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Health Capital Investment in Ireland

Dealing with Uncertainty & Risk: The Application of Reference Class
Forecasting to Future Capital Investment in Healthcare

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Paper Summary:

1. This paper is the third in the series “Health Capital Investment in Ireland”
2. The paper examines relevant policy literature on the topic of large project management and capital investment.
3. Specifically, the paper examines the challenges of frequent cost underestimation and benefits shortfalls, which occurs repeatedly across countries and sectors.
4. The paper explores the potential of reference class forecasting as a tool to mitigate cost variance. This implements an approach recommended within the Public Spending code (2019).

Key Findings:

1. Significant cost variance pertains to large capital investment projects internationally, so much so that the “iron law of megaprojects” is identified as a main challenge to megaproject management: "Over budget, over time, under benefits, over and over again." (Flyvbjerg, 2017).
2. From the Suez Canal to the Boston Big-Dig, large capital investment projects surprise stakeholders with ex-post realisation of cost underestimation and benefit overestimation.
3. Ireland is not an exception to this challenge, with a history of large capital investment projects suffering from the same phenomenon empirically across all sectors and industries (Irish Fiscal Advisory Council, 2019).
4. In the Health sector, a sample of 25 domestic and international healthcare projects had an average cost variance of 100%.
5. Using this sample as the basis of a preliminary reference class forecasting model and applying this to the healthcare National Development Plan (NDP), the model is used to estimate the final costs for 6 projects valued at more than €100m that are currently at the Appraisal Stage. The model highlights a potential 66% increase in costs (€1.4bn) from the 2018 estimates to deliver the same projects.

Policy Implications:

1. Preliminary use of the reference class forecasting technique, as recommended by the Public Spending Code, raises questions around the deliverability and affordability of the NDP portfolio in the event of project cost variance.
2. It is possible that the costs contained in the current NDP portfolio may be underestimated. Therefore, fewer projects may be able to be delivered than is planned for a similar level of expenditure.
3. This highlights the need for competitive internal prioritisation of potential infrastructural investment projects within a Strategic Investment Framework to deliver on the NDP objectives in healthcare.
4. Proven cost mitigation strategies identified in the literature should be employed to ensure efficient delivery of the portfolio. These include standardisation, “hard” deadlines, and robust business cases evaluation in line with the Public Spending Code.

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Please note, the group is made up of personnel from a number of organisations, but the individuals and/or their critical review do not represent the views of their organisations.

All errors are the authors' own.

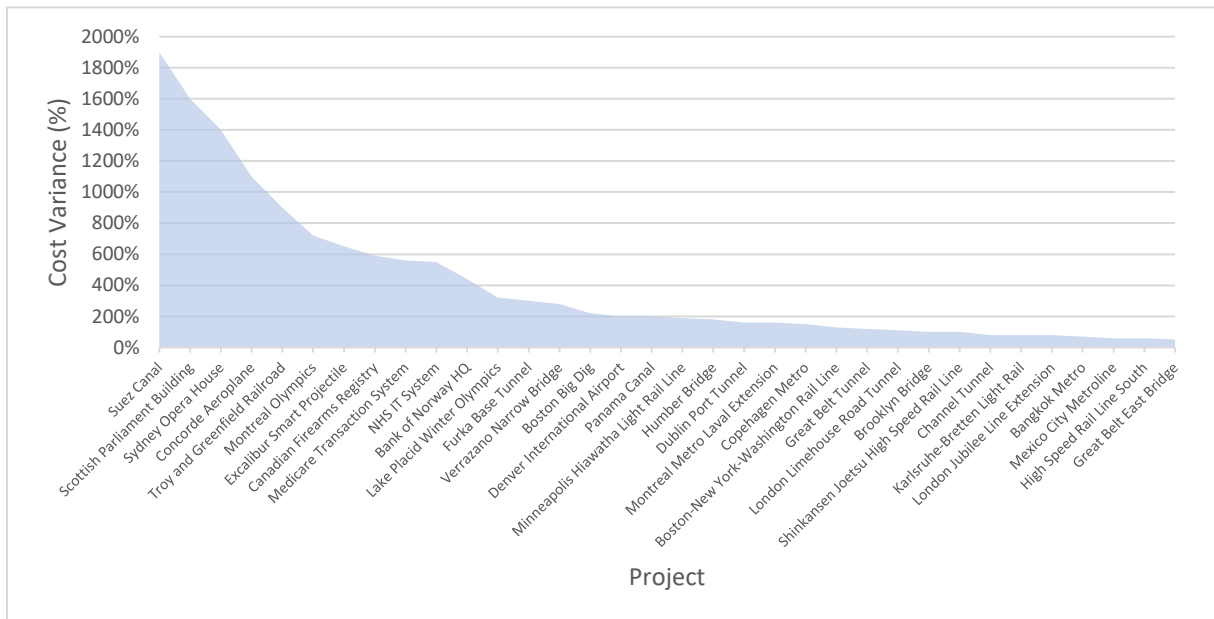
1 Introduction

Large capital projects have the potential to deliver long-term societal benefits and enable productivity growth. However, large-scale capital projects have also historically underperformed, with many experiencing significant cost overruns relative to their initial estimated cost (Flyvbjerg, 2017). Figures 1.1 to 1.3 highlight the large cost variances that can occur for projects of this type.

The literature points to universal challenges which have contributed to this underperformance. In particular, various authors highlight the prevalence of cost underestimation and benefit shortfalls in the context of the delivery of large capital projects specifically, with scale being a key contributor to the occurrence of these errors. Cost variances are common across industries, continents, and sectors, with projects both publicly and privately funded prone to cost underestimation. (Flyvbjerg, 2004; Cantarelli, 2010; Flyvbjerg, 2014). Ireland is no exception to this challenge and has experienced cost overruns in the delivery of large capital projects across all sectors and industries (IFAC, 2019).

