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Overdesign in Civil Infrastructure Systems? The Influence of Infrastructure Funding, Finance, and Procurement on Facility Design and Delivery

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16. Abstract
This research project has examined the issue of overdesign in infrastructure. Based on a thorough literature review, the research team developed a questionnaire on the nature and extent of overdesign and practices to avoid it or correct it when it does occur. Confidential interviews using this questionnaire were conducted with subject matter experts across a broad range of industry roles and experience, including state departments of transportation, toll road authorities, consultants and advisors, and infrastructure developers. Interview results confirmed the widespread presence of overdesign across multiple modes of transportation and identified potential mechanisms for avoiding overdesign it.

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CHAPTER 1: INTRODUCTION

BACKGROUND

Do states and other asset owners overdesign their facilities? They often do, say former state transportation CEOs, private infrastructure developers, and other industry leaders, speaking only off the record.

But what is overdesign? As the word suggests, overdesign is the design of facilities that are larger and more costly than necessary. For example, their pavements might be thicker than needed, their capacity might be larger than needed, or their materials might be more expensive than needed.

Why would asset owners overdesign? One possible reason is that facilities may be designed to cost more initially in order to rely less on ongoing maintenance, even at a higher lifecycle cost. Capital budgets provide funding for up-front costs, while ongoing operations and maintenance are contingent on less reliable annual appropriations. So, for example, an owner might specify concrete pavements, which usually require larger up-front investment and are more costly and difficult to replace at maturity. But they also require less year-to-year maintenance.

Another possible reason may be a "now or never" effect. That is, because of the difficulty in getting projects through the planning and programming process to actual procurement, owners and project advocates may believe that they will have only one chance in a generation to build a project. On that basis, they may overdesign a project on the expectation that it will be years or decades before an opportunity arises to add features or capacity to a project and that it is therefore more desirable to build it bigger now. The downside of such decisions, of course, is that the extra features or capacity cost more and require maintenance in perpetuity.

One possible countervailing factor against overdesign may be a tendency on the part of the state to "build on the cheap" because of tight capital budgets. If this were the case, one might expect to find projects that are too small or use subpar construction materials to make short-term fixes that ultimately increase long term lifecycle costs.

In most cases, overdesigned facilities will cost more. In the presence of fixed budgets, these more costly facilities will crowd out other worthy projects. At the same time, overdesigned projects may increase environmental impacts.

Overdesign may also contribute to the high cost of infrastructure delivery in the U.S. (Brooks and Liscow 2021; Goldwyn et al. 2023; Mehrotra, Turner, and Uribe 2024) to the extent that overdesign increases the scale and environmental impact of projects, it may also be a contributing factor to these costs.

Additionally, overdesign may be present across multiple transportation modes. Levinson (2022) argued recently that the cost of light rail has increased substantially because of excessively high design standards. New York University's "Transit Costs Project" has also documented substantial cost elevation in public transit (Goldwyn et al. 2023). And Flyvbjerg has documented an extensive history of megaproject cost problems, where overdesign may be a large contributing factor (see, e.g., Flyvbjerg & Gardner, 2023).

More costly projects also delay project start dates while projects wait for funds necessary to pay for them. Later starts, and the ensuing later completions, delay the societal benefits that projects are intended to deliver. Moreover, costlier projects may contribute to the nation's backlog of deferred maintenance (American Society of Civil Engineers 2017).

The purpose of this project has been to understand if, how, and why overdesign has occurred in civil infrastructure projects, and particularly how it has been influenced by funding, financing, and procurement. By conducting confidential interviews with government and industry practitioners as well as academics, we have sought to elicit candid accounts of the prevalence and causes of overdesign in practice, opinions on measures that could be taken in response, and to identify potential case studies for more in-depth analysis. We hope to provide useful guidance to decision-makers on how to identify and avoid overdesign and give an account of the potential structural and institutional influences on overdesign.

LITERATURE REVIEW

Overdesign

"Overdesign" occurs when some aspect of a project or product is designed to a standard higher than the minimum needed for its intended purpose. In construction, this might be building a column to bear a higher load, or in technology including an extra feature. Overdesign is closely related to the concept of "margin," "the difference between a design parameter's minimum required value to ensure functionality, and its actual capability" (Eckert, Isaksson, and Earl 2019). Although sometimes the term is used in an inherently negative way (as in "too much margin"), often it is in reference to explicit requirements or specifications, such that a little bit of overdesign to account for uncertainties can be a good thing (Eckert et al. 2020). Additionally, overdesign can refer to a qualitative rather than quantitative exceeding of specifications.

One virtue of overdesign is that it can provide for flexibility as requirements change, either in the design process or in deployment, to avoid the need for redesign. Allen et al. (2019) compare the NPV of overdesign and redesign, finding that overdesign is better when changes in requirements arise quickly, low discount rates are appropriate, incremental R&D cost, price or cost of goods sold is low, and when initial R&D cost to provide for the initial requirements or incremental cost of the redesigned product is high. Overdesign can also mitigate risk, such as when building to a higher tolerance than necessary to account for unexpected events or building redundancy into a system to ensure functionality despite partial failures (D. Jones and Eckert 2023).

Overdesign will be more of a normative concept when the requirements or specifications of the design are more complete, or when the comparator is not a specification but the ground reality; Ronen & Pass (2007) define it as "designing and developing products or services beyond what is required by the specifications and/or the requirements of the customer or the market," the latter clause being the more normative. If a project is overdesigned compared to the specifications, that may or may not be bad - if it is overdesigned relative to the thing the specifications are intended to accomplish (social welfare, product demand, environmental conditions, etc.) that will be bad.

Overdesign can occur when margins are determined separately for different aspects of a project and added together rather than integrated accounting for the overlap, or are determined by ballpark or rule-of-thumb estimates rather than calculation (D. A. Jones, Eckert, and Gericke 2018). Such heuristics are often used in the absence of data, but poor proxy data can also lead to overdesign, as when old estimates are extrapolated with higher growth rates than actually occurred (Intini et al. 2020). Optimizing rather than satisficing can lead to overdesign if relevant factors like cost are treated as a constraint rather than an optimized variable, or simply aren't included at all. Coman & Ronen, (2010) and Belvedere et al., (2013) categorize this source of overdesign, and the general attempt to make a product the "best possible" regardless of demand, as one of the behavioral problems that cause overdesign. They contrast this with the organizational problems that can cause it; performance measurement, pricing policy and budgeting rules, such as when something that designers particularly want to work on can be embedded into a funded project.

The primary costs of overdesign are time and money, but in recent years environmental impacts have received greater attention due to the carbon emissions involved in concrete construction (Habert et al. 2020). The flip side is that overdesigned systems are subject to opportunity costs, and to the foregone technological advances due to building early rather than redesigning or expanding later. The costs of underdesign occur uncertainly, however, when a situation that pushes the limits of the requirements happens and the design fails.

Agency Theory and the Principal-Agent Problem

Agency theory is the study of delegation and incentives under the conditions of rational self-interest. In the basic model, one individual (the "principal") has a goal or goals they wish another individual (the "agent") to achieve on the principal's behalf. Without totally shared interests, the agent may have incentives to make decisions on the agent's behalf that do not optimally pursue the delegated goal, or to put in less than their full effort. Even if the principal were to monitor every decision made by the agent (which could take a degree of effort and attention that would largely obviate the benefits of delegation), the principal may not be *able* to judge effectively whether those decisions serve their interests – typically an agent is chosen in part because they (are believed to) have expertise the agent does not. Even after the fact, the principal may not be able to evaluate adequately the agent's performance. This combination of divergent interests and information/knowledge asymmetry, and the way it incentivizes the agent not to maximize the principal's payoffs, is referred to as "the principal-agent problem."

Agency theory is the study of how best to structure the principal-agent relationship to minimize the agent's incentive to pursue the goals of the principal. The main aspects of the relationship studied are monitoring (Milgrom & Roberts, 1992, p186, 226), incentive contracts (Baker et al., (1994), i.e., "pay-for-performance" and when it should be used), and risk-sharing (Berhold, 1971; Milgrom & Roberts, 1992, p211; Shavell, 1979). Agency theory makes a distinction between two types of principal-agent models, based on where/when the information asymmetry occurs.

Adverse selection models have the disadvantage occur in the selection process of the agent – i.e., before a contract is formed – with the goal being to select the best agent despite the agent having more information about their characteristics. Agents have an incentive to conceal information about their abilities, and so when a principal is selecting for the agent they evaluate as best, they are selecting not only for true ability but also for the difference between their true ability and the principal's evaluation. Moral hazard models apply to the agent's actions after they have been selected. The concern here is that an agent will perform poorly, either due to putting in less effort, or to making choices that benefit themselves at the expense of the principal.

