Citation
Love, P. and Ahiaga-Dagbui, D. 2018. Debunking fake news in a post-truth era: The plausible untruths of cost underestimation in transport infrastructure projects. Transportation Research Part A: Policy and Practice. 113: pp. 357-368.
http://doi.org/10.1016/j.tra.2018.04.019

Debunking Fake News in a Post-Truth Era: The Plausible Untruths of Cost Underestimation in Transport Infrastructure Projects

Peter E.D. Love
School Civil and Mechanical Engineering,
Curtin University, GPO Box U1987, Perth, Western Australia, 6845 Australia

Dominic D. Ahiaga-Dagbui
School of Architecture and Building,
Deakin University, Geelong, Victoria, 3222, Australia

Debunking Fake News in a Post-Truth Era: The Plausible Untruths of Cost Underestimation in Transport Infrastructure Projects

Abstract: The methodology, analysis, and the unfounded conclusions presented in the paper "Underestimating costs in public works projects: error or lie?" by Flyvbjerg, Holm, and Buhl (2002), published in the Journal of the American Planning Association are critically questioned. Flyvbjerg, Holm, and Buhl attribute the cause of cost underestimation in transport infrastructure projects to delusion (optimism bias) and deception (strategic misrepresentation). The bifurcation of the cost underestimation problem into error or lie presents a false dichotomy - an either/or choice that is invalid when juxtaposed with the real-world nature of procuring large infrastructure assets. Put simply, the conclusions presented by Flyvbjerg, Holm, and Buhl are akin to being fake news. Unfortunately, the persistent reverberation of these convenient narratives and factoids in both academia and media has led to these explanations becoming an accepted norm. In this paper, the claims made by Flyvbjerg, Holm, and Buhl are debunked. A call is made for policy-makers to embrace and utilize evidence-based research, so that informed decisions about capital cost estimates and potential risks can be better ascertained at the front-end of major transport infrastructure projects.

Keywords: Cost underestimation, debunking, fake news, optimism bias, strategic misrepresentation, transport

1. Introduction

> We [journalists] don't report the news, we make it. Accuracy is so time-consuming. Fiction is the new fact – Roger, *American Dad!* (s10e19: "News Glance with Genevieve Vavance")

The manipulation of the truth for political gain is something that the general public has become all too accustomed to when the capital costs of transport infrastructure projects is examined. Propaganda regarding project costs has formed the cornerstone of the political landscape, as incumbent governments, opposition parties, journalists, and even academics leveraging the branding of their institution to engage in campaigns of mis-information to play out their agendas. With the dawning of the post-truth era, a new world of *epistemological nihilism*[1] appears to have come to the fore. This has been driven by cherry-picking data by those protagonists who attribute the cost underestimation of transport infrastructure projects to delusion and deception (e.g., Flyvbjerg *et al*., 2002; Flyvbjerg *et al*., 2007; Flyvbjerg, 2008;

[1] Nihilism, often associated with Friedrich Nietzsche (1844-1900) is the belief that all values are baseless and that nothing can be known or communicated (Brobjer, 2008).

Flyvbjerg, 2009). The corollary is that such emergent explanations have become just as valid as others that actually reflect the truth (i.e. in accordance with reality and fact). The rhetoric that is used to repeatedly and deliberately promote and reinforce the mis-information that has been established by those who advocate delusion and deception *via* academic outlets, public and social media, is akin to being fake news. This has resulted in previously well-established work based upon a scientific underpinning being delegitimized and cast as being of the same ilk.

The perpetual inability of the public sector to address the cost underestimation phenomena that plagues transport infrastructure projects (e.g., Terrill and Danks, 2016) has resulted in many agencies becoming disillusioned with explanations of their causal rationality. Instead, they have been replaced by those of a sensationalist nature. For example, Flyvbjerg (2013), has used statements such as "a majority of forecasters are fools or liars" to explain inaccurate cost estimates (p.772). Such an attention-seeking statement, intentionally crafted to be provocative and controversial, has no scientific merit and has been simply contrived to gain attention. Moreover, declarations of this nature demonstrate sheer ignorance and disregard for the complexities and nuances of the design and estimating process of transport infrastructure projects. It is, however, surprising how many media outlets that have been drawn to this falsehood and given it credence without actually examining the facts and educating themselves about the processes involved in estimating the capital costs of transport projects.

Supporters of the delusion and deception explanations have been just as crafty as Machiavelli (1515), as they have feigned and dissembled information to promote their own line of inquiry. Indeed, they are master storytellers, who have been and continue to use convenient narratives to win over many government authorities who are rightly searching for a silver bullet that will ensure their transport projects are delivered successfully according to pre-determined deliverables. Unfortunately, it would appear policy-makers and the media have accepted, at face value, the delusion and deception explanations of cost underestimation causation, despite the lack of empirical evidence to support these conclusions. The danger associated with accepting the delusion and deception explanation results in disincentives to improve or optimize project practices. A solution is, therefore, inflated estimates or even to punish those that are deemed to be too low referring them to as being criminal acts. Then, this creates the incentive to overestimate.

As will be put forward in this paper, the mis-information that has been and continues to be used to argue these perspectives are debunked and a call for focus on evidence rather than rhetoric and opinions in future discourse surrounding cost underestimation causation. If policy-makers are to make headway in ensuring that their projects are delivered cost-effectively and continually improve in performance, then it is necessary they stop listening to the rhetorical spin that has been frequently promulgated by Flyvbjerg *et al.* (2002) and instead rely on facts that can be used to make informed decisions about capital cost estimates and potential risks.

2. Debunking the Rhetoric

The literature is replete with studies that have examined the magnitude, causes and consequences of transport infrastructure project cost underestimation, also more commonly referred to as overruns (e.g. Merewitz, 1973; Sebastian, 1990; Thurgood *et al*., 1990; Hinze *et al*., 1992; Bordat *et al*., 2004; Odeck, 2004; Shane *et al*., 2009; Terrill and Danks, 2016; Love *et al*., 2017a). While there is widespread consensus that cost overruns are a pervasive problem, their causes remain matters of contention (Love *et al*., 2015). This has been, in part, due to the limited access to cost information that is used to produce estimates and the availability of reliable data that can be used to prove causes (Siemiatycki, 2009: p.143).

In science, the primary criterion and standard of evaluation is the provision of evidence, not proof. Notably, a proof exists only in mathematics and logic, which are both closed self-contained systems of propositions. Science is fundamentally empirical in nature and therefore the created knowledge is tentative and provisional. An accepted theory of cost overrun causation, for example, would merely provide the most fitting explanation among all alternatives that are made available. The status of an accepted theory would, inexorably, be subject to change, if there appeared to be a better one or new evidence that could challenge its ability to provide a better explanation of cost overrun causation.

At this juncture, it needs to be pointed out that there is no universally accepted theory that is able to explain cost overrun causation exists (Love *et al*., 2016). This is largely due to the contextual embeddedness and systemicity that prevails with this problem (Ahiaga-Dagbui *et al*., 2017). Two schools of thought, however, have emerged and their respective positions provide a platform for understanding and examining this phenomenon (Ahiaga-Dagbui and Smith, 2014). These schools are the: (1) Evolutionists who suggest that overruns are the result of changes in scope and definition between the inception stage and eventual project completion; (2) Psycho-strategists who attribute overruns to deception, planning fallacy and unjustifiable optimism in the setting of initial cost targets. A detailed discussion of these two schools of thought can be found in Ahiaga-Dagbui and Smith (2014) and Love *et al*. (2016)

While considerable inroads have been made by the evolutionists to explain cost overrun causation, (e.g., Jahren and Ashe, 1991; Bordat *et al*., 2004; Ellis *et al*., 2007; Odeykina *et al*., 2012), the mitigation and containment strategies that have been developed to combat this phenomenon have fallen short of their intended goal. This point has been made by Altshuler and Luberoff (2003) who stated:

> "It is striking that this long-standing pattern [of cost overruns], which appears to prevail worldwide, continues unabated despite major improvements in technical capacity for cost estimation – suggesting that its causes lie primarily in the realm of politics rather those of engineering or accounting" (p.221).

Naturally, this had left door open to present alternative explanations. Taking advantage of this opening, several have suggested that psychological (i.e. optimism bias) and political-economic explanations and strategic misrepresentation provide an adequate justification for the systematic underestimation of project costs in transport projects (e.g., Flyvbjerg *et al*., 2002; Altshuler and Luberoff, 2003; Flyvbjerg, 2007; Canteralli *et al*., 2012a,b,c).

