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A Cost–Benefit Analysis of BIM Methodology Implementation in the Preparation and Construction Phase of Public Sector Projects

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Abstract

This article evaluates both economic and non-economic benefits associated with the implementation of Building Information Modeling (BIM) and the digitization of processes within public sector construction projects of the Czech public sector organization (PSO). The study is based on empirical data from three real projects: the Children's Sanatorium with Speleotherapy, the Air Rescue Services Base, and the Neurorehabilitation Center. For one of those projects, cost–benefit analysis (CBA) was applied to quantify direct financial savings and indirect operational improvements; however, other projects supported the investigation. Data sources include real project data such as BIM documentation and project budgets. The analysis reveals that BIM adoption led to measurable reductions in rework, improved coordination among stakeholders, and enhanced facility management efficiency, resulting in a cost–benefit ratio of more than 4.5. Results from this article support the results of other already made research and prove the consistency of those results. These findings demonstrate the practical value of BIM in public infrastructure delivery and provide actionable insights for decision-makers seeking to improve project outcomes through digital transformation.

Keywords: financial evaluation; benefit evaluation; collision detection; digital information model

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1. Introduction

The construction industry is undergoing a profound transformation driven by digital technologies, with Building Information Modeling (BIM) emerging as a cornerstone of this evolution. BIM represents a significant advancement in this modernization effort. Its implementation not only offers the potential for direct financial savings but also improves the quality of project management, streamlines communication among stakeholders, facilitates more efficient facility management, and enhances the overall value of the resulting projects [1]. BIM is an integrated platform for managing detailed, interoperable building data across all stages of a facility's life cycle, from planning and design to construction and maintenance [2]. It is not merely a technological tool but a strategic solution for addressing both technical and economic challenges in construction. Growing societal demands for transparency and accountability in public infrastructure spending further support the adoption of such data-driven approaches [3]. This observation is consistent with findings in the Czech context, where significant differences in corporate approaches to non-financial reporting have been identified [4].

Implementing BIM in a project is not always easy, and it takes a lot of effort and costs. Thus, owners of a project often hesitate about whether to implement BIM or proceed with the project in the same way as before, especially when they do not have the appropriate knowledge of this method. In this managerial decision it is a cost–benefit analysis (CBA) that provides an insight. CBA is a widely used method for assessing the economic efficiency of projects, investments, or policy decisions. It seeks to compare total project costs with associated benefits, ultimately determining whether a given activity is economically justifiable. The adoption of modern technologies and the digitization of construction processes have become indispensable in contemporary project management, particularly within the public sector.

At the European level, the transition toward greener and more digitalized construction practices has been identified as a strategic priority [5]. Methodologies for calculating the costs and benefits of these practices have already been developed. BIM is currently widely adopted in countries such as the Netherlands, Norway, Finland, Sweden, and Singapore [6–8]. France mandated the use of BIM in public procurement as early as 2017, and Germany followed suit in 2020. In North America, BIM is often referred to as Virtual Design and Construction (VDC) and is integral to the design, construction, and maintenance of large infrastructure projects. For example, in the United Kingdom, BIM principles are compulsory for all publicly funded civil engineering projects [8]. The advantages of BIM have been further validated through emerging software solutions used in life cycle assessment (LCA) [9,10], demonstrating its practical relevance and economic appeal.

This study explores the impact of BIM implementation in the context of public sector healthcare construction projects in the Czech Republic by applying the CBA.

The Czech Republic presents a particularly relevant case for such analysis. As a member of the European Union, it is actively aligning with EU directives promoting digitalization and sustainability in construction. In the Czech Republic, the public sector is being guided by the legislative framework of the forthcoming "Act on the Management of Information on Construction, Building Information Models and the Built Environment, and on Amendments to Certain Acts" (hereinafter referred to as the "BIM Act"). In alignment with this initiative, a selected public sector organization (PSO) has proactively implemented BIM in several projects, most notably the "Children's Sanatorium with Speleotherapy" (hereinafter "Children's Sanatorium"). Additional projects—including the Neurorehabilitation Center and the S-Centre—are currently underway.

This article aims to provide a more detailed technical and economic description of these benefits through case-specific cost–benefit analysis. Therefore, this paper contributes new empirical evidence based on real data from publicly funded healthcare infrastructure projects.

