



COST OVERRUNS IN PUBLIC INFRASTRUCTURE PROJECTS: RE-EVALUATING PROCUREMENT IN AN ERA OF DIGITIZATION

P.E.D. Love ¹, J. Smith ^{2,4} and M. Regan ³

¹ School of Civil and Mechanical Engineering, Curtin University, Perth, WA 6845, Australia.

^{2,3} Institute of Sustainable Development and Architecture, Bond University, Gold Coast, QLD 4229, Australia.

⁴ jismith@bond.edu.au

Abstract: A case study is used to examine the cost performance of 67 public sector infrastructure projects delivered by a contractor. Change orders were found to contribute to a 23.75% increase in project costs. A positive association between an increase in change orders and the contractor's margin was identified. Taxpayers pay for this additional cost, while those charged with constructing assets are rewarded with an increase in their margins. As the public sector embraces an era of digitization, there is a need to improve the integration of design and construction activities and engender collaboration to ensure assets can be delivered cost effectively and future-proofed. The research paper provides empirical evidence for the public sector to re-consider the processes that are used to deliver their infrastructure assets, in order to reduce the propensity for cost overruns and enable future-proofing to occur.

1 Introduction

A significant problem that has been consistently identified as a contributor to increasing an asset's construction costs is the quality of the contractual documentation that is produced (Jarkas, 2014). The errors and omissions that often materialize in contract documentation typically do not come to light until construction has commenced, and can therefore result in change orders occurring (i.e. additional work and/or rework). Fundamentally, change orders lead to unintended consequences. In their basic form there is an increase in project costs for the public-sector client, but for contractors this can result in increased margins. There has been a tendency to overlook this dynamic as data is not readily available due to commercial confidentiality. A change order is essentially a client's (or their representative's) written instruction to a contractor, issued after the execution of a construction contract, which authorizes a change (or variation) to the work being undertaken which may affect the contract time and/or amount.

There is widespread acknowledgement by Governments that there is a need to provide the public with value for money (VfM) including design and construction innovation rather than to procure assets at the lowest price. A VfM consideration should also contribute to the advancement of Government's priorities, no-cost issues (e.g. fitness-for-purposes and quality), and cost issues (e.g. whole-life-cycle costs, and transaction costs associated with acquisition, use, holding, maintenance and disposal). Consequently, they have attempted to address this issue by adopting non-traditional procurement methods (e.g. Project Alliances) and alternative finance mechanisms (e.g., Public Private Partnerships (PPPs)) to deliver major capital works. In the case of non-major capital works, there is a proclivity for traditional procurement methods to be selected, irrespective of their inherent drawbacks (Love *et al.*, 2012). In this paper, the cost performance of a wide range of infrastructure projects completed between 2011 to 2014 are analyzed and discussed to illustrate the prevailing problem that confronts the public sector when delivering their assets.

The research presented in this paper provides much needed empirical evidence for the public sector to reconsider the processes that are used to deliver their infrastructure assets to reduce the tendency of cost overruns occurring.

2 Cost Performance

Managing the cost performance of the public sector's portfolio of projects is essential to ensure taxpayers are being provided with VFM. This is a critical metric, as it quantifies the cost efficiency of the work that is completed. Cost performance is generally defined as the value of the work completed compared to the actual cost of progress made on the project (Baccarini and Love, 2014). For the public sector, the ability to reliably predict the final cost of construction for an infrastructure asset and ensure it does not experience a cost overrun is vital for ensuring the planning and resourcing of other projects, or those in the pipeline. In this case, a cost overrun is defined as the ratio of the actual final costs of the project to the estimate made at *full funds authorization* measured in escalation-adjusted terms (time-adjusted real costs). Thus, a cost overrun is treated as the margin between the authorized initial project cost and the real final costs incurred after adjusting for expenditures due to escalation terms.

Deloitte Access Economics (2014), for example, have revealed that on average, completed economic infrastructure projects in Australia experience a cost overrun of 6.5% in excess of their initial estimate. Moreover, projects more than AU\$1 billion have been found to experience an average cost overrun of 12.7%. Higher values have been reported in Flyvbjerg *et al.* (2002) who examined the cost overruns of 258 transportation projects and revealed a mean cost overrun of 32.8% from the budget estimate to the completion of construction. Contrastingly, Love (2002) found that cost overruns from the final tender sum to completion of construction for a sample of 169 projects had a mean cost overrun of 12.6%. Terrill and Danks's (2016) comprehensive analysis of 836 transportation infrastructure projects valued in excess of AU\$20 million revealed that 90% of the total increase in costs incurred in Australia can be explained by 17% of projects that exceed their cost by more than 50%. In addition, Terrill and Danks (2016) revealed that 24% of projects exceeded the cost announced by the incumbent Government, and interestingly, 9% were delivered under their publicized budget.

