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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 the relevant policy literature on the topic of large project management and capital investment.
3. Specifically, the paper examines the challenge identified in that literature of frequent cost underestimation and benefits shortfalls, which occurs internationally and across multiple sectors.
4. The analysis then focuses on Irish Healthcare projects, using cost estimates from the 2018 NDP and latest estimates from the 2021 NDP review.
5. The paper explores the potential of Reference Class Forecasting as a mitigation tool to this challenge, as this tool is recommended in 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 capital, shows 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 NDP, the model highlights a potential 66% increase in costs (€1.4bn) from the 2018 estimates, to deliver the 6 projects >€100m currently at Appraisal Stage.

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 portfolio in its entirety, as it currently stands.
2. It is possible that the costs contained in the current NDP portfolio, may be underestimated. Therefore, fewer projects will likely 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, robust business cases evaluation in line with the Public Spending Code.

Contents

1 Introduction

Large capital projects have the potential to deliver long-term societal benefits and enable productivity growth. However, empirically, large-scale capital projects have historically underperformed internationally (Flyvbjerg, 2017). The literature points to universal challenges which have caused this underperformance, while highlighting potential mitigation strategies. The literature highlights the prevalence of cost underestimation, and benefit shortfalls. Cost variances occur 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 delivering large capital projects across all sectors and industries (IFAC, 2019).

The IFAC report (2019) 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 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). Therefore, just as this challenge presents itself across all countries, cost variance is also a phenomenon which is experienced by all sectors.

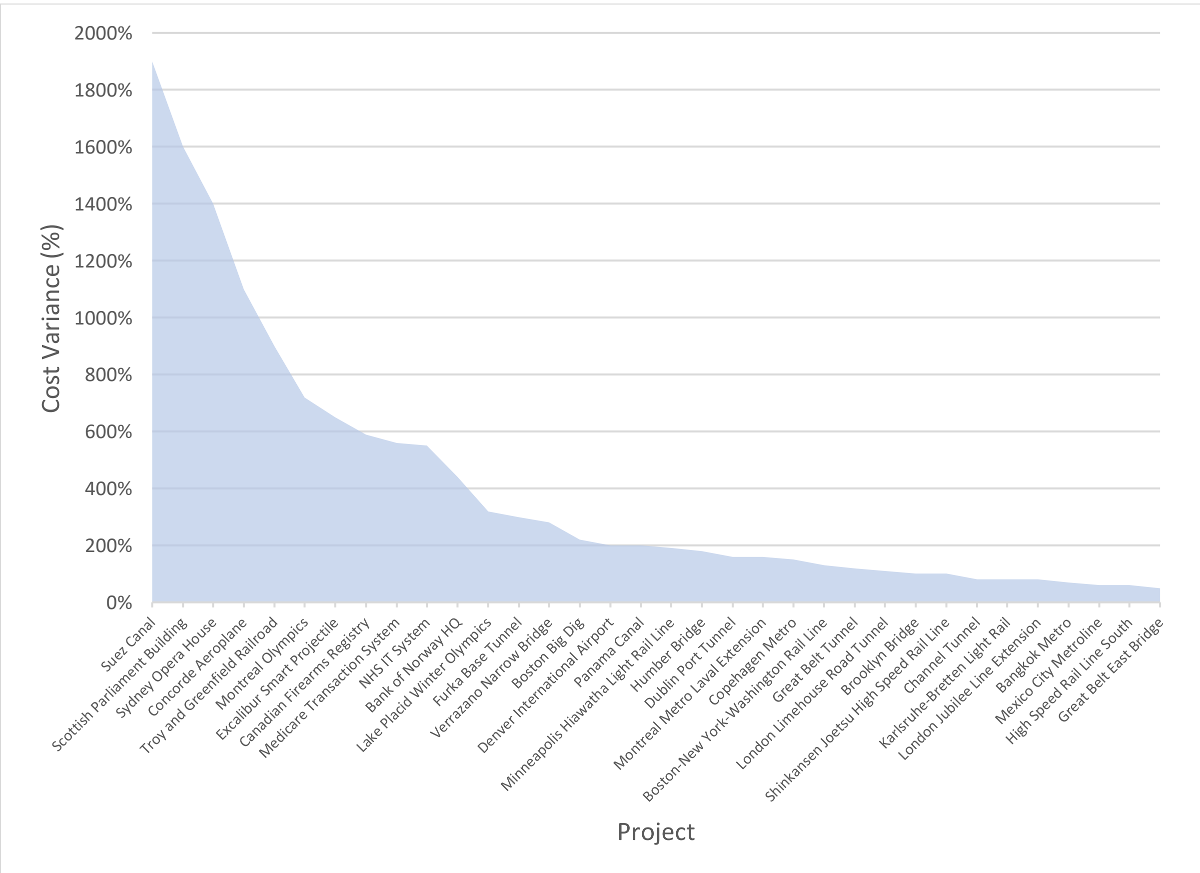
Fig.1.1: Overview of Large Cost Variances across the World.

