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PAPERS

Toward a Systemic View to Cost Overrun Causation in Infrastructure Projects: A Review and Implications for Research

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ABSTRACT

Infrastructure cost overruns receive a significant amount of attention in the academic literature as well as the popular press. The methodological weaknesses in the dominant approaches adopted to explain cost overrun causation on infrastructure projects are explored in this article. A considerable amount of cost overrun research is superficial, replicative, and thus has stagnated the development of a robust theory to mitigate and contain the problem. Future research should move from single-cause identification and the traditional net-effect correlational analysis to a search for causal recipes through systems thinking and retrospective sensemaking to address the high-level interactions between multiple factors.

KEYWORDS: causality; cost overruns; systems thinking; retrospective sensemaking

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INTRODUCTION

Major infrastructure projects, particularly those funded by the public sector, routinely make news headlines, not for being remarkable engineering accomplishments that will support and stimulate economic growth and the social integration of communities, but rather for being poorly managed and often over budget. According to the works of Flyvbjerg, Holm, and Buhl (2002), transport infrastructure projects (e.g., roads, bridges, and rail) are reported to have an 86% probability of outrunning their set cost targets. The average sizes of these overruns can be as high as 45% for rail projects, 34% for bridges, and 20% for road projects. Furthermore, Love, Sing, Wang, Irani, and Thwala (2012) and Odeck (2004) found that overruns could be as high as 70% and 183% more than the initial estimate, respectively.

Determining the causal nature of cost overruns is arguably a complex and challenging exercise. However, the phenomenon is often attributed to a variety of sources, including scope creep and rework (Love, Edwards, & Smith, 2005), unrealistic cost targets, and misguided trade-offs between project scope, time, and cost (Ahiaga-Dagbui & Smith, 2014a), a poor understanding of the systemic and dynamic nature of projects (Eden, Ackermann, & Williams, 2005; Love, Ahiaga-Dagbui, & Irani, 2016a), unidentified or improperly managed risk and uncertainty (Okmen & Öztas, 2010) and suspicions of foul play and corruption (Wachs, 1990). A review of the normative cost overrun literature reveals that a plethora of studies have been dedicated to understanding this problem (Hinze, Selstead, & Mahoney, 1992; Flyvbjerg, 2008; Cantarelli, Flyvbjerg, Molin, & van Wee, 2010; Durdyev, Ismail, & Bakar, 2012; Ahiaga-Dagbui & Smith, 2014b). Most of these studies identify several purported causes of overruns and make recommendations for mitigating and containing this phenomenon. Yet, there is no evidence these works have been alleviating the problem or improving the reliability of cost estimates, despite the use of techniques such as Reference Class Forecasting (Flyvbjerg, 2008). Needless to say, the industry has earned itself the unenviable repute of delivering projects late and over budget, again and again, leaving clients dissatisfied and the taxpayer often out of pocket.

As a result of the need to improve the performance of construction projects, there has been a shift away from using traditional procurement methods (i.e., design-bid-build) to collaborative forms of project delivery.

Such procurement methods have engendered teamwork and improved communication practices between project participants. With the support of online collaborative platforms for effective communication, design, visualization, simulation, control, and coordination of the entire construction process, it would normally be expected that projects would be better positioned to achieve their cost targets, but this does not currently seem to be the case.

Several underlying questions need to be addressed if progress toward reducing the incidence of cost overruns is to be made. For example, why do they still occur irrespective of the significant attention they receive from policymakers, clients, and industry practitioners? Why has there not been an improvement in the reliability of initial cost estimates despite advances in the processes of cost planning and the emergence of Building Information Modeling (BIM)? Thus, despite the advances in technology and changes in the ways projects are delivered, cost overruns remain, and probably will continue to do so, unless robust theoretical lenses are established to better understand, explain, and predict their occurrence (Love et al., 2016a). Against this contextual backdrop, previous cost overrun research is critically reviewed to identify some of the embedded methodological weaknesses. The article is structured as follows: a discussion of the scale and nature of the cost overrun problem facing the construction industry is followed by a critique of the replicative, superficial, and stagnated nature of much of the cost overrun research found in the extant literature. The article specifically highlights the poor understanding of project systemicity and lack of demonstrable causality; a focus on independent, single-cause identification and traditional net-effect correlational analysis; as well as a dependence on poorly designed survey instruments. Recommendations for the future directions of cost overrun research and mitigation are then presented.

