws and regulations.

36. PPPs are also referred to through one of their many variants, most commonly as design-build-finance-maintain-operate (DBFMO) contracts.

37. The Natixis sample of major project finance projects (Blanc-Brude and Makovšek 2013) includes, for example, liquidated damages in case of delay (per day or per week), performance

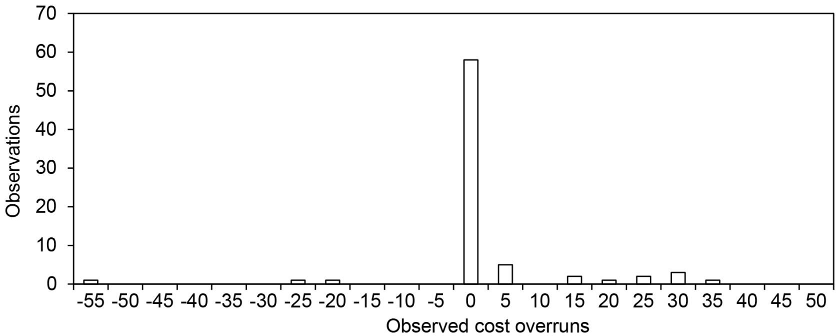

Fig. 5.2 Cost overruns in project finance (NATIXIS dataset, *n* = 75, 1993–2010)
Source: Blanc-Brude and Makovšek (2013).

Blanc-Brude and Makovšek (2013) analyzed a database of 75 project finance schemes, ranging in size from US$24 million to US$13 billion. The sample is a mix of private-private transactions as well as PPPs.[38] The projects come from five continents and different sectors, including transport (14 roads and 12 other types). This dataset is unique in the sense that it represents the performance of the contractor as reported to the lenders and not the performance of the project company. Effectively, cost overruns in this case represent the construction risk exposure of the lenders and owners in the project company. The mean cost overrun of the sample is 2.6 percent (standard deviation = 11.4). With the median cost overrun at 0 percent, the risk is diversifiable; hence, project finance completely insulates the investors from the risk. However, unlike the rich distribution of cost over- and underruns around the mean in other (publicly financed) procurement options, in this case 18 projects were delivered with cost overruns, three with cost underruns, and 54 projects exactly on cost (figure 5.2).[39]

Raisbeck, Duffield, and Xu (2010) collected data on 21 PPPs and 33 traditionally procured projects (the procurement dimensions are not reported) from different sectors in Australia. The authors confirm that PPPs suffer almost no delays, compared to traditional procurement. The authors can-

guarantees, and full completion guarantees (a third-party guarantee that the project will be completed even if the main contractor defaults).

38. The data do not allow explicit identification. Nevertheless, the sector implies whether the projects were PPPs or private-private transactions. In total 43 projects were marked as to transport, social accommodation, and "environmental." In all these sectors, project finance arrangements would have to be PPPs (for example, roads, social housing projects, landfills). The average cost overrun of these projects was 1 percent.

39. Cost underruns do not imply that the contractor saved money and gave it back (it is a lump-sum contract), but that the project was canceled or the project scope was reduced. Conversely, cost overruns can be a result of scope increases introduced by (and paid for) by the client.

not, however, confirm with statistical significance that cost overruns measured versus the contract award stage are smaller (2.4 percent for PPPs versus 13.8 percent for publicly financed projects). Raisbeck, Duffield, and Xu include a review of literature commonly used in policy discussions, which are mainly industry studies suffering from a variety of sampling or representativity issues.

In this particular case the evidence does suggest that engineering-procurement-construction contracts are more complete and cost overruns are much lower than in other procurement alternatives investigated so far. Given that design-build projects represent a very similar procurement format, with the majority of the design risk transferred to the contractor, it is not immediately clear why the engineering-procurement-construction format or PPPs would perform substantially better. One possible explanation, however, is that the complicated financial and legal structure of PPPs makes changes prohibitively expensive for the public authorities.

5.8 Do High-Powered Incentives Mix Well with Complete Contracts?

Contract theory predicts that the cost-plus (bill of quantities) payment mechanism is more suitable for dealing with renegotiations than a lump-sum arrangement (Bajari and Tadelis 2001). Thus lump-sum contracts should be used when no or few renegotiations are expected. As noted during our review of theory, though, this proposition does not take into account uncertainties bidders face when pricing the contract. In our evidence review on the impact of precontract information exchange in auctions, substantial effects were measured in relatively small and by extension simpler projects.

In the following, we review evidence that provides some insights about how much uncertainty bidders face in contract pricing and what the impact of high-powered incentives on cost per physical unit could be.

5.8.1 Incentive Power and Performance in Small Contracts

In cost-plus design-bid-build contracts, bids are typically submitted through a bill of quantities, which lists expected quantities for the items and unit prices next to them. Bajari, Houghton, and Tadelis (2014), in their measurement of adaptation cost in such contracts, also revealed how much uncertainty bidders face. The authors found that bidders foresaw which items had quantities underestimated and strategically priced them. Bidders increased the prices for items for which quantities had been underestimated and reduced prices on quantities that had been overestimated to still achieve a lower total.

In an extension of the Bajari, Houghton, and Tadelis (2014) approach, Bolotnyy and Vasserman (2019) measured how risk averse bidders are in design-bid-build contracts. The authors simulated what would occur to project cost if the incentive power were to be increased. Their data build on Massachusetts Department of Transportation data on 440 bridge maintenance projects executed between 1998 and 2015 with an average contract value of US$2.7 million.

When bidders reduce their ex ante bid in the expectation of ex post adjustments, their main uncertainty is that they misestimate the adjustments. Bolotnyy and Vasserman (2019) demonstrated a substantial accuracy in the strategic behavior of bidders. The bidders could accurately foresee in the bill of quantities for which items quantities are underestimated. On average, for each 1 percent of quantity underestimation in an item, its unit price is increased by 0.085 percent.[40]

The same study also assessed what would happen with the price of the average winning bid had the procuring authority switched from a cost-plus to a lump-sum contract under which there would be no ex post adaptation. This condition implies that bidders would need to estimate well not only which items there will be quantity changes to but also what the changes in quantities will be. Bidders would have to express their full revenue expectations in the winning bid. Based on estimating bidders' risk aversion, the study showed that the switch would make an average winning bid in the sample 133 percent more expensive.

On the other hand, the results of Bolotnyy and Vasserman (2019) suggest that, even if the objective of contract completeness could be met, uncertainty interfering with the pricing of contract would still lead to significant additional cost. This result does not align well with the predictions of contract theory, which sees adaptation cost as the main challenge to incentive power selection.

This section observed small projects with an average size well below US$5 million. How does the level of adaptation cost develop for projects in the range of several tens or hundreds of millions of US dollars? What would happen if we applied bundled delivery models and lump-sum requirement on much larger projects, where the design is not necessarily complete at the time it needs to be priced?

