BENCHMARKING NEW ZEALAND
INFRASTRUCTURE PROJECTS AGAINST INTERNATIONAL DATA

Report version 2.4

Oxford Global Projects
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1. Introduction

This report provides high-level benchmarks of the costs and timeframes of six categories of New Zealand infrastructure projects compared to similar projects in other countries. It investigates whether there are meaningful and/or statistically significant differences in infrastructure delivery costs between New Zealand and other countries. It also provides information on the distribution of cost and schedule overruns for each project category, focusing on lessons drawn from international projects.

The purpose of this report is to motivate and guide further research and investigation into New Zealand project performance and performance drivers. The report identifies differences in cost performance but does not seek to explain observed differences.

The report provides statistical evidence on the per-unit delivery costs and timeframes of six infrastructure project types: (1) motorways, (2) road tunnels, (3) rail stations, (4) electricity transmission lines, (5) wind farms, and (6) hospitals. Additionally, the report investigates geographical differences in costs and timeframes. Data treatment in terms of inflation and exchange rate treatment is also covered. Finally, the report includes international figures for cost and schedule uncertainty through information on the historical level of cost and schedule overrun.

2. Methods

2.1. Approach to unit cost benchmarking

Project benchmarking requires a like-for-like comparison of both delivery costs and outputs. This entails:

- Selecting and comparing projects that are similar in terms of scope and design
- Selecting a common measure of project size or scale to calculate per-unit costs
- Converting delivery costs into common prices, adjusting for price inflation over time and exchange rates between countries

2.1.1 Selecting and comparing similar projects

Cost benchmarks were prepared for six infrastructure project types: (1) motorways, (2) road tunnels, (3) rail stations, (4) electrical transmission lines, (5) wind farms, and (6) hospitals. Categories were defined to ensure that projects were mostly comparable in terms of scope and scale. For instance, road tunnels were not compared with rail tunnels because the latter usually include significant costs for underground stations and (sometimes) rolling stock purchases.

However, projects within each category may vary in terms of context or design, and hence these are best seen as indicative benchmarks rather than true like-for-like comparisons. In some cases, project categories were further segmented to focus on sub-categories that were most similar, for instance urban versus rural motorways or on-shore versus off-shore wind farms.

2.1.2 Calculating unit costs

The size of projects varied within each project category. For instance, wind farm projects ranged between 2 MW capacity and 1547 MW capacity. For each project, unit costs were calculated by dividing total project costs by a measure of project size.

2.2.1 Adjusting costs into common currency units

In the underlying data, project costs were stated in nominal (non-inflation-adjusted) national currencies. It was therefore necessary to convert nominal costs into real (inflation-adjusted) costs and then convert them into a common currency. For ease of comparison with international data, which is often reported in US dollars, all costs were converted to 2021 US dollar terms.

First, price levels were adjusted to 2021 prices using country-specific implicit GDP deflators from the World Bank.[1] The GDP implicit deflator is the ratio of GDP in current local currency to GDP in constant local currency. World Bank GDP deflators were chosen to ensure comparability to international cost figures by using the same deflation methodology for all the projects in the data set.

Second, all national currencies were converted to US dollar terms using purchasing power parity (PPP) conversion factors from the World Bank.[2] PPP exchange rates measure the relative purchasing power of different currencies in their respective domestic markets and depend on the relative price levels of both tradable and non-tradable goods. The underlying idea is that the cost of a good or service (or a basket of goods and services), once prices are converted to a common currency, should cost the same in different countries, the so-called Law of One Price. Hence, using PPP exchange rates over nominal market exchange rates makes for a more robust basis to bring construction costs expressed in various national currencies to a common base.[3]

2.2. Approach to Statistical Analysis

We carried out the following statistical analysis within each project category.

To begin, basic descriptive statistics were calculated and reported for each project category and country grouping. These included the number of projects in each project category/country group as well as the

[1] GDP implicit deflators are based on World Bank national accounts data and OECD National Accounts data files. Source: "GDP Deflator (Base Year Varies by Country)." *The World Bank Data*, World Bank, https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS.

[2] PPP conversion factor is a spatial price deflator and currency converter that controls for price level differences between countries, thereby allowing volume comparisons of gross domestic product (GDP) and its expenditure components. Source: "PPP conversion factor, GDP (LCU per international $)" *The World Bank Data*, World Bank, https://data.worldbank.org/indicator/PA.NUS.PPP.

[3] see Best, R. and Langston, C. (2006): "Converting construction costs to a common currency base: an unresolved problem." Proceedings of Construction in the XXIst Century: Local and Global Challenges. Rome, October 18-20

mean, standard deviation and selected percentiles of unit cost, project size and project duration (minimum, 25th percentile, 50th percentile, 75th percentile, and maximum). The distribution of unit costs in each project category/country group was also plotted using a box-and-whiskers plot.

Descriptive statistics provide a simple overview of patterns in the data, including any differences in means or differences in distributions. However, due to the small sample sizes in some project category/country groups, differences are not always statistically significant.

Next, two approaches were used to test whether New Zealand unit costs were statistically significantly than unit costs in other country groupings. First, we use two-tailed Wilcoxon rank-sum tests, also known as Mann Whitney U tests, to test whether the distributions of unit costs differed between New Zealand and other country groups. The Wilcoxon rank-sum test is used to test whether two samples are likely to derive from the same population (i.e., that the two populations have similarly shaped distributions). This test is sometimes interpreted as a test of the null hypothesis that the medians of two distributions are equal. The tests were adjusted using Holm-adjustments to control for family-wise error rates.[4] Wilcoxon rank-sum tests are preferable to classic t-tests when the data do not follow normal distributions. For each test completed, W- and p-statistics are reported.[5]

Second, we use ordinary least squares (OLS) regressions to test whether there are statistically significant differences in unit costs between countries after controlling for other observable project characteristics that may affect costs.[6] These regressions used unit costs as the dependent variable and included project characteristics (e.g., project size) and country grouping as explanatory variables. All unit costs are log-transformed, which helps approaching the assumptions of normality and constant variance used in OLS but makes the interpretation of magnitude of the coefficients tedious.[7]

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[4] This adjustment for multiple testing (Holm–Bonferroni method) is performed because the probability of committing Type I errors considerably increases when more than one hypothesis is simultaneously tested. One implication of using Holm-adjustments is that the displayed p-values also depend on the specific grouping of countries and the number of resulting categories.
[5] The test statistic W is determined from the ranks by adding up the number of times each observation in sample A is exceeded by an observation in sample B. The p-value, or probability value, is a statistic describing how likely it is that the data would have occurred by random chance.
[6] Additionally, general least squares regression (GLS), as well as Maximum Likelihood Estimation (MLE) for the gamma distribution have been run for each category. Both confirm the results of the OLS in a qualitative manner.
[7] The exponentiated coefficient is the ratio of the geometric mean for the country group under investigation to the geometric mean for the New Zealand group.

Whereas OLS compares the average values of a numeric outcome between two groups, the Wilcoxon rank sum test looks at their medians. This means that the latter is less sensible to extreme values, i.e., it is more robust to outliers in the data. Furthermore, the Wilcoxon rank sum test is a non-parametric approach, implying a reduction of modeling biases due to incorrect specification of traditional parametric methods such as OLS. Therefore, when conducting Wilcoxon rank sum tests, it is not necessary to pose the question whether a parametric family adequately fits a given data set. On the other side, OLS can be used to draw conclusions about effect sizes of several discrete and continuous explanatory variables on the unit cost, whereas the Wilcoxon method only makes inferences about the ordinal ranking of two samples divided by one categorical variable.

Since the Wilcoxon rank sum test makes less assumptions, it is used in this report as the overall test to evaluate if systematic differences in unit cost between infrastructure projects of different geographical regions exist. To control for continuous project characteristics, e.g., scale of the project, the OLS approach is used as a second statistical method to test for differences in unit cost. Furthermore, the OLS regression model can be understood as a type of robustness check, which signals whether previous results can be confirmed and complemented under stronger assumptions.

2.3. Overview of Dataset

For this project, data was collected and collated from 6 different types of infrastructure projects: (1) motorways, (2) road tunnels, (3) rail stations, (4) electrical transmission lines, (5) wind farms, and (6) hospitals

The projects were grouped into geographical regions using both a seven-continent and an OECD/non-OECD classification. Projects from Australia and New Zealand were excluded from this categorization and maintained as independent geographical units in the sample for interpretative purposes.

Data on non-New Zealand projects was sourced from Oxford Global Project's infrastructure projects database, which holds project performance data from 17,085 projects in 126 countries. Data on New

Zealand projects was provided by the NZ Infrastructure Commission.[8] The information required to calculate cost benchmarks and cost and schedule overruns was compiled from various sources, including investment papers, business cases, briefing papers, progress reports, project close out reports, press releases or public proposals and bids. Data on key technical project characteristics, such as project size, have been obtained from a variety of sources such as official public documents.

The total project counts for each project type listed in this section relates to the total number of projects for which we had the necessary variables for unit cost benchmarking. In addition, for many projects there was also information available on duration as well as cost and schedule overruns.

A full list of New Zealand projects that were included in this analysis is provided in *Appendix A: List of included New Zealand projects.*

2.3.1 MOTORWAYS

We collected data for a total of 401 motorway projects that involved building new at-grade motorways as well as widening works on pre-existing motorways. As shown in Figure 1, most of the motorway projects in the dataset are from European countries.[9] North American projects in the sample are from the United States and Canada. All Asian projects are from China. Information was available on 33 New Zealand motorway projects and 5 projects in Australia. For motorway projects, data was collected on estimated cost, actual cost, estimated duration, actual duration, number of lanes, length, area definition as urban or non-urban, type of construction work as new road or widening and location.

Project completion dates for motorway projects range between the years 1958 and 2021, with 95% of the projects completed in the last three decades, 60% completed in the last two decades and 35% completed in the last decade.

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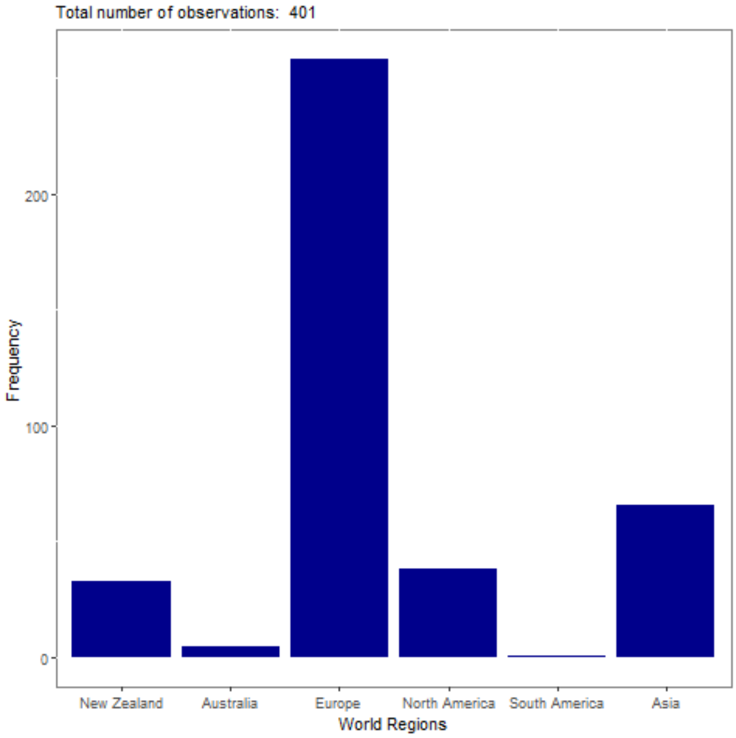
[8] The NZ Infrastructure Commission only provided data on projects where costs and design characteristics had been publicly announced, or where the infrastructure provider had agreed to share data.

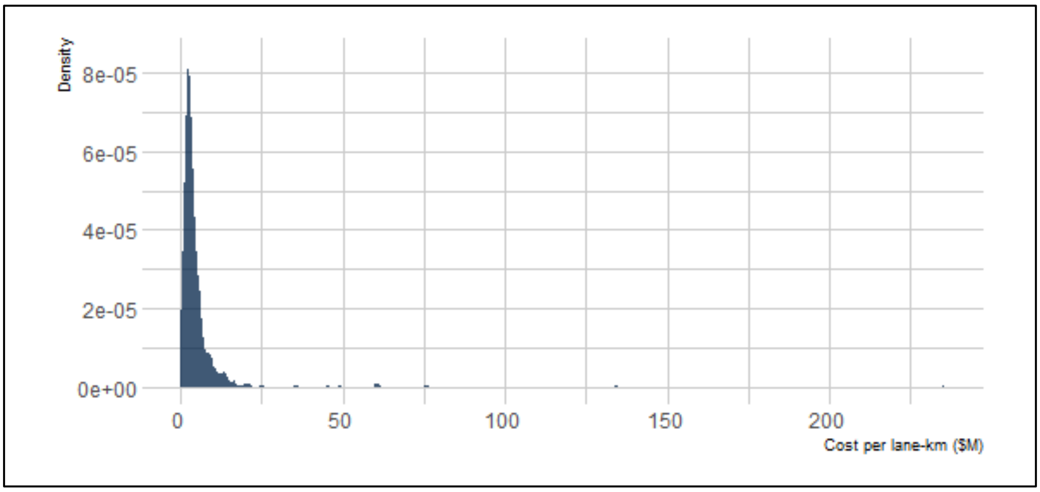
[9] Countries included in this group are Denmark, France, Germany, Greece, Ireland, Netherlands, Norway, Poland, Slovakia, Slovenia, Spain, Sweden and the United Kingdom.

FIGURE 1 - HISTOGRAM OF MOTORWAYS BY GEOGRAPHY



The chosen unit cost benchmark for motorways was **cost per lane kilometer**. It is calculated as $\frac{Project\ cost}{Length * Lanes}$ where project cost is measured in 2021 USD, the length of the motorway is measured in kilometers (km), and the number of lanes is an integer. The distribution of this data can be seen in Figure 2.

FIGURE 2 – COST PER LANE-KM DISTRIBUTION OF MOTORWAYS

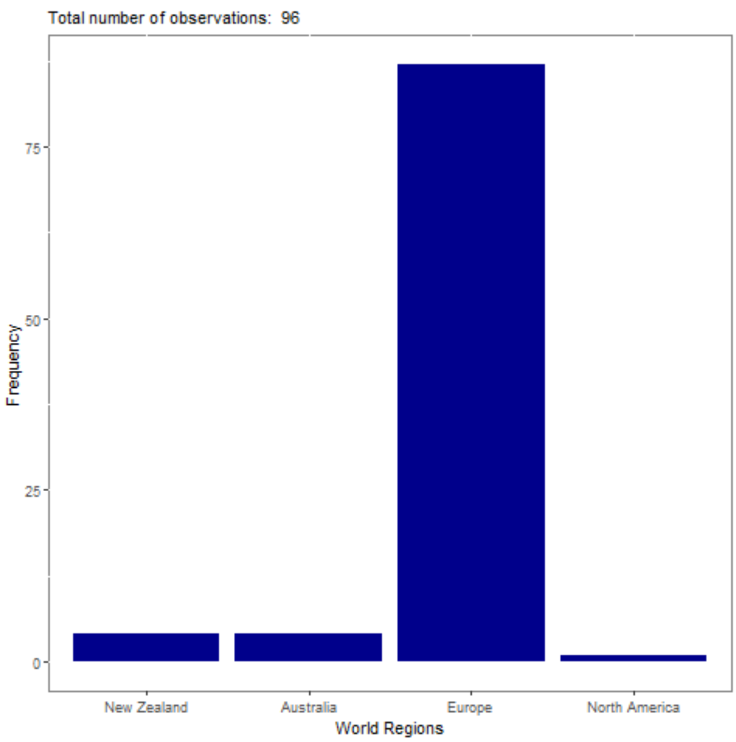


2.3.2 Tunnels

We collected data for a total of 96 road tunnel projects. This comparison focuses on road tunnels as New Zealand has more recently completed and proposed road tunnels rather than rail tunnels. As shown in Figure 3, most of these projects are from Europe.[10] Information is also available on 4 projects from New Zealand, 4 projects from Australia and 1 project from the United States. Data has been collected on the following variables: actual cost, actual duration, outer diameter, length and location.

Project completion dates for road tunnel projects range between the years 1927 and 2021, with 98% of the projects completed in the last three decades, 86% completed in the last two decades and 78% completed in the last decade.

FIGURE 3 – HISTOGRAM OF ROAD TUNNELS BY GEOGRAPHY

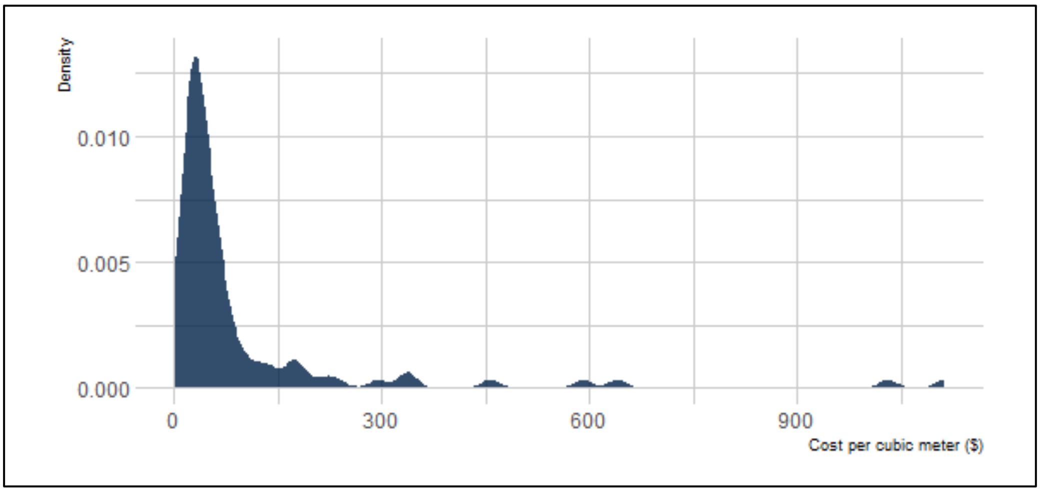


The chosen unit cost benchmark for tunnels was **cost per cubic meter**. It is calculated as $\frac{Project\ cost}{Volume} = = \frac{Project\ cost}{\pi * Length * Radius^2}$ where project cost is measured in 2021 USD, tunnel length and outside diameter

[10] 57 road tunnel observations are from Switzerland, followed by Norway with 13 observations. Other countries included in the group of Europe are Austria, Denmark, France, United Kingdom, Greece, Ireland, and Netherlands.

is measured in meters (m).[11] The volume of the tunnel is measured in cubic meters (m^3) and has been calculated as indicated, assuming an idealized cylinder shape of the tunnel. The distribution of this data can be seen in Figure 4.

FIGURE 4 - COST PER CUBIC METER DISTRIBUTION OF TUNNELS



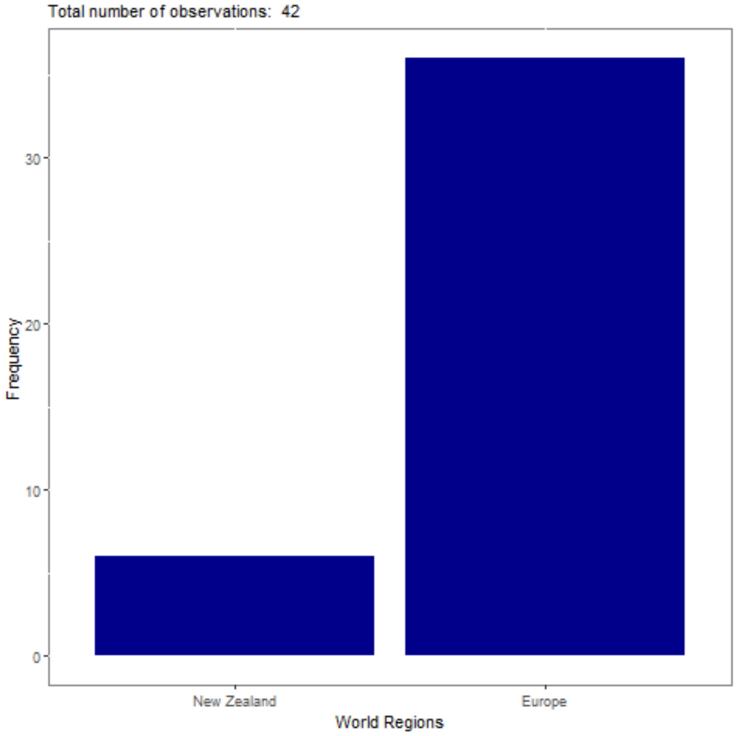
2.3.3 Rail Stations

We collected data for a total of 42 surface level rail rapid transit station projects. As shown in Figure 5, most of these projects are from European countries.[12] There are 5 projects from New Zealand. Data has been collected on the following variables: estimated cost, actual cost, estimated duration, actual duration, number of tracks and location.