The 2019 Irish Fiscal Advisory Council (IFAC) report highlights cost variances in the delivery of domestic projects including the National Broadband plan, the Luas, the New Children’s Hospital, and the Port Tunnel. In the international literature, cost variances across many sectors were identified with roads having on average a 20% cost variance, bridges a cost variance of 34%, and rail projects a cost variance of 45% (Flyvbjerg, 2004).

Fig.1.2: Graphical representation of large cost variances internationally.



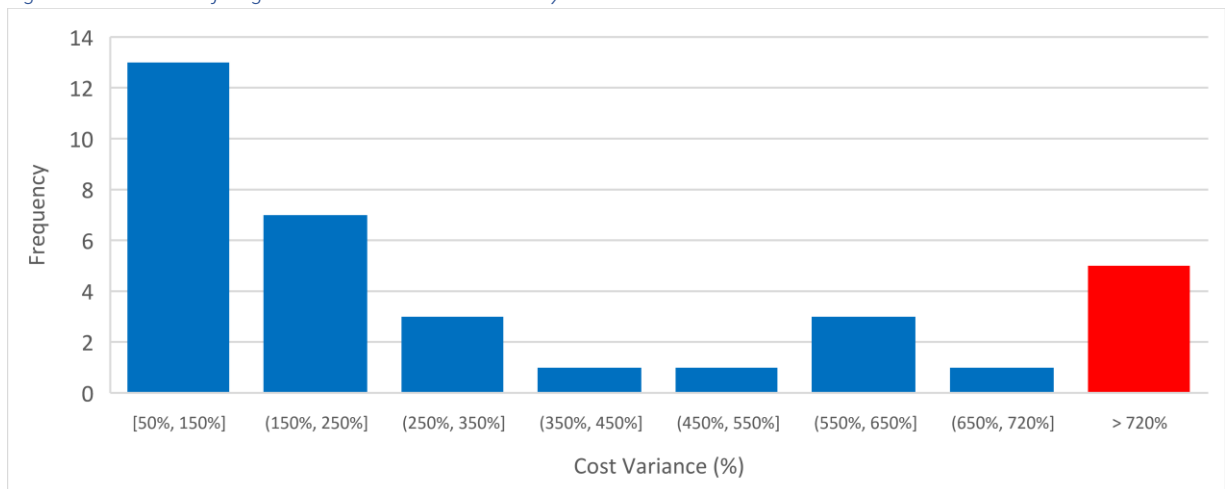
Source: (Bent Flyvbjerg, 2017)

Fig.1.1: Overview of large cost variances internationally.

| Project | Country | Cost Variance (%) |
|--|-------------|-------------------|
| Suez Canal | Egypt | 1900 |
| Scottish Parliament Building | Scotland | 1600 |
| Sydney Opera House | Australia | 1400 |
| Concorde Aeroplane | UK/France | 1100 |
| Troy and Greenfield Railroad | USA | 900 |
| Montreal Olympics | Canada | 720 |
| Excalibur Smart Projectile | USA/Sweden | 650 |
| Canadian Firearms Registry | Canada | 590 |
| Medicare Transaction System | USA | 560 |
| NHS IT System | UK | 550 |
| Bank of Norway HQ | Norway | 440 |
| Lake Placid Winter Olympics | USA | 320 |
| Furka Base Tunnel | Switzerland | 300 |
| Verrazano Narrow Bridge | USA | 280 |
| Boston Big Dig | USA | 220 |
| Denver International Airport | USA | 200 |
| Panama Canal | Panama | 200 |
| Minneapolis Hiawatha Light Rail Line | USA | 190 |
| Humber Bridge | UK | 180 |
| Dublin Port Tunnel | Ireland | 160 |
| Montreal Metro Laval Extension | Canada | 160 |
| Copenhagen Metro | Denmark | 150 |
| Boston-New York-Washington Rail Line | USA | 130 |
| Great Belt Tunnel | Denmark | 120 |
| London Limehouse Road Tunnel | UK | 110 |
| Brooklyn Bridge | USA | 100 |
| Shinkansen Joetsu High Speed Rail Line | Japan | 100 |
| Channel Tunnel | UK/France | 80 |
| Karlsruhe-Bretten Light Rail | Germany | 80 |
| London Jubilee Line Extension | UK | 80 |
| Bangkok Metro | Thailand | 70 |
| Mexico City Metro line | Mexico | 60 |
| High Speed Rail Line South | Netherlands | 60 |
| Great Belt East Bridge | Denmark | 50 |

Source: (Bent Flyvbjerg, 2017)

Fig.1.3: Distribution of large cost variances internationally.



Source: (Bent Flyvbjerg, 2017)

2 Data and Methodology

Although project specific data is limited, the Department of Health and the HSE have combined domestic and international data to create a database of 25 projects across 15 countries to inform this analysis. All costs have been converted to euros to allow for the comparison of projects across countries.

As in the previous papers in this series, NDP data was analysed to identify trends in health capital projects. Within the NDP health capital portfolio there are 12 projects which are estimated to cost greater than €100m.

This sample formed the basis for the regression analysis which was used to create a reference class forecasting model for the health sector (see section 4). The reference class forecast was estimated by regressing final or estimated final costs, on initial estimated costs. This approach was reiterated multiple times using transformations of the variables and the best specified model in terms of predictive power and goodness of fit was selected. The use of Bayesian Information Criteria and Akaike Information Criteria were the primary determinants of best fit for model selection. Within the appendices the distribution of both the response and the prediction variables can be seen. These variables both exhibit significant right skews. Thus, the use of logistic transformations was decided upon to comply with the assumptions of Ordinary Least Squares. This is the model that is referenced in section 4.3.

2.1 Data limitations

The costs assigned to projects during the appraisal stage are early estimates, which in turn are used to estimate the total NDP health capital allocation. These figures are often placeholders until a detailed design brief is commissioned, thus the post-tender cost could vary significantly from the original early estimate. This is an old practice which is associated with legacy projects; currently the National Investment Office recommends probabilistic cost estimate intervals.