The disparity between the reported magnitude of cost overruns experienced probably arises due to the 'point of reference' from where they are determined in a project's development process (Love *et al.* 2016). A review of the literature reveals cost overruns have been typically determined between the: (1) initial forecasted budget (i.e. base estimate) and actual construction cost (Cantarelli *et al.* 2012); (2) detailed planning stage and actual construction costs (Odeck, 2004); and (3) establishment of a contract value and actual construction costs (Love *et al.*, 2015).

These differences, in part, arise as there is a tendency for public infrastructure projects to engage in a lengthy 'definition' period after the decision-to-build and a base estimate has been established. Such a protracted period can result in projects being susceptible to experiencing change orders, which can lead to cost increases being incurred. With this in mind, it is suggested that it is misleading to make direct comparisons between the base estimate at the time of the decision-to-build and actual construction costs, as the estimate that is initially prepared is typically based upon an early conceptual design. Put simply, the accuracy of an estimate improves as more information becomes available (e.g., scope is defined and users' requirements are identified). At this juncture, it is important to mention that the Royal Institution of Chartered Surveyors under the auspices of the 'New Rules of Measurement' advocate that all estimates are expressed as a single figure (RICS, 2012). The use of such a precise figure is failing the basic tests of validity: accuracy and precision (Newton, 2012). The inadequacies of the traditional estimating process are camouflaged using deterministic percentage additions that take the form of a contingency, which cater for an increase in a project's cost due to: (1) variability; (2) risk events; and (3) unforeseeable situations (Baccarini and Love, 2014). In stark contrast to the deterministic approach, it has been suggested the application of a probabilistic approach to determining a construction cost contingency based upon empirical analysis of a wide range of infrastructure projects should be applied (e.g. Love *et al.*, 2016).

Generally, the construction contingency percentages applied to public infrastructure projects have been unable to accommodate increases in cost that are incurred. For example, Baccarini and Love (2014)

analysis of 228 water infrastructure projects revealed that the mean percentage addition was 8.46% of their contract value, but the construction contingency requirement for the final cost was 13.58%; a shortfall in contingency in the region of 5%. The magnitude of this percentage addition, while evidently inaccurate, can vary with the nature of the project and the type of procurement method adopted. For example, in the case of a greenfield project that is being delivered via a traditional procurement method (e.g., Construct Only), the design and specifications (including drawings and Bills of Quantities (BoQ)) for a project are supposed to be complete at contract award and thus a construction contingency between 2% and 5% is often provided. Thus, there is a perception that a high degree of cost certainty will ensue, but in reality, this is fallacy, as complete drawings and BoQs are seldom available when a project goes to tender.

3 Research Method

Most research studies that have examined the cost performance of infrastructure projects have tended to rely upon heterogeneous datasets (e.g., Flyvbjerg *et al.*, 2002; Cantarelli *et al.*, 2012). Such datasets are loosely connected and thus there is a propensity for them to possess a considerable amount of 'noise', as a morass of missing information is needed to explain the nature of a project's cost performance (e.g. the asset owners' aims and objectives, planning requirements, contractors, project teams, technologies, and contractual arrangements). Instead, this research sought to obtain an ameliorated understanding of the impact of change orders on the public sector and contractors financial performance.

To illustrate how the cost performance of infrastructure projects vary and provide an insight to the problem that confronts the public sector, a case study is used (Fry *et al.*, 1999). The case study serves to make the 'unfamiliar, familiar', and provide a common language about the nature of infrastructure projects' cost performance. A homogenous dataset (i.e. in terms of technologies, procedures and processes) from a contractor who completed a wide range of infrastructure projects between 2011 to 2014 were examined, where their final accounts had been completed. That is where the final payment made to the contractor on completion of the works described in the contract and payments owing being made at the end of the defects liability period have been paid. Selecting only those projects that had their final accounts completed enabled an accurate assessment of their cost to be determined. No project sampled was subjected to open tendering, and several were delivered within a Building Information Modelling (BIM) environment. Individual names, locations, and the BIM 'Level of Detail' (LOD) specification of projects are withheld and the data aggregated for reasons of commercial confidentiality.