Project completion dates for rail station projects range between the years 2002 and 2021, with 80% of the projects completed in the last decade.

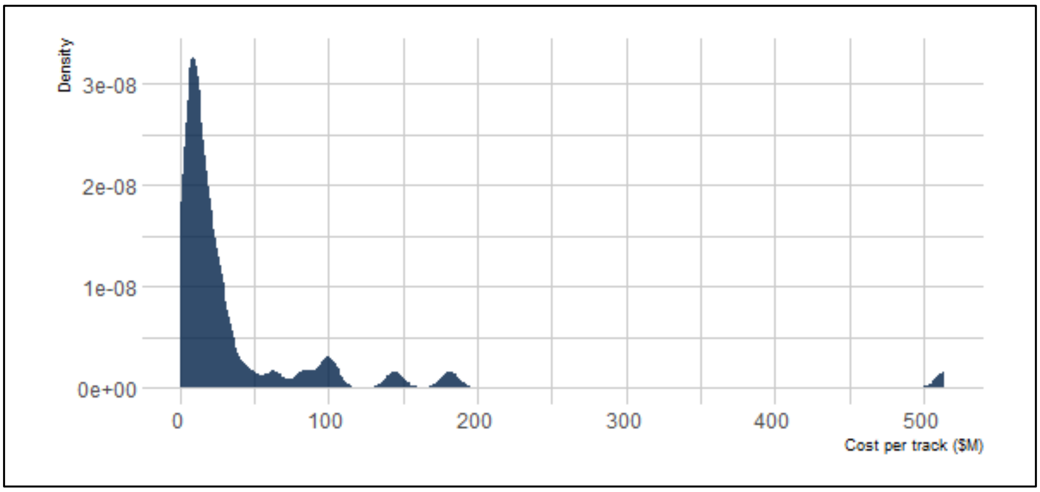
[11] Tunnel radius is equal to half of the tunnel outside diameter.
[12] 35 of those projects are in the United Kingdom and one project is in Portugal.

FIGURE 5 - HISTOGRAM OF RAIL STATIONS BY GEOGRAPHY



The chosen unit cost benchmark for rail stations was **cost per track**. It is calculated as $\frac{Project\ cost}{Number\ of\ tracks}$, where project cost is measured in 2021 USD and number of tracks is an integer. The distribution of this data can be seen in Figure 6.

FIGURE 6 - COST PER TRACK DISTRIBUTION OF RAIL STATIONS



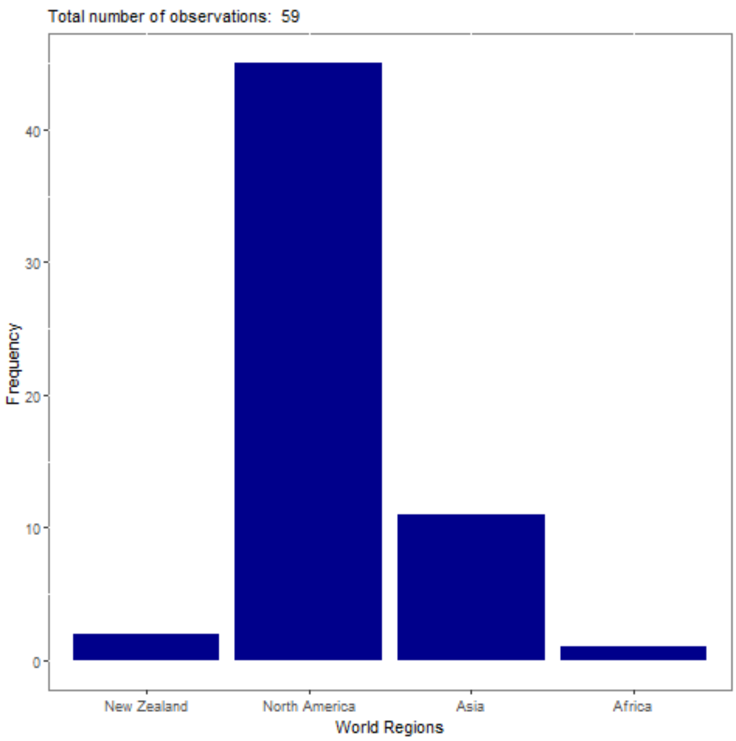
2.3.4 Electricity Transmission Lines

We collected data for a total of 59 electricity transmission lines. As shown in Figure 7, most of these projects are from North America, and in particular the United States, along with some project data from Asia and Africa.[13] Information was available on 2 projects from New Zealand.

Data has been collected on the following variables: estimated cost, actual cost, estimated duration, actual duration, length of transmission line, voltage and location. An important limitation of this analysis is that data was not available on whether transmission lines were HVAC (High Voltage Alternating Current) or HVDC (High Voltage Direct Current), which is an important technical characteristic that tends to affect cost.[14]

Project completion dates for electricity transmission line projects range between the years 2012 and 2014.

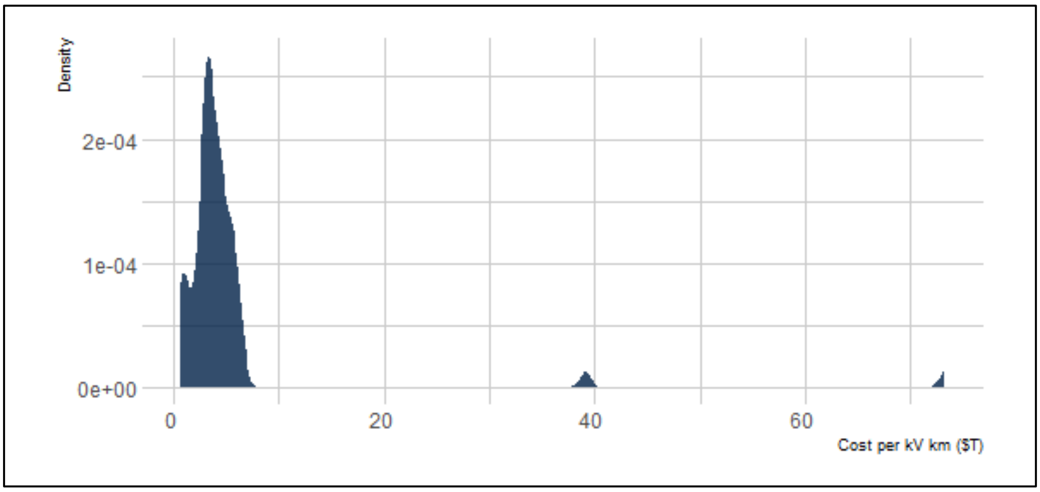
FIGURE 7 - HISTOGRAM OF ELECTRIC TRANSMISSION LINES BY GEOGRAPHY



[13] Asian projects are from China, India, and Kazakhstan. African projects are exclusively from the Democratic Republic of the Congo.
[14] Transmission lines in this sample are broadly comparable in terms of voltage. The voltage of international projects ranges from 345 to 800 kV, with most (80%) of the sample being 345kV transmission lines. The two projects located in New Zealand are 220kV and 400kV. Hence there should be some commonality between the projects in terms of this specific cost driver.

The chosen benchmark for electricity transmission lines was **cost per kilovolt-kilometer**. It is calculated as $\frac{Project\ cost}{Length * Voltage}$ where actual cost is measured in 2021 USD, the length of the electricity transmission line is measured in kilometers and its voltage in kilovolt. The distribution of this data can be seen in Figure 8.

FIGURE 8 – COST PER KV PER KILOMETER DISTRIBUTION OF ELECTRICAL TRANSMISSION LINES



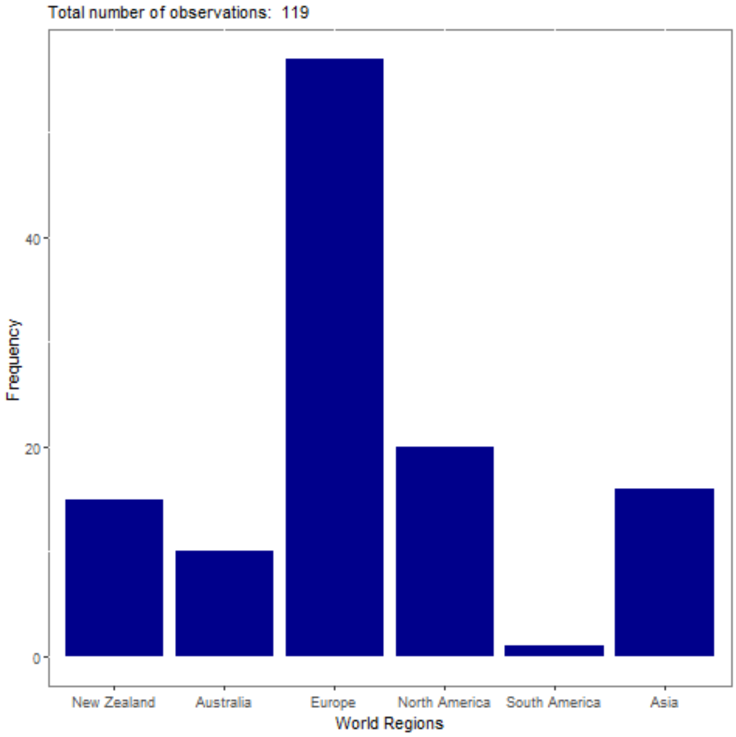
2.3.5 Wind Power Projects

We collected data for a total of 119 wind farm projects. As shown in Figure 9, most of these projects were from Europe,[15] along with data from two North American countries, four Asian countries, and one South American country.[16] Finally, the data sample also includes data from 18 projects from New Zealand and 7 projects from Australia. Data were collected on the following variables: estimated cost, actual cost, estimated duration, actual duration, energy capacity, onshore or offshore windfarm type, and location.

Project completion dates for wind power projects range between the years 1999 and 2021, with 90% of the projects completed in the last decade.

[15] European data comes from projects in the United Kingdom (24 observations), Belgium, Denmark, Finland, Germany, Portugal, Spain and Sweden.
[16] North American countries Canada and the United States. Asian countries are China, Japan, Pakistan and South Korea. The country in South America is Costa Rica.

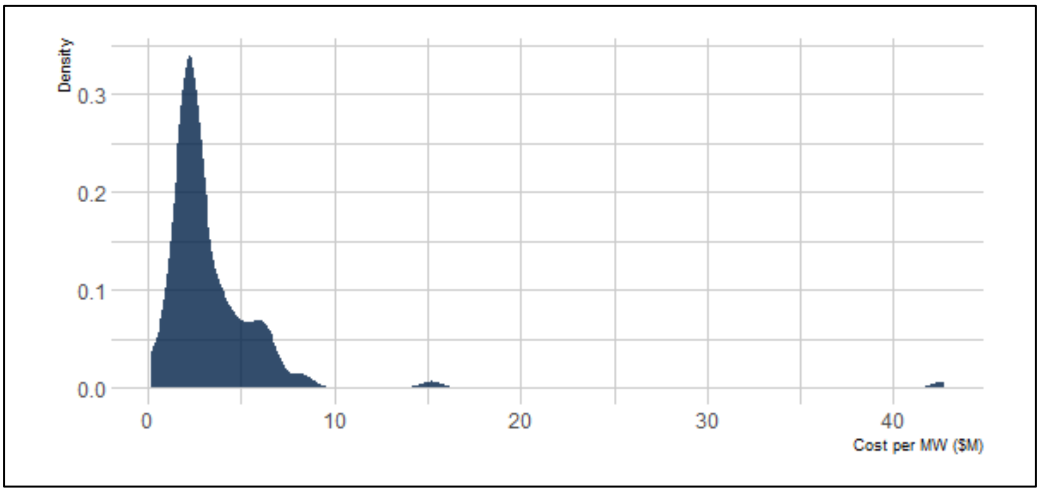
FIGURE 9 – HISTOGRAM OF WIND POWER PROJECTS BY GEOGRAPHY



The chosen unit cost benchmark for wind farm projects was **cost per megawatt** installed capacity. It is calculated as $\frac{Project\ cost}{Installed\ capacity}$,where project cost is measured in 2021 USD, and the installed capacity of the wind farm is measured in megawatts (MW).[17] The distribution of this data can be seen in Figure 10.

[17] Levelized cost of electricity, or the total capital and operating cost per megawatt-hour of power produced, is more commonly used for benchmarking within the electricity generation sector. However, levelized cost of electricity depends upon the capacity factor of wind turbines (i.e., the share of the time that the wind is blowing strongly enough to generate power) as well as the cost to install the turbines. Benchmarking cost per MW of installed capacity focuses more closely on the cost to deliver infrastructure.

FIGURE 10 – COST PER MW INSTALLED CAPACITY DISTRIBUTION OF WIND POWER PROJECTS



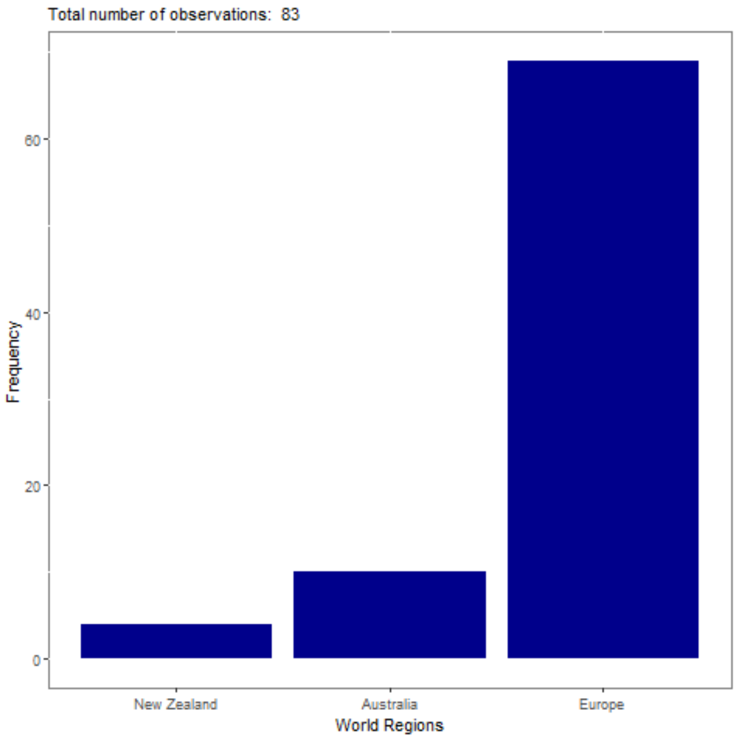
2.3.6 HOSPITALS

We collected data for a total of 83 hospital projects. As shown in Figure 11, most of the data comes from European projects.[18] Information is also available on 4 projects in New Zealand and 18 projects in Australia. Data has been collected on the following variables: estimated cost, actual cost, estimated duration, actual duration, gross internal area and location.

Project completion dates for hospital projects range between the years 1997 and 2021, with 82% of the projects completed in the last decade.

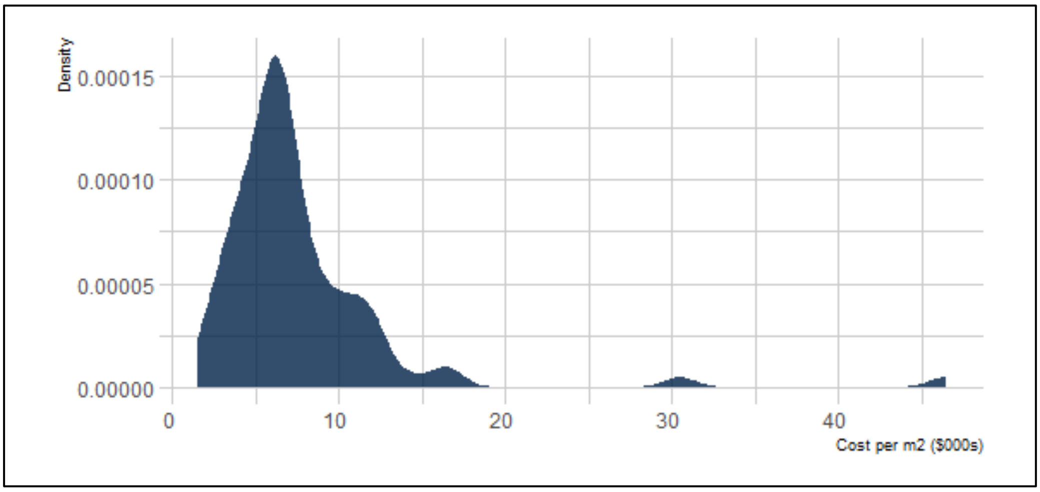
[18] Most projects are in the United Kingdom (59). Other countries included in this group are Denmark and Spain.

FIGURE 11 - HISTOGRAM OF HOSPITALS BY GEOGRAPHY



The chosen unit cost benchmark for hospitals was cost per square meter. It is calculated as $\frac{Project\ cost}{Size}$ where project cost is measured in 2021 USD and the size of the hospital is measured in square meters (m^2). The distribution of this data can be seen in Figure 12.

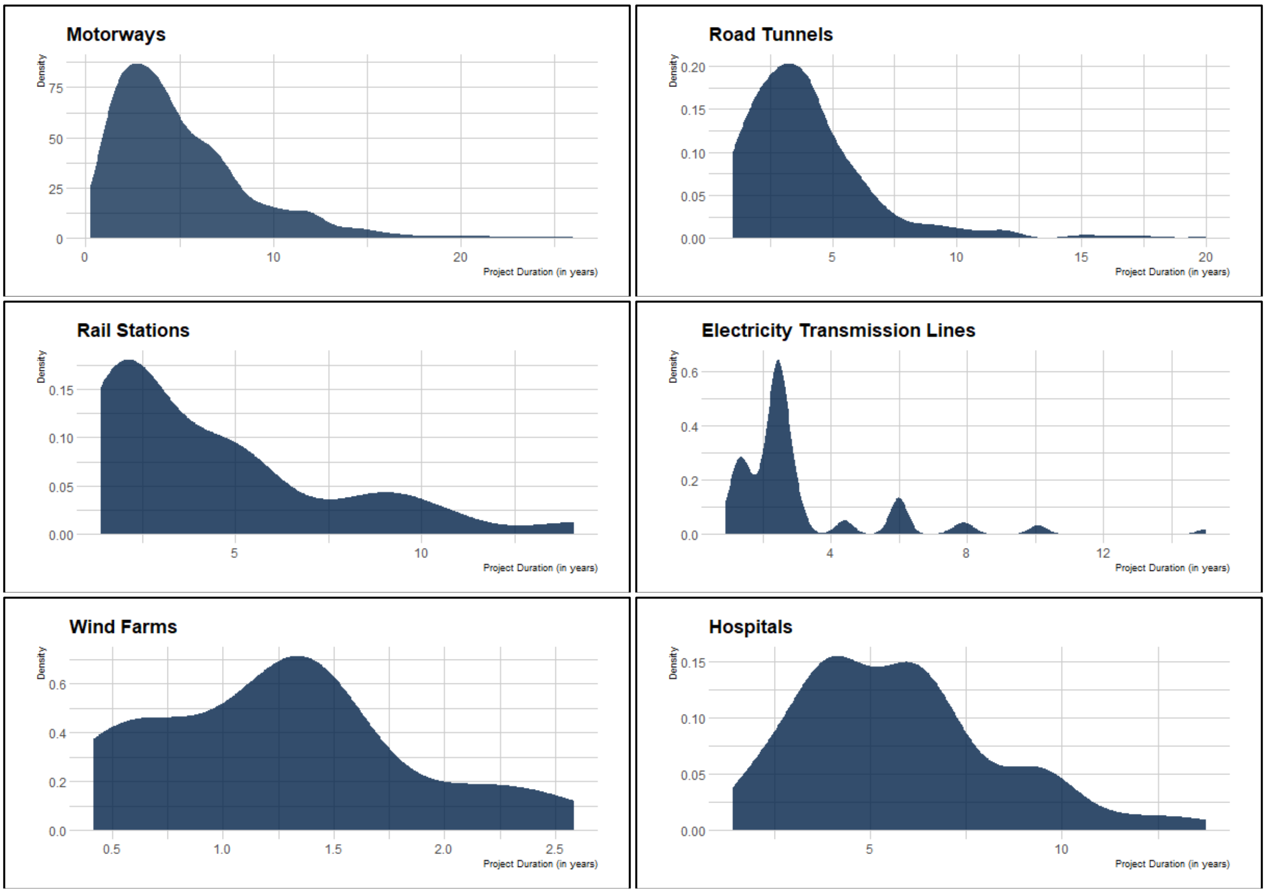
FIGURE 12 - COST PER SQUARE METER DISTRIBUTION OF HOSPITALS



2.3.7 Duration of Projects

Project duration is the time between the start of a project's construction and the date of substantial completion/opening, i.e., when the project enters operation. It is measured in years. The distribution of this data can be seen in Figure 13.