In addition to the principal-agent model, another branch of agency theory is the positivist theory of agency (Eisenhardt 1989; Jensen 1998), focusing on identifying conditions where agents and principals conflict and describing governance mechanisms that address those conditions – addressing agency problems through the distinction between ownership and control. One particular feature of this branch is explaining the choices of firms and governments to make the choices they do – for example, when tasks are contracted out. Agency theory has been used extensively in the analysis of public sector reforms, to explain their adoption and success or failure, with mixed results (Thiel 2016).

Agency problems occur in the public sector at at least three levels: the ability of voters to control elected officials, the ability of elected officials to control bureaucrats (or alternatives) (Niskanen 2017), and the ability of bureaucrats (or politicians) to control developers or contractors.

In the study of the relationship between voters and elected officials, there is considerable overlap with public choice theory. In the public choice context, the information asymmetry between the "principals" (voters) and their "agent" (politician) is almost maximized, because individual voters are largely (rationally) ignorant of political and policy issues (Downs 1957). However, interest groups have a much greater incentive both to monitor and intervene in politics because their policy interests are much less diffuse. This distinction leads to regulatory capture (Shughart and Thomas 2019).

The time-bound periodic nature of elections is another significant agency issue; voters exercise sanction over their principals at predetermined intervals; when combined with the information deficit, this gives politicians an incentive to minimize costs and burdens near elections. The "fiscal illusion" hypothesis is that politicians can effectively mislead citizens about the size of government (Mueller, 2003), including that future costs (including taxes) are more difficult for voters to evaluate. Although the hypothesis in general (about the size of government) lacks empirical support, it is sometimes still marshaled as an incentive for politicians to make specific policy choices with less transparent funding structures. Policies where costs are deferred into the future are particularly incentivized, since in addition to the possibility of a fiscal illusion, there is some probability that the politicians ultimately deciding the policy will not be in office when those future costs are incurred on the public.

The agency problem faced by elected officials seeking to delegate aspects of the provision of public goods appears in two guises: first, agency problems as applied to bureaucrats and administrative agencies, and second, the comparison of that possibility to alternatives like privatization. Cavaliere and Scabrosetti, (2008) review several contributions to the analysis of privatization.

Finally, we have the application of agency theory to the provision of public contracts. As observed by Sappington and Stiglitz (1987), the principal (government) may have better information about the subject of the contract than the agent (e.g., about the difficulty), in which case they may have an incentive to conceal that. In general, public procurement has double-sided information asymmetries, which makes adverse selection harder to analyze.

Public-Private Partnerships (P3s)

A third alternative to public provision and privatization that has gained international interest and adoption is the public-private-partnership (P3). P3s don't have an agreed-upon definition, but some common threads are the existence of a long-term contract between the government and a private entity (often specifically set up for the P3) and some degree of joint decision making and risk sharing (Vining, Boardman, and Poschmann 2005). A prominent model is the long-term infrastructure contract (Hodge and Greve 2017), in which the private entity is involved in the design, construction, and operation phases of an infrastructure project - contrasting with the more traditional design-bid-build (DBB) or design-build (DB) model where the government owns and operates after construction is complete. In the US, P3s are typically design-build-finance-operate-maintain (DBFOM) concessions, in which the private partner invests its own money (or money it raises), and commits to operating and maintaining infrastructure for a defined period of time (usually 30+ years) in exchange for an ongoing stream of funding (availability payments) and/or the right to collect tolls or user fees, subject to performance standards (FHWA, 2023).

The arguments in favor of P3s are that in various ways they combine the best of both public- and private- sector development. On the one hand, private financing enables governments to commit to projects without having to allocate all the funds in a single budget year (or biennium), deferring the expenditure across time, while on the other hand it is hoped to act as a disciplining mechanism for overoptimistic planning as the private sector rejects non-viable partnerships. In the build phase P3s avoid time and cost overruns through delivery incentives for the developer, and a defined contract disincentivizing ongoing modifications and feature or "scope creep" (Makovšek 2013; Makovšek and Moszoro 2018). Private sector efficiencies in general are argued as a benefit of P3s, as the concessionaire has incentives to keep overall costs down – including, if necessary, by spending more during the development to minimize maintenance costs. When there is a separate financier, risk-aversion will lead them to demand higher-quality management to reduce uncertainty, lowering costs and the probability of schedule delay (Demirag et al, 2011).

Opponents of P3s argue that higher costs are "baked in" to P3 contracts (Moore and Vining 2023), and that many of the possible benefits are more than offset by the risk premium demanded by the private partner if they materialize at all. They argue that evaluations of P3s that use a (hypothetical) public sector comparator are highly sensitive to the discount rate, and are usually conducted by the administering agency (A. E. Boardman and Vining 2010). Peterson (2019) reviews empirical studies evaluating P3s against a business case, public sector comparator, real benchmark figures from similar projects or another appropriate counterfactual and finds mixed evidence suggesting P3s are on average more costly and provide equivalent value-for-money to traditional procurement.

Moore and Vining (2023) argue for the use of a generalized social welfare approach in evaluating P3s, rather than the more common value-for-money approach or categorical determinations of success. This approach would evaluate the effects on uses, on involved firms, on employees of those firms, on government tax revenue and on other parties (externalities). They argue that principal-agent theory predicts that P3s will underperform relative to traditional procurement under this criterion, and that evaluations bear this out. They explain the prevalence of P3s despite this fact with another application of agency theory, this time with the government executive as the agent and citizens as the principals. Politicians and political parties favor P3s because of cash flow timing – low up-front costs with most expenditures deferred to the future – and a greater likelihood of an "on time and under budget" determination. Then, the establishment of P3s leads to regulatory capture and the continuation of P3-favorable behavior.

Project Evaluation and Evaluative Criteria

The appropriate or best way to evaluate public infrastructure projects in general and PPPs in particular is an open question. Numerous evaluative criteria exist, ranging from the simple to the complex. Furthermore, while as public projects the appropriate normative criterion is social welfare, there is disagreement over which aspects of social welfare are relevant. Some methods of evaluation trade comprehensiveness for rigor or clarity and use evaluators from different disciplines. Hodge (2010) identifies fifteen instrumental objectives of PPPs, with varying degrees of legibility for any individual project. Moreover, the various relevant disciplines have approached and defined the evaluation problem with different emphases; Hodge sketches accountants, engineers and bureaucrats, economists, political scientists, and policy and planning scholars as among these disciplines.

Value For Money

Value for Money (VfM) is a framework or family of approaches for evaluation, not a method, and is most commonly used by governments to decide whether to procure a project. It seeks to compare the cost (to the government) over the lifetime of the project to the value it delivers under a range of alternative procurement methods. How exactly to characterize the "value" is the varying aspect; some VfM analyses assume that the value delivered by the PPP and the PSC will be the same in expectation and so simply compare the costs; others adjust for the decreased risk to the government, while some include other socio-economic benefits. Some common characterizations of the values to be considered include "cost, quantity, quality, and features" (Burger and Hawkesworth 2011), "economy, efficiency, and effectiveness" (ICAI 2011), "all material economic, social and environmental impacts" or "total well-being of the public as a whole" (United Kingdom Department for Transportation 2021).

When evaluating PPPs, the most common test is that of the public sector comparator – a counterfactual of what would result from "traditional procurement." Although arguably a necessary comparison to make in performing an ex-ante evaluation to decide whether or not to use a P3, it is often used in ex post studies as well – in part because they make use of the initial evaluations. The PSC is underspecified, however, and some jurisdictions (Virginia, UK, Australia) have begun moving away from it in favor of considering a broader range of considerations without respect to a specifically imagined alternative.

Discount Rate Selection

Calculation of the costs (or benefits) over the life-cycle of a project requires the use of a discount rate. However, several alternative ways of choosing the discount rate exist, and both governments and theoreticians disagree(Helby Petersen 2019) on the appropriate choice for P3s specifically. Moreover, the choice of discount rate may well be determinative – a high discount rate can favor a PPP over traditional procurement (Contreras 2014; Parks and Terhart 2009; Sundaram et al. 2016). The main two approaches are to use a social discount rate or a financial discount rate. If the latter, there is a secondary question of whether to use a risk-free rate. Boardman and Hellowell (2017) argue that whether to use a rate higher or lower than the risk-free one depends on the type of good provided (inferior or normal) and the way the P3 is structured (usage- or availability-based), due to the differences in systemic risk (risk correlated with market performance in general, and therefore with all government programs).

