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Cost Overrun Risk Assessment in the Public Investment Projects: an Empirically-Grounded Research

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The article deals with the issue of how to accurately assess the Risk (risk of cost overrun) in PIPs (public investment projects). Problematic and, as a result, rare application of quantitative risk assessment tools in the public sector determines the relevance of systemization and facilitation of techniques, which would allow increasing accuracy of Risk assessment as well as efficiency and transparency of public finance management. The purpose of this article is to analyze the peculiarities of Risk in PIPs and to find the PDs (probability distributions) that best enable to assess the Risk in PIPs more specifically. Summarizing the scientific literature, it was revealed that, due to a complex of problems, risk assessment based on historical data gives place to the qualitative tools such as personal expertise, which is prevailing in practice. However, under the circumstances analyzed in the article, the application of historical data allows getting more accurate results, and the public sector, despite the lack of experience in comparison with the private one, has more advantages in this case. The performed case study enabled to present a methodology of how to systemize data for the assessment of Risk in PIPs. The peculiarities of Risk were analyzed in groups (PIP groups), their classification was based on PIP accounting plan of long-term assets in Lithuania. The findings of the article showed the difficulties of the public sector to ensure sufficient financing as well as the problems to manage Risk in PIPs. The case study disclosed the inability of the so called "traditional" PDs to accurately describe this tendency of success of the public sector to implement PIP within the estimated budget, while the Loglogistics and its parameters were tested as the most suitable PD to assess the Risk not in a general case, but also in different PIP groups.

Keywords: *public sector, public investment project, probability distribution, risk assessment, investment cost, cost overrun, increase of public finance transparency.*

Introduction

The question of the public sector's accountability is relevant since it is budgeting from taxpayers for the satisfaction of public interest. The efficient and transparent management of public finance is the essential part of this process and gets a lot of attention from the public, especially in the context of various financial crises when governments are constrained to perform a strict financial policy and maintain fiscal discipline. Under any circumstance, the effective performance requires tools which would enable to take reasonable decisions and behave in a rational way. Although, usually the public sector tends to be criticized for the lack of accountability and transparency (Mutiganda, 2013), the demonstration of responsible financial approach firstly requires clear argumentation due to which the public sector is forced to change. The decisions for implementation of PIPs have to be based on sound assessment and, primarily, reliable estimation of investment costs. Therefore, various tools applied in private sector long ago slowly penetrate into the public areas. Application and systemization of various techniques, which would enable to increase the accuracy of cost estimation in PIPs, is very relevant. However, both in theory and practice this process is not without problems.

Many authors such as (Tang *et al.*, 2012; Jorgensen *et al*., 2012) in their papers disclosed the complexity of cost estimation process, especially in the construction projects. Generally, the more PIP is complex i.e. the amount of investments is larger, a number of investment objects is higher, technologies planned to use are less proven, a duration of the construction phase is longer, etc., the more it is difficult to accurately estimate the investment costs. All these aspects determine the uncertainty due to which there is always a risk that the estimated investment cost will be overrun. Therefore, the widely used method of cost estimation, i.e. predicting the construction costs and simply calculating the total is deterministic and insufficient (Okmen & Oztas, 2009). The risk adjusted costs have to be estimated (Zavadskas *et al.*, 2010).

This risk is related to the fact that, due to increased investment costs, the price of PIP can become so high that the project promoter may face the problems of securing additional financing to implement PIP and/or it may become financially and economically not worth to implement it. According to (Okmen & Oztas, 2009; Xu *et al.*, 2010; Tamosaitiene *et al.*, 2013; Mahamid, 2011), this risk can be determined by various risk factors such as weather conditions, labor productivity, underground conditions, mistakes in the construction plan, changes of public sector requirements, etc. There is possibility that they can determine not only negative, but also the positive effects, i.e. actual costs may be less than planned costs. Therefore, in cost estimation, one of the major steps is to assess the potential risks and their risk factors (Mousavi *et al*., 2011; Marhavilas *et al.*, 2011).

Literature is rich in papers addressing risk assessment. Traditionally, despite the difficulties to obtain the objective probabilities and frequencies it is focused on quantitative risk assessment (Taroun, 2014; Tah & Carr, 2001) where investment costs, usually using simulation methods such as Monte Carlo (Loizou & French, 2012; Almarri & Blackwell, 2014), are estimated at the probability of particular level, usually 70 % (Mirdamadi *et al.*, 2013). Funding the public investment programs at this confidence level or above certainly raises the probability of project being implemented successfully, but naturally requires a higher level of funding. These extra resources could be used for the implementation of other potential PIPS. Therefore, in order to use resources efficiently, it is important to assess the potential overrun of estimated costs as accurate as possible. This aspect is even more relevant in a case when the public sector is going into the public-private partnerships (PPPs) and seeks to assess the value of transferred risks for the private subjects (Chen *et al.*, 2012; Demirag *et al.*, 2011; Phang, 2007). The more cost overrun risk is accurately assessed, the better possibilities to rationally allocate it between the partners as well as arrange the financial conditions of partnership (Demirag *et al*, 2011; Ng & Loosemore, 2007). Also, the importance of accurate risk assessment for efficient risk management is acknowledged (Taroun, 2014; Marhavilas *et al.*, 2011; Grimsey & Lewis, 2002; Carr & Tah, 2001).