5.8.2 Large(r) Projects and the Relevance of Incentive Power

The structural models in papers that tested contract theory propositions offer a precision view of how well bidders foresee ex post contract changes in the project, what part is the added cost of adaptations, and what part are the profit margins. Similar studies do not exist for larger, more complex projects. A single study to date investigated the relative performance of construction cost per physical unit for "traditional procurement" (design-bid-build

40. Bidders cannot push this approach to the extreme regarding the unit prices of underestimated items and discounts for the items for which they suspect the quantities are estimated accurately. When the procuring authority can detect a bid is materially imbalanced, a bidder could be disqualified. The advantage on the side of the bidders in practice is that it is difficult to determine with precision what "materially imbalanced" means.

contracts)[41] and PPPs (engineering-procurement-construction contracts) (Blanc-Brude, Goldsmith, and Välilä 2009). The sample is based on road contracts, tendered between 1990 and 2005 in the European Union. The study stands out from the others in that it targets large contracts, ranging from €20–300 million, consisting of 56 PPPs and 101 traditionally procured projects. Controlling for road type, terrain, economies of scale, portions of bridge and tunnel work,[42] size, and country (institutional environment), the study found that the ex ante (award) PPPs cost 24 percent more per lane kilometer.

An important characteristic of the Blanc-Brude, Goldsmith, and Välilä (2009) sample is also that the projects in question were supported by the European Investment Bank. This implies that the preparation and the execution of the bidder selection process benefited from the bank's advice, due diligence, and potential technical assistance. Thus, as far as quality of preparation or the execution of the bidder selection process is concerned, the performance of the sample is expected to be above average. There are no other indications in this study that the results (the difference between the PPPs and traditionally procured projects) could be affected by potential selection bias.[43]

As the Blanc-Brude, Goldsmith, and Välilä (2009) study captured contract cost at or close to award[44] and not ex post cost, further elaboration is necessary, and we cannot yet conclude that engineering-procurement-construction contracts carry a substantial cost premium over low-powered alternatives. As laid out in Makovšek and Moszoro (2018), two issues need to be acknowledged.

First, given all we know about cost overruns, the 24 percent cost premium for PPPs seems to be much higher than the average cost overrun observed in design-bid-build contracts. In addition, PPPs too exhibit cost overruns, albeit small. In table 5.1, cost overruns in design-bid-build projects reach at most 9 percent. As discussed in the previous section, engineering-procurement-construction projects have been recorded to reach cost overruns of 2 percent. Hence, indications are that even if Blanc-Brude, Goldsmith, and Välilä (2009) had ex post data on final contract cost, a significant premium would persist.

Second, a major argument why infrastructure would be more expensive in PPPs as opposed to traditional procurement is life-cycle cost optimization. Arguably, the long-term involvement in the project incentivizes the

41. According to the study, the majority of the "traditional procurement" sample are design-bid-build cost-plus contracts with a small presence of design-build lump-sum contracts.

42. Large bridges were separate projects and were excluded from the sample.

43. As noted in the beginning of the section, the study did control for numerous dimensions that would affect complexity and performed several robustness checks across several alternative subsample specifications.

44. The study's interpretation of ex ante cost estimate data was also addressed in greater detail in Makovšek (2013).

private owners to build a higher-quality infrastructure to save on maintenance cost later. While this may indeed be the case, there is no empirical evidence to show the observance of this principle is systematically worse in publicly financed infrastructure. Moreover, despite declarative embrace, there were practical obstacles to the introduction of these principles (Meng and Harshaw 2009). The UK National Audit Office (National Audit Office 2007) found that hospitals procured through PPPs were not built to a higher standard of quality. For roads specifically, the German Court of Audit (Bundesrechnungshof 2014) investigating German motorway PPPs came to the same conclusion.[45]

In summary, high-powered (that is, lump-sum engineering-procurement-construction) contracts procured through negotiation can lead to more complete contracts (greater cost certainty) but are substantially more costly than low-powered alternatives. In road infrastructure, limited available evidence suggests this premium is not a result of building to a higher standard.

Against our review of how economic theory informs procurement choices and the evidence on procurement outcomes, the next section looks at how governments procure in practice.

5.9 How Are Procurement Choices Informed Today?

Advanced public infrastructure clients ideally have a procurement strategy guidance defined, with more detailed support found in separate documents. The procurement strategy typically begins with a statement of objectives, a description of requirements, and an analysis of the market and client capability and then moves toward informing the delivery model (for example, Department of Infrastructure and Regional Development 2008; Federal Transit Administration 2016; HM Treasury 2016). Bidder selection process and incentive power are in most cases a result of the selected delivery model, whereby the first is strictly regulated by law.

5.9.1 Bidder Selection Choices Are Enshrined in Law

The bidder selection choice is subject to detailed description of the process (for example, Florida Department of Transportation 2015) and is broadly framed by the procurement legislation in any jurisdiction. In the European Union, directives on procurement negotiations for simpler projects are to be avoided, if competition can be secured. For more complex projects, when public authorities choose delivery models using an output specification (such as design-build), negotiations and competitive dialogue are allowed.

45. Two potential explanations were put forward. First, building to a different standard is inhibited by strict technical rules and regulations. Second, risk-averse lenders may prefer tried and tested methods rather than experimentation.

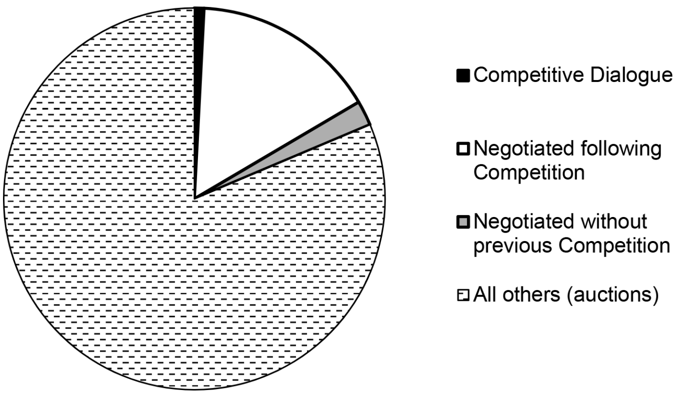

Fig. 5.3 Procurement procedures in the EU market for rail and road projects above €50 million (2006–2016; *N* = 1520)

Note: Sourced from TED electronic database, including all projects, where data on the procurement process were available.

Source: Based on data in Roumboutsos (2019).

Similar bidder selection options are now available in other jurisdictions (for example, in the US since 2004, Federal Acquisition Regulation [FAR], 48 CFR;[46] Scott 2006).

The use of negotiated procedures has been slowly increasing but is (at least in Europe) still limited (figure 5.3). In principle, the choice of procedure should be heavily related to the choice of the delivery model, but there may be other circumstances guiding this choice as well.[47]

5.9.2 The Delivery Model Is Chosen through MAUA

A common tool to inform the choice of the delivery model are simple descriptions of the pros and cons of various delivery models (for example, Federal Transit Administration 2016). Another widespread approach is the weighing of perceived attributes of individual approaches in pursuing project objectives (quality, being on time, cost, and so on). This method is

46. FAR in the US regulates procurement with federal funding (https://www.acquisition.gov/browse/index/far). The states themselves also developed procurement legislation, which follows similar basic principles.

47. For example, from the perspective of ex ante information exchange, where the delivery model requires a specification of needs such as with the design-and-build or engineering-procurement-construction models, the competitive negotiation (US)/competitive dialogue (EU) should be a necessity (Kennedy et al. 2018). That said, public clients could face impediments that affect their procedure choice related to, for example, available time to execute the tender, in-house capacity, or capabilities to run a competent negotiation. There is no systematic evidence showing whether there is a match between bidder selection procedures and delivery models.

called the multi-attribute utility approach, or MAUA (Chang and Ive 2002). Derivatives of this approach have been developed since the 1970s. Today, MAUA is enshrined in numerous government procurement practice guidelines (for example, Molenaar, Harper, and Yugar-Arias [2014] for highway infrastructure in the US; Department of Infrastructure and Regional Development [2008] in Australia).

