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CIVIL ENGINEERING

S-model for project cost management in value engineering for construction companies

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Abstract. Today's fast-changing environment for construction companies requires rapid responses and adaptation of their projects. Despite the multitude of tools applied for project cost management in engineering and construction companies, there is a need to form comprehensive solutions. The purpose of the study is to form a methodological approach to project cost management in the field of engineering construction based on alternative models to diagnose the development, assessment and selection of functional areas and content of cost management in the construction project, which allows one to increase adaptability and flexibility in the process of its implementation. The basis of research methodology is modeling, which allows one to adjust the economic and financial flows based on three *S*-curves, one for each component of the total cost of the work: direct costs, indirect costs and reserves. These curves include the direct cost curve for the main purchasing packages as well. This brings financial flows closer to reality because it is possible to adjust the *S*-curves according to the behavior of each subsystem. The contribution of the study is the proposed approach of integrating concepts related to the coordination and development of project design and production management (lean construction), forming a "3D model of management", in a broad and comprehensive management system. It assumes a comprehensive and complete way to manage civil engineering projects. The proposed methodological approach can make a significant contribution to the preparation of forecasts and estimates by planners and controllers in the context of construction projects.

Key words: cash flow; construction management; cost control; engineering construction; scenario modelling; value management.

1. INTRODUCTION

The dynamic nature of the business environment in which enterprises operate, the instability of modern market relations, the complexity of internal business processes, the limitations of alternative forecasting of development in uncertain times and the spread of pandemics all contribute to the importance of measures to prevent deviations from construction projects as a component of preventive anti-crisis management of construction enterprises. Economic conditions in the modern era and the spread of the COVID-19 pandemic have necessitated the application of rational research methods and techniques, as well as the development of new methods based on technological advancements in construction production [1]. It is essential to maintain cost control throughout the life of a construction project, beginning already with the initial design stage. All feasible options should be considered for projects, which is especially critical during the design stage to achieve the lowest possible cost. The purpose of this study is to evaluate project cost management tools, from budgeting to commissioning that are based on estimates, cost control over the level of expenditures, and the project budget, all of which comprise value engineering (VE). This term was coined relatively recently among construction professionals. VE was pioneered by General Electric during World War II and is now widely used in a variety of industries, including defense, transportation, construction and healthcare. VE is a proven method for lowering costs, increasing productivity and enhancing quality [2].

VE as a collection of solutions to a variety of tasks is a cutting-edge and modern product that is gaining traction in the construction services market daily. This is especially true in modern times when one of the primary objectives of any construction organization involved in professional real estate activities is cost reduction [3]. VE is a term that refers to the process of improving products, organizational services and manufacturing technologies. The core of VE is an organizational procedure for determining the best balance between a product's utility and the costs of its development, improvement and use. The cost engineering system's primary benefits include risk reduction for the organization, growth of competitive advantages in domestic and international markets, reduction of work deadlines and associated costs, and an increase in return on investment due to the emergence of project budget levers [4].

The construction sector is characterized by uncertainty as a result of the pandemic's spread, which emphasizes the importance of planning and control specialists' activities involved in cost management processes at the company's facilities, which are the subject of this study. These professionals add value to

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the organization by ensuring that budget estimates are founded on a thorough understanding and comprehension of the activities, methods and resources required to carry out an enterprise's tasks, as well as of the risks it faces [5]. Any deviation from budgets or forecasts can create a tough situation, jeopardize an enterprise's expected outcome, and result in losses for both the company and its clients [6]. Thus, this study contributes to the development of tools and models that construction professionals can benefit from. Additionally, it provides an overview of the fundamental concepts used in construction cost management.

The analysis of recent studies and publications on VE shows that at present there are many tools for construction contractors. However, there is a need to develop a comprehensive approach that would allow them not only to formally describe all the stages of VE in the internal environment of the construction company, but also to identify the economic, organizational and managerial benefits of implementing VE, taking potential changes during its implementation into account [7, 8]. The purpose of this study is to develop an applied scientific and methodological approach to diagnose the development, assessment and selection of functional areas and content of cost management in the construction project, which allows for greater adaptability and flexibility in the process of its implementation. The following tasks are defined and solved under the set objective. First, principles, methods and management systems for selecting cost management directions for a construction project have been developed. Simultaneously, the methodological tools have been enhanced to enable a holistic assessment and selection of projects based on cost management. The cost management toolkit developed as a result of this study demonstrates the feasibility of cost management in a construction project. It enables an enterprise to overcome crisis phenomena and gain competitive advantages through incremental cumulative economic, organizational, administrative, marketing, production and engineering improvements. The toolkit developed will provide proper justification and information to the management of a construction company regarding the competitive advantages, economic growth and systematic improvement of the operational cycle quality that the company should receive as a result of implementing cost management in the construction project.