4 Analysis and Findings

Cost data from 67 completed infrastructure projects were provided, which included their procurement method, original contract value (OCV), final contract value, contractor's margin, total of client approved change orders, and final contractor's margin. 'Building' (n=16, 24%) (e.g., hospitals, schools and civic assets) and 'Rail' (n=16, 24%) and 'Civil' (n=22, 33%) (i.e., miscellaneous works such as dam upgrades and earthworks) were the most popular types of projects that were constructed. A variety of procurement methods were selected by the public sector to deliver their assets (Table 1); 65 (44%) were traditional 'Construct Only' lump sum contracts, the remainder were non-traditional methods with the most popular form being 'Design and Construct', (n=13,19%).

4.1 Cost Performance

The value of the contracts awarded by the public sector varied, though a significant proportion were less than AU\$100 million (n=55, 82%). The contract value of the projects ranged from approximately AU\$1.8 million to AU\$318 million, with a mean of AU\$48 million. More specifically, 'Civil', (43%) 'Building' (25%) and 'Rail' (20%) project types accounted for most of the contractor's turnover from 2011 to 2014. The cost performance of projects ranged from -42.88% to + 270.93% of budget with a mean cost overrun of 23.75% as a proportion of the OCV. This finding is in stark contrast to Love (2002) who reported a mean cost overrun of 12.6% of the OCV, with 48% being attributable to change orders and the remaining 52% being due to rework. All projects that utilized BIM were to a minimum of LOD 300 and all experienced cost increases. In this instance, with the LOD 300 the specific model elements are demonstrated as specific assemblies accurate in terms of quantity, size, shape, location and orientation.

A total of 67% (n=45) of projects incurred a cost overrun of less than 25% of their OCV and 9% (n=6) experienced a cost underrun. A *Grubbs* test was used to detect outliers from a Normal Distribution with the tested data being the minimum and maximum values. The result is a probability that belongs to the core population being examined. If the data is approximately normally distributed, then outliers are required to have Z-scores ± 3 . Outliers possessing a Z-score in the range ± 2 to 3 can be considered to be 'borderline' outliers. As denoted in Figure 1, two projects were identified as being 'borderline' with Z-scores being between +2 and +3 and two outright outliers being in excess of +4. Considering these Z-scores, the 'best fit' distribution was determined. Considering the outliers that were present, a Normal Distribution was not deemed to be the 'best fit' distribution for the data.