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%

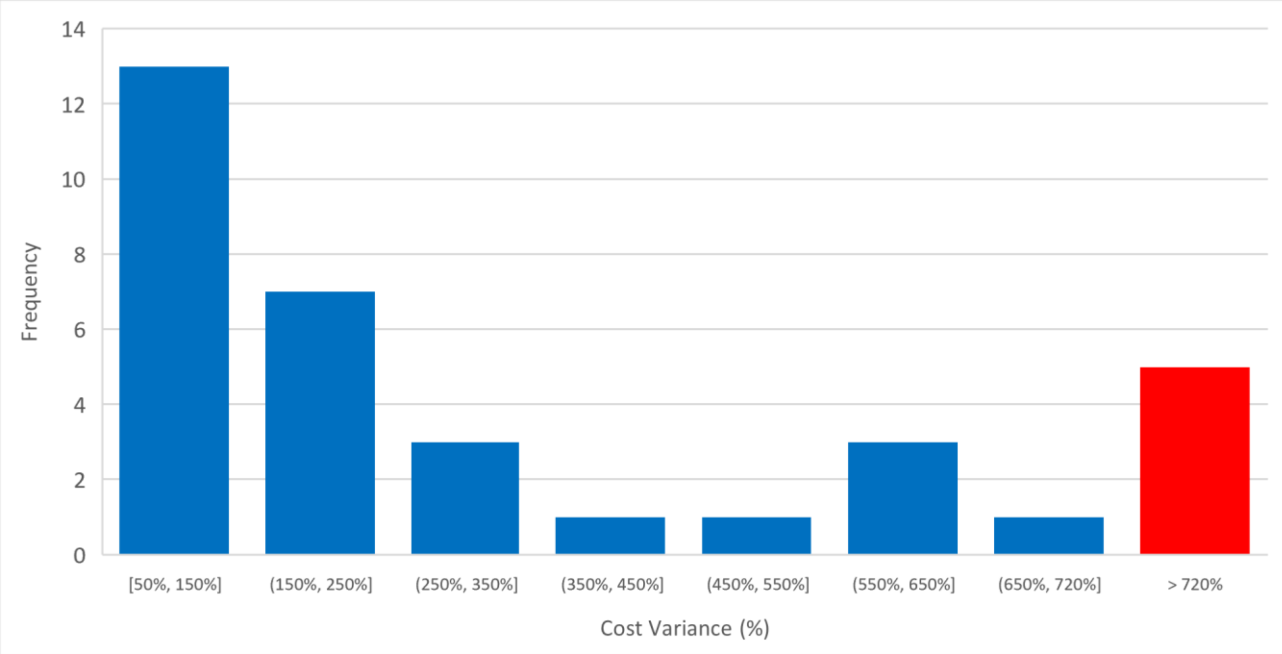
Source: (Bent Flyvbjerg, 2017)

Fig.1.2: Graphical Representation of Large Cost Variances across the World.



Source: (Bent Flyvbjerg, 2017)

Fig.1.3: Distribution of Large Cost Variances across the World



Source: (Bent Flyvbjerg, 2017)

2 Data and Methodology

Although project specific data is very 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. These costs where all converted into euros to allow for comparison.

As within the previous papers in this series, NDP data was analyzed to identify trends in Health Capital projects. Within the NDP Health Capital portfolio there are 12 projects which are estimated to cost >€100m.

This sample formed the basis of the regression analysis which created the reference class forecast model, see section 4. The reference class forecast was completed by regressing the final/ estimated final costs on the initial estimated costs. This approach was completed multiple times using transformations of the variables to find the most predictive model with the best fit. This resulted in the development of the model below in section 4.3.