An important problem for construction projects, both civil and industrial ones, is the discrepancy between the project cost of construction and the actual cost of its implementation. Such discrepancy makes it impossible to make accurate and balanced plans of financial flows both for the investor and the construction company itself [9]. A tool for managing the cost of a project from budgeting to commissioning, based on control over cost levels and project budgets, is value engineering. This term appeared relatively recently among construction industry professionals in the General Electric Corporation during World War II and is widely used in such fields as defense, transportation, construction and healthcare, among others. VE is an effective method for reducing costs, increasing productivity and improving quality [10]. VE is a field of activity on implementing cost calculations (justifications) at all stages of the investment and construction project, which determines the economic relations among the participants [11].

VE is also seen as a systematic and low-cost approach to estimating project costs. Typically, projects can use this to achieve the following benefits: cost savings, time savings (schedule savings), quality improvements, and elimination of design flaws [12]. Studies are present that show aspects and problems of the construction industry as compared to the manufacturing industry. CBR (case-based reasoning) conceptual experts have substantiated the bases for implementing documentation, which is a form of coherent framework for describing virtually any VE expert model. The proposed concept outlines the structure of knowledge and its relations in the VE mastery. The model is advantageous for the use of fuzzy approach in processing uncertainty in the evaluation phase of the methodology [13]. Another study, focusing on one component of ICD (integrated collaborative design), examines existing reactive design methods and their importance, and determines the need for an integrated approach by identifying their shortcomings [14]. Context value management is described when integrating cost optimization techniques into continuous design processes. The study examines the ability to leverage the design experience of an information action modeling vendor [15]. Research has been developed on the production of holistic cost engineering estimates as used in the U.S. construction industry by studying current theory and practice. This involves evaluating technical projects and calculating the savings achieved by them [16]. Another approach looks at how value engineering contributes to the process of obtaining an optimal solution when solving the problem of building design [17, 18]. There are also studies that emphasize that VE does not only stand for cost reduction, but it is a systematic method for increasing the value of goods and services through research function [19].

Cost optimization comes close to management cost because it relies on cost reduction paths as specific items or activities. However, it does not take into account the overall project picture or the daily performance record, as it targets only specific items in design, procurement and construction. In this regard, VE should focus on analyzing the functions of an object or process to determine the best value or best value-price relationship. In other words, the best ratio is the product or process that consistently performs the necessary basic functions and has the lowest life-cycle cost [20]. Due to the fact that "costs" are measurable, cost reduction is often perceived as the only criterion for a VE program, and this is primarily addressed in most of the current studies being reviewed. However, the true goal of VE is to increase value, which may not always result in immediate cost reduction.

One of the main issues that construction project managers face is that important decisions are made to keep projects running without the availability or completeness of the data required to support such decisions [21]. In other words, one of the primary tasks in construction is the management of information and its transformation into the enterprise over time [22]. This information becomes available during the development of projects and other technical documentation, which typically occurs concurrently with the execution of work. Simultaneously, the degree of uncertainty that managers face when managing a project begins at a high level and gradually decreases throughout the project, forming a so-called spiral of uncertainty [23].

Sequential wave planning, as described in the PMBOK Guide, is a similar concept in which project planning becomes more detailed as new information becomes available to the project team [24]. The "rolling wave" principle, which can also be interpreted as successive waves, is another equivalent concept in which long-term goals are considered more broadly and short-term goals are considered in greater detail [25].

Another important point to keep in mind when it comes to how engineering and construction companies run their businesses is that the concepts and management tools used in this industry are typically derived from manufacturing engineering. To rephrase it, these theories were created with the primary goal of benefiting industries and plants in mind. However, given the differences between a construction site and an industrial enterprise, the application of these concepts always requires attention [26]. In general, if the industry is represented by highly sequential work that is constant and in a stable and controlled environment, then the construction site is represented by work with a high degree of interference between stages, very changeable, and in an environment full of disturbances and unpredictability [27].

Other aspects of the construction industry that have an impact on the management of development implementation include the following: the products produced are one-of-a-kind; the production area (construction site) is not permanent and falls subject to inclement weather; teams performing work are assigned temporarily [7, 28]. All of these factors contribute to the difficulty of budgeting for and evaluating projects. The primary issues in this area are difficulties with assessing the quality and accuracy of initial cost estimates, difficulties describing early-stage work scope decisions, difficulties determining the variability and uncertainty of work scope and costs, and finally, difficulties tracking the impact of various project changes on costs [29]. All of these issues eventually have a direct impact on the project's cost management during implementation.

On the other hand, taking into account socio-economic factors, the civil engineering industry as a whole is characterized by high production costs, waste of various types (e.g. large amounts of production waste) [30], and a large number of employed workers, most of whom are not qualified [31, 32]. However, due to its significant importance and the scale of the production chain, taking care of modernization and innovation in the construction industry is necessary and requires the attention and dedication of all the parties involved, especially professionals working on the market and especially those involved in cost management during projects [33].