FIGURE 13 - DISTRIBUTION OF PROJECT DURATIONS FOR THE SIX PROJECT TYPES



3. Benchmarking Analysis

Here, we report the results of the benchmarking analysis for each of the six project categories addressed in this research. As described in the methodology section, the analysis includes descriptive statistics on unit costs for each project category and country group as well as statistical tests to determine whether there exist statistically significant differences between New Zealand's unit costs and unit costs in other country groups. The methodologies used to do this are non-parametric Wilcoxon rank sum tests and parametric ordinary least square regressions.

It should be noted that in some of the cases small sample size can lead to large but not statistically significant differences in project cost means. Small sample sizes can result in 'under-powered' tests that may not be able to distinguish between genuine differences and differences driven by random chance. Getting a non-significant outcome from such a test is not necessarily conclusive evidence that there are no important differences.

3.1. Motorways

3.1.1 Descriptive Statistics

Table 1 presents an overview of data on *urban motorway projects*. Across all countries, unit costs for motorway projects average approximately US$14 million per lane kilometer. However, most projects are cheaper than average as this average is dragged up by a small number of extremely high-cost projects. The middle 50% of motorway projects (P25-P75) have costs between US$3.35 million and US$5.88 million per lane-kilometer. The average duration to finish a motorway construction project is approximately 5.6 years.

Similarly, Table 1 also shows how the urban motorway projects in New Zealand compare to the overall sample of urban projects, as well as to each region in particular. Motorway unit costs in New Zealand average US$9.76 million per lane-kilometer, with the middle 50% of projects (P25-P75) costing between US$4.52 and US$10.37 million per lane-kilometer. Unit costs in New Zealand seem to be comparable with those in Europe and Australia in terms of the median and the middle 50% of projects, but they are higher than costs in North America.

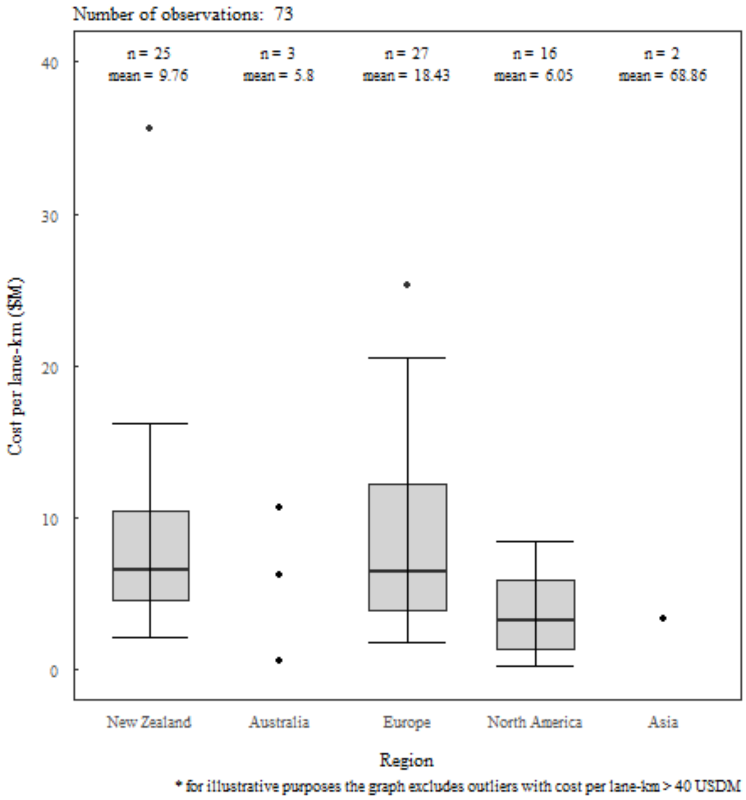
In addition, the size of the motorway projects can be seen in Table 1. On average, motorway projects in New Zealand tend to be short in terms of their length in lane kilometers than the average project overall. The median motorway in New Zealand measures roughly 30 lane km, whereas the overall sample median motorway has a length of 105 lane km.

TABLE 1 - DESCRIPTIVE STATISTICS FOR URBAN MOTORWAY PROJECTS

	Mean (std dev)	*Min*	*Max*	*Median (P25, P75)*	*Count*
Cost per lane-km (USD $M)					
New Zealand	9.76 (10.60)	2.03	48.96	6.54 (4.52, 10.37)	25
Australia	5.80 (5.07)	0.54	10.65	6.21 (3.37, 8.43)	3
Europe	18.43 (44.96)	1.77	235.58	6.40 (3.83, 12.18)	27
North America	6.05 (10.83)	0.24	45.60	3.21 (1.31, 5.88)	16
Asia	68.86 (92.64)	3.35	134.36	68.86 (36.10, 101.61)	2
Total all countries	13.61 (32.03)	0.24	235.58	5.78 (3.35, 10.37)	73
Lane kilometers (km)					
New Zealand	37.77 (29.17)	2.30	108.00	28.00 (18.40, 56.00)	25
Australia	137.33 (88.93)	84.00	240.00	88.00 (86.00, 164.00)	3
Europe	96.00 (250.63)	4.00	1292.80	36.40 (9.30, 58.50)	27
North America	198.84 (137.89)	13.60	496.80	204.50 (100.38, 248.80)	16
Asia	282.50 (355.67)	31.00	534.00	282.50 (156.75, 408.25)	2
Total all countries	105.41 (182.70)	2.30	1292.80	42.00 (20.00, 96.40)	73
Duration (years)					
New Zealand	NA	NA	NA	NA	0
Australia	5.77 (3.57)	3.25	8.30	5.77 (4.51, 7.03)	2
Europe	9.68 (3.63)	5.00	19.43	9.75 (7.01, 11.01)	21
North America	6.84 (3.24)	2.67	11.01	6.00 (5.50, 9.01)	5
Asia	3.46 (2.53)	1.67	5.25	3.46 (2.57, 4.36)	2
Total all countries	8.53 (3.86)	1.67	19.43	8.05 (5.63, 10.76)	30

Figure 14 uses a box and whiskers plot to visually show the distribution of the unit costs in different country groups. This shows that New Zealand urban motorway unit costs are comparable to Australian, and European urban motorway unit costs, but higher than North American costs.

FIGURE 14 – DISTRIBUTION OF COST PER LANE-KM OF URBAN MOTORWAYS (USD, 2021)



Note: Box and whiskers plots visually display how data is distributed. The grey-shaded box shows the 25th percentile value (lower end of box), 50th percentile/median value (black line in middle of box), and 75th percentile value (top end of box). Whiskers show the minimum and maximum values, excluding any outliers. Dots above and below the ends of the whiskers show outlier values. Outliers are defined as outside 1.5 times the interquartile range (size of the grey-shaded box) above the upper quartile and below the lower quartile. "n" is the number of observations per group and "µ" the group average. For visualization the plot has been cut off at the top in a way that not all outlier values are observable.

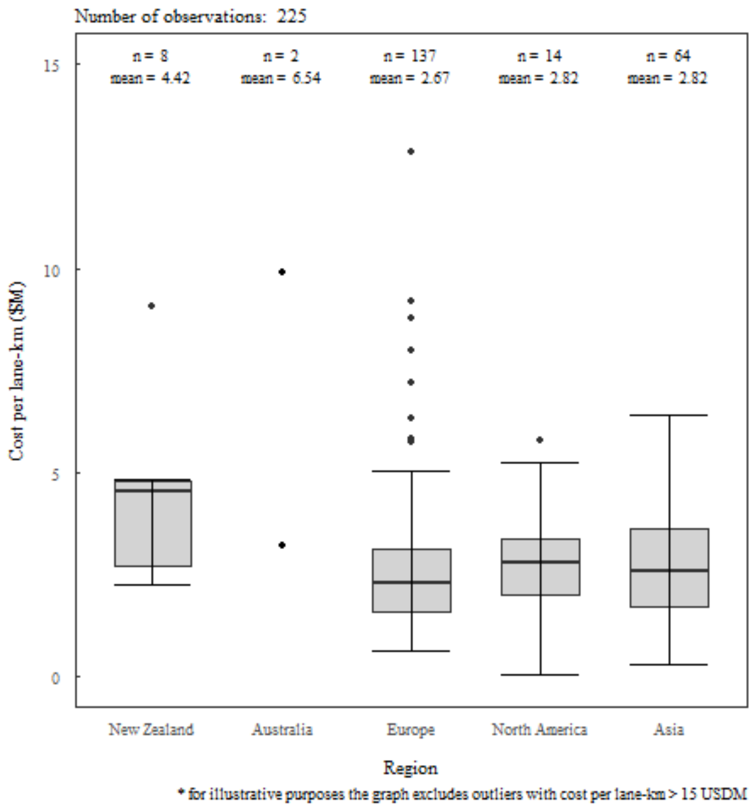
Table 2 presents an overview of data on *rural motorway projects*. Unit costs for rural motorway projects are with approximately US$3 million lower on average than unit costs for urban motorway projects. The median rural motorway in New Zealand seems to be more expensive compared to Europe, North America and Asia. Compared to Australia, on the other hand, median and middle 50% unit cost seem to be lower in New Zealand. The average duration to finish a rural motorway construction project is approximately 5 years.

TABLE 2 - TABLE DESCRIPTIVE STATISTICS FOR RURAL MOTORWAY PROJECTS

	Mean (std dev)	*Min*	*Max*	*Median (P25, P75)*	*Count*
Cost per lane-km (USD $M)					
New Zealand	4.42 (2.16)	2.26	9.07	4.53 (2.70, 4.78)	8
Australia	6.54 (4.72)	3.20	9.88	6.54 (4.87, 8.21)	2
Europe	2.67 (1.73)	0.61	12.87	2.27 (1.57, 3.10)	137
North America	2.82 (1.60)	0.03	5.80	2.76 (2.00, 3.35)	14
Asia	2.82 (1.55)	0.26	6.40	2.58 (1.71, 3.61)	64
Total all countries	2.82 (1.77)	0.03	12.87	2.50 (1.66, 3.36)	225
Lane kilometers (km)					
New Zealand	47.55 (22.97)	19.20	87.20	47.60 (28.70, 61.60)	8
Australia	175.00 (21.21)	160.00	190.00	175.00 (167.50, 182.50)	2
Europe	40.33 (60.46)	1.50	542.40	18.60 (6.44, 54.00)	137
North America	245.03 (387.23)	18.00	1492.80	121.40 (51.80, 231.50)	14
Asia	542.74 (343.54)	42.00	1360.00	504.00 (318.10, 706.70)	64
Total all countries	197.43 (306.99)	1.50	1492.80	52.40 (16.00, 244.00)	225
Duration (years)					
New Zealand	NA	NA	NA	NA	0
Australia	3.00 (1.53)	1.92	4.08	3.00 (2.46, 3.54)	2
Europe	6.92 (2.75)	1.00	12.01	7.00 (5.04, 8.01)	26
North America	10.79 (13.19)	3.00	26.02	3.34 (3.17, 14.68)	3
Asia	4.07 (1.44)	0.67	10.85	4.00 (3.32, 4.59)	64
Total all countries	5.04 (3.14)	0.67	26.02	4.17 (3.46, 6.00)	95

Figure 15 plots data for *rural motorway projects*, which represent roughly half of the full dataset. This shows that the distribution of New Zealand rural motorway unit costs overlaps with the distributions of unit costs in Europe, North America and Asia but is towards the upper end of costs in these countries.

FIGURE 15 - DISTRIBUTION OF COST PER LANE-KM OF RURAL MOTORWAYS (USD, 2021)



Note: Box and whiskers plots visually display how data is distributed. The grey-shaded box shows the 25th percentile value (lower end of box), 50th percentile/median value (black line in middle of box), and 75th percentile value (top end of box). Whiskers show the minimum and maximum values, excluding any outliers. Dots above and below the ends of the whiskers show outlier values. Outliers are defined as outside 1.5 times the interquartile range (size of the grey-shaded box) above the upper quartile and below the lower quartile. "n" is the number of observations per group and "µ" the group average. For visualization the plot has been cut off at the top in a way that not all outlier values are observable.

3.1.2 Statistical Tests

Table 3 reports the results of Wilcoxon rank-sum tests that are used to identify whether there is a statistically significant difference in the distribution of unit costs in New Zealand versus in other country groups.

When bundling together all types of motorway projects, we found that there exist statistically significant differences between New Zealand and North America, Asia (i.e., China) and Europe, but not Australia. The Wilcoxon rank-sum tests indicate that the cost per lane kilometer is greater for New Zealand (Mdn = 8.46) than for Europe (Mdn = 5.67), $W = 6381$, $p = 3e\text{-}06$; greater than for North America (Mdn = 4.47), $W = 953$, $p = 1e\text{-}04$; and greater than for Asia (Mdn = 4.82), $W = 1814$, $p = 8e\text{-}08$.

However, these differences diminish when controlling for whether motorways are urban or rural. For rural motorway projects, the difference between New Zealand costs and European costs is statistically significant at the 5% level *(W = 876, p = 0.046)*. For urban motorway projects, the difference between New Zealand costs and North American costs is statistically significant at the 10% level *(W = 302, p = 0.057)*.

TABLE 3 – WILCOXON RANK-SUM TESTS FOR STATISTICAL SIGNIFICANCE OF DIFFERENCES IN MOTORWAY UNIT COSTS

Differences between New Zealand unit costs and:	*All motorway projects (p-value)*	*Urban motorway projects (p-value)*	*Rural motorway projects (p-value)*
Australia	1.000	1.000	1.000
Europe	4e-05***	1.000	0.046*
North America	0.002***	0.057	0.870
Asia	1e-06***	1.000	0.253

*Note: Statistical significance indicators: Reject null hypothesis that samples derive from the same distribution at the following levels: * p<5%; ** p<1%; ***p<0.1%*

Table 4 reports ordinary least squares regression models for motorway unit costs. The dependent variable in each regression is the natural logarithm of cost per lane kilometer, and explanatory variables include project characteristics and country groups. Regression models do confirm previous results partly and do not find statistically significant differences between New Zealand and other geographical regions, when controlling for the broad characteristics of motorway projects. However, they do indicate that New Zealand motorway project costs are higher than other OECD countries in general – the difference between average New Zealand costs and average OECD costs is statistically significant at the 1% level after controlling for broad project characteristics.

OLS model results also confirm that unit costs for urban motorways, holding everything else equal, seem to be higher than unit costs for rural motorways. Small and statistically insignificant coefficients for Length and Lanes seems to indicate that there are no strong economies of scale for motorway projects.

TABLE 4 – OLS REGRESSION MODELS FOR MOTORWAY UNIT COST ($M)

Outcome variable	**US$ per lane-km**	**Model 1**	**Model 2**
	Intercept	14.88 ***	14.87 ***
Project characteristics	Length (km)	-0.0007	-0.0007
	Lanes (#)	0.03	0.03
	Widening indicator	-0.42	-0.42
	Urban indicator	0.96 ***	0.97 ***
Geography (reference category: New Zealand)	Asia	-0.20	
	Australia	-0.47	
	Europe	-0.25	
	North America	-0.49	
	Non-OECD		-0.17
	OECD		-0.38 **
Number of observations		148	148
R2 (model fit)		0.27	0.26

*Notes: Coefficient estimates are reported in each row, with standard errors in parentheses. Statistical significance indicators: Reject null hypothesis that coefficient is equal to zero at the following levels: * p<5%; ** p<1%; ***p<0.1%*

3.2. Tunnels

3.2.1 Descriptive Statistics

Table 5 presents an overview of data on road tunnel projects. Across all countries, unit costs for road tunnel projects average approximately US$100 per cubic meter. As this average is dragged up by a small number of extremely high-cost projects, the median road tunnel costs US$42 per cubic meter and the middle 50% of the projects cost between roughly US$27 and US$75 per cubic meter. On average, constructing a road tunnel takes about 6.4 years to finish.

Table 5 also shows how the road tunnel projects in New Zealand compare to the overall sample of projects. Road tunnel unit costs in New Zealand average US$333 per cubic meter, with a median cost of US$275. However, few road tunnels have been completed or planned in recent years in New Zealand.

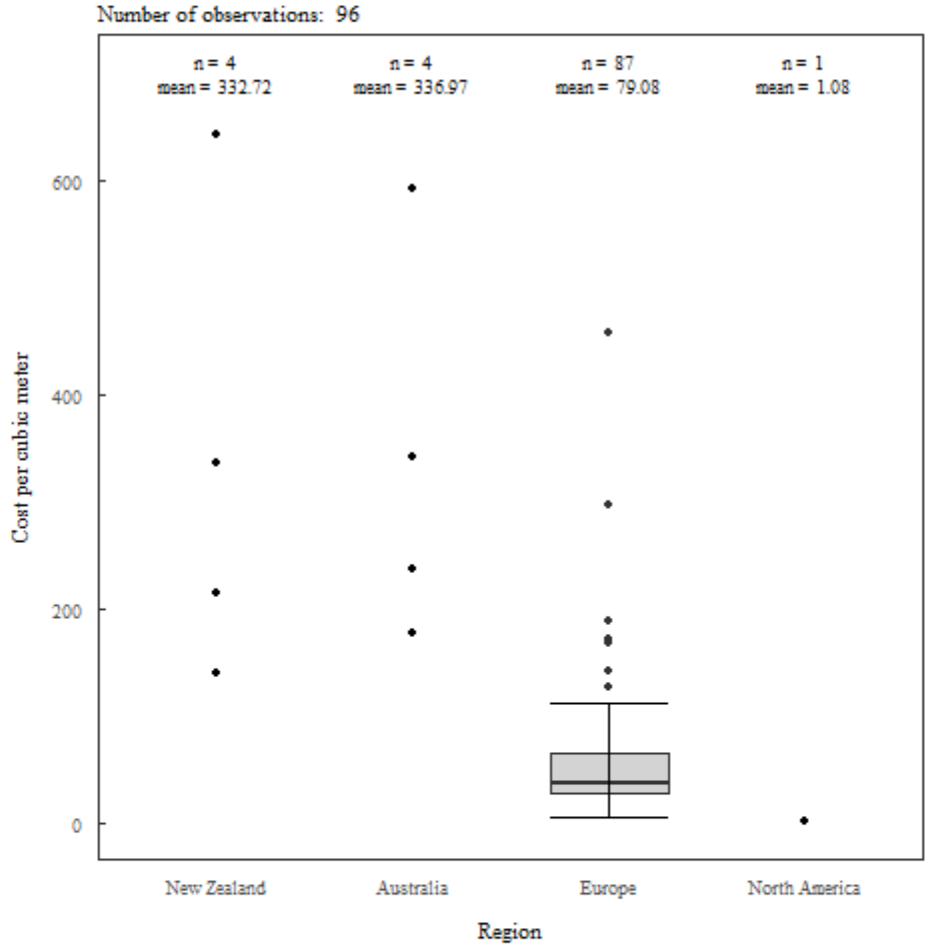
Furthermore, road tunnel from New Zealand average around 800,000 cubic meters and are therefore larger than most other road tunnel included in this sample.

TABLE 5 – DESCRIPTIVE STATISTICS FOR ROAD TUNNEL PROJECTS

	Mean (std dev)	*Min*	*Max*	*Median (P25, P75)*	*Count*
Cost per m3 (USD)					
New Zealand	332.72 (221.24)	138.86	641.62	275.21 (196.05, 411.88)	4
Australia	336.97 (183.10)	177.55	592.05	289.14 (221.84, 404.27)	4
Europe	79.08 (165.70)	5.08	1113.4	36.71 (26.76, 64.04)	87
North America	1.08 (NA)	1.08	1.08	1.08 (1.08, 1.08)	1
Total all countries	99.58 (180.57)	1.08	1113.4	42.28 (26.98, 75.06)	96
Volume (m3 T)					
New Zealand	797.64 (904.72)	53.24	2075.61	530.86 (223.31, 1,105.20)	4
Australia	364.08 (178.75)	216.00	579.66	330.32 (217.59, 476.81)	4
Europe	340.70 (295.26)	19.62	1559.26	250.90 (141.69, 428.72)	87
North America	1,274	1274	1274	1,274 (1,274, 1,274)	1
Total all countries	370.44 (350.53)	19.62	2075.61	258.89 (147.30, 486.16)	96
Duration (years)					
New Zealand	NA	NA	NA	NA	0
Australia	6.00 (3.46)	4	10	4.00 (4.00, 7.00)	4
Europe	6.20 (3.13)	2	17	6.00 (4.00, 7.00)	76
North America	20 (NA)	20	20	20 (20, 20)	1
Total all countries	6.36 (3.46)	2	20	6.00 (4.00, 7.00)	80

Figure 16 uses a box and whiskers plot to visually show the distribution of the unit costs in different country groups. This shows that New Zealand unit costs are similar to Australian unit costs but tend to be higher than European unit costs.