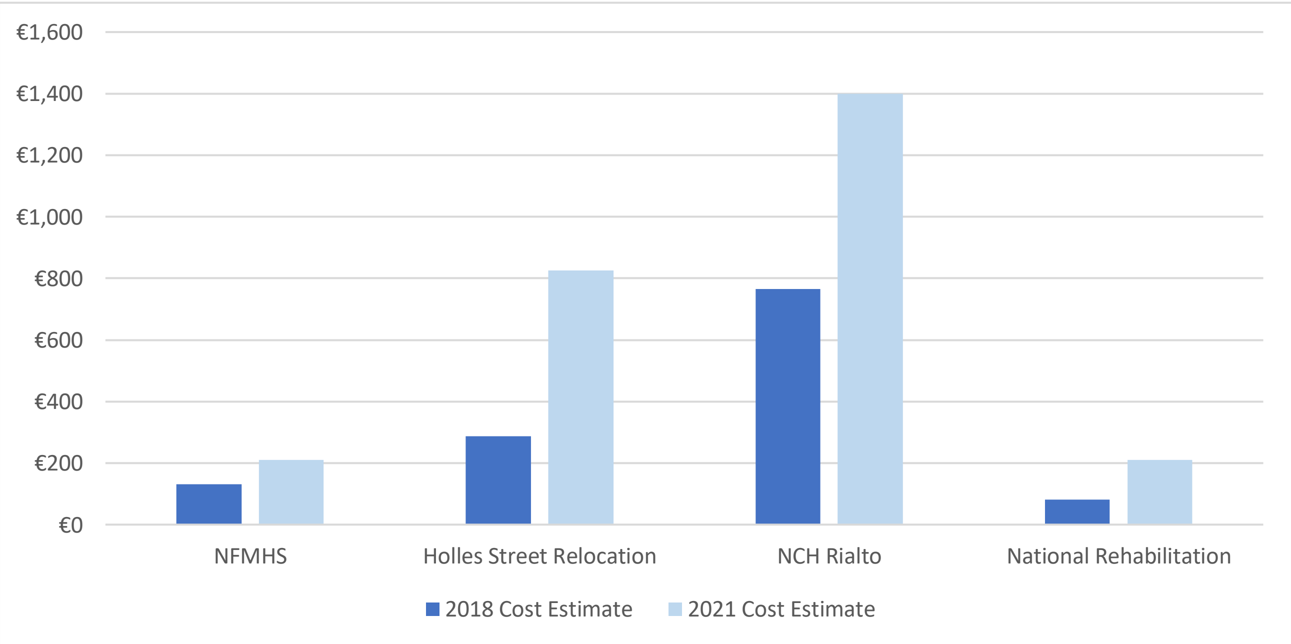
2.1 Data limitations

The cost estimates assigned to projects within the appraisal stage are early estimates used to estimate the total NDP Health capital allocation. Given that these figures in many instances are placeholders initially until a detailed design brief is commissioned, the post tender cost could vary significantly from the original early estimate. This is an old practice which is associated with legacy projects and current National Investment Office advice recommends the use of probabilistic cost estimate intervals. Although the healthcare capital portfolio is comprised of over 250 projects, data quality reduced the scope of this analysis to focus on the 12 large projects >€100m. Although specific project data is limited, this initial analysis is of benefit in showing risks in the current plan and pipeline and the benefits that RCF can bring. As time progresses and improved data becomes available (including through the National Estates Information System currently being implemented in the HSE) this work can be progressed.

2.2 Cost Estimates

As identified with the literature cost variance is a phenomenon which affects all industries, using NDP data on 4 projects > €100m. It can be seen from the graph and table below that cost variances have been observed. These projects are all 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 experiences an upward shift also with the 2021 median cost being €518m an increase of €308m on the 2018 median cost.

Fig 2.4: Cost Estimates by Project 2018-2021



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

Source: Internal Data

3 Potential Causes

3.1 Cost Uncertainty

Cost uncertainty was identified in 2019 as a significant issue in the delivery of large capital projects by the Irish Fiscal Advisory Council. The presence of cost uncertainty is common within large capital projects and can arise for many reasons some which can be mitigated and others which cannot. Cost uncertainty can arise from a variety of reasons such as noise, cognitive bias, black swans, poor business cases and inflation (Sibony,2021) (Taleb,2007) (Flyvbjerg,2014). The presence of cost uncertainty within projects can have a significant impact on the overall portfolio performance and the value for money.

3.1.1 Noise

Noise is the unwanted variability in professional judgments[1]. The presence of noise within cost estimates can create an underestimation (or in some cases an overestimation) of the actual costs of projects (Sibony, 2020). Therefore, the introduction of additional forecasting methods within business cases can enable better procedure-based approaches which could reduce the noise within estimates.

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 are[2]. The introduction of this bias is usually innate and can be classed under political, technical, or psychological.