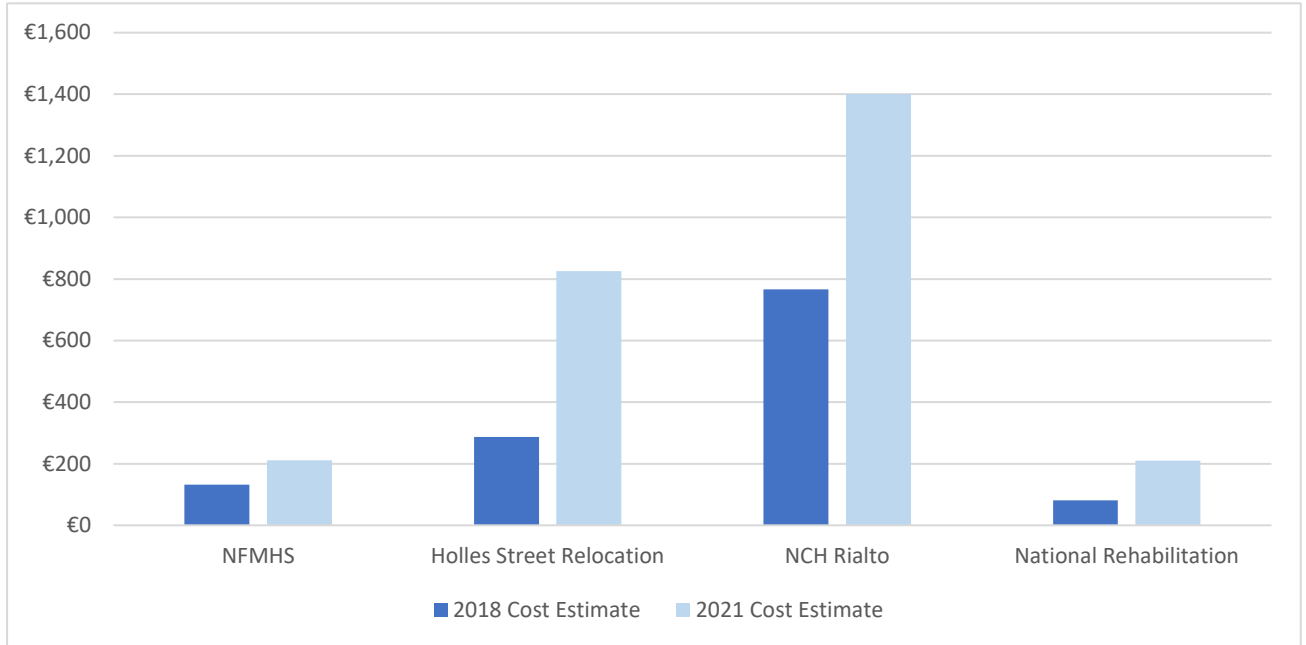
While specific project data is limited, this initial analysis allows an examination of the risks in the current plan and the benefits that recurrent cost forecasting can bring. As time progresses and improved data becomes available (for example, through the National Estates Information System under implementation by the HSE), this work can be further improved.

2.2 Cost Estimates

As identified in the literature cost variance is a phenomenon which affects all industries (Flyvbjerg, 2017). Using NDP data on 4 projects valued at more than €100m past the appraisal stage, figure 2.4

shows that cost variances are evident. These projects are in construction, commissioning, or operational stages, with an average cost of €670m in 2021, an increase of €299m on the 2018 average cost. The median cost also increases, the 2021 median cost is €518m, an increase of €308m on the 2018 median cost.

Fig 2.4: Cost estimates by project 2018-2021 (€millions)



| | 2018 | 2021 |
|--------------------|-------|-------|
| Mean Cost | €371m | €670m |
| Median Cost | €210m | €518m |

Source: Internal Data

3 Potential Causes

3.1 Cost Uncertainty

Cost uncertainty is common in large capital projects and has many contributors, with possible strategies for mitigation, varying depending on the underlying driver of costs. In 2019, cost uncertainty was identified as a significant issue in the delivery of large capital projects by IFAC. Cost uncertainty can arise for several reasons such as noise, cognitive bias, black swans, poor business cases and inflation (Sibony, 2021; Taleb, 2007; Flyvbjerg, 2014). Cost uncertainty can have a significant impact on overall portfolio performance and value for money.

3.1.1 Noise

Noise is unwanted variability in professional judgments¹. The presence of noise within cost estimates can lead to an underestimation, or occasionally in some cases an overestimation of the actual costs of projects (Sibony, 2020). The introduction of additional forecasting methods within business cases can enable better evaluation of project costs, which in turn can reduce the impact of noise.

3.1.2 Bias

Optimism bias is a cognitive bias leading people to think they are more likely to succeed or are less at risk of failure or of experiencing a negative event than they really are². The introduction of this bias is usually innate and can be classed as political, technical, or psychological.

3.1.3 Uniqueness Bias

Uniqueness bias is an issue which plagues large projects. It arises from the fact that “Technology and designs are often non-standard, leading to ‘uniqueness bias’ amongst planners and managers, who tend to see their projects as singular, which impedes learning from other projects.” (Flyvbjerg, 2015).

¹ McKinsey Quarterly, 2021, Sounding the Alarm on Noise

² Behavioral Insights Team, 2017, A review of optimism bias, planning fallacy, sunk cost bias and groupthink in project delivery and organisation decision making, Department of Transport UK

3.1.4 Black Swans

A Black Swan is an event that has a low probability of occurring, but a large impact once it occurs. These events or occurrences are almost impossible to predict and mitigate due to their low likelihood³. The presence of black swans cannot always be averted, but their prevalence in large capital investments is well documented (Flyvbjerg, 2017).

3.1.5 Investment Fragility

The characteristics of large projects (projects costing >€100m) including their scale and complexity can increase the risk of cost overruns, delays and benefit shortfalls occurring. This is described in the literature as “investment fragility”, defined as the vulnerability of a financial investment to becoming non-viable (Flyvbjerg, 2017). While the benefits of economies of scale are well understood in general, the scale of large projects can create challenges not experienced by smaller ones (Flyvbjerg, 2017). For example, Flyvbjerg (2017) observes that; “An economy with too many assets prone to fragility is at a heightened risk of system-wide failure due to the domino-like effect of inherited fragility that can spread from one corner of the system to the whole”.

