Portfolio Management in the Construction Industry – Pricing Strategies Considering the Chance/Risk Ratio for Several Projects

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Abstract
The portfolio theory was developed by Markowitz (1952) and was originally a subfield of capital markets theory. Its starting point is a defined available investment amount distributed across several asset classes, such as equities or bonds, by its spreading or diversification. This diversification aims to reduce the associated risk relative to the variance and percentage of the return compared to an investment in only a single asset class. In relation to the capital market, this raises the question which securities to aggregate in a portfolio at which proportions. On the practical level, such an aggregation of investment opportunities happens through the establishment and marketing of funds, such as equity funds. In practice, theoretical considerations on how to establish an optimal portfolio are compromised by uncertainties of data and information on available investment alternatives as well as by market volatility.
In the construction industry, contractors are faced with a similar situation since they submit bids for various projects or requests for proposals. Contractors use the bid price as the key award criterion and thus manage both the chance/risk ratio in relation to the contract award and the economic success of the project if they are actually selected as the winning bidder.
Contractors thus need not only focus on individual current or new projects; they should also integrate the interactions between these different projects and departments into their considerations. This means that the portfolio approach provides a sound basis for decision-making with respect to the pricing of future projects.

Keywords
management of chances and risks; portfolio management; chance; risk; Monte Carlo simulation; construction contractor; project volume; chance/risk ratio

1. Introduction

In the engineering sciences, the concept of resilience refers to the capability of technical systems to not fail completely in the event of a partial breakdown (Bonstrom and Corotis, 2014). In this sense, any major project that a single contractor or consortium is unable to compensate financially by other projects (or insurance coverage, cf. El-Adaway and Kandil, 2010) constitutes a risk with respect to resilience. If a major project incurs substantial losses, this can pose a threat to the continued existence and operations of the company.

Elements of project portfolio management are utilized to investigate the resilience of a business or of one of its departments in respect of current and potential future projects. In this context, a (project) portfolio comprises a set of projects that are being jointly managed in order to yield a greater benefit for the business or department compared to independently managing each individual project. This exercise aggregates similar projects that can be allocated to a defined part of the organization.

Project portfolio management focuses on projects of a single management unit and deals with the permanent planning, prioritization, overall management, and monitoring of these projects. Key responsibilities include the assessment of future projects and continuous monitoring of current projects as well as tasks related to information and knowledge management across projects. Unlike project management, project portfolio management does not end with the completion of the considered project. Rather, it is a permanent management task that must be repeated in each subsequent cycle.

