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PUBLIC CIVIL ENGINEERING PROJECTS – BETTER THAN THEIR REPUTATION?

Christian Koch, Nicolaj Frederiksen
Department of Technology and Innovation, University of Southern Denmark, Odense, Denmark

Abstract

While awaiting the final cost and time overrun for the Stuttgart's new central station—yet another complex megaproject seemingly gone wrong—a broader look at civil engineering projects might reveal a different pattern. The Danish Auditor General analysed 41 civil engineering projects in Denmark (railroads, stations, motorways, bridges, etc.) costing €10,3B in 2024. 60% were delayed, mostly due to changes in the specification of deliveries. 18% exceeded budget, whereas 47% ended under budget by more than 10%, primarily due to the lack of requested changes. Adopting a complexity perspective, this paper scrutinizes how complexity occurs in civil engineering projects. A framework for understanding complexity is developed, juxtaposing four approaches. First the Flyvbjergian notion of the "iron law of megaprojects," arguing that complexity stems from issues inherent in the project surroundings. Second Barnes' notion "the iron triangle," viewing complexity as inherently within projects. Third, Kreiner's notion of "drifting environments," where complexity emerges from changing conditions in the project surroundings. Fourth and final, the notion of the "hiding hand," positing that complexity emerges inside the project. An analysis of the 41 Danish civil engineering projects concludes that projects do not go wrong but rather feature a diverse set of outcomes. Complexity is then proposed as a rhetorical device used by professionals and importantly leading as often to positive as to negative results. This suggests that civil engineering projects as such may be better than their reputation implies.

Keywords: civil engineering projects, emergent complexity, project complexity, project management.

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1. Introduction

The Stuttgart 21 megaproject aims to construct an underground train station and urban bypass, replacing traditional terminus with a through-line [1]. Construction began in 2010 with an expected completion in 2019. However, the latest estimate from 2024 expects it to be December 2026. By summer 2025, the project will be about seven years behind schedule. The cost has similarly risen from an initial estimate of €2.6B to €12B [1]. From the outset, its geographical scope and composition of several large sub-projects already signaled *complex*. While Stuttgart 21 certainly appears disastrous in cost and time, focusing only on this and similar projects may obscure the broader landscape of project performance. On this basis, this study asks: would a broader view of civil engineering projects reveal a different pattern than those of projects such as Stuttgart 21? We are also concerned with the overuse of "complexity." The term often appears rhetorically without further clarification. This paper therefore adopts a complexity perspective to scrutinize how complexity occurs in civil engineering projects. A conceptual framework is developed to this end.

2. Framework of understanding

We identify four concepts of complexity, each understanding this feature in distinct ways. They are juxtaposed along two axes: whether complexity is seen as a feature of the project environment or the project itself, and whether it is inherent or emergent. The framework combines these, emphasizing emergent complexity.

Corresponding author email address: ckoc@iti.sdu.dk

2.1. Complexity as inherent in the project environment

Where the "iron law" is usually used to portray tensions and contradiction between time, cost and quality, [2], as a result of their studies of large civil engineering projects, proposed that an iron law of megaprojects would be defined as 'over budget, over time, over and over again' [2]. It is understood as a recurring pattern in the planning and execution of large-scale projects, where cost and time estimates tend to be overly optimistic [3].

The iron law of megaproject approach claims that large-scale projects are prone to budget overruns, benefit shortfalls, and unrealistic projections [2], due to "optimism bias" and "strategic misrepresentation" [2]. Optimism bias refers to the tendency of planners and stakeholders to be overly optimistic in their initial assessment. A clear incentive, according to Flyvbjerg, is the need to obtain resources and support, creating an inclination to underestimate costs and overestimate benefits—something Flyvbjerg [2] labels strategic misrepresentation.

These are intentional efforts by project stakeholders to present a project in a more favorable light than justified by available information, downplaying risks, inflating benefits and manipulating project data to create a more attractive business case. Such practices sow the seeds for future complexity. As Flyvbjerg [2] elaborates, politicians, planners, or project champions deliberately and strategically overestimate benefits and underestimate costs to increase the likelihood that their projects—rather than their competitor's—gain approval and funding.