Cost Overrun: The Scale of the Problem

Cost estimates prepared in the early stages of a project allow a client to evaluate tenders, secure funding, and/or perform a cost–benefit analysis. These estimates also often become the basis for cost control during a project's delivery (Ahiaga-Dagbui & Smith, 2014a). When a project is a commercial asset, the initial capital investment to deliver it must be balanced with the cost of maintenance and operations over its lifetime to ensure it remains profitable, and planned returns on investment are achievable. Thus, decisions made during the formative stages of a project carry far-reaching economic consequences and can seal its financial fate. Effective cost planning, therefore, relates design of buildings to their cost, potential scope changes, quality, utility, appearance, as well as other risks that might affect the delivery of the project on time and an agreed-on budget.

A significant number of infrastructure projects, however, routinely overrun their cost estimates. The statistics on infrastructure cost overrun has been well-documented in the literature, official government publications, and the popular media (e.g., Love, Smith, Simpson, Regan, & Olatunji, 2015). For example, the Auditor General of Western Australia assessed the management and performance of 20 capital-intensive projects, including sports venues, schools, and hospitals. The expected cost of all these projects at the time was AU$6.157 (US$4.66) billion, a staggering AU$3.275 (US$2.48) billion (114%) more than the total original approved budget estimates. A total of 15 of the 20 projects were expected to exceed their original approved budgets, of which four were expected to exceed their budgets by more than 200% (Auditor General of Western Australia, 2012).

Alex, Al Hussein, Bouferguene, and Siri Fernando (2010) reported that there was up to a 60% discrepancy between actual and estimated costs of over the 800 water and sewer projects they sampled. The 2012 London Olympics bid was awarded at approximately US$2.92 billion in 2005, which was adjusted to about US$11.46 billion in 2007 after significant changes in scope. The project was eventually completed at US$10.97 billion in 2010 (National Audit Office, 2012). In Scotland, The Edinburgh Trams project exceeded its initial budget leading to significant scope reduction to curtail the ever-growing cost (Miller, 2011; Railnews, 2012). The project, was initially expected to cost about £375 (US$462) million, but was completed three years late at a reported £776 (US$956) million (City of Edinburgh Council, 2014).

The City of Boston's Central Artery project (referred to as the Big Dig) was to cost US$2.6 billion, but was completed at US$14.8 billion and seven years late in 2006 (Gelinas, 2007). The United Kingdom (UK) Government commissioned a report in 1998 on the construction industry's performance and it was revealed that over 50% of projects overspent their budget (Egan, 1998). A similar report in the United States suggested that 77% of projects exceeded their budget, sometimes to the tune of over 200% (General Accounting Office, 1997). These rather unfortunate statistics have often led to extensive claims, disputes, and litigations, which have contributed to marring the construction industry's reputation.

Cost Overrun Research: Superficial, Replicative, and Stagnated

The generic research process often involves an initial research design, data collection, its analysis, and interpretation (Figure 1). Research designs, however, span the broad philosophical assumptions about the nature of knowledge, to the specific methods of data collection and validity of the conclusions reached. It is crucial that the research design is appropriately tailored to the type and nature of problem under investigation. If an unsuitable data collection

Figure 1: Research process.

method or analysis is adopted, the results and conclusions reached can be misleading, thus providing no useful direction for understanding the phenomenon under study.

Contrary to the generic research process outlined in Figure 1, the goal of most qualitative research approaches is to generate theory as an outcome of the research (advocacy research or ethnographies may be notable exceptions (Creswell, 2009). The social, economic, context-dependent, and organizational embeddedness of the cost overrun problem means that the majority of cost overrun research tends to be more qualitative in nature. Cost overruns are embedded in the context of people and organizations interacting in the complex web of business models, governments, technology, market structures, procurement strategies, risks, and uncertainty. It becomes difficult to isolate the root causes of overruns using generic broadcasted surveys instruments that are divorced from context (Love et al., 2016a).