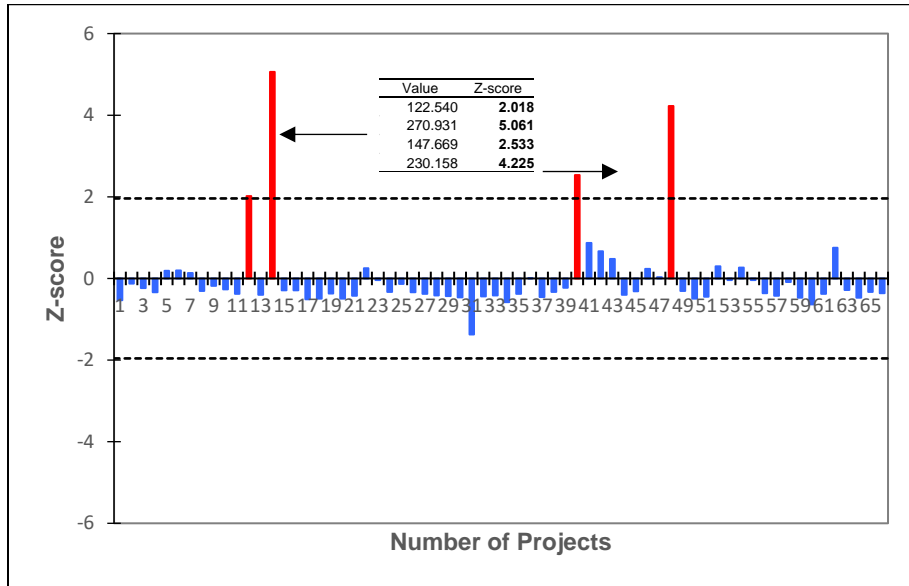


Figure 1: Outliers for cost performance

The detailed financial summaries provided to the researchers by the contractor revealed that client change orders contributed to the cost deviations that were subjected to public sector clients' approval. Non-conformances also materialized in the projects, but the rectification costs did not impact the final contract value paid by the clients as these were the responsibility of the subcontractors and suppliers. The correlation analysis revealed that the size of a project in terms of its OCV, its type, and the procurement method used were not significantly related to cost performance ($p < 0.01$). Studies examining the relationship between project size and the extent of cost overrun incurred remains inconclusive and has been the subject of debate (e.g., Odeck, 2004). In pursuant of this unresolved issue, the analysis sought to determine if there was a significant difference between a project's size (i.e. OCV) and cost performance. A one-way Analysis of the Variance (ANOVA) was used in this instance to test for differences. Levene's test for homogeneity of variances was not found to be violated ($p < 0.05$), which indicates the population variances for project size and cost performance were equal. Thus, there were no significant differences between 'project size' and cost performance, $F(4,62) = 1.096$, $p < 0.05$. Furthermore, to determine whether there was a difference between procurement methods and cost performance, a *t*-test was undertaken using the categories of 'traditional' and 'non-traditional'. At the 95% confidence interval, no significant difference in cost performance was experienced in projects delivered under the different procurement categorizations that were established.

4.2 Change Orders

The mean amount of client approved change orders that occurred in projects was approximately AU\$5.1 million (10.6%). In addition, the total change orders accounted for 11% of the value of the work that was undertaken by the contractor between 2011 and 2014. To determine if there was a significant difference

between the change orders and project size an ANOVA was undertaken. Levene's test for homogeneity of variances was found to be violated ($p = 0.00$), which indicates the population variances for project size and cost performance were not equal. Significant differences between change orders and project size were found to occur, $F(4,62) = 5.525$, $p < 0.01$). A Tukey's HSD post-hoc tested showed that projects with a lower a OCV experienced smaller volumes of change orders ($p < 0.05$).

4.3 Margin

According to the NAO (2013) there is limited available knowledge and a lack transparency surrounding the margins of contractors. In contributing to this gap in knowledge, the analysis revealed that the contractor's mean margin was 9.89% of the OCV. The mean margin allocated for each type of project ranged from 8.76% to 10.61%. The lowest record margin was 3.98% of the OCV for a 'Civil' project that had an OCV of AU\$48.4 million and a final contract value of AU\$65.9 million. However, in this project the contractor's expected margin at the commencement of the works was AU\$3.8 million, but declined to AU\$3.2 million (-15.57%) due to issues surrounding rework, which they were accountable for. This scenario was observed in several projects. For example, a AU\$64.7 million 'Construct Only' 'Civil' project had an expected margin of AU\$2.9 million.

With the client issuing scope changes, the final contract value was AU\$61.6 million, a cost underrun of 4.06%. The contractor experienced a staggering loss of AU\$38.2 million, which occurred due to an array of issues that included rework, product non-conformances and delays to works. Disastrous projects of this nature can, and often do, result in contractors going into liquidation. If, however, as in this case, they are able to shoulder such costs, then their stock value, reputation and image within the public and private sectors and the general community can be adversely impacted. Losses in one project can be offset against gains in others that form part of a contractor's portfolio of work in progress. For example, the maximum recorded final margin was AU\$80.18 million for a project that had an OCV more than AU\$1 billion and incurred a cost increase of 7.5%.

The project that had the highest margin (> 30%) was a 'Building' project with an OCV of AU\$3.38 million, which increased by 25.76% in value to AU\$4.87 million due to change orders. In contrast to the aforementioned example, this project's margin increased from an expected value of AU\$641,608 to AU\$1.37 million (114.33%). Surprisingly, the projects with margins in excess of 20% of their OCV varied in size, type, and location. Figure 2 identifies three 'borderline' and two 'outlier' projects that possessed high margins. For example, a 'Civil' project had an OCV of \$138 million with a margin of 22.82%. Conversely, a 'Building' project had an OCV of AU\$2.5 million with a margin of 28.98%.