During the last several decades both of the theoretical models and computerized tools used for quantitative assessment of risk were developed widely enough (Marhavilas *et al.*, 2011). However, there is still a wide gap between theory and practice. According to (Teoh, 2013; Winch, 2003), many project managers simply rely on subjective probabilities and in many cases risk is subjectively dealt with through adding an approximate contingency sum. (Taroun, 2014) summarizing the research papers about actual practice of cost estimation in the construction projects concluded that, in the managers point of view, personal experience and subjective judgments were kept as the most effective and widely used technique for managing the risks. Most of the managers have not performed any form of statistical analysis of risk as well as have not used any sophisticated quantitative tools. The reasons such as 1) the unique nature of every construction project due to which it is complicated to apply general probabilities; 2) the difficulties to get reliable inputs, and 3) limited understanding as well as a lack of experience in such methods, were revealed as an explanation. This shows that although the quantitative methods of risk assessment in principle have a high potential in order to do them more usable in practice they have to be understood easier and more convenient. Therefore, the simplicity and facilitation of the practical experience are kept to be the key of future development of quantitative risk assessment tool.

The development of quantitative methods is also relevant in the context of the research, which disclosed that experts using their personal experience usually underestimate the risk (Veres, 2009) and rarely can identify 60 % of the possible uncertainty range and never did better than 70 %, i.e. approximately one sigma (Capen, 1975). This shows that although the actual practice of risk assessment is very much based on qualitative methods and tools, their accuracy is quite limited. The complex application of both the quantitative and qualitative methods would the best and herewith standard solution in most of the cases.

Considering the earlier mentioned problem related to the unique nature of every PIP, the application of quantitative risk assessment methods in the public sector can be more pragmatic in terms of accuracy than in the private one. In the public sector a lot of PIPs are implemented under PCIPs (Public capital investment programs) and, considering the investment object, can be grouped into the project types. In each of the type the nature of Risk is very similar and numbers of PIPs are usually large enough to collect empirical data and apply the general probabilities as well as the statistical tools for the assessment of Risk. For instant, under one of the programs, the public sector implementing a certain number of typical secondary school renewal projects is able to collect data from the former PIPs and uses them as the inputs for quantitative assessment of Risk in latter ones (Wu, 2012). While, in the private sector a diversity of projects is much larger and a number of the same projects is usually lower. Therefore, comparing both sectors in this respect, the public one usually has more opportunities and can better use the advantages of the application of quantitative risk assessment tools in practice.

Although the use of quantitative risk assessment techniques in practice is wrapped by many problems, literature is still poor in researches where they would be analyzed. The particularities of Risk as well as the application of PDs for the assessment of Risk in PIP are not exceptions. One of the rare examples is the United Kingdom National Audit Office's reports in which it was revealed that only from a quarter till nearly a half of all PIPs, depending on the year, have been implemented within the estimated budget (NAO, 2003; 2009). However, in this fragmental information any quantitative data about probabilities and values of risk was provided. In case of PDs in most of papers such as prepared by (Acebes *et al.*, 2014; Chou, 2011; Scherer *et al.*, 2003; Jiang, 2003), it is analyzed the features of the so-called "traditional" PDs such as normal, triangular, lognormal, beta etc. to assess various uncertainties, but not their appropriateness to assess Risk. A lack of these empirical data determines the problems to estimate amounts of risk-adjusted investment costs as well as to choose PDs best enable to estimate Risk.

Every year millions are spent for PIPs most of which are implemented under PCIPs in Lithuania. It has been collected a considerable amount of data about the planned and actually used assignations for these projects. However, in order to assess Risk as well as reveal its particularities, at the project level the analysis has never been done yet. Therefore, considering poor knowledge about the particularities of Risk and t PDs best enable to assess it as well as the requirement to facilitate the use of quantitative risk assessment tools in practice, *the problem analyzed in this article* is raised by a question: what PDs are the most suitable to assess the risk of cost overrun in the PIPs?