A faulty understanding of the systemicity described above has unfortunately led to poor research designs that are superficial and replicative, leading to stagnation in the incremental understanding of the nature and sources of cost overrun on construction projects. For example, Memon, Rahman, and Aziz (2012) undertook an investigation into the ’causes’ of cost overrun in large construction projects in Malaysia. Using the extant literature, they first identified 35 different factors that could lead to cost overrun and then required *clients, consultants, and contractors* to rank these factors on a five-point Likert scale, ranging from ‘not significant’ to ‘extremely significant.’ These factors include ‘poor project management,’ ‘lack of coordination between parties,’ ‘mistakes during construction,’ and ‘slow information flow between parties.’ A Relative Importance (RI) index, defined in equation one, was then used to weight these factors. The strength of correlation between the various factors was also measured using the Spearman’s rank correlation, ρ, to add some statistical rigor to the study.
Where

$$\text{Relative Importance Index} = \frac{\sum_{1}^{5} w.x}{A.N} \qquad \text{Equation 1}$$

w = weighting given to each factor by respondents
x = frequency of response given for each cause
A = highest weight (i.e., 5 in this case)
N = total number of participants

Out of the 150 questionnaires distributed, 103 were returned, with 97 of them being valid. Fluctuation in prices of materials, contractor cash flow problems, and client payment delay were the top three ‘causes’ of overrun. Respondents were also required to recall the approximate extent of cost overrun (cost beyond contract sum) for the projects they were involved with within the past ten years. A majority (61%) of the respondents reported a range of 5% to 10% of contract sum; only approximately 20% of the respondents recalled overruns beyond 20% of contract sum.

Durdyev et al. (2012) also investigated the factors that lead to cost overruns in the construction of residential buildings in Turkey using a questionnaire survey distributed to project management consultants, contractors, and subcontractors. They considered 40 different factors in their study and requested that respondents rate the levels of impact of these factors on the project’s final cost using a five-point Likert scale (very low to very high impact). Just as in the Memon et al. (2012) study, they computed the RI of the factors using the rankings provided by the respondents to determine the most importance cost overrun influencing factors. The top five factors identified were: (1) “improper planning”; (2) “inaccurate project cost estimation”; (3) “high cost of needed resources (money, men, materials, and machinery)”; (4) “lack of skilled workforce”; and (5) “price of construction materials and high land prices.” It is worth noting that cost estimation is a planning function, and thus “inaccurate project cost estimation” is a sub-factor of “improper planning.” Similarly, “high cost of needed resources” cannot really be separated from “price of construction materials and high land prices.”

The aforementioned approach to cost overrun research is not untypical—Mansfield, Ugwu, and Doran (1994), Kaming et al. (1997), Ameh, Soyingbe, and Oudusami (2010), and Rosenfeld (2014) have all conducted almost identical studies, albeit in different contexts. A detailed examination of these studies reveals common pathologies, including a poor understanding of project systemicity and lack of demonstrable causality; a focus on independent, single-cause identification, and traditional net-effect correlational analysis; the use of poorly designed survey instruments; and the use of superficial and ambiguous factors are discussed hereinafter.

Project Complexity and Systemicity

A poor understanding and treatment of project complexity and systemicity (i.e., the complex, dynamic behavior exhibited by systems) is the most common shortcoming of cost overrun research that has been undertaken. Although there is now a growing body of research that applies systems thinking to investigate cost and schedule overruns in infrastructure projects (Ackermann & Eden, 2005; Boateng, Ahiaga-Dagbui, Chen, & Agunlana, 2015), the vast majority of studies frame the overrun problem in a manner that ignores the complex, multiple feedback, and highly dynamic context of projects. For example, a vast majority of studies identify single points in a causal chain in which an intervention may have reasonably been implemented to change performance and prevent an undesirable outcome (Love, Smith, & Edwards, 2016b). The identification of singular and independent causes, which in most cases only describe the proximal causes, is counterproductive, because overrun causation can only be understood by looking at the whole project system in which it occurs and how variables dynamically interact with one another. Simply identifying and listing factors that may contribute to a cost overrun does not provide evidence of causation and the ability to draw conclusions about the underlying dynamics that lead to their occurrence (Love et al., 2016b).