No empirical evidence, however, has demonstrated that these explanations directly contribute to cost underestimations in transport infrastructure projects (Merrow, 1988; Bolan, 2015; Love *et al*., 2015). Needless to say, these explanations should not be discounted altogether and may be valid in some instances (Merrow, 1988; Love *et al*., 2016). For example, strategic misrepresentation, which is the planned, systematic distortion or mis-statement of fact, in the budgeting process of the public sector has been a widely-acknowledged practice (e.g., Wildavsky, 1964; Preffer and Salanick, 1974; Jones and Euske, 1991; Wachs, 1989). Similarly, from a political stance, politicians often announce projected cost of infrastructure projects well in advance of detailed engineering drawings and costing, usually to fulfil pre-election commitments or to attract new voters.

The Australian Commonwealth and Victorian State Governments, for example, are spending AU$438 million on the Geelong to Colac road with a benefit-cost ratio of 0.08:1 (Terrill, 2016). Thus, for every dollar spent it is expected that the project would return 8 cents when completed in 2019, which according to Infrastructure Australia[2] will be lower than the break-even point (Infrastructure Australia, 2015). Without a detailed assessment by Infrastructure Australia, the government agreed to fund the construction of the road in the 2014-2015 budget, as it was located in electorates that had been prominent in previous state elections where swinging voters resided (Terrill, 2016).

Terrill and Danks (2016) have revealed that transport projects that are subjected to their costs being announced before any formal budget commitment is made experience the most significant cost overruns. In addition, incumbent governments often select projects where they can harvest support and attract votes at elections, but opposition parties have a duty to keep them honest by calling for their justification and costings to be made public (Love *et al*., 2017b). There will, without doubt, be disagreements about the location and modes of transport to be selected as well as the project costings provided questioned; but this is politics, which is fundamentally the art of obtaining what a party wants.

2.1 Creation of a Self-Fulfilling Prophecy

The research undertaken by Flyvbjerg *et al*. (2002) has been popularized by the notion of delusion and deception under the auspices of strategic misrepresentation and optimism bias. Affirming this popularity, Siemiatycki (2009;2016) notes that the findings reported in Flyvbjerg *et al*. (2002; 2005) have been one of the highest profile studies of cost overruns on transport projects, attracting a morass of media coverage worldwide. Professor Bent Flyvbjerg, the papers' lead author, is one of the most cited scholars on the field of megaproject management. The Flyvbjerg, Holm and Buhl (2002) paper is amongst the five most cited papers in the history of the *Journal of the American Planning Association* and 15 years after its publication remains a source for newspaper articles around the world. Thus, there is no doubt that this research has attracted a considerable amount of attention, but a close examination of

[2] Infrastructure Australia is an independent statutory body with a mandate to prioritize and progress nationally significant infrastructure. It was established to provide advice to the Australian Government under the *Infrastructure Australia Act 2008*. Infrastructure Australia provides advice to all levels of government, investors and owners about infrastructure projects and reform required to ensure their effective delivery as well as meet economic and community needs and demands. Infrastructure Australia has the responsibility to strategically audit Australia's nationally significant infrastructure, and develop 15-year rolling Infrastructure Plans that specify national and state level priorities.

the findings reveal that they are based on supposition and mis-information. Undoubtedly, this was fake news at the time it was reported, but still continues to be perpetuated. A self-fulfilling prophecy prevails, and unfortunately continues to gain momentum.

This has occurred as a result of the repeated use of the same dataset presented in Flyvbjerg *et al*. (2002) with different slants on the original narratives, which have been played out within the literature (e.g., Flyvbjerg *et al*. 2003a; 2004; 2005; Flyvbjerg, 2007; 2008). Then, building on the case that is established, the argument is re-packaged in Flyvbjerg *et al*. (2009) and Flyvbjerg (2009) presented as plausible cost overrun explanations, which have emerged as a series of factoids. For example, David Uren, the Economics Editor for The Australian newspaper, commenting on the Australian Federal Government's consideration of an inland rail line from Melbourne to Brisbane, by-passing Sydney, wrote (Uren, 2017):

> "University of Oxford economist Bent Flyvbjerg says mega-projects — those worth $1 billion or more — are governed by a kind of inverse Darwinism where only the "un-fittest" survive. "The projects that are made to look best on paper are the projects that amass the highest cost overruns and benefit shortfalls in reality," he says. His survey of major rail projects around the world found the average cost overrun was 44.7 per cent while the average shortfall in traffic, compared with the original projections, was 51.4 per cent".

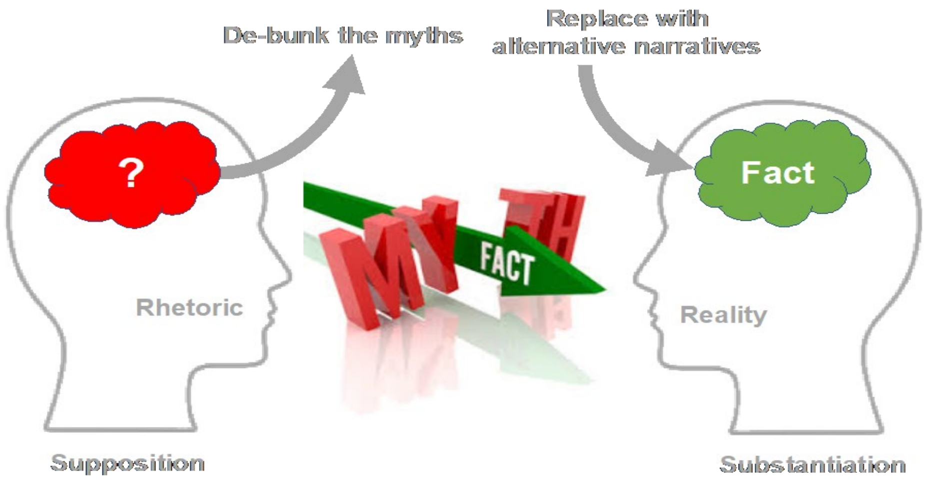
If this Economics Editor had examined the original analysis presented in Flyvbjerg *et al*. (2002), he would have seen that the average cost overrun figure reported for rail projects was not for those in excess of US$1 billion; the range in dollar values for the 58 projects were not presented. Therefore, it is not possible to identify the number of mega-projects (i.e. >US$1 billion) that formed part of this sample. Furthermore, if the Editor had also read Flyvbjerg's (2009) paper he would have immediately realized the data does not, unequivocally, demonstrate that projects with greater cost overruns deliver a benefit shortfall (i.e. this situation is referred to "survival of the un-fittest"). No empirical evidence is presented justifying the claim being made, no matter how conceivable this may appear to be. Just because a project has a low-cost benefit ratio does not mean it will experience a cost overrun.

The mis-information regarding the causal explanations for cost overruns originally suggested by Flyvbjerg *et al*. (2002) has resulted in the creation of a mind-set whereby people have become conditioned to receiving the myths that have been created over 15 years ago, which have then consistently reinforced by the rhetoric presented via the media every time there is a case of an increase in the capital costs of a major transport project is experienced.

Undeniably, the research presented in Flyvbjerg *et al*. (2002) has made an impact with public sector procurement. It brought has brought to attention issues that were possibly being overlooked or endorsed, even though they were acknowledged to exist. The 'elephant in the room' has been recognized, which has subsequently spurred many public-sector agencies into action to redress such concerns (Love *et al*., 2017b). For decades, cost overruns were considered a project management issue; that is, they could be addressed through better methodologies for cost estimation and project execution. Instead, Flyvbjerg *et al.* (2002) indicated that the problem lay within the institutional domains and therefore requiring a focus on governance specifically how projects are initiated, their selection and the sharing of accountability between the actors involved in the planning of transport infrastructure projects.

Consequently, the issues of strategic misrepresentation and optimism bias have been given considerable attention during the planning process of infrastructure projects by many public agencies in developed economies to ensure cost certainty. In the United Kingdom (UK), for example, a guide has been developed by the National Audit Office (2013) to address over-optimism. Furthermore, countries such as Canada, Denmark, Norway, Netherlands, UK and Sweden have introduced third party quality assurance, independent from the agencies responsible for projects, to root out deliberate bias or unintentional error in the estimates that are presented to decision makers (Samset *et al*., 2016). While third party reviews, afford a much-needed step toward providing accountability, benchmarking can the provide empirical support to stimulate improvements in practice and project outcomes over-time (Hollman, 2016).

By debunking the myths that have been created, this mind-set can be replaced with an alternative narrative based on facts as illustrated in Figure 1. Prior to debunking the myths that originated from Flyvbjerg *et al*. (2002), concerns with the reliability of the dataset are raised.