FIGURE 16 – DISTRIBUTION OF COST PER CUBIC METER OF TUNNELS (USD, 2021)



Note: Box and whiskers plots visually display how data is distributed. The grey-shaded box shows the 25th percentile value (lower end of box), 50th percentile/median value (black line in middle of box), and 75th percentile value (top end of box). Whiskers show the minimum and maximum values, excluding any outliers. Dots above and below the ends of the whiskers show outlier values. Outliers are defined as outside 1.5 times the interquartile range (size of the grey-shaded box) above the upper quartile and below the lower quartile. "n" is the number of observations per group and "µ" the group average. For visualization the plot has been cut off at the top in a way that not all outlier values are observable.

3.2.2 Statistical Tests

Table 6 reports the results of Wilcoxon rank-sum tests that are used to identify whether there is a statistically significant difference in the distribution of unit costs in New Zealand versus in other country groups. The Wilcoxon rank-sum tests in this study indicate that the cost per cubic meter of constructed tunnel is greater for New Zealand (Mdn = 275.21) than for Europe (Mdn = 36.71), W = 331, p = 0.012.

TABLE 6 – WILCOXON RANK-SUM TESTS FOR STATISTICAL SIGNIFICANCE OF DIFFERENCES IN ROAD TUNNEL UNIT COSTS

Differences between New Zealand unit costs and:	*All road tunnel projects (p-value)*
Australia	1.000
Europe	0.012
North America	1.000

*Note: Statistical significance indicators: Reject null hypothesis that samples derive from the same distribution at the following levels: * p<5%; ** p<1%; ***p<0.1%*

Table 7 reports ordinary least squares regression models for tunnel unit costs. The dependent variable in each regression is the natural logarithm of cost per square meter, and explanatory variables include project characteristics and country groups. These regression models indicate that there are statistically significant differences in unit cost between New Zealand and Europe, North America and OECD countries in general, after controlling for project size. Furthermore, there seems to be a scale effect, as unit costs for road tunnel decreases with larger tunnel volume. New Zealand road tunnels in this sample are on average larger and should therefore have lower unit costs. However, the data did not allow for testing whether these differences are partly due to other project characteristics, such as urban or rural location.

TABLE 7 - OLS REGRESSION MODELS FOR TUNNEL UNIT COSTS ($)

Outcome variable	**US$ per cubic meter**	**Model 1**	**Model 2**
	Intercept	5.81 ***	5.22 ***
Project characteristics	Volume (m3)	-2 e-07 **	-2 e-07 **
Geography (reference	Australia	0.84	
category: New Zealand)	Europe	-1.93 ***	
	North America	-3.32 *	
	OECD		-1.76 **
Number of observations		92	92
R2 (model fit)		0.30	0.30

*Notes: Coefficient estimates are reported in each row, with standard errors in parentheses. Statistical significance indicators: Reject null hypothesis that coefficient is equal to zero at the following levels: * p<5%; ** p<1%; ***p<0.1%*

3.3. Rail Stations

3.3.1 Descriptive Statistics

Table 8 presents an overview of data on rail station projects. Across all countries, unit costs for rail station projects average approximately US$40.5 million per track. However, this average is dragged up by a small number of high-cost projects. The middle 50% of rail station projects (P25-P75) have costs between US$7.2 million and US$26.4 million per track. The average duration to finish a rail station construction project is approximately 3.7 years.

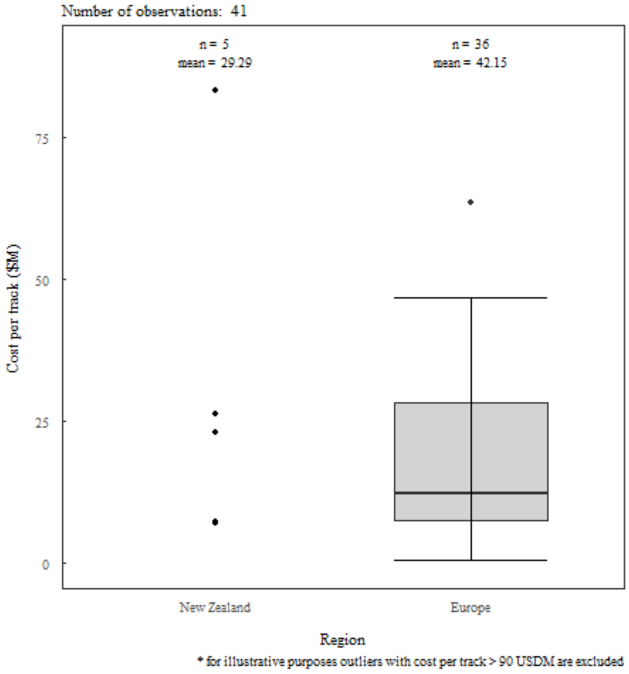
Table 8 also shows how rail station projects in New Zealand compare to the overall sample of projects. Rail station unit costs in New Zealand average US$29.3 million per track, with a median value of US$22.9 million. This is lower than the average and higher than the median in European countries. Looking at the middle 50% of unit cost, it seems that New Zealand projects are comparable with other international projects.

TABLE 8 – DESCRIPTIVE STATISTICS FOR RAIL STATIONS

	Mean (std dev)	*Min*	*Max*	*Median (P25, P75)*	*Count*
Cost per track (USD M)					
New Zealand	29.29 (31.33)	7.04	83.09	22.87 (7.24, 26.22)	5
Europe	42.15 (90.63)	0.5	514.37	12.20 (7.37, 28.05)	36
Total all countries	40.58 (85.46)	0.5	514.37	12.83 (7.24, 26.38)	41
Number of tracks					
New Zealand	2.20 (0.45)	2	3	2 (2, 2)	5
Europe	4.97 (5.02)	1	19	2.50 (2.00, 5.25)	36
Total all countries	4.63 (4.79)	1	19	2 (2, 4)	41
Duration (years)					
New Zealand	NA	NA	NA	NA	0
Europe	3.66 (2.60)	1.38	9.63	2.54 (1.86, 4.85)	15
Total all countries	3.66 (2.60)	1.38	9.63	2.54 (1.86, 4.85)	15

Figure 17 uses a box and whiskers plot to visually show the distribution of the unit costs in different country groups. This shows that New Zealand rail station unit costs are similar to European unit costs.

FIGURE 17 - DISTRIBUTION OF COST PER TRACK OF RAIL STATIONS (USD, 2021)



Note: Box and whiskers plots visually display how data is distributed. The grey-shaded box shows the 25th percentile value (lower end of box), 50th percentile/median value (black line in middle of box), and 75th percentile value (top end of box). Whiskers show the minimum and maximum values, excluding any outliers. Dots above and below the ends of the whiskers show outlier values. Outliers are defined as outside 1.5 times the interquartile range (size of the grey-shaded box) above the upper quartile and below the lower quartile. "n" is the number of observations per group and "µ" the group average. For visualization the plot has been cut off at the top in a way that not all outlier values are observable.

3.3.2 Statistical Tests

Table 9 reports the results of Wilcoxon rank-sum tests that are used to identify whether there is a statistically significant difference in the distribution of unit costs in New Zealand versus in other country groups.

No statistically significant differences in unit costs between New Zealand and Europe have been found.

TABLE 9 – WILCOXON RANK-SUM TESTS FOR STATISTICAL SIGNIFICANCE OF DIFFERENCES IN RAIL STATION UNIT COSTS

Differences between New Zealand unit costs and:	***European rail station projects (p-value)***
Europe	0.74

*Note: Statistical significance indicators: Reject null hypothesis that samples derive from the same distribution at the following levels: * p<5%; ** p<1%; ***p<0.1%*

Table 10 reports ordinary least squares regression models for rail station unit costs. The dependent variable in each regression is the natural logarithm of cost per track, and explanatory variables include project characteristics (number of tracks) and country groups. The regression models do not find statistically significant differences between different country groups, but find a statistically significant effect in economies of scale. Stations with more tracks seem to have higher unit cost.

TABLE 10 - OLS REGRESSION MODELS FOR RAIL STATION UNIT COSTS ($M)

Outcome variable	**US$ per track**	**Model 1**	**Model 2**
	Intercept	16.55 ***	16.55 ***
Project characteristics	Tracks (#)	0.10 *	0.10 *
Geography (reference category: New Zealand)	Europe	-0.46	
	North America	1.43	
	OECD		- 0.46
Number of observations		41	41
R2 (model fit)		0.13	0.13

*Notes: Coefficient estimates are reported in each row, with standard errors in parentheses. Statistical significance indicators: Reject null hypothesis that coefficient is equal to zero at the following levels: * p<5%; ** p<1%; ***p<0.1%*

3.4. ELECTRICITY TRANSMISSION LINES

3.4.1 DESCRIPTIVE STATISTICS

Table 11 presents an overview of data on transmission line projects. Across all countries, unit costs for transmission lines average US$5.35 thousand per kilovolt-kilometer. This average is dragged up by a small number of high-cost projects. The middle 50% of transmission projects (P25-P75) cost between US$2.85 thousand and US$4.64 thousand per kilovolt kilometer. The average duration to finish a transmission line construction project is three years.

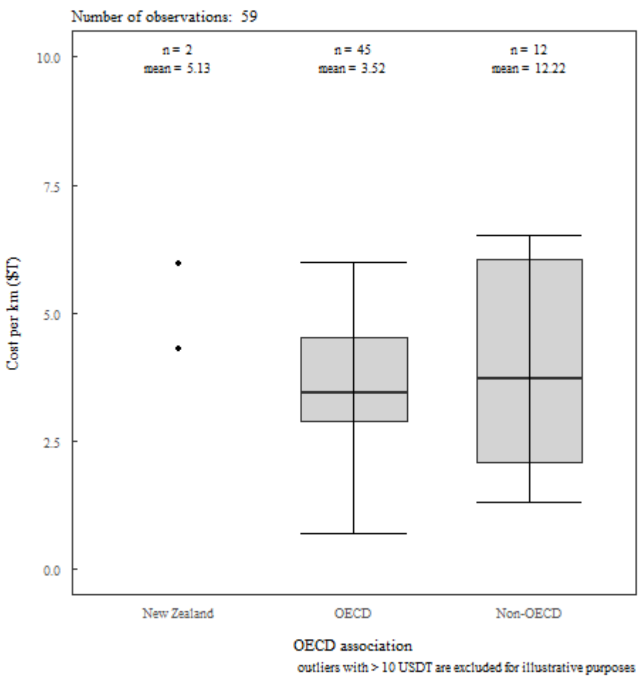
Table 11 also shows how transmission projects in New Zealand compare with the overall sample of projects. Transmission line unit costs in New Zealand average US$5.13 thousand per kilovolt-kilometer. However, this is based on only two projects completed in the last decade.

TABLE 11 – DESCRIPTIVE STATISTICS FOR ELECTRICITY TRANSMISSION PROJECTS

	Mean (std dev)	*Min*	*Max*	*Median (P25, P75)*	*Count*
Cost per kV km (USD $000)					
New Zealand	5.13 (1.19)	4.29	5.97	5.13 (4.71, 5.55)	2
OECD	3.52 (1.44)	0.68	5.98	3.43 (2.89, 4.52)	45
Non-OECD	12.22 (21.86)	1.3	73.26	3.73 (2.08, 6.03)	12
Total all countries	5.35 (10.23)	0.68	73.26	3.46 (2.85, 4.64)	59
Length (km)					
New Zealand	117 (112)	38	196	117 (78, 157)	2
OECD	101 (67)	16	309	80 (55, 142)	45
Non-OECD	359 (480)	17	1700	163 (81, 444)	12
Total all countries	154 (242)	16	1700	87 (55, 146)	59
Voltage (kV)					
New Zealand	310.00 (127.28)	220	400	310 (265, 355)	2
OECD	339.24 (49.60)	138	500	345 (345, 345)	45
Non-OECD	440.00 (89.85)	220	560	450 (400, 500)	12
Total all countries	358.75 (73.62)	138	560	345 (345, 345)	59
Duration (years)					
New Zealand	NA	NA	NA	NA	0
OECD	2.14 (0.59)	0.92	3.17	2.33 (1.69, 2.50)	44
Non-OECD	5.88 (3.89)	1.17	15	6.00 (2.50, 8.00)	13
Total all countries	3.00 (2.45)	0.92	15	2.50 (1.75, 2.75)	57

Figure 18 uses a box and whiskers plot to visually show the distribution of the unit costs in different country groups. This shows that New Zealand transmission line unit costs tends to be similar to projects in other OECD countries (principally United States data) and non-OECD countries.

FIGURE 18 - DISTRIBUTION OF COST PER KM OF TRANSMISSION LINES (USD, 2021)



Note: Box and whiskers plots visually display how data is distributed. The grey-shaded box shows the 25th percentile value (lower end of box), 50th percentile/median value (black line in middle of box), and 75th percentile value (top end of box). Whiskers show the minimum and maximum values, excluding any outliers. Dots above and below the ends of the whiskers show outlier values. Outliers are defined as outside 1.5 times the interquartile range (size of the grey-shaded box) above the upper quartile and below the lower quartile. "n" is the number of observations per group and "μ" the group average. For visualization the plot has been cut off at the top in a way that not all outlier values are observable.

3.4.2 Statistical Tests

Table 12 reports the results of Wilcoxon rank-sum tests that are used to identify whether there is a statistically significant difference in the distribution of unit costs in New Zealand versus in other country groups.

No statistically significant differences in costs per kilovolt km have been found between New Zealand and other regions included in the analysis. However, it must be highlighted that the sample includes only two New Zealand projects. Therefore, the statistical tests have very little power and any conclusion from the test result might be misleading.

TABLE 12 – WILCOXON RANK-SUM TESTS FOR STATISTICAL SIGNIFICANCE OF DIFFERENCES IN TRANSMISSION LINE UNIT COSTS

Differences between New Zealand unit costs and:	*All transmission line projects (p-value)*
OECD	0.400
Non-OECD	1.000

*Note: Statistical significance indicators: Reject null hypothesis that samples derive from the same distribution at the following levels: * p<5%; ** p<1%; ***p<0.1%*

Table 13 reports ordinary least squares regression models for transmission line unit costs. The dependent variable in each regression is the natural logarithm of cost per kilovolt-kilometer, and explanatory variables include project characteristics and country groups. Regression models confirm previous results, suggesting that there is no difference in unit cost for transmission line construction between New Zealand and OECD countries or between New Zealand and Non-OECD countries. The model does find that unit costs in African countries are higher compared to New Zealand, but small sample size biases might be present in this estimation since there is only one African project in the data. Furthermore, model 1 estimates a statistically significant negative effect of the length of the electricity transmission line on its unit cost. However, project length and voltage are the only controls for project characteristics included in these models, and it is possible that these differences reflect other unmeasured factors, such as topography, and whether transmission lines were HVAC (High Voltage Alternating Current) or HVDC (High Voltage Direct Current).

TABLE 13 - OLS REGRESSION MODELS FOR ELECTRICITY TRANSMISSION LINE UNIT COSTS ($T)

Outcome variable	US$ per lane-km	Model 1	Model 2
	Intercept	9.51 ***	9.52 ***
Project characteristics	Length (km)	-0.002 *	-0.0002
	Voltage (kV)	-0.002	-0.003
Geography (reference category: New Zealand)	Asia	0.45	
	Africa	3.52 *	
	North America	-0.45	
	Non-OECD		0.41
	OECD		-0.41
Number of observations		59	59
R2 (model fit)		0.20	0.14

*Notes: Coefficient estimates are reported in each row, with standard errors in parentheses. Statistical significance indicators: Reject null hypothesis that coefficient is equal to zero at the following levels: * p<5%; ** p<1%; ***p<0.1%*

3.5. Wind Farm Projects

3.5.1 Descriptive Statistics

Table 14 presents an overview of data on wind farm projects. Across all countries, unit costs for wind farm projects average approximately US$3.5 million per megawatt of installed capacity. The middle 50% of wind farm projects (P25-P75) have costs between US$1.9 million and US$4 million per megawatt. The average duration to finish a wind farm construction project is a little over 2 years.

Table 14 also shows how wind farm projects in New Zealand compare with the overall sample of projects. Wind farm unit costs in New Zealand average US$2.15 million per megawatt installed capacity, with the middle 50% of projects (P25-P75) costing between US$1.61 million and US$2.44 million per megawatt. However, New Zealand's average costs are lower in part because all New Zealand projects are onshore wind farms, whereas many overseas projects are higher-cost offshore wind farms.

TABLE 14 – DESCRIPTIVE STATISTICS FOR WIND FARM PROJECTS

	Mean (std dev)	*Min*	*Max*	*Median (P25, P75)*	*Count*
Cost per MW (USD $M)					
New Zealand	2.15 (0.86)	1.13	4.17	1.86 (1.61, 2.44)	15
Australia	2.10 (0.48)	1.61	2.90	1.89 (1.81, 2.37)	10
Europe	3.77 (2.30)	0.26	15.21	2.96 (2.25, 5.12)	57
North America	2.17 (1.70)	0.19	8.45	2.29 (1.29, 2.48)	20
South America	6.62 (NA)	6.62	6.62	6.62 (6.62, 6.62)	1
Asia	6.04 (9.93)	1.8	42.68	3.30 (2.46, 3.99)	16
OECD	3.65 (4.62)	0.19	42.68	2.61 (1.89, 4.15)	92
Non-OECD	3.91 (2.24)	1.8	8.28	3.09 (2.30, 4.59)	12
Total all countries	3.49 (4.16)	0.19	42.68	2.52 (1.89, 3.96)	119
Capacity (MW)					
New Zealand	66.63 (61.41)	2.50	222	58.00 (22.84, 92)	15
Australia	165.57 (146.24)	48.30	420	115.50 (55, 196.05)	10
Europe	274.80 (297.26)	4	1381	180.00 (90, 352.8)	57
North America	278.40 (363.10)	2	1547	225.00 (9.25, 345)	20
South America	15.30 (NA)	15.3	15.3	15.3 (15.3, 15.3)	1
Asia	97.58 (116.34)	14	500	49.50 (49.23, 100.5)	16
OECD	252.33 (295.49)	2	1547	168.00 (60, 345)	92
Non-OECD	104.12 (133.64)	15.30	500	49.50 (49.23, 100.5)	12
Total all countries	214 (273)	2	1547	110 (49.5, 290)	119
Duration (years)					
New Zealand	NA	NA	NA	NA	0
Australia	5.01 (3.46)	1.33	9	5.90 (1.50, 7.30)	5
Europe	1.93 (1.72)	0.5	7.5	1.42 (1.25, 1.94)	24
North America	1.48 (1.56)	0.42	6	0.92 (0.58, 1.50)	13
South America	NA	NA	NA	NA	0
Asia	2.83 (1.89)	1.5	5	2.00 (1.75, 3.50)	3
OECD	2.22 (2.19)	0.42	9	1.42 (0.92, 2.23)	9
Non-OECD	1.75 (0.35)	1.5	2	1.75 (1.62, 1.88)	2
Total all countries	2.20 (2.14)	0.42	9	1.42 (0.92, 2.17)	45

Figure 19 and Figure 20 use a box and whiskers plots to visually show the distribution of the unit costs in different country groups. The first figure groups countries by continent and the second figure groups non-New Zealand countries by OECD/non-OECD groups. These charts show that New Zealand wind farm unit costs are similar to, or lower than, unit costs in other country groups. Moreover, average wind farm unit costs appear to be slightly higher in OECD countries compared with non-OECD countries.