A social discount rate is based on notions of public utility, or welfare. In principle, it's the rate at which society or government is willing to trade present value for future value, but the philosophical underpinnings are less determinate – it implicitly commits a government to a view about how important future generations are compared to the current population. In practice, some governments have an established rate or procedure for generating such a rate which need merely be applied to a given infrastructure project (e.g., the social time preference rate in the UK Treasury).

Real Options

One proposed reason for (perceived) overdesign is creating or preserving option value. Projects may be overbuilt relative to their short-term use because they are intended to operate long into the future, and it may be more cost-effective to build in some capacities or features at the time of first construction than to add them later, such as building a bridge to bear a greater peak load than its immediate role in the transportation network would require. Similarly, aspects that are especially costly to modify may be overbuilt in the anticipation of later expansion, even if they do not immediately increase capacity. Although those features are not initially used to their full extent, they can be seen as maintaining the flexibility to expand or develop further at a later date. If this is part of a concrete plan, it can be accounted for in a discounted benefit-cost analysis or other evaluation approach. However, often the expected value of future use is highly uncertain, as it is not *known* when or whether the projected need will occur. Future development may be contingent on economic or social factors that affect usage, and may not occur at all if demand is unfavorable. A straightforward discounted cash flow analysis will fail to adequately account for features of a project designed to provide flexibility to account for high-risk environments or for uncertain but high-value opportunities. Real options are one way to value such features.

Real options analysis is taken from financial pricing theory, designed first to value options on risky asset classes. An option is a right or ability to take a certain action without obligation to do so – in finance, a contract providing the option to buy or sell an asset at specific prices and times. Real options analysis takes techniques to value such instruments and applies them to real assets. Unlike with financial instruments, which are typically purchased from a separate entity, real options are often more internal; the capacity to expand or contract a project can be built into the plan itself, for example by having staged development where later stages can be cancelled with no (or at least less) impact on the viability earlier stages, if demand does not meet expectations. When that flexibility incurs up-front costs, we can think of it as an option premium analogous to the price demanded for a financial option by the issuer of the contract to compensate for the risk they assume.

De Neufville (2008; Wang & Neufville, 2006) distinguishes between two types of real options; options "on" a project and options "in" a project. Options "on" a project deal with options regarding the process of the project itself, choices that can be made in the process of development. Options "in" a project are concerned with building into the resulting system the ability to make choices altering it at any stage; expanding capacity or switching technologies even after the planned development is entirely complete – though exercising that option may itself require further development (Zhao and Tseng 2003). This latter kind of option typically requires engineering or technical design changes, while the former is more associated with investment and funding decisions.

Valuing financial options is traditionally done using any one of a set of sophisticated mathematical models, one factor that may have contributed to the limited uptake of real options in management and project evaluation. In the infrastructure context, the most frequently used are discrete-time models. Borison (2005) classified these approaches into five categories, applying each one to an oil and gas example. He found that the different methodologies resulted in a broad range of valuations, and different recommendations.

Real options valuation is one way of incorporating real options, but it suffers from the flaws that it is mathematically opaque to many decision-makers involved in capital budgeting, and that its formal assumptions rarely apply exactly, especially to infrastructure projects. Another approach is what has been called "real options reasoning," the incorporation of real options through heuristics and verbal reasoning with structured frameworks rather than analytical methods (Krystallis, Laraqui Mahi, and Di Maddaloni 2024).

Garvin and Ford (2012) propose six barriers to the adoption of real options analysis in infrastructure, including that assumptions of formal valuation methods are often violated, that project managers lack resources (including cognitive recourses) to fully evaluate real options, and that the models assume repeated events rather than one-off decisions. They report that managers often describe justified options purchases as the ones that are "no brainers."

CHAPTER 2: METHODOLOGY

Overdesign is a sensitive topic; discussion of potentially overdesigned projects may embarrass related decision-makers, jeopardize professional relationships, and undermine support, whether for discussed projects or for infrastructure spending more generally. We proceeded by conducting off-the-record confidential interviews about the subject, in the hopes that confidentiality would allow more candid answers than public statements have previously provided. We provided interviewees with a list of intended questions in advance (Interview Protocol, questions in Appendix B), although not all the questions were asked in every interview. Interviewees were encouraged to speak conversationally, and often gave answers that were relevant to one or more questions without them explicitly being asked, and raised important points that the questions did not address (such as causes and sources of overdesign other than the specific ones we had questions on).

The interview protocol was reviewed and approved by the George Mason University Institutional Review Board and the procedures for protection of research subjects were followed.

We also conducted a case study of a project that had been mentioned during the development of the proposal for this project, the Presidio Parkway project in the San Francisco Bay Area. However, the case study revealed that overdesign was not a particularly salient factor for that project. The case study is included for completeness as Appendix A.

All told, we contacted 10 experts known to the authors through personal contacts and recommendations from early interviewees, and secured interviews with 9. Three had experience as state department of transportation chief engineers, two as chief engineers for toll road authorities, three as infrastructure developers for public projects, one as an academic with relevant expertise and one in a consulting firm serving the infrastructure delivery industry. Several had experience in multiple roles, and had served in a mixture of executive and technical positions.

Although we were able to interview most of those that we contacted, the initial pool of people was chosen from the PI's personal contacts, introducing a definite potential for bias (particularly when it comes to an interest in P3s). Two were not on that initial list and were recommended in early interviews. A further two were on the initial list but were also recommended by another interviewee.

Table 1: Interviewee Experience

Interviewee Experience	Count	Interviewee
Academic	1	A
State DOT senior executive	4	B, C, G, I
Toll road authority senior executive	2	E, G
Design-build firm (public and private clients)	1	B
PPP infrastructure developer	2	F, H
Consulting firm serving infrastructure delivery industry	1	D
Modes:		
Roads	5	B, C, D, F, I
Bridges	2	B, C
Airports	3	D, F, I
Rail	3	D, F, I
Other civil infrastructure	3	B, D, I
Domain of Experience:		
Maintenance	2	C, G
Operations	4	C, D, F, G
Design & Construction	4	B, C, F, G
Management	5	D, E, F, G, I
Policy	3	D, E, I
Finance	3	E, F, I
Engineering	4	B,C, E,G
Significant experience outside the US	3	D, F H

We introduced the concept of "misalignment" to frame the concept of overdesign. "Institutional misalignment" occurs when the constraints and incentives of a system lead to it optimizing for values or goals which are not its stated or intended goals. In the context of civil infrastructure design, the "system" in question consists of the aspects of the government commissioning the infrastructure that are responsible for its design and development.

Part of the motivation to use the concept came from preexisting impression the authors had about an example of purported overdesign mentioned earlier, the choice to use concrete of asphalt as a road surface. As a toy model to illustrate the impression, suppose we have an infrastructure project currently in the planning phase, with just one choice remaining to be made - whether to use a more expensive but longer-lasting material, or a cheaper option that will have higher ongoing maintenance costs. Suppose that the up-front costs are $10 and $5 billion respectively, and the more expensive option will save approximately $10 million/year in maintenance. Amortized over a 10 or even 30 year timeline, the increased capital investment won't be offset by the savings, so the cheaper option has a better life-cycle cost. However, this assumes that the $5 billion is available on an ongoing basis; if the budget available at the initial construction phase isn't going to be there for the future years and decades (or is uncertain), then from the perspective of the success of the *project*, the capital-intensive option may still be best. If a planner takes the approach that the budget they have available is use-it-or-lose-it, they may make a socially suboptimal choice that is nevertheless best for the project. We can see this by comparing the choice to that which would be made by a less constrained planner, one who could for example set aside the $5 billion against future maintenance costs – then, the optimal choice would be to choose the material with a better life-cycle cost, and set aside the extra amount needed for maintenance.

Institutional misalignment is in a way a generalization of principal-agent theory. The name comes from analogy to the idea of aligned interests, since what we're doing is comparing the behavior or interests of a group or institution against the public interest, that may or may not be those of a specific individual or group. An entity is *aligned* with, say, social welfare considered generally if the combination of their incentives and constraints cause them to take the action which optimizing the social welfare function would dictate. Including constraints is important - in the toy model outlined above, the planner *is* aligned if we consider the restriction on savings to be a hard limit that a socially-optimal planner would also face, but not if we think of it as part of the institution we are analyzing. If we are analyzing individual decision-making, and looking for misaligned incentives, we want to represent constraints on those individuals as a restricted action set of options, but if we are looking at the institution more broadly, we want to consider it as simply a choice the institution as a whole is not taking.

As the interviews proceeded we started making a distinction between this and a more focused version of the concept, "design misalignment". D*esign* misalignment is associated with a specific project, and is a mismatch between that project as implemented and its specific goals or values, whereas *institutional* misalignment is a systematic mismatch between the systems and processes of a governmental entity and the public interests it should be serving. Design alignment or misalignment can therefore be assessed and discussed in a more cause-neutral way.