3.1.6 Business Cases

A recurring challenge of projects is cost underestimation and benefit overestimation, arising from ex-ante business cases (Flyvbjerg, 2021). This phenomenon is persistent over time, with large cost variances evident in projects such as the Sydney Opera House (1400%), the Channel Tunnel (80%), Berlin Brandenburg Airport (350%), and Olympics programs (with the Montreal Olympics experiencing a 720% overrun) (Flyvbjerg, 2011). Large projects with poorly estimated costs, benefits and timelines vastly outnumber projects those that are delivered on time, and within budget. Flyvbjerg (2017) observes that there is a 10% chance of achieving cost, benefit, or time targets for large projects.

Weak business cases are often characterized by the absence or weakness of methods such as cost benefit analysis, risk analysis and multi criteria analysis. These factors can contribute to the presence of bias when cost estimates for projects are being produced, resulting in upward cost variance as the project progresses through its lifecycle. Similarly, benefits tend to be over-estimated because of the same issues, meaning that costs often exceed benefits in cases where weak business cases are present. This highlights the need for the production of strong business cases free from bias and error to mitigate cost variances and deliver more effective projects (Flyvbjerg, 2021).

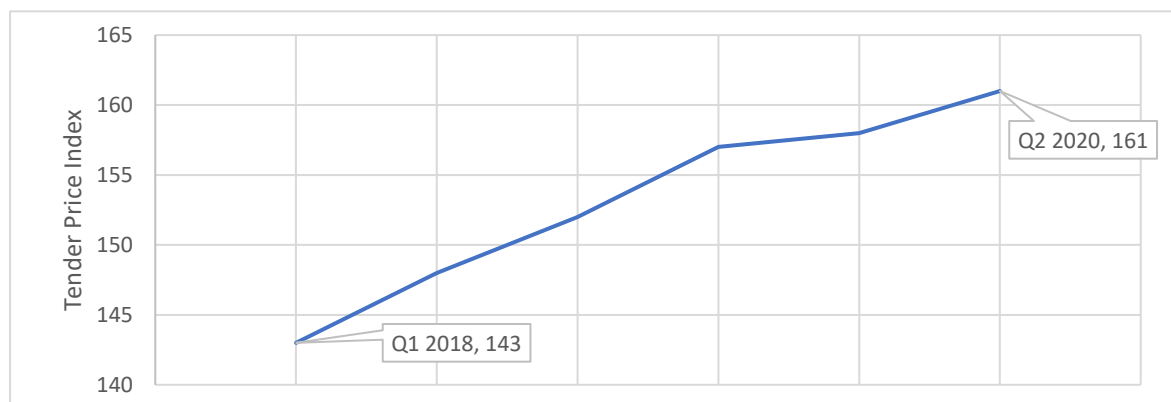
³ Nassim Taleb, 2007, *The Black Swan: The Impact of the Highly Improbable*, Random House

In Ireland, weaknesses associated with the development of business cases motivated the formulation of a more stringent set of rules underpinning the evaluation of large capital infrastructure projects.⁴ These rules are described in detail in the Public Spending Code (2019). Most notably, the requirement for government approval has now changed, with projects at the final business case stage not receiving approval until after market engagement has occurred and final costs for delivery are known. This ensures that the levels of cost uncertainty experienced in the past in Ireland will not reoccur in the future, with project costs at completion much more likely to align with cost estimates post market engagement rather than at an earlier stage in the appraisal cycle.

3.2 Inflation

The increase of the costs of building materials is one issue which large projects are particularly exposed to. Due to long time horizons, expected costs can increase substantially from the time of project initiation to post tender delivery. Figure 3.1 shows the effects of inflation on the tender cost of projects over the time horizon 2018-2020. As seen in figure 3.1, construction prices increase from an index value of 143 in 2018 to a value of 161 in Q2 of 2020. This equates to a 12.5% increase in tender price index over the time horizon.

Fig 3.1: Construction Tender Price Index 2018-2020



Source: Society of Chartered Surveyors, Tender Price Index April 2021

4 Reference Class Forecasting

One solution to this issue which is identified within the Public Spending Code (2019) is reference class forecasting. This approach enables an unbiased forecasting of cost estimates based on previous projects which have been completed.

4.1 What is RCF

Reference class forecasting is a methodology to estimate project costs which attempts to mitigate optimism bias. It predicts the outcome of a planned action based on actual outcomes in a reference class of similar interventions to that being forecast (Public Spending Code, 2019). Reference class forecasting promises more accuracy in forecasts by taking a so-called “outside view” on projects being forecasted, while conventional forecasting takes an inside view. The outside view on a given project is based on knowledge about actual performance of comparable projects in the same reference class⁵.

4.2 Reference Class Analysis:

The Department of Health and HSE compiled a sample of 34 international Healthcare projects. This sample of 34 projects was reduced to remove projects with a final cost less than €100m and combined with the 4 Irish projects from the NDP portfolio which were past appraisal stage. The combined size of this sample was 25 projects, which formed the basis of the model. The composition of the projects can be seen in Figure 4.1.