An ANOVA was used to determine the influence of a project's OCV contract award and the margin that was applied ($p < 0.05$); the population variances for project size and margin are equal. Thus, there were no significant differences between 'project size' and margin, $F(4,62) = 3.04$, $p < 0.05$). A significant association, however, was found to be present with the percentage increase of the final margin with project size, $r = -0.38$, $n = 67$, $p < 0.01$, two tails and cost performance and $r = -0.46$, $n = 67$, $p < 0.01$, two tails. It can be therefore implied that the likelihood of an increase in expected margin at contract decreases with smaller OCVs. In addition, the margins of a contractor increase as a project experiences larger cost overruns. To determine whether there was a difference between procurement methods and margin, a *t*-test was undertaken using the categories of 'traditional' and 'non-traditional'. At the 95% confidence interval, no significant difference in margins was determined under the different procurement categorizations that were established.

The dominant way of thinking within the public sector assumes that differing procurement options can provide varying degrees of cost certainty and will influence the level of a contractor's margin, which reflects their risk profile. However, the findings presented from this case study suggest the contrary, and provide a basis for the public sector to better understand the unintended consequences of change orders that can arise during the delivery of their assets. The level of a contractor's margin is a small component of their cost, yet having an understanding of this amount is important, as the balance of risk and reward can distort their behavior if they are not aligned. Thus, the balance of risk and reward is dependent upon the structure of the contract and how well it is managed.

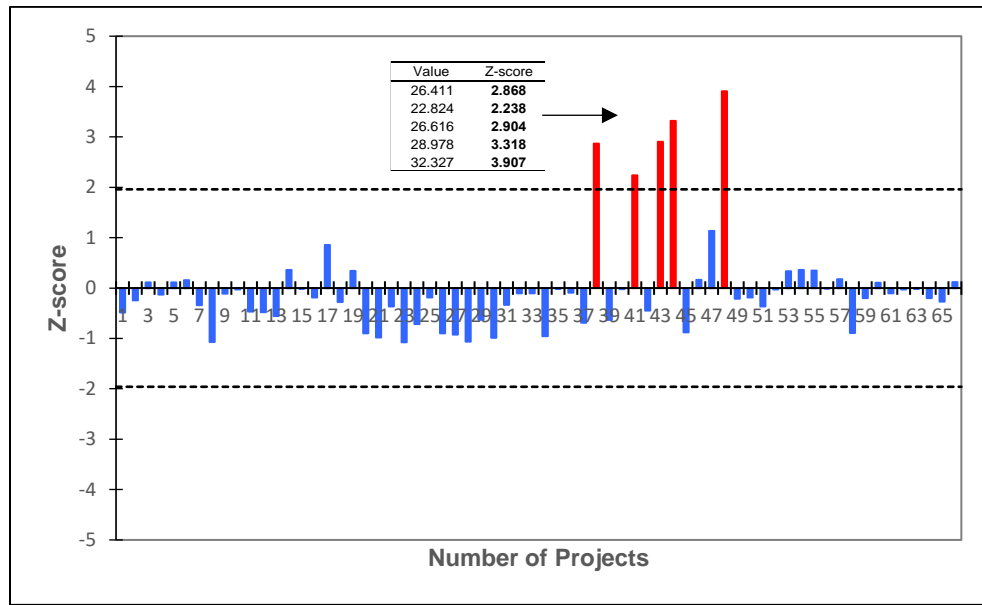


Figure 2. Outliers for margin

5 Discussion

The magnitude of change orders that occur in public sector projects is troublesome as they hinder the ability to secure cost effectively to ensure an asset can be 'future proofed'; that is, resilient to unexpected events and adaptable to changing needs, uses or capacities. Changes during construction may lead to sub-optimal solutions (e.g., design, functionality, materials, running costs) being incorporated into an asset's fabric to minimize cost and meet the committed completion date. Irrespective of the procurement strategy adopted, change orders were found to materialize during construction; changes in scope, and errors and omissions in documentation predominated. Such levels of change indicate that the 'design' process has not been effectively managed, irrespective of the procurement option, including the use of BIM, though as noted this was only used in a limited number of projects.

Considering the *status quo*, cost overruns due to change orders will continue to prevail and could even be exacerbated as there is a misconception that digitization of the design process enabled by the use of BIM will reduce errors and omissions. Simply superimposing a 21st century innovation such as BIM to procurement practices where contracts do not wholly support collaborative working and have been essentially developed for the 20th century, will not leverage the benefits that can be delivered from its adoption. Thus, to mitigate change orders, behavioral, cultural, legal and structural issues associated with the delivery of public sector assets need to be transformed to effectively accommodate the benefits that can be ensured by BIM, especially if they are to be future-proofed. The inclusion of contractors and asset managers in the design process is needed to help reduce changes by using visualization and enabling future-proofing to take place. At the heart of the future-proofing process is the ability to capture data at the appropriate time and location during an asset's life-cycle. This is enabled by digitization and provides the ability to capture data in real-time to improve decision-making, productivity, safety and reduce costs and carbon emissions. Visualization enabled by BIM can assist in clearly defining the requirements of the public sector. Figure 3 provides an overview of an asset's visualization to the development Construction Operations Building Information Exchange (COBie) sheet that can be used for the purposes of operations and maintenance.

