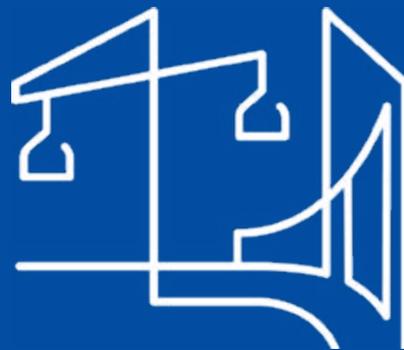


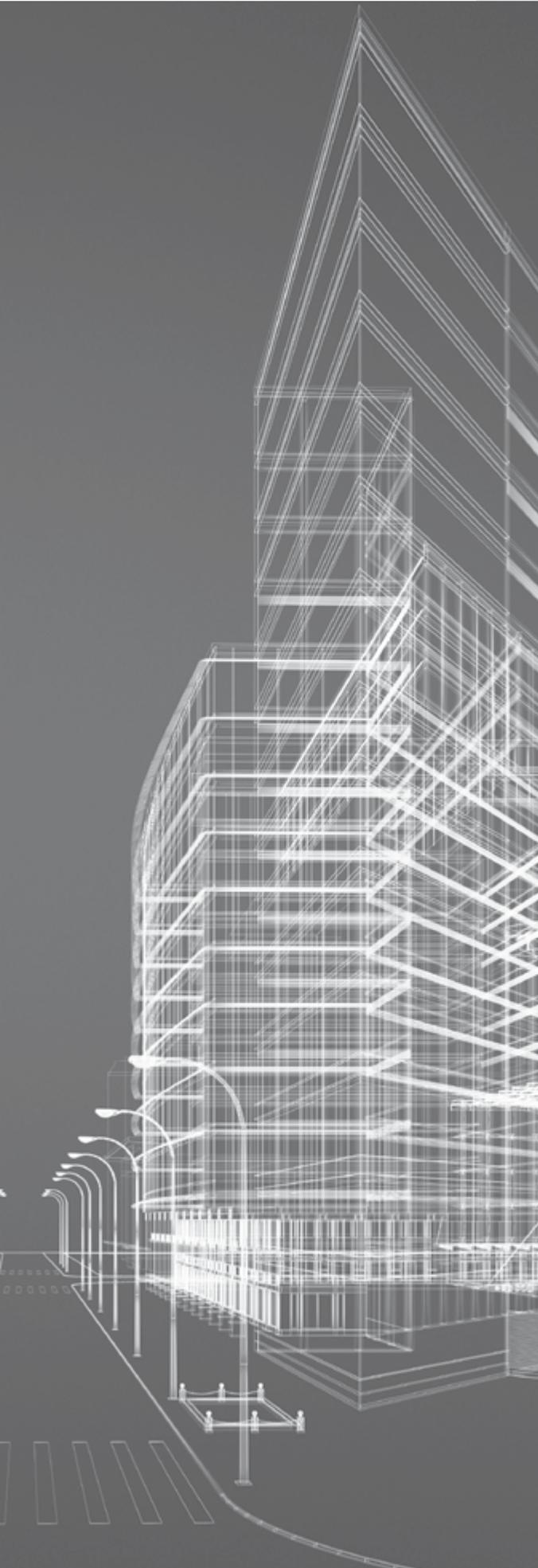


European
Commission



Calculating Costs and Benefits for the use of Building Information Modelling in Public tenders