2. Project Description

This study focuses on the Neurorehabilitation Center, a publicly funded healthcare facility commissioned by a PSO (South Moravia Region in the Czech Republic). This region comprises approximately 1.19 million inhabitants, covers an area of around 7188.3 km^2, and includes more than 670 municipalities (ranging from small villages to larger towns).

The project was selected due to its complexity, public relevance, and the comprehensive application of BIM methodology throughout its lifecycle.

Implementing BIM and digitization in construction is inherently multifaceted and involves the integration of various digital systems, including Enterprise Resource Planning (ERP), Electronic Site Diaries (ESDs), invoicing software, and attendance monitoring systems. Due to the broad scope of these systems, this paper concentrates on two core

components of BIM from a cost–benefit perspective: the Common Data Environment (CDE) and the digital building model (DBM).

The Neurorehabilitation Center project involved the integration of BIM from the early design phase through construction and into facility management planning. BIM was used to coordinate architectural, structural, and MEP disciplines, enabling early clash detection and reducing the need for costly rework. The digital building model (DBM) served as the central repository of project data, supporting interdisciplinary collaboration and technical validation.

Also, the usefulness of BIM for quantity take-offs has been substantiated by existing literature [11,12], and its technological and economic advantages have been further discussed in numerous studies [5,13–15].

The subject of this cost–benefit analysis (CBA) is the implementation of BIM methodology and the digitization of workflows in construction projects across the region. The primary goal of this initiative is to reduce cost overruns and streamline construction workflows. For the identification of costs and benefits of BIM implementation in healthcare projects, data from other projects were synthesized to support the investigation and establish a broader base of costs and benefits occurring generally in healthcare projects. Data for the identification are specifically from the Children's Sanatorium and the Neurorehabilitation Center. The analysis considers both financial and qualitative impacts of BIM implementation, including the costs associated with deployment and the resulting operational and economic benefits.

This paper aims to build upon those findings by highlighting additional benefits and providing a more technically detailed analysis.

3. Cost Identification

This section outlines the key cost components associated with the implementation of BIM in public construction projects. These include the acquisition of DBM, procurement of technology and software, employment of a BIM manager, and staff training.

Also, this section, as mentioned above, is a summarized result of cost identification findings from two healthcare projects. Those findings were used for the following calculations.

3.1. Cost of DBM Acquisition

DBM constitutes a fundamental element of the BIM methodology. It is a structured, object-oriented representation of a building or its components, incorporating both graphical representations and detailed metadata. DBM supports interdisciplinary coordination, technical visualization, reporting, optimization, and other project-specific purposes.

The cost of creating a BIM model is contingent upon the complexity and scale of the project. Similar to conventional two-dimensional (2D) documentation, the level of complexity is determined by the project's total construction value. Client-specific requirements—such as modeling depth, data integration, or life-cycle analysis—can significantly influence overall costs. For instance, some projects may require highly detailed models for construction phases, while others may emphasize energy efficiency or operational simulations.

Model elements must be developed with appropriate geometry and attribute data. Specifications related to modeling standards, data formats, coordinate systems, and detail levels are typically outlined in the contractual documentation. These technical details are formalized in the BIM Execution Plan (BEP), a supplementary contractual document prepared by a qualified BIM or VDC specialist [8].

One of the principal advantages of BIM is its applicability throughout the entire asset lifecycle—from conceptualization to demolition. In addition to design and construction, BIM supports post-construction processes such as facility management and long term maintenance [13].

Given that these projects are publicly funded, the BIM models are delivered using open data standards, specifically the Industry Foundation Classes (IFC) format [16].

3.2. Cost of Acquiring Technology

The digitization of workflows is primarily facilitated through the use of a Common Data Environment (CDE), a centralized platform for storing, managing, and distributing project documentation. The CDE also enables automated workflow processes, including information sharing, task management, and approval tracking, thereby enhancing overall project governance.

In the projects studied, the CDE was provided by either the design team or the contractor. While its use in the Children's Sanatorium project was largely limited to document storage and approval workflows, the Neurorehabilitation Center project incorporated additional features such as structured documentation, sampling logs, and system integration.

To effectively utilize DBM, clients must acquire specialized software tools that enable model viewing and validation. Some software solutions allow advanced functionalities, including 4D construction animations and immersive walkthroughs. The cost of such tools varies, though free or open-source options also exist. In some cases, CDE platforms offer built-in DBM viewing functionality, reducing the need for separate licenses.