Fig 4.1: Table of Sample projects

| Project/Country | Estimated Cost €m | Actual/Projected Cost €m |
|------------------|-------------------|--------------------------|
| England | €873 | €1,240 |
| England | €803 | €1,156 |
| US | €648 | €1,176 |
| Canada | €714 | €1,657 |
| Northern Ireland | €109 | €176 |
| Northern Ireland | €261 | €415 |
| Australia | €187 | €223 |
| Australia | €199 | €210 |
| Australia | €554 | €588 |
| China | €110 | €114 |
| Scotland | €192 | €262 |

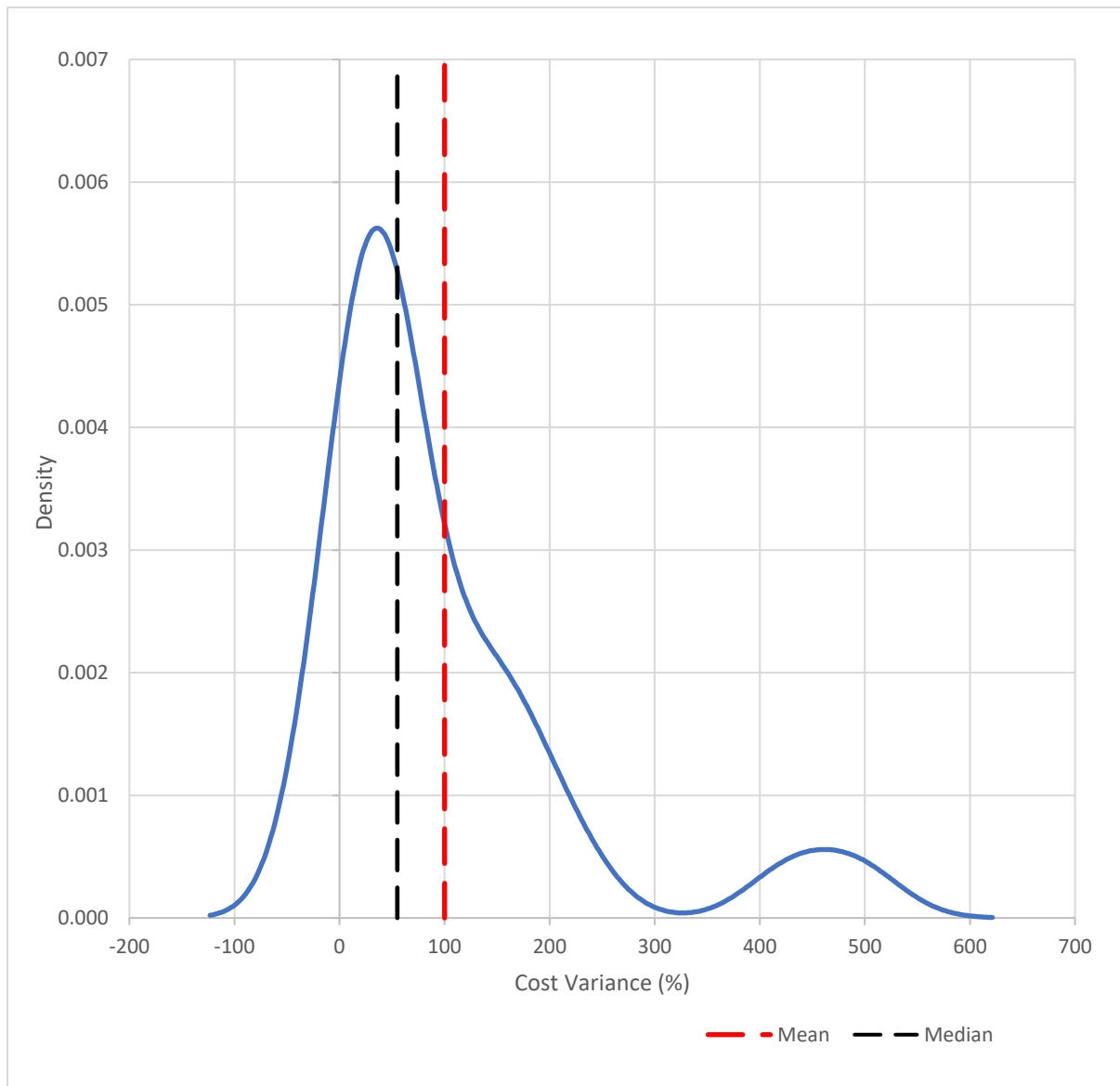
⁵ Bent Flyvbjerg, 2006, From Nobel Prize to project management: getting risks right, Paper presented at PMI Research Conference: New Directions in Project Management, Montreal, Canada, Project Management Institute

| | | |
|---------------------------------|--------|--------|
| Wales | €129 | €200 |
| Canada | €268 | €641 |
| Romania | €400 | €980 |
| Latvia | €91 | €122 |
| Finland | €160 | €175 |
| New Zealand | €263 | €310 |
| Sweden | €5,096 | €5,586 |
| US | €451 | €1,453 |
| Trinidad and Tobago | €114 | €604 |
| Malta | €98 | €583 |
| NFMHS | €132 | €211 |
| Holles Street Relocation | €287 | €825 |
| NCH Rialto | €983 | €1,433 |
| NRH | €81 | €210 |

Source: Internal Data

Figure 4.2 shows the distribution of the cost variances within the sample. The graph shows that although the peak of the cost variances is around 45%. The median cost variance is 55% and the mean cost variance is 97%.

Fig 4.2: Probabilistic Distribution of Cost Variances of the Sample



Source: Authors' Calculations

In Figure 4.3, the cumulative distribution highlights the significant levels of risk for above average cost variances, with approximately 10% of projects within the sample having a cost variance greater than 200%. The median cost variance of 55% is surpassed by 53% of projects. Meanwhile, 32% of projects have a cost variance greater than mean cost variance (97%). This highlights the additional risk of large cost variances when the projects are constrained to the health sector.