MAUA is typically represented in the form of a table or a matrix (for example, Department of Infrastructure and Regional Development 2008). The first column lists the objectives or the desired outcomes of the project that the client considers important (such as speed of delivery, cost certainty, potential for innovation). In the second column the user attributes weights to these objectives (namely, decides which are more or less important). The remaining columns each represent one procurement option (such as traditional procurement, design and build, alliancing, PPP). For these, the user then scores how well the user believes a particular procurement option will satisfy the individual procurement objectives. In the end the weights of the objectives are multiplied by a utility factor representing the extent to which a procurement option satisfies each attribute. The most desirable procurement is the option with the highest score. The projects can also be subject to straightforward characterizations (for example, complex, simple) and procurement models designated as to which is best to match which type of project.

We should note that this approach asks many (research) questions on how well suited a particular procurement option is to meet a particular objective. As can be seen from this chapter so far, however, the performance of different procurement options is not well understood. Most available evidence is predominantly associated with cost overruns, delays, and construction speed. Aspects such as quality, value, or cost per physical unit are almost never captured. Empirically, as shown in this chapter so far, the trade-offs are not well understood. For more recent (collaborative) methods such as alliancing, there is practically no robust quantitative evidence available.

5.9.3 The Incentive Power Depends on the Delivery Model and Whether the Project Is Considered to Be "Simple"

The choice of incentive power to a large extent depends on the choice of the delivery model— by choosing the delivery model we also determine the payment mechanism. For the design and build or engineering-procurement-construction delivery models, the lump-sum payment mechanism is the default choice.

As regards the use of the lump-sum mechanism in relation to the design-bid-build delivery model, the guidance road agencies use tends to be prescriptive. Lump-sum contracts are allowed to be used only on very simple projects. For example, the Florida Department for Transportation (road) Design Manual specifically notes:

> Lump Sum Projects should be identified during the scope development process, rather than during or after the design process. . . . Lump Sum contracting should be used on simple projects. "Simple" is defined by the work activity, not by the project cost. (Florida Department of Transportation 2019)

The manual also provides examples of projects that may be good lump-sum contracting candidates: (1) bridge painting, (2) bridge projects, (3) fencing, (4) guardrails. Interestingly, design and build projects are also considered to be simple, because the manual assumes they have a well-defined scope for all parties and because such projects are thought to have a low possibility for change during all phases of work. As for the use of other payment mechanisms, when these are not a consequence of a particular delivery model, professional judgment is applied.

5.9.4 Recent Advances

In recent years, advances in the area of procurement in the UK and Australia signal a departure from the traditional perception of what a "procurement strategy" should entail. Specifically, important choices that will impact the outcomes of a procurement are made already before we start considering the questions of bidder selection, delivery model, and incentive power.

5.9.4.1 Expanding the Concept of Procurement Strategy in the UK

The UK has rolled out a series of initiatives with the aim of increasing the efficiency of procurement of infrastructure and in general. Specifically related to informing procurement choices, however, the new guidance moves beyond the core procurement choices pursued in this chapter. The newly deployed functional standards in relation to procurement identify the make-or-buy decision as the first choice to be made (HM Government 2019). The Project Initiation Route Map (HM Treasury 2016) explicitly introduces a step called project "packaging" alongside other, softer procurement dimensions (such as communication). The packaging concerns the question whether a (larger) project should be broken down into multiple contracts and where the boundaries between them should lie.

These two steps require a mindset that sees any project as a set of activities. These steps precede the procurement choices pursued in this chapter and importantly predetermine the procurement outcomes. For example, not insourcing an activity that we frequently need but that is available only from a single supplier will lead to an inefficient final procurement outcome, regardless of our choice of delivery model or incentive power. An example of bad "packaging" would be to procure a large project as a single contract in which, out of many, one activity has only two suppliers. As a consequence, two consortia would form around the two suppliers, and the competition benefits for all other activities would be reduced as well.

Both questions—the make-or-buy and packaging—go beyond the purview of auction and contract theory and move into the realm of the theory of the firm and new institutional economics. While the recent UK guidance asks that these questions be considered, it does not yet offer a tool to address them. To date, in infrastructure procurement such decisions have been left to professional judgment.

A tool that seeks to use economic theory to address the two questions discussed here and the three procurement choices we have dealt with in this chapter is currently being tried in Australia and is briefly explained next.

5.9.4.2 A New Tool to Inform a Procurement Strategy in Australia

The method proposed by Bridge and Tisdell (2004) and applied in Bridge and Bianchi (2014) and Teo (2014) rejects MAUA as tautological because it defines the cause—namely, procurement mode utility (for example, EPC contracts have better on-budget delivery)—in the same terms as the effect (for example, on-budget delivery for this project will be important). In consequence, MAUA simply points to the choice of the model that aligns with the buyer's preferred result. MAUA does not scientifically inform what the best procurement approach would be, given the nature of the project, when a simple broad description (for example, it is complex) is insufficient.

The first step in the Australian model is to identify the activities that concern the project's design, construction, maintenance, and operation. Each activity must be technologically bounded (distinct knowledge, skill set, or both) and correspond to the highest level of firm specialization available on the market. Table 5.7 represents an activity breakdown for a major road project case study.

In the second step, the model assesses each of the project-specific activities in terms of their transaction cost economics (TCE) attributes (frequency, asset specificity, uncertainty) and resource-based theory (RBT) attributes (rarity, cost to imitate). The assessment allocates the activities into eight brackets—competitive states (figure 5.4) that serve to predict which activities might lead to ex ante contract failures (low competition) or ex post contract failures (such as holdup).

Activities that are assigned a pattern 1 through 4 are considered most efficiently insourced, and so the remaining steps in the model focus only on the procurement of those activities assigned a pattern 5 through 8. For example, in pattern 8 the characteristics of variables are such that a firm (the supplier) could maintain a sustainable competitive advantage in the market. This would be because the activity is of large scale or size, or requires a rare technology, or both (Barney 2002). This limits the number of market firms that are capable of carrying out the activity, resulting in limited number of potential bidders (Teo 2014).

In the third step the model guides the user to explore bundling of activities—the model informs about whether the project should be split

Table 5.7 **Activity analysis**

Design	Construction	Operations and Maintenance
Design of construction 1. Civil and structural engineering design 2. Civil and structural engineering design to the driven tunnel 3. Traffic engineering design 4. Mechanical and electrical engineering design, including air quality and ventilation 5. Fire safety design for tunnels 6. Landscaping and urban finishes design *Design of performance, specification of maintenance* 7. Plan for routine maintenance, programmed maintenance, and rehabilitation of road pavement, road furniture, drainage maintenance, and ITS 8. Plan for reactive and programmed maintenance to specialist linings, mechanical and electrical and fire elements in driven tunnel	*Cut and cover tunnels* 9. Relocation of existing public utility plant, 10. Removal works, 11. Traffic management, 12. Bored piles, 13. Excavate and shotcrete, 14. Earthworks, 15. Structural, 16. Precast concrete, 17. Waterproofing, 18. Drainage, 19. Pavement, 20. Modifications to existing bridge and footpath, 21. Demolition, 22. Realignment of rail track *Driven tunnel* 23. Excavation in tunnel and shotcrete, 24. Waterproofing, 25. Structural, 26. Precast concrete—barriers, kerbs, and wall, 27. Drainage, 28. Trimming and backfill of main tunnel, 29. Pavement, 30. Ventilation fan *Road at grade* 31. Bulk excavation, 32. Subgrade preparation, 33. Drainage, 34. Concrete pavement, 35. Precast concrete: barriers, kerbs, 36. Retaining walls, 37. Asphalt pavement, 38. Realignment of existing busway, 39. Traffic management *Bridge, ramps, median, walkway, and bikeway structure* 40. Traffic management, 41. Earthworks, 42. Pile foundation, 43. Structural works, 44. Precast concrete barriers, kerbs *Bus stations* 45. Water and stormwater, 46. Electrical and communication, 47. Pile foundations, 48. Cast in situ concrete (lift wells, platforms, and bus bays), 49. Structural steelwork, 50. Roofing and draining, 51. Cladding and louvres, 52. Glazing, 53. Mechanical service, 54. Lift installation in bus stations	*Remaining construction activities in multiple parts of the project* 59. Intelligent Transport Systems and traffic operations 60. Inspections and data collection, including implementation of reactive routine and programmed maintenance to all parts of in project (including driven tunnel)—roads/pavement and furniture 61. Inspections and data collection, including implementation of reactive (emergency) maintenance

Source: Teo (2014).

