Financial Evaluation of Project Solutions Using Building Information Modelling and Artificial Intelligence

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Abstract

Construction industry has recently undergone rapid transformations driven by technological progress, increased market volatility, and challenges of transitioning to sustainable development principles. Making the most appropriate decisions in these dynamic conditions is crucial for success of a project, and since no construction project can be implemented without funds (this is a key, integrating resource), special attention should be paid to financial aspects. Best practices have emerged in the world to improve the financial assessment of project decisions, with a focus on risk reduction, cost optimisation, and value creation.
The object of the study is project decision-making process in the context of discounted cash flow methods (DCFMs) under the influence of two different modern trends (increasing uncertainty due to the high dynamics of changes, on one hand, and increasing determinism due to the latest information technologies, on the other).
Scientific novelty of this paper lies in the development of an improved conceptual model of financial evaluation of project solutions in construction, which complements discounted cash flow methods with the ability to obtain more reliable and complete data about a construction project (in particular, thanks to BIM and AI) and inclusion of other useful components in the system.

Keywords

discounted cash flow methods, building information modelling, artificial intelligence

1. Introduction

Construction industry has recently undergone rapid transformations driven by technological progress, increased market volatility, and challenges of transitioning to sustainable development principles. Making the most appropriate decisions in these dynamic conditions is crucial for success of a project, and since no construction project can be implemented without funds (this is a key, integrating resource), special attention should be paid to financial aspects. Best practices have emerged in the world to improve the financial assessment of project decisions, with a focus on risk reduction, cost optimisation, and value creation. These practices use innovations such as building information modelling (BIM) and advanced data analytics based on artificial intelligence (AI), integrating them with traditional financial assessment methods to improve project results.

Object of the study is project decision-making process in the context of discounted cash flow methods under the influence of two different modern trends (increasing uncertainty due to the high dynamics of changes, on one hand, and increasing determinism due to the latest information technologies, on the other).

The subject of the research is conceptual modeling of financial evaluation of project solutions in construction with integration with BIM and AI in the context of modern challenges.

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The work is aimed specifically at improving financial management of projects using AI/BIM in IT environment.

2. Analysis of research and publications

Cost estimates should take into account the degree of uncertainty associated with a project. Cost estimation procedures should provide an ability of impact modeling of risks on capital costs early in project life cycle in a quantified manner. Project team should communicate this information to all stakeholders [1]. BIM and AI are tools that can help address this issue.

As stated in the GPM P5 Standard, humanity is living in a way that consumes more resources than the planet can provide. In other words, global economy has begun to "steal resources from future years to provide for current excess consumption" [2]. Based on the fact that benefit-cost ratio (BCR) method is the method that best aims at saving resources [3], it should be the key in the model for evaluating project decisions (in pair "NPV – BCR").

Draft recovery plan of Ukraine [4] names the lack of building life cycle management as one of the problems. To address this problem, the first stage plans to "create methodological prerequisites for the implementation of building life cycle management and methodological approaches for modelling life cycle cost analysis," and the second stage plans to "create a database of indicative prices for construction products, works and services; operational characteristics of buildings and structures; methodological approaches for managing buildings during operation, including usage of BIM models" [4]. This entire set of tasks is closely related to the issue of forecasting cash flows and, accordingly, the financial assessment of project solutions.

BIM technology has had a profound impact on construction industry since its inception. BIM provides significant benefits for decision-making throughout an entire project and asset life cycle, including design, construction, and management [5].

Project participants can take steps to reduce or control an impact of various cost escalation factors throughout a life cycle of a construction project. However, "the key to success is to recognize and understand the problems early in the planning process, develop strategies to address them, and set accurate and achievable expectations" [6]. A multidimensional picture of a project can be created using BIM and analysed by using AI.

Cash flow is the basis for financial evaluation of project decisions. The more detailed the data provided, the more accurate the cash flow forecast will be [7]. Modern project management tools, such as BIM, can help make project financial planning more accurate and realistic.

