Cost overruns in Dutch transportation infrastructure projects

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Samenvatting

Kostenoverschrijdingen in Nederlandse transport infrastructuur projecten

Dit paper gaat in op de kostenoverschrijding van transport infrastructuur projecten in Nederland. Een database van 84 projecten (weg, rail of kunstwerken) is geconstrueerd, en door middel van statistische analyses zijn kenmerken van de kosten van projecten achterhaald. De gemiddelde kostenoverschrijding is 10.3% en per project type afzonderlijk is dit 18.5, 7.6, en 4.5% respectievelijk voor weg, rail en kunstwerken (verschillen zijn echter niet significant). De kostenoverschrijdingen verschillen ook per project grootte waarbij grote projecten (112.5-225 mln) de grootste gemiddelde kostenoverschrijdingen hebben van 21.0%.

De overschrijding van kosten van het project is beschouwd op verschillende momenten in het besluitvormingsproces; voor de formele besluitvorming, voor de start van de bouw en na de start van de bouw. De gemiddelde kostenoverschrijding voor de formele besluitvorming is lager dan de totale overschrijding, namelijk 8.8%. Een onderverdeling per project type of project grootte leverde geen significante verschillen op. Een verdeling van de kostenoverschrijding voor of na de start van de bouw liet verschillen zien tussen de project typen. Voor kunstwerken waren de voornaamste overschrijdingen na de start van de bouw terwijl dit juist voor railprojecten voor de start van de bouw was. Voor wegenprojecten ontstonden kostenoverschrijdingen zowel voor als na de start van de bouw.

Een regressie analyse is uitgevoerd om de kostenoverschrijdingen te verklaren. De variabele kostenoverschrijding voor de formele besluitvorming kan 5.1% van de totale kostenoverschrijdingen verklaren. Voor kleine projecten kan het aantal tracks, de eerste kostenschatting en de kostenoverschrijding voor de formele besluitvorming 49.7% van de totale kostenoverschrijding verklaren. Voor de overige projecten zijn niet-lineaire modellen nodig om kostenoverschrijdingen te schatten.

De Nederlandse resultaten verschillen behoorlijk van de wereldwijde bevindingen op dit gebied. De gemiddelde kostenoverschrijding is 10.3% voor Nederlandse projecten tegenover 28% voor internationale projecten. Niet alleen de gemiddelde overschrijding verschilt, maar ook de rangorde van project typen die de meeste overschrijding kent. Voor Nederlandse projecten kennen wegprojecten de grootste kostenoverschrijding terwijl deze categorie bij de internationale projecten de laagste kostenoverschrijding kent. Deze verschillen kunnen een aantal oorzaken hebben waaronder: het verschil in de steekproef, verschil in manier waarop data is verkregen, de verdeling van de kostenoverschrijdingen van de projecten en het verschil tussen de projectfasen in verschillende landen. Meer onderzoek naar de oorzaken van de kostenoverschrijdingen in Nederland en de oorzaken van de verschillen met ander internationaal onderzoek wordt behandeld in een volgend paper.

1. Introduction

Investments in infrastructure are a large burden on a country's gross domestic product. For example, in the year 2005 the Dutch government invested about 8 billion euros (CBS, 2005 in KIM, 2007) in infrastructure, which amounts to 1.55% of the gross domestic product of that year. This large amount is an even greater concern if one recognises the inefficient allocation of financial resources involved in infrastructure planning as a consequence of decisions taken by decision makers based on misinformation (Flyvbjerg, 2005, De Bruijn and Leijten, 2007). Estimates of the costs (and benefits) of projects are inaccurate and consequently the ranking of projects based on project viability is inaccurate as well. Inevitably, this incorporates the danger that eventually inferior projects are implemented, that resources are used which could have been assigned more appropriately, and that projects are implemented which cannot recover their costs.

