COMPLEXITY OF LARGE INFRASTRUCTURE PROJECTS -DISCUSSION OF GEOTECHNICAL CHALLENGES AND RISK TRAJECTORY TO EXTREM COST OVERRUNS

P. Kylmänen[1], K. Viking[2], S. Hintze[3]

KEYWORDS

large infrastructure projects, project complexity, geotechnical challenges, cost overruns

ABSTRACT

When considering large infrastructure projects, the phrase "it's a very complex project" is often heard. But what exactly contributes to the complexity of these projects? This paper outlines a conceptualization of complexity and examines the relationship between large Swedish transportation infrastructure projects and cost overruns, focusing on variables such as project type, scale, and geotechnical challenges through the lens of a geotechnical narrative.

1. INTRODUCTION

Mega-infrastructure projects are characterized as complex, politically-sensitive and often involving a large number of partners [1.]. They are carried out under conditions of high uncertainty, ambiguity and with extremely tight deadlines and budgets and managed in the context of very complex operations, paradoxes, uncertainties, influences and ambiguities which surround these projects [2.].

Comprehending the intricacies of the project holds significance in project management as it correlates with challenges in decision-making and achieving goals [3]. However, extensive infrastructure projects are rarely comprehensively evaluated for the influence of different factors on their results [4].

Frequently, the incapacity of clients - encompassing project managers, team members, and sponsors - to precisely gauge the extent of complexity they confront is recognized as a fundamental underlying problem.

[1] Geotechnical specialist, Swedish Transport Administration (STA), Solna
[2] Senior geotechnical specialist, STA, Solna
[3] Senior project manager, STA, Solna

In most, if not all, one could find as a root cause the inability of the clients [5.]. They often recognize the complexity far too late to effectively address it in order to gain control.

Unanticipated geological conditions and the associated geotechnical problems are known to be a major contributing factor to cost and time overruns in large infrastructure projects [6.] and [7.]. While it is recognized that it is more economically efficient to define geological conditions as early and accurately as possible to reduce surprises during the planning phase rather than during construction [8.]. Despite numerous efforts to address these realities by including various clauses in contract documents, the problem persists.

Therefore, client project managers and planers need to be aware of project complexity from the beginning in order to develop appropriate strategies and assign competent team members.

Purpose

The purpose of this paper is to shed light on the problem of cost overrun within a geotechnical context since there are few theories on how and why it arises. Although there might be several other factors than the variables mentioned in this paper, but another purpose is to hopefully increase the awareness of the problem in order to contribute to launching future studies on geotechnical causes to the problem with extreme cost overruns.

Limitation

The availability of public data is the main limitation of this paper. The data and fact presented in this paper is openly available by sources such as; Swedish National Audit Office (Riksrevisionen), publications found in DIVA (Digitala Vetenskapliga Arkivet), journal articles and news reporting. It should also be mentioned that due to contractor confidentiality, the authors have abstained from providing further details regarding location and properties of mentioned super-structures.

2. THEORETICAL FRAME

Cost overruns are a common issue affecting large infrastructure projects (LiP)s, both domestically in Sweden and internationally. Therefor a good understanding of the *complexity* of the LIPs, see Fig. 1, is vital for project management because it is associated with difficulties in decision making and goal attainment [3.], [8.] [9.].

Figure 1. The Northern Link project, illustrating complexity of LiPs [10.].

The *complexity* of a LIP, along with the level of *uncertainty*, is the characteristic most commonly associated factors. In the literature one can find various types of relationships between *complexity* and *risk* see Fig.2, i.e. *uncertainty*, which can be categorized in the following three groups:

- *Uncertainty* and *complexity* are independent characteristics [1.], [2.],
- *Complexity* is compounded by *uncertainty* [11.],
- Projects *complexity* is the source of *uncertainty* in projects [12.], [3.].

Since above relationships are in contradiction to each other, therefor the following question was raised: – "how are *complexity* and *uncertainty* related in the large infrastructure projects"?