FIGURE 19 – DISTRIBUTION OF COST PER INSTALLED MW CAPACITY OF WIND FARMS (USD, 2021)

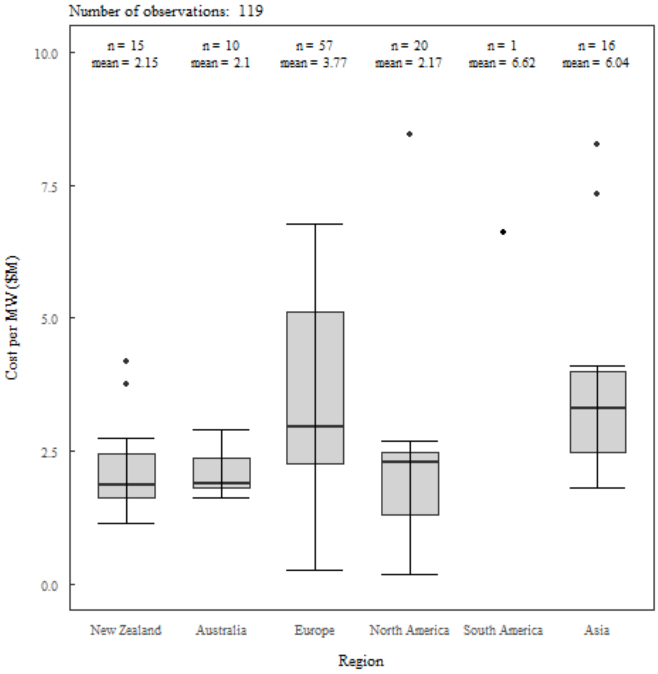
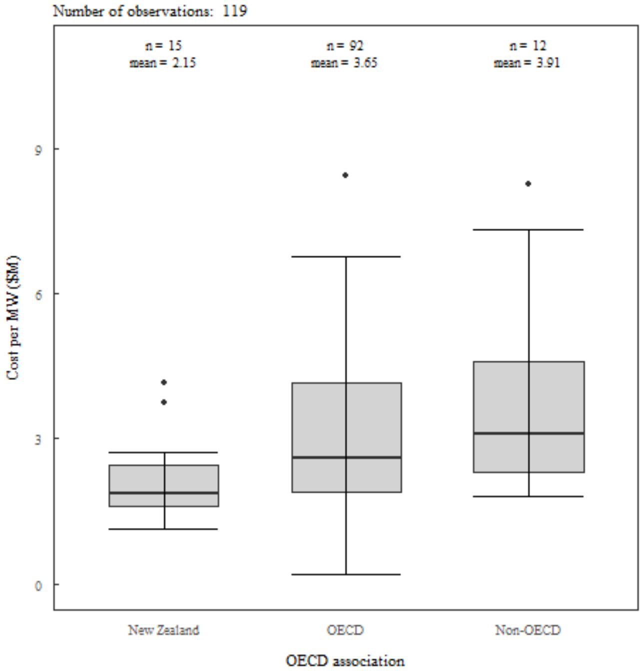


FIGURE 20 – DISTRIBUTION OF COST PER INSTALLED MW CAPACITY OF WIND FARMS BY OECD ASSOCIATION (USD, 2021)



Note: Box and whiskers plots visually display how data is distributed. The grey-shaded box shows the 25th percentile value (lower end of box), 50th percentile/median value (black line in middle of box), and 75th percentile value (top end of box). Whiskers show the minimum and maximum values, excluding any outliers. Dots above and below the ends of the whiskers show outlier values. Outliers are defined as outside 1.5 times the interquartile range (size of the grey-shaded box) above the upper quartile and below the lower quartile. "n" is the number of observations per group and "μ" the group average. For visualization the plot has been cut off at the top in a way that not all outlier values are observable.

Table 15 shows an overview of a subset of onshore wind farm projects exclusively. Notice that the numbers for New Zealand are the same as before in Table 14, meaning that all New Zealand wind farm projects are onshore. New Zealand's average unit costs for onshore wind farm projects is now close to the overall sample average (approximately US$2.3 million per megawatt of installed capacity).

TABLE 15 – DESCRIPTIVE STATISTICS FOR ONSHORE WIND FARM PROJECTS

	Mean (std dev)	*Min*	*Max*	*Median (P25, P75)*	*Count*
Cost per MW (USD $M)					
New Zealand	2.15 (0.86)	1.13	4.17	1.86 (1.61, 2.44)	15
Australia	1.75 (0.12)	1.61	1.83	1.80 (1.70, 1.81)	3
Europe	1.01 (1.06)	0.26	1.75	1.01 (0.63, 1.38)	2
North America	1.99 (0.55)	1.36	2.34	2.29 (1.82, 2.31)	3
Asia	3.37 (2.01)	1.8	8.28	2.51 (2.23, 3.96)	9
OECD	2.24 (1.08)	0.26	4.09	2.06 (1.72, 2.66)	12
Non-OECD	3.34 (2.77)	1.8	8.28	2.23 (2.07, 2.32)	5
Total all countries	2.37 (1.39)	0.26	8.28	2.06 (1.75, 2.53)	32

Figure 21 and Figure 22 plot data for onshore wind farm projects only, which represent roughly one-quarter of the full dataset but all of the New Zealand projects. This shows that New Zealand onshore wind farm unit costs are similar to onshore wind farm costs in both OECD and non-OECD countries.

FIGURE 21 – DISTRIBUTION OF COST PER INSTALLED MW CAPACITY OF ONSHORE WIND FARMS (USD, 2021)

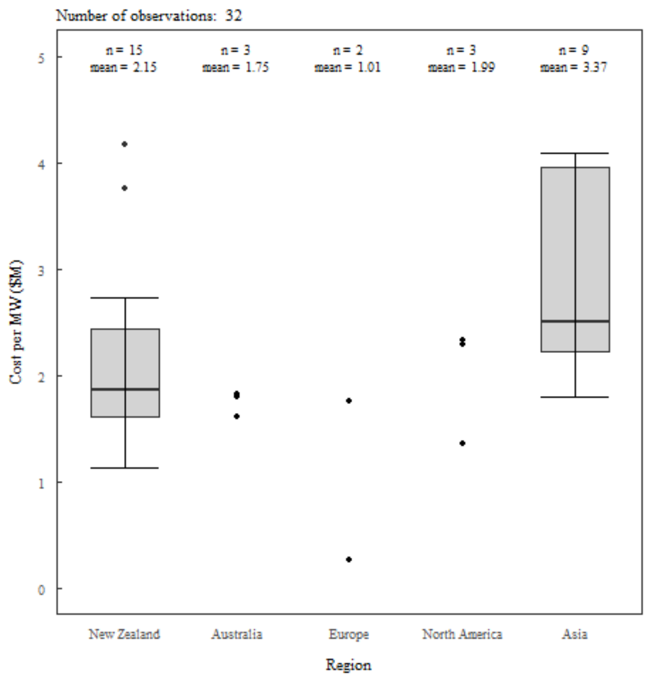
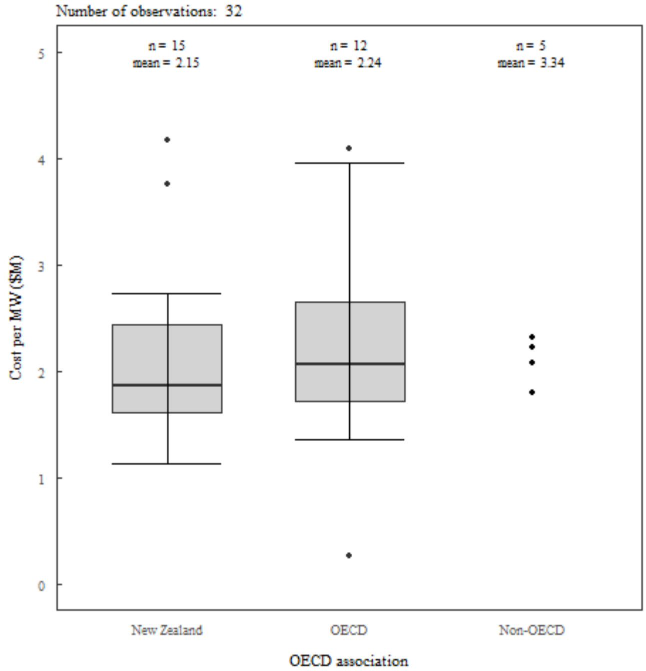


FIGURE 22 – DISTRIBUTION OF COST PER INSTALLED MW CAPACITY OF ONSHORE WIND FARMS BY OECD ASSOCIATION (USD, 2021)



Note: Box and whiskers plots visually display how data is distributed. The grey-shaded box shows the 25th percentile value (lower end of box), 50th percentile/median value (black line in middle of box), and 75th percentile value (top end of box). Whiskers show the minimum and maximum values, excluding any outliers. Dots above and below the ends of the whiskers show outlier values. Outliers are defined as outside 1.5 times the interquartile range (size of the grey-shaded box) above the upper quartile and below the lower quartile. "n" is the number of observations per group and "μ" the group average. For visualization the plot has been cut off at the top in a way that not all outlier values are observable.

3.5.2 Statistical Tests

Table 16 reports the results of Wilcoxon rank-sum tests that are used to identify whether there is a statistically significant difference in the distribution of unit costs in New Zealand versus in other country groups.

When bundling together all types of wind farm projects, weak statistically significant differences in cost per megawatt installed capacity have been found between New Zealand (Mdn = 1.86), Europe (Mdn = 2.96), $W = 193$, $p = 0.018$ and Asia (Mdn = 2.51), $W = 44$, $p = 0.026$. It seems that wind farm projects in Europe cost more than in New Zealand.

However, these differences disappear when focusing only on onshore wind farm projects. There is no statistically significant difference in onshore wind farm unit costs between New Zealand and any of the other regions.

TABLE 16 – WILCOXON RANK-SUM TESTS FOR STATISTICAL SIGNIFICANCE OF DIFFERENCES IN WIND FARM UNIT COSTS

Differences between New Zealand unit costs and:	*All wind farm projects (p-value)*	*Onshore wind farm projects (p-value)*
Australia	1.000	1.000
Europe	0.018*	1.000
North America	1.000	1.000
South America	1.000	NA
Asia	0.026*	0.35
OECD	0.024*	1.000
Non-OECD	0.022*	0.800

*Note: Statistical significance indicators: Reject null hypothesis that samples derive from the same distribution at the following levels: * p<5%; ** p<1%; ***p<0.1%*

Table 17 reports ordinary least squares regression models for wind farm unit costs. The dependent variable in each regression is the natural logarithm of cost per megawatt, and explanatory variables include project characteristics and country groups. Regression models confirm previous results and find statistically significant differences in unit cost between New Zealand and Europe. Furthermore, the model finds that unit costs for onshore wind farm projects are lower than unit costs for offshore wind farms, a difference that is statistically significant.

TABLE 17 – OLS REGRESSION MODELS FOR WIND FARM UNIT COSTS ($M)

Outcome variable	**US$ per megawatt**	**Model 1**	**Model 2**
	Intercept	2.00 ***	1.46 ***
Project characteristics	Onshore indicator	-1.30 ***	-0.76 ***
Geography (reference category: New Zealand)	Asia	0.30	
	Australia	-0.21	
	Europe	-0.65 *	
	North America	-0.04	
	Non-OECD		0.22
	OECD		-0.02
Number of observations		104	104
R2 (model fit)		0.29	0.30

*Notes: Coefficient estimates are reported in each row, with standard errors in parentheses. Statistical significance indicators: Reject null hypothesis that coefficient is equal to zero at the following levels: * p<5%; ** p<1%; ***p<0.1%*

3.6. Hospitals

3.6.1 Descriptive Statistics

Table 18 presents an overview of data on hospital projects. Across all countries, unit costs for hospital projects average US$7,690 per square meter. The middle 50% of hospital projects (P25-P75) have costs between US$5,210 and US$8,770 per square meter. The average duration to finish a hospital construction project is approximately 4 years.

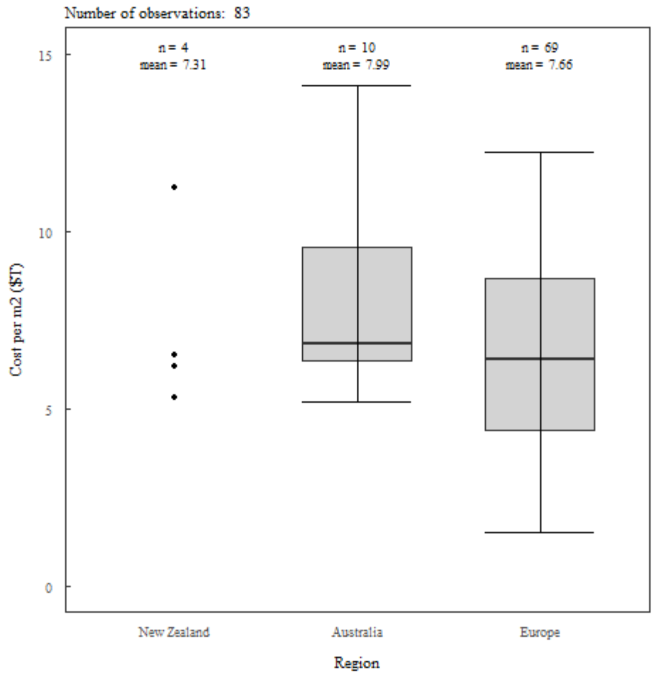
Table 18 also shows how hospital projects in New Zealand compare to the overall sample of projects. The average cost of recently completed hospital projects in New Zealand is US$7,310 per square meter, which is very similar to the average for other countries. The average duration to finish a hospital construction project in New Zealand is less than 4 years.

TABLE 18 – DESCRIPTIVE STATISTICS FOR HOSPITAL PROJECTS

	Mean (std dev)	*Min*	*Max*	*Median (P25, P75)*	*Count*
Cost per m2 (USD $000)					
New Zealand	7.31 (2.66)	5.32	11.23	6.34 (5.97, 7.68)	4
Australia	7.99 (2.86)	5.21	14.14	6.85 (6.36, 9.57)	10
Europe	7.66 (6.36)	1.52	46.44	6.38 (4.41, 8.68)	69
Total all countries	7.69 (5.89)	1.52	46.44	6.47 (5.21, 8.77)	83
Size (000 m2)					
New Zealand	27.60 (24.79)	8.50	62	20 (10, 37.55)	4
Australia	58.76 (56.66)	9	165	36 (16, 84.25)	10
Europe	44.87 (60.21)	0.25	269	23 (10.35, 54.70)	69
Total all countries	45.71 (58.46)	0.25	269	25 (10.52, 55.01)	72
Duration (years)					
New Zealand	4.42 (1.23)	2.84	5.51	4.67 (3.77, 5.32)	4
Australia	3.52 (1.12)	1.93	5.33	3.46 (2.69, 4.11)	10
Europe	3.64 (2.31)	1	13.34	2.82 (2.17, 4.02)	66
Total all countries	3.67 (2.15)	1	13.34	3.00 (2.20, 4.37)	80

Figure 23 uses a box and whiskers plot to visually show the distribution of the unit costs in different country groups. This shows that New Zealand hospital costs are similar to Australian costs. European project costs vary more than costs in either Australia or New Zealand, but they vary around a similar average and median.

FIGURE 23 - DISTRIBUTION OF COST PER SQUARE METER OF HOSPITALS (USD, 2021)



Note: Box and whiskers plots visually display how data is distributed. The grey-shaded box shows the 25th percentile value (lower end of box), 50th percentile/median value (black line in middle of box), and 75th percentile value (top end of box). Whiskers show the minimum and maximum values, excluding any outliers. Dots above and below the ends of the whiskers show outlier values. Outliers are defined as outside 1.5 times the interquartile range (size of the grey-shaded box) above the upper quartile and below the lower quartile. "n" is the number of observations per group and "μ" the group average. For visualization the plot has been cut off at the top in a way that not all outlier values are observable.

3.6.2 Statistical Tests

Table 19 reports the results of Wilcoxon rank-sum tests that are used to identify whether there is a statistically significant difference in the distribution of unit costs in New Zealand versus in other country groups.

We found no statistically significant differences in costs per square meter between New Zealand and other regions included in the analysis.

An important matter to notice is that hospitals are very heterogenous in services and characteristics. To be able to compare different hospital projects, many different variables must be taken into account. Therefore, this report and its conclusions on hospital construction cost should be understood as a high-level benchmark.

TABLE 19 – WILCOXON RANK-SUM TESTS FOR STATISTICAL SIGNIFICANCE OF DIFFERENCES IN HOSPITAL UNIT COSTS

Differences between New Zealand unit costs and:	*All hospital projects (p-value)*
Australia	0.960
Europe	0.960

*Note: Statistical significance indicators: Reject null hypothesis that samples derive from the same distribution at the following levels: * p<5%; ** p<1%; ***p<0.1%*

Table 20 reports ordinary least squares regression models for hospital unit costs. The dependent variable in each regression is the natural logarithm of cost per square meter, and explanatory variables include project characteristics and country groups. Regression models confirm the previous result and do not find statistically significant differences between different country groups, although they do find a statistically significant effect of hospital size on unit cost. Larger hospitals seem to be less expensive per square meter.

TABLE 20 – OLS REGRESSION MODELS FOR HOSPITAL UNIT COSTS ($T)

Outcome variable	**US$ per square meter**	**Model 1**	**Model 2**
	Intercept	8.95 ***	8.95 ***
Project characteristics	Size (m2)	-3e-06***	-4e-06***
Geography (reference	Australia	0.20	
category: New Zealand)	Europe	-0.03	
	OECD		-4.704e-03
Number of observations		83	83
R2 (model fit)		0.17	0.15

*Notes: Coefficient estimates are reported in each row, with standard errors in parentheses. Statistical significance indicators: Reject null hypothesis that coefficient is equal to zero at the following levels: * p<5%; ** p<1%; ***p<0.1%*

4. Summary of Benchmarking Analysis

Table 21 summarises key conclusions from this analysis, based on differences in average unit costs and statistical tests of differences in the distribution of unit costs between countries. We found statistically significant differences between unit costs in New Zealand and some other countries for some project types, but not others.

This benchmarking analysis has several important limitations. First, there are a small number of New Zealand projects in some project categories (e.g. tunnels, transmission lines, and hospitals), which means that it is difficult to identify statistically significant differences in costs or to generalize from these findings to other projects. Second, information was not available on some project attributes that affect cost, such as urban or rural location, topography, and design specifications. This limits our ability to provide an exact like-for-like comparison for New Zealand projects.

TABLE 21 – SUMMARY OF BENCHMARKING RESULTS

Project type	Conclusion
Motorways	There is **some evidence of statistically significant differences** in the unit cost to build motorways between New Zealand and other country groupings. The difference in unit costs of urban motorways between New Zealand and North America is statistically significant at the 10% level, and the difference in unit costs of rural motorways between New Zealand and Europe is statistically significant at the 5% level.
Tunnels	There is **some evidence of statistically significant differences** in the unit cost to build road tunnels in New Zealand and other countries. New Zealand is statistically significantly more expensive than Europe. However, were unable to control for urban / rural location, which might affect cost.
Rail Stations	There are **no statistically significant differences** in the cost of building rail stations in New Zealand versus in Europe or North America.
Electricity transmission lines	There are **no statistically significant differences** in the unit cost of building transmission lines in New Zealand relative other countries included in the analysis. However, we were unable to control for some project characteristics that might influence costs.
Wind farm projects	There are **no statistically significant differences** in the unit cost of building onshore wind farms in New Zealand relative to other countries included in the

	analysis. However, New Zealand's onshore wind farms tend to be cheaper to build than offshore wind farms, which are more common overseas.
Hospitals	There are **no statistically significant differences** in the unit cost of building hospitals in New Zealand relative to Australia or Europe. However, we were unable to control for project scope and complexity, which might affect cost.

5. Cost and Schedule Overruns

This section provides statistical benchmarks for cost and schedule overruns for each project category. This data can be used to support reference class forecasting of project cost and schedule outcomes.

Due to lack of data for the estimated versus actual costs and durations for all New Zealand projects, we were unable to benchmark and test for geographical performance differences in overruns between New Zealand infrastructure projects and international projects. However, we did create international reference classes for all six project types. This section of the report explains the benefit of using historical data on cost and overruns and presents reference class data for the six project types.

3.7. Why reference class forecasting?

About seven out of ten rail projects have cost overruns. Overruns of up to 50% in real terms are common and overruns over 50% are not uncommon. For example, nearly 30% of rail projects exceeded their cost estimates by more than 50%. Use of this historical data can be used to increase projects' chances of succeeding against the odds common in transport infrastructure projects. Specifically, the data can be used to remove bias from project estimates.