Statistical techniques, such as multiple regression analysis (MRA), typically aim to measure how each independent variable contributes to explaining the variation that is observed in a dependent variable. Such models are primarily intended to provide an evaluation of the *net-effects* of independent over dependent variables. Ragin (2008) states:

> "In conventional quantitative research, independent variables are seen as analytically separable causes of the outcomes under investigation. Typically, each causal variable is thought to have an autonomous or independent capacity to influence the level, intensity, or probability of the dependent variable." (p. 112)

However, the focus on net-effect contribution of variables, assumed to be linear and independent, may be insufficient to cope with the systemicity in complex systems such as construction projects, as variables of causation tend to be interrelated and interdependent as well as dynamic over the project's life cycle. The approach is also deterministic in nature and does not accommodate the probabilistic nature of outcomes in a complex system (Love et al., 2016b).

Simon (1981) describes a complex system as one in which the behavior of the whole is difficult to deduce from understanding the individual parts. It follows that, although it might be easy to know the variables that impact a project and its outturn, "it can be difficult to understand intuitively how the latter came from the former." (Williams, Ackermann, Eden, & Howick, 2005, p. 220). This may be due to project systemicity or complexity, as they can produce a totality of effect beyond the sum of the results that would be expected from individual causes. Hamilton (1997) outlines two important properties of systems thinking that would be useful in cost overrun research: (1) every part of a system has properties that it loses when separated from the system; and (2) every system has some essential properties that none of its parts do. Thus, when a system is taken apart, it loses its essential properties (Von Bertalanffy, 1956). It follows that the crucial skill in understanding cost overrun is not just the ability to list or rank factors but the capacity to see connections between the various causal factors as well as how they dynamically evolve over the course of the project.

Love, Edwards, and Irani (2008) investigated the factors that contributed to the 10.5% cost overrun experienced on two residential projects with a contract value of AU$10.96 million; they found that 3.15% of this overrun could be attributed to rework that was design induced and as a result of defects. Change orders initiated by the client accounted for up to 7.35% of the overrun experienced. A further exploration of the causal nature of rework on the project revealed that it was not readily easy to isolate single or independent causes for rework. Its sources were interconnected in complex ways.

The use of the singular cause identification approach has led to inappropriate risk assessments for cost overrun to be developed: the interdependency between causal variables has not been considered and accommodated. Cost overruns seldom occur as a result of a stand-alone cause. Even though they may superficially appear to be different, sources of poor performance in infrastructure projects are interrelated in complex ways. As suggested by Rodrigues and Bowers (1996), traditional approaches to investigating project management–related problems usually assume that if each element of the project can be understood, then the whole system may be controlled and delivered effectively. Naturally this approach has yet to assist project managers in delivering their projects to their pre-determined outcomes.

Project cost overrun may arise from a variety of different combinations of causal conditions—this is referred to as multiple conjunctural causation (Ragin, 2004), in which many causes/variables combine to produce several causal recipes, each of which may be sufficient to result in the outcome. This resonates with organizational theories of *equifinality* by Von Bertalanffy (1956), who posits that a system can reach the same final state, from different initial conditions, and by a variety of different paths. To investigate this type of causation, Woodside (2013) suggests a move toward the examination of high-level interactions between multiple factors. It will important, therefore, to adopt systemic and probabilistic approaches when investigating complex problems such as cost overruns, particularly in large infrastructure projects.

The Use of Multiple Regression Analysis

Related to the issue of lack of systems thinking is the use of Multiple Regression Analysis (MRA) for establishing best fit relationships for predicting cost overrun or project success (Iyer & Jha, 2005; Arif, Lodi, & Azhar, 2015). Multiple Regression Analysis is an established statistical method useful for problems with a small number of variables, large amounts of reliable and valid data, and well-established causal relationships such as elasticity of income or price (Armstrong, 2012). However, where significant complexities and interdependency exist between variables, regression models tend to return rather spurious results (see Armstrong, 1970; Woodside, 2013). For example, using stepwise regression, a study beginning with 31 observations and 30 potential variables included only variables with a t value greater than 2.0. The adjusted R square was 0.85 with eight significant predictive variables. This would seem to be a model with good fit on perfunctory examination until it is revealed that the original data was from a book of *random numbers* (Armstrong, 1970). Goldstein and Gigerenzer (2009) thus note that "achieving a good fit to observations does not necessarily mean we have found a good model, and choosing the model with the best fit is likely to result in poor predictions." Armstrong (2012) further adds:

> "Analysts assume that models with a better fit provide more accurate forecast. This ignores the research showing that fit bears little relationship to ex ante forecast accuracy. Typically, fit improves as complexity increases, while ex ante forecast accuracy decreases." (p. 691)

The lesson here is that even random datasets can result in seemingly good models and the challenge is a move toward reporting predictive validity instead of fit validity only. Furthermore, R is a measure of linear relationship only; therefore, there may be an exact connection between two variables but if it is not a straight line, R is no help. Armstrong (2012) thus warns of how misleading t, p-value, F, and R-Squares can be and also suggests not using more than three variables in a regression model, as most are linearly dependent on each other and thus lead to spurious results. This rule of thumb has also be advocated by Goldstein and Gigerenzer (2009). There is an on-going discussion in the social science and strategic management literature about the inappropriate use of statistical constructs such as p-values and the null hypothesis (Bettis, Ethiraj, Gambardella, Helfat, & Mitchell, 2016). This connects well with the arguments established above.

Illusion of Causality

Several studies have attempted to identify the 'root causes' of cost overruns, but invariably only end up scratching the surface of this complicated problem using statistical measures of correlation between variables (e.g., Mansfield et al., 1994; Ubani, Okoroch, & Emeribe, 2013; Rosenfeld, 2014). However, identifying correlations between factors does not mean they are causes. For example, the fact that high 'graffiti' (Skogan, 1990) and 'broken window' neighborhoods (Wilson & Kellig, 1982) correlate rather strongly with high crime levels does not mean that graffiti or broken windows cause the crimes.

A correlation provides circumstantial evidence implying a causal link, but the weight of such depends greatly on the particular circumstances involved. However, a number of studies rely solely on establishing a correlation between several factors and a project's cost overrun. These studies are usually correlational in nature and symmetric, thus positing that the presence of a given plausible causal condition will lead to the occurrence of the outcome. Implicitly, they also assume *causal asymmetry*, that the absence of a given cause or set of causal conditions thought to be associated with the outcome will result in the absence of the outcome. It is argued that this symmetry needs not be so, and that there can be several possible causal paths for a cost overrun (Ragin, 2000). This was demonstrated by Love et al. (2008) in their analysis of the causal nature of design-induced rework that leads to cost overruns on construction projects. The argument also follows that a variable with a weak correlation coefficient can combine with another to result in a very high impact on a project's performance. To fully understand cost overrun causation, the emphasis should thus move from independent, single-cause identification and traditional net-effect correlational analysis to look for plausible causal combinations, or *recipes*, that can be associated with the occurrence of overrun (Ragin, 2000).

Ubani et al. (2013), for example, set out to investigate factors that cause cost and schedule overruns in Nigeria and developed a questionnaire based on "110 hypothetical cost overrun" factors derived from the literature. The returned questionnaires from respondents were then analyzed by measuring the RI and correlation coefficients. They found that material-related issues, including price fluctuation and shortages were the main causes of overrun. They rejected the hypothesis that contractual relationships, labor, and design had any significant influence on cost overrun. They then recommended that clients, contractors, and consultants "should pay more attention to both material and external factors for there to be effective and efficient delivery on construction projects at the right time and cost" (p.73). It is obvious that the framing and design of the research led to the superficial findings, such as material shortage being the main cause of overrun. Also, it is perhaps unlikely that valid causation can be adequately demonstrated using the research formulation above.

Ambiguous and Superficial Factors

Poor project management, lack of coordination between parties, mistakes during construction, and slow information flow between parties are some of the factors used in the survey by Memon et al. (2012). Other factors, including inadequate control procedures, slow decision making, waiting for information or poor documentation, as used in Frimpong, Oluwoye, and Crawford (2003), are rather too ambiguous. They could easily be misinterpreted by the respondents, particularly if they are all not thinking within the context of a particular project or situation. They may also evoke countless possible scenarios and examples depending on the context, thus giving an indication that such factors are rather too superficial and therefore must be broken down further if real sources of overrun are to be identified. Questionnaires may be a quick and easy way of sampling the views of respondents, but can also be problematic if the researcher's definition of a factor does not correspond with the respondent's understanding.