Various studies have addressed the issue of cost overruns in transportation projects already. Merewitz, for example, suggests that the average cost overrun of infrastructure projects is a little above 50 percent (Merewitz, 1973). Morris (1990) found that projects under implementation, which were scheduled for completion during or before 1987, had an average cost overrun of 82%. Nijkamp and Ubbels (1999) conducted a comparative study between several Dutch and Finnish transport projects investigating the reliability of estimates, and found similar results. In most of the projects, cost overruns were common varying between 2 and 20%. Odeck (2003) investigated the statistical relation between actual and estimated costs for Norwegian road projects. His findings showed a mean cost overrun of 7.9%. A study by Flyvbjerg et al. (2003a) indicates that in 86 percent of the projects under consideration cost overruns appear with an average cost overrun of 28 percent.

Whereas many of the studies on large-scale transportation projects indicate cost overruns, the extent of these overruns varies considerably. This can partly be explained by the differences in the sample (the size of the sample but also the projects' characteristics like the project type). The studies by Merewitz and Nijkamp and Ubbels, for example, have a much smaller sample size compared to the sample size in the research by Flyvbjerg et al. Due to a smaller sample size, results of statistical analyses are likely to be based on random properties rather than general findings (Flyvbjerg, 2005). Another reason why the extent of cost overruns indicated in literature varies is because of differences in the way data is handled (see for a more extensive elaboration Flyvbjerg et al., 2003b). However, the foremost cause of the differences in the extent of cost overruns is the fact that some researches use current prices (study of Nijkamp and Ubbels) whereas others use constant prices (study of Flyvbjerg et al.). This difference of current and constant prices makes it difficult to compare projects. It is therefore hard to conclude at this moment that the cost overruns in Dutch projects are smaller than in other countries (conclusions Nijkamp and Ubbels).

This research aims to increase the insight on the performance of Dutch transportation infrastructure projects regarding estimated and actual costs. By means of descriptive analyses characteristics of Dutch projects regarding the costs are derived and compared with the worldwide findings (based on the research of Flyvbjerg because it is considered 'leading research' in this field of study). Next to this, variance analyses are carried out to distinguish project performance regarding costs between different subgroups and regression analyses are conducted to identify the factors that impact cost overruns.

The structure of the paper is as follows. Section 2 describes the sampling, data collection and methodology. Section 3 provides the empirical results of the analysis on cost overruns. Section 4 explains cost overruns by estimating a regression model. After that, the findings are discussed in section 5 and the conclusions are drawn in section 6.

2. Sampling, data collection and methodology

Sampling

The population consists of all large-scale land-base transport infrastructure projects (road, rail and fixed links (tunnels and bridges)) in the Netherlands that were completed after the year 1980. Large-scale projects are often defined as major infrastructure projects that cost more than US$1 billion, or projects of a significant cost that attract a high level of public attention or political interest because of substantial direct and indirect impacts on the community, environment, and budgets. The definition also depends on the context, the size of the project in relation to the size of the city (Flyvbjerg et al., 2003a). For Dutch projects, therefore, smaller sized projects that cost more than EU €1 million, are considered large-scale projects.

Random sampling was not possible due to incomplete data of the population. A sample was drawn based on data availability. As a result, a conservative bias was created in the sample. In spite of difficulties regarding data collection, after almost two years of data collection and preparation, a sample of projects with data on construction cost development for 87 projects was established. The projects were rather equally distributed among the three project types: 29 road projects, 28 rail projects and 30 fixed links.

Data collection

Cost overrun is measured as actual out-turn costs minus estimated costs in percent of estimated costs. Actual costs are defined as real, accounted construction costs determined at the time of project completion. Estimated costs are defined as budgeted or forecasted construction costs determined at the time of formal decision to build (ToD). This is sometimes also called the "decision date, "the time of the decision to proceed," the "go-decision" (Flyvbjerg, 2003a). At that moment, cost estimates were often available as data for decision-makers to make an informed decision. If these costs are not known, the closest available estimate is used, resulting in a conservative bias in measurement[1]. In order to determine the appropriate ToD in Dutch projects the decision-making process is considered. For Dutch projects five decision-making moments are distinguished: initial decision, plan study decision, track decision, implementation decision and opening decision. The track decision is typically considered the time of formal decision to build.