The aim of this paper is to analyze the peculiarities of risk of cost overrun in PIPs. Specifically, it was aimed to find PDs best enable to describe this Risk. Respectively, in order to reach the aim, *the objectives* such as: firstly, to analyze the peculiarities of application of probabilities to assess Risk in PIPs; secondly, to disclose the tendency of the public sector's success to implement PIPs within the estimated budget, and; thirdly, to find PDs best enable to assess Risk. *Research methods* used in this research are: systematic and comparative analysis of literature, logical abstraction and conclusion generation methods, statistical analysis method and simulations.

In terms of additional value to literature and practice, the research provides useful insights as to: 1) how to systemize the data of PIPs; 2) how to choose PDs best enable to assess Risk by applying combination of quantitative as well as qualitative risk assessment methods. Moreover, prepared methodology and findings i.e. estimated parameters of PDs enable to facilitate the assessment of Risk in terms time saving and data available for the estimators. This contributes a wider use of quantitative risk assessment tools.

This paper is organized as follows. In the following section, it is introduced to quantitative risk assessment and application of PDs more specifically. In the section followed, it is presented the methodology of the research performed. The results of the comparative analysis of planned and actual used assignations in PIPs of Lithuania as well as PDs best enable to assess Risk are presented in the fourth section. Closing remarks are presented in the last section.

Application of Probability to Assess Risk

The assessment of investment costs is more a forecasting exercise than a simple calculation of the total investments needed and numerous researches disclose a diversity of problems related with a forecasting. Many factors such as imperfect information, misleading assumptions, various errors, unpredictable changes in the project, new or unproven technology, optimistic bias, etc. (Memon *et al.*, 2013; Ke *et al.*, 2011; Fischer *et al.*, 2010) may cause deviations from the initial prognosis due to which actual investment costs may vary in either an adverse or a favorable direction.

Usually, this variation consists of a spectrum of respectively distributed potential values. The larger uncertainty is, the broader a spectrum may exist. Therefore, Risk as being quantitative concept can be assessed by PDs indicating the likelihood of a variable of the planned investments falling within stated limits. As a result, although there is still some attempts to deny that risk can be quantitative, even in theory (Campbell, 2005), it is usually expressed in quantitative measures at a certain probability level or in probability of occurrence of the desirable result e.g. particular probability that the project will be implemented within the estimated costs.

The realized value and its probability of occurrence these two parameters are needed to transform simple uncertainty into defined risk. In order to do that, PD of variables i.e. CDF (cumulative distribution function) also has to be known. Depending on the particularities of risk and data available, several techniques can be used to get variables. In literature the probability-impact (P-I) risk model is prevailing (Taroun, 2014). The reasons such as simplicity, flexibility, tendency to be cheap, possibility to compare risks visually and as a result easy understandability enable to explain its popularity (Bowers & Khorakian, 2014; Kmec, 2011). However, despite these advantages this model is also strongly criticized. Due to mostly used qualitative categorization, subjective ranking and impossibility to maintain perfect congruence between qualitative and quantitative rankings, for most risks by using it neither the probability nor the impact can be accurately quantified (Cox, 2008). Due to these reasons the P-I model is flawed, should be used with caution.

The alternative way to estimate potential investment costs is to use a historical data which can help to assess risk more accurately, though their use also has some pitfalls. Mostly because of historical data are not always available and firstly allows disclosing risk experienced in the past. Meanwhile actual values may lie outside the range of historical records and due to this reason critical risk factors may be ignored (Bowers & Khorakian, 2014; Yang, 2005). However, due to the same reason it can be justified to use historical data for risk assessment if it is expected that observed past behavior will continue in the future (Makovsek, 2014;). The papers of (Gokiene, 2010; Mecario, 2010; Tang *et al.*, 2010) disclosed that this assumption may be quite difficult to apply for ex-ante assessment in a case of the whole-life costs which consist the investment costs as well as the long-term operating costs needed to forecast as e.g. in the complex PIPs implemented under PPP. But this might be much easier in the case of the implementation of very similar projects as in the example of the secondary schools' renewable projects mentioned earlier. In this case data obtained from the former projects allow envisaging the tendency of success to implement this kind of projects within the estimated budget which can be described by appropriate PD (Rostami *et al.*, 2013)

When historical data is used to assess risk, it involves an attempt to fit theoretical PD to the data and to verify its goodness-of-fit statistically. For this purpose usually statistics such as Kolmogorov-Smirnov, Anderson Darling, Cramer-von Mise, Shapiro-Wilk, Filiben, $X^{2,}$ etc. (Beaulieu *et al.*, 2014; Heo *et al.*, 2013; Jimenes-Gamero *et al.*, 2009), are used, and the fitness is measured by quantifying a distance between empirical and appropriate theoretical CDFs. The closer is the distance, the better theoretical PD reflects a sample. In some cases it can be many potentially suitable PDs. Therefore, in order to save time looking for the most suitable PD manually, the fitting process is usually done by software packages such as Crystal Ball, EasyFit, @RISK, etc. A typical result is a list of statistically "good" PDs and their associated parameters, based on which the estimator of risk can select the most proper one.