We had three main reasons to want talk about "misalignment" with our interviewees. Firstly, we wanted to encourage neutrality about under- vs over-design, as well as to avoid priming as much as possible given the title of the project. There may be causes that don't simply promote overdesign or underdesign alone, but make both more likely – e.g., things that increase uncertainty.

Secondly, we recognized the issues raised by some of the more theoretical models, like principal-agent theory, which characterize problems as deviations from an ideal or optimal process in which agents are "aligned" with their principals. Why not just talk about aligned incentives? Because it may not be a disincentivized agent that causes the problem, but some other kind of institutional problem, like a lack of a particular kind of capacity. For instance, a choice that is optimal when a decisionmaker has the ability to bind the government to a future action (e.g., spending, by establishing dedicated funds) may *not* be optimal absent that capacity. Even an appropriately incentivized agent may (correctly) take a theoretically suboptimal choice if there is an institutional barrier making the optimal choice impractical.

Thirdly, talking about misalignment emphasizes the question "alignment with *what*?" In a governmental context, some notion of the public benefit is essential, but how exactly that is characterized affects the analysis greatly – a piece of infrastructure overdesigned by the standard of "safe and efficient transportation" may not be overdesigned by a standard that also considers the value of the infrastructure as a public monument or community improvement, something that was mentioned by several of our interviewees.

CHAPTER 3: FINDINGS

OVERVIEW

All our interviewees were able to identify some kind of overdesign in projects they were familiar with, although with a range from "not typical, and usually with no systemic bias between under and overdesign" to "dozens of overdesigned projects, with underdesign rare." Interviewees often gave more general responses about the causes and influences of overdesign rather than or in addition to naming specific projects or talking about commonality. Many examples mentioned by our interviewees were averted, in that there was at some point a design or plan that they were judged overdesigned but that it was successfully addressed after they or others identified it. Others were questionable – interviewees often noted examples or types of cases that they said might be *perceived* to be overdesign, but where the extra capacity was designed to achieve some other goal such as to support future expansion, although such expansion had yet to eventuate.

The most commonly mentioned cause of overdesign was poorly forecasting demand. Overly narrow design thinking was the most commonly mentioned cause of overdesign that was *averted* when spotted and addressed by someone with a less narrow perspective. Nontraditional goals beyond "safely and effectively meeting transportation needs" – such as aesthetics, community improvements, incorporating multiple modalities, or anticipating future demand or expansions – were the most commonly mentioned sources of misperceived overdesign. Note that many of the cases dealing with anticipating future demand or expansions are relatively recent, so the anticipated demand or expansions haven't happened yet.

Some of the comments we have categorized as "causes" and "practices to address" were not explicitly tied to design alignment, but merely mentioned as problems or good practices respectively. Interviewees were informed about the topic of the research before the interviews, but some of these may have been meant as more general observations about infrastructure design, procurement, or management practices.

One focus in this project was the investigation of institutional causes of overdesign – situations in which doing what may be locally best for the project given operational and political constraints or capacities results in a design that is arguably overdesigned. Several types of (potentially overlapping) situations were identified: cases where funds came from multiple sources with different sets of conditions attached to each, cases where budgetary constraints and the inability to convert between capital and operational funding led to a more expensive initial design that might not be optimal under a life-cycle cost analysis, attempting to put more than is ideal into one project, negotiations between multiple jurisdictions or decision-makers, and building to overly strict or misapplied standards whether out of habit or requirement (sometimes averted due to the ability to get exceptions). Interviewees didn't always agree with the issues others mentioned, and several brought up an issue someone else saw as serious and explained how it can be worked around in their experience.

Overdesign vs. Underdesign

Although the project was initially focused on overdesign, we clarified that by "design misalignment" we meant to include both cases of over- and underdesign; some interviewees addressed their experience of underdesign specifically in addition to overdesign.

Interviewee A discussed decades-old structures that haven't been kept up to standard with the growth of the modern economy, specifically the growth in the size of container ships, bulk carriers, and energy demand. Bridges may not have been underdesigned at the time of construction, but they are for the traffic we see today. A said whether that was the right choice or not at the time, given the expectation that the economy would grow faster than the infrastructure changes is a hard question.

Interviewee C said that they had seen both under- and overdesign, and that they didn't think there was generally a systemic bias one way or the other – they pointed to bad engineering as the most common problem.

In many cases interviewees mentioned cases of *averted* overdesign, when an initial design was proposed that *was* overdesigned, but it was caught before implementation and fixed. Five interviewees (B, C, D, E, H) talked about such cases and two mentioned the LBJ Expressway and the North Tarrant Expressway specifically.

Frequency Analysis

Here we present more detailed results counting how many interviewees mentioned a number of different common points. Not every interviewee was asked every question, and many things came up in places other than as a response to the most directly on-point question, so there is some judgement involved in this count and it shouldn't be understood as a proportion (except where stated). Asterisks next to a category or interviewee indicate a further discussion in the text below. In some cases an asterisked interviewee mentioned the same thing but in an opposite direction to other interviewees.

Table 2: Cases Mentioned by Multiple Interviewees

Project	Count	Interviewee
Springfield Interchange (VA)	2	F, G
Woodrow Wilson bridge (MD, DC, VA)	3	F, G, I
LBJ Expressway (averted) (TX)	2	D, H
Tappan Zee (NY)	2	A, F
North Tarrant Expressway (averted) (TX)	2	D, H

Table 3: Causes of Overdesign

Cause	Count	Interviewee
Failure of forecasting	5	B, C, D, G, I
Trade-offs between capital costs and ongoing O&M costs	3	A, C, G
Concrete instead of asphalt*		B*, F, H
Environmental Standards*	3	C, E, G
Safety Standards*	2	C, F
Traditional design standards	3	B, D, F
Strings from different funding sources*	3	C, E, G
Jurisdictional overlapping	2	F, H
Lack of personnel (esp. knowledgeable/experienced personnel)	3	C, D, E
Knowledge gap/information asymmetry		D
One-shot due to concern about getting to do a second project in the future	5	A, B, D, H, I
Changing political leadership	2	E, F
Other political aspects (earmarks, project location)	2	E, F
Note: *Entries marked with asterisks are discussed in the accompanying text.		

Interviewees C, E and G discussed strings attached to funding, but also ways to navigate strings without compromising design. C observed it was only a difficulty in the period before revenue (e.g., from tolls) came in, where that was available, and that it was much more challenging in the past because the number of different types of federal funds was greater. Now, with rare exceptions, everything is run as if it were federally funded because of the switching cost. Interviewee G talked about strings from above as well as desire for features from localities, and that the more localized a project is the more demand there is for specialty features. They also said that it seems like the problem of strings has lessened over time, due to better collaboration over time between federal, state and local officials.

Concrete vs. asphalt is a commonly alleged example of overdesign, as something more expensive up front that results in less spending on maintenance but that isn't worth the overall life cycle cost. Three interviewees expressed an opinion on that issue. Interviewee B named it as an example of something that would receive more consideration if maintenance were more involved in design decisions. They said that while concrete is an excellent ride surface, it's much harder to replace overnight when that becomes necessary. They didn't address whether less frequent need for maintenance would make up for that. Interviewee F and H both thought that concrete was superior on a life-cycle costing basis, but F thought that the problem with concrete was more of a contractor and political issue, while interviewee H thought that the cause was that federal funds go towards investment while DOTs pay for maintenance out of their own pockets.

Lack of knowledgeable or experienced personnel is another category that contains a lot of variability – specifically in the type of personnel discussed, due to the interviewees' areas of experience and focus. Interviewee D talked about having too few people overseeing and vetting private bids on the

exceptions.

Interviewees C and E discussed overly burdensome environmental and safety standards, but also ways that they could be navigated by experienced personnel without compromising design.

When talking about projects that were built larger due to the difficulty/unlikelihood of going back in and doing expansions or follow-on projects, interviewees mentioned both design/engineering constraints (A, B) and political constraints (D). Interviewee D thought that the public sector was right to do that, even if it sometimes results in overdesign, because of how disruptive it can be for the public. Interviewee E said that there's so much need that such cases are rarely overdesigned, especially when done in multiple phases.