Forecasting the actual future cost of projects accurately does not receive the attention it deserves. Therefore, there is an urgent need for research in this area and for development of certain methodological approaches to the formation of realistic financial plans and forecasts concerning the future value of construction. The purposes of such a study are to determine the deviations between the design cost of construction and its final cost, to study the causes of deviations in the main cost elements, and to develop ways to reduce them.

Existing cost forecasting theories and methodologies frequently refer to a single outcome. Generally, the point result does not aid in decision-making, given the degree of uncertainty associated with the prerequisites considered during their development. For instance, value-added analysis can provide critical information about the current state of a project but should be used with caution when forecasting the future [34, 35]. All of this contributed to the study's purpose: to provide forecasting tools and models that will enable construction planning and control specialists to improve the way they prepare cost forecasts and to increase the efficiency of construction project cost management. Given the high level of uncertainty in the construction industry, as previously stated, risk analysis and potential future scenarios are necessary for businesses to develop strategies and action plans in the event of any contingency.

2. METHOD

The methodological approach incorporates concepts related to project coordination and development, as well as production management (including lean construction), resulting in a "3D management model" within a comprehensive and integrated management system.

The proposed approach is aimed at a management system that incorporates the PMBOK Guide's project management concepts and best practices, as well as the option of integrating these concepts into a specific quality management system, such as the one certified by ISO 9001 (quality), ISO 14001 (environment) or OHSAS 18001 (occupational health and safety). The process of integrating these concepts results in the formation of a "3D model" (Fig. 1). According to it, a construction company's integrated management system should integrate three critical areas of knowledge:

- project management: refers to all of PMBOK Guide's outlined concepts,
- product management: refers to the processes and activities required for project development and coordination (design),
- production management: refers to the processes and activities involved in performing and controlling a particular job. This area encompasses critical concepts such as logistics, production planning and control, and lean construction.

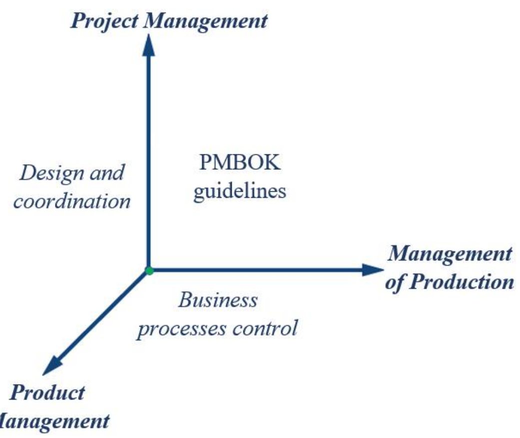

Fig. 1. 3D Model of project cost management in engineering and construction companies. Source: created by the authors

The model developed in this study is a platform for reformatting the integrated management system, and it was created using the participating engineering construction company's materials. The materials from the engineering construction company project were used to test the proposed methodological approach. It is an engineering and construction company that has been on the market for forty-five years. In general, the company seeks private clients interested in building facilities for their own activities (hotels, hospitals, shopping centers) or for real estate operations for sale or lease (commercial buildings, logistics warehouses), covering a wide range of developments. Five projects were considered for this study: construction management for a hospital, outfitting a corporate building, outfitting when expanding a commercial building, a logistics warehouse, and a shopping mall. The focus of the company is on comprehensive developments, where it is possible to work together with customers on projects and value engineering, always striving to find the best solution, the one that adds the most value for the customer and their operations. Less complex or smaller projects are not the focus of the company because in these cases there is usually no opportunity to step in to find better technological solutions that add value to the building, and in addition, competition with smaller companies makes projects less attractive.

The methodology used in this study is an analysis of the *S*-curve, which takes account of inclination adjustment, the location of the maximum inclination (change in curvature) and initial costs (advance payment). The forecasted start of work (or the actual start in the case of work in progress), as well as the duration of work, are used in addition to the budget information. These data are required to create *S*-curves, which are used to generate financial flows. The *S*-curve is a popular tool for forecasting financial aspects of a project as well as for monitoring physical progress. The following formula was used to obtain the *S*-curve [36]:

$$y(x) = p + (1-p) \times \frac{\dfrac{1}{1+\mathrm{e}^{k(ax-1)}} - \dfrac{1}{1+\mathrm{e}^{-k}}}{\dfrac{1}{1+\mathrm{e}^{k(a-1)}} - \dfrac{1}{1+\mathrm{e}^{-k}}}. \tag{1}$$

This equation was introduced for all variants of the cash flow model considered in this study. Changing these three parameters of logistic or sigmoid function (p, k, a) provides a set of curves that, in this case, describe all potential project options. The parameter k in this function can adjust the slope of the *S*-curve. Parameter a can have an influence on the position of the maximum slope (which corresponds to half of the planned budget volume). Parameter p can express the share of the total amount (prepayment to the contractor) and determine the initial step on the generated curve, taking into account parameters a and k.