Adapted from Cook and Lewandowsky (2012)

Figure 1. From supposition to substantiation: Changing mindsets

2.2 The Source of the Fake News: The Dataset

The dataset in Flyvbjerg *et al*. (2002) comprises 258 transport infrastructure projects: 58 rail, 167 roads and 33 bridges and tunnels. Construction costs of the sampled projects ranged from US$1.5 million[3] to US$8.5 billion (1995 prices). The projects were drawn from a sample constructed between 1910 and 1998 from 20 countries and five continents. The cost data was collected using primary and secondary sources. Flyvbjerg *et al*. (2002) state "we collected primary cost data for 37 projects in Denmark, France, Germany, Sweden and the UK" (p. 294). Then, Flyvbjerg *et al*. (2002) piggy-backed off the data collected and published by other researchers, and included them in their sample. This has resulted in no empirical or measurable evidence to support the laws of causality[4] being used to explain cost underestimation causation. This issue has been previously highlighted in Love *et al*. (2012).

The extreme heterogeneity of Flyvbjerg *et al.*'s (2002) data should be a cause of concern for anyone using it as a reference. In fact, it is possible that today's peer-review process of many of the world's leading journals would have addressed this weakness as the authors do now. The so-called Peer Reviewer's Openness Initiative (Morey *et al.*, 2016) has called for greater

[3] There is a widespread belief that this dataset contained only mega-projects – this is an incorrect assumption. See Flyvbjerg *et al*. (2002: p.293)
[4] This law of logic states that every effect must have an antecedent cause.

openness and transparency in scientific publishing and that data should be made publicly available to allow for evaluation and reproduction of the results.

The approach adopted by Flyvbjerg *et al*. (2002) signals methodological alarm bells with regard to: (1) the quality of the data, particularly, relating to its accuracy and the rigor used in its collection; (2) issues of validity and reliability, as well as the format of the data. The use of a data that not collected in the same format can lead to invalid results. For example, Flyvbjerg *et al*. (2002) states "even if the project planning process varies with project type, country, and time, it is typically possible to locate for a given project a specific point in the process that can be identified as the time of decision to building the project" (p.293). This is a misconception, as no international standards exist to determine the level of detail needed to formulate an estimate at the time the decision-to-build is made; it will naturally therefore vary depending on governments decision-making processes. The lack of international standards has resulted in the establishment of International Construction Measurement Standards Coalition at International Monetary Fund (IMF) in Washington D.C in 2015. The Royal Institution of Chartered Surveyors (RICS) a founding member of the coalition states (2016):

> "The standards used to calculate the cost of construction projects differ markedly throughout the world. In simple terms the 'line items' which make up the project cost total differ depending on where the project is being carried out. This makes it difficult to understand and compare project costs between markets. It also compromises our ability to interpret the social, economic and environmental 'footprint' of a construction project on a consistent basis".

What is even more apparent is that undertaking any form of comparative study of the accuracy of estimated costs with this dataset and subsequent analysis is nonsensical to those who are experienced in this area of research as the: (1) use of different technologies (e.g., construction methods, plant and equipment), standards and requirements exist at various point in time and between countries; (2) the forms of project delivery strategy would vary, particularly the funding mechanisms used to finance projects; (3) legal systems are inherently different between countries and naturally these would have evolved and become more mature over the period; (4) environmental regulations, requirements and restrictions placed on projects in 1928, for example, are different from those in 1950 and in 1995 for all countries. In consideration of the above, the authors leave it to the reader to decide as to the credibility of the data.

3.0 Key Myths: Inhibitors of Progression

According to Baeten (1996) "myths stymie the movement of history by substituting quickly a congealing 'false nature'" (p.179). By Flyvbjerg *et al*. (2002:2003a;2004;2005) incessantly making apparent their "mythicized causes of significance"[5], evidence has been replaced with rhetoric, and facts have been suppressed with notions of plausibility. This has been counterproductive, as it hindered the discovery of relevant and practical containment and mitigation strategies to alleviate the problem. The media and even policy-makers have been drawn to the populist rhetoric provided by Flyvbjerg *et al*. (2002), but have been unable to progressively reduce the magnitude and occurrence of cost overruns. Hereinafter the key myths created by Flyvbjerg *et al*. (2002) are identified and debunked. Noteworthy, these myths are based on mis-information and misinterpretation and not dis-information.

3.1 Myth: The Sample is the Largest of its Kind and the First Statistical Study of Cost Escalation

In a flagrant strategy to garner attention, Flyvbjerg *et al*. (2002) commence their paper with the following statement: "This article presents results from the first statistically significant study of cost escalation[6]" (p.279). As will be shown below this was not the case at the time the research was undertaken.

As mentioned above, Flyvbjerg *et al.*'s (2002) sample is heterogeneous, covering different types of projects, from a diverse range of countries over a 70-year period. During the period of analysis thousands, if not hundreds of thousands, of transport infrastructure projects were constructed ranging in size and nature; the population for selecting projects is therefore vast. To obtain a statistical significant sample, Flyvbjerg *et al*. (2002) would have needed a considerably larger than the mere 258 projects that they have relied upon.

So, assuming only 100,000 transport infrastructure projects had been constructed worldwide over a period in excess of 70 years, ranging in the same dollar values (US$1.5 million to US$8.5 billion), a 95% confidence interval (i.e., the level of certainty that an estimate represents a true value of the population), a margin error of 5% (i.e., the degree to which an estimate may vary

---

[5] A term coined by Baeten (1996;p.179)

[6] To highlight Flyvbjerg *et al*.'s (2002) limited understanding of project controls, they inappropriately refer to cost overruns as being an escalation. The mis-use of the term is a common mistake (e.g., Shane *et al*., 2009), but cost escalation refers to an "anticipated upsurge in the cost of construction as a result of time and market forces (e.g., inflation) and is not due to project content changes" (Love *et al*., 2015; p.494).

from the true value) and a Normal distribution, then the optimum sample size should have been 383. Flyvbjerg *et al*.'s (2002) study falls short of providing a statistically representative sample of the population, based on a conservative estimation of the population of projects that would have been available, which would have been required to afford confidence in the results presented.

Agreeably, as noted by Flyvbjerg *et al*. (2002), "data on actual costs on transportation infrastructure projects is hard to come by" (p.293). However, liaising directly with public authorities, cost consultants (e.g., quantity surveyors) and contractors and ensuring commercial confidentiality can provide them with the trust needed to ensure access to actual estimates and costs. For example, Thurgood *et al*. (1990), Hinze *et al*. (1992), Vidalis and Najafi (2002) and Ellis *et al*. (2007) obtained access to primary data and actual construction costs. Relatedly, Love *et al*. (2017b) were provided access to the actual costs that were incurred for 16 rail projects constructed by a contractor between 2011 and 2014, which ranged from AU$3.4 to AU$353 million in value. It is difficult for scholars to obtain data, but not impossible as has been demonstrated in the studies prior to that presented in Flyvbjerg *et al*. (2002).

An over reliance on secondary sources, again reaffirms the unreliable nature of the data that was presented. By their own admission, Flyvbjerg *et al*. (2002) state:

> "Reconstructing the actual costs of a public project, therefore typically entails long and difficult archival work and complex accounting. For private projects, even if funding and accounting practices may be more conducive to producing data on actual total costs, such data are often classified to keep them from hands of competitors. Unfortunately, this tends to keep them from scholars. And for both private and private projects, data on actual costs may be held by project owners because more often than not, actual costs reveal substantial cost escalation and cost escalation is normally considered somewhat of an embarrassment to promotors and owners. In sum, establishing reliable data on actual costs for even a single transportation infrastructure project is often highly time consuming or simply impossible" (p.293)

More reliable statistical studies using larger samples had been undertaken prior to Flyvbjerg *et al*.'s (2002) study. For example, Thurgood *et al*. (1990) examined the cost overruns of 817 highway projects delivered by the Utah Department of Transportation (UDOT) between 1980 and 1989. Similarly, Hinze *et al*. (1992) studied the nature of cost overruns of 468 highway projects procured by the Washington State Department of Transportation (WDOT). In Flyvbjerg *et al*. (2005: p.131) they continued to contend that their study contained "the largest sample of its kind" eschewing to acknowledge Vidalis and Najafi (2002) research on cost overruns based on 708 roads projects as well as Bordat *et al*.'s (2004) analysis of 659 transportation schemes constructed by the Indiana State Department of Transportation.

Similarly, recognizing the need to improve the cost performance of transportation, Ellis *et al*. (2007) examined the effectiveness of alternative contracting strategies used to deliver 1160 projects from the Florida Department of Transportation database. Studies by the Departments of Transportation have been much larger than Flyvbjerg *et al*. (2002) and based upon homogenous datasets; consistent rules, polices and estimating practices involved with their implementation. Has this myth arisen due to an error or a lie? Again, the reader is left to decide.