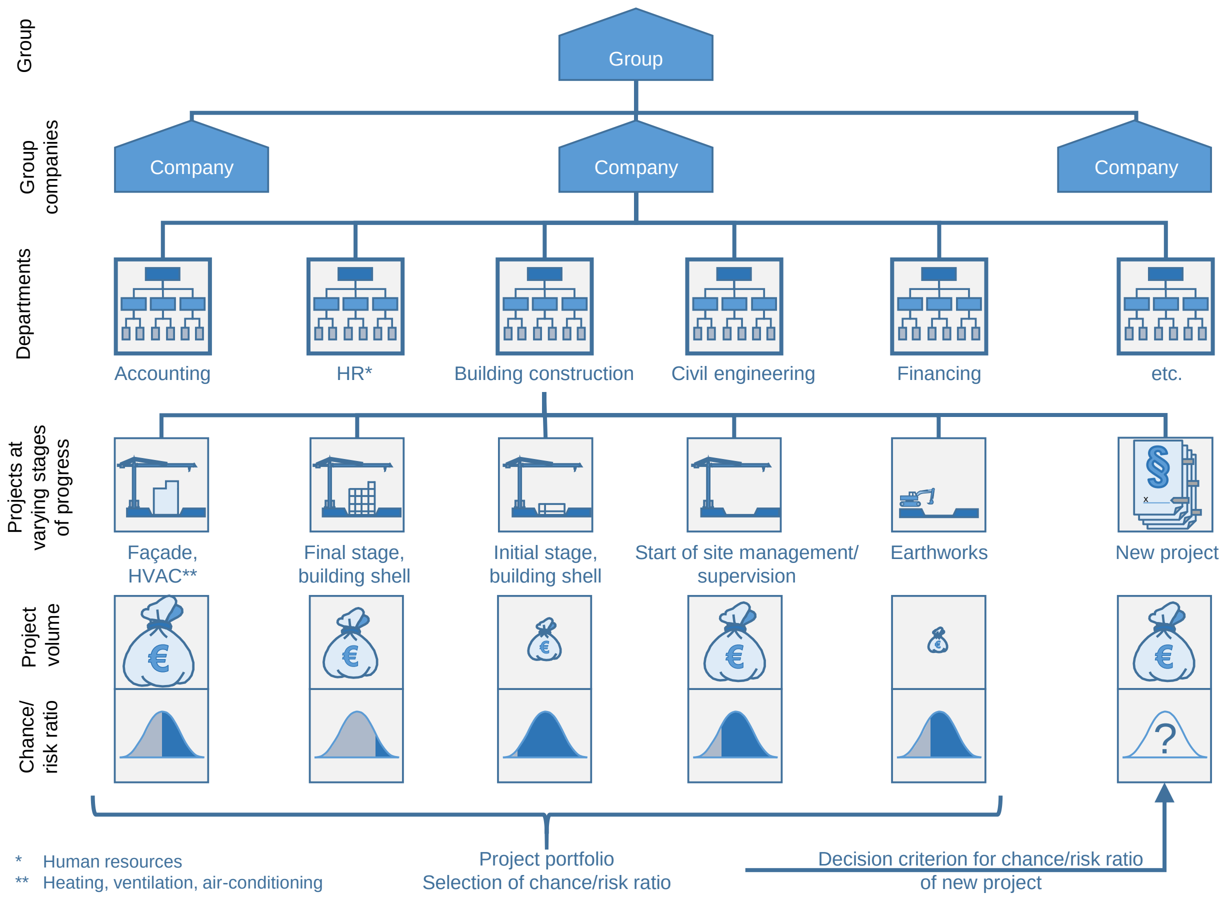

Figure 1: Selecting the chance/risk ratio for new projects

Fig. 1 shows a schematic representation of the structure of a company (or a group of [construction] companies). This company is subdivided into various departments that each manage projects of various sizes (project volumes) and at various stages of progress. In the first step, the chance/risk ratio of the existing project portfolio can be determined if a probabilistic cost estimate was previously performed for each of the projects, or if the chance/risk ratio can at least be stated that was assumed for the individual projects on the basis of the bid price. It is then possible to incorporate the probabilistic cost estimate in the portfolio for each new project and to determine the total marginal bid price from within the given range by performing a reverse calculation or selecting a chance/risk ratio.

At this stage, project portfolio management considers projects managed by identical departments, but it can also be extended towards the top, for instance by forming a portfolio comprised of several departments or companies. In so doing, cost calculations for projects in the execution phase must be continuously updated to enable project-related conclusions regarding the current chance/risk ratio.

2. Modeling

Fig. 2 shows the flowchart developed by Hofstadler and Kummer (2017) that is applied to modeling a portfolio management system that builds upon the chance/risk ratio of individual projects or of the entire portfolio. In the first step, the chance/risk ratio of a project portfolio is determined (control instrument), followed by calculating the bid price of a new project on the basis of a target chance/risk ratio (management instrument).

Initially, all current projects managed by the department or company must be listed with their contract volume or total amount. For projects in later completion phases, the contract amount needs to be adjusted by any quantity over- or underruns and additions to the contract. The total is derived from the deterministic contract volume data. This amount is subsequently used to calculate the chance/risk ratio of the current project portfolio.

Each project needs to be checked with regard to the existence of a probabilistic cost estimate (adjusted to project progress). If such a probabilistic cost estimate is available, it should be directly applied to modeling the cost distribution for the respective project. If no probabilistic cost estimate exists, further information or qualified estimates of the current project situation are necessary. This information comprises potential cost deviations (minimum and maximum values) as well as the probability (expressed as a percentage) of over- or underrunning the (adjusted) bid price. Overall, these two percentages, which reflect the chance/risk ratio for the individual projects, must give 100% (probability and counterprobability). Additional information, such as shape parameters, might be required depending on the distribution function selected for the cost distribution per project (Kummer, 2015).