However, although nowadays derivation of PD is very computer-assisted, the results can be very different depending on inputs used. The estimator has to ensure appropriate methodology to get meaningful results. In cost estimation there is a logical lower boundary of uncertainty, i.e. investment costs cannot be negative. Therefore, in practice it is discouraged to employ PDs that have values less than zero or to truncate the lower limit at zero for all PDs (Jiang *et al.*, 2003). The second way is even less recommended because such truncation moves the mean of PD to the right making it more conservative estimate. However, the estimator is free to choose the best PD depending on the specific requirements.

There are a quite limited number of studies in which the suitability of appropriate PDs under various conditions would be analyzed. In the papers of (Acebes *et al.*, 2014; Chou, 2011; Chou *et al.*, 2009; Jiang *et al.*, 2003), there are met such well-known PDs as normal, beta, triangular, lognormal, uniform, etc., their suitability to reflect historical data is usually analyzed in context of whole-life costs estimation of the project. These studies suggested that lognormal PD could be the most appropriate and universal in this case. However, there is no information about PDs best enable to describe the tendency of the public sector's success to implement PIPs within the estimated budget, herewith to assess Risk. Therefore, this is the purpose of this article.

Research Methodology

Considering the studies of application of probability to assess risk, the research methodology consists of two main parts: 1) data systemization, and; 2) performance of the very research in which, firstly, the comparative analysis of estimated and actual investment costs in PIPs was done and, secondly, PDs best enable to assess Risk were revealed.

Risk was analyzed by calculating R (the ratio) between I_r (actual investment costs) and I_p (estimated investments costs) in PIPs, where values, $R = (I_r/I_p)$, can vary in a range $[0; +\infty)$, where: $R=0$ means that no actual costs have been experienced; $R=1$ shows that PIP has been implemented fully used all estimated budget, and; $R>1$ shows overrun of the estimated budget. $R<1$ can imply the savings or the result of underfinancing. Therefore, considering the fact that assessment of Risk is meaningful only in PIPs kept as implemented, the lower bound of ratio satisfying this criterion has to be determined. On other hand, very high ratios can imply ineffective performance or can be calculated due to misleading data published in the statements. Therefore, in order to avoid the impact of the results gone beyond the common sense, the upper bound also has to be determined.

No universally excepted practice exists to determine this appropriate gap of values satisfying the mentioned criterions. Therefore, case-based reasoning solution is presented in the case analysis of this article.

Risk was estimated in the general sample of PIPs as well as in the different PIPs which have been classified according their investment purposes into the groups based on PIP accounting plan of long-term asset in Lithuania. In total, seven groups such as: A1 - land; A2 - real estate; A3 - construction, major repairs and other repairs; A4 - equipment and machineries and other assets; A5 - projection, technical maintenance and other services related with investment into A1-A4; A6 – reinvestments, and; A7 - other services are classified. The significance of differences between the results in these groups was tested using Kruskal-Wallis and Mann-Whitney statistics.

The suitability of PDs to assess Risk was tested by using Kolmogorov-Smirnov statistics. The analysis was performed using *MS Excel*, *SPSS* and *EasyFit* programs.

Empirical Research

Inputs. The research was performed using data of 2006–2012 planned and actually used assignations for PIPs implemented under PCIP in Lithuania. In total, seven annual reports of planned assignations as well as the same number of reports about actually used ones have been analyzed. After an initial assessment it was observed that in most of PIPs that are being implemented longer than one year, total amounts of estimated investments vary from year to year and are likely to increase resulting the existence of Risk. However, it was also revealed that, for the purpose to analyze Risk, the reports are very flawed: 1) Tables of annual reports differ by number of data columns and information fields they contain; 2) The projects do not have unique identification codes based on which it would be easy to retrace the data of every PIPs between the annual reports, while a great number of unique PIPs have been recorded by different titles and, as a result, existed as separate PIPs; 3) Moreover, a great part of records were incomplete. All these weaknesses disclosed the problems related with the accounting of assignations for PIPs in the level of individual projects funded under PCIPs in Lithuania as well as, under these circumstances, the difficulties to monitor the costs of every individual PIP. Therefore, in order to analyze the peculiarities of Risk and get the reliable results, the appropriate arrangement of raw data was needed as well as the following solutions to eliminate their weaknesses have been applied.