Fig.4.3: Cumulative Distribution of Sample Cost Variance

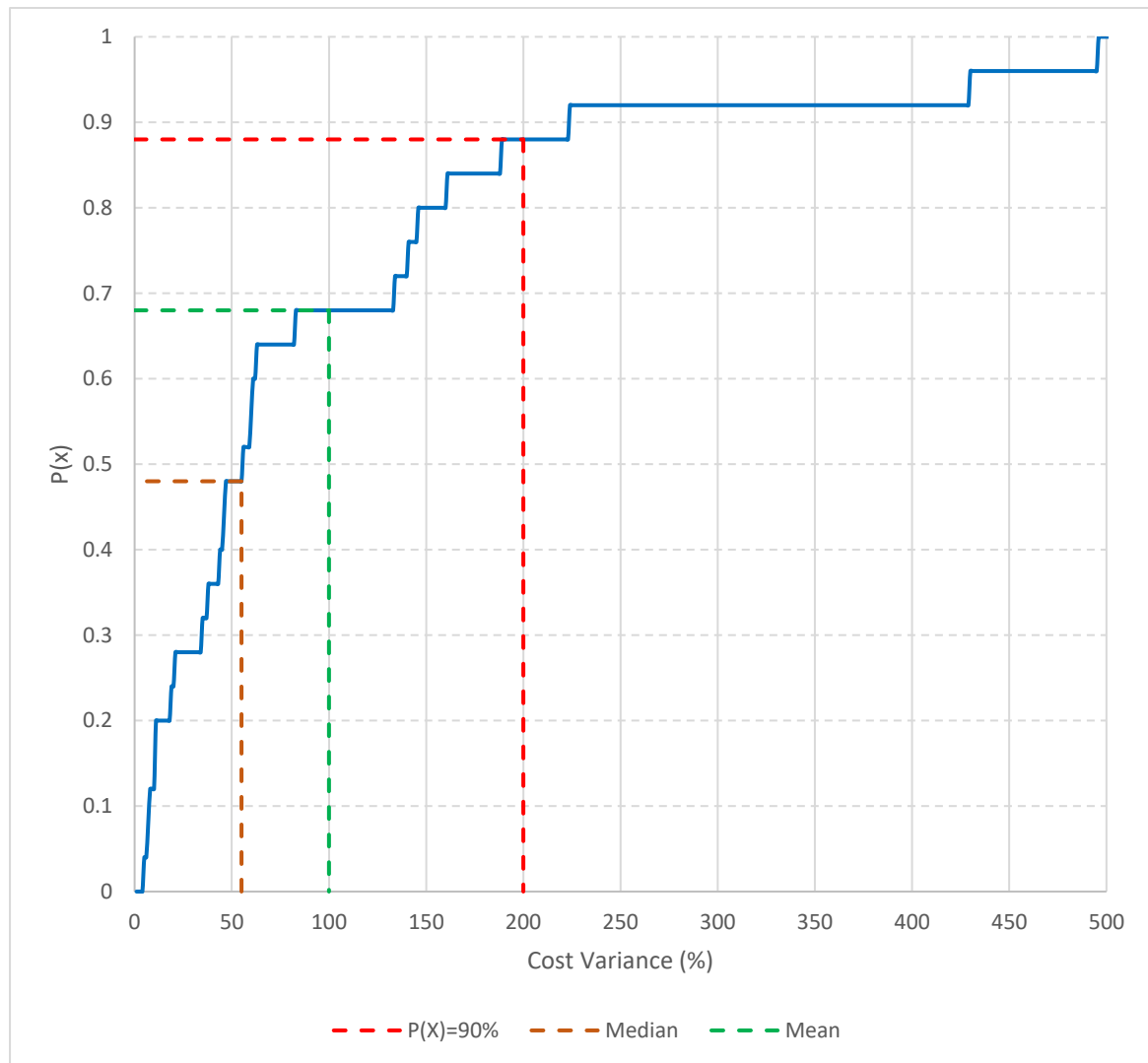


Fig.4.4: Breakdown of Initial Project Costs by Expenditure Quantum.

| Initial Cost | Average Variance % | Median Variance % | Max Variance % | Min Variance % | N |
|--------------|--------------------|-------------------|----------------|----------------|---|
| <=€100m | 229 | 59 | 494 | 34 | 3 |
| <=€200m | 75 | 59 | 429 | 4 | 9 |
| <=€300m | 101 | 99 | 187 | 18 | 4 |
| >€300m | 71 | 44 | 222 | 4 | 9 |

Source: Internal Data

Figure 4.4 breaks down our healthcare project sample by expenditure quantum. The highest average variance, and highest maximum variance are both present in projects with an initial cost lower than €100m. Average cost variances for all other quantum of expenditure are similar, ranging between 71% and 101% of a projects initial cost.

4.3 The Model

The goal of developing a reference class forecast is to improve the accuracy of cost estimation. The model that was developed after multiple iterations and refinements can be seen below:

$$\log(\text{Actual Cost}) = 1.22 + 0.88(\log(\text{Estimated Cost}))$$

All information relating to the model parameters and measures of fit can be found in the summary table denoted Figure.4.5 below.

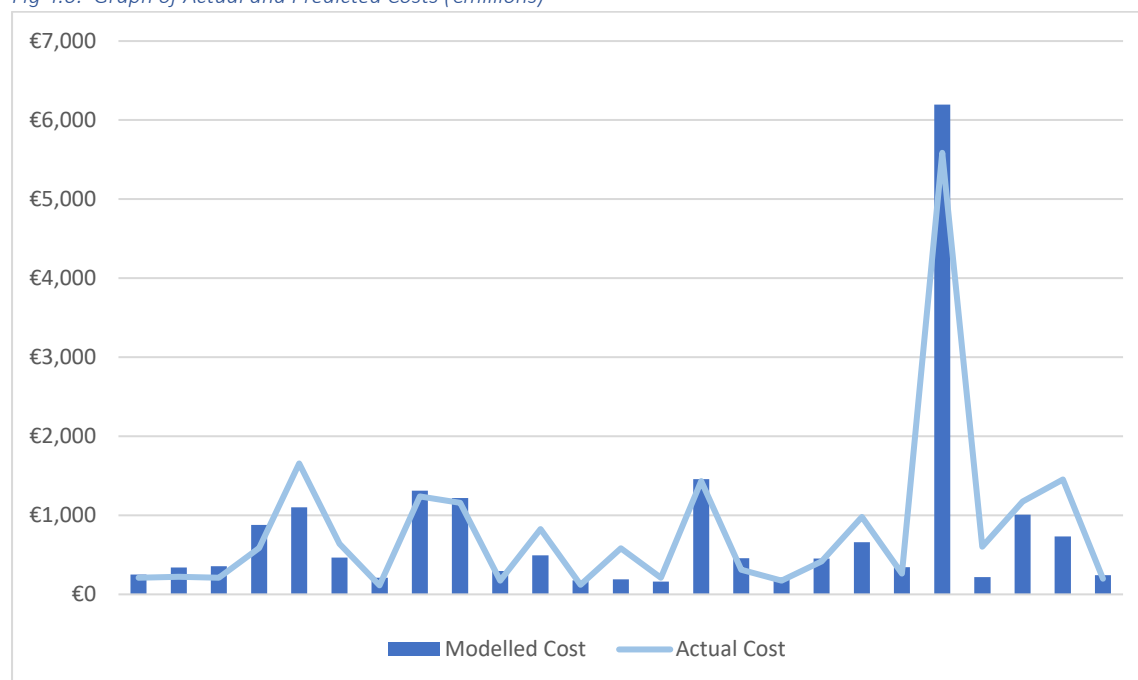
In Figure.4.6, the actual final cost or projected final cost is represented as a line and the predicted cost using the reference class is represented as bars. The graph shows in some instances that the model has poor predictive power around extremes. Overall, the graph shows that the model provides for an informed estimate. Within the below table, the regression analysis and coefficients are outlined. The model has an adjusted R-square of 0.77, and a MSE of 0.44. The model was selected based on its low values of Akaike Information Criteria and Bayesian Information Criteria versus other models fitted.