To apply this formula, deadlines and costs must be standardized (i.e. take values from 0.0 to 1.0). Therefore:

$$x = \frac{\text{period incurred}}{\text{period total}} = \frac{\text{current date-start date}}{\text{final(planned) date-start date}}, \tag{2}$$

$$y = \frac{\text{incurred cost}}{\text{budget}}. \tag{3}$$

The use of the *S*-curve involves defining the following three parameters:

- k – slope control, which can vary from 0.001 to 10.000. A value of 0.001 returns a linear distribution;
- a – adjusting the position of the maximum inclination (change in curvature), which can range from 0.001 to 3.000. That said, this study assumes that the higher the cost, the earlier the cost occurs;
- p – the parameter of initial costs (initial payment), which demonstrates the amount of incurred costs, from which the curve S is formed. This parameter can take values from 0 to 1.

The financial flow is created in this study when creating the cost calculation model, taking into account the input data and the auxiliary parameters to generate scenarios.

Along with the *S*-curve parameters, this study defines parameters for calculating stressed scenarios, such as changes in work deadlines and the resulting penalties; changes in calculated costs based on their volume (VC – volume of client or CV – company volume); financial parameters (tax deductions, contract deductions, payment deadlines, etc.); parameters that help make a price closing decision (change in the tariff to be charged, cost reduction due to EVA (earned value analysis), IC (indirect costs) discounts, etc.); and parameters for *S*-curves used for DC (direct cost), IC and CTG (contingency) (Fig. 2).

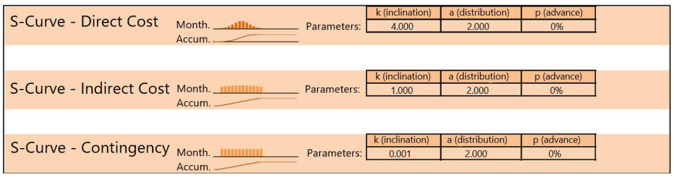

Fig. 2. Parameter entry for the model's *S*-curves
Source: created by the authors

In this study, parameters related to variations are taken into account when generating stressed scenarios (Table 1), including variations only of costs, deadlines, costs and deadlines, etc.

The initial estimated costs are allocated by month by applying an *S*-curve (specific to each type of cost: CD, DI and CTG). Thus, the cost formation for a given month is obtained. The percentage of variation calculated according to the selected parameters is applied to this part (for example, if a parameter is set to perform a global variation, an additional percentage of costs is applied which varies between 0% and the maximum variation of costs set in the parameters, in the example given, 5%). Based on the costs, the revenues that these costs generate are calculated according to the rules of each contract form (e.g. in management contracts the rate is calculated on the costs, in performance contracts or PMGs the revenues are calculated until the allowed maximum value is reached, etc.).

Based on the results of certain parameters obtained in this study, the calculation was performed following the steps described below (Fig. 3).

Table 1
Parameter entry for generating stressed scenarios

Scenario generator	0 = benchmark	Positive values return the reference scenario but generate the analysis graphics. Negative values return a sample stressed scenario. 1 = overall variation ∣ 2 = costs variation CV ∣ 3 = costs variation VC ∣ 4 = term variation ∣ 5 = costs only variation		
Variation company costs	1 = benchmark	1	Var. max. cost CV	5%
Costs variation client	1 = benchmark	1	Var. max. cost VC	5%
Variation deadlines	1 = benchmark	1	–	–

Source: Created by the authors

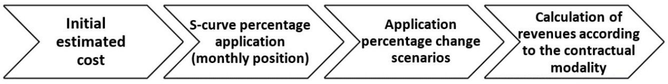

Fig. 3. The study's logical calculation chain
Source: created by the authors

The model developed in this study satisfied both study requirements. The first is a more streamlined preparation of financial flows to facilitate risk analysis during the proposal preparation stage. The second is to conduct scenario analysis using reports on the cost dynamics of ongoing work. To accomplish this, the model generates modified (or stressed) scenarios based on the benchmark scenario in response to evaluation parameter variations. This considers the benchmark scenario, which the planner believes should occur over time [37]. This scenario is also known as the "most likely" one, as it is constructed using the best information available to the scheduler at the time. Stressed scenarios are designed to allow for the examination of the effect of model parameter fluctuations, thereby determining the degree of risk associated with a particular project. Stressed scenarios do not correspond to either optimistic (because the most likely scenario is a benchmark scenario) or pessimistic expectations. Additionally, optimistic scenarios were excluded because they do not aid in decision-making (if the project performs better than expected, once can only be happy). Throughout the life of the business all actions will be taken to improve the project's efficiency as much as possible.

3. RESULTS

The *S*-curve is used in this study to determine the following three parameters. k – the inclination adjustment, which can range from 0.001 to 10. Linear distribution is returned when the value of 0.001 is used. a – the adjustment of the maximum inclination (change in curvature) position, which can range from 0.001 to 3. The study assumes that the higher the cost, the sooner the cost arises. A symmetrical curve is obtained when the value of 2 is used. The value of 3 generates a curve with 50% of the budget spent during 33% of the project's implementation period. A value of 1.5 generates a curve with 50% of the budget spent over 66% of the project's duration. The amount of costs incurred from which the *S*-curve is created is defined by parameter p – initial part (advance payment). It can take values ranging from 0 to 1.