It also follows that when questionnaire respondents are not thinking within the framework of the same or similar projects, their frames-of-reference can differ significantly. Unless they were perhaps used as part of a structured-case study, for example, it is argued that questionnaires alone may not be suitable for investigating complex and systemic problems like cost overruns. For example, 'good project management' or 'efficient document management' will mean very different things to respondents. The factors are simply too high level to help in getting to the heart of the problem itself. Interviews allowing the surfacing of deep tacit knowledge and also enabling the capture of relationships can provide a much more comprehensive and effective representation of the situation as demonstrated in the works of Ackermann and Eden (2005) and Love et al. (2008).

Availability Heuristics

Heuristics are mental shortcuts that help people make decisions and judgments quickly without investing a lot of time in analyzing information. One such heuristic is termed the 'availability heuristic.' According to Gilovich, Griffin, and Kahneman (2002), the availability heuristic is employed when someone estimates the frequency or probability of an event based on the *ease* with which instances or associations could be brought to mind. Even though heuristics can be extremely helpful, they can easily become a hindrance to deep and careful thinking. In their seminal work on heuristics, Tversky and Kahneman (1973) posited that availability can often be affected by various factors, which are completely unrelated to the actual frequency or probability of the event under review—how busy the respondent is, his or her interest in the subject under study, level of experience, peculiarities of the most salient examples he or she can recall, his or her understanding of the questions in the survey, or the time available to complete a questionnaire. Tversky and Kahneman (1973) thus warn that if availability is applied to the analysis of an event, these factors "will affect the perceived frequency of the classes and the subjective probability of events; consequently, the use of the availability leads to systematic biases" (p. 209).

Without carefully designed research and an established context of those projects being evaluated, results of the questionnaires, such as the ones conducted by Ameh et al. (2010), Durdyev et al. (2012), and Memon et al. (2012) become problematic. Whereas the same factors consistently identified from questionnaire surveys are poor estimation, poor project management, inadequate risk management, unexpected ground conditions, scope changes or material price changes, there is no acknowledgment of systemicity, multiplicity of interpretation, or action. It will take more thoughtful research design, perhaps research conducted within the context of a particular project, to be able to partly circumvent these default responses that have yet to help mitigate or contain cost overrun in construction.

Heterogeneous Viewpoints

To further complicate matters, respondents are often drawn from different professions within the industry. This may seem a prudent approach because it helps to investigate the problem from different perspectives. However, Durdyev et al. (2012) and Memon et al. (2012) for example, surveyed clients, consultants, and contractors without controlling for the different perspectives of these professionals. The perceived sources or size of overruns reported will significantly vary, depending on whether the construction professional works for a client or for a contracting firm. It will be useful to survey these groups separately to maintain the integrity of the varying viewpoints. This problem of context and cross-perspectives could at least be partially addressed by using structured case studies, as all respondents would be reviewing the same project(s). Structured case studies are usually more appropriate when an in-depth knowledge of an individual example is more helpful than fleeting and superficial knowledge about a larger number of examples.

Replication

Replication is the performance of another study to statistically substantiate, or challenge, a hypothesis, has significant value for research, and therefore has been the cornerstone of scientific and social studies. It is based on a simple concept: "trust, but verify." Where a replicative study results in different findings, it may indicate that the original hypotheses may have been incorrect or only partially correct, and that an alternative formulation may be able to reconcile apparent divergent results. Replication is therefore essential to establish or disprove causal inferences, determination of generalizability of findings, and even stimulate new research. When carried out in a cumulative manner, it can be used to build on previous studies and facilitate a better understanding of a phenomenon.