Table 4: Practices that Prevent or Address Overdesign

Practice	Count	Interviewee Labels
Alternative Technical Concepts	2	A, H
Fostering creative engineering/design	3	B, C, D
Multi-phase projects	3	E, C, F
Use initial project to prove concept and justify later expansions	2	C, F
Life-cycle costing	3	A, D, F
Financial feasibility requirement in environmental review	1	E
Cost-sharing of maintenance with developers who want higher standards*	1	G
Sufficient oversight of design	3	D, E, F

Practice	Count	Interviewee Labels
CBA, quantifiable ROI	2	B, F
Early community/public involvement	3	C, F, G
More/better communication or integration between interested parties (industry, funding agencies, owner)	2	C, E
State/federal/local dialogue	1	G
Integration within government throughout the life of a project	3	B, E, F
Adaptive capacity (building in the ability to expand or add features later)	5	A, C, E, F, I
Note: *Interviewee G mentioned specifically cost-sharing or shared responsibility for maintenance and landscaping with private developers of neighborhoods, not just public-private partnerships on roads themselves.		

Some of our interviewees wanted to mention types of cases which risk being falsely seen as overdesign but could have sufficient justification.

Table 5: Sources of Misperceived Overdesign

Source	Count	Interviewee
Building for peak rather than average load	2	A, G
Building for anticipated future capacity	2	E, G
Adaptive capacity (building in the ability to expand or add features later)	4	A, C, E, F
Building in features and aesthetic aspects		A*, B*, F, G

Interviewees A and B saw building in special features and aesthetic elements as a source of overdesign, while G saw it as a misperception and F was more noncommittal.

Noteworthy Observations

Here we present observations that are more difficult to simply count, or which were only mentioned by one interviewee but seemed important. They're paraphrases organized by category, though some interpretation is involved particularly in the choice of category, and some categorizations may be stretched to avoid a large "misc" category.

Table 6: Interviewee Comments

Interviewee	Comments
A	**Bias in Policy:** One example of bias caused by policy is infrastructure as stimulus; it led to poor project selection after 2008 and a loss of construction was done that didn't need to be. **Best Practices:** Other countries are better at setting aside money for O&M and do better public sector budgeting. They point out that GASB doesn't think current US standards do a good job of accounting for long-term liabilities like O&M cost streams. **Considerations:** When it comes to overdesign as a result of predictions, we need a model of the original design choice to tell if any given example really is or isn't.

Interviewee	Comments
B	**Maintenance:** DOTs don't design projects to need full rehab – they're intended to last in perpetuity with only normal maintenance; the concern is ensuring that maintenance actually happens when needed. **Best Practices:** Maintenance considerations are in theory involved in the design process by being built into the standards; not in practice. **Considerations:** Road improvements are a combination of need and politics, and maintenance gets told how much budget they have and given some standards and to do their best – their people are not involved in design.
C	**Overdesign:** Tradeoffs between capital and ongoing O&M are very important in shaping design. Overbuilding for future capacity is risky because you have to maintain it until the capacity is needed; it's better to just have the right of way. **Best Practices:** Designing for easy expandability is less obvious sometimes standards or materials or the development change and it can't be made to fit anyway. **Considerations:** Sometimes it's a just good bet that doesn't pay off.
D	**Decision-making:** For many institutional setups, the bureaucracy will blink before the theoretical benefits occur if there's pressure from private partners. The public sector has the ultimate performance obligation, but they have less information. **Best Practices:** When done properly, life cycle costing should result in a lower overall cost, but it's the approach that saves the money, not who does it. **Considerations:** Serious failures result in blame falling on the public sector whether or not it's their fault, and nobody gets fired for putting an extra layer of concrete on something, but everyone gets fired when a bridge deck ripples.
E	**Design Practices:** Engineers by default want to design the system which functions best sometimes not adequately accounting for cost or right-of-way disruption without oversight. **Best Practices:** O&M is needs-based, it gets funded first from both state and federal dollars; capacity comes last. **Considerations:** Smaller, more heavily federally funded states may not have the state funds to mix in with the federal funding and make up for shortfalls from matching funds.
F	**Procurement:** Three sources of potential overdesign: designing to community and social needs that go beyond safe and efficient transportation, designing based on today's experience or technology and locking things in, and overdesigning due to a lack of tension around cost to contain affordability. **Best Practices:** If you have a megaproject to deliver, avoid relying on a large ingrained bureaucracy and instead set up a separate entity within government to deliver it, avoiding the accumulated requirements, standards, and habits that have built up over decades. **Considerations:** Projects wouldn't have happened at all without strong leadership, which needs to be weighed against overdesign.
G	**Procurement:** It's the ownership of the asset at the end that matters for maintenance, not necessarily the procurement method, so there are a lot of different arrangements that can work. **Best Practices:** Subdivision roads that were overly wide and intended to improve connectivity between neighborhoods are now being repurposed to include parking, road diets, or things like bike lanes to accommodate different modes. **Considerations:** Having a sidewalk, a bike lane, and a multipurpose trail might seem overdesigned but in some cases that's replacing something that is overdesigned because it's too car-centric.

Interviewee	Comments
H	**Bias in Policy:** There isn't this difference of the state versus the federal in other countries, so the money is coming from the same pocket. In the US, the state government is often trying to get money from the federal government, use it, and then move on to the next thing without necessarily trying to optimize their own budget. **Overdesign:** Overdesign includes an overinvestment or overly early investment of capital, potentially political capital as well as money capital. **Considerations:** In the US, there's always the idea that they'll make the highway fund bigger and that there will be more money for infrastructure from the federal government.
I	**Decision-making:** When you have a short planning horizon but you're trying to plan for long-term needs, there's a tendency to overdesign. Planning horizons are much shorter now than in the past. **Best Practices:** Adaptive capacity – rather than building initially to a long-term need, just build the structural capacity to be able to go and build out to that need when it eventuates. **Considerations:** Overdesign includes an overinvestment or overly early investment of capital, potentially political capital as well as money capital.

P3s/Delivery Method

Interviewees were all asked about "whether they have an impression one way or the other about whether P3s are better than traditional product development at avoiding overdesign." Interviewees disagreed about whether P3s were better in general, but most of those that didn't fully endorse them said that they would be the right approach for some projects and not others. Three (A, F, H) expressed a clear opinion that P3s are generally better. Only one interviewee, E, suggested another delivery approach (Design-build) was superior. However, several brought up some downsides of P3s, including those who were generally in favor of them – we collect those here, sorted less precisely.

Both B and D observed that there's an incentive for the project to be handed off to the owner at the conclusion of the project in poor condition. Contracts try to address that, but there's a back-and-forth contest between P3 owners and operators to outsmart those. The *ideal* case for the operator is to hand it off just when the condition is poor enough that operation suffers.

A observed that part of the tradeoff with P3s is a loss of budgetary flexibility – in a sense, they're *designed* to reduce the government's flexibility by requiring payments to the operator, but that does mean the government can't draw as much from the maintenance budget to address emergencies – either transportation-related ones or unrelated ones (such as national emergencies which may also be curtailing federal emergency funds)

C said that in their state a P3 would have to have the potential for revenue, and they would never recommend an availability payment model – though that's because of the availability of money at a low rate, in states with lower ratings where private partners can get cheaper financing that may be less true

D pointed out that P3s may miss out on economies of scale that a DOT can get by managing or operating large numbers of projects, like large maintenance fleets, and the possibility for cross-subsidization. F said that the sequencing of work can give you efficiency gains from delivering multiple projects at the same time, but often the nature of the government budgeting process means you don't have that flexibility.

H said that P3s need a good fit between contractor and investor, who work fluidly together, in order to get an optimized balance of up-front capital costs and ongoing maintenance.

E said some of the P3 challenges that have occurred have been primarily to do with cost and shortage of labor and materials, particularly when additional (state or federal) funding came out and the owner started too many new projects in the area, increasing the cost to the P3.

Interviewee I distinguished between P3s with different kinds of partners based on how long-term they're thinking, emphasizing that an investor with the plan of selling their investment five years after opening is not going to be as focused on long term life cycle and lower maintenance cost design.

CHAPTER 4: ANALYSIS

CONCEPTUAL

One of the concerns that came up frequently, perhaps prompted by our mention to the interviewees of the alignment concept, was the question of how to identify or characterize “true” over- and underdesign. There are at least three questions that need to be answered before making such an evaluation: firstly, the standard against which projects are to be compared; secondly, the viable alternatives that are available; and thirdly, how the project matches up against each.

Several cases of averted overdesign that were mentioned were averted because someone else came into the project and identified an approach or solution that the initial designers hadn’t considered that was significantly less costly; the modification of the North Tarrant Expressway from the original plan of a tunnel is one significant example. Overdesign can only exist if there is an alternative design achieving the appropriate goals at less “cost,” whether that cost be measured in budgetary expenses, disruptions to neighboring communities, or some other social cost. Identifying those alternatives is one of the challenges in finding conclusive examples of realized overdesign, as opposed to averted overdesign. Unless they appeared and were not pursued at some point in the planning process or are simple modifications of the existing design of the project, proving that there is such an alternative may be prohibitive.