BIM has emerged as a digital platform through which project participants can effectively exchange information to improve decision-making [8]. The created model becomes an integrated system that provides an opportunity to obtain a synergistic effect from multifaceted information support for management. At the same time, the financial dimension of a project, in our opinion, is key in such a system, because it is it that is able to reflect various aspects of a long-term project in a single, unifying form (using discounted cash flow methods). At the same time, the issue of financial assessment of project solutions in construction in digital economy, and in particular when using BIM and AI, has not yet received proper attention.

3. Formulation of the purpose of the paper

Decision-making is crucial throughout project cycle, especially during the engineering phase, where a detailed concept is developed based on stakeholder requirements and project constraints. Various digital technologies are used to improve the design of a project, providing stakeholders with comprehensive data to make informed decisions [9]. This article aims to highlight how BIM and AI can be appropriately incorporated into financial evaluation model of project decisions and contribute to return on investment.

4. Statement of the main research material

Economic fluctuations, inflation, and exchange rate instability create unpredictability regarding future costs and revenues for construction projects. Within this framework, specific factors that can lead to significant overruns of project budgets are the instability of prices for materials, fluctuations in labour costs, and increased costs for renting or operating construction machinery and mechanisms. On the other hand, for example, in case of a significant drop in demand for products of a newly built enterprise, its revenues may decrease significantly, which will lead to the fact that previously made financial assessment of project solutions and the corresponding conclusion will turn out to be erroneous. In other words, it may even happen that production capacity utilization of the newly built enterprise (or commercial real estate), in contrast to the forecast made, will be such that the break-even point will not be crossed.

Technological complexity of a new building, which is in some way related to the above group of problems, complicates the calculation of project budget and the corresponding forecasting of cash flow. The more complex the building is, the more components it has. And the number of relationships between components increases exponentially as the number of constituent elements increases. This complicates the technological process of building construction itself, including the issue of attracting builders of different specializations and qualifications, as well as usage of different sets of construction machines and equipment. In addition, each component can have several standard parameters (for example, types and sizes) and be purchased from different manufacturers. This, in turn, entails different operational characteristics of the components, their different prices and different supply chains (therefore, the price of delivering a certain material to construction site also has several possible options).

Related to these problems are delays in project implementation due to supply chain disruptions, which can increase costs and reduce financial efficiency of a project. In addition, the delivery of a construction project may encounter delays due to claims between client and contractor. It is obvious that with the increase in project complexity and the increase in turbulence of the economic environment, the above risks increase.

Another challenge is that strengthening environmental regulations mean additional costs for project solutions to meet sustainable development requirements. Projects must meet green building standards and not create risks that contradict climate change policies, which may require project solutions of an even higher level of complexity.

Summarizing the above, it is possible to create a graphical platform of modern key challenges that can negatively affect the correctness of financial assessment of project solutions (Fig. 1). This necessitates the usage of modern information technologies.