After modeling all cost curves as distribution functions, a Monte Carlo simulation can be performed to derive the cost distribution total. This addition results in a histogram whose range also contains the deterministic value of the total derived from the contract volumes. The probability of over- or underrunning this value within the range of the derived histogram corresponds to the chance/risk ratio of the current project portfolio.

For any new project that is to be integrated in the product portfolio by submitting a bid, a probabilistic cost distribution must be determined and added up together with the other cost distributions of current projects. This step results in a histogram of the cost distribution within the new portfolio.

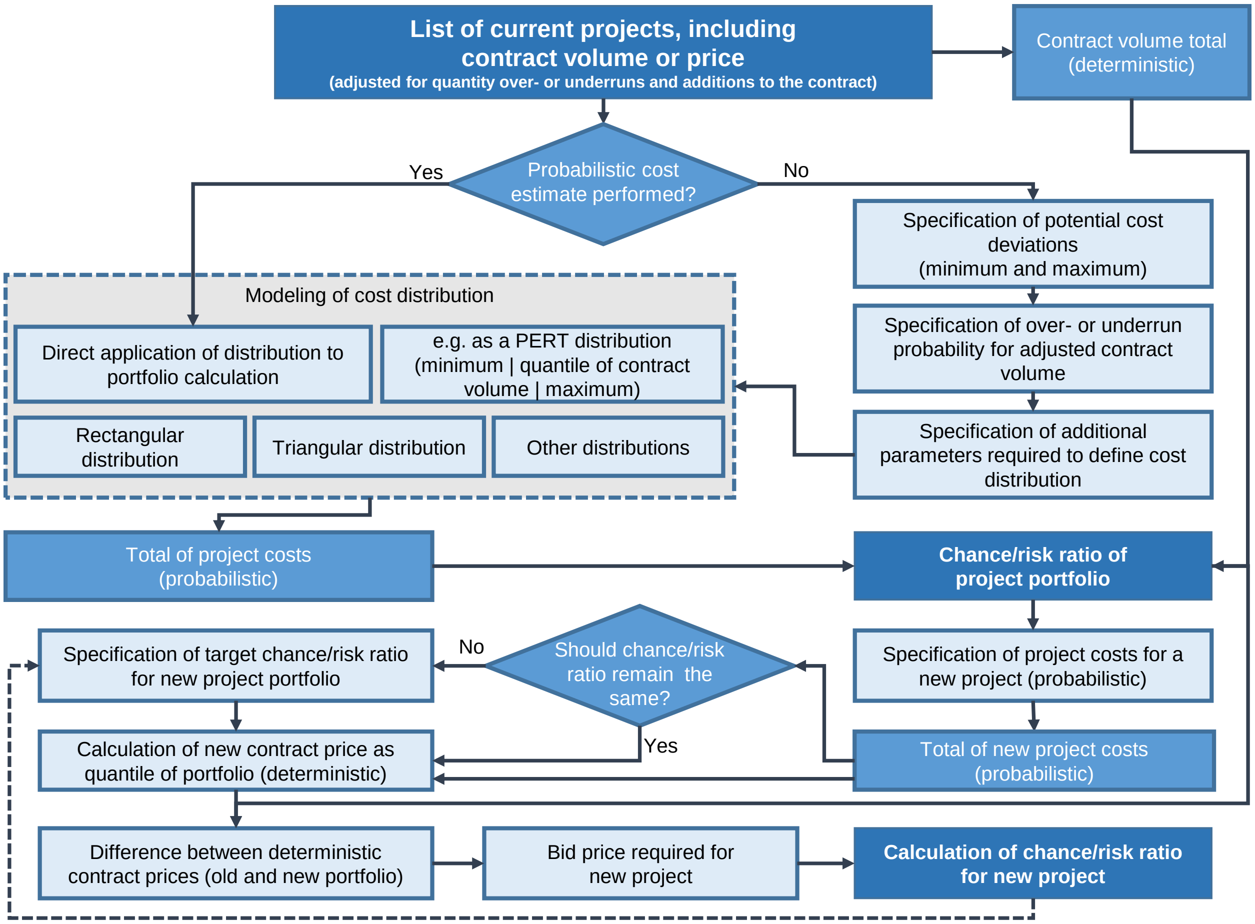

Figure 2: Flowchart – chance/risk ratio – project portfolio

In the next step, a decision must be made as to whether the previous chance/risk ratio should still be used after adding the new project to the portfolio, or whether this ratio needs to be adjusted. If such an adjustment is intended, the new ratio should be stated, and the histogram representing the new total should be used to determine the corresponding quantile of bid prices for the new portfolio.