The standard against which to measure overdesign came up frequently. Some of the existing literature in other contexts identifies overdesign as being a potential good, to hedge against uncertainties, to provide flexibility or mitigate risk. In the case of infrastructure, where timelines are long and capital costs are high, this poses particular difficulties. Our interviewees tended to say that cases where this kind of justification was reasonable were *not* examples of overdesign, suggesting that some explicit accounting for risk and option value should be part of the standard – that is, a project which is overbuilt for its use at a particular point in time should not be considered overdesigned unless the likelihood that that overbuilding will be needed or desired in the future is too low. That analysis can either be baked into the concept of overdesign, or as an additional step to determine if a project is “too overdesigned,” but it is particularly important in infrastructure projects.

As such, the role of forecasting in infrastructure projects is particularly important to the identification of under- and overdesign. A failure of forecasting was the most mentioned potential cause of overdesign among our interviewees, but all mentioned the ambiguity about some forecasts as a potential caveat – whether something was a good bet that simply failed to pay off, or a result of *bad* forecasting was considered essential to whether it results in overdesign. Infrastructure projects almost always have a significant forecasting component, usually of demand, but also implicitly of future technology and even *values*. We are primarily interested in institutional design, so the relevant question is whether there are ways project design processes could be (or have been) improved to avoid overdesign, but the evaluation of existing infrastructure (e.g., for potential repurposing or redesign) poses different questions.

One dimension of the appropriate standard which was particularly contentious among our interviewees was the degree to which it should include special features beyond those necessary for safely and effectively meeting transportation needs – for example, aesthetics, community development, or quality of life improvements. To a degree this mirrors the debate in P3 evaluation about the use of a broad social welfare standard compared to categorical success criteria or a value-for-money approach; most would qualify as externalities, with the exception of features that provide an additional transport modality (sidewalks, bike paths, multipurpose trails). Bringing the value of such amenities into the standard of evaluation makes it more aligned with the ultimate purpose of an infrastructure project, the public benefit, but also makes it more difficult to perform the evaluation, as their value is difficult to quantify or even categorize as successful or not. The simplest, most straightforward standard articulated by our interviewees was the provision of safe and effective transportation – or, framed categorically, safely and efficiently meeting transportation needs.

A more variable approach would be to consider the stated goals of the project, perhaps individually, and see whether each instance of potential overdesign addressed one of them and if so, whether it was excessive to meet that need. Indeed, in discussing specific cases of overdesign, interviewees often spoke not of the project as a whole being overdesigned, but of a specific feature that was excessive for its role in the project. One concern here is that stated goals may be incomplete or may change through the planning process, bringing in the potential concern of feature creep, but this is not always the case. A project initially intended to serve as a commuter connection may turn out to also serve an important role in connecting individual communities in its path, and features which serve that purpose alone should not be considered overdesigned. The expansion of projects beyond their originally planned intentions (scope creep) may be a concern, especially if systematic, but should not be considered *overdesign* if the design changes efficiently achieve legitimate public goals.

A final conceptual difficulty in identifying overdesign is the role of transactional politics. In some cases, seemingly overdesigned features are included to satisfy important stakeholders, and may even have been necessary to achieve project approval even when they poorly serve the goals of the project. When it comes to informally securing support (as opposed to meeting specific standards), distinguishing when extra features are truly necessary to the project could be impossible even with full and complete knowledge of every relevant detail, since it depends on the counterfactuals of stakeholder negotiations. Extra features that are truly necessary to secure support could be seen as measures to compensate for the costs the project imposes on stakeholders, bringing in distributional concerns, or they could be seen as part of making sure the project is successfully completed – there may be a "better" design in the abstract, but not one that is practically achievable. Although practically alternative designs rather than ideal designs are the appropriate comparator for overdesign, it may make more sense to consider these separately, potentially as form of "necessary overdesign."

CAUSES OF OVERDESIGN

We can categorize some of the identified causes of overdesign by sorting them into the ways they vary from an idealized design process. These may be variances due to the structure of the government departments that commission infrastructure projects, both in combination and individually, or due to constraints imposed on project designers by other parts of government. Some identified causes of overdesign also arise from straightforward failures or competency concerns in a way that could potentially be addressed by personnel decisions or improved training or management.

Our first category addresses a major "missing" governmental capacity: control over budgets. Most governments, and in particular departments that design and manage public infrastructure, lack the ability to commit to future budgetary expenditures in a principled way, and those responsible for project design choices are not fully responsible for their budgets. Someone in a department of transportation who is honestly pursuing optimal public infrastructure may nevertheless overdesign projects due to uncertainty about the feasibility of future needed expansion. Moreover, when designers are not involved in budgetary planning across multiple projects, they may be unaware of or have an overly blasé attitude about tradeoffs between the project they are working on and alternatives that may have a more pressing need. Even when considering those tradeoffs reasonably, cost savings on one project may not always be *able* to be spent instead on a higher-priority project, though the degree to which our interviewees considered transportation money fungible varied. All of these potentially contribute to a "use-it-or-lose-it" approach to expansions in the scope of a project. The individuals making those decisions may be well-intentioned, but even someone doing their best to meet public transportation needs may lead to overdesign when they're acting within an institutional structure that does not incentivize or allow them to consider or act on all tradeoffs.

One such tradeoff was identified as that between initial capital costs and ongoing ones. In designing a project, government officials may have the choice to invest more in the initial development in order to save on maintenance costs. Lacking the ability to instead dedicate those funds to future maintenance, the immediate best choice *for the project* can be to spend more up-front than is efficient from the perspective of the project's full life-cycle. Some of this effect also comes from additional funding sources available for project development like federal grants that cannot be repurposed for ongoing costs, shifting the expenditure onto regular maintenance budgets. As such, it also falls into a category of causes concerning multiple agents.

Broadly speaking, two kinds of contributors to overdesign were identified by our interviewees as impacting design choices in a way that *may* lead to overdesign; strings attached to funding sources from third parties (primarily the federal government) and joint decision-making (primarily when dealing with overlapping jurisdictions, but including local governments when the project is one they're more involved in) forcing unhappy compromises or delays.

There was a general consensus both that problems arising from federal funding sources has improved, and that there are ways to manage them by combining flexibility where it exists and sources with different conditions, but also that managing them imposes costs, whether from the limitations that are accepted or from the time and resources dedicated to avoiding them by rearranging funding sources, negotiating exceptions, or designing around them.

Our next category, constraints and standards, overlaps somewhat with the previous one as those conditions from funding sources which cannot be avoided operate as constraints. Our interviewees identified environmental standards, excessive or unnecessary safety standard, accessibility standards and traditional design standards as potential causes of overdesign. The latter should only be considered a *constraint* when it has some formal force, however – traditional design standards are also adhered to out of simple habit or a lack of creative thinking by designers, in which case it would fall into our next category. Traditional design standards may have some formal force even when they aren't *requirements*, however, when adhering to them is considered a sufficient reason for a design choice, or when departing from them requires an exception. The line between a lack of creative thinking and a weak requirement is somewhat fuzzy.

Finally, we address a source of overdesign which does not appear to have any direct institutional grounding. Here, we're combining biased forecasting with failures of creativity or engineering, because they share a more individual grounding. When a design team fails to see and consider a cost-saving design choice or makes a clearly flawed forecast about future demand, that can lead to overdesign without any institutional problem except, perhaps, one of management and training. It should be noted that all our interviewees who mentioned flawed or biased forecasting hastened to add that forecasting is extremely difficult, and just because a forecast turns out to be wrong wouldn't mean that it's flawed or biased.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

This research project has examined the issue of overdesign in infrastructure. Based on a thorough literature review, the research team developed a questionnaire on the nature and extent of overdesign and practices to avoid it or correct it when it does occur. Confidential interviews using this questionnaire were conducted with subject matter experts across a broad range of industry roles and experience, including state departments of transportation, toll road authorities, consultants and advisors, and infrastructure developers.

The subject matter experts interviewed for this project generally agreed that overdesign was prevalent, arising from a wide range of causes from forecasting errors to changes in political leadership (see Table 3).

This research has identified several mechanisms for preventing or addressing overdesign (see Table 4). Among the most salient of these are the following.

One way to prevent or reduce overdesign is to encourage the development of technical alternatives that meet infrastructural needs through a different approach. Design teams should be set up and managed so as to support more creative design and engineering, emphasizing a broad-minded approach to meet a need or solve a problem without defaulting to traditional solutions or building to a standard.

A further action is that whenever possible, specifications to contractors or private partners should focus on identifying the need a project is intended to meet and leaving open-ended how it should be solved, allowing competition between bidders to incentivize unanticipated approaches that can creatively solve problems while still addressing the infrastructure need.