Fig:4.5: Summary Table of Regression Analysis

| Variable | Coefficient | Std. Error | t-Statistic | Prob | AIC | BIC |
|-------------------|-------------|------------|-------------|--------|-----|-----|
| Intercept | 1.22 | 0.56 | 2.19 | 0.04 | 38 | 42 |
| Log (Estimate) | 0.88 | 0.1 | 9.142 | 0.0000 | | |

Source: Authors Calculations

Fig 4.6: Graph of Actual and Predicted Costs (€millions)



Source: Internal Data

4.4 The Estimation Effect

The developed model was used to estimate the actual cost of delivering the remaining NDP projects which are in the appraisal stage. The below costs were generated using the 2018 cost estimates as the estimated costs. The table highlights a potential €1.4bn or 66% cost increase. This additional information raises questions around the deliverability and affordability of the portfolio.

Fig 4.7: Table of Predicted Cost Increases

| Project | % Change |
|---------|----------|
| A | 71% |
| B | 71% |
| C | 54% |
| D | 71% |
| E | 81% |
| F | 71% |

Source: Authors Calculations

4.5 Further Limitations

Evidently the size of the sample is small, and all the data is secondary data. Therefore, the collection of other variables is not possible. With more data the refinement of this initial model may enable more accurate estimates as the sample size grows. However, even with these limitations this preliminary model can be used as a complementary tool to help inform the management of large healthcare capital projects. Further research can focus on the expansion of this model incorporating new data and other project types including Health ICT projects.

5 Measures to Mitigate Cost Variance

While the evidence highlights the salience of cost variance amongst large capital investment projects across regions and sectors, there are several mitigation strategies which could be deployed. These include:

1. Standardisation⁶ (Flyvbjerg, 2021)
2. Fixed Deadlines (Flyvbjerg, 2017)
3. Flexible Planning & Governance (Flyvbjerg, 2017)
4. The Strategic Investment Framework

While cost variance is unlikely to be entirely eliminated through any one mechanism, a combination of the best practice methods of appraisal advocated in the Public Spending Code, coupled with the approaches outlined below could allow for a greater level of consistency between initial and final costs.

5.1 Standardisation

Throughout the literature the concept of “uniqueness” arises, with the consistent delivery of new and unique projects leaving policymakers unable to learn lessons from previously completed ones. This problem of uniqueness leads to uncertainty and greater risk during the development and progression of a project. These unique projects can be defined by the terms ‘slow and bespoke’.

A solution to this issue is identified in the project management literature, advocating instead for the creation and adoption of standardised designs for different infrastructure projects which can be ‘fast and iterative’ (Flyvbjerg, 2021). There are three key advantages of this approach. Firstly, standardised project designs are cheaper and easier to produce, allowing for increased flexibility at earlier stages in a project’s lifecycle. Secondly, standardisation allows for reference to be made to completed project costs when costs for new projects are being estimated. Finally, standardisation of project design allows for greater ex-post evaluation of comparable projects than if unique projects are pursued. Therefore, the common risks associated with a given standardised project are more easily identified and alleviated.

Examples of Successful Standardised/ Modular Projects⁶:

1. Empire State Building- USA
2. Hornsea One -UK

⁶ Bent Flyvbjerg, 2021, Research shows how to slash the costs of megaprojects while boosting delivery speed, Said Business School, Oxford

3. Bhadla Solar Park-India
4. Madrid Metro- Spain
5. Tesla Gigafactory 1- USA

These projects have two core characteristics which make them comparable. They were successfully delivered with speed relative to their scale and delivered using an iterative and modular process. For example, the Empire State Building was completed in 1 year and 45 days, the Madrid Metro in 3 years and Hornsea One (offshore windfarm) in 2 years.

5.2 Fixed Deadlines

Another approach which has proven effective in mitigating the risk of cost variance, is the use of fixed deadlines for large infrastructure projects. This is where projects are given a “hard” rather than “soft” deadline, limiting the ability of stakeholders to alter the scope of the project once it has been agreed. While these changes can improve a project, they often negatively impact on the final versus expected cost. Project risk and uncertainty increases with the length of a project’s time horizon. The setting of a credible “hard” deadline for a project incentivizes a greater level of pre-commitment to design than in the traditional case. This approach proved a major success during the construction of the BAA terminal 5 in London England, which was completed on schedule and within budget. (Flyvbjerg, 2017)

5.3 Flexible Planning & Governance

The literature highlights how strong, flexible governance can be used to identify risks and adjust project plans to overcome unforeseen issues, thus reducing cost variance. The literature examines the application of this strategy in a number of contexts (Flyvbjerg, 2017).