The difference between the (deterministic) bid prices of the original and the new portfolio results in the (minimum) bid price for the new project required to achieve the risk-diversified target chance/risk ratio for the entire new portfolio.
Finally, entering the derived deterministic bid price into the cost distribution of the new project enables determination of the corresponding project-specific chance/risk ratio. If the derived chance/risk ratio or bid price for the new project is unacceptable, for instance because of an exceedingly high risk for the single project, the target chance/risk ratio must be adjusted for the portfolio, or the project should not be added to the portfolio at all.

3. Worked Example

A worked example (Hofstadler and Kummer, 2017) demonstrates for a corporate department how the chance/risk ratio can be determined for the portfolio of current projects and how a new project can be integrated into the portfolio.
Cells 1 to 5 of Table 1 list currently executed projects with their designations (Column A) and current stage of progress (Column B). Column C specifies the deterministic individual contract volumes or bid prices

(adjusted for quantity over- or underruns and/or additions to the contract). The total of these contract volumes is calculated in cell C6. Thus, the project portfolio is comprised of projects with varying levels of progress and different sizes (project volumes). Likewise, the individual projects are associated with varying chance/risk ratios.

Columns D and F contain the possible absolute cost deviations from the contract volume per project. Contract volumes must lie within the range specified in columns D and F. Columns E and G state the percentage deviations of minimum and maximum values on the basis of the deterministic bid prices shown in column C.

Minimum and maximum values can be used to define rectangular distributions if no probabilistic calculations of cost distributions were performed for the individual projects. Another approach would be to use the minimum value (column D), the contract volume (column C) and the maximum value (column F) to define a triangular or PERT distribution. However, since the contract volume need not necessarily correspond to the expected value (mode) of, for instance, a PERT distribution, columns H and I provide the option to specify probabilities of contract volume over- or underruns. The total of both percentages must amount to 100%. These percentages also reflect the chance/risk ratio of the relevant project. Column J contains the cost distributions of the individual projects. This is where existing distributions derived from probabilistic cost calculations or newly defined distributions, such as rectangular or triangular distributions, can be entered as far as they are available and/or have been updated or adjusted.

In the worked example, PERT distributions determined by the contents of columns C, D, F, and H are consistently used to demonstrate the applied methodology. The function =RiskPertAlt(“min“;D;H;C;“max“;F) is applied to generate input distributions in the *@Risk* software, which is used for the purpose of these calculations. In this exercise, the letters D, H, C, and F correspond to the values in lines 1 to 5 of the respective columns in Table 1. This definition of the distribution by means of a quantile instead of the expected value makes it possible to directly integrate the estimated probabilities for contract volume over- or underruns into the cost distribution. For Project C, the PERT distribution is thus defined using the following command: =RiskPertAlt(“min“;1,100,000;0.10;1,200,000;“max“;2,000,000).

Table 1: Worked example – project portfolio

Item No.	Project designation	Project progress	Contract volume/ bid price*	Potential cost deviations*				Underrun probability	Overrun probability	Project cost distribution
				Minimum		Maximum		Chance	Risk	
		[%]	[€]	[€]	[%]	[€]	[%]	[%]	[%]	[€]
0	A	B	C	D	E	F	G	H	I	J
1	Project A	80,00 %	30.000.000	28.000.000	-6,67 %	32.000.000	6,67 %	40,00 %	60,00 %	30.192.650
2	Project B	60,00 %	15.000.000	12.000.000	-20,00 %	15.500.000	3,33 %	55,00 %	45,00 %	14.814.020
3	Project C	35,00 %	1.200.000	1.100.000	-8,33 %	2.000.000	66,67 %	10,00 %	90,00 %	1.398.542
4	Project D	30,00 %	17.500.000	15.000.000	-14,29 %	21.000.000	20,00 %	35,00 %	65,00 %	17.989.584
5	Project E	5,00 %	800.000	700.000	-12,50 %	1.000.000	25,00 %	50,00 %	50,00 %	805.251
6	**Total**		**64.500.000**					**31,83 %**	**68,17 %**	**65.200.047**
7	Project NEW	0,00 %	10.875.985	9.000.000	-17,25 %	12.500.000	14,93 %	**82,28 %**	**17,72 %**	10.250.000
8	**New total**		**75.375.985**					**48,00 %**	**52,00 %**	**75.450.047**