The use of standards such as COBie can be used as a mechanism to capture the data needed to deliver a consolidated operations and maintenance manual, which can be imported directly into the Computerized Maintenance Management Systems (CMMS) and asset management software. COBie a non-proprietary data format focused on delivering asset data rather than geometric information. Essentially, COBie is a performance-based specification for facility asset information delivery. By 'thinking of the end at the

Asset management focuses on ensuring the optimal management of an asset's life-cycle in a sustainable way. PAS-55 and ISO-5000 provide the policies and procedures for implementing effective asset management and endorses the standardization of processes. As mentioned above, the information that is required for asset management can be defined by the operator's 'Asset Information Requirements' at the onset of the project. In particular, PAS 1192-3 'Specification for Information Management' for operational management of an asset can be used with BIM to develop a digital plan of deliverables, which can be specified in a contract and enabled by COBie.

Having access to information at the right time, in the right format instantaneously improves productivity, reduces costs and enables effective decision-making. Typically, asset owners are provided with 'as-built' documentation at hand-over in a paper-format that does not actually reflect what has been installed (Love *et al.*, 2016). Moreover, such documentation often contains errors and omissions, which can jeopardize the integrity of the asset (Love *et al.*, 2016). If a rail network, for example, experiences a major disruption due to an unexpected shutdown, the down-time that occurs can be considerably reduced if asset managers have immediate access to information about the part of the infrastructure that needs attention. As information exists in disparate locations and is in a paper format, the down-time may be extenuated as information is difficult to obtain and analyze.



Figure 4. Information at hand-over

Smart technologies (e.g., barcodes, quick response, sensors, radio-frequency-identification, and general packet radio system) that are interoperable with a BIM can be used to produce intelligent assets that can react with data. Predictive modelling can be used, for example, to understand and examine renewal, maintenance, upgrade and operating costs, as well as visualize geographic information to identify patterns and trends to inform long-term decision-making. The process of checking and monitoring procedures can be automated so that physical inspections will seldom be required, enabling assets, therefore, to be virtually managed. Enterprise asset management can provide real-time control over the location and knowledge about use and status of assets. Armed with reliable knowledge of service records and life-cycle of items, managers would be better positioned to consolidate asset management activity and plan for long-term development, ensuring that assets are resilient and adaptable to change.

6 Conclusion

In examining the cost performance of public infrastructure projects a case study was undertaken. Cost information from 67 projects constructed between 2011 and 2014 were provided by a contracting organization. The cost overruns/underruns that were experienced were calculated from the contract award

to when final accounts were completed. The analysis revealed that the cost performance of projects ranged from -42.88% to + 270.93%, with a mean cost overrun of 23.75%. and a probability of occurring of 73%. In alignment with previous research no significant differences in the magnitude of cost overruns were found to exist by a project's contract value, types, and procurement method. It revealed that change orders accounted for a significant proportion of the cost overruns that emerged in the projects, with a mean of 10.6% as a proportion of the original contract value. Notably, significant differences were found to occur between a project's size and change orders; that is, those with a smaller original contract value experienced a smaller volume of change orders.

Limited knowledge has existed about the margins that contractors apply to projects. This research has been able to afford realistic figures, providing the public sector with data of the risks that are being allocated because of the tender documentation supplied to contractors. The mean margin applied to the sample of public sector projects was 9.89%, and the likelihood of such a value being applied was computed to be 62%. The analysis revealed that the margin applied by the contractor did not vary with project type, its size and the procurement method being used to construct the asset. The analysis also demonstrated a positive association with an increase in change orders and the contractor's margin. More specifically it was found that contractor's margins increase with larger cost overruns. A significant proportion of the projects were delivered using traditional 'Construct Only' and there is no incentive for contractors reduce change orders as they were not involved in the design process. Even when the contractor was involved in the design process, change orders still occurred, though their extent was unable to be determined.