3.3. Cost of a BIM Manager

The role of the BIM manager is critical to the successful deployment of BIM methodology. Responsibilities include:

- Reviewing and approving the BEP.
- Verifying adherence to contractual BIM requirements.
- Configuring and managing the CDE in alignment with client needs.
- Overseeing workflow structure and compliance.
- Defining directory structures and naming conventions.
- Validating data content within DBM for consistency and completeness.

Additionally, the BIM manager is tasked with detecting and resolving interdisciplinary clashes within the DBM, ensuring technical accuracy, and resolving formatting inconsistencies. They also coordinate compliance with digital project publicity requirements, such as submission of visualizations, video content, and construction progress documentation.

3.4. Employee Training

For the BIM methodology to be effectively implemented, relevant personnel within the PSO must be adequately trained. This includes not only technical training in the use of DIMS and CDE but also process-based education to adapt to the digital project environment. Such training ensures that employees can fully exploit the efficiencies offered by BIM and participate meaningfully in digitally managed construction projects.

4. Benefits Identification

The implementation of Building Information Modeling (BIM) yields numerous economic and non-economic advantages. According to the European Commission (EC), the adoption of BIM across various projects within the EU has consistently resulted in financial savings that exceed the initial implementation costs. Cost–benefit analyses (CBAs) conducted by the EC have demonstrated that the net present value (NPV) of

BIM adoption is positive across all evaluated cases, including residential, commercial, and institutional buildings.

The return on investment (ROI), i.e., the ratio of savings (the financial evaluation of the application of the BIM method on the project) to costs (this is the cost of implementing the BIM method), is higher than 1.5 (150%) for all projects. On average it is 3.5 (350%), and in selected cases it reaches values exceeding 10 (1000%).

In 2021, the authors of this concept prepared a CBA for the preparation and construction phase (i.e., from the start of work on the design to the final approval thereafter in a very short period of sale or handover of the property) of residential and administrative projects. In addition, a CBA has been prepared for the construction phase of transport infrastructures. The results revealed that the cost of BIM implementation constituted approximately 0.8% of total construction costs, while the ROI exceeded 320% for office buildings and 240% for residential buildings. For transport infrastructure the cost is 0.4% of the total construction costs, and the ROI is 340%. The ROI is calculated from the savings on extra work that arises to a limited extent as a result of the application of the BIM method on the project.

In the area of CAFM, the Regulatory Impact Assessment (RIA) of the BIM Act indicates a 10–15% reduction in asset management and maintenance costs using DBM and CAFM. The costs of managing and maintaining real property assets are not centrally available, and quantification of expected savings in management and maintenance cannot be predicted. The implementation of the BIM method also brings non-financial benefits such as information availability, work efficiency, and substitutability. The PSO know-how development and increasing the competitiveness of design and construction companies are also significant, but financially difficult to quantify, benefits for the region.

Studies also indicate potential savings of 13–21% during the preparation and construction phases, with an additional 10–17% reduction in operational costs. While BIM may increase expenditures during project preparation, it delivers substantial savings during the construction and maintenance stages.

This section is a summarized result of benefit identification findings from two healthcare projects. Those findings were used for the following calculations.

4.1. More Efficient Engineering and Coordination

The use of BIM and the digitization of processes significantly reduces the time required in project preparation and construction. Tools such as the CDE ensure better collaboration and communication between stakeholders, which is crucial for a smooth process.

By using one common space for sharing and managing information, the CDE ensures access to up-to-date information is ensured for all. The required documents are always in one place, easily traceable and accessible, with information on approval or comment status.

CDEs can be customized to accommodate project-specific needs and workflows. Once configured, they significantly reduce the time required to launch new projects by automating approval chains, version control, and access rights.

Additional features—such as contact management, document permissions, workflow tracking, and graphical dashboards—improve transparency and accountability across teams.

Within the CDE, ticketing systems can be included that greatly facilitate the management and organization of tasks within projects. They allow tracking of individual requests, assigning them to responsible persons, setting priorities, and tracking deadlines. This enables efficient management of workflows, an overview of the status of tasks, and a quick response to any potential delays. Some systems may include QR code generation features that simplify access to necessary information without printing documents, while others offer various ways to integrate with other software tools or platforms. Regardless of

the specific features, all ticketing systems provide a clear structure for task management, thereby increasing efficiency and clarity within team collaboration.