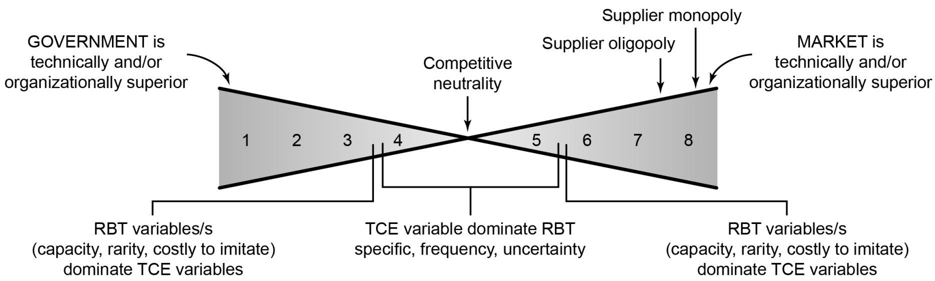

Fig. 5.4 Make-or-buy analysis

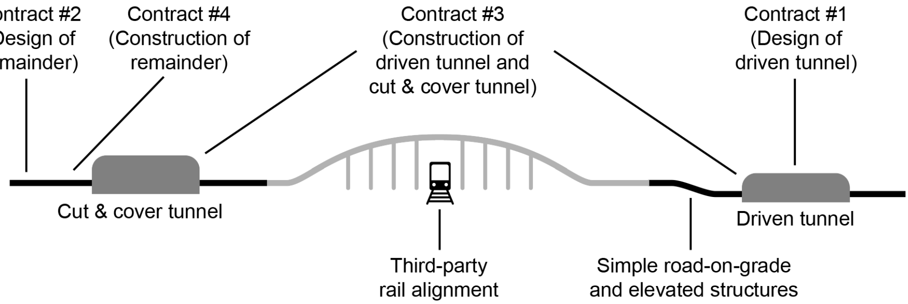

Fig. 5.5 Bundling analysis
Source: Based on Teo (2014).

into multiple contracts and which contract should particular activities be. At the risk of oversimplifying the process, the aim is to create bundles of activities that have a solid potential to attract many competitors and filter out those that do not, contracting them separately. This step corresponds to the "packaging" question in the recent UK procurement guidance introduced earlier. An actual major road project in Australia that was procured as a single alliancing contract was assessed by this model in figure 5.5 (Teo 2014).

The analysis showed that contracts 2 and 4 would have been most efficiently procured with a lowest price competition. Only for contracts 1 and 3 could alternative contracting methods such as alliancing, which rely on negotiations and do not derive their efficiency incentives from competition, be considered.

The model involves further steps to deal with other procurement dimensions, such as contract power. At time of the case study just discussed, the model did not yet acknowledge an important issue raised in this chapter: the role of uncertainty not only as a source of opportunistic behavior but also as a source of ex ante risk pricing failures.

In summary, the existing considerations of procurement in economic theory and construction management literature take the contract scope as a given and provide advice from that point on. For major projects, important decisions that will strongly affect procurement outcomes will have already been made by that point.

5.10 Discussion: The Opposing Forces in Contracts

The objective of this chapter is to provide an overview of what we know about how procurement choices affect procurement outcomes. Our scope was limited to a few well-established delivery models, which received most of the attention from the researchers; robust quantitative analysis that involves competent authorities in advanced economies is rare.

Where empirical evidence seems to depart especially vividly from the predictions of the economic theory is in the expectation that project phase bundling will reduce the need for renegotiation and that renegotiation is the primary challenge for the use of high-powered incentives or lump-sum contracts in our case. The available evidence does not support the expectation that negotiations and bundling lead to less renegotiation per se. This seems to be the case for road projects up to several hundred million US dollars. The issue is that cost overruns in design-bid-build projects are not very large; therefore, even if design-build projects could yield better results (and engineering-procurement-construction contracts actually do), the improvement would be a few percentage points. A marginal gain in cost (and time) certainty, however, yields a disproportionate cost premium.

In our discussion we first focus on this latter issue: why high-powered contracts are disproportionately more costly. Second, we stress that the same information that could help reduce uncertainty contractors face in bidding for infrastructure contracts would also help us better understand the performance of different procurement choices. Finally, recent developments suggest that the modern approach to procurement should be fundamentally revisited to optimally balance what the government is procuring from the market, in what contract sizes, and boundaries between contracts. These choices precede much of the discussion in this chapter, but will fundamentally codetermine procurement outcomes.

5.10.1 The Performance of High-Powered versus Low-Powered Contracts

Contract theory predicts low-powered contracts are a better solution for dealing with adaptation cost and suggests high-powered incentives should be applied, when contracts are sufficiently complete. This could be the case when a project is sufficiently simple or when the delivery model makes the contract "complete" by transferring property rights. Contract theory does not deal with the relevance of precontract exchange of information or when in the development cycle of the project its price must be established.

The evidence capturing projects with average sizes of US$1–200 million shows that all projects with cost-plus design-bid-build contracts will experience systematic cost overruns of a single-digit percentage and therefore adaptation cost.

Regarding the uncertainty the bidders face, for small projects, low profit margins and effective competition were demonstrated, and contractors had a reasonably precise grasp of the risks they are taking. When bidding, they could predict in the bill of quantities which items had been underestimated. Yet even in such simple settings, a risk premium of 133 percent was estimated (in Bolotnyy and Vasserman 2019) if the same projects were procured through a complete contract, where a detailed design is available and any remaining uncertainty must be fully priced in advance. The premium is disproportionate to the potential cost overrun of a few percentage points it has to absorb. Similarly, other cited examples also point to disproportionate responses of reducing precontract uncertainty (for example, Kosmopoulou and Zhou 2014).

In the bundled contract formats, the bidders must themselves develop a design during bidding. Construction risk is also comprehensively transferred and implies uncertainties much larger than guessing which items in the bill of quantities have been underestimated.

Moreover, contractors cannot assess risk in the same way as investors do.[48] Whereas investors could hope to rely on large time series of performance data, this is not the case for contractors. The pricing of design and construction risks relies heavily on expert risk workshops, in which experienced practitioners make informed guesses about the corresponding probabilities and impacts (Makovšek and Moszoro 2018). A further unhelpful factor is that governments have not fully exploited the possibilities of ex post analysis and performance benchmarking (OECD 2017).