* Adjusted for quantity over- or underruns and additions to the contract

Cell J6 in Table 1 calculates the cost distribution total of current projects. A subsequently performed Monte Carlo simulation (50,000 iterations; Latin Hypercube sampling) serves as a basis to derive the histogram of the total and to enter the deterministic contract volume total (column C6) (see Fig. 3). For the entire portfolio of currently executed projects (i.e. A to E), a chance of about 32% results for the actual costs being lower than the invoiced contract volume (cell C6). On the other hand, there is a risk of approximately 68% (counterprobability) for actual costs to exceed the invoiced contract volume.

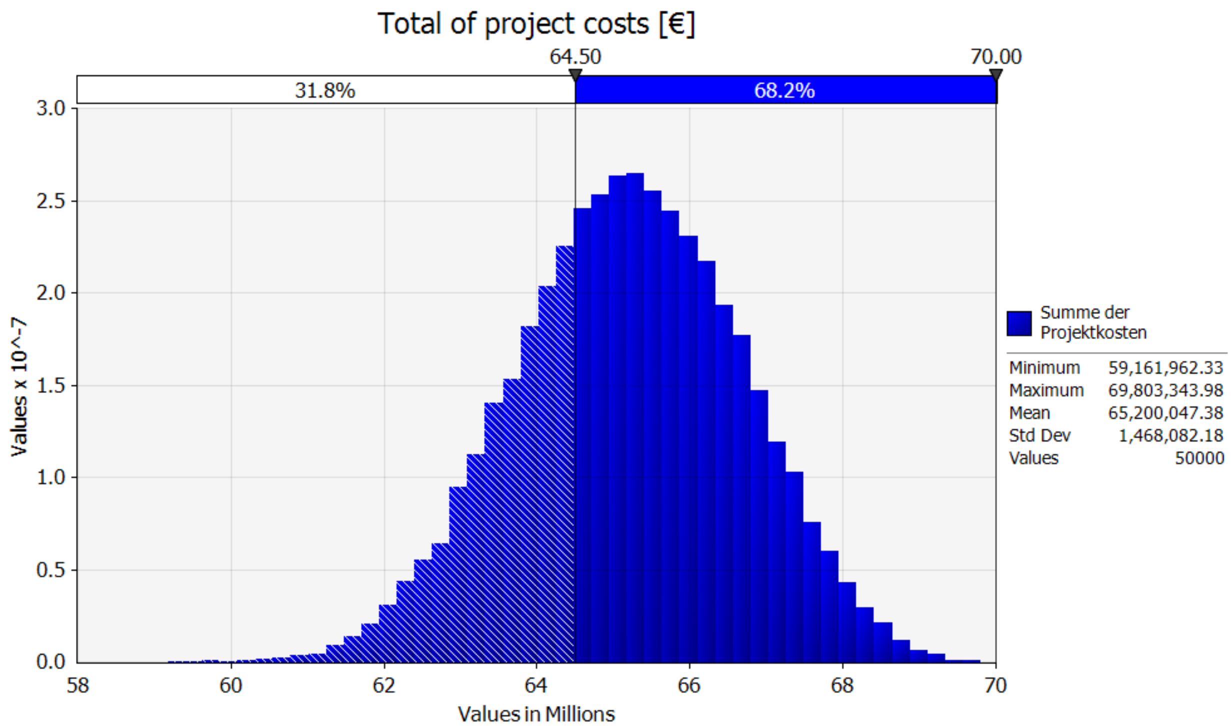

Figure 3: Histogram – cost distribution total (Projects A to E)