Figure 4 illustrates the result of applying the curve. The following parameters were used in this case: $k = 5$; $a = 1.5$; $p = 0.1$.

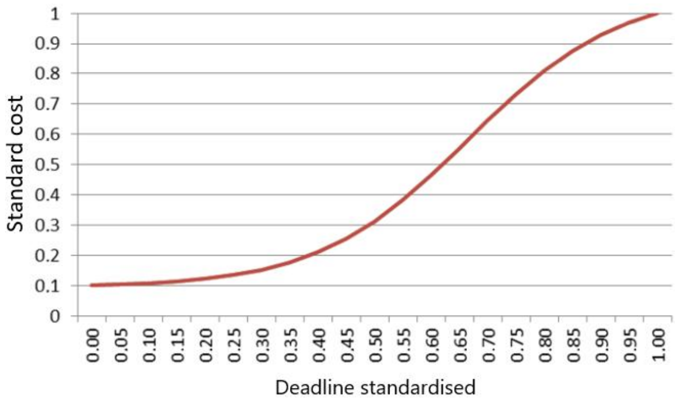

Fig. 4. Application indicators of the *S*-curve model
Source: created by the authors

Figure 5 shows how the curve changes when the parameter $k = 5$ is kept constant while parameter a is changed.

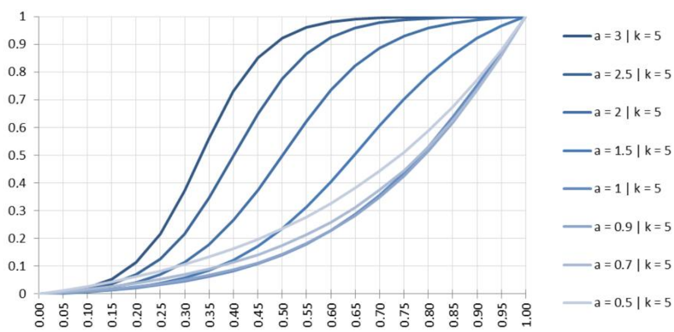

Fig. 5. Changes in the *S*-curve due to changes in parameter a
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Similarly, Fig. 6 illustrates how the curve changes when the parameter $a = 2$ is kept constant while parameter k is changed.

These parameters should be defined in light of the expected behavior of the project or applied element (since the proposed

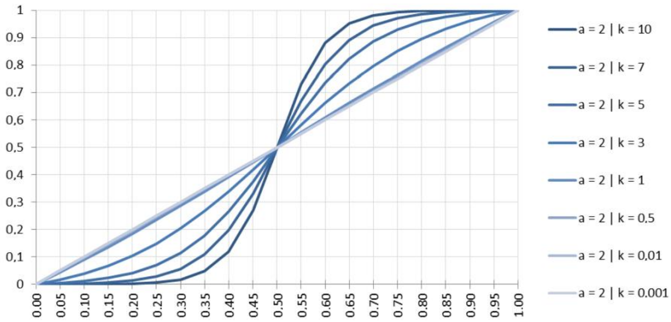

Fig. 6. Changes in the *S*-curve due to changes in parameter *k*
Source: created by the authors

model allows for the addition of three *S*-curves: one for DC, another for IC, and a third for CTG – contingency).

Along with the *S*-curve parameters, it is possible to define parameters for calculating stressed scenarios, such as changes in work deadlines and the resulting penalties; changes in calculated costs based on their volume (VC or CV); financial parameters (tax deductions, contract deductions, payment deadlines, etc.); parameters that help make a price closing decision (change in the tariff to be charged, cost reduction due to EAV, IC discounts, etc.); and parameters for *S*-curves applied for DC, IC and CTG.

By using an S-shaped curve, the initial estimated costs are distributed over months (specific for each type of cost: DC, IC and CTG). This generates a cost package for the current month. This part receives the percentage of cost variation calculated based on the selected parameters (for example, if the parameter is set to perform a global variation, an additional percentage of costs is applied, ranging from 0% to 5% – the maximum cost variation set in the parameters in the example shown). The income that these costs bring is calculated according to the rules of each contractual form based on the costs (for example, in management contracts, the rate is calculated based on costs, in contracts for the performance of works or MPG, income is calculated until the permitted maximum is reached, etc.). Thus, one obtains a monthly flow of results that is equal to revenue excluding costs (Fig. 7).

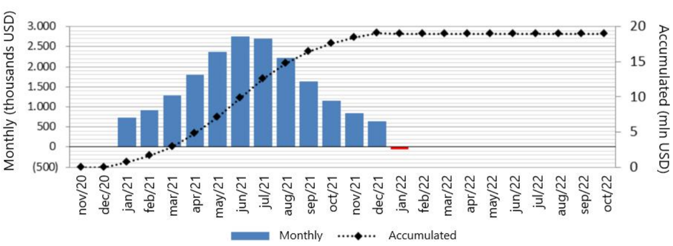

Fig. 7. Model 2 output: monthly and cumulative cash flow result for the project. Source: created by the authors

Following that, monthly positions of receipts and payments that contribute to the project's cash flow are calculated using the parameters included (Fig. 8).