3.2 Myth: Using the Decision-to-Build to Determine Cost Underestimation

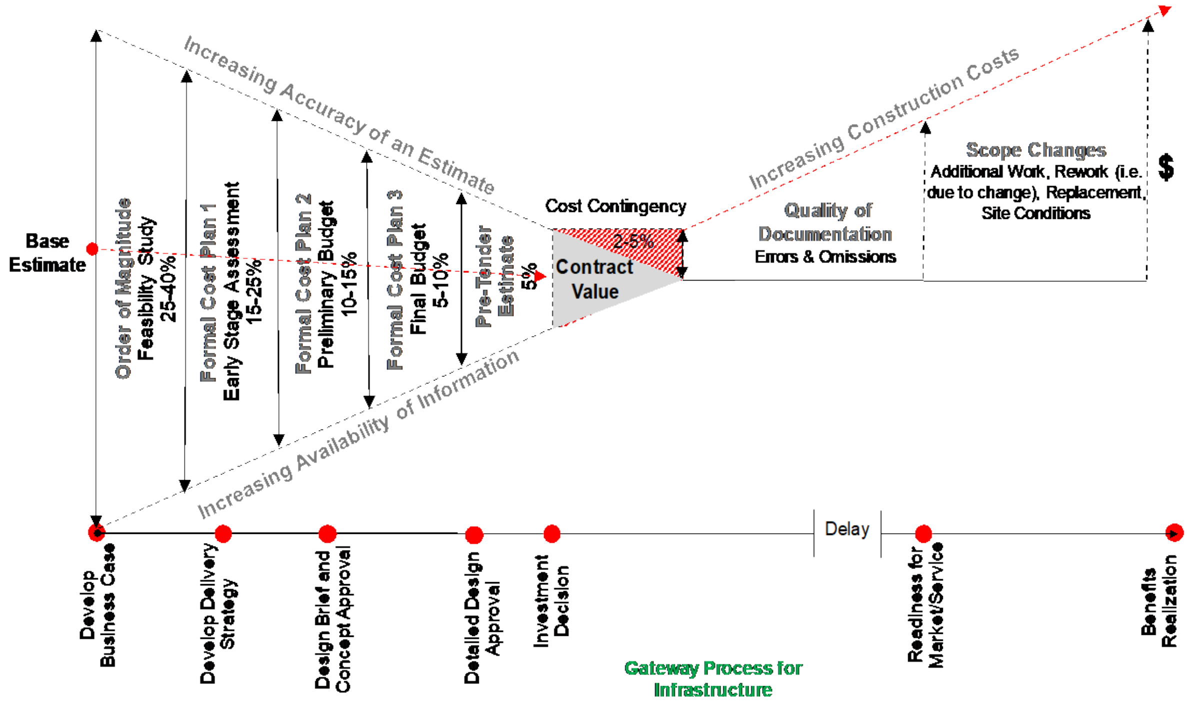
As previously highlighted, there is no international standard that has been established that determines the level of reliability required to create an estimate at the point of decision-to-build, particularly at the time Flyvbjerg *et al*. (2002) conducted their study. In fact, the decision-to-build could be taken after tenders have been received so as to acquire an understanding of market prices. Figure 2 provides an overview of stages used to produce an estimate during the pre-contract phase of a project. It can be seen that when an initial budget estimate is established, it is based upon very limited information to inform a business case. However, as information becomes available the reliability of an estimate improves. This is an issue that Flyvbjerg *et al*. (2003b) out rightly refutes as evident in their response to Remington (2002;p.451) who had suggested that "it costs money to gather detailed information required for more detailed forecasts". Flyvbjerg *et al*. (2003b) responded by stating:

> "Maybe Remington thinks gathering information always makes the cost estimates higher. This would be rather unusual attitude toward forecasting. The burden of proof is on Remington and other proponents of technical explanations. The statistics of the matter indicate that it will be very difficult to lift this burden. Political and economic explanations of cost underestimation account for better the data, as we show in the article" (p.83).

In defense of Remington, the authors concur with his view that gathering more detailed information during the design process will produce more reliable estimates that may result in higher or even reduced costs (Figure 2). The production of an estimate demands knowledge of what will occur, though the challenge is to produce one that provides an accurate reflection of reality (Carr, 1989; Smith *et al*., 2016). The acquisition of such knowledge is dependent upon the completeness of the information made available at a specific point of time during the design development process.

For decades, it has been suggested that greater emphasis should be placed on ensuring the design and documentation is complete prior to the commencement of construction. This, however, rarely happens in reality, but as design process become digitized, enabled by Building Information Modelling, cost estimates will improve, as they are linked directly with levels of design detail (Love *et al*., 2008; Love *et al*. 2017a;b;c). Nonetheless, having greater access to and planning the flow of information during the design process has been consistently identified as being pivotal to ensuring projects are able to be delivered on time, to budget and their desired quality (e.g., Bishop, 1972; Love and Gunasekaran, 1997; Austin *et al*., 1996; Titus and Bröchner, 2005; Eastman *et al*., 2008).

Flyvbjerg *et al*. (2002) uses the budget estimate at the time of the decision-to-build, as the point of reference to measure cost performance. This budget estimate should not be construed as the price that the public sector will need to pay for a project. Determining the price to be paid will invariably be dependent on the procurement strategy and a series of negotiations between the public sector and/or the consortium/contractor surrounding a project's scope. Noteworthy, in Figure 2, if a Gateway Process is adopted to procure transport infrastructure then the formal decision-to-build will be made after tenders have been received from contractors. It is the price at this stage that becomes a binding contractual benchmark between client and contractor. Thus, it should be the reference point or benchmark to measure cost performance, not the estimates made during the conceptual phases of a project. However, each phase of pre-construction should be benchmarked to measure the increase/decrease of estimates.



Source: Love *et al.* (2017c:p.1082)

Figure 2. Simplified version of estimating accuracy and the infrastructure gateway process

3.2.1 Estimate variability: Project definition period

The use of the budget at the decision-to-build may lead to inflated cost overruns being propagated, especially as it does not reflect market prices. Most large publicly funded projects also tend to go through a long definition period, which can take years after project inception during which many changes to scope and accompanying costs occur (Ahiaga-Dagbui and Smith, 2014a). In fact, the time taken from establishing initial brief and budget estimate to obtaining planning permission may take from 12 weeks to 10 years (Sidwell, 1984). Estimates can vary significantly during this period. For example, research undertaken by Adafin *et al.* (2015a) revealed that the variability in cost between the elemental cost plans[7] and final tender sums can range from −14% and +16%. A project' s scope can increase or decrease depending on an array of factors (e.g. economic, political and environmental).

---

[7] Elemental cost planning is often referred to as 'designing to a cost' since a cost limit is fixed for the scheme and the architect/engineers must then prepare a design not to exceed this cost (Smith *et al.*, 2016). It relies upon the adoption of a Standard Form of Cost Analysis that allows costs to be compared on a common format and forms the basis of the benchmarking analysis central to the concept of Elemental Cost Plans (ECP). Refer to the Building Cost Information Service (BCIS), an arm of the RICS in the UK, who have developed industry standards for preparing ECP such as 'BCIS Elemental Standard Form of Cost Analysis'.

It is no surprise that Terrill and Danks (2016) for example found that 66% transport projects begin to experience cost overruns *before* actual construction commences. A pertinent example, is the case of the Honolulu Rapid Transit project that had an original budget in 2012 of US$5.2 billion and since construction commenced its forecasted completion cost at the end of 2016 is set to rise by 83% to US$9.5 billion (Hrushka, 2016). Construction was originally scheduled to begin in December 2009. Legal proceedings to prevent the project from going ahead as well of delays in the review process and in obtaining federal approval of the environmental impact statement, delayed the original commencement by more than two years. When the budget estimate was established, Hawaii was in the midst of a recession. An unfortunate consequence of the delay was that during this period a construction boom occurred, which resulted in potential contractors not having the capacity and willingness to competitively bid for contracts. Prices naturally increased, but funding had been anchored to the budget estimate and not amended to reflect prevailing market conditions. When it is convenient for politicians they can become susceptible to exaggerating, and using this reference point to justify why a piece of infrastructure should not have been constructed or to highlight the supposed mis-management of costs by an incumbent government.

Bolan (2015) notes that Flvvbjerg *et al*. (2002) lacked an understanding of the construction process, as he stated:

> "There appears to be little understanding or experience on the part of Flyvbjerg pertaining to the construction process involved in building tunnels, bridges, and roads (p. 274).