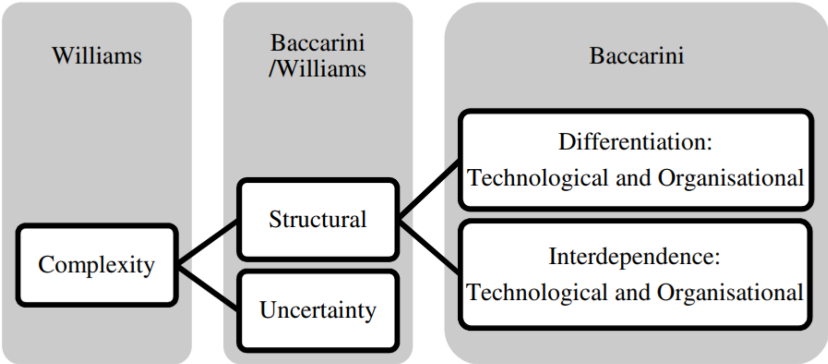

Figure 2. The development of the complexity model, [11.].

Background

The background to the concept "the project complexity" comes from a systematic approach, which forms the basis of project management [13.] and [14.]. Were it was argued that the complexity of a project reflects "a lot of different interdependent parts".

This was further elaborated to a narrower definition consisting of two types of complexity – organizational and technological [11.].

Mega-large infrastructure projects, and planning for such, in general have the following common characteristics [15.]:

- projects are risky due to long planning and complex interfaces,
- technology is often not standard,
- decision making and planning are often multi-actor processes with conflicting interests,
- project scope or ambition level often change significantly over time,
- such unplanned events are often unaccounted for,
- leaving budget contingencies sorely inadequate.

A common consequence is; misinformation regarding costs, benefits as well as risks is quite normal. The result is cost overruns and/or benefit shortfalls within a majority of mega-large infrastructure projects.

Understanding

Comprehension of the primary reasons behind cost overruns in mega-large infrastructure projects is crucial. Research indicates that factors including limited experience, project scale, design errors, fluctuations in overall costs, inaccurate estimates and scope adjustments significantly contribute to cost overruns.

Reasons

Three primary types of explanations are proposed by [15.] to elucidate inaccuracies in forecasts of costs and benefits: technical, psychological, and political-economic rationales.

The technical explanations attribute cost overruns and benefit shortfalls to imperfect forecasting techniques, insufficient data, unintentional errors, inherent challenges in future prediction, and limited experience among forecasters, among other factors. According to this explanation, enhancing forecasting models, improving data quality, and cultivating experienced forecasters may diminish or eradicate technical errors.

The psychological explanations attribute cost overruns and benefit shortfalls to phenomena such as the planning fallacy and optimism bias, as identified by psychologists.

Political-economic explanations suggest that planners and promoters intentionally overestimate benefits and underestimate costs when forecasting project outcomes. This strategic approach aims to enhance the likelihood of securing approval and funding for their projects over competing ones.

Audit of problems

The STA has pursued a procurement strategy cantered on the concept of a “purely client role”, aiming to increase the volume of turnkey contracts to increase contractors’ freedom regarding project management and execution. However, according to NAO this strategy lacks empirical support, as measurements indicate that the quantity of roads and railways has not increased with turnkey contracts, contrary to the expectations of; the government, the parliament and the STA [18.].

Further analysis conducted by the Swedish National Audit Office indicates the presence of systematic factors influencing LIP:s cost variations. These factors include variances among entrepreneurs, the organizational structure of the STA and the duration of contracts.

Curatives

It’s evident that there is a need for reform in the planning and execution of large infrastructure projects [15.], [18.] and [20.].

However, it's important to recognize that while costs and benefits are significant factors, they shouldn't be the sole determinants in the decision-making process regarding launching such projects [21.]

When contemplating what can be reformed, it’s needed to distinguish between the two following situations: – planners and advocates prioritize accurate forecasts of costs, benefits, and risks and – planners and advocates may prioritize launching projects over precise forecasts, viewing optimistic projections as essential for project initiation.

3. LESSONS LEARNED

The long-term lessons learned from LiPs in the STA remain understudied in the literature. As mentioned, there are limited published historical STA analyses available to offer insights into significant events, particularly earlier projects with a geotechnical narrative angle, in the decision-making process of LiPs or other events that influenced the realization of the LiP.

However, by studying and comparing the few analyses found, [18.], [21.], [22.], [23.], [24.] and [25.] the following four general observations can be made.

Patience

LiP:s requires patience and the remarkable bridge Øresund project is a good example. A LiP with the longest planning history that had the shortest realization time [21.]. For rail projects the average time from planning to construction is ten years and another ten years for the construction period itself. Experience shows that the time for delivery is normally somewhat optimistic. Another extreme example is the Hallandsås railway tunnel project, [25.] with a 23-year construction time, containing complex geotechnical challenges that were unforeseen from the beginning.