Ideally, estimated costs should be based on the real decision to build. This is the moment before the formal decision to build in which decision-makers informally decided upon the project. However, it is difficult to identify the real decision to build and even harder to specify the respective estimated costs. Cost estimates usually become more accurate over time, and because the formal decision to build takes place after the real decision to

[1] When the formal decision to build (ToD) was not known, the following rules of thumb were used (in order of application): ToD was taken one year before the procedures were finished, one year before the project was in phase implementation/realization, one year before the project was indicated as "to be constructed" (for older projects) and otherwise the year for which the first costs were known.

build, cost overruns based on the real decision to build will be larger as compared to cost overruns based on the formal decision to build.

Next to data on cost variables, data on time and technical variables were collected. Technical variables include variables that describe the characteristics of the project in technical terms and include such variables as the length and the number of tracks. Table 1 provides a list of the other variables.

Table 1 List of variables

	Variable	Measure	Explanation
1	Type	Categorical	Type of project (road, rail, fixed links)
2	Length	Scale (m)	Length of the project
3	ToD	Date	Time of decision to Build
4	Estimated opening	Date	Planned opening year at ToD
5	Actual opening	Date	Actual opening year
6	Start construction	Date	Year in which construction started
7	Delay	Scale (years)	Difference between actual and planned opening
8	Implementation period	Scale (years)	Difference actual opening and ToD
9	Construction period	Scale (years)	Difference actual opening and start construction
10	Age	Scale (years)	Difference 2009 and actual opening
11	Estimated costs	Scale (mln)	Estimated costs at ToD
12	Actual costs	Scale (mln)	Actual costs at opening
13	Costs at start construction	Scale (mln)	Costs at start construction
14	Costs first estimate	Scale (mln)	Costs of first estimate
15	CO total	Scale (%)	Ratio of actual to estimated costs
16	CO after construction start	Scale (%)	Ratio of costs after start to estimated costs
17	CO before construction start	Scale (%)	Ratio of costs before start to estimated costs
18	CO before ToD	Scale (%)	Ratio of costs before ToD to estimated costs

Different methods were used to collect data: interviews with former project leaders and project teams; archives research at the ministry of Transport, RWS direction large projects and RWS direction Zuid-Holland; and documentation research on the reports of the More Annual Infrastructure Program of the years 1984 to 2008 (MIT)[2]. The MIT foremost provided data on road and rail projects whereas the other methods, interviews and archives research, mainly gave data on tunnels and bridges.

Methodology

Projects are made comparable by discounting prices to the same year and converting the costs to the same currency. In line with the study of Flyvbjerg et al. (2003a), that was used to compare the Dutch findings with the worldwide findings, data was converted to the 1995 level and costs were presented in Euros.

Each project type has distinguishing characteristics and requires different indices for discounting: GWW-index for road projects, standard index of ProRail for rail projects and the CROW-index for fixed links.

The data of the Dutch projects is analyzed by means of statistical analyses. An analysis of variance test is conducted to compare the average mean cost overrun between project types. Furthermore, descriptive and regression analyses are carried out to examine the relation between data variables and to investigate the impact of variables on the extent of overruns. The conventional terms are used when referring to significance: very strong significance ($p<0.001$), strong significance ($0.001 \le p < 0.01$), significant ($0.01 \le p < 0.05$), nearly significant ($0.05 \le p <0.1$) and non-significant ($0.1 \le p$)

[2] With the exception of MIT 1985

3. Empirical results

Cost overruns

Of the 87 projects three projects were rejected because of unreliable data. Figure 1 shows a histogram with the distribution of cost overruns for the projects in the database. About 64 percent of all projects have cost overruns, most of them with overruns smaller than 20 percent. The amount of projects with cost under-runs is also considerable, 30 of 84 projects (36%). Again, most of these had cost under-runs up to -25% (24 percent).

