

# Overdesign in Civil Infrastructure Systems

The Influence of Infrastructure Funding, Finance, and  
Procurement on Facility Design and Delivery

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# Background

- Infrastructure delivery costs are unusually high in the US, both historically and internationally, particularly in public transit (Goldwyn et al. 2023). 'Megaproject' cost problems are especially well documented. (e.g., Flyvbjerg & Gardner, 2023)
- Anecdotally, former transportation CEOs, private infrastructure developers and other industry leaders say, speaking off the record, that states and asset owners overdesign their facilities.
- We wanted to investigate how prevalent overdesign is, and get some idea of the contributing causes and potential mitigation or prevention steps that could be taken.

# Overdesign

‘The design of facilities that are larger and more costly than necessary.’

- Examples: Thicker pavements, more capacity, more expensive materials than needed. Additional features or extensions.
- Potential consequences: Increased cost, leading to other projects being crowded out.

Delays in project start dates or increased completion times.

Environmental impacts (e.g from increased concrete use (Habert et al. 2020))

Other downsides stemming from the two, like contributing to the backlog of deferred maintenance (American Society of Civil Engineers 2017)

# Potential Causes

- A preference for increased up-front costs to save on maintenance as capital budgets are more reliable than annual appropriations.
  - choosing concrete pavements, which require more money and work at installation and to replace at maturity, but which require less year-on-year
- 'Now-or-never': the difficulty in getting projects through planning and development may lead to the belief that there's only one chance to build a project in a generation
- Overdesigning for the future: an (over)reliance on forecasts of growth and demand may lead to facilities that appear to be overdesigned until the demand is realized.
  - if it never does, the additional capacity is wasted, and if it's too far in the future building now may be less efficient than building later
- 'Scope creep': New features get added to a project either at stakeholder request or to ensure compliance. Over time they become standard, or are harder to resist without significant effort.

# Misalignment

- Concept to frame overdesign, both on the recognition end and the analysis end.
- Misalignment occurs when a system optimises for something other than its stated or intended goals.  
‘Design misalignment’: A mismatch between a project as implemented its specific goals or values; when an alternative design could clearly serve them better.
- ‘Institutional misalignment’: a systematic mismatch between the systems and processes of a governmental entity and the public interests it should be serving.

# Why misalignment?

- Neutrality between under- and over-design. Some projects may have both.
- Combines (mis)aligned incentives with other institutional problems – constraints, lack of capacities – to make locally ideal choices when from a system-wide view the choices are suboptimal
- Emphasizes the subject; alignment with *what*? Some notion of the public benefit, but how narrow? Different scopes might label some things over- or under- designed.
- The design/institutional distinction separates investigation of the causes of misalignment and its evaluation.

# Is overdesign always bad?

- Often it's talked about like it is; 'too []' or 'more [] than *necessary*'. But often we shouldn't design things to minimum standards. We could think of some examples of overdesign as *margin*. (Eckert et al. 2020).
- In product design, overdesign is a comparison to explicit requirements or specifications. When those are more complete and closer to the fundamental purpose of a design, 'overdesign' is more normative. When there are missing requirements, factors not included in the spec, or it relies more on proxy values 'overdesign' labels are less normative.
- Overdesign can be thought of as providing flexibility for changes in requirements, avoiding the need for redesign or expansion. It can also mitigate risk, as in redundancies or building to higher tolerances to account for unexpected situations (Jones and Eckert 2023) . Allen et al. (2019) compare overdesign to redesign, finding 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.

# Methods

- Overdesign can be sensitive – talking about specific examples is often a criticism of the projects in question. So, we conducted off-the-record and confidential interviews to encourage candor.
- Semi-structured interviews: all interviewees were provided the same list of questions in advance, but digressions were encouraged and not all questions were explicitly asked in each interview.
- Interviewee expertise guided the interviews; we tried to give them as much understanding of the questions we were interested in and they brought up many relevant and important points that went beyond the questions.
- 9 interviews conducted across a wide range of expertise. The initial pool was chosen from personal contacts, and interviewees were asked to recommend others who would be good to contact – two of the interviewees were recommendations not on the initial list (and another two were recommended who were)

# Interviewee details

Interviewee Experience	Count	Interviewees
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
<u>Modes:</u>		
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

Interviewee Experience	Count	Interviewees
<u>Domain of Experience:</u>		
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

# 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*	3	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

# Causes of overdesign

- Some other notable causes mentioned included tradeoffs between capital and ongoing O&M costs, designing to a 'standard' without sufficient questioning of the standard, and the involvement of multiple jurisdictions or agencies.
- Tradeoffs in general were mentioned by three interviewees, while the concrete vs asphalt issue was specifically mentioned by another three.
  - However, one of those was unsure about the direction it pointed.
- The nature standards in question varied – 'traditional design standards' were entirely internal to the design process, following 'the book' rather than looking for exceptions, while environmental and safety standards refers to more formal requirements
- Multiple jurisdictions or funding sources are similar in that the issue is unfocussed decision-making, making it harder to get approval for exceptions, to resist unneeded features or include unusual cost-saving ones

# Causes of overdesign - Caveats

- Interviewees discussed the problems of funding strings, but also ways to navigate them without compromising design, and said that the situation has improved in the last ~decade.
- B thought that the maintenance side of concrete was more ambiguous – it costs less to maintain, but when maintenance is needed it's more burdensome as it's hard to do overnight.
  - Contractor influence vs federal funds for up-front and maintenance from DOTs
- Lack of personnel included people overseeing/vetting bids in govt, engineers to find creative solutions, and people with experience arranging for exceptions.
- 'One-shot projects' included both design/engineering and political constraints making it difficult to follow on. One interviewee said when it came to political constraints the public sector was often right to avoid multiple projects.