One contributor to overdesign that was emphasized by our interviewees was complications in the relationship between overlapping jurisdictions and funding agencies. The more that are involved in a project, the more difficult it is to waive requirements or resolve issues that would otherwise require unnecessary construction or overdesign, or to allow nonstandard approaches to be developed. Improving communication between and among all parties was frequently cited, as was having it happen early and often.

This research has several limitations. First, the data primarily comes from nine confidential interviews with subject matter experts, most of whom were professional acquaintances of the lead researcher or referred by early participants, limiting the representativeness of the sample. Second, the confidentiality of the interviews restricted the researchers' ability to verify certain claims. Lastly, overdesign is inherently subjective, adding complexity to the analysis.

Further research on the subject could investigate in greater depth some of the specific cases mentioned by the interviewees (see Table 2). Future research could also be enhanced by collaborating with asset-owning agencies to closely observe the design process and tradeoffs.

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APPENDIX A: PRESIDIO PARKWAY CASE STUDY

BACKGROUND

The research team conducted a case study of a project that had been mentioned during the development of the proposal for this project, the Presidio Parkway project in the San Francisco Bay Area. However, the case study revealed that overdesign was not a particularly salient factor for that project. The case study is included for completeness below.

The project sponsor commissioned a "qualitative analysis" of the project. The research team obtained a confidential copy of a 2016 draft, which is referenced herein as the qualitative analysis. The final report does not appear to be publicly available.

This case study is drawn from the qualitative analysis and other published or publicly available source material (Ortega and Melehani 2016; Jones Day 2016; Jimenez and Nossaman LLP 2015; Antillón, Javernick-Will, and Molenaar 2015; Golden Link Concessionaires LLC v. State of California Department of Transportation 2015).

INTRODUCTION

The Presidio Parkway project was a construction project to reconstruct a segment of US Route 101.Planning for the reconstruction began under the aegis of the Doyle Drive Replacement project, and construction began in 2009, almost ten years after the draft Environmental Impact Statement. Presidio Parkway was one of many alternative designs for the project, and was a "top alternative" by the time the DEIS was completed in 2005. It was chosen as the "Preferred Alternative" in 2006, and received formal confirmation that it was ready to be implemented in 2008. The parameters of the project were complicated and design criteria (especially the aesthetic goals) were unusually strict due to its proximity to the Golden Gate bridge. Another source of complexity was shared jurisdiction, with two main landowners having a significant stake in the project. The Golden Gate Bridge Highway and Transportation District had primary jurisdiction over the project area, but the National Park Service (owning ~20% of the land) and the Presidio Trust (a federal agency owning ~80% of the land) were also significant actors.

The project had two co-sponsors, Caltrans and the San Francisco County Transportation Agency. The involvement of two landowners each distinct from the project sponsors and reporting to two different authorities was a source of considerable difficulty for the sponsors in Phase I and the developers in Phase II.

PROJECT PHASES

Phase I of the project lasted from 2009-2012, and consisted of the construction of a bridge, battery tunnel, and a temporary bypass. Upon completion, traffic moved from the old roadway onto the newly constructed bridge, tunnel and bypass. Phase II was formally completed in 2016, and consisted of the removal of the old roadway, construction of three other tunnels, and an interchange. Three months after traffic was shifted from the temporary bypass to the new permanent facilities, late 2015, Phase II was considered "substantially complete."

The significance of the Presidio Parkway project is that it began as a design-bid-build project along the lines Caltrans traditionally operates. The project phases were initially conceived of as two sets of four contracts, with Phase I consisting of four contracts all awarded by 2010 through the DBB approach. During this process, however, P3 enabling legislation was passed and signed by the California Senate, which opened up the possibility of delivering Phase II through a P3 agreement. Although contracts for Phase I had already been entered into and construction had begun, Presidio Parkway was determined to be the best project that was ready to be implemented as a P3; "they needed a project that was already environmentally cleared in order to meet the timeline, and that ... needed to be sufficiently large to justify the transaction costs associated with doing a P3, and it needed to be a project that was eligible under the legislation."

Presidio Parkway was the only project meeting these criteria, and so Phase II of the project became a testbed for the P3 process. The significance of not only being one of the first P3s entered into under the California legislation, but also having the construction split between the P3 and the traditional DBB process, is why the project is of particular interest. In fact, the P3 ended up combining the design, building and financing of the project with ongoing operation and maintenance of all facilities. The initial Value for Money report concluded that implementing the project as a P3 would offer significant cost savings, as well as an improved risk profile. The estimated costs were approximately 23% lower than continuing with the DBB process. The report also concluded that a P3 including operations and maintenance would offer better cost and schedule certainty due to the risk of overruns being allocated to the entities best placed to manage them, a higher level of operations and maintenance operations post-construction due to budget constraints under a public-servicing regime, and would be an overall better use of public funds than either a traditional project or a P3 responsible only for construction.

ANALYZING THE PRESIDIO PARKWAY P3

The Qualitative analysis report analyzed the project in the three stages of the P3 life-cycle: Policy and Planning, Transaction, and Implementation - which itself in this case was split into the design and construction in Phase II of the project, and the ongoing maintenance after the completion of the project.

With regard to the first stage, it concluded that the P3 design was made further along than was ideal, with Phase I having already begun construction and ~50% of design already having been completed (including for Phase II, which would be the P3's responsibility to construct). The fact that the institutional structure around P3's was new and untested may have worsened the effect of this - a challenge to the validity of the P3 under the new law caused significant delays, and "institutional inertia and fears of cultural change" identified in phase II may have been worsened by attempting P3 implementation in a project that was already so far along in its planning. The state (Caltrans) appeared to have had issues engaging with the project in the "spirit" of a P3, attempting to manage the details of delivery rather than to set ultimate project/performance goals and rely in the contractor's incentive to deliver (see quotes at the end).

To some degree, you could consider these issues as a necessary part of a pilot program - *some* P3 had to be the first, and face that initial institutional and cultural inertia. The concern is that as a project already so far through its development, Presidio Parkway faced more than a brand-new project would have, and so poorly served its role in establishing norms for future California P3s. These issues recurred in the transaction phase, although private financing of the project was successfully acquired and leveraged to prevent the need for public-sector funding throughout Phase I so the cost improvements were realised, and a partial transfer of risk to the private side of the partnership was achieved - albeit less of one than ideal for a P3, due to the commitments already made in the earlier iteration of the project. The procurement process was significantly more complicated for the P3 than it was for the Phase I DBB contracts. The project sponsor executive said "*in California the procedures for doing a traditional design-bid-build project are well established. There is a lot of precedent history and court cases, we know exactly how to do that and it is quite straightforward. The P3 was new so we were inventing procedures at the time which is more difficult.*"

The implementation stage of the P3 is where most of the difficulties started to become apparent. Caltrans didn't engage with the contractor in the way they anticipated, particularly with regard to quality management. Their expectation was that they would take responsibility for quality control and assurance, and that Caltrans would provide only high-level quality oversight. But Caltrans was used to using it's own QA staff, and the developer reported that Caltrans didn't give much regard to the developer's own quality control work, and did a lot more hands-on work themselves. Construction experienced significant delays, though without cost increases. The analysis reports that schedule growth was around 16%, however, which was still less than the traditional Phase I contracts. In A P3, the concessionaire/design-builder is expected to assume responsibility for "day-to-day" QA/QC, and Caltrans failure to meet the developers expectations in this regard caused inefficiencies. Quoting from the analysis report:

"A misalignment between the project sponsors' and developer's expectations for the quality management methods and processes implemented to ensure and verify quality standards for the project has resulted in difficulties in ensuring quality is met for Phase II."

Caltrans, on the other hand, felt like they weren't trying to micro-manage the design-builder, simply provide their in-house experience in QA/QC. They felt that since they were a DOT with a significant history of in-house design, their quality management contributions would be additive, and that the design-builder's QA was lacking with regard to "detailed record keeping and detailed inspections", and "signing and approval of certain things before other things happen in the construction."