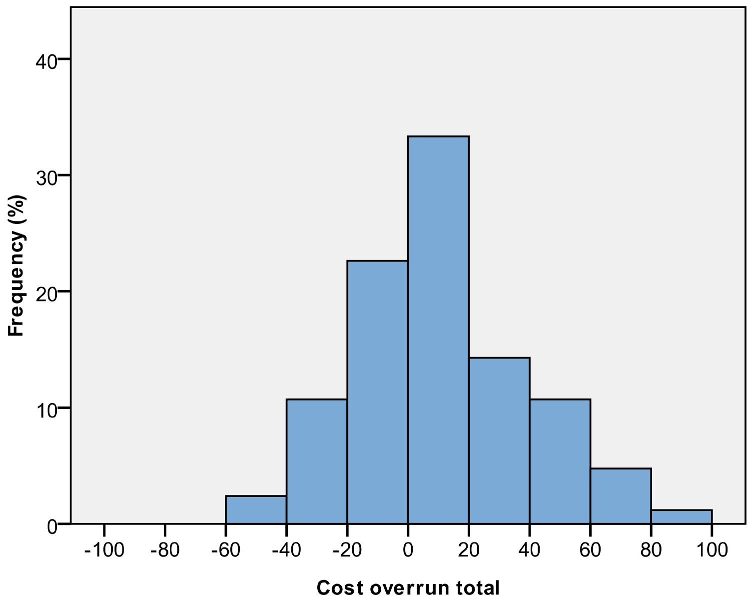

Figure 1 Distribution of cost overruns

The average cost overrun is quite moderate and is 10.3%. However, the range (-46.8 to 90.3%) and standard deviation (28.8) are large, indicating a large variety around the mean for the data of individual projects.

These findings are different from the statistics on cost overruns of the worldwide research. The average cost overrun in the worldwide database is much higher, 27.6%, with a standard deviation of 38.7. Next to this, the data shows a less even distribution of cost overruns and cost under-runs. About 15% of the 258 projects included in the study had cost under-runs (Flyvbjeg et al., 2002).

Project size

Projects were divided into four different groups according to their size. In line with standard convention, the estimated costs were used as a measure of the size of the project. Very large projects were defined as projects with a size larger than 225 million Euros in accordance with the used marginal value in the More Annual Infrastructure Program (MIT). Small projects were defined as projects below 50 million Euros. The distribution of projects regarding project size is as follows:

- Small: < EU €50 million: 22
- Medium: EU € 50 million – EU € 112.5: 31
- Large: EU € 112.5 million – EU € 225: 13
- Very large: > EU € 225 million: 18

Table 2 presents the statistics of cost overruns in percentages categorized by the size of the project.

Table 2 Cost overruns divided between different project size

Size (mE)	Mean	Median	N	St. d.	Range	% of CO
Small (<50)	-4,8	-10,8	22 (26%)	31,6	-46,8 to 77,1	-12,2
Medium (≥50 <112.5)	14,6	12,2	31 (37%)	24,8	-32,8 to 90,3	52,4
Large (≥112.5<225)	21,0	17,9	13 (16%)	24,6	-15,7 to 76,0	31,5
Very large (≥ 225)	13,6	7,9	18 (21%)	29,3	-35,0 to 72,9	28,3
Total	10,3	7,7	84	28,8	-46,8 to 90,3	100

In terms of average cost overruns small projects have the lowest cost overruns of -4.8%. The difference in average cost overrun with project size is statistically significant (0.029, F-test). The differences between the small, medium and large sized projects are nearly significant. The difference in average cost overrun of very large projects with the average of other sized projects is non-significant.
The median represents the middle value. For example, the median is 7.7, thus half of the projects have cost overruns above this value and the other half have cost overruns lower than this value. The mean is higher than the median which means that the extent of cost overruns is higher compared to the extent of cost under-runs. The last column of table 2 indicates the extent to which the cost overrun of a category contributes to the total cost overrun in percentages. Medium sized projects are responsible for more than half of the total percentage cost overruns.
Despite the significant difference in average between different project sizes, for all size projects, the standard deviation and range are large (standard deviation even twice or three times higher), pointing to uncertainty in results regarding cost overruns.

Project type
Three different project types were distinguished; fixed links, road and rail projects. Table 3 provides a summary of the average cost overrun for each project type.