According to the iron law of megaprojects, performance challenges are more the rule than the exception, largely due to the features of the environment in which these projects are born. Flyvbjerg [2] emphasizes that various stakeholders (e.g., politicians, projects planners, citizens) engage in optimism bias and strategic misrepresentation to ensure necessary project approvals and funding. In this way, optimism bias and strategic misrepresentation can be considered interpretative repertoires employed in the early stages to mask project conditions likely to lead to performance challenges, thereby increasing the likelihood project realization. A consequence, however, is that efforts to mask certain critical conditions become a source of complexity, as projects are approved and initiated on the basis of overoptimistic information and expectations so high that they are likely unattainable.

In the iron law of megaprojects, complexity can be considered as being an inherent feature of a large-scale project environment. This complexity is a result of stakeholders in the early stages of such projects masking critical project conditions to increase the likelihood of project realization.

2.2. Complexity as inherent in the project

Martin Barnes is ascribed with authoring a triangle with cost, time, and quality at each vertex [4], later known as the "iron triangle," "project management triangle," or "triple constraint" [5]. The triangle suggested an integrated framework for controlling the interconnectedness between these three parameters, deemed inherent features of every project [4]. Central to the iron triangle is the understanding that cost, time, and quality are interrelated, and that changes in one inevitably affect the others [4]. For example, a project can be inexpensive only if quality requirements are correspondingly low. Similarly, completing a project in the shortest possible time will likely require a larger budget than usual.

In this regard, cost refers to the economic resources assigned to the project, covering labor, materials, and overhead. Time refers to the duration allocated for completion, determined by timeline and deadline. Lastly, quality represents the standard of excellence and the desired level of performance or features.

Since Barnes introduced the iron triangle, it has gained widespread use in project studies and, since the 1970s, has been one of the most preferred approaches by practitioners and project scholars for assessing project success [6] and measuring project performance [7]. Studies suggest that if projects begin with an imbalance between cost, time, and quality—e.g., high-quality requirements combined with low-cost requirements—complexity becomes inherent, leading to performance challenges [5].

As the iron triangle comprises the three parameters of cost, time, and quality, these also represent interpretative repertoires that stakeholders can engage with to prevent complexity and preserve performance. In the iron triangle, complexity can thus be considered as an inherent feature of a project. This complexity is a result of an imbalance between cost, time, and quality—resulting from imbalances that make it impossible to meet the demands of all three project parameters, as they are inherently contradictory.

2.3. Complexity as emerging in the project environment

Kristian Kreiner's [8] concept of "drifting environments" is intended to represent an increase in project complexity due to the dynamic and changing nature of the external project environment, which significantly influences project activities [8]. Environmental drift, succinctly defined as a phenomenon where 'something diverges from its projected course' [8, p.338], occurs when the projected environmental conditions on which the project was designed and planned change.

Kreiner observes that 'projects are social organizations, but fairly atypical ones' [8, p. 335], and emphasizes that all projects are designed based on a set of assumptions about the environment in which they are meant to perform and achieve results [9]. Drawing on the work of James March, Kreiner argues that projects should co-evolve with the drifting environment to maintain relevance over time [8], implying a need for adaptation. He further asserts that project plans, crafted to prepare for reality, must adapt realistically to the constant flux of reality, enabling rational decision-making within the project [10]. Acknowledging complexity, uncertainty, and ambiguity as inherent conditions in project management becomes crucial, as stated by Kreiner [10, p. 716].

Kreiner's self-proclaimed position, aligned with his idea of drifting environments, asserts that complexity, uncertainty, and ambiguity are constitutive qualities of all organized action [10]. This perspective underscores the importance of recognizing and navigating these inherent qualities in organized actions for effective project management.

The “drifting environments” concept incorporates a notion of complexity as emerging from the project environment. This arises from the fundamental perception that projects are not inherently complex initially; rather, complexity emerges when the project environment drifts, altering the conditions in which the project is executed.