[1] https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/sounding-the-alarm-on-system-noise

[2] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/627790/lit-review-exploration-of-behavioural-biases.pdf

3.1.3 Uniqueness Bias

The uniqueness bias is an issue which plagues large projects, it arises from the fact " 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,2014)

3.1.4 Black Swans

The Black Swan Theory is when something rare and unexpected occurs that has a large impact. The impact of the highly of improbable. These events or occurrences are almost impossible to predict[3]. But in retrospect they look as if they were obvious and inevitable[4]. The presence of black swans cannot always be averted but their prevalence in large capital investments is well documented, "their tendency to suffer from uniqueness bias, to their over exposure to black-swan events". (Flyvbjerg, 2017)

3.1.5 Big is Fragile (Flyvbjerg, 2017)

The nature of large projects (projects costing >€100m), their characteristics of scale (very large) and complexity, increase their risk of: cost overruns, delayed delivery, and benefit shortfalls. This is classed as "investment fragility,". We define this as the vulnerability of a financial investment to becoming non-viable, (Flyvbjerg,2017). The benefits of economies of scale are well understood, however, in large projects scale creates challenges (Flyvbjerg, 2017). In Big is Fragile the authors state 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 of systems to the whole" (Flyvbjerg, 2017).

3.1.6 Business Cases

The literature identifies a recurring challenge of project sponsor cost underestimation coupled with benefit overestimation, emanating from ex-ante business cases. (Flyvbjerg, 2021). This phenomenon has occurred persistently and hasn't improved with time, projects such as the Sydney Opera House (1400%), the Channel Tunnel (80%), Berlin Brandenburg Airport (350%), and all Olympics programs most notably Montreal (720%) (which took 30 years after the event to be fully paid (Flyvbjerg,2011) see Figure.1.1. The number of overrun large projects which have failed to deliver on cost, on time or

[3] https://weblogibc-co.com/wp-content/uploads/2019/02/The-Black-Swan-Nassim-Nicholas-Taleb-1.pdf

[4] https://capital.com/the-black-swan-theory-definition

on the predicted benefits, is significantly greater than the number which satisfy any of these criteria. The literature identifies a 1 in 10 chance of achieving cost, benefit, or time targets (Flyvbjerg,2017)

This literature finds that if a project has poor governance and a poor business case it will never be able to achieve the expected costs and benefits no matter how good the project management is. It notes that "Instead project managers and promoters are getting used to the healthy fact that different stakeholders hold different forecasts and that forecasts are not only products of objective science and engineering but of negotiation". (Flyvbjerg,2011).

Poor governance occurs for a variety of reasons and tends to be linked with the absence of a strong business case. (Flyvbjerg, 2017) The absence of strong governance is usually due to the presence of biases within the project champions. The absence of a strong business case can occur from the absence of methods such as credible cost benefit analysis, risk analysis and other methods such as multi criteria analysis. This inability to achieve the expected costs is due to the presence of bias within the estimates which results in a cost estimate well below the final cost of delivering the project. Similarly, with the benefits tending to be overestimated, the overall costs will outweigh the benefits. This highlights the need for a strong business case which is free from bias and error which can be included within methods such as cost benefit analysis (Flyvbjerg, 2021).

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.[5] 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.