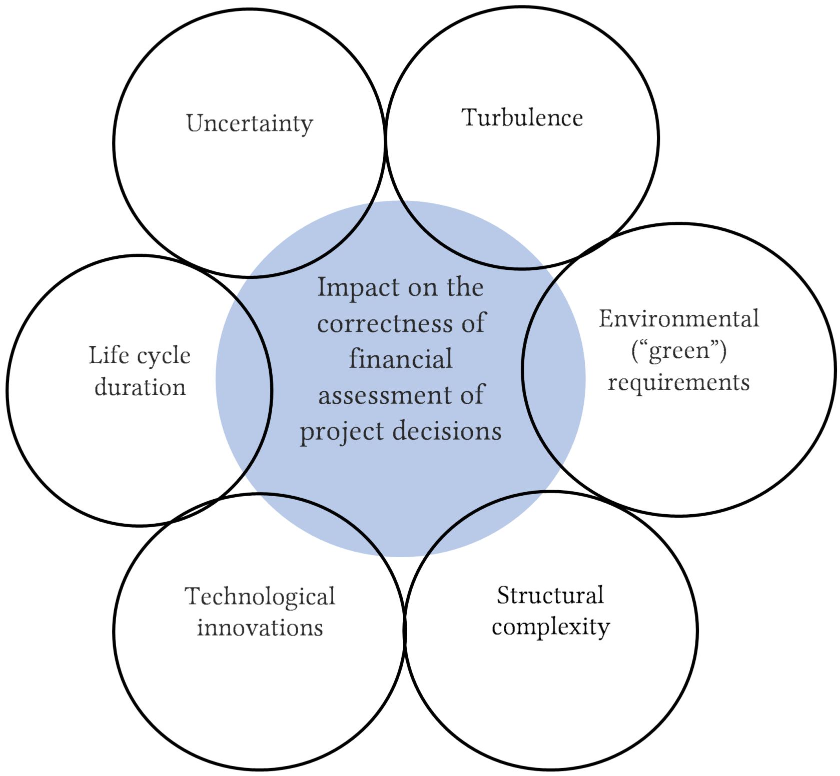

Figure 1: Framework of key challenges affecting the correctness of financial assessment of project solutions in construction (created by the authors).

The structural and logical diagram of the proposed conceptual model is presented in Fig. 2. This flowchart requires some explanations, which are given below.

The process of forming/developing a project solution begins with the fact that, based on the concept of "project-asset" life cycle with possible usage of artificial intelligence, a session of value engineering is held (the first VE session is the most important, productive and, at the same time, difficult). Integrated with this is BIM. Such information model includes a cross-section of a project's financial parameters, and this cross-section should be the focus in the context of this paper.

The financial assessment of project solutions is based on DCFM, so the key source of data for further analysis is the cash flow forecast. This forecast, at this stage, has only one option – the basic one. This forecast can be verified using system dynamics tools, in particular – "Stella Architect" software product. Then, the general conceptual model moves on to financial analysis under uncertainty.