In other words, the developer felt that Caltrans was overstepping relative to the planned quality management approach, while Caltrans thought that despite seeing no evidence that construction was suffering, the developers QA/QC processes were lacking, requiring them to step in. It may be that the management plan for the project failed to adequately specify Caltrans' expectations in this regard, this is a hidden failure in the procurement stage

In conclusion, Phase II of the project experienced significant schedule delays, but potentially less than would have been experienced without a P3. This is in spite of the fact that a significant source of the delays was the lawsuit aimed solely at the validity of the project under the new P3 legislation (filed by public sector employees union and claiming, in brief, that the agreement did not qualify and so was not authorised by the legislation due to the lack of user fees or tolls). The project did *not* experience cost increases during construction, coming in at exactly the contracted amount (and significantly less than the estimated cost. However, a settlement for a number of claims filed by the developers did incur significant costs - the resulting settlement appears to have resulted in an additional 16% over the contracted amount - still 25% less than the estimated cost. The developer alleged that significant additional work was required in order to complete the project that was not covered by the original contract , much of it to satisfy the Presidio Trust. The disputes about those claims appears to have been somewhat contentious, and the developer eventually filed a lawsuit alleging that Caltrans had failed to engage in the contracted dispute resolution process in good faith. The settlement for the lawsuit, around 90 million, represents only a facial cost overrun, however, since the project's planning anticipated costs resulting from disputes with contractors, and after including the settlement and contracted cost the project's expenses came at 25% less than the anticipated amount.

Ongoing Operations and Management

The two major advantages of including operations and management in the P3 are the inclusion of design improvements from the developer resulting from considering the design process from a life-cycle perspective rather than an up-front one, and the prospect of a dedicated O&M budget. Life-cycle design improvements in Presidio parkway were limited, in part due to the late stage of the design process when the P3 started, but included both a ventilation system and lighting control system change. The analysis report considered these to be relatively small/incremental. However, the O&M budget commitment was substantial - funds were appropriated for payments to the concessionaire throughout the contracted 30-year O&M period, and such payments are linked to performance requirements for pavement integrity. Over the limited amount of time the parkway was in operation prior to the analysis, the hope of the P3 improving the ongoing condition of the road appears to have been borne out, sith significantly better pavement condition to similar projects. Similarly, the service requirements appear to have been doing their job, meeting and exceeding Caltrans requirements for response times (requirements which are not met statewide.)

TAKEAWAYS

The issues that plagued the project were mainly due to the hybrid nature of the project and the lack of a culture fit between Caltrans' norms and procedures and the intended advantages of a P3. One particularly interesting feature for our misalignment interests is the apparent unusualness of life-cycle analyses and value-for-money calculations being an important part of project decision-making, something we're including questions about to try to gauge prevalence.

It's hard to make any firm conclusions about overdesign based on the project because of the limited scope for design improvements – quite plausibly any relevant factors were locked in by the Phase I process, the concrete aspect that initially sparked the idea would be an example here. Maintenance standards do seem to be unusually good relative to similar projects, but that's only with a few years to review.

Several quotations from interviews in the analysis report stood out:

- "So if you are the state, you are Caltrans, you have a great temptation to tell the contractor not just what to deliver, but how to deliver it. And when you start telling them how to deliver it, you lose all of your leverage... but those things are harder to control if you are the organization that is overseeing what the contractor is doing and is very set on a particular way of doing things, because then the people in the organization will be tempted to lecture the contractor about how you should do things, "because that is how we do it here" and then you immediately grab all that risk and bring it back unto yourself. You just violated that main rule, which is you need to tell them what the ultimate product is or what the performance justification is, and let them figure out how to deliver that performance specification." – Project Sponsor Executive
- "I think that just having the concept of value for money on the table is quanta leap [sic] from where we were from a public policy standpoint, because once you put that on the table and you start making comparisons between one delivery method and the other, it becomes inescapable that one method is better than the other. So just having the metrics is fundamental because you can't have these discussions on a one- year budget, which is why it is so important to burst that discussion open in state legislatures, and at national levels, that you can't have a 30-year infrastructure program one year at a time." – Project Sponsor Executive

APPENDIX B: INTERVIEW PROTOCOL

PROJECT TITLE

Overdesign in Civil Infrastructure Systems? The Influence of Infrastructure Funding, Finance, and Procurement on Facility Design and Delivery

PROJECT SUMMARY AND INTERVIEW PROTOCOL

Project Summary (to be shared with interviewees)

This project is exploring the influence of funding, finance, and procurement policy on the existence and extent of overdesign, its potential impacts, and possible remedies, as well as whether specific institutional structures such as P3s may be less (or more) prone to overdesign.

It will also explore the degree to which such policies create institutional incentives and constraints that create a mismatch between what a system of project development is intended to achieve and what it does.

The interviews will focus on assembling information to support a qualitative analysis of these considerations

Glossary (to be shared with interviewees)

- Overdesign – the design of facilities that are larger and more costly than necessary
- Public-private partnership (P3) – a long-term (usually multi-decade) agreement between a public infrastructure asset owner and a concessionaire for the design, construction, finance, operation and/or maintenance of that asset.
- Institutional misalignment - When the constraints and incentives of a system lead to it optimizing for values or goals which are not its stated or intended goals.

Interviews (Goal: 12)

The research for this project will encompass a series of interviews with state government officials (i.e. toll authorities and state DOTs), coalitions and advocacy organizations (e.g., the Association for Investment in American Infrastructure, AIAI), and private development stakeholders (e.g., Cintra, Transurban) as well as academic communities (e.g., Transportation Research Board committees (e.g., the Committee on Economics and Finance, and its Subcommittee on Public-Private Partnerships). The list is still being finalized with specific interviewees. *Table* 1 describes the general categories.

Categories of Potential Interviewees

- State department of transportation current and former chief engineers
- Toll road authority current and former chief engineers
- Design-build firms serving public and private clients
- Public-private partnership infrastructure developers
- Consulting firms serving the infrastructure delivery industry, such as financial, technical, and legal advisors
- Academics and authors of relevant publications

Interview Questions

The objective of the interviews is to gather information regarding the forms of cooperation, the terms of the contract during these downtime events, and the relationships between both parties when the downtime occurs. Below are the general and sub-questions drafted to date:

Informed consent

- We sent you a disclosure and consent document. Did you receive it? Do you grant your consent for this interview to be recorded and transcribed?

Context

- Please describe the kind of infrastructure projects you have been involved in and your role in the structure of your organization.

Prior Experience

- Are you aware of any government projects which you would now say were overdesigned? If so, was that something which you think should have been foreseeable at the planning stage or only in retrospect?
- Can you think of any government projects where you felt there were significant implicit purposes or values in the planning process that were not reflected in the stated goals?
- Can you think of any government projects where you felt there were significant implicit purposes or values in the project as implemented that were not reflected in the stated goals?

Specific Causes and Sources

- In your experience, how important are tradeoffs between initial capital costs and ongoing O&M costs in the design of projects?
- "Are you aware of projects where the source and matching features of funds affect the design, and in particular, the tradeoff between initial construction and ongoing O&M?
- "Have you observed any differences in such tradeoffs across different procurement approaches, such as design-bid-build, design-build, and P3?"

Funding and Financing

- What proportion of projects are you aware of where being able to meet maintenance and operations costs using uncertain future budgets was a significant concern?
- What proportion of projects are you aware of where there were dedicated funds set aside for future operations and maintenance costs?”
- What proportion of projects are you aware of where an explicit value-for-money calculation was done? If so, what kind of analysis was involved?

- What proportion of are you aware of where a value for money calculation or life cycle cost analysis was completed, but was given less weight because of issues with year-on-year budgeting?

Ambition and Size of Projects

- Are you aware of any projects where a more ambitious design was chosen due to a concern that there would only be "one shot" at a successful project – that future expansions would be unlikely or infeasible?
- Are you aware of any projects where a choice was made to pursue a less ambitious design because multiple smaller projects would be more effective?
- What do you feel are the most salient factors that determine the size and scope of government projects?

Specific Institutional Designs

- In what ways do you think projects can best enhance or value flexibility in creating and evaluating project development plans? In what ways can they best do so as development proceeds?
- Are you aware of any projects in which a particular institutional design (e.g., P3s) was successful at avoiding the above problems?
- Are you aware of any cases in which a particular institutional design (e.g., P3s) was intended to but was unsuccessful?
- Do you have an impression one way or the other about whether P3s are better than traditional project development at avoiding overdesign?

Request for Literature

- Are you aware of any literature connecting overdesign to misaligned incentives in government projects?
- Are you aware of any literature that seems particularly relevant to the misalignment concept?
- Are you aware of any literature on how infrastructure projects can or do best value flexibility in evaluating project development plans? On how projects can increase flexibility as development proceeds?

Opinions on the Research Concept

- Do the questions raised in this research have any relevance for or applicability to your organization?

Questions Specifically for Developers

- As a private developer do you observe differences in the way capital expenditures and operating expenditures are evaluated in your private projects compared with the way the government agencies you work with do, or to the way P3s do?

Open-Ended Questions

- Can you suggest any relevant examples of cooperation, publications, articles, or potential interviewees that might help us pursue our research?
- Is there anything else you would like to share with us?