For cost overrun research, however, replication has largely been a case of reinventing the wheel—doing the same thing over and over again. Edge (1995) aptly describes this sort of research as "the mass production of a standard product" lacking in "intellectual expansion" of the field. However, expansion in the depth and detail of cost overrun research must take priority over mere quantity and bulk. Having reviewed the normative literature, it was found that there has been little methodological advancement in most cost overrun studies. Some of these include the studies by Mansfield et al. (1994); Kaming, Olomolaiye, Holt, and Harris. (1997); Ameh et al. (2010); Enshassi, Kumaraswamy, and Al-Najjar (2010); Memon et al. (2012); and Durdyev et al. (2012). The dominant method used in these studies involves mostly compiling a long list of supposed 'causes' of overruns in a questionnaire and requiring respondents to rank them using their perceived frequency or importance. It comes at little surprise that Flyvbjerg et al. (2002) observed that the sizes of overruns have not reduced over the 70 years since they've been studied. They also concluded that "no learning that would improve cost estimate accuracy seems to take place." That may well be partly due to the stagnation in rigor and robustness of research dedicated to ameliorating the problem.

Making Sense of Cost Overrun Causation

Dekker (2014) states that a "cause is not something you find. Cause is something you construct. How you construct it and from what evidence, where you look, what you look for, who you talk to, what you have seen before, and who you work for" (Dekker, 2014). Bearing in mind this view, the methods used to construct a cause of a particular problem are just as important as the validity and usefulness of the findings. Meaning is also intrinsically linked to the environment and context within which actions and responses, as well as interactions between dynamic parts, take place. The phenomenon of cost overrun in projects is contextually embedded; that is, *why* and *how* cannot be fully understood if decoupled from the environment of their occurrence. Projects are traditionally seen as unique, with varying degrees of embeddedness and dependencies. The argument thus follows that to fully understand the causal nature of overruns in construction, the context and environment of the project have to be clearly articulated and the methods used for their investigation need careful consideration.

Retrospective sensemaking is a well-established technique for developing meaning of complex problems, events, and environment (Weick, 1988). Thomas, Clark, and Gioia (1993, p. 240) defined sensemaking as the three-pronged process of "reciprocal interaction of information seeking, meaning ascription and action" that includes environmental influences and associated responses. Weick, Sutcliffe, and Obstfeld (2005) described a number of characteristic features of sensemaking—the process is collective and collaborative, designed to be retrospective to help a group make meaning of the events and circumstances that affect them or the causal nature of a particular problem. The process helps the group to begin noticing specific uncertainties and explicitly or implicitly ask questions, such as: 'Why did this event happen?' 'How does this event relate with this other event?' 'How are these causal factors related?' The group then builds plausible causal narratives and related actions often guided by the use of mental models and other mapping techniques. Cognitive mapping (Eden & Ackermann, 1988; Ackermann & Eden, 2005) and System Dynamics (Forrester, 1993) are two modeling techniques that accommodate systemicity and can be utilized under the auspices of retrospective sensemaking to understand and model interdependencies.

Modeling Interdependencies

Cognitive mapping (CM) is a set of techniques used to identify, structure, analyze, and make sense of accounts of problems (Eden, 2004). Swan (1997, p. 188) describes cognitive maps as "internally represented schemas or mental models for particular problem-solving domains that are learned and encoded as a result of an individual's interaction with their environment." These maps, elsewhere known as 'cause maps' when used to explore causal relationships (Ackermann & Eden, 2005), can be a really effective and interacting way of making sense of messy and complex problems particularly when they are constructed by a group. The general approach involves the use of a range of mapping techniques to extract statements from individuals or groups about subjectively meaningful concepts and relationships in particular problem areas. These concepts and relationships are then illustrated in some kind of diagrammatical representation (Swan, 1997).

System Dynamics (SD) is a modeling technique used to help decision makers learn about the structure and dynamics of complex systems, to design high leverage policies for sustained improvement, and to catalyze successful implementation and change (Rodrigues & Bowers, 1996). SD is particularly suitable for analyzing highly dynamic systems that consist of multiple interdependent components involving several nonlinear relationships, as is the case of cost overrun causation on construction projects. The totality of the relationships between these components defines the "structure" of the system. Hence, it is said that the "structure" of the system, operating over time, generates its "dynamic behaviour patterns" (Vlachos, Georgiadis, & Iakovou, 2007). The approach is primarily based on cause–effect diagrams to understand the causal nature of particular problems and to model the dynamic nature of these causal factors throughout a project.