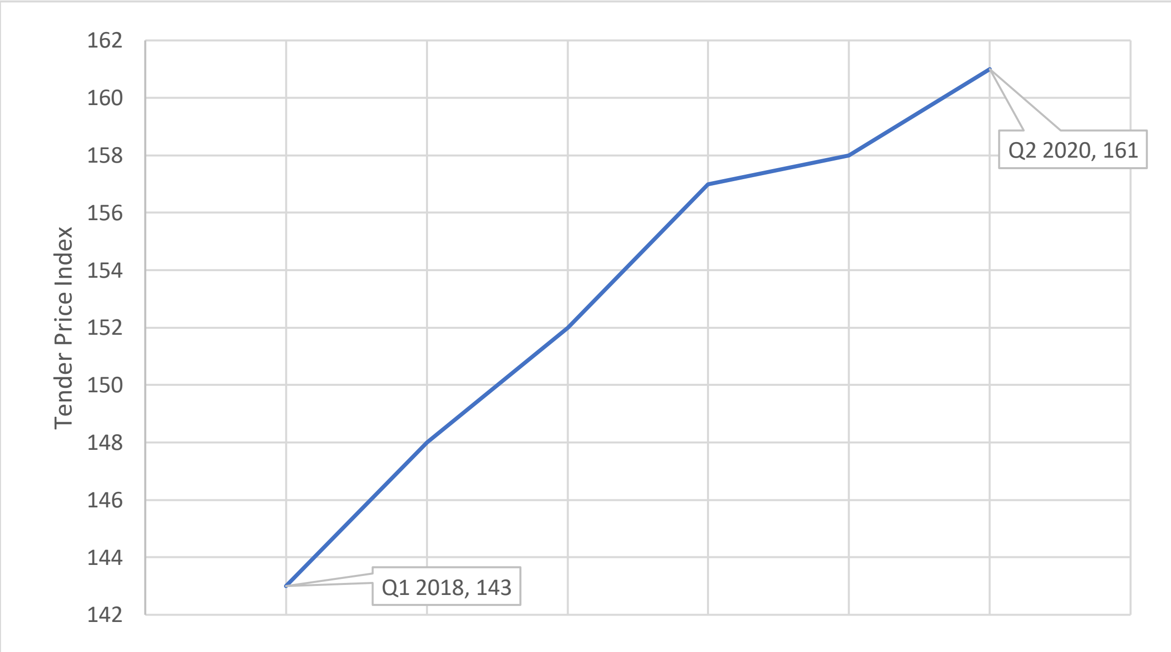
3.2 Inflation

The increase of the cost of building materials is one area in which large projects are exposed to. Due to long time horizons, the costs can increase substantially from the time of project initiation to post tender delivery. The graph below shows the effects of inflation on the tender cost of projects over the time horizon 2018-2020. As seen in the graph prices increase from an index value of 143 in 2018

[5] https://pai.ie/the-new-public-spending-code-guide-to-evaluating-planning-and-managing-public-investment-in-ireland/

to a value of 161 in Q2 of 2020. This equates to a 12.5% increase in tender price index over the 4 quarters.

Fig 3.1: Construction Tender Price Index 2018-2020



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

4 Solutions

One solution to this issue which is identified within the Public Spending Code (2019) is reference class forecasting. This approach allows 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 prospects 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 class[6].

[6] https://www.pmi.org/learning/library/nobel-project-management-reference-class-forecasting-8068

5 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 <€100m and combined with the 4 Irish projects from the NDP portfolio which where past appraisal stage. The combined size of this sample was 25 projects forming the basis of the model. The composition of the projects can be seen within the below table.

Fig 5.1: Table of Sample projects

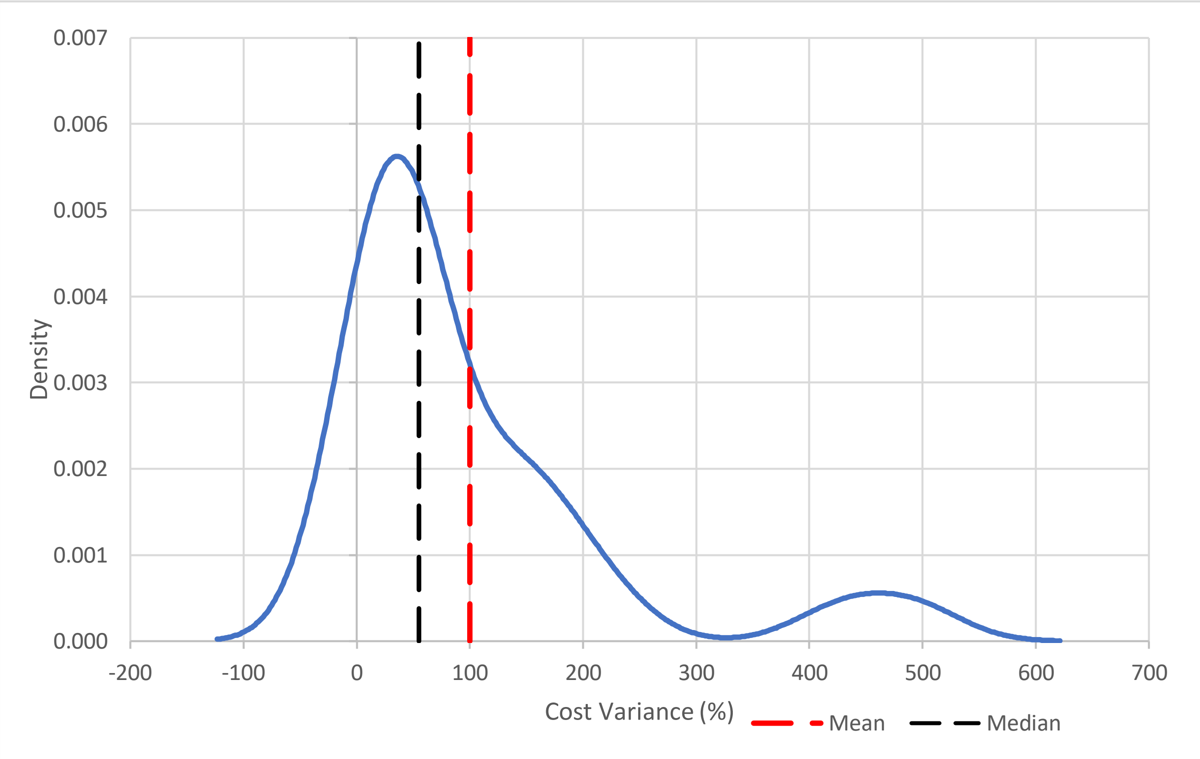
Project/Country	Estimated Cost €m	Actual/Projected Cost €m
England	€873	€1,240
England	€803	€1,156
US	€648	€1,176
Canada	€714	€1,657
Northern Ireland	€109	€176
Northern Ireland	€261	€415
Australia	€187	€223
Australia	€199	€210
Australia	€554	€588
China	€110	€114
Scotland	€192	€262
Wales	€129	€200
Canada	€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

The below graph denoted Fig 5.2 shows the distribution of the cost variances. 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%.