Table 3 Cost overruns divided between different project types

Size (mE)	Mean	Median	N	St. d.	Range	% of CO
Fixed links	4,5	2,3	26 (31%)	19,4	-29,8 to 72,9	13.6
Road	18,5	22,0	28 (33%)	23,1	-35,0 to 64,9	59.9
Rail	7,6	3,7	30 (36%)	38,0	-46,8 to 90,3	26.5
Total	10,3	7,7	84	28,8	-46,8 to 90,3	100

Road projects have the largest average cost overrun of 18.5%. Rail projects and fixed links have considerably lower overruns. Although the difference between the three categories is clear, an F-test (p=0.167) showed no significant differences. This might be the result of the large standard deviation and large range around the average.
These findings are quite different from the findings from the worldwide research. First of all, cost overruns by project type differ considerably. The average cost overruns from the worldwide research are 33.8, 20.4 and 44.7% compared to the 4.5, 18.5 and 7.7% in the Dutch research for fixed links, road and rail projects respectively. The average cost overrun for road projects is similar but for fixed links and rail projects, the average cost overrun for Dutch projects is considerably smaller. A second difference concerns the ranking of project types based on performance. For Dutch projects, road projects perform the worst (have the highest cost overrun) whereas this category performs the best on a worldwide scale.

Time

Delay is the difference between the actual and the estimated opening of the project. The average delay for all projects in the Dutch database is 1 year and 11 months. Other time variables are the implementation period, the construction period and the age of projects. The implementation period concerns the difference between the actual opening and the time of decision to build and is on average 8 years and 7 months. The construction period is the difference between the actual opening and the start of construction and is 6 years and 4 months. The mean age of the projects is 6.5 years. Table 4 provides several statistics on time variables for the different project types.

Table 4 Delay, implementation period, construction period and age (years, months)

	Delay			Implementation period		Construction period		Age	
	N	**Mean**	**St. d.**	**Mean**	**St. d.**	**Mean**	**St. d.**	**Mean**	**St. d.**
Fixed Links	26	(1,1)	2.8	(8,2)	3.6	(5,6)	2.7	(7,10)	6.8
Road	28	(2,4)	2.6	(10,6)	4.9	(7,1)	4.0	(5,1)	3.5
Rail	30	(2,2)	2.3	(7,0)	2.6	(6,5)	2.4	(6,7)	4.0
Total	84	(1,11)	2.6	(8,7)	4.0	(6,4)	3.1	(6,6)	4.7

The standard deviations are very large for the variable delay, twice the size of the average delay and about half the size of the average for the implementation and construction period. Large standard deviations make conclusions regarding the average more uncertain. Only the difference in means of the implementation period was statistically significant (p=0.002, F-test). Subsequently, a Bonferroni test is carried out to establish the actual difference between the categories of project types for the implementation period. The difference between the implementation period of rail projects and road projects is 3 years and 6 months (p=0.002). The difference between road projects and fixed links is nearly significant and concerns 2 years and 4 months (p=0.84)

Research by Flyvbjerg et al. (2003b) showed that cost estimates have not improved over time. Whether this is also the case for Dutch projects is investigated in this subsection.
Figure 2 shows a plot between the cost overruns and the year of decision to build for the 84 projects. The plot does not show an effect of improvement regarding the performance of cost estimation; cost overruns did not decrease over time. An F-test indicated no difference between the cost overruns over the years (p=0.634 is non-significant).