By shifting the focus from simply ranking variables and correlational analysis, researchers including Williams, Ackermann, Eden, and Howick (1997), Love, Holt, Shen, and Irani (2002), Ogunlana, Li, and Sukhera (2003), Howick (2005), and Boateng et al. (2015) have demonstrated the complexities of project actuality, systemicity, and performance. Specifically, Ackermann and Eden (2005) also studied the causal nature of delays and disruption on eight different projects, with a total value in excess of US$2 billion (none of the projects had a value less than US$60 million).

All of the projects, however, experienced cost overrun greater than 30% and were delivered late. Ackermann and Eden (2005) used causal mapping with Group Support Systems to elicit an understanding of failure occurs in complex projects. Using triangulated data from interviews, questionnaires, and non-participant observation, Boateng et al. (2015) identified different economic risk factors on the Edinburgh Tram Project in Scotland. These factors include increases in foreign exchange and inflation, change in government, disputes, change in tax regime, and energy price increases. These factors were then modeled using SD to reveal their interdependences and the causal nature of the significant time and cost overruns experienced on the project. Bayer and Gann (2006) explored bidding strategies and workload dynamics within project-based organizations using system dynamics to provide insight into how these relate to productivity, rework, and cost overrun within project portfolios. They described the ‘phenomenon of error amplification,’ in which overruns on one project led to further overruns in other projects within the same portfolio—rework and consequent overruns generated in individual projects bind the resources required for the successful and timely completion of other projects.

System dynamics and causal mapping have also been effectively combined by Howick, Ackermann, and Andersen (2006) to allow client groups to visualize and comprehend the linkage between event thinking and structural thinking in a complex system as they provide a meaningful way to both deal with interdependency of different causal variables and how they evolve over time. Studies of this nature are essential building blocks for understanding cost overrun causation and theory development and will pave the way for designing more effective ameliorating strategies. Unfortunately, studies of this kind are few and far between in the current cost overrun literature.

Conclusions

We have explored some of the methodological deficiencies in the approaches adopted in a majority of the cost overrun research. These deficiencies include a poor understanding of systemicity and embeddedness of the sources of overruns, a dependence on correlational analysis, a lack of demonstrable causality, and superficiality of the research design. We found that cost overrun research has largely stagnated in the refinement and advancement of the knowledge area—the bulk of it has largely been replicative. We would particularly like to highlight the lack of systems approach in cost overrun studies, which invariably leads to the identification of independent, single-cause variables justified in using traditional deterministic net-effect correlational analysis.

We submit that this approach is a flawed simplification of the cost overrun problem and may be counterproductive. It is suggested that a significant paradigm and methodological shift may be required to properly understand the nature and sources of cost overruns. Overrun causation can only be understood by looking at the whole project system in which it occurs and how several variables dynamically interact with each other. It may be important to reiterate here that the crucial skill in understanding cost overrun is not the ability to list or rank factors but the capacity to analyze connections, interactions, and plausible causal combinations.

Finally, this article is not intended to discredit previous works, rather map out future directions for cost overrun research. It is simply an attempt to look back, so that we might be able to look forward. This is perhaps particularly important, and timely, especially against the backdrop of overwhelming evidence that cost overrun is as much a problem today as it was decades ago. Furthermore, what is the benefit of doing the same thing over and over again if it is not yielding transformative results?

The case for accommodating multiple-conjunctural causation, in which many causes/variables combine to produce several causal recipes, each of which may be sufficient to result in the outcome, has already been made in this article. This perspective is anchored in the organizational theories that a system can reach the same final state from different initial conditions, and by a variety of different paths. It is suggested that future research should focus on examining cost overrun causation using probabilistic approaches and system dynamics to address the interdependence and high-level interactions between multiple factors.

The central idea behind probabilistic theories of causation is that causes change the probability of their effects, so that an effect may still occur in the absence of a cause or failure to occur in its presence. This approach recognizes the centrality of probabilities in project outturns and will represent a move from independent, single-cause identification and traditional net-effect correlational analysis to look for plausible causal combinations, or *causal recipes*, that can be associated with the occurrence of overrun. These causal combinations can be graphically illustrated using the causal mapping techniques described in earlier sections of the article. The outputs and publications from the ongoing study will thus help in new theory development regarding the causal nature of overruns in infrastructure projects.

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