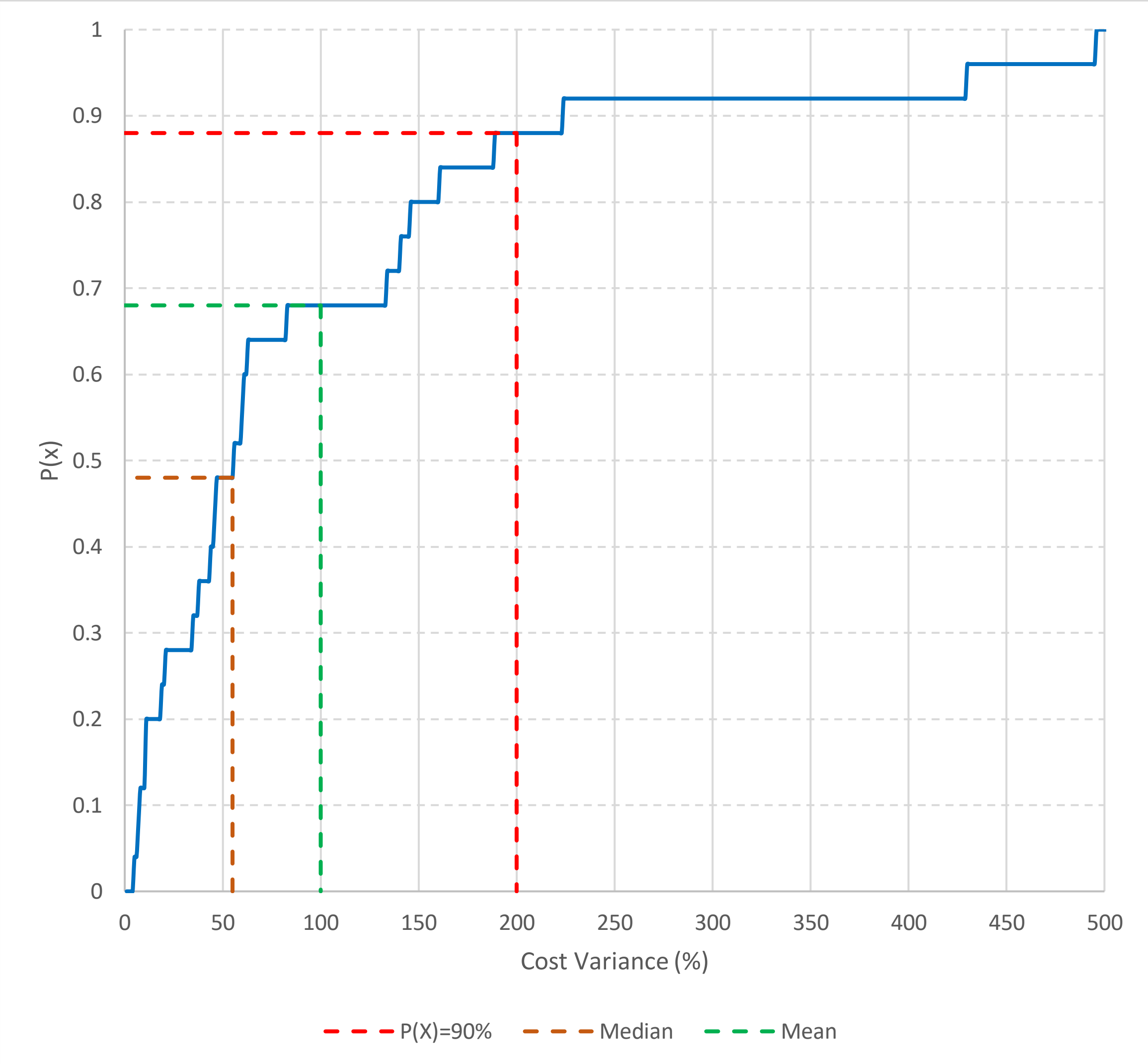
Fig 5.2: Probabilistic Distribution of Cost Variances of the Sample



Source: Authors Calculations

In Fig.5.3, the cumulative distribution highlights the significant levels of risk for cost variances with 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. The average cost variance of 97% has 32% of projects with a cost variance greater. These statistics should provide a greater understanding of how the Health sector is not unlike other sectors highlighted above in Fig.1.1, with such high variances occurring across all sectors action must be taken to mitigate such unknowns occurring again and again as the Iron Law of Project management proposes (Flyvbjerg, 2017).