Traditional project cost forecasting methods include three-point estimates, Monte Carlo simulations and Earned Value Management (EVM). The use of these methods has led projects to experience large cost overruns and schedule delays. One of the main explanations for this is optimism bias, the tendency to be overly optimistic about future actions, resulting in underestimation of cost and schedule. Project owners may disregard or underestimate risk and uncertainty in forecasts. Optimism bias is often the result of taking an 'inside view' of projects, rather than looking for 'outside' information on risk and uncertainty.

Traditional forecasting techniques typically take an 'inside view'. They include a fixed contingency to the project cost estimate to account for risk and uncertainty in cost estimation, often 10% of the estimated cost. However, contingencies derived using traditional methods are often smaller than needed to address cost overruns that occur in practice.

Reference Class Forecasting (RCF) is an estimating approach that deals with optimism bias by taking an 'outside view' in determining the contingency amount based on statistical analysis of actual outcomes for similar projects.

The effectiveness of RCF depends on the availability of a large enough pool of sufficiently similar projects. If these criteria are met, RCF will outperform other approaches for estimating the distribution of cost and schedule risk. Independent research has shown that this RCF outperforms conventional forecasting and monitoring techniques, such as trend analyses and EVM.

3.8. What are the steps of Reference Class Forecasting?

Reference Class Forecasting follows three steps:

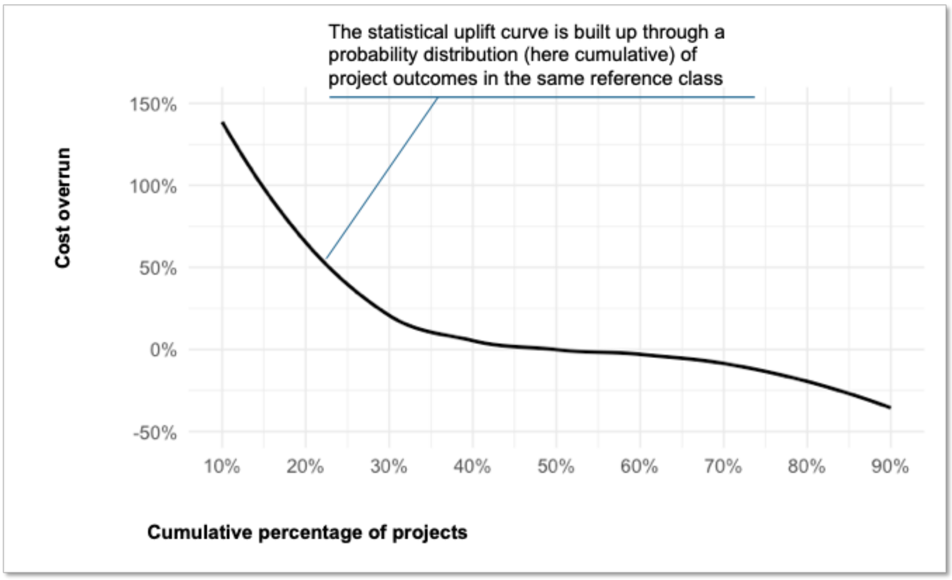
1. Identify a sample of past, similar projects – typically a minimum of 20-30 projects is enough to get started, but the more projects the better;
2. Establish the risk of the variable in question based on these projects – i.e. identify the cost overruns of these projects; and
3. Adjust the current estimate – through an uplift or by asking whether the project at hand is more or less risky than projects in the reference class.

First, a reference class is selected. The key to a reasonable reference class is to draw upon a large number of past projects and use statistical analysis to identify projects that are most similar in terms of scope, scale, and context. Optimism bias should not be re-introduced into the analysis by excluding data on some comparable or potentially comparable projects.

Second, the distribution of the data in question is analyzed. The cumulative distribution of cost and schedule overruns is constructed. This involves sorting past projects from largest to smallest overrun, calculating the relative share of each data point in the sample is calculated (e.g., if 25 projects are in a reference class each project has 4% share), and summing up cumulative weights so that the distribution ranges from 0% to 100% (i.e., the project with the largest overrun project represents 4%, the second highest overrun 8% and so on.

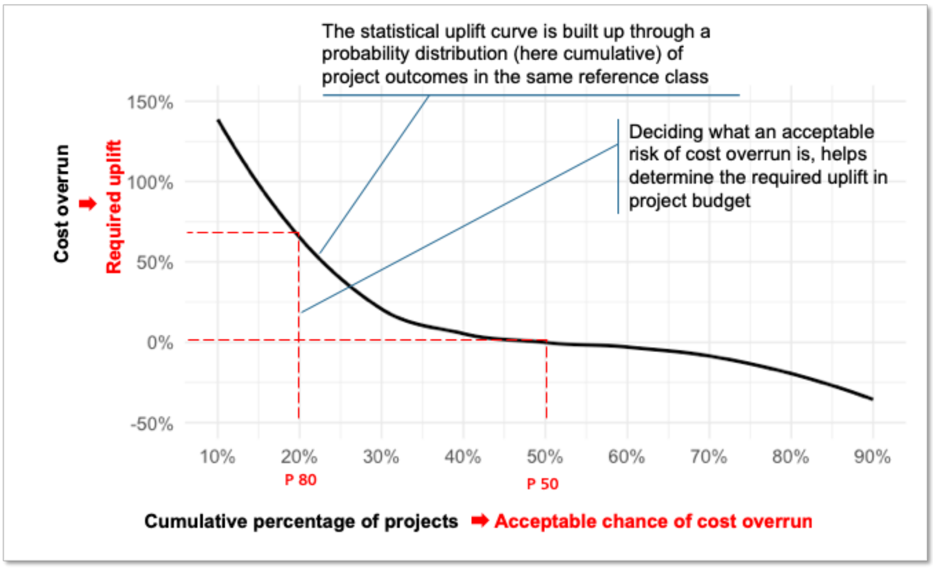
Figure 24 depicts how a cumulative distribution curve is then charted.

FIGURE 24 – CUMULATIVE PROBABILITY DISTRIBUTION OF OVERRUN IN THE REFERENCE CLASS (CONCEPTUAL)



Third, the cumulative distribution is then used to identify the necessary cost or schedule uplift required to de-bias forecasts created based on an 'inside view' of the project. The cumulative distribution of overruns can be used to identify the amount of uplift to apply to arrive at a 50th percentile, 80th percentile, or another percentile cost estimate. Figure 25 illustrates how this can be done.

FIGURE 25 – ESTABLISHING THE UPLIFTS AS A FUNCTION OF THE ACCEPTABLE CHANCE OF COST OVERRUN BASED ON THE CUMULATIVE DISTRIBUTION OF COST OVERRUN IN THE REFERENCE CLASS (CONCEPTUAL)



The historical overrun combined with the risk appetite of decision makers for the project then becomes the uplift necessary to de-bias the inside estimate. A higher percentile value implies a lower tolerance for cost or schedule overruns. For example, if decision makers accept a 50% chance of overrun (i.e. they require a 50% certain estimate or P50) then a certain uplift should be added. If decision makers are more risk averse and only accept a 20% chance of overrun (i.e. they require a 80% certain estimate or P80) then a larger uplift needs to be added.

It should be noted that the distribution is based on the historical overruns in similar, completed projects. Thus, projects might need to consider whether any additional adjustments to the chosen level of certainty are needed. For instance, if a project has progressed further with a detailed design development at a given stage than other projects in the reference class, then it may be appropriate to reduce cost overrun assumptions to reflect better quality planning. Any adjustment in the final step ought to be **based on hard evidence** to avoid reintroducing optimism back into the estimate.

Because Reference Class Forecasts are based on the actual outcomes of similar past projects, the method estimates not only the known unknowns of a project, i.e. risks identified ex-ante. The method also estimates the unknown-unknowns for the project, i.e. risks that have not been identified but may nevertheless impact the project.

Reference Class Forecasting has been used by the UK Department for Transport since 2004 to implement the HMT Green Book. The method has been endorsed by the American Planning Association and is recommended practice in Switzerland, Denmark, The Netherlands, and Australia.

3.9. INTERNATIONAL REFERENCE CLASSES FOR THE SIX PROJECT TYPES

With the available data, we constructed six project specific international reference classes for cost and schedule overruns for each of the six project types.

Cost overrun is calculated as *Actual Cost / Estimated Cost – 1*, where estimated cost is the cost estimate at the full business case or final investment decision stage and actual cost at project completion. The estimated cost is the base cost, i.e. the estimated cost excluding provisions for risk or uncertainty.

Schedule overrun is calculated as *Actual Schedule / Estimated Schedule – 1*, where estimated schedule is measured as the duration from estimated construction start to the date of planned opening/substantial completion. Actual schedule is measured as the duration from construction start to the date of substantial completion/actual opening.

Table 22 displays an overview of the international reference classes for each project category, while Table 23 shows the full data distributions. Charts showing RCF curves can be found in Appendix A.

TABLE 22 – OVERVIEW OF INTERNATIONAL REFERENCE CLASSES

	Cost/schedule overrun (mean)	*50% certainty of the estimate (P50)*	*80% certainty of the estimate (P80)*
Roads			
Cost overrun	22%	16%	47%
Schedule overrun	20%	11%	57%
Tunnels			
Cost overrun	36%	24%	68%
Schedule overrun	22%	2%	44%
Rail stations			
Cost overrun	43%	18%	60%
Schedule overrun	40%	17%	53%
Electrical Transmission Lines			
Cost overrun	8%	0%	15%
Schedule overrun	7%	0%	0%
Wind Power Projects			
Cost overrun	12%	1%	22%
Schedule overrun	28%	15%	38%
Hospitals			
Cost overrun	23%	0%	23%
Schedule overrun	45%	28%	68%

TABLE 23 – COST AND SCHEDULE OVERRUN DISTRIBUTIONS FOR INTERNATIONAL REFERENCE CLASSES

	Motorways		Tunnels		Rail Stations		Electrical Transmission		Wind Power		Hospitals	
Percentage of projects (%)	Cost overrun (%)	Schedule overrun (%)	Cost overrun (%)	Schedule overrun (%)	Cost overrun (%)	Schedule overrun (%)	Cost overrun (%)	Schedule overrun (%)	Cost overrun (%)	Schedule overrun (%)	Cost overrun (%)	Schedule overrun (%)
5%	-23%	-30%	-22%	-13%	-11%	-10%	-29%	0%	-14%	-18%	-8%	-11%
10%	-14%	-22%	-17%	-12%	-7%	0%	-16%	0%	-4%	-14%	-3%	-1%
15%	-7%	-17%	-8%	-6%	-4%	0%	-7%	0%	-1%	-10%	0%	0%
20%	-3%	-12%	-2%	-4%	-2%	1%	-5%	0%	-1%	-6%	0%	0%
25%	1%	-7%	0%	-3%	-2%	7%	-3%	0%	0%	0%	0%	0%
30%	3%	-3%	6%	-1%	1%	11%	-1%	0%	0%	0%	0%	7%
35%	7%	0%	12%	0%	5%	13%	0%	0%	0%	0%	0%	13%
40%	9%	0%	18%	0%	10%	13%	0%	0%	0%	5%	0%	18%
45%	13%	7%	22%	1%	11%	15%	0%	0%	0%	10%	0%	25%
50%	16%	11%	24%	2%	18%	17%	0%	0%	1%	15%	0%	28%
55%	19%	15%	26%	5%	21%	21%	0%	0%	3%	18%	2%	32%
60%	22%	19%	32%	11%	27%	28%	1%	0%	5%	22%	5%	41%
65%	27%	26%	33%	11%	36%	44%	6%	0%	7%	25%	7%	46%
70%	31%	27%	46%	14%	42%	50%	9%	0%	11%	28%	13%	51%
75%	38%	41%	52%	31%	49%	51%	12%	0%	13%	33%	16%	60%
80%	47%	57%	68%	44%	60%	53%	15%	0%	22%	38%	23%	68%
85%	59%	69%	72%	69%	84%	72%	17%	0%	32%	47%	35%	100%
90%	70%	100%	108%	79%	129%	89%	24%	12%	35%	65%	81%	126%
95%	102%	121%	157%	85%	185%	99%	33%	43%	54%	125%	136%	147%
N	977	340	69	26	71	54	50	49	84	53	89	95
Average overrun	22%	20%	36%	22%	43%	40%	8%	7%	12%	28%	23%	45%

Appendix A: List of included New Zealand projects

Motorways

Project Name	Year	Type	Length (km)	Lanes	Urban/non-urban	Actual Cost (millions, 2021 USD)	Cost per lane km (millions, 2021 USD)
Christchurch Northern Motorway	2020	New road	16	3.5	Urban	201.8229294	3.603980882
Christchurch Southern Motorway Stage 1	2012	New road	8	3.25	Urban	117.9655099	4.537134995
Christchurch Southern Motorway Stage 2	2020	New road	7.5	4	Urban	135.7085215	4.523617383
Christchurch Western Belfast Bypass	2017	New road	5	4	Urban	91.39678622	4.569839311
Kapiti Expressway: Mackays to Peka Peka	2017	New road	18	4	Urban	471.9670108	6.555097373
Kapiti Expressway: Otaki to North of Levin	2021	New road	24	4	Urban	807.3446837	8.409840455
Kapiti Expressway: Peka Peka to Otaki	2021	New road	13	4	Urban	272.4788307	5.239977514
Manawatū Tararua Highway	2021	New road	11.5	4	Non-urban	417.1280866	9.068001882
Penlink	2021	New road	7	2	Urban	497.8625549	35.56161107
SH1 Albany-Silverdale (2000)	2000	New road	14	4	Urban	137.9745703	2.463831612
SH1 Manukau to Papakura widening	2021	Widening	9.2	2	Urban	239.5122562	13.01697044
SH1 Newmarket to Greenlane (2011)	2011	Widening	2.3	1	Urban	11.52685784	5.011677322
SH1 Northcote-Sunnynook widening (2008)	2008	Widening	4.4	1	Urban	8.945440636	2.03305469
SH1 Northern Gateway (2009)	2009	New road	7.5	4	Urban	311.0008377	10.36669459
SH1 Papakura to Drury South Stage 1	2021	Widening	4.5	2	Urban	440.6756399	48.96395998
SH1 Puhoi to Warkworth	2020	New road	18.5	4	Urban	610.6883467	8.252545226
SH16 Lincoln to Westgate widening (2019)	2019	Widening	4.5	2	Urban	78.13246559	8.681385065
SH16 NW Widening (2011)	2011	Widening	13	2.2	Urban	84.13764847	2.901298223
SH16 Upper Harbour-Greenhithe (2007)	2007	New road	6.5	4	Urban	103.0231643	3.962429397
SH16 Upper Harbour-Hobsonville (2012)	2012	New road	7.5	4	Urban	185.3743727	6.179145756
SH20 Manukau Extension (2011)	2011	New road	4.5	6	Urban	176.6890618	6.544039326
SH20 Mt Roskill Extension (2009)	2009	New road	4	4	Urban	178.6033382	11.16270864
Takitumu North Link Stage 1	2021	New road	6.8	4	Urban	440.6756399	16.20131029
Takitumu North Link Stage 2	2021	New road	7	4	Urban	366.6690438	13.09532299

Tauranga Eastern Link	2015	New road	21	4	Urban	361.1887295	4.299865828
Transmission Gully	2021	New road	27	4	Urban	840.9840455	7.78688931
Waikato Expressway: Cambridge	2015	New road	16	4	Non-urban	144.4754918	2.25742956
Waikato Expressway: Hamilton bypass	2021	New road	21.8	4	Non-urban	408.3818525	4.683278125
Waikato Expressway: Huntly	2020	New road	15.2	4	Non-urban	266.545455	4.3839713
Waikato Expressway: Longswamp	2020	New road	5.9	4	Non-urban	64.0265845	2.712990869

ROAD TUNNELS

Project Name	Year	Length (km)	Lanes	Diameter (m)	Actual Cost (millions, 2021 USD)	Volume (m3)	Cost per m3 (2021 USD)
LGWM Mt Vic Tunnel	2021	1400	4	12.2	60.23340664	280000	215.1193094
SH1 Victoria Park Tunnel (2011)	2011	440	1.5		34.15988528	53240	641.6206852
SH20 Waterview (2016)	2016	2400	6	14.4	108.5494056	781728.7832	138.8581411
Additional Waitemata Harbour Crossing road tunnel	2020	5500	8	15.5	695.9411358	2075610.996	335.294589

RAIL STATIONS

Project Name	Year	Type	Tracks	Actual Cost (millions, 2021 USD)	Cost per Track (millions, 2021 USD)
Panmure Station (completed 2014)	2014	Surface	2	14.08962	7.044809
Otahuhu Station (completed 2016)	2016	Surface	3	21.70988	7.236627
Puhinui Station (completed 2021)	2021	Surface	2	45.74953	22.87477
Rosedale Station (2017 estimate)	2017	Surface	2	52.44078	26.22039

Electricity Transmission Lines

Project Name	Year	Length (km)	Voltage (kV)	Actual Cost (millions, 2021 USD)	Cost per KM (millions, 2021 USD)
North island grid upgrade	2012	196	400	336.2017032	4288.28703
Wairakei-Whakamaru C line	2014	38	220	49.9175047	5970.993385