4.2. Savings on Construction Costs

The implementation of the BIM methodology enables substantial savings in construction costs through accurate calculations of material requirements for the entire building. DBM can be linked to lists of works, supplies, and services, allowing for the creation of detailed bills of quantities. As a result, material orders can be optimized during the early phases of project preparation, ensuring that only the necessary quantities are procured. This approach minimizes material surpluses, which would otherwise contribute to waste and incur additional costs related to storage or disposal.

For contractors, DIMS provides a clear and comprehensive overview of the materials, products, and construction elements to be implemented—detailing the required quantities and their respective locations. This allows for more accurate cost estimation, streamlined logistics planning, and optimized workflow scheduling. Consequently, resources are used more efficiently, unnecessary expenditures are eliminated, and the overall management of the construction process is enhanced.

By reducing surplus materials and improving procurement accuracy, the BIM methodology supports a more sustainable and environmentally responsible approach to construction. Minimizing waste and avoiding unnecessary production contribute to the reduction of environmental impacts, such as carbon dioxide (CO_2) emissions associated with the manufacture and transportation of excess materials.

4.3. Clash Detection

Another significant source of cost savings lies in the early identification and resolution of design conflicts—or "clashes"—between different building systems. Through detailed planning and design using BIM, DIMS enables the early detection of areas where inconsistencies or potential construction errors may occur.

The BIM manager is responsible for reviewing the DIMS and identifying such conflict zones. The outcome of this review is a list of clashes between different disciplines, which is subsequently used by designers to coordinate and adjust their respective models.

Clashes may involve various building components, such as walls, ceilings, mechanical systems, or installed equipment. The BIM manager conducts clash detection tests by comparing two digital models (e.g., the automated control system and the HVAC system) to identify areas of interference.

Resolving these issues at the design stage prevents costly modifications, delays, or disruptions during the construction phase. Studies demonstrate that early clash detection using BIM significantly reduces rework and supports better interdisciplinary coordination [17]. By addressing nonconformities in advance, the risk of project delays is minimized, construction quality is enhanced, and overall implementation efficiency is improved. This leads to measurable savings in direct costs, as well as in time and logistical coordination.

4.4. Workflow Optimization

The digitization of construction-related workflows—particularly document approval processes—significantly enhances both efficiency and clarity. Traditionally, the approval of project documentation (e.g., design packages, samples, and change orders) in paper format is inefficient and outdated. Paper-based documents are susceptible to loss, damage, and administrative errors, such as incomplete or inaccurate records. Moreover, manually transferring physical documents among stakeholders results in delays throughout the approval chain.

Even when conducted via email, these processes present limitations. While technically digital, email-based workflows are unstructured and inefficient for monitoring complex tasks. In contrast, a CDE provides a well-organized and transparent workflow system, complete with automatic alerts, reducing approval delays, and a digital audit trail ensuring reliable information tracking [18].

Within a CDE, users can monitor the real-time status of documents, including who has approved or rejected specific items, what changes have been made, and which version is current. The system also ensures that all relevant parties are automatically notified of pending actions, reducing the risk of oversight and delay.

This structured, digital approach facilitates improved communication and coordination among all project participants. It enables comprehensive tracking of both revisions and comment histories, ensuring transparency and accountability at every stage of the approval process. As a result, workflows become more efficient, less error-prone, and significantly more cost- and time-effective.

4.5. Maintenance and Operational Savings

The final version of the DBM contains comprehensive information on all building components, from materials and equipment to technical systems. Upon completion of the construction phase, the DBM becomes an essential tool for facility management and long term maintenance.

All critical information—such as product specifications, warranty durations, technical documentation, and inspection schedules—is integrated into a single, accessible system. This digital repository facilitates effective building management, supports proactive maintenance planning, and enables rapid problem resolution, ultimately resulting in substantial long term operational savings. Studies indicate that BIM supports lifecycle cost control and operational efficiency when integrated into facility management systems [19].

5. Quantification of Costs and Benefits

Cost–benefit analysis was conducted for the Neurorehabilitation Center project. Due to limited availability of some data, the analysis remains general and illustrative as an example of a public project in the Czech Republic. The assumptions and calculations are applicable to other public projects in this region.

The overall project is expected to span four years, consisting of a one-year preparation phase followed by a three-year implementation phase. The discount rate applied for all financial calculations is 3.5%, in accordance with guidelines issued by the Czech National Bank (CNB).