In this context it is surprising that the actual premium for achieving cost certainty, such as in engineering-procurement-construction contracts in PPPs, is not much higher than the 24 percent measured in Blanc-Brude, Goldsmith, and Välilä (2009)![49] Although in the particular case there is

48. A more recent version of the approach also considers project-specific versus network-specific activities in cases where the design and construction pertain to the delivery of network infrastructure. In this case maintenance and operations can be performed network-wide, and thus economies of scale need to be considered as well.

Until recently, investors in infrastructure assets could not price risk efficiently because the adequate indices on the risk-return profiles of homogenous groups of infrastructure assets did not exist even after several decades of increased private investment into infrastructure. Recently progress was made toward establishing infrastructure as an asset class with a precise definition and benchmarks (https://edhec.infrastructure.institute/). Another G20 initiative is underway.

49. It is not straightforward to conclude that these premiums transform into abnormal profits for major contractors for a variety of reasons. For example, construction firms generally pursue multiple business lines, so the profitability of major projects would be drowned in the noise of other projects. Construction firms can be organized in several complementary profit centers. In the case of PPPs, for example, it is not uncommon to see an equity investor and a contractor being part of the same holding structure. The owners can choose when the profits will be expressed through the equity investment and when through the contractor. There is noise due to market cycles. Finally, construction firms can also dump risk down the supply chain,

only limited evidence to argue that the 24 percent premium is not the result of building to a higher standard, other evidence (as discussed earlier) corroborates that building on time and on budget alone will yield a disproportionate premium.

The order of magnitude difference with the 133 percent estimated in Bolotnyy and Vasserman (2019) can at least in part come from their approach, which involves the assumption of constant absolute risk aversion, an exponential function. It may not reflect real life. On the other hand, Nobel Prize–winners Kahneman and Tversky (1979) suggest that individuals tend to underweight larger probabilities but overweight those that approach zero. Thus the presence of low-probability, high-impact events could substantially affect contractors' risk perceptions and in consequence risk pricing. This is exactly what cost overrun distributions asymmetric to the left with a tail to the right imply. Indeed, in larger, more complex projects, the consequences of low-probability, high-impact events could be detrimental not just to the project but also to the contractor.[50] Hence, a small transfer of risk or uncertainty is still expected to yield a disproportionate premium.

Against these points, precontract information exchange will play a decisive role, but only limited empirical research on its impact has so far been pursued. Evidence on procurement of rail and road infrastructure in projects above €50 million in the EU suggests that less than a quarter relied on negotiated procedures and only a fraction of those on competitive dialogue (Roumboutsos 2019). The potential of these methods is not a given but must be exploited; public clients could significantly increase their efforts in identifying and sharing risk-related information (Kennedy et al. 2018).

Following our review of the relevance of procurement choices, the theory, and the evidence, we have to acknowledge that these lead to a nexus of opposing forces. Strengthening precontract information exchange through negotiation reduces uncertainty for the contractor at the expense of competition. Bundling design and build may reduce adaptation cost during project execution but implies greater uncertainty in risk pricing at the bidding stage. Finally, these choices interact with incentive power—how much cost certainty we want up front. Contract and auction theory have not yet reconciled these dimensions in a unified approach.

This discussion also implies that characteristics of PPPs, such as bundling and the high power of incentives, face trade-offs that could more than offset the potential benefits of the model. To date, though, no study has managed

which would imply that they are not necessarily the ones making money—their insurers and subcontractors could be the ones.

50. For example, in 1991 as the undersea Stoerebelt connection in Denmark was being constructed, water broke in through the face of the tunnel bore. Against the rules a worker forgot to close a bulkhead door, which flooded the tunnel and the Tunnel Boring Machine (TBM), resulting in massive delays and damage (Vincentsen and Smedegaard Andersen 2018).

to secure the data to allow a comparison of life-cycle cost with an adequate public counterfactual.[51]

In summary, at present public policy makers (or the industry) have no complete view of the consequences of their procurement preferences. Owners report simple reasons for why one procurement approach was preferred over another. For example, the primary reason for choosing the design-build delivery model is faster delivery (Songer and Molenaar 1996). Data on cost overruns are becoming more commonly available, and being on budget and on time involves reputational concerns. Comparative information on cost, however, is unavailable. The same is true for information about "value" or quality. These gaps in evidence could lead to suboptimal decision-making or, worse, create perverse incentives.

We turn to the issue of data availability, the role of governments, and what our review suggests for the future of procurement in the final subsection.

5.10.2 Reducing Uncertainty through Public Information

Our exposition so far has stressed the role of information in risk and procurement outcomes. Recently the International Transport Forum at the OECD (ITF) (Kennedy et al. 2018) mapped some of the best practices that are applied in reducing bidder uncertainty in major projects.

As noted earlier, however, one of the major challenges, especially in public infrastructure, is the absence of comprehensive and systematic benchmarking in terms of project outcomes. This has been a major inhibition also in the writing of this chapter, which has focused mainly on cost. Extending on categories of time and quality or adding maintenance on top would reveal even more scarcity of evidence.

To date, for example, it is not possible to compare infrastructure cost per physical unit in a robust (normalized) fashion. We are unable to say whether a kilometer of a 2×2 motorway built to a similar standard in, say, the UK is more or less expensive than in Germany, and if so why.[52] The same is true for railways and many other types of infrastructure. No international database that would with any confidence compare infrastructure project outcomes exists.

More recently however limited progress has been made. The UK committed in its Transport Infrastructure Efficiency Strategy (UK Department for Transport 2017) to pursue infrastructure benchmarking and issued the

51. In a comparison of a public road agency, which is funded from the general budget and dependent on annual budgetary discussions and a PPP, the latter would likely win. Such comparisons, however, are deceptive. The PPPs do not make road tolling possible. The introduction of tolling is a political challenge. If tolling can be introduced, the road infrastructure manager can be public or a PPP. Hence, an adequate comparison would involve a state-owned road company (such as those in Austria and Slovenia), which is funded through tolls and a toll-funded PPP.

52. The UK tried to benchmark with the Netherlands several years ago with very limited success (Infrastructure UK 2010).

first benchmarking principles in 2019.[53] Australia has been pursuing infrastructure benchmarking for several years.[54] A comprehensive road asset management standard has also been developed in multiple countries, though it does not yet extend to procurement choices and outcomes.[55] As project sizes increase, however, fewer potential observations become available. This makes it less likely that individual countries (unless they are among the largest economies) could successfully pursue a quantitative analysis.

The ITF (at the suggestion of the principal author of this chapter at the time) recently proposed an international transport infrastructure benchmarking initiative that would give a quantitative analysis the best possible chance, but countries have been slow to step forward (International Transport Forum 2018b). The benchmarking would begin with road infrastructure delivered in the recent past with the database updated on a periodic basis as the partnering organizations—the data owners—would deliver new projects. The data owners, the ITF, and potential research partners (such as universities) would have to agree on the data points per project collected and benchmarking objectives. Over time, the database could grow to include data preceding procurement (concerning planning and quality of project selection) and data on operations and maintenance (service levels and quality).

In conclusion, we do not argue that the lowest cost (at a given quality) is the only noble goal in infrastructure procurement. Other goals matter as well, depending on the context. We do argue, however that we do not have a sufficient empirical understanding of the trade-offs of procurement choices. While the majority of transport infrastructure budgets are spent on smaller and simple contracts, which are relatively well understood, potential suboptimal procurement choices on fewer but larger projects will have greater impact.