Flyvbjerg (2015) has argued that in the absence of delusion and deception, a lack of sufficient, reliable and accurate project data will result in a final cost variance that is normally distributed around zero (i.e. initial costs should be just over-estimated as they are under-estimated). This argument may appear to be credible upon perfunctory examination. However, early order of magnitude estimates is normally based on unreliable historical average unit costs, usually stated as cost *per* kilometer of roads or rail work and adjusted for inflation with available cost indices. This unit cost typically contains no specific details or design information pertaining to the new project being appraised. To the authors knowledge, Flyvbjerg, Holm and Buhl have, to date, not undertaken any research examining the nuances of estimating. They were at the time of their study not qualified in this area to make such judgments about their accuracy and level of detail required to produce them.

3.2.2 Cost underestimation: The drawing of a long-bow

Using the decision-to-build, Flyvbjerg *et al*. (2002) reported for a sample rail projects to have experienced a mean cost underestimation of 45% (n=58). Other studies in the United States (US), for example, have also used the decision-to-build, but have made it explicit that this was after preliminary engineering had been completed and had requested Federal Transit Approval (FTA) (e.g., Pickrell, 1990; O'Toole, 2015). If a Full Funding Grant Agreement is given, a project can proceed to the final design phase, which includes obtaining right-of-way specifications, construction cost estimates, and tender documentation. In other countries, the formal decision to build may be taken at an earlier or later stage in the project development process (Love *et al*., 2017b).

In the US, for example, Pickrell (1990) examined 10 rail transit projects constructed before 1990 and found that the average cost overrun was 50%. More specifically, 9 out 10 projects experienced cost overruns of 13% to 106% and one experienced an underrun of -11%. Similarly, Dantata *et al*. (2007) examined a further 16 rail projects completed after 1994 and revealed a mean cost overrun of 30%. Drawing on the dataset produced by O'Toole (2015) for light transit rail (LRT), Love *et al*. (2017b) calculated the mean overrun of 42% from the FTA's predicted capital costs for a sample 31 projects constructed between 1989 and 2013. Notably, the Pittsburgh and San Diego LRTs constructed in 1989 experienced underruns of -10% and -11%, respectively. There are several examples of LRT projects that have been delivered on or under their budgeted capital costs, but they are seldom acknowledged as a success, particularly by the media. In Canada, for example, the Northwest line extension in Calgary, which commenced operation in 1987, was approximately US$3 million under budget and cost US$104 million (TRB, 1989).

Contrastingly, when the contract award is used as a reference point, Love *et al*. (2017a) found the actual costs expressed as a percentage of the contract value for 16 rail projects constructed by a contractor ranged from -4.19% to 96.73%, with a mean of 23%. Contracts that provide a traditional lump price experienced a mean cost increase of 11%. However, rail projects procured using a cost reimbursement form of contract incurred a mean cost increase of 75%.

All of the projects cost increase occurred due to scope changes. Cost reimbursement (also referred to as cost-plus) contracts are used when performance, quality or delivery time is a much higher concern than cost, and there is a need for flexibility, allowing for changes in specification to made. Flyvbjerg *et al*. (2002;2003a;2004;2005;2009) and Flyvbjerg (2009) have not considered or acknowledged the influence of procurement methods and other project practices that can have on large-scale transport infrastructures projects outturn costs.

In the case of roads, Flyvbjerg *et al*. (2002) a cost underestimation of 20% (n=167) was reported. Using a reference point at the completion of detailing planning where design, specification and final costs are determined for roads, Odeck (2004) revealed a modest mean cost overrun of 7.9%. Using the contract award as an anchor Thurgood *et al*. (1990) examined cost overruns rates between 1968 to 1988. They found that cost overrun rates fluctuated were below 5% (n=817) until 1984, and then the proportion of projects exceeding this amount from 1984 to 1988 increased. This increase was attributable to having less experienced pre-construction staff employed within the UDOT due staff retiring. Similarly, Hinze (1991) reported a mean cost overrun for roads constructed by WDOT to be circa 5% (n=468). A higher figure has been reported in Love *et al*. (2014) who revealed a mean cost overrun for roads to be 12.49% (n=44) at contract award.

There has, however, been limited research that has examined the cost overruns of bridges and tunnels, though those that have been undertaken are poles apart in their estimates primarily due the reference point used. Flyvberg *et al*. (2002) reported a mean of cost overrun of 33.8% (n=33) whereas Love *et al*. (2012) a significantly lower figure of 11.62% (n=12). Considering the ambiguity that surrounds determination of projects using the decision-to-build and the changing and emerging nature of scope during the pre-construction stage, Flyvbjerg *et al*. (2002) have drawn a long-bow by stating their cost underestimation claims, especially as most of the data originates from secondary sources where original estimates and actual costs are unable to be verified.

3.3 Myth: Costs are Underestimated in 9 out of 10 Transport Infrastructure Projects

A never-ending factoid that has emerged from the original Flyvbjerg *et al*. (2002) study and resonates throughout the literature is that 9 out 10 transport projects worldwide experience cost overruns. Despite the unrepresentative nature of the sample, many academics have and continue to peddle this canard. For example, Shane *et al*. (2009), incorrectly state:

> "In one study by Flyvbjerg *et al*. (2002), it was found that this underestimation occurs in 9 out of 10 transportation infrastructure projects around the world" (p.222).

Flyvbjerg (2015) has continued to promote this assertion, despite the methodological flaws associated with the original data's collection presented in Flyvbjerg *et al*. (2002) as he states:

> "The article shows that as a consequence of cost underestimation nine out of ten large public works projects have cost overruns. Cost overruns are large, even when measured in conservative terms, i.e., excluding inflation and using the final business case as base line" (p.158).

It is not only an exaggeration to claim that almost all transport projects (i.e. 9 out 10) are delivered over budget. It is misleading. For example, Terrill and Danks (2016) analysis of a much larger dataset of 836 transport projects valued at AU$20 million or more, planned or completed since 2001 in Australia, revealed that "the majority of projects come in close to their announced costs" (pg. 10). In fact, 66% were either delivered on budget or under the budget. Only 34% overrun their budget. That said, an important trend that Terril and Danks (2016) do show is that when projects do exceed their expected costs, the size of the overrun is usually significant. They found that 90% of Australia's cost overrun problem is explained by only 17% of projects.

The contract values for the Flyvbjerg *et al.* (2002) publication ranged from US$1.5 million to US$8.5 billion. It does not take much to realize that not all the projects in the dataset are large by the standards of transport infrastructure projects. In fact, by their own admission Flyvbjerg *et al*. (2002) acknowledge that:

> "Our own data collection concentrated on large European projects because too few data existed for this type of project to allow comparative studies. For instance, for projects with actual construction cost larger then 500 million Euros (1995 prices; EUR 1=US$1.29 in 1995), we were only able to identify two identify from other studies only two European projects for which the data were available on about actual and estimated costs. If we lowered the project size and looked at projects larger than 100 million Euros, we were able identify such data for eight European projects" (p.294).

Issues associated with the reliability of the data and point of reference need to be considered here. Moreover, the use of currency conversations has no meaning for comparing the costs of construction unless issues associated with an economy's Purchasing Power Parity are taken into consideration.

3.4 Myth: Underestimation Cannot Be Explained by Error and is Best Explained by Strategic Misrepresentation, that is, Lying

Flyvbjerg *et al.* (2002) entitled their original paper "Underestimating costs in public works projects: Error or lie?" with the aim of ascertaining whether the cost underestimation problem should be attributed to an error or lie? However, their bifurcation of the cost underestimation problem into error or lie intentionally presents the reader with a false dichotomy; an either/or choice that is practically invalid when juxtaposed with the real-world nature of procuring large infrastructure assets. This false dichotomy forces the reader to reject complexity in complex decisions and focus on only the two extremes presented, with the assumption that no middle options are available. When Flyvbjerg *et al*. (2002) posit the error or lie false dichotomy, they fall foul of the *Fallacy of the Excluded Middle*[8] as there are many other explanations of cost underestimation. The error or lie framing is a false alternative, a misleading and a naïve diagnosis of the cost underestimation problem. In particular, Hollman (2016) states that:

> "Industry data does not support strategic misrepresentation as being a primary risk driver, even for public infrastructure projects. However, that may not but true if politicians understand, if politicians understood our profession's failure to address the level of scope definitions and other systemic risks in risk quantification" (p.301)

Osland and Strand (2010) have been particularly critical of the Flyvbjerg *et al*. (2002) of the strategic misrepresentation and optimism bias explanations. Like the authors, they questioned the theoretical and methodological validity of their study claiming that the strategic misrepresentation framework "does not offer any variation on the institutional variable nor when it comes to variation in planners (actors) motives and rationality." Osland and Strand (2010) concluded that Flyvbjerg *et al*. (2002) applied the logic-of-suspicion in their claim that inaccurate cost forecasting is a result of optimism bias. They specifically state:

[8] The fallacy of the Excluded Middle relates to the third of the Three Laws of Logic – the Law of the Excluded Third, after Aristotle (Metaphysics, Book IV (Part 7). It can be simply explained as a claim that a statement is either true or false and that there is no middle option.