The results and margin for each scenario are obtained through iteration of the calculation described above. The values

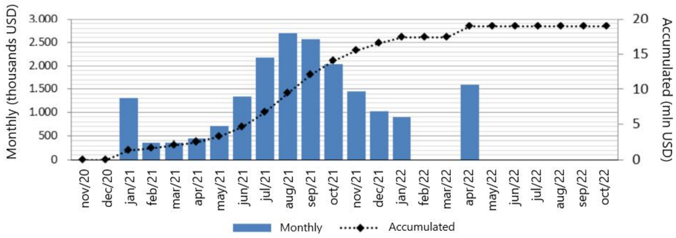

Fig. 8. Model 3 output: project cash flow
Source: created by the authors

of the results calculated in these iterations are shown in Fig. 9, and a histogram of these results is shown in Fig. 10.

Fig. 9. Model data: sampling results
Source: created by the authors

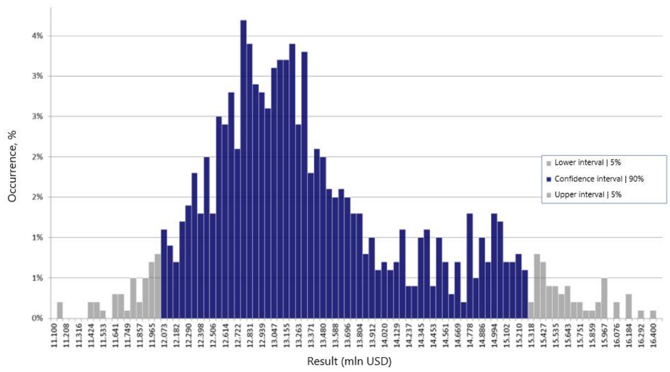

Fig. 10. Stressed scenario histogram
Source: created by the authors

The model allows for the generation of a summary of scenarios based on the resulting data, as illustrated in Fig. 11. The values of the benchmark scenario and the expected values are highlighted in this figure, based on the calculated data of stressed scenarios.

Table 2 summarizes the resulting indicators that contribute to the generation of stressed scenarios.

The results of this model enable an analysis of the impact of a change in tariff on the contract's result and margin forecast

Table 2

Resulting indicators that scenarios use (fragment)

No.	18.992.001.60	9.95%	Budgeted result, USD	Result. inf., USD	Result. sup., USD	Budgeted margin, %	Margin inf., %	Margin sup., %
6	16.084.482.33	8.43	18.992.001.60	15.298.495.48	17.102.888.02	9.95	8.02	8.96
7	16.894.722.14	8.85	18.992.001.60	15.298.495.48	17.102.888.02	9.95	8.02	8.96
8	16.776.719.49	8.79	18.992.001.60	15.298.495.48	17.102.888.02	9.95	8.02	8.96
9	15.816.225.87	8.29	18.992.001.60	15.298.495.48	17.102.888.02	9.95	8.02	8.96
10	16.147.499.26	8.46	18.992.001.60	15.298.495.48	17.102.888.02	9.95	8.02	8.96
11	15.722.071.54	8.24	18.992.001.60	15.298.495.48	17.102.888.02	9.95	8.02	8.96
12	15.104.574.30	7.92	18.992.001.60	15.298.495.48	17.102.888.02	9.95	8.02	8.96
13	15.943.002.47	8.36	18.992.001.60	15.298.495.48	17.102.888.02	9.95	8.02	8.96
14	16.687.909.57	8.75	18.992.001.60	15.298.495.48	17.102.888.02	9.95	8.02	8.96
15	15.290.236.57	8.01	18.992.001.60	15.298.495.48	17.102.888.02	9.95	8.02	8.96
16	15.759.431.96	8.26	18.992.001.60	15.298.495.48	17.102.888.02	9.95	8.02	8.96
17	15.635.477.74	8.19	18.992.001.60	15.298.495.48	17.102.888.02	9.95	8.02	8.96
18	16.361.085.18	8.58	18.992.001.60	15.298.495.48	17.102.888.02	9.95	8.02	8.96
19	16.202.898.80	8.49	18.992.001.60	15.298.495.48	17.102.888.02	9.95	8.02	8.96
20	15.843.136.49	8.30	18.992.001.60	15.298.495.48	17.102.888.02	9.95	8.02	8.96
21	15.549.013.71	8.15	18.992.001.60	15.298.495.48	17.102.888.02	9.95	8.02	8.96