Benchmarking initiatives, such as those discussed in this chapter, could be an important step toward informing major procurement improvements. This is the state of the art in an era when a transition is slowly occurring from traditional procurement, in which the lowest price competition was the backbone to delivery models that forfeit price competition in favor of collaboration and are based on negotiation. Against the increased repertoire of different project delivery models, it seems to be even more pertinent to pursue decision support tools that comprehensively inform what we should buy from the market; how we should break down the projects into contracts;

53. UK Infrastructure and Projects Authority, *Best Practice in Benchmarking*, March 1, 2019, updated June 2, 2020, https://www.gov.uk/government/publications/best-practice-in-benchmarking.

54. Australian Government, Department of Infrastructure, Transport, Regional Development and Communications, "Cost Benchmarking for Infrastructure Investments," n.d., https://www.bitre.gov.au/data_dissemination/priority_projects/cost_benchmarking_infrastructure_investments.aspx.

55. The Australian example is available here: https://austroads.com.au/publications/asset-management/ap-t334-18.

and on which contract we should apply which bidder selection, delivery model, and incentive power choices.

References

Adkins, L., and R. A. Adkins. 2014. *Handbook to Life in Ancient Rome*. Infobase publishing. https://doi.org/10.5860/choice.32-1097.

Bajari, Patrick, Stephanie Houghton, and Steven Tadelis. 2014. "Bidding for Incomplete Contracts: An Empirical Analysis of Adaptation Costs." *American Economic Review* 104 (4): 1288–1319.

Bajari, Patrick, Robert McMillan, and Steven Tadelis. 2009. "Auctions versus Negotiations in Procurement: An Empirical Analysis." *Journal of Law, Economics, and Organization* 25 (2): 372–99.

Bajari, Patrick, and Steven Tadelis. 2001. "Incentives versus Transaction Costs: A Theory of Procurement Contracts." *RAND Journal of Economics* 32 (3): 387–407.

Baltrunaite, Audinga, Cristina Giorgiantonio, Sauro Mocetti, and Tommaso Orlando. 2018. "Discretion and Supplier Selection in Public Procurement." Bank of Italy Working Paper 1178.

Barney, Jay. 2002. *Gaining and Sustaining Competitive Advantage*. 2nd ed. Upper Saddle River, NJ: Prentice Hall.

Beuve, Jean, Marian W. Moszoro, and Stéphane Saussier. 2019. "Political Contestability and Public Contract Rigidity: An Analysis of Procurement Contracts." *Journal of Economics and Management Strategy* 28 (2): 316–35.

Bhargava, Abhishek, Panagiotis Ch. Anastasopoulos, Samuel Labi, Kumares C. Sinha, and Fred L. Mannering. 2010. "Three-Stage Least-Squares Analysis of Time and Cost Overruns in Construction Contracts." *Journal of Construction Engineering and Management* 136 (11): 1207–18.

Blanc-Brude, Frédéric, Hugh Goldsmith, and Timo Välilä. 2009. "A Comparison of Construction Contract Prices for Traditionally Procured Roads and Public-Private Partnerships." *Review of Industrial Organization* 35 (1–2): 19–40.

Blanc-Brude, Frédéric, and Dejan Makovšek. 2013. "Construction Risk in Infrastructure Project Finance." Working paper, EDHEC Business School.

Bolotnyy, Valentin, and Shoshana Vasserman. 2019. "Scaling Auctions as Insurance: A Case Study in Infrastructure Procurement." Working paper 3887, Stanford Graduate School of Business.

Bordat, Claire, Bob G. McCullouch, Samuel Labi, and Kumares C. Sinha. 2004. "An Analysis of Cost Overruns and Time Delays of INDOT Projects." Publication FHWA/IN/JTRP-2004/07, Joint Transportation Research Program, Indiana Department of Transportation and Purdue University. https://doi.org/10.5703/1288284313134.

Börjesson, Maria, Jonas Eliasson, and Mattias Lundberg. 2014. "Is CBA Ranking of Transport Investments Robust?" *Journal of Transport Economics and Policy* 48 (pt. 2): 189–204.

Bridge, Adrian, and Robert Bianchi. 2014. *Major Infrastructure Procurement Research Project 2009–2013: Reforming the Procurement of Construction and Financing of Australian Infrastructure: Advancing Capacity, Competition and Investment*. Final report. Queensland University of Technology and Griffith University. https://eprints.qut.edu.au/76520/1/76520_Verification_Material.pdf.

Bridge, Adrian J., and Clem Tisdell. 2004. "The Determinants of the Vertical Bound-

aries of the Construction Firm." *Construction Management and Economics* 22 (8): 807–25.
Brooks, Leah, and Zachary D. Liscow. 2019. "Infrastructure Costs." *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3428675.
Bulow, J., and P. Klemperer. 1996. "Auctions versus Negotiations." *American Economic Review* 86 (1): 180–94.
Bundesrechnungshof. 2014. "Bericht an Den Haushaltsausschuss Des Deutschen Bundestages Nach 88 Abs. 2 BHO Über Öffentlich Private Partnerschaften (ÖPP) Als Beschaffungsvariante Im Bundesfernstraßenbau." Technical report.
Calahorra, M., C. Torres-Machi, and Keith R. Molenaar. 2019. "Information Exchange in the Procurement Process of Design-Build Transportation Projects: Digging into the What, the When, the Who, and the How." University of Colorado Boulder.
Cantarelli, C. C., B. Van Wee, E. J. E. Molin, and B. Flyvbjerg. 2012. "Different Cost Performance: Different Determinants? The Case of Cost Overruns in Dutch Transport Infrastructure Projects." *Transport Policy* 22 (July): 88–95.
Chabrost, M. 2018. "Three Empirical Essays on the Impact of Discretion on Public Procurement Performance." Doctoral dissertation, Université Panthéon-Sorbonne-Paris I. https://tel.archives-ouvertes.fr/tel-01997216.
Chamorro, M. A., J. Soler, R. Ripoll, and E. Vilagran. 2018. "Building Contracts in the City of Girona from the 14th to the 18th Century." In *Building Knowledge, Constructing Histories: Proceedings of the 6th International Congress on Construction History (6ICCH 2018)*, edited by Nicolas Le Brun. London: CRC Press.
Chang, Chen Yu, and Graham Ive. 2002. "Rethinking the Multi-Attribute Utility Approach Based Procurement Route Selection Technique." *Construction Management and Economics* 20 (3): 275–84.
Chen, Qing, Zhigang Jin, Bo Xia, Peng Wu, and Martin Skitmore. 2016. "Time and Cost Performance of Design-Build Projects." *Journal of Construction Engineering and Management* 142 (2).
Chever, L., and J. Moore. 2017. "Negotiated Procedures Overrated? Evidence from France Questions the Commission's Approach in the Latest Procurement Reforms." *European Procurement & Public Private Partnership Law Review* 7 (4): 228–41.
Coase, R. H. 1937. "The Nature of the Firm." *Economica* 4 (16): 386–405.
Coviello, Decio, Andrea Guglielmo, and Giancarlo Spagnolo. 2018. "The Effect of Discretion on Procurement Performance." *Management Science* 64 (2): 715–38.
Department of Infrastructure and Regional Development. 2008. *National Public Private Partnership Guidelines*, vol. 1: *Procurement Options Analysis*. Canberra: Australian Government.
De Silva, Dakshina G., Timothy Dunne, Anuruddha Kankanamge, and Georgia Kosmopoulou. 2008. "The Impact of Public Information on Bidding in Highway Procurement Auctions." *European Economic Review* 52 (1): 150–81.
De Silva, Dakshina G., Georgia Kosmopoulou, and Carlos Lamarche. 2009. "The Effect of Information on the Bidding and Survival of Entrants in Procurement Auctions." *Journal of Public Economics* 93 (1–2): 56–72.
Du Plessis, Paul. 2004. "The Protection of the Contractor in Public Works Contracts in the Roman Republic and Early Empire." *Journal of Legal History* 25 (3): 287–314.
Eliasson, Jonas, and Mogens Fosgerau. 2013. "Cost Overruns and Demand Shortfalls: Deception or Selection?" *Transportation Research Part B: Methodological* 57: 105–13.
Ellis, Ralph, Jae-ho Pyeon, Zohar Herbsman, Edward Minchin, and Keith Molenaar. 2007. *Evaluation of Alternative Contracting Techniques on FDOT Construc-*