# (Mis)perceived 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

# (Mis)perceived overdesign

- Interviewees disagreed on whether special features and aesthetic were a source of overdesign – although the specifics they discussed didn't entirely overlap.
- Adaptive capacity refers to things like building a bridge to higher tolerance so that it can bear the load of rail in the future, while building for anticipated future demand refers to building in capacities that *could* be used now (like higher tunnels or more lanes) but that are only constructed because they are expected to be used in the future. Both cases were highlighted as potential overdesign and a potential misperception.

# 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
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

# Practices that prevent or Address Overdesign

- These are practices interviewees advocated for or expected to help. They're a mixture of practices which interviewees have observed to help where they're taken, but aren't universal; practices which they observed to help and thought should be more frequent or streamlined; practices which are common in other areas or in the private sector and which should be more used in public infrastructure
- Adaptive capacity, multi-phase projects, and proof-of-concept were all proposed as an alternative to fully one-shot projects, but also potentially as something which should be done more in general.
- Cost-sharing of maintenance referred to sharing maintenance, including of landscaping and amenities, with neighborhood developers – not just public-private partnerships on roads.

# Analysis - Conceptual issues with overdesign

- Interviewees had different conceptions of overdesign itself, and of evaluating ‘true’ vs. perceived overdesign. Three things came up repeatedly; the standard, the alternatives, and the difficulty of comparison
- Identifying overdesign involves a set of values or a standard against which to compare; is the goal simply “safe and efficient transportation”? Or does it include goals beyond meeting transportation needs - aesthetics, community development, or quality of life improvements?
  - this mirrors the debate in P3 evaluation and other evaluation contexts about using a broad social welfare standard, compared to VfM or categorical criteria (Moore and Vining 2023)
- Identifying one part of a project rather than the project as a whole
- Risk and uncertainty; is ‘overdesign’ sometimes good, as a hedge or to retain flexibility? Or is that only overdesign when it’s excessive?

# Conceptual issues with overdesign - comparator

- In order to talk about overdesign, we need an alternative design to compare it to. Often this is simple – using a different material, or not including a feature – but sometimes a more substantial redesign is needed, for example to *avoid* a problem rather than solve it.
  - Ex: LBJ Express Highway, modified from a true tunnel to a cut-and-cover. North Tarrant Expressway, modified from an elevated viaduct to road going up-grade.
- Identifying one part to change makes things simpler, but can overlook those solutions.

# Conceptual issues with overdesign - Evaluation

- How should we think about overdesign when an alternative isn't raised or made public during the planning process? Many projects may be overdesigned in the sense that a creative alternative could exist but wasn't found. Should we count this?
- How to deal with forecasts. Interviewees all emphasised that designing for future demand with a *reasonable* forecast shouldn't be thought of as overdesign - but forecasting over the 30+ year timescales some public infrastructure is built for is very hard! Over those lengths, values and technology change as well as demand. Improving forecasts and dealing with poor forecasts in planning better might be the most valuable thing to do to address overdesign – it also might be the most difficult.

# Analysis – Causes (budget)

- We categorise some of the causes of overdesign by the ways they vary from an idealised design process; the constraints that exist or missing capacities. Some of the causes are non-institutional or a mix of institutional and not.
- Control over Budget: Most governments doing public infrastructure design lack the ability to commit to future expenditures, whether for maintenance or expansion, as firmly as they can commit up-front capital costs.
  - moreover, the commitments they can make are often not adequately accounted for as liabilities on the public balance sheet.
- Cost savings on one project with dedicated funds may not be *able* to be spent on other projects or be dedicated towards future project costs, encouraging a ‘use-it-or-lose-it’ attitude.

# Analysis - Causes (Multiple funding and decision-making)

- Strings or limitations attached to funding sources reduce flexibility and may cause overspending on an area with specific funds allocated. Funds may also come with requirements that don't fit the specific project, and obtaining exceptions can be difficult.
- Where there are many funding sources in play, navigating the interactions between them by rearranging funding, negotiating exceptions or designing around them can become difficult, requiring time and effort from experienced personnel.
- Similar problems can occur with overlapping jurisdictions.

# Analysis - Causes (Standards)

- Some standards are informal – just ‘how it’s done’, at least by the book (traditional design standards). Others are constraints with some formal force – environmental, safety, and accessibility standards. In some cases adhering to traditional design standards can be a protection against formal requirements.
- The latter can be considered a constraint, while the former is an ability or competency issue (when the standard is inappropriate).

# Tentative recommendations

- Encourage the development of technical alternatives that meet infrastructural needs through a different approach.
- 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.
- Improving communication between and among all parties involved in a project, and having it happen early and often. This includes public dialogue about the needs and preferences of the people impacted, as well as between agencies and jurisdictions.

# Limitations

- The interviews were conducted a nonrepresentative, small sample of experts, either known to the lead researcher or referred by other interviewees.
- The confidentiality limited verification of some claims by the interviewees, and means that most examples mentioned to explain a claim or perspective can't be publicly disclosed.
- Overdesign involves inherently subjective judgements, and in many cases expectations about future changes in demand. Almost all examples used were projects recent enough that planning horizons are still in the future.
- Some participants highlighted changes in specific areas; our interviewees typically had long careers, but their more recent experience was often in different domains, so some uncertainty over whether improvements would have been noticed or attributed correctly.

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