> "Flyvbjerg and other proponents for the hermeneutics of suspicion, the actors actually admitting telling lies can be seen as the 'tip of the iceberg'. However, it is also a perspective that would not be falsified if no examples of actors admitting lying were found. On the contrary, it could easily be interpreted as a verification that they were lying also for the researchers." (p. 81)

A lie is a false statement that is deliberately created by someone to intentionally deceive others; deception requires justification. There needs to be a motivation to enact the lie. But, the grounds for producing deceitful cost estimates are not empirical examined in Flyvberg *et al.* (2002;2003a;2004;2005;2009). No evidence is provided to link cost underestimation and the process of estimating and outcomes. This contributes to the phony conclusions that have been presented, but as such information is repeated, many people have become accustomed to viewing this myth as being a reality. This has been assisted with passage of time, as very few researchers have challenged the original findings presented in Flyvbjerg *et al*. (2002). Evidently, the logic-of-opposition paradigm comes into being here (Lindsay, 1990); people have chosen to adopt the mis-information that they have been presented with, as they are unable to recollect the details of the original study and therefore accept them as facts. Over time, the continual distortion of the narrative relating to the causal nature of cost underestimation leads to the *mis-information effect* being experienced (Loftus *et al*., 1989) - episodic memories that were grounded in the facts associated with cost underestimation have been blurred by the reinforcement of these myths.

3.4.1 A case of fitting the distribution to the data, and not data to the distribution

Ahiaga-Dagbui and Smith (2014b) have argued that a robust explanation of cost underestimation must factor in process and product, funding, procurement, risks, as well as sources of change to scope. The Flyvbjerg *et al*. (2002) study simply rely on a Normal distribution information in their dataset and measures of *p*-values to reach the sweeping conclusions made regarding the motives of planners and project sponsors. They did not even determine the best fit probability distribution for the data the analyzed. The use of Normal distribution never reflects what actually arises in reality. As the Normal distribution is symmetrical and not skewed, the mean is in the middle. Thus, the standard deviation represents a unit of uncertainty around the mean.

Emanating from Flyvbjerg *et al*.'s (2002) research, and to address optimism bias and strategic misrepresentation, Flyvbjerg and COWI (2004) and Flyvbjerg (2008) suggested the use of *Reference Class Forecasting* (RCF). Its implementation is based on the original dataset presented in Flyvbjerg *et al*. (2002) and utilizes a Normal distribution. Yet, not all datasets are normally distributed and bell-shaped and therefore it is important to determine their tails and identify the best fitting distribution to determine appropriate probabilities of occurrence for the purpose of risk analysis. The inaccuracies associated with the use of Normal distribution to determine uplifts to accommodate additional costs that may be incurred in transport infrastructure projects have been previously identified in Love *et al*. (2015a;b).

An example where RCF was applied and an inappropriate distribution used to determine up-lifts to the original estimate was the Edinburgh Tram and Airport Link project in the UK (Love *et al*., 2013). The project was originally estimated to cost £320 million, which included a risk contingency based-estimate (Auditor General for Scotland and Accounts Commission, 2011). Taking all the available distributional information into account, by considering a reference class of comparable rail projects (e.g. London Docklands Light Rail), the reference class estimated an 80th percentile value of £400 million. The project was completed three years late in the summer of 2014 at a reported *construction cost* of £776 million (City of Edinburgh Council, 2014). Considering claims and contractual disputes, which partly occurred due to errors and omissions in contract documentation, a revised estimated final cost of over £1 billion was forecasted, including £228 million in interest payments on a 30-year loan to cover the funding shortfall (BBC, 2011).

RCF has several limitations and the relative effectiveness of Risk Based Estimation methods developed has yet to be adequately demonstrated (e.g., Liu and Napier, 2010; Liu *et al*., 2010). Thus, Love *et al*. (2015b) have suggested that to improve the reliability of risks in the form of a contingency estimate at Final Approved Budget, the empirical distributions of cost overruns need to be examined to determine their best fit probability so that an appropriate construction contingency sum can be determined. In this case, by determining the best fit probability distribution for the homogenous sample provided, the likelihood of a portfolio of projects meeting their desired cost performance can be attained (Love *et al*., 2017b). In addition, it is more appropriate to use the median rather than the mean, which Flyvbjerg (2008) utilizes when applying RCF, as it is not skewed so much by extremely large or small values, and thus provides a better idea of a 'typical' value of a cost overrun (Hollman, 2016).

Unfortunately, RCF has been adopted by governments in several countries based on the recommendations by Flyvbjerg and COWI (2004) as they have sold it as being best-practice. At a minimum, an estimate for a large infrastructure project should include the estimated uncertainty measured by the relative standard deviation and identify the main risk drivers. Risk is project-specific, and they are interdependent. To simply assume that a given project is comparable to past and completed projects and that a lump sum up-lift could be added to account for all uncertainties is a gross oversimplification of reality.

4.0 Conclusion

The paper of Flyvbjerg, Holm and Skarmis (2002) attracted considerable attention and stirred significant commentary, but limited criticism followed despite its methodological and practical flaws. As noted by Siemiatycki (2016) the paper was constructed to create an impact, which it has successfully managed to do. Moreover, the paper has been identified as making a seminal contribution to the area of mega-project management. Yet a detailed examination of the Flyvbjerg, Holm and Skarmis research raises serious questions regarding the methodology adopted, the analysis undertaken, and unfounded conclusions reached. Needless to say, the authors should probably be congratulated, as they have fooled many people with their creative and rather convincing narratives that sensationalize the causes of cost overrun in transportation projects. This can be seen in subsequent papers by the authors that perpetuate the mis-information that was originally presented, and now continues as a series of myths and factoids. A detailed critic at the time would have revealed the findings were akin to fake news. For example, the sample of projects is statistically unrepresentative. The dataset is unreliable and the reference point from which cost underestimation is determined is ambiguous, resulting in inaccurate and exaggerated cost overrun figures being reported. The primary myth, however, is that: "Underestimation cannot be explained by error and is best explained by strategic misrepresentation, that is, lying."

For those who have become avid believers and have been taken-in by Flyvbjerg, Holm and Skarmis's error or lie conclusion, then this paper will present readers with uncomfortable knowledge[9]; it may be denied, dismissed, diverted or displaced. No evidence at all supports the

[9] Flyvbjerg (2015:p.276) provides an account of how the American Planning Association (APA) allegedly breached its own ethics. In doing so, he refers Rayner's notion of 'uncomfortable knowledge' as the APA did not accept the findings reported in Flyvbjerg *et al*. (2002).

causal claims of delusion and deception as the main explanations for cost underestimation in transport infrastructure projects.

The myths arising from Flyvbjerg, Holm and Skarmis (2002) have, unfortunately, become an accepted norm amongst many transport and planning academics and practitioners. Challenging such myths since they were first published over 15 years may appear to be futile to some readers, but is necessary as many policy makers who have engaged with these ideas and have commenced on a journey where the road leads to nowhere; practices have not improved and cost underestimation still prevails. It is quite likely that this *status quo* will continue unless facts and evidence are used to establish the causal nature of cost underestimation. The establishment of facts to acquire an ameliorated understanding of this phenomena is a challenge and will inevitably require new lines of inquiry based upon the derivation of empirical evidence.

If cost underestimation is to be effectively addressed and good decisions at the outset of a project are to be made in the future, then there is need for these estimates to be based on reality and not on delusion or falsehoods. Weakening the link between evidence and decisions not only jeopardizes the quality of transport policy making, it threatens the entire enterprise of scientific research, whose business is to find out the facts so that well-informed decisions can be made.

Acknowledgments: The research presented in this paper forms part of an Australian Research Council funded research project (DP160102882). The authors would acknowledge the constructive comments provided by the anonymous reviewers, Emeritus Professor Richard S. Bolan, and Mr. John K. Hollman, which have helped improve the quality of this manuscript.

References

Adafin, J., Rotimi, J. O. B., and Wilkinson, S. (2015). Why do the design stage elemental cost plan and final tender sum differ in New Zealand? *Journal of Financial Management of Property and Construction*, **20**(2), pp. pp.116 - 131

Ahiaga-Dagbui, D. D. and Smith, S.D. (2014a). Rethinking construction cost overruns: Cognition, learning and estimation. *Journal of Financial Management of Property and Construction* **19**(1), pp.38-54.