All data used for the calculations are based on real-project data. Some percentage assumptions are made according to the author's experience from other studies.

5.1. BIM Implementation Costs

In 2021, the authors of this study conducted a cost–benefit analysis of BIM implementation during the preparation and construction phases of office and residential projects. The results indicated that the cost of implementing BIM amounted to approximately 0.8% of the total construction budget (*Total* in Table 1). This figure includes:

- Human resource costs related to model development, coordination meetings, and training.
- Software acquisition costs for modeling, data sharing, and automated clash detection tools.

This cost structure reflects the comprehensive nature of BIM deployment, encompassing both personnel and technological infrastructure required to support digital project delivery.

Table 1. Structure of BIM implementation costs.

To acquire DBM	0.2%
Technology (SW and HW), BIM manager, training	0.6%
Total	**0.8%**

The BIM implementation costs can be divided into two groups according to cost identification: DBM acquisition and technology, BIM manager, and training.

Based on the results of the analysis, BIM implementation costs can be determined using a straightforward calculation in Table 2.

Table 2. BIM implementation costs of the Neurorehabilitation Center.

Total costs of the Neurorehabilitation Center	CZK 637,705,616
Total discounted cost of BIM	CZK 5,307,250.35
Initial costs (preparation phase)	CZK 2,231,969.66

Initial costs include the acquisition of the DBM and one-quarter of the total cost of technology, BIM management, and training—reflecting the distribution of these expenditures across the four-year project duration.

5.2. Benefits

The considered savings of using BIM and digitizing work processes are organized in Table 3 by project phase.

Table 3. Savings in the use of BIM and digitization of processes.

	Project Preparation		**Construction Implementation**	
Bill of Quantities and Budget	Saving time during creation	30% of the price for the creation of SQ	Savings on surplus	2% of total costs
Digitization of processes	Time savings	2 h/week	Time savings	4–5 h/week
	-	0	Saving money on printing	500 CZK/week
Collision check	-	0	Savings on repairs, modifications, and changes	CZK 1,633,100.00

The estimated cost of producing the statement of quantities is 0.35% of the total cost.

The calculation of the time savings for each person involved includes the hourly rate, the employer's social and health insurance contributions, other costs, overhead, sickness, leave, holidays, and efficiency.

The time savings are calculated according to the total personal costs of each person involved in the construction project. Hourly rates are taken from databases of payroll data providers, e.g., Platy.cz https://www.platy.cz/platy (Accessed on 10 September 2024), NSP.cz; https://nsp.cz (Accessed on 10 September 2024), Jooble.org https://cz.jooble.org (Accessed on 10 September 2024), and Indeed.com https://cz.indeed.com (Accessed on 10 September 2024). These calculations can be found in Table 4.

To calculate the financial benefits associated with digitization, the following roles are considered during the preparation phase:

- PSO investment officer
- Building Technical Supervision (BTS)

Table 4. Calculation of total hourly costs of project participants.

	Number of	Hourly Rate [CZK]	Total Personnel Costs [CZK/h]
Inv. officer JMK	1	218.75	580.95
Construction manager	1	400.85	1064.57
Builder's technical supervision (BTS)	1	332.95	884.25
PM of the contractor	1	593.75	1576.88
Site manager	1	384.67	1021.60
Master	4	293.75	3120.56
Technician	5	241.49	3206.79
Preparer	2	287.43	1526.68

For the implementation phase, the following positions are considered:

- PSO investment officer
- Construction manager
- BTS
- Contractor's project manager
- Site manager
- Foremen (masters)
- Technicians
- Design preparers

The savings related to clash detection are estimated proportionally, based on the relative size of the Neurorehabilitation Center project compared to a previously evaluated office building project for which a cost–benefit analysis had already been conducted. The value in Table 3 represents total projected savings, which are subsequently distributed across the construction years and discounted.

6. Analysis and Interpretation of Results

The stated costs and benefits are completely calculated and divided into 4 years of project duration in the cash flow table: Table 5.

Based on this cash flow, the following values were calculated in Table 6.

Net present value (NPV) is a key metric in cost–benefit analysis. It quantifies the extent to which projected benefits exceed costs when the time value of money is taken into account. In this case, the NPV is strongly positive, indicating that the project is economically viable and yields significant long term financial returns.