For this purpose, the unification of individual PIPs' titles and assignment of unique codes for them was done. The records with incomplete data due to which it was impossible to identify them as a unique project or classify to one of unique projects were eliminated from the further research. In total, more than 14,000 records about planned and actual used assignations have been trying to systemize. As a result, after elimination of nearly 600 incomplete records and additional manual arrangement, a little bit more than 2,800 PIP titles, in total, 2,891 unique PIPs were identified and further used in the research.

Among them, to compare the planned and actual investments, the assessment of Risk is meaningful only in PIPs which, during the analyzed period: 1) have been started and finished; 2) as well as can be considered as implemented. Therefore, only the PIPs satisfying both criterions could be included in the further analysis. Considering the first criterion, 1,304 PIPs have been selected. In respect to the second one, 52 PIPs, in which real investments have not been experienced, have been removed from the further analysis as unsatisfying this criterion. Moreover, for the fulfilment of current criterion, the rest of 1,252 PIPs have been tested under additional assumptions presented below.

The analysis of 1,252 PIPs revealed that, in general case, PIP could be expected to be financed only by ¾ of amount of planned assignations i.e. PIPs were considered as implemented when more than ¾ of planned investments have been implemented. However, the estimated values, especially of marginal variables, strongly varied between PIPs from 98 % of insufficient financing till excess of 3513 times determining the strong distortions of average ratio meaning. On the one hand, there is a reason to assume that PIP cannot be considered as implemented when its ratio is closed to the observed lowest meanings. On the other hand, in the point of rational planning, the real investments should not increase as many as they would exceed the plan by observed hundred or even thousand times. Therefore, in order to eliminate the impact of extreme variables for the results of general sample, the appropriate selection of data was done based on the following assumptions: 1) maximum insufficient financing should not be higher than the estimated average value 25,12 % (R=0,7488) that the PIP would be considered as implemented; 2) in a sample of PIPs characterized by excess of estimated investments, the excess varied in a range from a little bit higher than 0 till 3512 times, where the average excess 2,9787 times (R=3,9787) allows stating that on overage estimated costs have been exceeded by nearly 3 times in these PIPs. This upper bound could be evaluated as enough high and the cross of this line probably would be morally unaccepted in respect of rational planning since the worst case scenario what can occur during the implementation of PIP is due to various risks, e.g. design risk, emerged a need to eliminate the infrastructure of the nearly implemented PIP and to reinvest into the creation of new one. Considering these assumptions, only the PIPs with R϶(0,7488; 3,9787) i.e. from a quarter of underfinancing till overrun by nearly 3 times, finally, in total 853, were selected for the analysis.

This detailed described process of arrangement or elimination of inadequate records allows to excluding unclear data the use of which as the inputs could cause the misleading conclusions. Meanwhile the selected data allow to expecting to get the reliable results.

Analysis and results. Considering the fact that during the period of PIP implementation the amounts of estimated investments are tended to increase, to assess the average probable overrun of estimated investments, the lowest estimated values were taken as a benchmark.

In order to evaluate differences between separate asset categories, these ratios were calculated not only for individual PIPs, but also in 7 groups. The highest number of PIPs were identified in groups A3 and A4, respectively 66,4 % and 30,4 % of all PIPs. The numbers of PIPs in other groups were 10 times lower: A7 consisted 23 projects (2,7 %), A1, A2 and A5 each consisted less than 5 PIPs, i.e. 1 % of all PIP. The last three groups were too small to get more detail statistics. Therefore, some assumptions have been done. Considering the similarities of risk between A5 and A7 groups the united group A5* was created from them. There is also a reason to assume that, in the point of risk, PIPs of reinvestment have similarities with PIPS of construction and equipment renewal. Therefore, group A6* was made from the general sample of 823 PIPs from both A3 and A4 groups.

The derivation of PDs and their parameters is the essential aspect in precise quantitative estimation of risks. However, their formation is only possible when sufficient number of variables is included in the projects. Therefore, considering the features of most of PD, alongside general sample, the search of PDs also has been performed for whose groups which consisted of more than 5 projects: A3, A4; A5*, A6* and A7. The particular exception is the groups A1 and A2 for those, due to lack of data, are applied the results of general sample by assuming that capabilities of public sector to manage Risk in these PIPs highly depends from the general capabilities to manage it.

Peculiarities of Risk. The analysis disclosed that on average the estimated budget is overrun by a quarter (R=1,2561). However, the observed tendency is not unambiguous. A little bit more than 2/3 of all analyzed PIPs have been implemented within the estimated budget of which 4/5 by fully used all planned assignations (1 table). On one hand, concentration of values around 1 could be explained by public sector's great efforts to properly estimate the investment costs and implement PIPs within the estimated budget. On another hand, usually there are many difficulties to get higher financing than planned assignations. Therefore, they may be finished without full implementation. This aspect of PIPs is low-analyzed and requests more detailed analysis in the following researches.