The difference between the contract volume total (the deterministic value in cell C6) and the cost distribution total (cell J6) results in a histogram that shows the potential profit or loss relative to the entire portfolio. The amount of the potential profit is represented by positive values on the x-axis, whereas the amount of potential losses is expressed by negative values on the x-axis. In the worked example, the risk of a potential loss outweighs the chance of a potential profit, resulting in an unfavorable chance/risk ratio with respect to the economic success of the department or company. Consequently, this trend should be reversed for any new projects, and the proportion of chances should be increased for the entire portfolio.

The worked example also examines the implications that a new project would have on the chance/risk ratio of the portfolio as well as the bid price that would be required in order to achieve a defined ratio. Line 7 of Table 1 adds a new project to the portfolio ("Project NEW"). For this new project, a probabilistic cost estimate or specification of a cost distribution is assumed. This distribution is entered in cell J7 of Table 1.

A simplified PERT distribution with the following cost values was assumed for the worked example:

Minimum (cell D7):	€9,000,000
Expected value (not shown in Table 1):	€10,000,000
Maximum (cell F7):	€12,500,000

This distribution is subsequently added to the cost distribution total (cell J6) and gives a new total in cell J8. In the next step, the new (target) chance/risk ratio of the new project portfolio (i.e. Projects A to E plus Project NEW) is stated in cells H8 and I8. The total of the two percentages must amount to 100%. In the worked example, a new target chance/risk ratio of 48% to 52% was specified to increase the proportion of chances for the entire portfolio.

Calculation of the 48% quantile of the new cost distribution total (cell J8) makes it possible to derive the deterministic value for the new contract volume total. Fig. 4 shows the new (target) chance/risk ratio for the project portfolio that was set using the sliders. The deterministic value that defines the limits between the two ranges on the upper edge of the diagram is the same as the amount stated in cell C8 of Table 1 (i.e. €75,375,985).

Calculating the difference between the contract volume totals with and without Project NEW (cells C8 and C6) results in the minimum contract volume for Project NEW in cell C7. This total is equivalent to the bid price that must not be underrun on the basis of the probabilistic cost distribution of the new project (cell J7) in order to achieve the target chance/risk ratio for the new portfolio. If a higher bid were placed for the project, this would increase the proportion of chances for the entire portfolio. If a lower bid price were stated, this would increase the proportion of risks not only for the project but also for the complete portfolio. The percentage deviations shown in cells E7 and G7 are related to the deterministic bid price in cell C7.

Finally, cells H7 and I7 are used to state the chance/risk ratio for Project NEW. This step proves that the proportion of chances for this project (with a corresponding project volume) must be defined at a relatively high level (chance: 82.28%; risk: 17.72%) to achieve the intended change in the chance/risk ratio for the entire portfolio. Generally speaking, major projects (with a large project volume) have a more significant influence on the entire portfolio than comparatively small projects. Likewise, the chance/risk ratios of such projects influence the portfolio more strongly than those of smaller projects.