Fig.5.3: Cumulative Distribution of Sample Cost Variance



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

From the table above it can be seen that the sample has been broken down by quantum and some interesting statistics appear such as the max variance of projects <=€100m being 494%. With the average cost variance differing across quanta. The average sample wide average cost variance can be seen to below the average variance in 2 out of the 4 quanta. This breakdown provides additional information on the phenomenon of cost underestimation, identifying which quanta tend to experience the largest cost underestimates.

5.1 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:

$$\log\,(Actual\ Cost) = 1.22 + 0.88(\log(Estimated\ Cost))$$

All information relating to the model parameters and measures of fit can be found in the appendix below.

In the graph below, 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 the model has poor predictive power around extremes, such as in the case of the project denoted "US" in which the model underestimates the actual cost of delivery. Overall, however the graph shows that the model provides for an informed estimate.

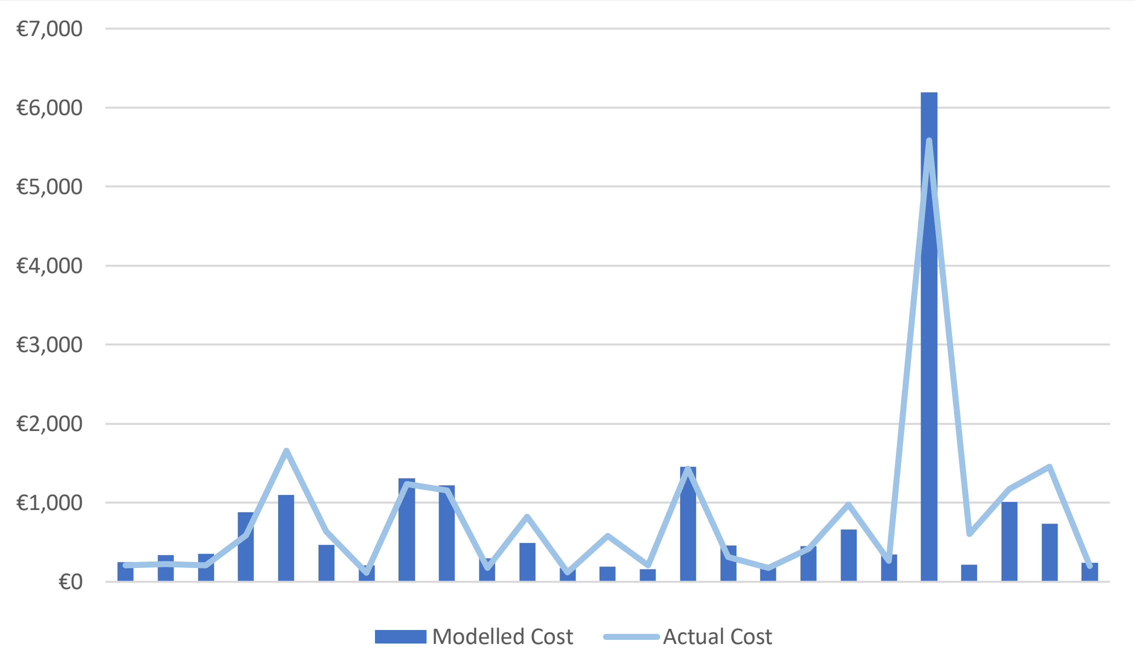
Within the below table is the regression analysis and coefficients. The model had an adjusted R-square of 0.77, and a MSE of 0.44.

Fig:5.4: 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 5.4: Graph of Actual and Predicted Costs



Source: Internal Data

5.2 The Estimation Effect

Using the equation above to estimate the actual cost of delivering the remaining NDP projects which are in the appraisal stage. The below costs where 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 5.5: Table of Predicted Cost Increases

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

Source: Authors Calculations

5.3 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, with these limitations this preliminary model can be used as a complementary tool to those currently in use and is a further step in the direction of data driven policymaking. With these limitations in both focus and scope further research will focus on expanding the use of Reference class forecasting to Health IT projects.

6 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 a number of mitigation strategies which could be deployed. These include:

1. Standardization[7] (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.

6.1 Standardization

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 standardized designs for different infrastructure projects which can be 'fast and iterative' (Flyvbjerg, 2021). There are three key advantages of this approach. Firstly, standardized

[7] https://www.sbs.ox.ac.uk/news/research-shows-how-slash-cost-megaprojects-while-boosting-delivery-speed

project designs are cheaper and easier to produce, allowing for increased flexibility at earlier stages in a project's lifecycle. Secondly, standardization allows for reference to be made to completed project costs when costs for new projects are being estimated. Finally, standardization 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 standardized project are more easily identified and alleviated.