- Search capabilities can be applied to address information inadequacies, allowing for the identification of risks to the project early in the project lifecycle (Flyvbjerg, 2017);
- Adaptive problem solving can be employed to deal with unexpected events and opportunities once a project is underway, allowing for a project to progress in spite of delays to some project areas (Flyvbjerg, 2017);
- Test and trial capabilities can be used to ensure that new technologies are reliable and proven prior to their introduction to a project, reducing risk. (Flyvbjerg, 2017);
- The application of lessons learned from both projects in the same sector and other sectors to strive for greater levels of efficiency. (Flyvbjerg, 2017).

The use of these methods in tandem is posited as a method to strongly augment project managers ability to deal with uncertainty and a rapidly changing environment, allowing for a corresponding reduction in cost variance relative to traditional project management approaches.

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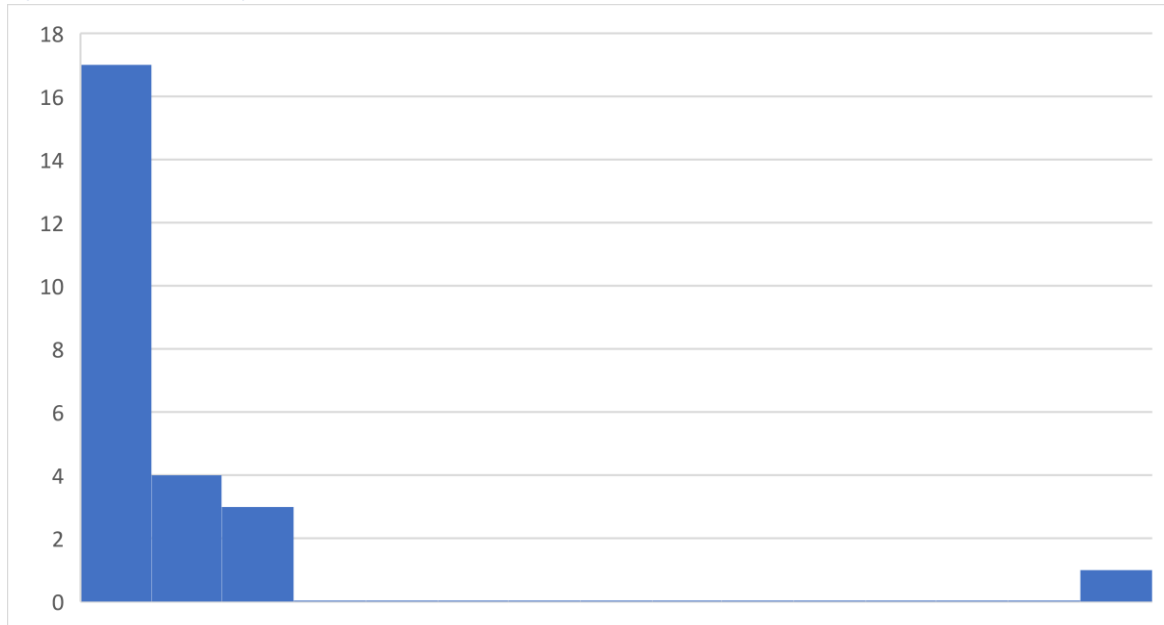
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Transport Infrastructure Ireland, 2017. *Reference Class Forecasting: Guidelines for use in connection to National Roads projects*, s.l.: Transport Infrastructure Ireland.

7 Appendix

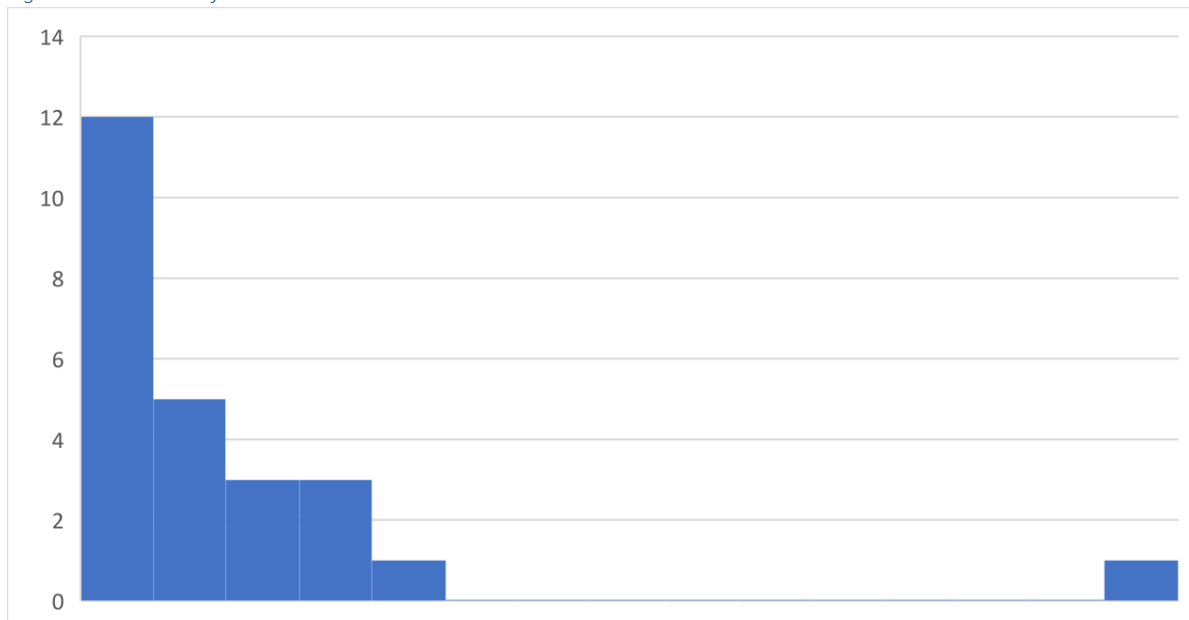
The below graphs denoted Fig 7.1, and Fig 7.2 show the distribution of the response and prediction variables are right skewed distributions and therefore the use of a logistic transformation of both variables is appropriate to assume the normality assumption of Ordinary Least Squares.

Figure 7.1: Distribution of Estimated Costs



Source: Authors Calculations

Fig 7.2: Distribution of Post Tender Costs



Source: Authors Calculations