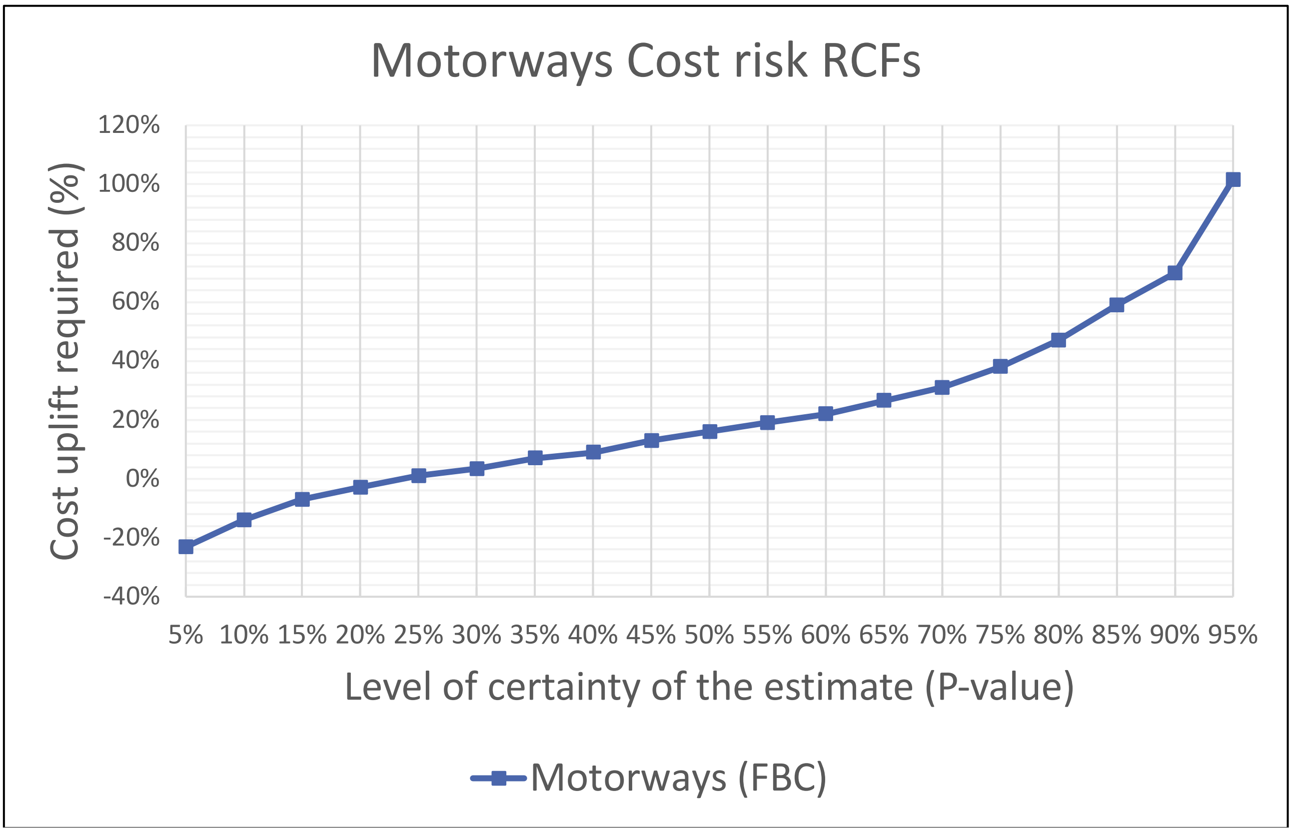
Wind Farms

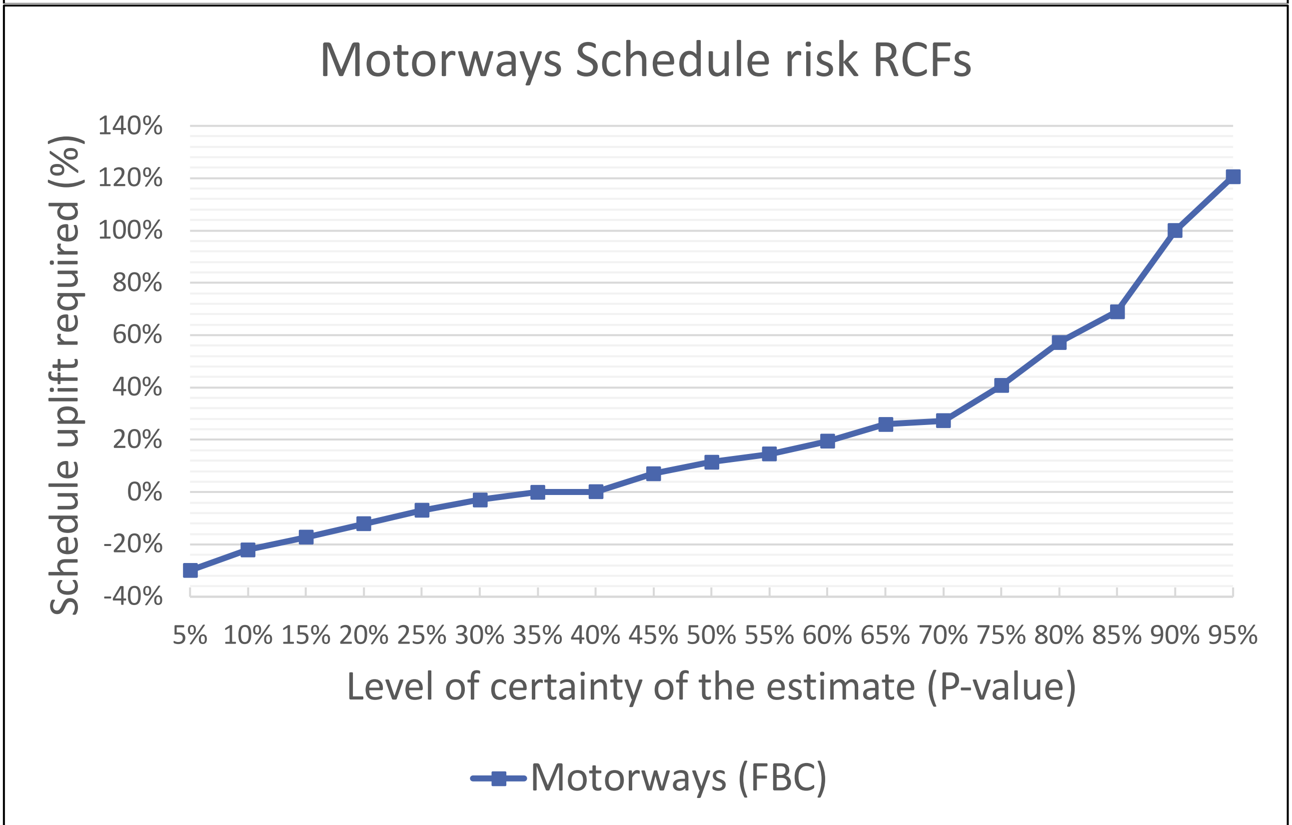
Project Name	Year	Subtype	Megawatt (MW)	Actual Cost (millions, 2021 USD)	Cost per MW (millions, 2021 USD)
Tararua Stage 1	1999	onshore	31.68	68.62694481	2.166254571
Tararua Stage 2	2004	onshore	36.3	63.00578782	1.735696634
Te Apiti	2004	onshore	91	186.779453	2.052521461
Te Rere Hau Stage 1	2006	onshore	2.5	10.43251093	4.173004372
Tararua Stage 3	2007	onshore	93	168.5833598	1.812724299
White Hill	2007	onshore	58	76.26390085	1.314894842
Te Rere Hau Stage 2	2009	onshore	14	52.6188286	3.758487757
West Wind	2009	onshore	143	390.9724817	2.734073298
Mahinerangi	2011	onshore	36	63.10323635	1.752867677
Te Uku	2011	onshore	64.4	168.2752969	2.612970449
Mt Stuart	2011	onshore	7.7	14.30340024	1.857584447
Mill Creek	2014	onshore	60	136.0654564	2.267757606
Flat Hill	2015	onshore	6.8	7.660376352	1.126525934
Waipipi	2019	onshore	133	196.0414591	1.473995933
Turitea	2019	onshore	222	329.5769458	1.484580837

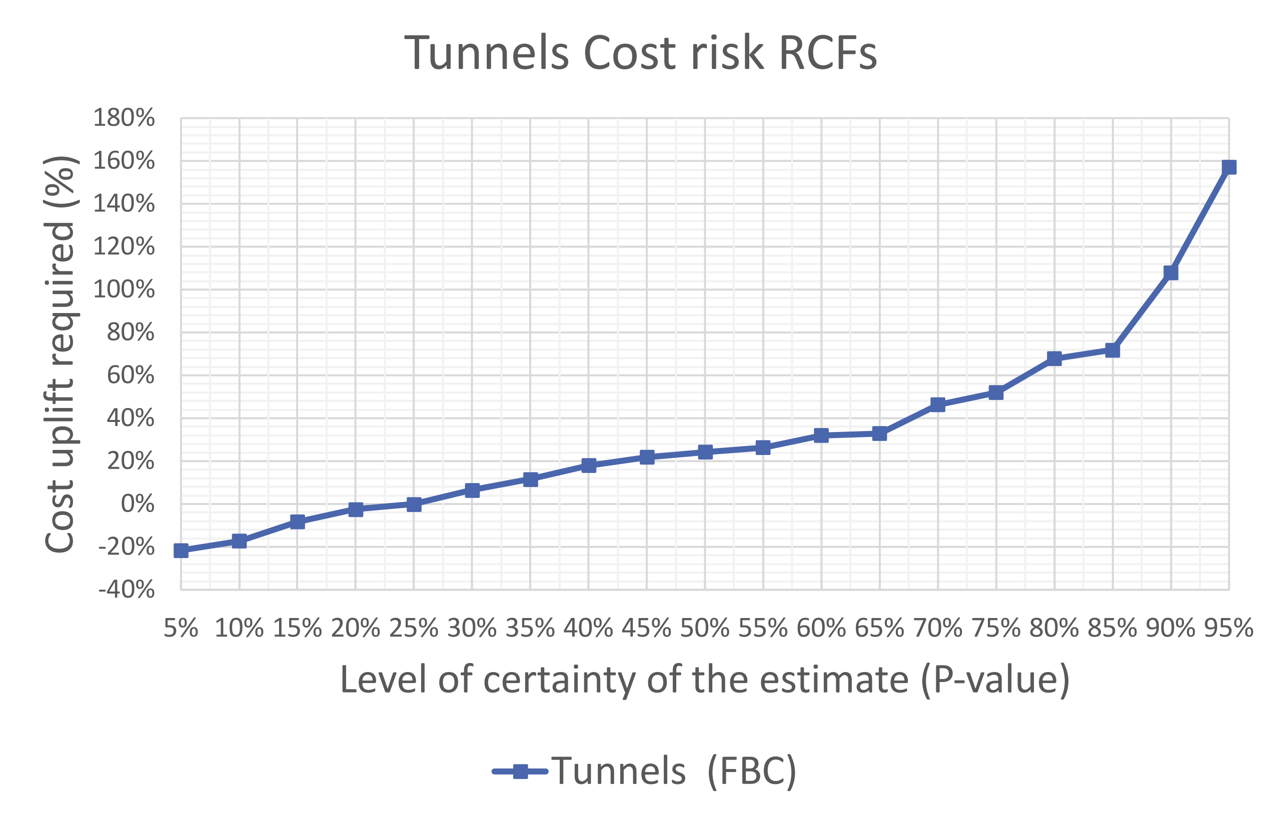
HOSPITALS

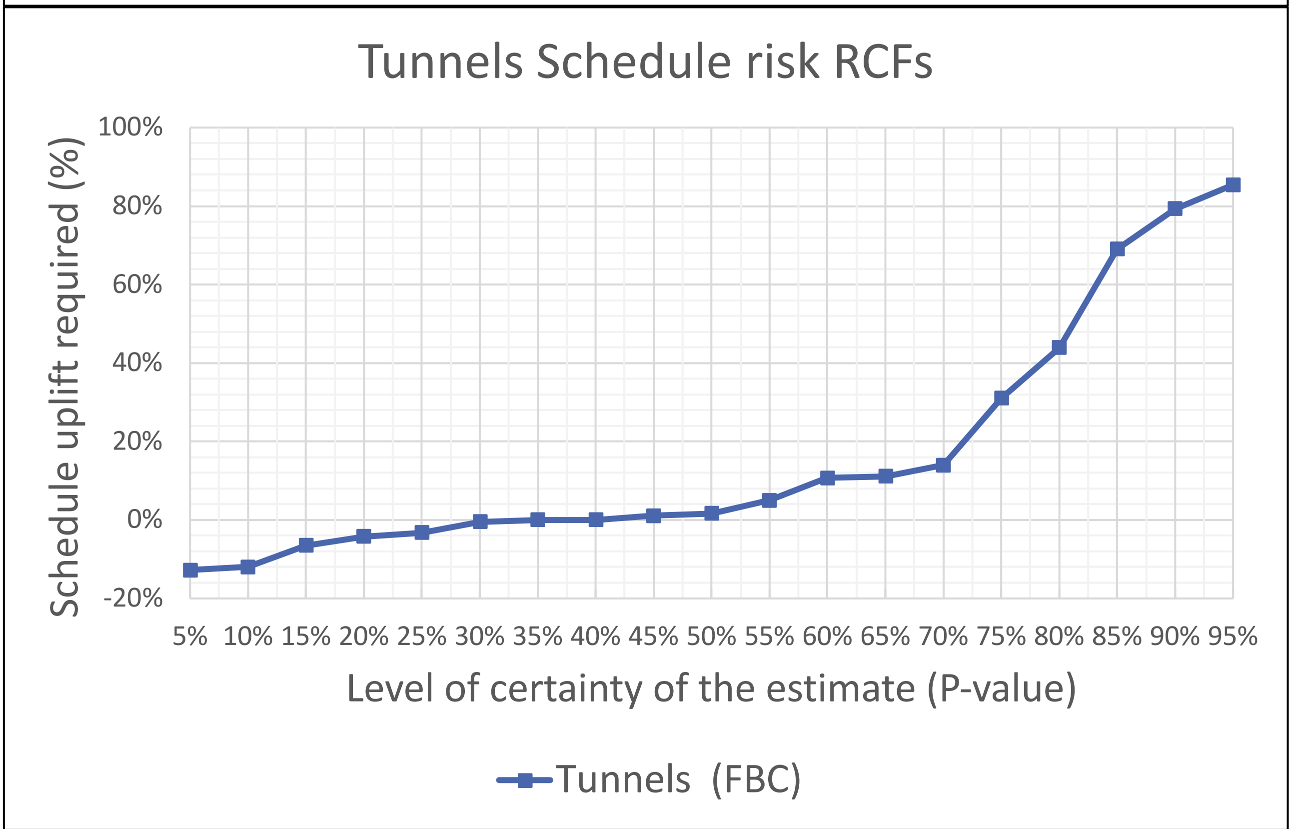
Project Name	Year	m2	Number of beds	Actual Cost (millions, 2021 USD	Cost per m2 (2021 USD)
Canterbury DHB – Burwood Redevelopment	2015	29400	230	181.7850968	6183.16656
West Coast DHB – Te Nikau	2018	8500	56	95.48706948	11233.77288
Canterbury DHB – Christchurch Acute Services Building (Waipapa)	2018	62000	413	402.8245887	6497.170786
Canterbury DHB – Christchurch Outpatients Building	2016	10500		55.82540861	5316.705582