Table 1

Descriptive statistics of comparative analysis of estimated and actual used investment costs in the PIPs

Gr.	N	Dist	Min	Max	Avg	St. Dev	Kurtosis		Excess		Quantiles		
	Stat.	Stat.	Stat.	Stat.	Stat.	Stat.	Stat.	Error	Stat.	Error	25 %	50 %	75 %
GS	853	3,32	0,75	3,98	1,256	0,6172	2,482	0,084	5,882	0,167	0,993	1	1,2105
A1	1	0	1,89	1,89	1,889	-	-	-	-	-	1,889	1,889	1,889
A2	2	0,005	0,995	1	0,997	3,54E-03	-	-	-	-	-	2,5E-03	-
A3	564	3,23	0,75	3,98	1,287	0,613	2,189	0,103	4,556	0,205	0,992	1	1,364
A4	259	3,22	0,75	3,97	1,185	0,604	3,23	0,151	9,882	0,302	0,995	1	1
A5	4	1,5	1	2,5	1,471	0,709	1,641	1,014	2,537	2,619	1	1,1925	2,221
A5*	27	2,902	0,765	3,667	1,263	0,749	2,491	0,448	5,424	0,872	0,898	1	1,048
A6*	823	3,22	0,75	3,98	1,255	0,613	2,489	0,085	5,958	0,17	0,994	1	1,217
A7	23	2,9	0,77	3,67	1,227	0,765	2,752	0,481	6,717	0,935	0,884	1	1,045

GS - General sample; A1 - Land; A2 - Real estate; A3 - Construction, major repairs and other repairs; A4 - Equipment and machineries and other assets; A5 - Projection, technical maintenance and other services related with investment into A1-A4; A5 - Projection, technical maintenance and other services related with investment into A1-A4, (A5 and A7); A6* - Reinvestments (A3 and A4); A7 - Other services.*

Remaining 1/3 of PIPs have been characterized by excess of the estimated budget. The descriptive statistics revealed that excess was not greater than 1/5 (R=1,2105) in 3/4 of the cases, however, the values between PIPs have been widely distributed. Within one standard deviation of the mean, values lie in a range of R϶ (0,6389–1,8733), whereas the asymmetry is positive. Considering this statistics, it can be assumed that it is more likely that the estimated investment costs will be exceeded than PIP will be implemented within the limits of the estimated budget.

The results of the groups disclosed similar tendencies as in the case of general sample. In the groups of more than 5 PIPs, the average ratio varied in a range of R€ (1,185–1,287) by allowing expecting the lowest excess in PIPs related with procurement of equipment and machineries (A4) while the highest in PIPs of construction (A3).

Difference between the results of these two groups was the only one of in total 21 identified pairs of groups which could be confirmed as statistically significant.

The lowest excess in the group A4 could be explained by results in the quartiles which revealed that not less than 3/4 of PIPs have been implemented within the estimated budget, while the same results could be confirmed only in less than a half of PIPs in other groups. Particular exception also is PIPs related with preparation of feasibility studies and strategic plans (A7) of which 3/4 have been implemented by exceeding the estimated budget less than 4 %. This shows better results of the public sector to manage Risk in these two groups of the analyzed PIPs than in other ones.

The groups A1 and A2 consisted of only several PIPs. Therefore, due to low number of variables any reasoned conclusions about peculiarities of Risk exertion in them could not be done. However, most of their results also strongly contributed the earlier revealed tendency of excess of investment costs. This enforces to address the public sector to the potential systematic problems of cost estimation in the country as well as encourages looking for better tools to estimate Risk.