Ahiaga-Dagbui, D. D. and Smith, S. D. (2014b). Dealing with construction cost overruns using data mining. *Construction Management and Economics*, **32**(7-8), pp.628-694.

Ahiaga-Dagbui, D., Love, P.E.D, Smith, S. and Ackermann, F. (2017). Toward a systemic view to cost overrun causation in infrastructure projects: A review and implications for research. *Project Management Journal*, **48**(2), pp.88-98.

Altshuler, A., and Luberoff, D. (2003). *Mega-projects: The Changing Politics of Urban Public Investments*. Brookings Institution, Washington DC

Auditor General for Scotland and the Accounts Commission. (2011). *Edinburgh Trams: Interim Report.* Available at www.audit-Scotland.gov.uk, Accessed 29th April 2017

Austin, S., Baldwin, A., and Newton, A. (1996). A data flow model to plan and manage the building design process. *Journal of Engineering Design*, **7**(1), pp.3–25

Baeten, E.M. (1996). *The Magic Mirror: Myth's Abiding Power*. State University of New York Press, Albany

BBC (2011). Council to borrow £231m for Edinburgh trams project. 19th August 2011, Available at http://www.bbc.co.uk/news/uk-scotland-edinburgh-east-fife-14594872, Accessed, 27th April 2017

Bishop, D. (1972). Information flow in the construction industry: a study and the development of its recommendations. *Aslib Proceedings*, **24**(2), pp.79-95

Bolan, R.S. (2015). *Letter to the Editor*. Cities, **42**, pp.274-275.

Bordat, C., McCullouch, B.G., Labi, S. and K.C. Sinha, K.C (2004). *An Analysis of Cost Overruns and Time Delays of INDOT Projects*. Transportation Research Board, Publication no. FHWA/IN/JTRP-2004/7, SPR-2811, Washington D.C., US Available at: http://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1482&context=jtrp, Accessed 10th May 2017

Brobjer, T. (2008). *Nietzsche's Philosophical Context: An Intellectual Biography.* University of Illinois Press, Urbana

Carr, R.I. (1989). Cost estimating principles. *ASCE Journal of Construction Engineering and Management*, **115**(4), pp.545-551.

Cantarelli, C.C. van Wee, B., Molin, E.J.E., and Flyvbjerg, B. (2012a) Characteristics of cost overruns for Dutch transport infrastructure projects and the importance of the decision to build and project phases. *Transport Policy*, **22**, pp.49-56.

Cantarelli, C.C. van Wee, B., Molin, E.J.E., and Flyvbjerg, B. (2012b) Different cost performance: different determinants? The case of cost overruns in Dutch transport projects. *Transport Policy*, **22**, pp.88-95.

Cantarelli, C.C., Flyvbjerg, B. and Buhl, S.L. (2012c) Geographical variation in project cost performance: the Netherlands versus worldwide. *Journal of Transport Geography*, **24**, pp.324-331.

City of Edinburgh Council (2014) *The Tram Project*. Available at: http://www.edinburgh.gov.uk/trams, Accessed 21st May 2017

Cook, J., and Lewandowsky, S. (2011), *The Debunking Handbook*. St. Lucia, Australia, University of Queensland. November 5th Available at: http://sks.to/debunk, Accessed 1st May 2017.

Dantata, N. Touran, A., and Schneck, D.C. (2006). *Trends in US rail transit project cost overrun*. TRB Annual Meeting, Available at: http://americandreamcoalition.org/transit/dantata.pdf Accessed 14th May 2017

Eastman, C.M., Teicholz, P., Sacks, R., and Liston, K. (2008). *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Architects, Engineers, Contractors, and Fabricators*. Wiley, Hoboken, NJ

Ellis, R.J., Pyeon, H., Herbsman, Z., Minchin, E., and Molenaer, K. (2007). *Evaluation of Alternative Contracting Techniques on FDOT Construction Projects*. Department of Transportation, RFP-DOT05/06-9024JP, Tallahassee, Florida
Available at: http://www.fdot.gov/research/completed_proj/summary_cn/fdot_bdc51_rpt.pdf, Accessed 9th May 2017

Flyvbjerg, B. (2007). Policy and planning for large-infrastructure projects: problems, causes and cures. *Environment and Planning B: Planning and Design*, **34**, pp.578-597.

Flyvbjerg, B. (2008). Curbing optimism bias and strategic misrepresentation in planning: Reference class forecasting in practice. *European Planning Studies*, **16**(1), pp.3-21.

Flyvbjerg, B. and COWI (2004). Procedures for Dealing with Optimism Bias in Transport Projects. The British Department of Transport, Guidance Document, Available at: http://flyvbjerg.plan.aau.dk/0406DfT-UK%20OptBiasASPUBL.pdf Accessed 31st May 2017

Flyvbjerg, B., Holm, M.K.S., Buhl, S.L. (2002). Underestimating costs in public works projects: Error or lie. *Journal of the American Planning Association*, **68**(3), pp.131-146.

Flyvbjerg, B., Holm, M.K.S., Buhl, S.L. (2003a). How common and how large are cost overruns in transport infrastructure projects. *Transport Reviews*, **23**(1), pp.71-88.

Flyvbjerg, B., Holm, M.K.S., Buhl, S.L. (2003b) Response to Remington. *Journal of the American Planning Association*, **69**(1), pp.83, Flyvbjerg, B., Holm, M.K.S., Buhl, S.L. (2004). What causes cost overruns in transport infrastructure projects. *Transport Reviews*, **24**(1), pp.3-18

Flyvbjerg, B., Holm, M.K.S., Buhl, S.L. (2005). How (in)accurate are demand forecasts in public works projects? The case of transportation. *Journal of the American Planning Associ*ation, **71**(2), pp.131-146

Flyvbjerg, B. (2009). Survival of the un-fittest: Why the worst infrastructure gets built – and what can we do about it. *Oxford Review of Economic Policy*, **25**(3), pp.344-367.

Flyvbjerg, B., Garbiou, M., and Lovallo, D. (2009). Delusion and deception in large infrastructure projects: two models for explaining and preventing executive disaster. *California Management Review,* 51(2), pp.170-193

Flyvbjerg, B. (2013). Quality control and due diligence in project management: Getting decisions right by taking the outside view. *International Journal of Project Management*, **31**(5), pp.760-774

Flyvbjerg, B. (2013). How planners deal with uncomfortable knowledge: The dubios ethics of the American Planning Association. *Cities*, **32**, pp. 157-163.

Flyvbjerg, B. (2015). More on the dark side of planning: Response to Richard Bolan. *Cities,* **42**, pp.276-278.

Hinze, J., Selstad, G., and Mahoney, J. P., (1991). *Analysis of WSDOT Construction Cost Overruns*. RPGC8719, Task 12, WA-RD 218.1, Prepared for Washington State Transportation Committee, Department of Transportation and the US Transportation Federal Highway Administration, Available at; http://www.wsdot.wa.gov/research/reports/fullreports/218.1.pd, Accessed 14th May 2017.

Hinze, J. Selstead, G., and Mahoney, J.P. (1992) Cost overruns on State of Washington construction contracts. *Transportation Research Record*, **1351**, pp.87-93

Hollman, J.K. (2016). Project Risk Quantification: A Practitioners Guide to Realistic Cost and Schedule Risk Management. Probabilistic Publishing

Hrushka, A. (2016). *A Year in Review: Honolulu Rail Project*. Pacific Business News, 27th December, Available at:http://www.bizjournals.com/pacific/news/2016/12/27/year-in-review-2016-honolulu-rail-project.html, Accessed 14th May 2017

Infrastructure Australia (2015). *2014-15 Assessment brief: Princes Highway West – Winchelsea to Colac Duplication*. Available at: http://infrastructureaustralia.gov.au/projects/files/Vic-Princes-Highway-West-Duplication.pdf Accessed 14th May 2017

Jahren, C.T., and Ashe, A.M. (1991). Predictors of cost overrun rates. *ASCE Journal of Construction Engineering and Management*, **116**(3), pp.548-552.

Jones, L.R., and Euske, K.J. (1991). Strategic misrepresentation in budgeting. *Journal of Public Administration Research and Theory*, **4**, pp.437-460.

Liu, L., Wehbe, G., Sisovic, J. (2010). The accuracy of hybrid estimating approaches: A case study of an Australian State road and traffic Authority. *Engineering Economist*, **55**, 225-245.