To mention a few Swedish ongoing LiP projects requiring patience; E4 the Stockholm bypass project [26], the west link project [27.], the Södertörn crosslink project [28.], the Slussen project (Stockholm) [29.] and [30.], Stockholm Metro expansion project [31.].

Reasons

Reasons for cost overruns and time delays of LIPs in general, have a tendency of not having a good reputation regarding cost and time control. Cost overruns and the need for more realisation time, have always been topics of disagreements as it is almost impossible to assign them to only one cause. However, from the NETLIPSE research, [21.], it was found that the origin of reasons for cost overrun and time delay more often was found to be related to the planning stage rather than to the construction phase.

The NETLIPS findings consistently indicated that the technical, environmental, and engineering or constructional requirements and scope were inadequately defined during the initial stages of the LiPs.

The geotechnical and geological risks, which always been one of the biggest factors related to uncertainties in LiPs, seems to be a controllable factor, yet, extra costs, caused by geotechnical and geological risks that's been identified, appears almost always to be within the given financial scope.

However, in the study of 258 cases of LiPs by [15.] regarding reliability of initial cost estimate against final cost is set out in table 1.

Table 1. Example of cost overruns by type of infra project, [15.].

PROJECT TYPE	NO. OF CASES	COST OVERRUN %	DEVIATION
RAIL	58	44,7	38,4
BRIDGE & TUNNELS	33	33,8	62,4
ROAD	167	20,4	29,9

Context

Changes of external context factors have a decisive influence on LiPs development. We believe that unexpected or changing conditions, for instance new legislation, change in parliament will always occur and will impact LiPs.

Performance audit has become increasingly common in the public administration and every democracy has today an independent National Audit Office.

In the reports by [16.] and [17.] on the Hallandsås project, it is stated that they conclude that the legal regulations have not effectively served as guiding and controlling instruments. They believe this to be structurally determined rather than simply a consequence of unfortunate circumstances.

Feedback

Public-Private Partnership (PPP) is often hailed as a fusion of the best of both worlds. Consequently, the two parties involved operate under divergent incentives. The public sector's aim is to serve the common good, utilize tax revenue judiciously, and combat corruption, while private entities strive to forge enduring relationships and reap profits from their investments of time and resources. [32.] mentions four major barriers for loops of feedback, trust, and long-lasting relationships to occur in PPP. These disparities can sometimes hinder the establishment of a partnership. Public actors adhere to a collaborative agenda based on the arm's length principle to ensure compliance with rules, regulations, and laws, thereby mitigating the risk of corruption allegations. However, the use of open tender processes may impede the cultivation of future relationships with contractors [33.], [32.] and [34.].

4. DISCUSSION

Large infrastructure projects entail a significant degree of irreversibility, which inevitably influences the decision process. The prevalence of opportunistic compromises in decision making for such projects appears to lead to suboptimal outcomes, [35.].

Numerous and evolving perspectives on policy options are inherent to large infrastructure projects, stemming directly from the distinctive sources of uncertainty and complexity associated with them. The key challenge appears to lie not in overcoming this aspect, but rather in shaping the interaction among stakeholders within a dynamic institutional framework, enabling ongoing learning and facilitating collaborative efforts.

The factors contributing to cost overruns include technical aspects, political considerations, and the perception of complexity influenced by social constructs. These factors often manifest as optimism bias, strategic misrepresentation, or a combination thereof, adding subject risk and the trajectory of cost overrun so complex.

5. CONCLUSION

Complexity, along with uncertainty, is a common aspect of large-scale infrastructure projects. As such, the research focused on understanding this characteristic, particularly because these two traits are closely linked and take on different roles relative to each other in various interpretations. Understanding the types of complexity has a significant influence on the selection of a management strategy.

The observation that project complexity, both overall and in specific forms, leads to two possible conclusions: either practitioners need to enhance their perception of complexity by considering additional elements (such as technical and strategic factors), or the perception itself may not be a valid method for analyzing project complexity.

The complexity and simplicity of large infrastructural projects are relative concepts that evolve over time and vary depending on perspective. This leads to the potential conclusion that either the characteristic of the project management approach should also evolve alongside the development of complexity in large infrastructural projects, or that the management approach itself requires further analysis.

We concluded that it still appears to be very challenging in practice to meet the conditions of uncertainty and complexity in large infra project decision making.

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