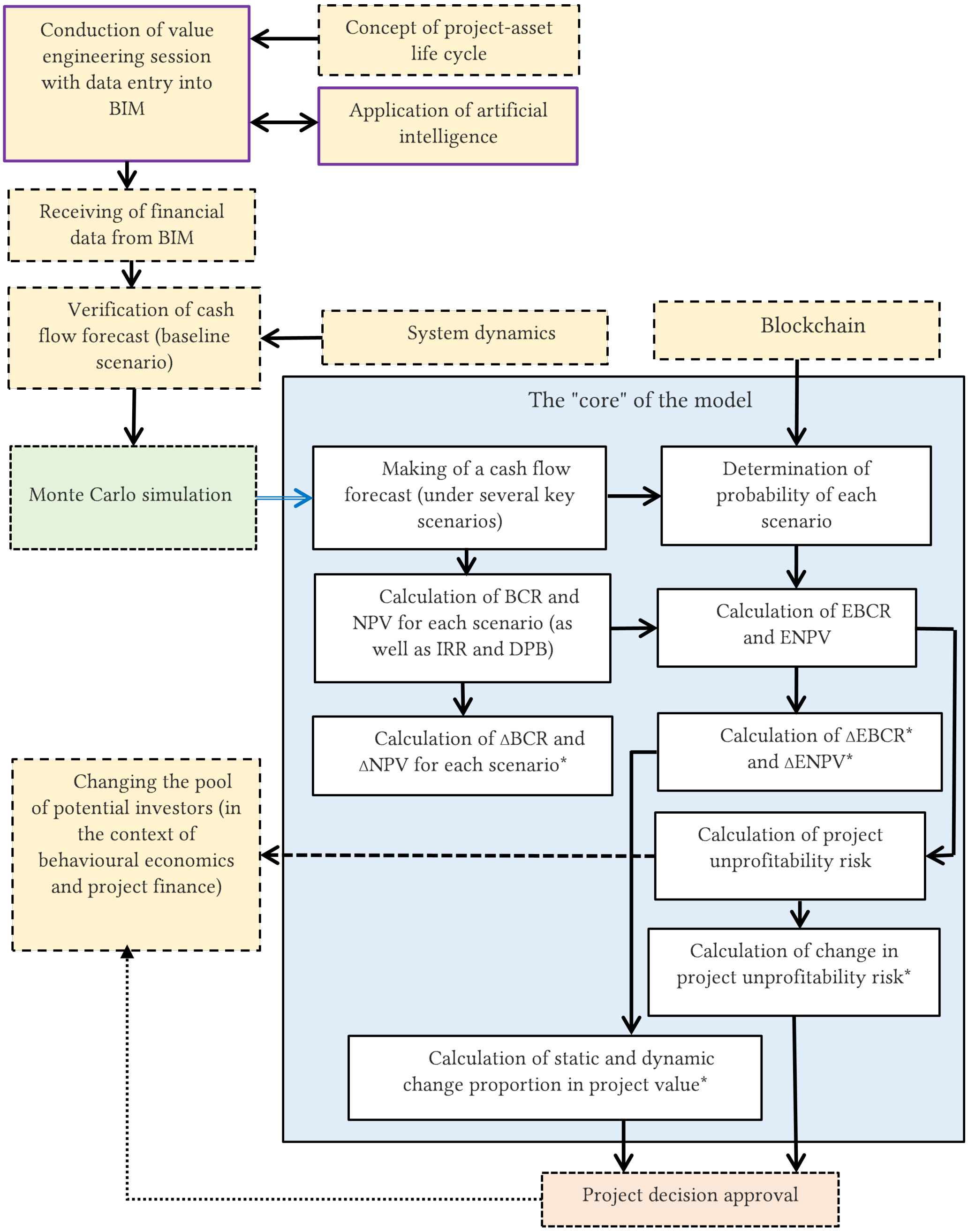

Figure 2: Structural and logical diagram of the conceptual model (created by the authors based on [3]).

Monte Carlo simulation allows to obtain a distribution of possible values of NPV, BCR, IRR, or another indicator of financial assessment of a project, based on random values of variables that are considered independent from each other. An example of a Monte Carlo simulation result is presented in Fig. 3.

*Compared to previous value engineering session.

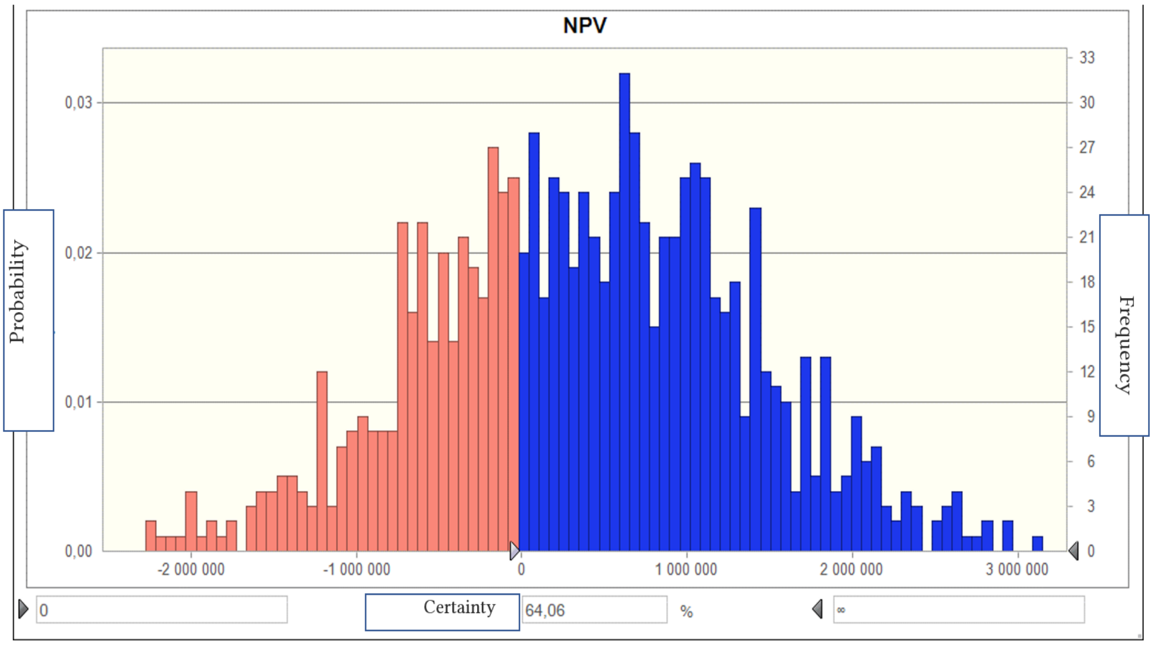

Figure 3: Result of NPV simulation for the project (created by the authors using Crystal Ball).