Source: Created by the authors

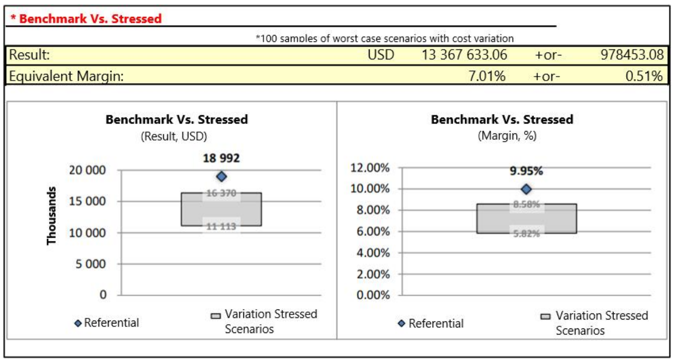

Fig. 11. Model output: margin and result variations
Source: created by the authors

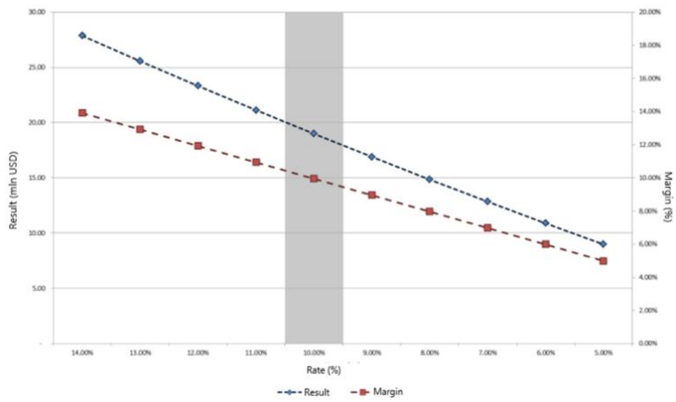

Fig. 12. Model output: comparison of margin and rate results/variations. Source: created by the authors

(Fig. 12). This analysis is critical in determining a sale value of an asset.

This model incorporates the functionality of the first model to facilitate comparisons between contract modalities (in this case, already using specific enterprise terms). Figure 13 illustrates this comparison with a graph. In this case, cost fluctuations of more than 20% render methods of contracting or MPGs ineffective, as they completely jeopardize the project's outcome.

The scenarios parameter can be used to test the behavior of the model in response to changes in a particular aspect (VC, CV, deadlines, etc.). Simultaneously, the following scenarios are possible: a variation in VC costs only; a variation in EV costs only; a variation in both VC and EV costs; a variation in the deadline only; general variability (VC, EV costs and a deadline).

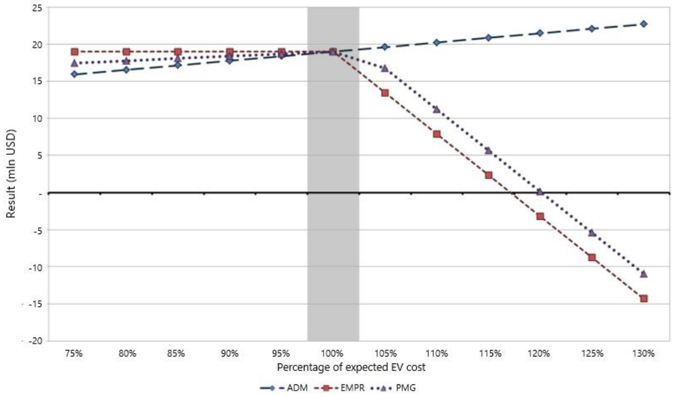

Fig. 13. Comparison of participating company's contractual forms
Source: created by the authors

The development used as a benchmark is MPG (maximum price guarantee), which means that the costs of CV (exposed companies) are limited to the IC portion of the development budget, which is a distinctly smaller portion of the overall development budget. Thus, the differences between stressed scenarios are reduced, and the obtained results are very close to those obtained for the benchmark scenario. On the other hand, varying the cost of VC (invoicing to clients), which accounts for the majority of the enterprise budget in MPG, results in scenario changes with a large amplitude and in variations from the benchmark scenario. Thus, regardless of how effective the management model adopted by the company is or how capable the project team assigned to a particular project proves, if the project is conceived with flaws and without regard for the requirements and needs of clients, it will become difficult to reverse it, both during implementation (due to delays and noncompliance with the budget) and during operation (high operating costs, lower than expected productivity, etc.). All parties involved must consider and promote necessary changes, striving for the sector's evolution as a whole. The common goal of all the parties involved is to increase the value of the project for the end-user not only during construction but also throughout its operation.

4. DISCUSSION

The model and tools presented in this study provide opportunities to improve the efficiency of construction project cost management. By comparing the proposed model to the findings of other scholars [26, 38], a platform for comparing the four major contracting methods has been created (management, MPG, contracting with and without direct billing). However, it does not permit the comparison of mixed forms of concluding contracts, which has become a very common solution for improved risk-sharing between the parties in recent years. This enhancement enables a more detailed examination of risk distribution in these mixed contract structures [39, 40].