Benefit–Cost Ratio (BCR) represents the ratio of the present value of benefits to the present value of costs. A BCR greater than 1 confirms that the benefits outweigh the costs. In this project, the BCR exceeds 4, meaning the benefits are more than four times greater than the costs incurred.

In addition to these quantifiable financial benefits, the adoption of BIM and digital workflows also generates significant non-financial value. It enhances the quality of public buildings—including schools, hospitals, and transport infrastructure—through improved accuracy in planning and design. This results in fewer errors, fewer delays, and buildings that better serve the public over the long term.

Table 5. Cash-flow investments in BIM and digitization of processes.

		Preparation Phase	Implementation Phase		
Czech National Bank discount rate	3.50%	year 1 [CZK]	year 1 [CZK]	year 2 [CZK]	year 3 [CZK]
COSTS	BIM acquisition	2,231,969.66	990,037.97	1,024,689.30	1,060,553.42
BENEFITS	Bill of quantities and budget	669,590.90	4,251,370.77	4,400,168.75	4,554,174.66
	Digitization of processes	152,380.82	2,966,981.63	3,070,825.98	3,178,304.98
	Printing of drawings and documents	0.00	26,000.00	26,910.00	27,851.85
	Collision control	0.00	544,366.67	563,419.50	583,139.18
Total costs		2,231,969.66	990,037.97	1,024,689.30	1,060,553.42
Total benefits		821,971.71	7,788,719.07	8,061,324.23	8,343,470.58
Total savings		**−1,409,997.94**	**6,798,681.10**	**7,036,634.93**	**7,282,917.16**

Table 6. Cost–benefit ratio.

Net present value (NPV)	CZK 18,296,324.07
Present value of benefits	CZK 23 397,969.00
Present cost value	CZK 5,101,644.93
Cost–benefit ratio (BCR)	4586

7. Public Sector Organization Region Projects

Based on the cost–benefit analysis, the average percentage of savings from BIM implementation relative to investment costs was calculated at 3.67%. As mentioned previously, the average cost of BIM deployment is 0.8% of the total investment cost.

These values were used to recalculate revenue and return on investment (ROI) figures for the public sector organization's upcoming investment plan, which was provided by regional authorities. The purpose of this projection is to highlight the economic impact of BIM adoption in each fiscal year.

For transport infrastructure projects, the cost of BIM implementation is 0.4%, with estimated savings reaching 1.68% of total investment.

The calculations for PSO construction projects can be found in Table 7.

Table 7. Calculation of benefits on building constructions in individual years.

Year	2020	2021	2022	2023	2024	2025	2026	2027
Total construction projects of buildings [CZK million]	1006	905	982	1866	2053	2258	2484	2732.00
BIM costs [CZK million]					16.00	18.00	20.00	22.00
Savings from the use of BIM [CZK million]					75.00	83.00	91.00	100.00
Revenue from using the BIM method for projects [CZK million]					59.00	65.00	71.00	78.00
Return to market (%)					359.00	359.00	359.00	359.00

8. Conclusions

CBA financial results are presented in Table 8:

Table 8. CBA financial results.

Net present value (NPV)	CZK 18,296,324.07
Present value of benefits	CZK 23,397,969.00
Present cost value	CZK 5,101,644.93
Cost–benefit ratio (BCR)	4586
BIM savings from investment costs	3.67%

Beyond the financial returns, BIM adoption yields significant non-financial advantages: improved project management, increased transparency, enhanced contractor coordination, and greater accountability. It also fosters sustainability, innovation, and competitiveness in public construction.

Importantly, the analysis shows that age is not a barrier to digital adoption within the PSO. Pilot projects are managed by staff across a wide age range, and no generational bias has been observed. Moreover, the internal cost of employing a BIM specialist has not increased, as the PSO already possesses the necessary hardware infrastructure for operating in a CDE environment. Staff training is incorporated into the mandatory education of civil servants.

In summary, this cost–benefit analysis confirms that the integration of BIM and the digitization of construction workflows bring substantial economic and qualitative gains. The high NPV and BCR values underscore the financial justification for investing in these technologies. It is therefore recommended that the PSO continue to expand the use of BIM in its construction portfolio, as the long term benefits clearly outweigh the costs.

These findings are consistent with similar evaluations conducted by the European Commission, where all analyzed projects demonstrated positive NPVs and high ROIs. The return on investment exceeded 1.5 across all projects and reached an average of 3.5, further validating the efficacy of BIM in public infrastructure delivery.

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