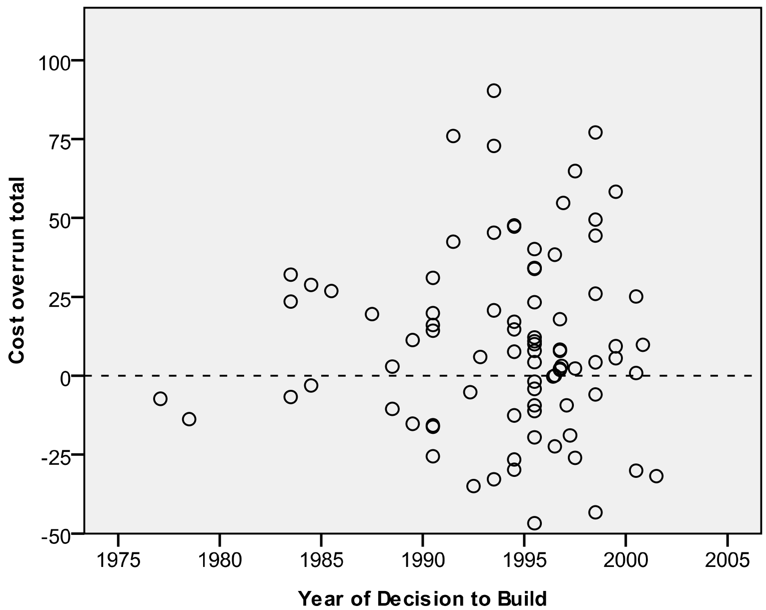

Figure 2 Cost overrun over year of Decision to Build

Similarly, cost estimates did not improve for the other time variables such as delay, implementation period, construction period, age, estimated opening, and actual opening. Overall, no statistically significant effects were noticed. However, for different sub-samples (based on project type or project size) some significant and nearly significant effects were identified.

- For fixed link projects cost estimates differ with the ToD (p=0.092), actual opening (p=0.072), construction period (p=0.010) and age (p=0.072)
- For small rail and fixed link projects cost estimates differ with the construction period (p=0.023 and p=0.045 respectively)
- For medium rail projects cost estimates differ with delay (p=0.099)

Cost overruns before ToD[3]

The cost overruns before the formal decision to build were also calculated. This is an important variable because it indicates how well decision-makers were informed when making a decision about a project. Data of the costs before the formal decision to build were only known for road and rail projects. This decreased the sample size for this analysis to 56 projects. The average cost overrun before ToD is 8.8% with a large range between -89.8 and 75.7%. The standard deviation is also quite large, 33.6. Cost overruns and cost under-runs are evenly distributed. 50 percent of the projects have cost under-runs, most of them up to -25%. Another 50% have cost overruns, 20 percent up to 25% and 30% with large cost overruns of more than 25%.

[3] Only projects with cost overruns before ToD < 200 mln and ≠ 0 are included, because these are considered most realistic

Regarding the project size (see Table 5 for statistics), cost overruns before ToD increase with project size; large projects have the largest cost overrun before ToD. However, the spread around the mean is large for all project sizes (standard deviations are more than 25). An F-test was carried out and it was concluded that the differences in mean between project sizes were not statistically significant (p=0.861).

Table 5 Cost overruns before ToD divided between different project sizes

Size (mE)	Mean	Median	N	St. d.	Range	% of CO
Small (<50)	3,6	0,8	11 (32%)	31,0	-60,1 to 48,2	13,1
Medium (≥50 <112.5)	6,8	-1,3	11 (32%)	44,1	-89,8 to 57,6	24,8
Large (≥112.5<225)	14,0	0,5	4 (12%)	27,4	-0,1 to 55,2	18,7
Very large (≥ 225)	16,3	0,7	8 (24%)	28,7	-5,0 to 75,7	43,5
Total	8,8	0,4	34	33,6	-89,9 to 75,7	100

The mean cost overrun before ToD for road projects is 9,7% and for rail projects 8,0%. The uncertainty with the average is large with standard deviations or 34,0 and 34,1. The differences are, however, not statistically significant (p=0.887, T-test).

For the time variables age, estimated opening, actual opening and time of decision to build no influence was noticed on the cost overruns before time of decision to build. For implementation period, construction period and delay, the following was concluded:

- For large sized projects, the cost estimates differ with the time of decision to build (p=0.016) and with the construction period (p=0.000)
- For very large sized projects, the cost estimates differ with the delay and implementation period (p=0.085 and p=0.043 respectively)

Cost overruns before and after construction start

It is interesting to investigate whether cost overruns are mainly caused by events in the decision-making process (before construction start) or during construction (after construction start).