Liu, L., Napier, Z. (2010). The accuracy of risk-based cost estimation for water infrastructure projects: preliminary evidence from Australian projects. *Construction Management and Economics*, **28**(1), pp.89-100

Lindsay, D.S. (1990). Misleading suggestions can impair eyewitnesses' ability to remember event details. *Journal of Experimental Psychology: Learning, Memory and Cognition*, **16**, pp.1077-1083.

Loftus, E.F., and Hofman, H.G. (1989). Misinformation and memory: The creation of new memories. *Journal of Experimental Psychology, General*, **118**, pp.100-104.

Love, P.E.D, Edwards D.J., and Irani, Z. (2008) Forensic project management: an exploratory examination of the causal behaviour of design-induced rework. *IEEE Transactions on Engineering Managemen*t **55**(2), pp.234–247

Love, P.E.D, Edwards, D.J., and Irani, Z. (2012). Moving beyond optimism bias and strategic misrepresentation: An explanation for social infrastructure project cost overruns. *IEEE Transactions on Engineering Management* **59**(4), pp. 560 – 571.

Love, P.E.D., Sing, C-P., Wang, X, and Tiong, R. (2013). Determining the probability of cost overruns in Australian construction and engineering projects. *ASCE Journal of Construction Engineering and Management*, **139**(3), pp. 321–330.

Love, P.E.D., Wang, X, Sing, C-P, Irani, Z, and Thwala, D., (2014). Overruns in transportation projects. *Structure and Infrastructure Engineering*, **10**(2), pp. 141–159

Love, P.E.D., Simpson, I., Olatunji, O. Smith, J. and Regan, M. (2015a). Understanding the landscape of overruns in transportation infrastructure projects. *Environment and Planning B: Planning and Design,* **42**(3), pp. 490 – 509.

Love, P.E.D., Sing, C-P., Carey, B. and Kim, J-T. (2015b). Estimating construction contingency: Accommodating the potential for cost overruns in road construction projects *ASCE Journal of Infrastructure Systems,* **21**(2) 04014035.

Love, P.E.D., Ahiaga-Dagbui, D. D. and Irani, Z. (2016). Cost overruns in transportation infrastructure projects: Sowing the seeds for a probabilistic theory of causation. *Transportation Research A: Policy and Practice,* **92**, pp.184-194.

Love, P.E.D. Ahiaga-Dagbui, D., Welde, M., and Odeck, J. (2017a). Cost Performance light transit rail: Enablers of future-proofing. *Transportation Research A: Policy and Practice*, **100**, pp.27-39.

Love, P.E.D., Zhou, J. Irani, Z., Edwards, D.J. and Sing, C.P. (2017b). Off the rails: cost performance of rail infrastructure projects. *Transportation Research Part A: Policy and Practice,* **99***,* pp.14-29.

Love, P.E.D. Irani, Z., Smith, J., Regan, M., and Liu, J. (2017c). Cost performance of public infrastructure projects: The nemesis and nirvana of change-orders. *Production Planning and Control*, **28**(13), pp.1081-1092

Machiavelli, N. (1515). *The Prince*. Translated by W.K. Marriot Available at: https://ebooks.adelaide.edu.au/m/machiavelli/niccolo/m149p/complete.html, Accessed 27th April 2017,

Merewitz, L. (1973). Cost overruns in public works. In Benefit Cost and Policy Analysis, Ed. By W. Niskanen, A. Hansen, and R. Havermann, R. Turvey and R. Zeckhauser, Chicago, pp.277-295.

Merrow, E. (1988). *Understanding the Outcomes of Megaprojects*. The Rand Corporation, Available at: https://www.rand.org/content/dam/rand/pubs/reports/2006/R3560.pdf, Accessed 3rd June 2017

Morey, R.D., Chambers, C.D., Etchells, P.J., Harris, C.R., Hoekstra, R., Lakens, D., Lewandowsky, S., Morey, C.C., Newman, D.P., Schönbrodt, F.D., Vanpaemel, W., Wagenmakers, E.-J., Zwaan, R.A., (2016). The Peer Reviewers' Openness Initiative: Incentivizing open research practices through peer review. *Royal Society Open Science*, 3:150547, doi: 10.1098/rsos.150547.

NAO (2013). *Over-Optimism on Government Projects*. A Report by the National Audit Office, December, London, UK.38

Odeck, J. (2004). Cost overruns in road construction – what are their size and determinants. *Transport Policy*, **24**, pp.43-53.

Odeyinka, H., Larkin, K., Weatherup, R., Cunningham, G., McKane, M., Bogle, G., (2012). Modelling Risk Impacts on the Variability between Contract Sum and Final Account (A Research Report submitted to Royal Institution of Chartered Surveyors. London, UK

Osland, O. and Strand, A. (2010). The politics and institutions of project approval-A critical-constructive comment on the theory of strategic misrepresentation. *European Journal of*

Transport and Infrastructure Research, 1(**10**), Available at: http://www.ejtir.tudelft.nl/issues/2010_01/abstracts/2010_01_06.asp.pdf, Accessed 21st May 2017

Pickrell, D.H. (1990). *Urban Rail Transit Projects: Forecast versus Actual Ridership and Cost*. Publication DOT-T-91-04. U.S. Department of Transportation. October, Available at: https://ntl.bts.gov/lib/56000/56600/56645/urbanrailtransit00unse_0.pdf, Access 14th May 2017

Preffer, J., and Salancik, G. (1974). Organizational decision-making as a political process: The case of a university budget. *Administrative Science Quarterly*, **19**, pp.135-151.

Remmington, R. (2002). Estimation process misunderstood. *Journal of the American Planning Association*, **68**(4), pp.451

Royal Institution of Chartered Surveyors (2016). *International Standards*. 2nd March 2016, Available at: http://www.rics.org/au/footer/international-standards/, Accessed 10th May 2016

Samset, K.F., Volden, G.H., Olson, N., and Kvalheim, E.V., (2016). *Governance Schemes for Major Investment Projects. A Comparative Study of Principles and Practices in Six Countries*. Concept Report No. 47. Trondheim: Ex Ante Academic Publisher

Sidwell, A.C. (1984) The time performance of construction projects. *Architectural Science Review*, **27**(4), pp.85-9 1.

Sebastian, M. (1990). Cost and time overruns in public sector projects. *Economic and Political Weekly*, November 24th, **XXV**(47), M-154-168.

Shane, J. Molenaar, K.R, Anderson, S., and Schnexnayder, C. (2009). Construction project escalation factors. *ASCE Journal of Management in Engineering*, **25**(4), pp.221-229.

Siemiatycki, M. (2009). Comparing perspectives on transportation project cost overruns. *Journal of Planning Education Research*, **29**(2), pp.157-170.

Siemiatycki, M., (2016). The making and impacts if a classic text in megaproject management: The case of cost overrun research. *International Journal of Project Management*, https://doi.org/10.1016/j.ijproman.2016.07.003

Shane, J., Molenaar, K., Anderson, S., and Schexnayder, C. (2009) Construction project cost escalation factors. *ASCE Journal of Management in Engineering*, **25**(4), pp.

Smith, J., Jaggar, D., Love, P.E.D., and Olatunji, O. (2016). *Building Cost Planning for the Design Team*. Oxon, England: Routledge.

Terrill, M. (2016). *Roads to Riches: Better Transport Investment*. Gratten Institute, Melbourne, Victoria, Australia, Available at: https://grattan.edu.au/wp-content/uploads/2016/04/869-Roads-to-Riches.pdf, Accessed 14th May 2017

Terrill, M. and Danks, L. (2016). *Cost Overruns in Transportation Infrastructure Projects*. A Gratten Institute, Melbourne, Victoria, Australia, Available at; https://grattan.edu.au/report/cost-overruns-in-transport-infrastructure/, Accessed 12th December 2016

Thurgood, G.S., Walters, L.C., Williams, G.R., and Wright N.D. (1990). Changing environmental for highway construction: The Utah experience with construction cost overruns. *Transportation Record*, **1262**, pp.121-130.

Titus, S., and Bröchner, J. (2005). Managing information flow in construction supply chains", Construction Innovation, **5**(2), pp.71-82,

TRB, (1989). *Light Rail Transit: New System Successes at Affordable Prices*. Transportation Review Board (TRB) Special Report 221, Initially presented at National Conference on Light Rail Transit, 8th –11th May, 1988, at San Jose, California, USA

Uren, D. (2017). Malcolm Turnbull's rail decision gets lost inside a pork barrel. 4th May, *The Australian*

Wachs, M. (1989). When planners lie with numbers. *Journal of the American Planning Association*, **55**(4), pp.476-479.

Wildavsky, A. (1964). *The Politics of the Budgetary Process*. Little Brown, Boston, MA