2.4. Complexity as emerging in the project

The idea of the “hiding hand” was coined by Hirschman in the opening chapter of his seminal book “Development Projects Observed” [11]. The hiding hand was proposed as an alternative explanation to the World Bank’s notions of projects and their appraisal [10], emphasizing that project success often stems from a paradoxical blend of ignorance and miscalculations.

At its core, the hiding hand revolves around the notion that creativity is an unpredictable force that can seldom be consciously summoned. Hirschman argues that creativity surprises individuals and that its occurrence is often unforeseen. Therefore, relying on creativity as a preconceived strategy for success is inherently unreliable. Instead, Hirschman suggests that individuals are more likely to engage in challenging tasks when they mistakenly perceive them as less complex, routine, or undemanding of creativity.

This strategic misjudgment becomes a crucial element in unlocking creative potential. By underestimating the true nature and difficulty of a task, individuals may be more inclined to embark on ventures they might otherwise consider too risky or challenging. The hiding hand operates on the premise that if we accurately assessed the creative demands and difficulties of a task, we might shy away from it due to the perceived risk of failure. However, by underestimating both our creative capacity and the task’s complexity, we become more susceptible to the allure of unexplored opportunities.

The concept proposes that successful enterprises often emerge from a fortuitous combination of unforeseen creativity and underestimated challenges. In essence, individuals are led astray by their own cognitive biases, tricked into tackling tasks that might seem daunting if viewed through a more realistic lens.

Hirschman's hiding hand incorporates a notion of complexity as emerging in the project. It highlights the unpredictable nature of creativity and the paradoxical relationship between ignorance and success.

Hirschman [11] argues that individuals, when underestimating task complexity, are more likely to engage in them, unlocking creative potential. This misjudgment becomes a key element, as successful projects arise from unforeseen creativity and underestimated challenges, challenging conventional rational decision-making. The concept introduces a dynamic where ignorance and miscalculation serve as catalysts for innovation and accomplishment, adding layers of complexity to the traditional understanding of project development.

2.5. Complexity as emergent feature of megaprojects

Here it is suggested to understand complexity as emergent internally as well as externally in megaprojects. It is quite common that a megaproject's internal development interacts closely with changes in the external environment and vice versa. Project plans, crafted to prepare for reality, must adapt realistically to the constant flux of reality, enabling purposeful decision-making in the project [10]. Acknowledging complexity, uncertainty, and ambiguity as inherent conditions in project management becomes crucial, as stated by Kreiner [10, p. 716]. Moreover, complexity might occur in qualitative and/or quantitative dimensions [12].

It is suggested that complexity emerges from internal and external processes of decision making and choices, and that complexity can be reduced or increased over time. Moreover, It is proposed to think of complexity not only as an external factor, but also as a rhetorical device used by professionals, and importantly as leading as often to positive as negative results.

3. Method

Inspired by a reflexive approach [13], the conceptual understanding of complexity derives from a literature review of 47 pieces dealing with complexity in and around projects. Here, due to page limitations, only the main contributions are referenced, which are taken to be the ones considered as constituting each of the four approaches identified.

The empirical material stems from two main sources. First, a 2025 analysis of megaprojects in Denmark within buildings and civil engineering conducted by The Danish Auditor General [14]. Second, the biannual reports on the progress of civil engineering projects in Danmark, made by the Ministry of Transport spanning the period 2010-2024. The Danish Auditor General's analysis consisted of 41 civil engineering projects at a cost of €10,3B. The projects in the study vary considerably in economic size, ranging from approximately €3M to one very large project with a budget of more than €3B. The analysis started by separating data on building projects and civil engineering projects. Secondly, a critical reading of the civil engineering part was carried out. Note that material written in Danish has not been quoted, even if extensively used here.

The analysis of emergent complexity is based on the annual reports on the progress of civil engineering projects in Danmark made by the Ministry of Transport, and importantly supplemented by media coverage, which often provides a more critical view, less politically correct than the authorities' reports.