The proposed model uses three *S*-curves, one for each component of the total cost of work: DC, IC, and CTG, to help develop financial flows. Similar findings have been obtained in more recent studies [36], where three curves, particularly the direct cost curve, can be classified into the major procurement packages (first or second level). This demonstrates that financial flows will be brought closer to reality, as the *S*-curves can be adjusted to reflect the behavior of each subsystem [41, 42]. Notably, the proposed model can incorporate a methodology that automatically adapts the *S*-curve to the values incurred during the project [43–45]. Additionally, a significant advantage of the proposed model lies in its potential for use in ongoing projects. Because the current project has a baseline budget and a completion estimate, variations in monthly cash flow positions for future months can be applied to create a range of stressed scenarios [8].

The proposed methodological approach has a limitation in that it requires constant revision of the *S*-curves, as changes begin to redistribute the balance over the remaining months. At this stage, the existing *S*-curve on the construction site can be used after it has been adjusted to reflect the current work progress. When combined with the previously described enhancement, the research conducted can significantly aid in the preparation of forecasts and estimates with the involvement of work planning and control specialists.

Simultaneously, the proposed approach can be used for project risk analysis and contingency budgeting. Identifying risks and developing action plans to avoid and mitigate negative risks (threats) and capitalize on positive risks (opportunities) is a significant benefit of the future application of the proposed model. It is possible to develop this initial proposed model further, primarily in terms of registering action plans, responsible persons and implementation history, to make this tool more comprehensive for the risk management process as a whole.

5. CONCLUSIONS

The use of project management concepts found in the PMBOK Guide is important, according to the results of this study, owing to the complexity of the company's projects. Although these concepts are extensive and require some commitment on the part of project teams, their application is immensely helpful because it enables them to address several critical aspects of project management in addition to the traditional cost, schedule and quality concerns. The fact that construction cost management is so closely aligned with the concepts and approaches of the PMBOK Guide demonstrates that its concepts and best practices are critical and should not be overlooked by managers and construction planning and control specialists. However, relying solely on PMBOK Guide concepts is insufficient to deal with the complexities and uncertainties inherent in construction projects. The combination of these concepts with those of coordination and development of project design and production management (lean construction), resulting in a 3D model, within a broad and integrated management system, demonstrates a more comprehensive and complete method of managing construction projects. This concept was successfully implemented and tested in this study.

The contribution of the study is the proposed approach of integrating concepts related to the coordination and development of project design and production management (lean construction), forming a "3D model of management", in a broad and comprehensive management system. It assumes a comprehensive and complete way to manage civil engineering projects. The proposed methodological approach can make a significant contribution to the preparation of forecasts and estimates by planners and controllers in the context of construction projects. The development used in the study as a benchmark is maximum price guarantee, i.e. the cost for the company refers only to the indirect costs part, which represents a smaller part of the total development budget. The differences between the stressed scenarios are smaller, and the results obtained are very close to the reference scenario. On the other hand, the variation of the cost in billing to the customer, which in the maximum price guarantee represents the largest part of the enterprise budget, leads to changes in the scenario and has a larger amplitude, with results that are different from the reference scenario. The practical results of this study prove the fact that project success does not depend only on cost management processes, but rather on a broad management system that takes into account several areas of expertise involved in the implementation of a construction project. The application of the proposed model represents a gradual innovation in the way a company manages the costs of its projects, primarily because it provides more information and alternatives for making strategic decisions.

MPG development was used as a benchmark scenario in this study, which means that the costs of CV (presented to the company) correspond only to that portion of the research work that is a smaller component of the overall project budget. Consequently, the differences between the stressed scenarios are smaller, and the results are as close to the benchmark scenario as possible. On the other hand, variation in VC costs (invoicing to clients) accounts for a sizable portion of the enterprise's budget in MPG. Simultaneously, because variation in VC costs implies scenario changes and has a large amplitude, it also has results that differ from the benchmark scenario. The results indicate that even if the company's management model is of the highest quality and the project team is highly effective, if the project was developed with flaws and without considering consumer conditions and needs, it will become difficult to reverse it both during implementation (delays and noncompliance with the budget) and operation (high running costs, productivity below expectations, etc.). Simultaneously, all parties involved must consider and promote necessary changes aimed at the sector's evolution as a whole. All stakeholders should share a common goal of increasing value for the end-user not only during the project's construction phase but also throughout its life.

The course of this research work has brought to light some interesting and relevant topics which could serve as topics for discussion, the development of new research, and the exploration of new possibilities. The use of BIM for planning and cost control during the execution of work (rather than just during the design stage of the project), i.e. its integration with ERP (enterprise resource planning), planning and control systems (such as Microsoft Project or Primavera), can help the study become more in-depth. The proposed model may be more easily implemented if forecasts and cash flows for construction enterprises are automated. In the future, the study can be expanded to include an assessment of the impact of other parties involved in the construction industry on cost management effectiveness in the implementation of construction projects, thereby stimulating the necessary changes in the sector, particularly concerning cost management.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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