However, in the financial analysis of project decisions, scenario analysis is more important as there are groups of factors within which a change in one factor entails a change in another one. Based on this, several key scenarios are determined, for each of which a cash flow forecast is carried out (as the initial block of the conceptual model, marked in blue in Fig. 2). When determining key scenarios, the results of Monte Carlo simulation method play an important role. The entrance to the “core” model in Fig. 2 is marked with a double blue arrow.

The “core” of the model is based on scenario analysis of two indicators – expected net present value (ENPV) and expected benefit-cost ratio (EBCR). In our opinion, the model for financial assessment of project decisions in construction should be based primarily on NPV and BCR [3], and the IRR and DPB methods can play a supporting role. At the same time, it should be noted that under certain circumstances and in some projects, decision-makers may be inclined to rely more on IRR and/or DPB. In such cases, EIRR (expected internal rate of return) and/or EDPB (expected discounted payback period) can be calculated accordingly.

Artificial intelligence is one of the starting blocks in the overall structural and logical scheme of the proposed conceptual model (Fig. 2) largely due to its potential to improve outcomes and reduce costs. Project planning is a stage where AI is particularly useful. At the same time, AI can improve project outcomes throughout the life cycle. AI algorithms can help optimize network schedules, predict project delays, and allocate resources more efficiently (each of which has its own dynamic price). Integration of AI-based modelling with BIM enables project teams to make informed choices between alternatives based on forecasts of potential outcomes through financial evaluation of project solutions.

AI can improve the results of joint work between managers, design engineers and financiers. Usage of tools and algorithms based on artificial intelligence makes it possible to more reasonably implement innovative solutions with increased accuracy of corresponding financial forecasts.

The approaches discussed that will be discussed further are comprehensively presented in Fig. 4. Some smart platforms may not be a single AI tool, but may combine several of them in one environment, contributing to the improvement of financial analysis of projects. Such platforms rely on BIM, historical data (including previously implemented projects), contract content analysis, system dynamics models, etc. Comprehensive AI-based dashboards provide stakeholders with complete information.