Table 6 Statistics cost overruns before and after construction start

		Before construction start		After construction start	
	N	Mean	St. d.	Mean	St. d.
Fixed links	6	-11.3	27.6	50.5	73.4
Road	28	19.3	50.9	6.3	26.7
Rail	28	9.5	31.0	-0.4	34.3
Total	62	11.9	41.4	7.7	38.6

On average, road projects are characterized by cost overruns before as well as after construction start. For fixed link projects the problems of cost overruns appear after construction start. For rail projects it is the other way around, cost overruns appear before construction start and on average cost under-runs appear after construction started.

4. Explaining cost overruns

Factors that can help explain the observed cost overruns are identified by means of regression analysis. In regressing the model, the stepwise method is used as an independent variable selection procedure. In this way, the unnecessary variables can be excluded from the model. The results are presented in Table 7.

Table 7 Results of the regression model

	Constant	Sign.	Coefficient	Sign.	R-square
CO ToD	10.40	0.02	0.06	0.09	0.051
Construction period	-2.06	0.77	1.96	0.05	0.045
Length Log	1.61	0.73	12.79	0.02	0.070
Start costs log	0.20	0.99	6.67	0.50	0.008
Est. opening x construction period	-2.07	0.77	0.00	0.05	0.045

Cost overrun before ToD is the only variable that can be included in a regression model with a constant and coefficient that are significant. The cost overrun before ToD has a nearly significant impact on the percentage cost overrun in total. The percentage cost overrun in total tends to be higher the higher the cost overruns before ToD are. The regression line is as follows: $Y = 10.40 + 0.06 * C_1$, where C_1 are the costs before ToD. Although the variable has an influence on the total cost overrun, the coefficient is very small resulting on an overall small influence of only 0.61% rise of the cost overruns for each percentage increase in the cost overruns before ToD.

Because the model to predict cost overruns did not provide much indicators, the analysis is carried out for different sub-samples based on project types and project sizes. The distinction in different project types did not bring about a better regression model. The division of projects by different project sizes did improve the models to explain cost overruns. The different regression models are as follows:

$$Y_{\text{Small}} = -21.69 + 21.64 * X_1 - 1.44 * C_1 - 0.98 * C_2$$

$$Y_{\text{Medium}} = -4964.99 - 0.45 * C_3 + 2.51 * T_1$$

$$Y_{\text{Medium}} = 231.63 - 0.02 * X_2{}^2 + 1.12 * T_2{}^2 + 80.75 * \frac{1}{T_3} - 126.70 * \text{Log}(C_3)$$

$$Y_{\text{Large}} = 12.359 - 43.41 * \text{Log}(C_2)$$

$$Y_{\text{Very Large}} = 72.44 - 408.71 * \frac{1}{T_3}$$

In which:

X_1 = number of tracks
X_2 = length
C_1 = cost overruns before ToD
C_2 = costs first estimate
C_3 = costs at start construction
T_1 = actual opening year
T_2 = delay
T_3 = Construction period

For large and very large projects only one variable is included and the regression model is non-linear. For small and medium sized projects, however, several variables could be used in the regression model to explain the cost overruns. The extent to which the variables can explain the cost overruns is considerable; 49.7% for small projects, 38.6% for medium projects, 70.5 for large projects and 78.7% for very large projects.

5. Discussion

The large standard deviations with the average cost overruns are disturbing. The introduction of this paper already indicated three possible reasons for the differences in results regarding average cost overrun between different studies. First of all, different results are obtained due to differences in sample. The number of projects in the database and the characteristics of the database regarding the project type differ. In the Dutch database the number of projects for each project type is similar whereas in the worldwide database the number of road projects is much larger compared to the number of rail projects and fixed links. Secondly, the way in which data is treated can explain the differences in conclusions about average cost overruns. The small percentage cost overrun in Dutch projects and foremost for fixed links and rail projects was surprising.