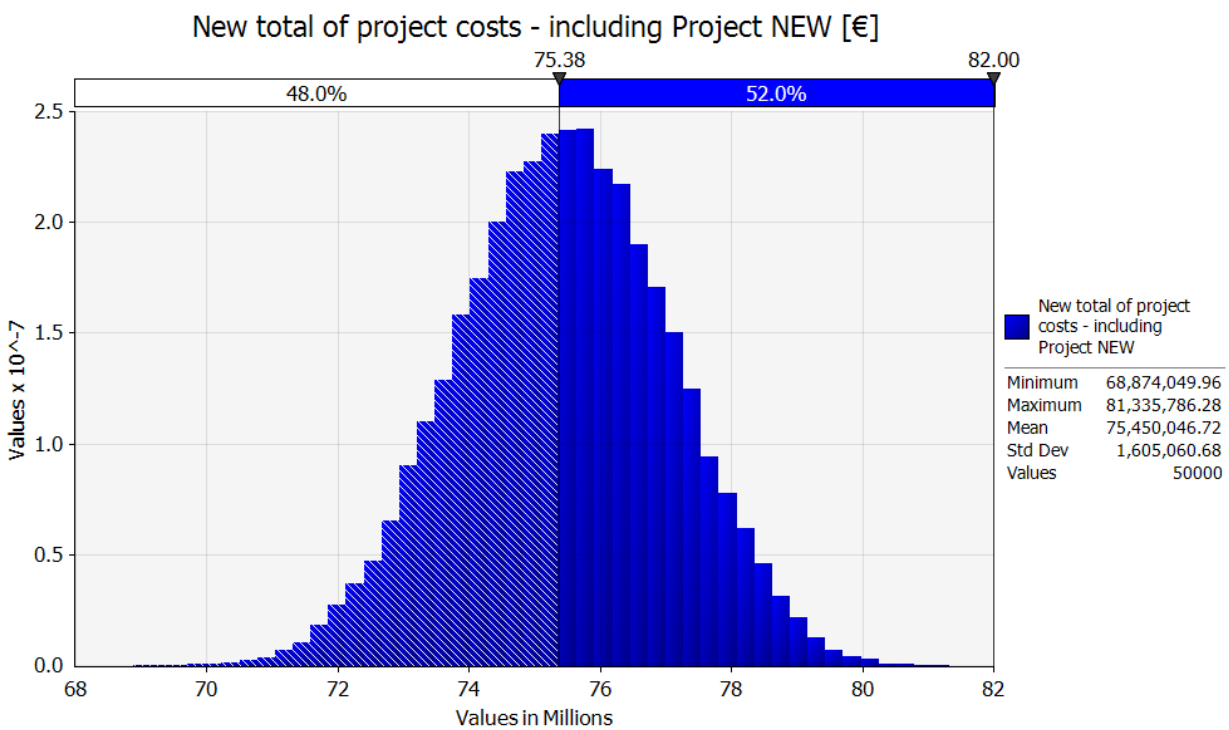

Figure 4: Histogram – new cost distribution total – including Project NEW

The target chance/risk ratio of the portfolio must be adjusted if the bid price determined for the new project using the above approach appears to be exceedingly high (in relation to the market price level). However, the lower the bid price for a new project is, the smaller the increase in the proportion of chances for the portfolio will be. This principle applies until a specific bid amount (marginal amount) is underrun, and the addition of the new project to the portfolio would result in an increase in the proportion of risks for the portfolio.

4. Conclusions

The method of managing and controlling the chance/risk ratio of a full set of current and new projects (portfolio) provides the advantage that bid prices of new projects can be proactively modified in iterative steps if the underlying data base is adjusted accordingly. In this process, the chance/risk ratio determined for the portfolio is used as a key management instrument.

The system outlined above makes it possible to effectively aggregate projects at varying stages of progress, with different contract volumes and chance/risk ratios in a single portfolio, which then permits conclusions regarding individual new projects.

Project portfolio management can thus be used both as a control instrument (monitoring the effects of a selected bid price on the chance/risk ratio of the portfolio) and as a management instrument (determining a minimum bid price to achieve a defined chance/risk ratio for the portfolio).

Clients can apply this methodology in a similar way. Their available budgets only enable completion of a certain number of projects. If no direct returns can be generated on these projects (such as in the field of infrastructure), the portfolio analysis will be restricted to the expense side (expenditure or costs) (see e.g. Dettbran et al. 2005). The client or principal should thus aim to prevent any overrun of the available total budget. However, this goal can be achieved only with a certain probability due to the uncertainties associated with future developments. Clients utilize the selection of projects to be completed or the narrowing of the cost ranges of individual projects (for instance by entering into lump-sum and/or fixed-price agreements) as management instruments. Depending on the type of client (public vs. private), there is a greater or lesser degree of flexibility in terms of project selection. Unlike financial mathematics, which, for instance, enables the purchase of any number of shares, the project portfolio management approach does not enable the "cutting into pieces" of individual projects. Any investment in a project is either effected in full or not at all.

The above model poses the particular challenge of correctly determining the chance/risk ratio for current projects and deriving an appropriate definition of distribution functions in order to arrive at conclusions for the entire portfolio and, subsequently, for individual projects.

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