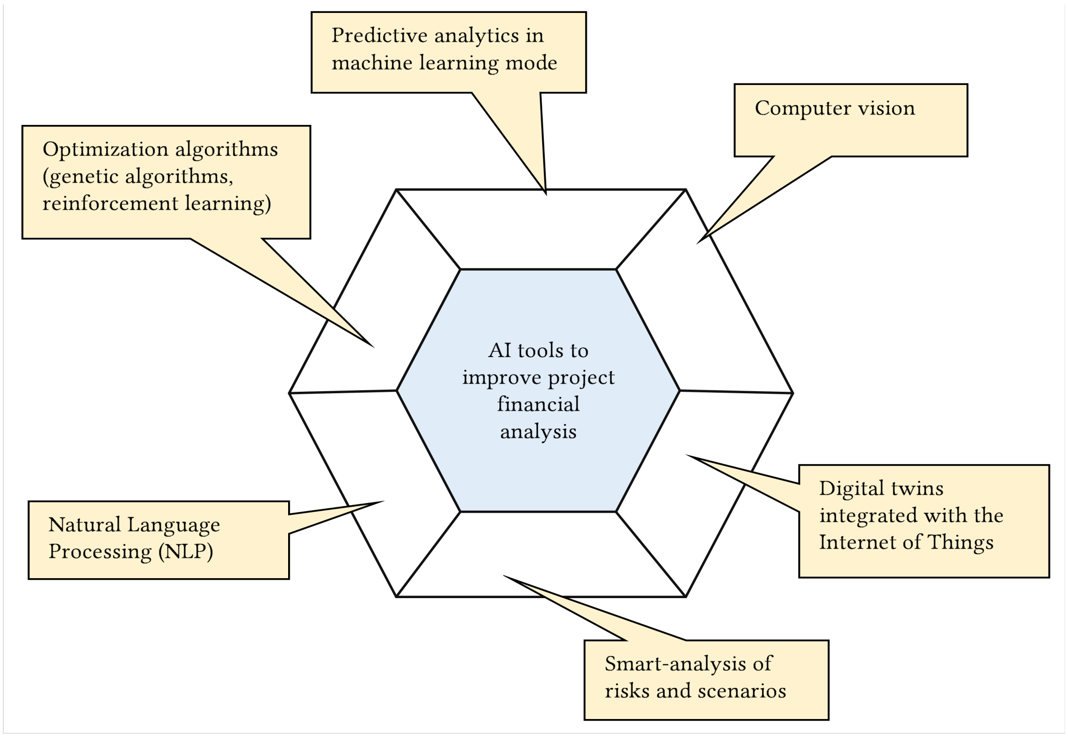

Figure 4: “Diamond” of artificial intelligence tools to improve the reliability and adaptability of financial assessment of project solutions in construction (created by the authors).

BIM-AI integration provides many opportunities for data processing in construction projects. In this context, the first AI tool (in context of our article) can be called predictive analytics, which works, among other things, in the machine learning (ML) mode. Such models use historical data from past projects (e.g., cost records, work schedules, interest rate dynamics) together with information generated by BIM (e.g., physical volumes of work, spatial parameters of the construction object, etc.) to predict the total cost of a project and its cash flow. At the same time, historical project data is used to train algorithms (e.g., regression models, neural networks) to understand certain patterns and their causes. After training, the model uses BIM information as input data and predicts financial results, which allows stakeholders to determine, for example, the risk of project budget overruns early in the life cycle.

It is worth noting here that ML works without the need for explicit programming, using pattern recognition to create models that can then evolve iteratively as new data enters the system [10].

The second tool in this context is natural language processing (NLP). NLP tools analyse unstructured data from contracts, specifications, change orders, and other text documents to extract important financial and risk-related information. This works as follows. AI algorithms scan the documents to extract cost figures, payment terms, and items that could impact financial results. This extracted information is then cross-referenced with BIM data to validate predictions made.

Another tool is optimization algorithms (genetic algorithms, reinforcement learning). Such algorithms are used to study several design and planning scenarios in the BIM model to find the most cost-effective solutions that meet project constraints. Therefore, this toolkit can be used as an auxiliary tool to improve the analysis results in parallel with the core of the structural and logical diagram of the conceptual model (Fig. 2). The process occurs in two complex steps. First, artificial intelligence iteratively models different sequences of construction work or design alternatives. Then, the algorithm determines, for example, the optimal plan that minimizes costs while adhering to quality and safety standards for construction and installation work.

The fourth AI tool in this context is computer vision and deep learning for BIM analysis. This tool analyses 3D geometry and visual components in BIM models to obtain quantitative data (e. g. volumes, weights of building components, surface areas, material quantities) needed for cost estimation. Component recognition means that deep learning models recognize and classify different building elements (walls, floors, roofs, etc.) from BIM geometry, as well as determine the physical volumes of work. The identified components are matched with databases of unit costs of physical volumes of work, which allows for automated and accurate cost forecasts. Combining this information with the work schedule enables automatic cash flow forecasting.

Another area of application of AI, with the aim of improving periodic financial analysis of project decisions in construction, are the so-called digital twins integrated with the Internet of Things (IoT). Digital twin platforms are virtual copies of physical construction projects. Combined with IoT sensors and artificial intelligence, these systems track the progress of events during the operation phase of a facility and dynamically update financial forecasts throughout the life cycle of the asset. Thus, IoT sensors transmit operational data (e.g., energy consumption, equipment performance) to the digital twin. Machine learning algorithms process this real-time data, adjusting maintenance cost forecasts and operating cost forecasts in real time, thus ensuring the relevance of the financial assessment. Such data can be useful for financial assessment in subsequent projects.

In the context of this study, it is also worth noting the possibility of using AI in the process of risk analysis and scenario modelling. Such tools model the risk profiles of various events, such as possible delays in the performance of work, cost overruns, supply chain failures, etc., and assess their potential impact on the financial performance of the project.