Examples of Successful Standardized/ Modular Projects[7]:

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

6.2 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 final versus expected cost. Project risk and uncertainty increases with the length of the projects 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 arrived on schedule and within budget. (Flyvbjerg, 2017)

6.3 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 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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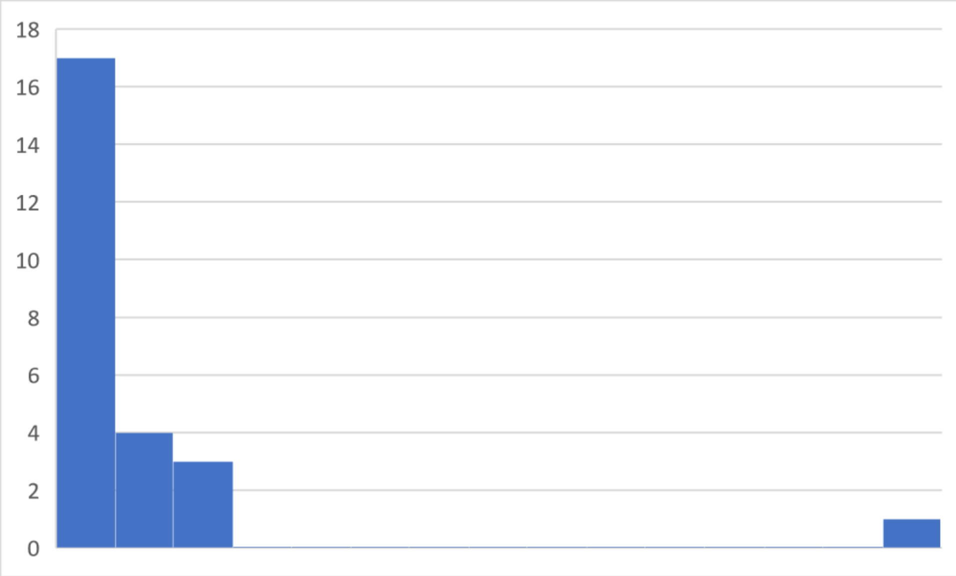
8 Appendix

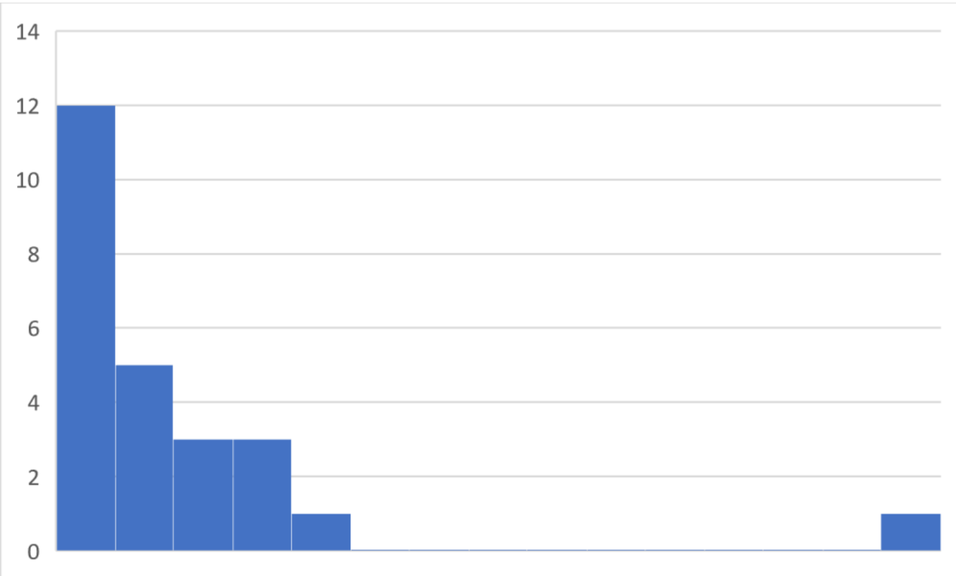
The below graphs denoted Fig 8.1, and Fig 8.2 show the distribution of the response and prediction variables are right skewed distributions and therefore the use of a logistic transformation of both variables is appropriate to assume the normality assumption of Ordinary Least Squares.

Figure 8.1: Distribution of Estimated Costs



Source: Authors Calculations

Fig 8.2: Distribution of Post Tender Costs



Source: Authors Calculations