tion Projects. Final report, University of Florida, Gainesville, and Florida Department of Transportation. https://trid.trb.org/view/825920.
Engel, E., R. D. Fischer, and A. Galetovic. 2014. *The Economics of Public-Private Partnerships: A Basic Guide.* Cambridge: Cambridge University Press.
European Union. 2014a. "Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on Public Procurement and Union Repealing Directive 2004/18/EC." Accessed April 24, 2014. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0024.
———. 2014b. "Directive 2014/25/EU of the European Parliament and of the Council of 26 February 2014 on Procurement by Entities Operating in the Water, Energy, Transport and Postal Services Sectors." Accessed April 24, 2014. https://eur-lex.europa.eu/eli/dir/2014/25/oj.
Federal Highway Administration. 2006. *Design-Build Effectiveness Study*. Final report to Congress, Federal Highway Administration.
———. 2016. *Quantification of Cost, Benefits and Risk Associated with Alternative Contracting Methods and Accelerated Performance Specifications*. Federal Highway Administration Project, Contract no. DTFH61-11-D-00009, 2013–2016.
Federal Transit Administration. 2016. *Best Practices Procurement & Lessons Learned Manual*. FTA Report 0105. Washington, DC: US Department of Transportation. https://rosap.ntl.bts.gov/view/dot/39038.
Florida Department of Transportation. 2015. "Design-Build Procurement and Administration."
———. 2019. "FDOT Design Manual."
Flyvbjerg, Bent. 2014. "What You Should Know about Megaprojects and Why: An Overview." *Project Management Journal* 45 (2): 6–19.
Flyvbjerg, Bent, Mette K. Skamris Holm, and Søren L. Buhl. 2002. "Underestimating Costs in Public Works Projects: Error or Lie?" *Journal of the American Planning Association* 68 (3): 279–95.
———. 2003. "How Common and How Large Are Cost Overruns in Transport Infrastructure Projects?" *Transport Reviews* 23 (1): 71–88.
Gkritza, Konstantina, and Samuel Labi. 2008. "Estimating Cost Discrepancies in Highway Contracts: Multistep Econometric Approach." *Journal of Construction Engineering and Management* 134 (12): 953–62.
Goeree, Jacob K., and Theo Offerman. 2003. "Competitive Bidding in Auctions with Private and Common Values." *Economic Journal* 113 (489): 598–613.
Goldberg, Victor P. 1977. "Competitive Bidding and the Production of Precontract Information." *Bell Journal of Economics* 8 (1): 250.
Grossman, Sanford J., and Oliver D. Hart. 1986. "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration." *Journal of Political Economy* 94 (4): 691–719.
Hart, Oliver. 1995. *Firms, Contracts, and Financial Structure*. Oxford: Clarendon Press.
———. 2003. "Incomplete Contracts and Public Ownership: Remarks, and an Application to Public-Private Partnerships." *Economic Journal* 113 (486).
Hart, O., and B. Holmstrom. 1987. "The Theory of Contracts." In *Advances in Economic Theory, Fifth World Congress*, edited by T. Bewley. New York: Elsevier.
Hart, Oliver, and John Moore. 1990. "Property Rights and the Nature of the Firm." *Journal of Political Economy* 98 (6): 1119–58.
Herweg, Fabian, and Klaus M. Schmidt. 2017. "Auctions versus Negotiations: The Effects of Inefficient Renegotiation." *RAND Journal of Economics* 48 (3): 647–72.
Hintze, J., and G. A. Selestead. 1991. "Analysis of WSDOT Construction Cost Overruns."
HM Government. 2019. "Government Functional Standard GovS 008: Commercial." London.

HM Treasury. 2016. "Improving Infrastructure Delivery: Project Initiation Routemap— Procurement Module." London. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/529340/Prourement_Module.pdf.

Holmstrom, B., and P. Milgrom. 1987. "Aggregation and Linearity in the Provision of Intertemporal Incentives." *Econometrica* 55 (2): 303.

———. 1991. "Multitask Principal-Agent Analyses: Incentive Contracts, Asset Ownership, and Job Design." In "Papers from the Conference on the New Science of Organization, January 1991," special issue, *Journal of Law, Economics, & Organization* 7: 24–52.

Infrastructure UK. 2010. *Infrastructure Cost Review: Technical Report*. London.

International Transport Forum. 2018a. "Motorway Cost Estimation Review: The Case of Slovakia." *Case Specific Policy Analysis*. Paris. https://www.itf-oecd.org/motorway-cost-estimation-review-slovakia.

———. 2018b. "Private Investment in Transport Infrastructure: Dealing with Uncertainty in Contracts." Paris.

Iossa, Elisabetta, and David Martimort. 2012. "Risk Allocation and the Costs and Benefits of Public—Private Partnerships." *RAND Journal of Economics* 43 (3): 442–74.

———. 2015. "The Simple Microeconomics of Public-Private Partnerships." *Journal of Public Economic Theory* 17 (1): 4–48.

Jahren, Charles T., and Andrew M. Ashe. 1990. "Predictors of Cost-Overrun Rates." *Journal of Construction Engineering and Management* 116 (3): 548–52.

Kahneman, D., and A. Tversky. 1979. "Prospect Theory: An Analysis of Decision under Risk." *Econometrica* 47: 263–91.

Kennedy, Jonathan, Aris Pantelias, Dejan Makovšek, Klaus Grewe, and Julian Sindall. 2018. "Risk Pricing in Infrastructure Delivery: Making Procurement Less Costly." Paris. https://trid.trb.org/view/1565397.

Klee, Lukas. 2018. *International Construction Contract Law*. *International Construction Contract Law*. Wiley-Blackwell. https://doi.org/10.1002/9781118717868.

Klein, B., R. G. Crawford, and A. A. Alchian. 1978. "Vertical Integration, Appropriable Rents, and the Competitive Contracting Process." *Journal of Law and Economics* 21 (2): 297–326.

Konchar, Mark, and Victor Sanvido. 1998. "Comparison of U.S. Project Delivery Systems." *Journal of Construction Engineering and Management* 124 (6): 435–44.

Kosmopoulou, Georgia, and Xueqi Zhou. 2014. "Price Adjustment Policies in Procurement Contracting: An Analysis of Bidding Behavior." *Journal of Industrial Economics* 62 (1): 77–112.

Kostof, S. (Ed.). 2000. *The Architect: Chapters in the History of the Profession*. Berkeley: University of California Press.

Laffont, J. J., and David Martimort. 2001. "The Theory of Incentives : The Principal-Agent Model / Common Agency View Project Mechanism Design without Transfers and Constrained Delegation View Project." https://www.researchgate.net/publication/31737757.