5. Discussion

Roles of the tools and concepts of the proposed model (Fig. 2) are summarized in Table 1.

Table 1
Roles of elements of the system under consideration in the financial analysis of construction projects

Tools and concepts	Role in financial analysis of construction projects
Monte Carlo simulation	To estimate the range and probability distribution plot of possible DCFM outcomes based on simulation by substituting random input data
System dynamics	Helps model the complex interactions between project variables over time, allowing to analyse feedback loops and nonlinear system behaviour to improve financial planning and risk management
BIM	To improve cash flow forecasting and risk assessment through a multidimensional digital environment that provides greater awareness and accuracy
Blockchain	Increases transparency and security of construction project financing, enables real-time transaction tracking within smart contracts, reducing financial uncertainty
AI	Uses advanced algorithms to process huge amounts of data, predict trends, optimize cost estimation, and improve risk management, thus supporting more informed decision-making
Behavioral finance concept	Takes into account the influence of human psychology and cognitive biases on decision-making, in particular due to a person's different attitude towards possible financial losses, on the one hand, and to probable profits, on the other

Value engineering	Systematically evaluates and optimizes project functions to maximize advantages while minimizing costs
The concept of the full project-asset life cycle	Integrates the assessment of costs, benefits and risks at all stages – from planning and construction to operation and disposal – providing a comprehensive assessment of long-term financial consequences

Integration of the tools listed in Table 1 with the "core" of the conceptual model allows for a more reliable, far-sighted, and well-founded assessment of project solutions in the face of modern challenges.

The approach proposed in this paper is a more expanded, adapted, and modern version of the conceptual model that was presented in the article [3].

6. Conclusion

Construction projects will be implemented in a complex environment of economic, technological and regulatory issues. On the other hand, the application of innovative financial approaches in integration with BIM and AI to reduce the degree of uncertainty of forecasts through access to a large amount of diverse information should be taken into account by advanced analytical DCFM models.

The platform of key modern challenges affecting the financial assessment of design solutions includes high uncertainty, turbulent development dynamics, increased environmental requirements, the structural complexity of newly created buildings, the introduction of breakthrough technological innovations and a flexible approach to the life cycle. Modern computational tools (software) provide new opportunities to conveniently model the assessment of projects using such complex methods as, for example, Monte Carlo. Building Information Modeling is becoming a comprehensive environment for the financial analysis of design solutions in construction. By combining technical and financial data, enabling advanced analysis, BIM enables stakeholders to make informed, more reliable and justified choices. As not only the construction industry, but the entire economy continues to transition to a digital basis, the role of BIM and AI in financial analysis will grow, contributing to greater efficiency and transparency of project implementation. Therefore, creating a modern conceptual model for the financial assessment of project solutions (design options) in the context of digital transformation is a relevant task.

The structural and logical scheme of the conceptual model of financial assessment of project solutions, in addition to the blocks of the "core" of the framework, has important auxiliary elements, such as: the concept of the "project-asset" life cycle, services based on artificial intelligence, system dynamics models, Monte Carlo tools, blockchain, value engineering, BIM and principles of behavioral finance. The "core" of the flowchart is built on the basis of calculating EBCR and ENPV, the risk of financial inefficiency of the project solution and calculating how much these indicators have changed as a result of the next session of value engineering. At the same time, the most interesting element, in our opinion, is the calculation of the proportion of static and dynamic changes in the value of the project.

AI-based financial valuation of project solutions uses historical cost data, market trends, project specifications, inflation rates, and other relevant variables. AI analyzes this data, identifying patterns and ultimately generating accurate forecasts and, accordingly, risk-adjusted estimates (ENPV, EBCR, EIRR, EDPB). Comprehensive analysis identifies correlations and relationships between variables that are often not captured by traditional methods.

The proposed conceptual model is a worthy response to a set of modern challenges and will contribute to the success of investment and construction projects, in particular, to improving financial results.

Declaration on Generative AI

During the preparation of this work, the authors used **ChatGPT** in order to: **Grammar and spelling check, Paraphrase and reword**. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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