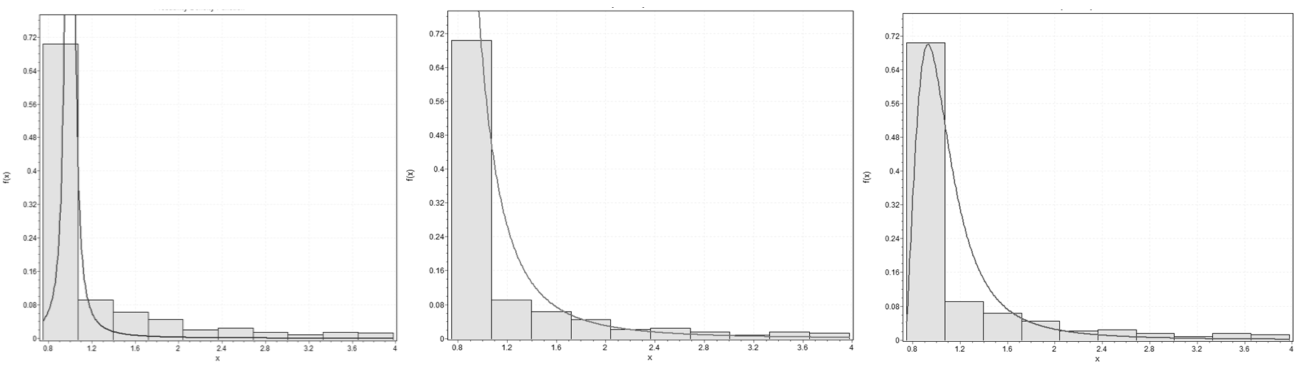
PDs. The results of analysis revealed a list of PDs statistically best enable to define Risk in PIPs. A table 2 presents the top 5 PDs in each of the group as well as in a general sample of which loglogistics (3 parameters), gen. pareto and cauchy have been the most often listed, respectively 6, 4 and 4 times. Cauchy was distinguished for a rank as “the most suitable” in 4/6 of the groups, while loglogistics was the only one listed in the top of every group. Considering the fact that the estimated distances between these theoretical PDs and the empirical samples are very similar, PDs have been matched only statistically and their significance of congruence is very identical, in order to choose the most appropriate one, it was important to consider the peculiarities of every PD since the parameters of theoretical PDs are determined such that total distances between PDs and samples would be the smallest. However, theoretical PDs formed in such a way can be very receded from the samples in their separate parts. This shows the requirement to complement quantitative risk assessment techniques by qualitative evaluation under these circumstances.

Table 2

Descriptive statistics of comparative analysis of estimated and actual used investment costs in PIPs

Rank	**Gen. sample**		**A3 (works)**		**A4 (equipment)**		**A5 (Services A1–A4)***		**A6 (reinvestment)**		**A7 (Other services)**	
	Stat.	**Dist.**	**Stat.**	**Dist.**	**Stat.**	**Dist.**	**Stat.**	**Dist.**	**Stat.**	**Dist.**	**Stat.**	**Dist.**
1	0,219	3	0,270	6	0,257	3	0,198	2	0,224	3	0,190	3
2	0,231	9	0,208	9	0,287	9	0,201	10	0,235	9	0,205	10
3	0,237	12	0,212	1	0,300	8	0,206	4	0,239	12	0,207	2
4	0,250	5	0,222	12	0,326	10	0,217	8	0,254	5	0,211	8
5	0,253	10	0,222	10	0,327	12	0,217	7	0,256	10	0,213	4
Dist.	**Stat.**	**Rank.**	**Stat.**	**Rank.**	**Stat.**	**Rank.**	**Stat.**	**Rank.**	**Stat.**	**Rank.**	**Stat.**	**Rank.**
11	0,330	37	0,293	37	0,423	32	0,359	36	0,332	35	0,377	32
13	0,332	40	0,295	38	0,416	36	0,377	41	0,332	36	0,432	39
14	0,524	53	0,470	55	0,656	54	0,540	51	0,524	53	0,661	54

1 - Beta; 2 - Burr (4P); 3 - Cauchy; 4 - Dagum (4P) ; 5 - Erlang; 6 - Erlang (3P); 7 - Frechet; 8 - Gen. Extreme; 9 - Gen. Pareto; 10 - Log-Logistics (3P) ; 11 - Lognormal; 12 - Log-Pearson (3P); 13 - Normal.



Cauchy **Gen. Pareto** **LogLogistics (3P)**

Figure 1. Graphs of probability density functions

Cauchy is a symmetrical PD which in comparison with normal characterizes by very high excess i.e. high concentration of values around the mode (Figure 1). Due to this feature, in a great part of its range it could reflect the observed tendency of a considerable part of the projects to be implemented within all estimated budget. However, due to the same feature risk estimates calculated by this PD are very small, i.e. in 70 % of the cases, the excess of the most expected value did not exceed 0,1–4,4 %, depending on the group, which is too low than a recommended minimum 10% level (Eliasson & Fosgerau, 2013). Therefore, cauchy was not the best option in this case. The application of gen. pareto whose mode consists with the lowest value in the sample also was not a solution since the assumption that the most expected value of estimated investment costs needed is the lowest possible value is unacceptable.