Laffont, Jean-Jacques, and Jean Tirole. 1993. *A Theory of Incentives in Procurement and Regulation.* Cambridge, MA: MIT Press.

Love, Peter E. D., Michael C. P. Sing, Lavagnon A. Ika, and Sidney Newton. 2019. "The Cost Performance of Transportation Projects: The Fallacy of the Planning Fallacy Account." *Transportation Research Part A: Policy and Practice* 122 (April): 1–20.

Makovšek, Dejan. 2013. "Public-Private Partnerships, Traditionally Financed Projects, and Their Price." *Journal of Transport Economics and Policy* 47 (1): 143–55.

———. 2014. "Systematic Construction Risk, Cost Estimation Mechanism and Unit Price Movements." *Transport Policy* 35: 135–45.

Makovšek, Dejan, and Marian Moszoro. 2018. "Risk Pricing Inefficiency in Public–Private Partnerships." *Transport Reviews* 38 (3): 298–321.

Makovšek, Dejan, Polona Tominc, and Klavdij Logožar. 2012. "A Cost Performance Analysis of Transport Infrastructure Construction in Slovenia." *Transportation* 39 (1): 197–214.

McAfee, R. P., and J. McMillan. 1986. "Bidding for Contracts: A Principal-Agent Analysis." *RAND Journal of Economics* 17 (3): 326–38.

Meng, Xianhai, and Fiona Harshaw. 2009. "The Application of Whole Life Costing in PFI/PPP Projects." In *Proceedings of the 29th Annual ARCOM [Association of Researchers in Construction Management] Conference*, 769–78.

Milgrom, Paul, and Robert J. Weber. 1982. "The Value of Information in a Sealed-Bid Auction." *Journal of Mathematical Economics* 10 (1): 105–14.

Minchin, R. Edward, Xiaoxiao Li, Raja R. Issa, and Gary G. Vargas. 2013. "Comparison of Cost and Time Performance of Design-Build and Design-Bid-Build Delivery Systems in Florida." *Journal of Construction Engineering and Management* 139 (10).

Molenaar, Keith, Christofer Harper, and Ivo Yugar-Arias. 2014. *Guidebook for Selecting Alternative Contracting Methods for Roadway Projects: Project Delivery Methods, Procurement Procedures, and Payment Provisions*. Prepared for Next-Generation Transportation Construction Management Transportation Pooled Fund Program Study TPF-5(260). University of Colorado Boulder.

Molenaar, Keith R., Anthony D. Songer, and Mouji Barash. 1999. "Public-Sector Design/Build Evolution and Performance." *Journal of Management in Engineering* 15 (2): 54–62.

Morgan, M. H. 1960. *Marcus Pollio Vitruvius, The Ten Books on Architecture; with Illustrations and Original Designs Prepared under the Direction of Herbert Langford Warren*. New York: Dover Publications.

National Audit Office. 2007. "Improving the PFI Tendering Process."

Odeck, James. 2014. "Do Reforms Reduce the Magnitudes of Cost Overruns in Road Projects? Statistical Evidence from Norway." *Transportation Research Part A: Policy and Practice* 65: 68–79.

OECD. 2017. *Ex-Post Assessment of Transport Investments and Policy Interventions*. ITF Roundtable Reports. OECD.

Palguta, Ján, and Filip Pertold. 2017. "Manipulation of Procurement Contracts: Evidence from the Introduction of Discretionary Thresholds." *American Economic Journal: Economic Policy* 9 (2): 293–315.

Park, Jane, and Young Hoon Kwak. 2017. "Design-Bid-Build (DBB) vs. Design-Build (DB) in the U.S. Public Transportation Projects: The Choice and Consequences." *International Journal of Project Management* 35 (3): 280–95.

Port, M. H. 1967. "The Office of Works and Building Contracts in Early Nineteenth-Century England." *Economic History Review* 20 (1): 94–110.

Raisbeck, Peter, Colin Duffield, and Ming Xu. 2010. "Comparative Performance of PPPs and Traditional Procurement in Australia." *Construction Management and Economics* 28 (4): 345–59.

Roumboutsos, Athena. 2019. "Competition in Large Projects: PPPs vs Traditional Procurement." Presentation, International Transport Forum, Paris, June 22.

Schexnayder, Cliff J., Sandra L. Weber, and Christine Fiori. 2003. *Project Cost Estimating: A Synthesis of Highway Practice*. Washington, DC: Transportation Research Board.

Scott, S. 2006. *Best-Value Procurement Methods for Highway Construction Projects. Best-Value Procurement Methods for Highway Construction Projects*. Washington, DC: Transportation Research Board.

Shrestha, Pramen Prasad, Giovanni Ciro Migliaccio, James T. O'Connor, and

G. Edward Gibson. 2007. "Benchmarking of Large Design-Build Highway Projects One-to-One Comparison and Comparison with Design-Bid-Build Projects." *Transportation Research Record* 1994 (1): 17–25.
Shrestha, Pramen P., James T. O'Connor, and G. Edward Gibson. 2012. "Performance Comparison of Large Design-Build and Design-Bid-Build Highway Projects." *Journal of Construction Engineering and Management* 138 (1): 1–13.
Songer, Anthony D., and Keith R. Molenaar. 1996. "Selecting Design-Build: Public and Private Sector Owner Attitudes." *Journal of Management in Engineering* 12 (6): 47–53.
Spagnolo, Giancarlo. 2012. "Reputation, Competition, and Entry in Procurement." *International Journal of Industrial Organization* 30 (3): 291–96.
Spiller, Pablo T. 2009. "An Institutional Theory of Public Contracts: Regulatory Implications." In *Regulation, Deregulation, Reregulation: Institutional Perspectives*, edited by Claude Ménard and Michel Ghertman, 5–66. Northampton, MA: Edward Elgar.
Teo, Pauline. 2014. "The Effect of Procurement on Competition and Flexibility: Determining the Suitability of Public-Private Partnerships in Major Infrastructure Projects." PhD diss., Queensland University of Technology, Brisbane.
UK Department for Transport. 2017. "Transport Infrastructure Efficiency Strategy." London: UK Government. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/664432/transport-infrastructure-efficiency-strategy.pdf.
Verweij, Stefan, Ingmar van Meerkerk, and Iris A. Korthagen. 2015. "Reasons for Contract Changes in Implementing Dutch Transportation Infrastructure Projects: An Empirical Exploration." *Transport Policy* 37 (January): 195–202.
Vincentsen, Leif, and Kim Smedegaard Andersen. 2018. *Risk Allocation in Mega-Projects in Denmark*. Paris: International Transport Forum.
Warne, Tom. 2005. *Design Build Contracting for Highway Projects: A Performance Assessment*. South Jordan, UT: Tom Warne & Associates.
Williamson, O. E. 1975. *Markets and Hierarchies: Analysis and Antitrust Implications*. New York: Free Press.
———. 1979. "Transaction-Cost Economics: The Governance of Contractual Relations." *Journal of Law and Economics* 22 (2): 233–61.
———. 1985. *The Economic Institutions of Capitalism: Firms, Markets, Relational Contracting*. New York: Free Press.

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It is quite clear from chapter 5 that not only are procurement practices ubiquitous and highly impactful for society, but they are also highly variable and comparatively understudied. The latter two conditions go hand in hand: there is such variety in conditions, restrictions, and requirements across procurement projects that the vast theoretical literature on contracts

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