For fixed link projects where data was collected based on interviews and documentation research, it might be the case that interests in data availability played a role; there was no interest in providing information on bad projects whereas there was for good projects. Next to this, project managers might feel tempted to present the data of the project as favorable as possible. For road projects and rail projects the data was rather well documented and this might explain the good performance as well. Projects that were managed well on data availability are likely to be managed well on project performance also (Flyvbjerg et al., 2002). Lastly, the difference in use of constant and current prices can explain the differences. This is, however, not the case in this study.

Another possible explanation for the small average cost overrun might be the distribution of cost overruns among the projects. This can influence the average cost overrun. In order to deal with this, the weighted average is used as a reference. The average cost overrun is higher (13.9%) and is 9.3, 18.2 and 4.8% for road, rail and fixed links respectively. The main difference between the average and the weighted average is the average cost overrun of road and rail projects. Instead of road projects with the largest cost overrun, rail projects have the largest average overrun. The difference in average cost overrun for rail projects can be explained by the small number of projects with very large cost overruns (9 projects of 30) and the large number of projects with small cost under-runs. This can also be seen by the fact that rail projects are responsible for 81.4% of the total cost overruns.

The methodology to calculate cost overruns can be another source to find different results in average overrun between different studies. First of all, the choice for the price indices can influence the outcome. A sensitivity analysis including different indices should be carried out to test this.

The main discussion point is the use of the formal decision to build as a reference for the estimated costs. Although for each country specific the same year was used as a base year, there might be a large difference between the length of the time between the real and formal decision to build. The low average cost overrun in the Netherlands can then be explained by the rather long period of time between the real decision to build and the formal decision to build compared to this period in other countries. The long period in between these two decision-making moments makes the estimate at the formal decision to build more accurate. The phases of the decision-making process of the Netherlands should be compared with other countries to identify possible differences and consequently provide an explanation for the difference in cost overruns. More research into the explanations of the findings on cost overruns in the Netherlands will be captured in a subsequent paper.

6. Conclusions

The phenomenon of cost overruns is also present in Dutch large-scale transportation infrastructure projects, though, to a much smaller extent compared with the worldwide findings. The average cost overrun in projects in the Netherlands is 10% compared to 28% in projects around the world. The cost overruns for each project type individually are 4.5, 18.5 and 7.7% for fixed links, road and rail projects respectively (however, not significant).

Another difference between the Dutch projects and projects from the worldwide database is the ranking of project types with the highest cost overruns. Road projects have the largest average cost overruns in the Netherlands (20%) whereas this is the smallest for the worldwide projects (28%). The differences between the average cost overrun for rail and fixed links are highly significant, 8% and 5% for Dutch projects against 34 and 45% for worldwide projects.

Except for very large projects, the difference in average cost overrun for project size is significant. Medium sized projects (between 50 and 112.5 mln euros) contribute for more than half of the total cost overruns. Similar to worldwide findings, cost overruns had not improved over time.

Cost overruns were estimated before the formal decision to build, before construction start and after construction start. The main results are as follows:

- The average cost overrun before ToD was 8.8% which differs significantly with the total average cost overrun of 10.3%.
- For small and very large projects, the percentage cost overruns overall are smaller, and for medium and large projects higher, than the percentage cost overruns before the ToD.
- Cost overruns before and after the start of construction differ largely for fixed links, which mainly have cost overruns after the start of the construction. For rail and road project it is the other way around; cost overruns appear mainly before the start of construction.

To explain cost overruns, a regression model including the cost overrun before ToD explained 5.1% of the cost overruns. For the project type separately, the following was found:

- For small projects, the number of tracks, the first cost estimate and the cost overrun before ToD can explain together 49.7% of the total cost overrun.
- For medium projects, costs at start of construction and actual opening year can explain 38.6% of the cost overruns and a non-linear regression model (with variables length, delay, construction period and costs at start construction) can even explain 70.5%.
- For large projects, a non-linear model including a constant and the variable first cost estimate can explain 78.7% of the cost overruns.
- For very large projects, the construction period can explain 83.4% of the total cost overruns.

The findings on cost overruns for Dutch projects differ from the worldwide findings and there are several reasons for this a.o. difference in: sample, the way in which data was treated, distribution of cost overruns among projects, and the length in time between the real and formal decision to build.

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