LogLogistics (LogLogistics of 3 parameters) consistently reflected the empirical samples in most of its range: 1) high excess and concentration of values around 1 reflect the fact of a great part of PIPs to be implemented within the estimated budget; 2) a positive skew illustrated the observed tendency of PIPs to be overrun in respect of estimated investment budget in the general case, and; 3) PD also reflect the small possibility of PIPs to be implemented with lower costs than it was estimated. Moreover, high ranks in the lists disclose its universality to be applied for risk assessment in the different long-term asset classes. These features determine loglogistics as the most suitable PD to assess Risk in PIPs.

Considering the literature where PDs such as normal, triangular and lognormal are the most often mentioned in the context of risk assessment in the investment projects, the results of research were fairly unexpected. However, the observed PDs of real values have been moved far away from these theoretical PDs ranking them only in the places of thirty-fifth decades (2 Table), on another hand, disclosing the high potential of loglogistics. The use of this PD would allow expecting to get the most accurate results of evaluation of Risk in PIPs. Based on this PD, a table 3 presents the estimated parameters which allow assessing Risk in every of 7 groups.

Table 3

The parameters of Loglogistics enabling to assess the Risk in PIPs

Group	Title	Parameters
A1	Land	α = 2,1121; β = 0,30732; γ = 0,74111; Mode = 0,9299
A2	Real estate	α =2,1121; β = 0,30732; γ = 0,74111; Mode = 0,9299
A3	Construction, major and other repairs	α =1,9673; β = 0,32927; γ = 0,74202; Mode= 0,92827
A4	Equipment and machineries and other assets	α =2,7906; β = 0,28554; γ = 0,72694; Mode = 0,945188
A5*	Projection, technical maintenance and other services related with investment into A1-A4, (A5 and A7)	α = 1,8405; β = 0,25464; γ = 0,75111; Mode = 0,88251
A6	Reinvestments (A3 and A4)	α =2,1274; β = 0,30981; γ = 0,73931; Mode = 0,931093
A7	Other services	α = 1,9247; β = 0,23155; γ = 0,7493; Mode = 0,876598

Considering early described PIP classification, these results also can be adopted for the estimation of Risk in appropriate long-term asset financial items. Different values of parameters describe the particularities of Risk in every of them. The authors of this article believe that research's results not only disclosed the particularities of Risk in PIPs in Lithuania, but also significantly contribute the attempts to assess it as accurately as possible.

Conclusions

Summarizing the scientific literature it was revealed prevailing practice to apply risk assessment techniques based on personal expertize, while the tools based on historical data due to a complex of reasons are given place. However, under the conditions of enough predictive environment their application can get more accurate results, and the public sector, in comparison with private one, through economy of scale usually has more possibilities to use their advantages. But, due to lack of skills and experience, for wider use of quantitative risk assessment techniques, the requirement for the solutions enabling to facilitate their application are appreciable.

The research revealed the permanent problems of public sector to raise sufficient financing as well as to manage Risk the PIPs. In the case of all analyzed PIPs, the underfinancing by a quarter was estimated.

By analyzing the peculiarities of Risk it was revealed that, among PIPs considered as implemented, on average the estimated investment budget was overrun by a quarter. The average overrun in the different groups has varied in a range from one-sixth till a little bit more than a quarter of estimated investment costs in PIPs of procurement of equipment and machineries and in PIPs of construction, respectively. The results in between disclosed the presence of different levels of Risk in every of the groups, however, only the difference of the results between mentioned marginal groups was statistically significant one. Therefore, only a phenomenon of PIPs of procurement of equipment and machineries to be likely lower overrun than PIPs of construction can be statistically confirmed.

The analysis of the peculiarities of Risk in the quantiles revealed that in all deeper analyzed groups not less than a half of PIPs have been implemented within the estimated budget. However, in the third quantile the results characterized by different level of cost overrun in almost every group. The highest cost overrun was estimated in the early mentioned PIPs of construction, while the group of PIPs of procurement of equipment and machineries distinguished as in which not less than three quarter of PIPs have been implemented within the estimated budget. Despite these differences between the groups, the observed general tendency of cost overrun leads the conclusion of presence of the problems related with the estimation of costs as well as the management of Risk in PIPs financed under PCIPs in Lithuania.

Cauchy, gen. pareto and loglogistics were ones of the most statistically suitable PDs to reflect the tendency of the estimated budget to be overrun in PIPs. However, considering their particularities, the last one is the only one recommended to use for the assessment of Risk. The list of these three PDs disclosed that phenomenon of the estimated budget to be exceeded in PIP is very far from the attempt to describe it by more so called "traditional" PDs such as normal, triangular, lognormal, etc. Therefore, in order to increase the accuracy of assessment of Risk in the PIP, to use loglogistics would be in comparison the better solution.

The findings of research contribute to the searches of universal tools for more accurate and convenient assessment of Risk as well as provide more possibilities for more efficient and transparent management of public finance.

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