It constitutes a limitation that the projects analysed are mostly finalized. This implies a lack of closeness to project processes. Yet, it is also a condition of possibility to be able to involve the results of the projects in the analysis.

4. Empirical results

In the investigation by The Danish Auditor General of civil engineering projects, there is a dominance of project from Banedanmark (a governmental body responsible for railroads in Denmark) and Vejdirektoratet (The Danish Road Directorate), both under the Ministry of Transport. These two clients represent 10 out of 12 projects exceeding €1B. Moreover, they are part of the same ministry (Ministry of Transport). In numbers, this amount to 39 out of 47 civil engineering projects. Of these 39 civil engineering projects, 47% have ended with less consumption of resources than budgeted, 35% have met the budget target, and only 18% represent an overrun. Only one project has a municipality as a client, but here the Danish Road Directorate has taken over managing the project. This also means that it is these two clients' specific project management models that have been used. The projects involve quite some diversity. for Banedanmark, it is railroad works, electrification of railroads, signal systems, and maintenance of rail roads. But most are track renewals. For the Danish Road Directorate, the projects encompass bridges, new motorways, maintenance of roads, and more.

4.1. Emergent complexity

The biannual reports from the Ministry of Transport report a number of factors that increase complexity, some that reduce complexity, and some factors/event that are neutral. Changes in complexity occur in all parts of the project, from early planning and pre-investigations to final test and operations. Some projects go according to plan year after year, only to shift status relatively abrupt to increased complexity.

The examples of reduced complexity include improved measurements and calculation technology in early planning, which extends the longevity of existing infrastructure, making way for a longer schedule of new builds. Another example is an adjacent second project with mutual dependency that overrides the time overrun in the first project. A third example is archaeological investigations that does not find anything to preserve.

The examples of increased complexity include: more than expected design mistakes; less progression than expected; Covid-19 (which, however, also decreases complexity when mitigation is found); the technical challenges that the contractor faced when assembling bridge elements; rising material prices; the need for improvements to an IT support system; a contractor who raised extra demands beyond the clients' acceptance; problems with the required lowering of groundwater for moulding concrete; and a soft and uneven terrain next to the building site.

5. Discussion

So, The Danish Auditor General finds that 60% of the studied civil engineering projects were indeed delayed. However, this is mostly due to changes in the specification of what was supposed to be delivered. In terms of budget, only 18% exceeded budget, but conversely, this was mostly due to the lack of requested changes. If extensions of functionality are made, one has to assume that the value of the project has increased, also changing the value/investment balance, that is, investments counted in time and money versus the value/quality.

It is thus remarkable that Steininger et al. [15] in their analysis of Stuttgart 21 and other German rail projects found overrun and delay in (only) six out of ten projects. And the delay of Stuttgart 21 is ascribed to a number of issues including scope changes. The found emergence of complexity is not only the case of increasing it. Rather, complexity emerges as growing, neutral, and diminishing over time. Moreover, Steininger et al. [15] do not find "complexity" to be the reason behind Stuttgart 21 delays and overrun. Rather, they find 'scope changes, geological conditions, high risk-taking propensity, extended implementation, price overshoot, conflict of interests and lack of citizens' participation' [15, p. 256].

This more dynamic feature of project complexity invites further investigations. It it for example so that project professionals argue for increased complexity when projects commence becoming delayed and or go over budget? And reduced complexity is argued for when the project is on time and budget?

6. Conclusion

This contribution sets out to investigate whether a broader look at civil engineering projects would reveal pattern than those of projects such as Stuttgart 21. The second purpose was to scrutinize how complexity occurs in civil engineering projects. To respond to this, a framework of understanding of complexity in and around project was developed, positing that complexity is emergent rather than inherent. The main result from the investigation by The Danish Auditor General is that civil engineering projects in Denmark do not only go wrong but rather feature a diverse set of outcomes. Moreover a number of occurrences of changes in complexity was found both increasing, decreasing and even maintaining the level of complexity as the project outfolds.

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