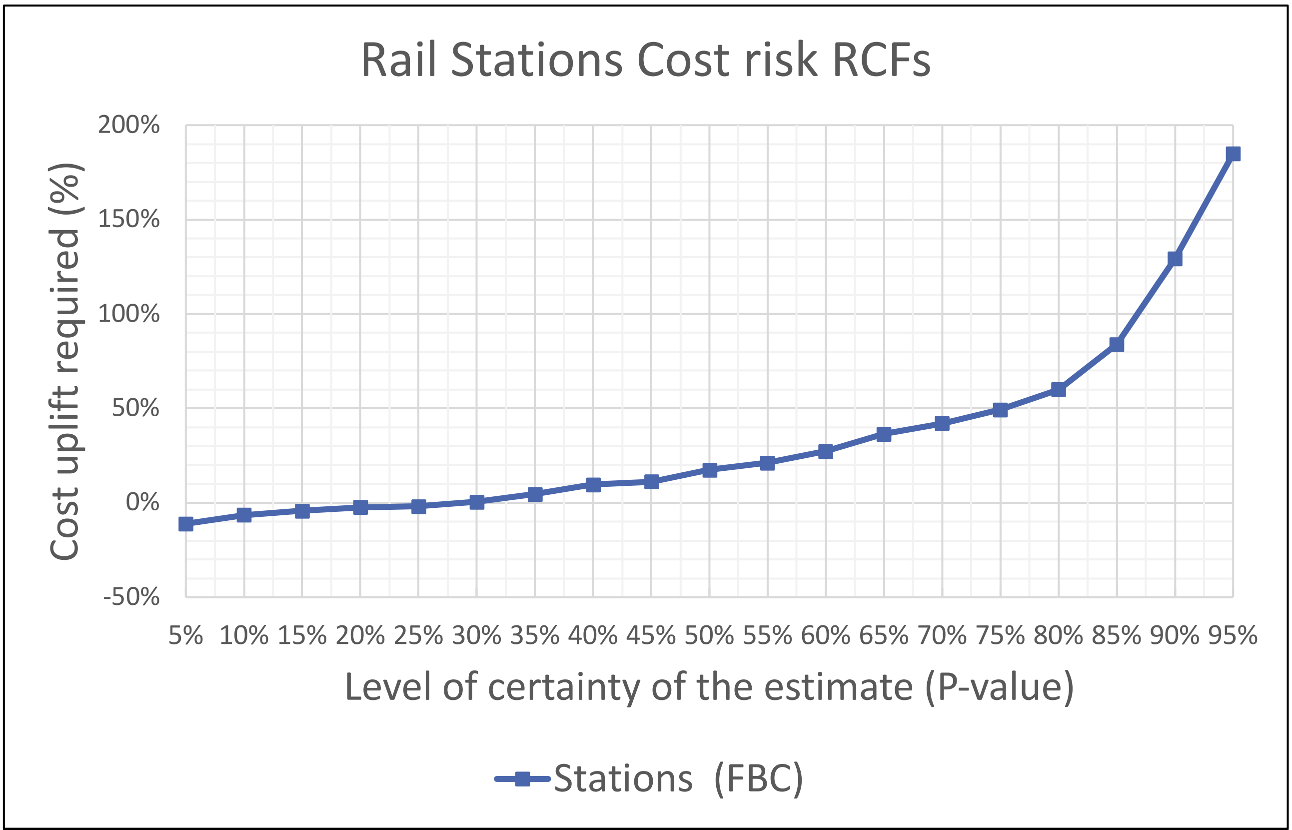
APPENDIX B: REFERENCE CLASS FORECASTING CURVES

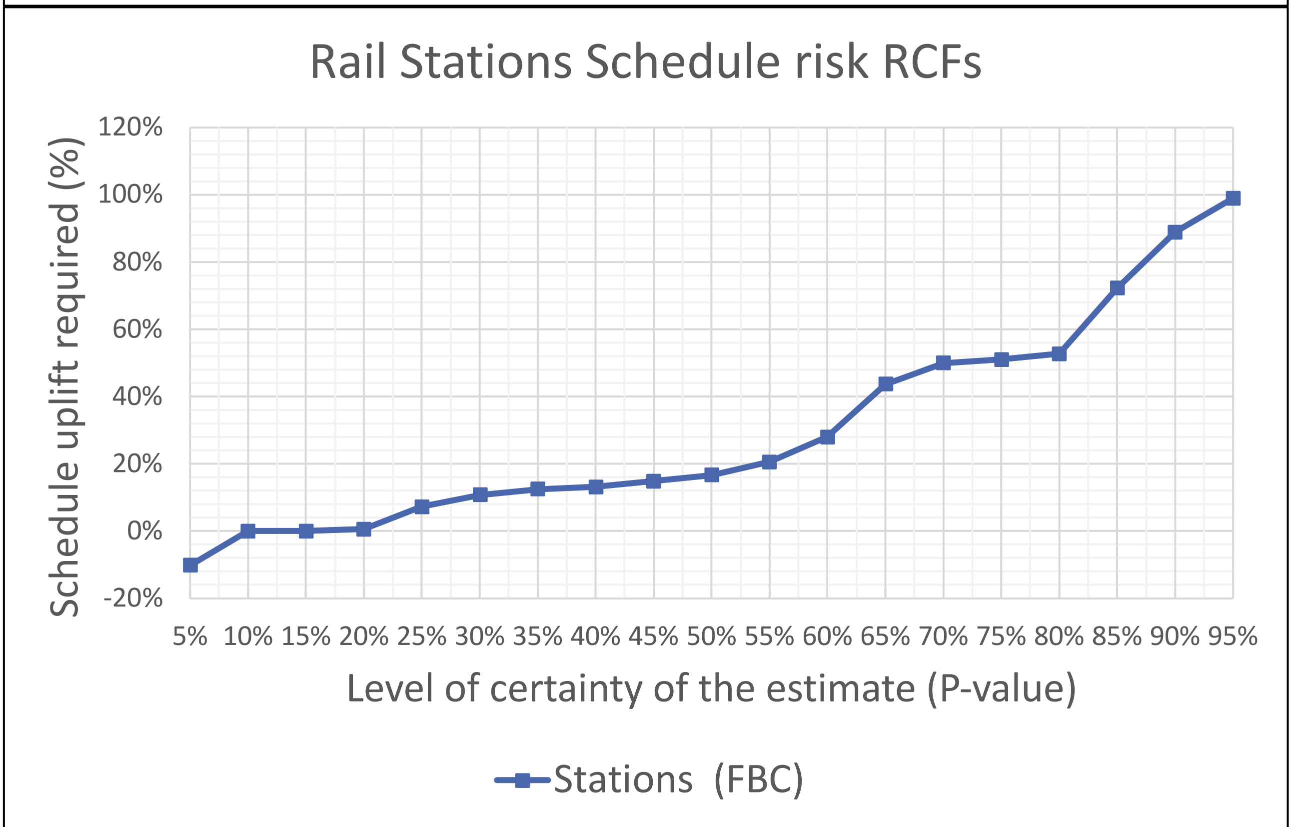


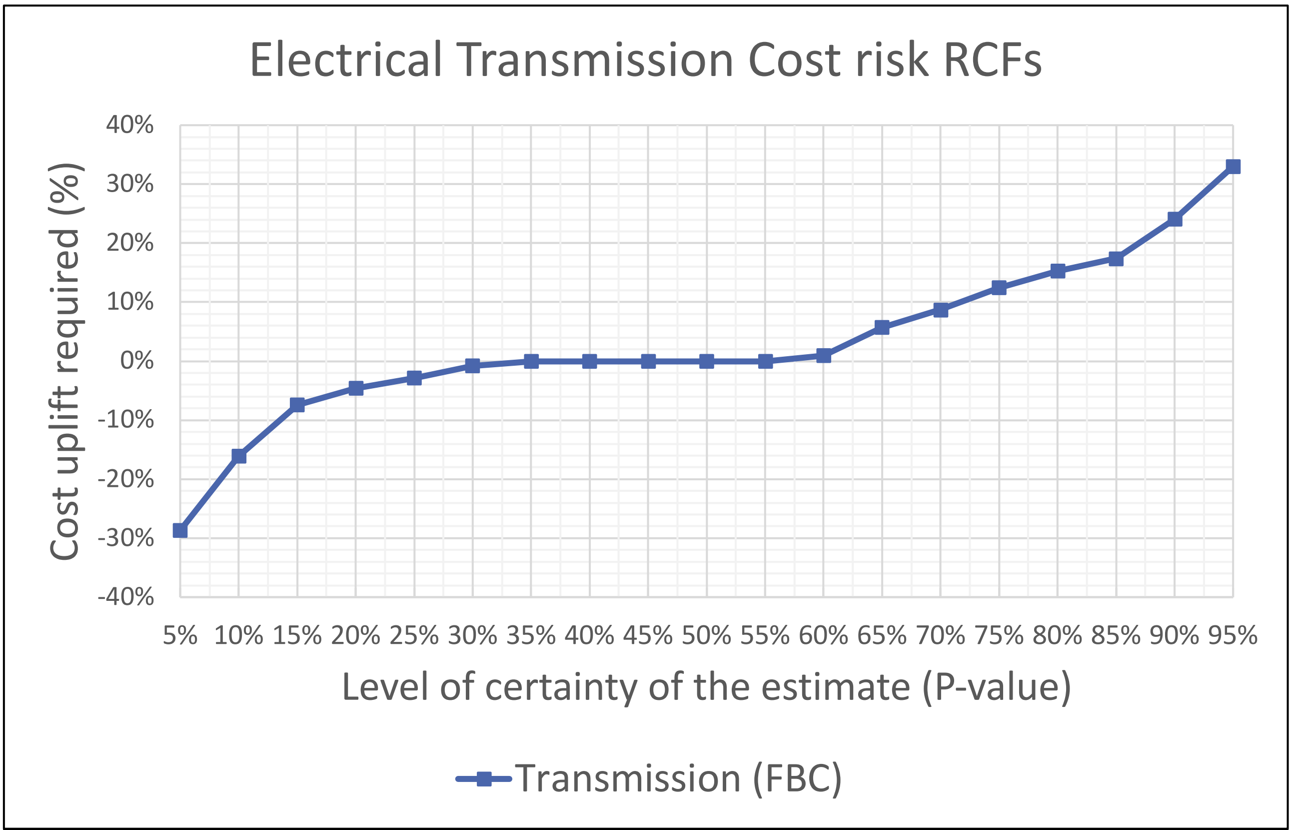


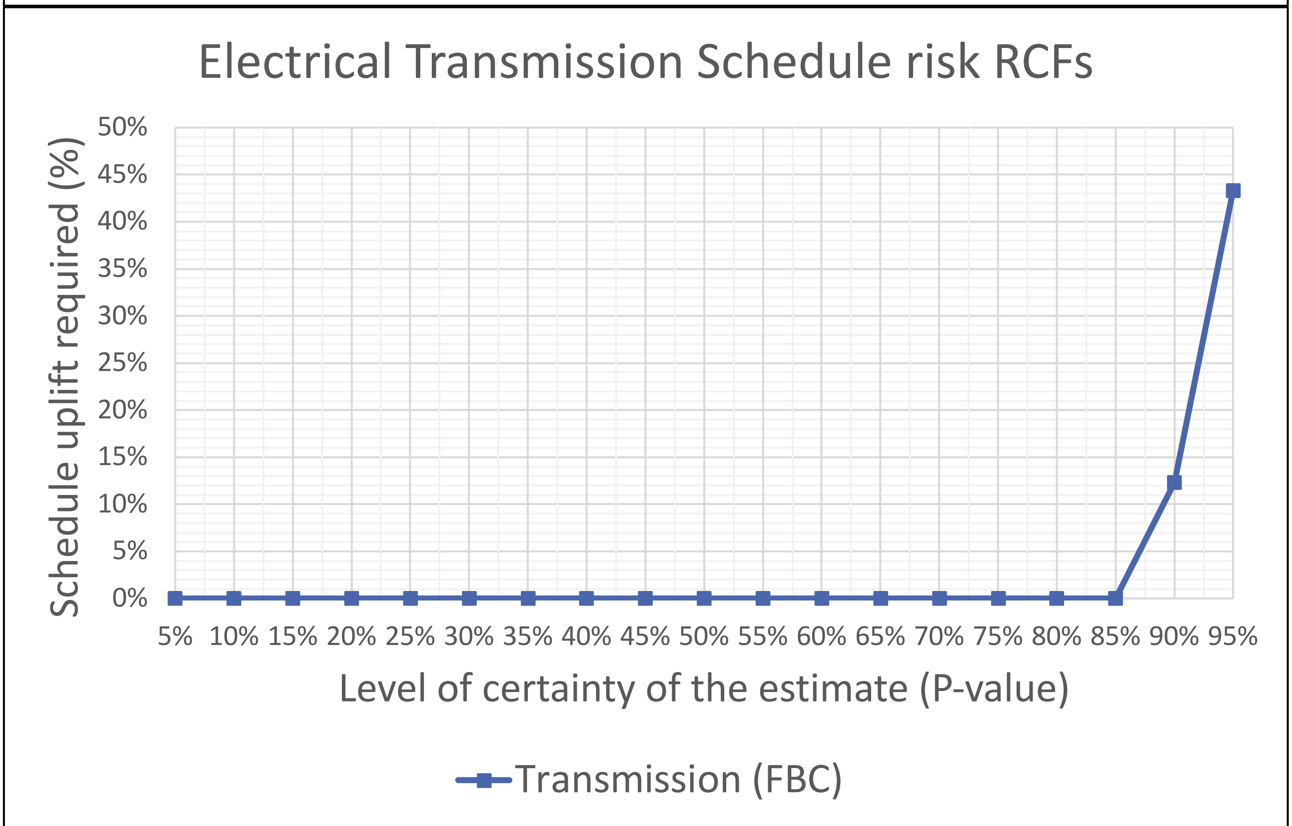

Tunnels Cost risk RCFs
Cost uplift required (%)
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
-20%
-40%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate (P-value)
Tunnels (FBC)

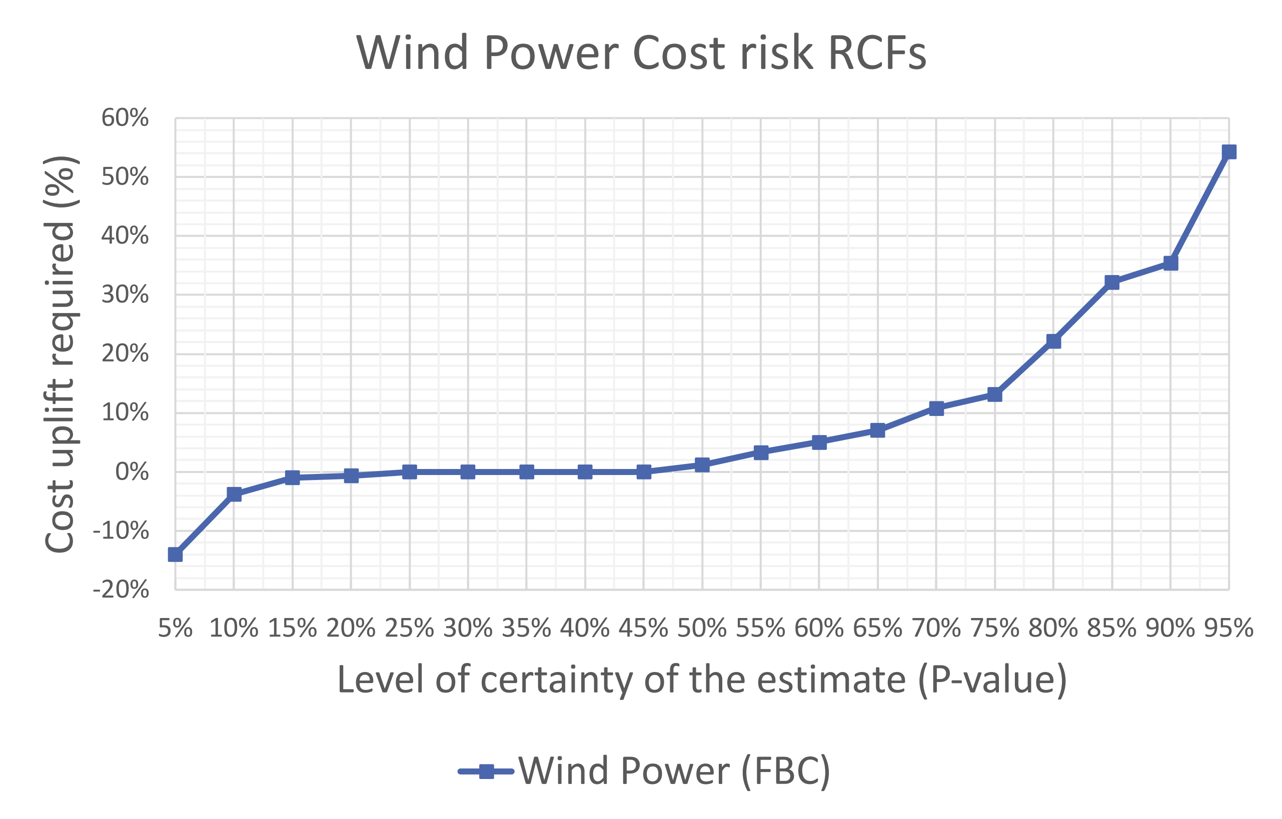

Tunnels Schedule risk RCFs
Schedule uplift required (%)
100%
80%
60%
40%
20%
0%
-20%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate (P-value)
Tunnels (FBC)


Rail Stations Cost risk RCFs
Cost uplift required (%)
200%
150%
100%
50%
0%
-50%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate (P-value)
Stations (FBC)

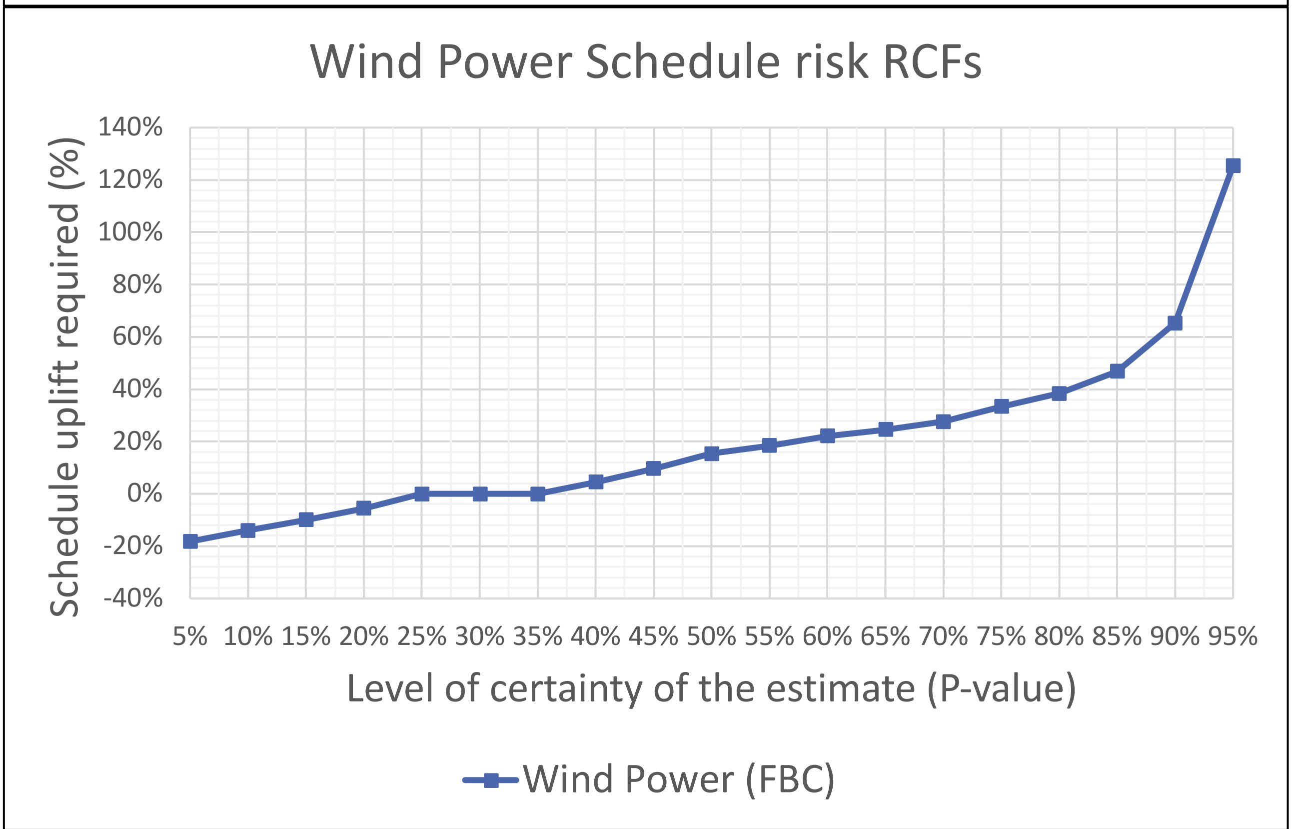

Rail Stations Schedule risk RCFs
Schedule uplift required (%)
120%
100%
80%
60%
40%
20%
0%
-20%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate (P-value)
Stations (FBC)


Electrical Transmission Cost risk RCFs
Cost uplift required (%)
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate (P-value)
Transmission (FBC)

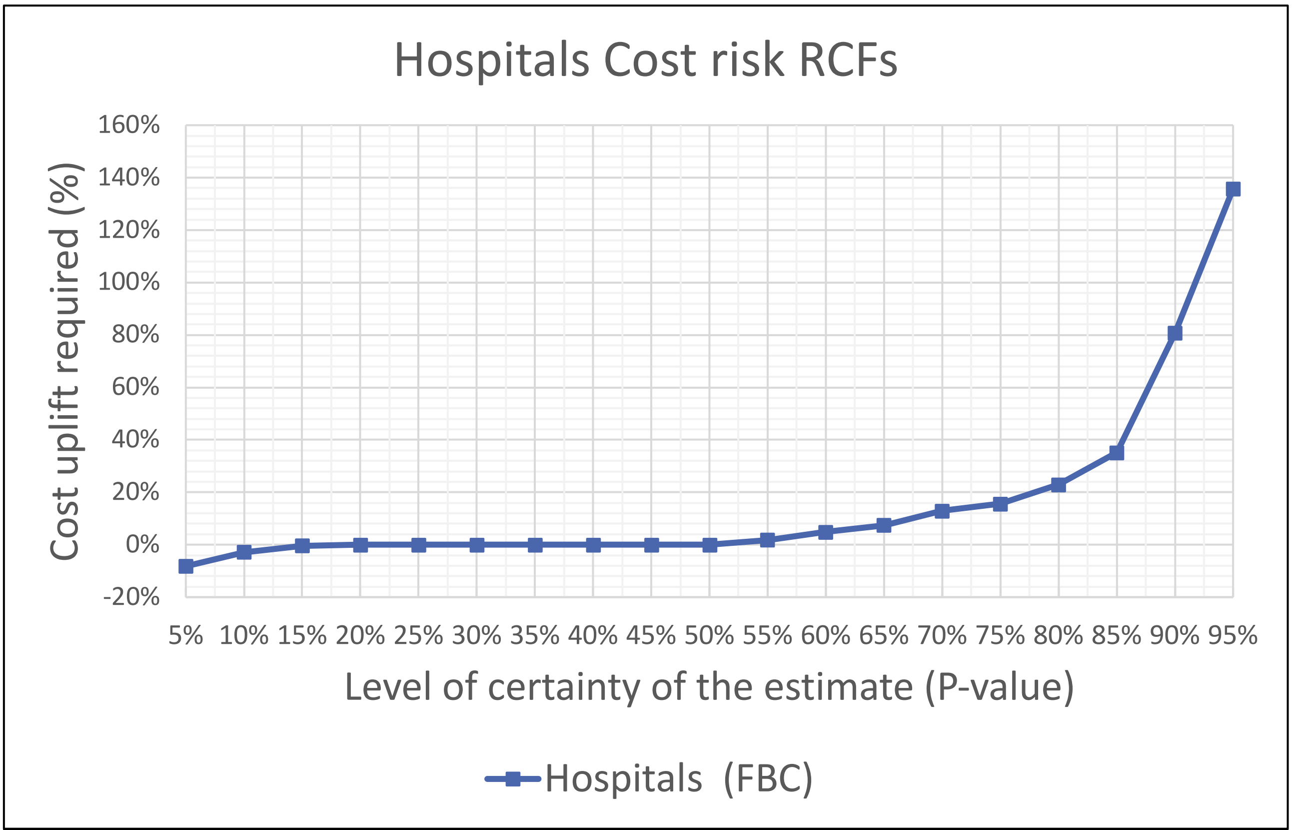

Electrical Transmission Schedule risk RCFs
Schedule uplift required (%)
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate (P-value)
Transmission (FBC)

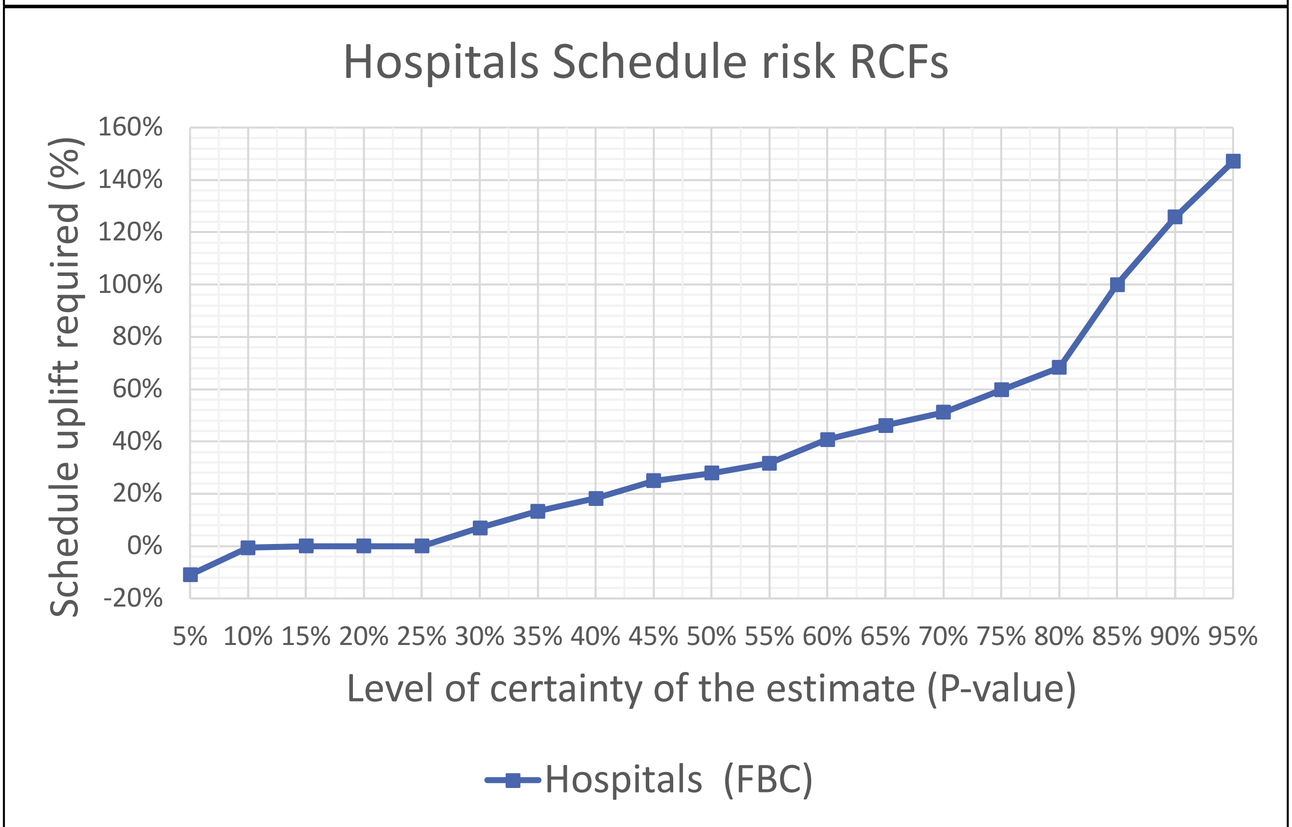


Wind Power Cost risk RCFs
Cost uplift required (%)
60%
50%
40%
30%
20%
10%
0%
-10%
-20%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate (P-value)
Wind Power (FBC)



Wind Power Schedule risk RCFs
Schedule uplift required (%)
140%
120%
100%
80%
60%
40%
20%
0%
-20%
-40%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate (P-value)
Wind Power (FBC)


Hospitals Cost risk RCFs
Cost uplift required (%)
160%
140%
120%
100%
80%
60%
40%
20%
0%
-20%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate (P-value)
Hospitals (FBC)


Hospitals Schedule risk RCFs
Schedule uplift required (%)
160%
140%
120%
100%
80%
60%
40%
20%
0%
-20%
5% 10% 15% 20% 25% 30% 35% 40% 45% 50% 55% 60% 65% 70% 75% 80% 85% 90% 95%
Level of certainty of the estimate (P-value)
Hospitals (FBC)