Involving the contractor as early as possible in the design process, providing incentives, and open-book tendering are considerations that should be enacted as initial steps to mitigate change orders. As the public sector embraces the era of digitization, which is being enabled by Building Information Modelling, the need to integrate design and construction and engender collaboration is imperative to ensure assets can be delivered cost effectively and future-proofed. Emphasis here should not necessarily be placed on the technology alone but ensuring information is structured in a standardized format, captured, openly-shared, stored and accessible so that parties can effectively work in a collaborative environment. The research in this paper provides invaluable empirical evidence to support the need for a change to the way the public sector procures their assets. If change is not embraced, then cost overruns will continue to be their fate.

Process and technological change is being enabled through digitization, but as identified in this paper, change orders were still a problematic issue in the projects that were utilizing Building Information Modelling. This research was not able to provide an explicit explanation as to why change orders materialized, even though it has been widely advocated that Building Information Modelling can reduce their occurrence. However, it suggested that the public sector and many of the organizations involved with the projects that were using Building Information Modelling had limited knowledge and experience with the new standards, software applications and processes that are required to deliver projects using this approach. Future research is required to understand the nature of change orders that arise in public sector projects that utilize Building Information Modelling.

References

- Autodesk 2012. *The Business Value of BIM for Infrastructure: Addressing America's Infrastructure Challenge with Technology and Collaboration*. Available at: http://images.autodesk.com/adsk/files/business_value_of_bim_for_infrastructure_smartmarket_report_2012.pdf, Accessed 30th January 2017
- Bradley, A., Li, H., Lank, R., and Dunn, S. (2016). BIM for infrastructure: An overview and constructor perspective. *Automation in Construction*, **71**, pp.139-152.
- Baccarini, D., and Love, P.E.D. 2014. Statistical characteristics of contingency in water infrastructure projects. *Journal of Construction Engineering and Management*, ASCE **140**(3), 04013063.
- Cantarelli, C., Flyvbjerg, B. and Buhl, S.L. 2012. Geographical variation in project cost performance: the Netherlands versus worldwide. *Journal of Transport Geography*, **24**, 324–331
- Deloitte Access Economics. 2014. Major infrastructure projects: costs and productivity issues. Australian Constructors Association. Available at <http://www.constructors.com.au/wp->

- content/uploads/2015/09/Major-Infrastructure-Projects-Costs-and-Productivity-Issues-7-March-2014.pdf
Accessed 24th June 2016.
- Flyvbjerg, B., Holm, M.K., and Buhl, S. 2002. Underestimating costs in public works: Error or lie. *Journal of the American Planning Association*, **68**(3), 279-295.
- Fry, H., Ketteridge, S., and Marshall S. 1999. *A Handbook for Teaching and Learning in Higher Education*, Glasgow, Kogan Page
- Jarkas, A.M. 2014. Factors impacting design documents quality of construction projects. *International Journal of Design Engineering*, **5**(4), 323-343
- Love, P.E.D. (2002). Influence of project type and procurement method on rework costs in building construction projects. *Journal of Construction Engineering and Management ASCE* **128**(1)18-29.
- Love, P.E.D. Edwards, D.J., Irani, Z., and Sharif, A. 2012. Participatory action research approach to public sector procurement selection. *ASCE Journal of Construction, Engineering and Management*, ASCE, **138**(3),311-322
- Love, P.E.D., Simpson, I., Olatunji, O. Smith, J. and Regan, M. 2015. Understanding the landscape of overruns in transportation infrastructure projects. *Environment and Planning B: Planning and Design*, **42**(3), 490 – 509.
- 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**,184-194.
- Newton, S. (2012). *Improving a cost estimate using reference class analytics*. In Proceedings United Kingdom: Birmingham School of the Built Environment, Birmingham City University, UK, pp. 73-83.
- Odeck, J. 2004. Cost overruns in road construction – what are their size and determinants. *Transport Policy*, **24**, 43-53.
- Royal Institution of Chartered Surveyors (2012). *RICS New Rules of Measurement*, Second Edition, Royal Institution of Chartered Surveyors, London, UK
- Terrill, M. and Danks, L. 2016. *Cost Overruns in Transportation Infrastructure Projects*. A Grattan Institute, Melbourne, Victoria, Australia, Available at; <https://grattan.edu.au/report/cost-overruns-in-transport-infrastructure/>, Accessed 12th December 2016