Methodology Handbook



RINA, B1P Group
May 2021



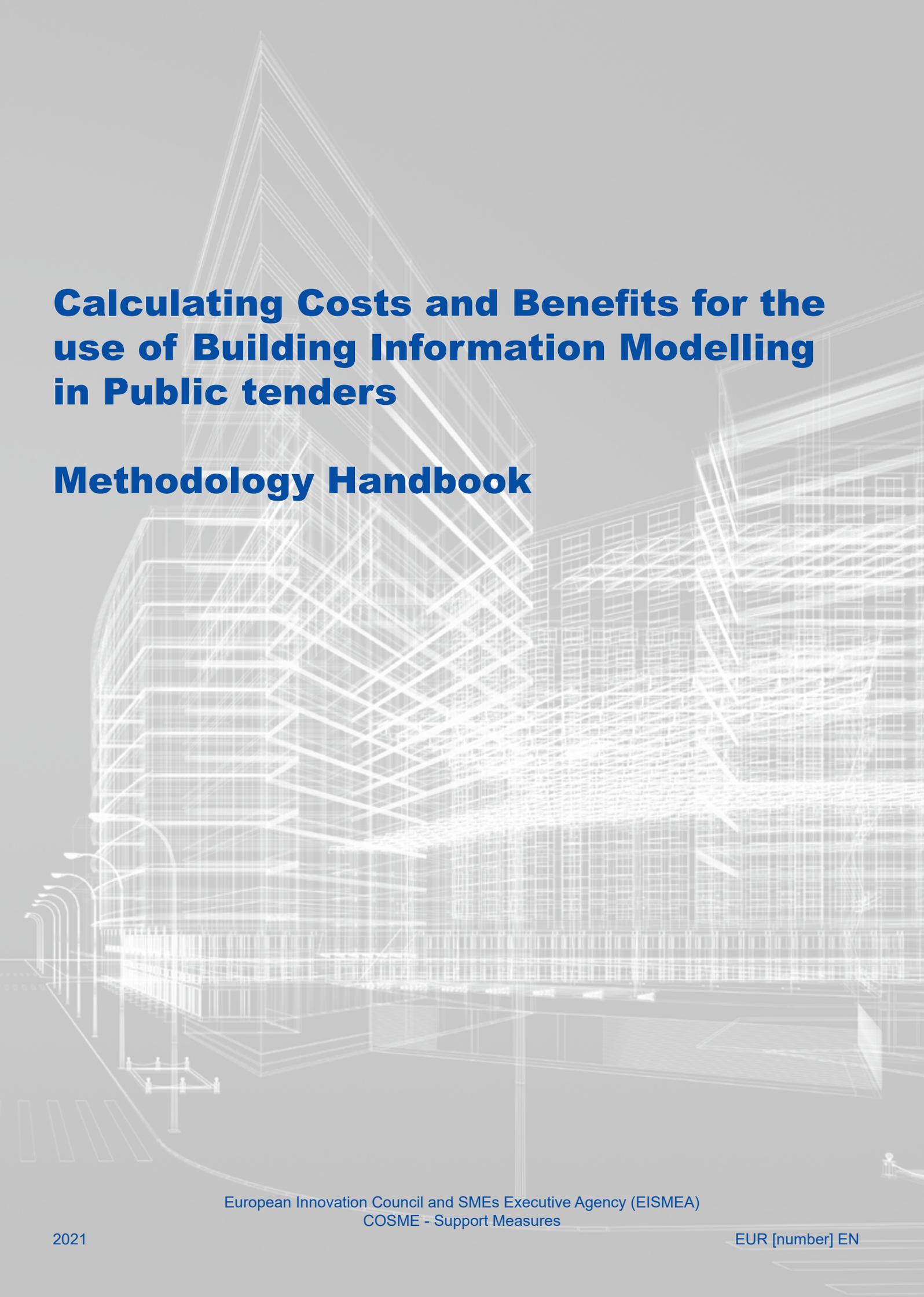
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Calculating Costs and Benefits for the use of Building Information Modelling in Public tenders

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Preface

The European construction ecosystem is at the centre of a tough but also promising set of economic, environmental and societal challenges. As one of the 14 industrial ecosystems in the European Union¹, it is responsible for almost 9% of the EU GDP, 7% of employment, and it is composed by 3.1 million businesses, most of them being SMEs².

The European Union has set the green and digital transition as high priorities for the years to come. The European Green Deal aims at transforming the European Union into a just and prosperous society with a modern, resource efficient and competitive economy. On the same time, the Commission is determined to make this a “Digital Decade for Europe”³, with a clear focus on data, technology, and infrastructure and strengthen EU’s digital sovereignty.

The construction ecosystem is transforming, grasping the benefits of digital tools and technologies. Building Information Modelling (BIM) is one of the principal tools that transforms the construction ecosystem and the management and interventions to the built environment. The EU Public Procurement Directive of 2014⁴ encourages public entities to use BIM when procuring for construction projects. On that basis, the European Commission has been collaborating with the EU BIM Task Group since 2016⁵. The “EU handbook for the introduction of Building Information Modelling by the European public sector ” was published in 2017 as one important result of this collaboration. The handbook, translated from English to 20 more languages, has been downloaded more than 30 000 times.

Certainly, there is more to be done in order to make BIM the norm in public procurement for construction. The methodology for a cost benefit analysis for the use of BIM in public procurement is one of the first deliverables of the Renovation Wave Communication (2020)⁷ and aims to build the case for the introduction of BIM in public procurement for individual public projects, by demonstrating costs and benefits from their perspective.

The methodology was developed as part of the service contract GRO-SME-20-F-101, EASME/2020/MV/0001 with three main objectives:

1. The creation of a model that measures the costs and benefits for using BIM in public construction projects, also taking into account expenditures, revenues and non-monetary benefits
2. The validation of this model, demonstrating its relevance and practical applicability through 6 case studies, representative of different types of projects
3. The drafting of an informative and easy-to-consult handbook, addressed to public entities in the EU that want to learn more about this model



¹ European Industrial Strategy. European Commission (2021) https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en

² European Construction Sector Observatory https://ec.europa.eu/growth/sectors/construction/observatory/data-mapper_en

³ Europe's digital decade. European Commission (2021) https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12900-Europe-s-digital-decade-2030-digital-targets_en

⁴ https://ec.europa.eu/environment/gpp/eu_public_directives_en.htm

⁵ <http://www.eubim.eu/>

⁶ <http://www.eubim.eu/handbook/>

⁷ Renovation Wave Communication. European Commission (2020) https://ec.europa.eu/energy/sites/ener/files/eu_renovation_wave_strategy.pdf



Abstract

This handbook represents the work carried out by RINA Consulting S.p.A. and its subcontractor, B1P Group S.r.l. in the framework of the service contract GRO-SME-F-101 'Methodology for cost-benefit analysis for the use of Building Information Modelling (BIM) in public tenders'. The document is structured in five main chapters which present the analysis performed during the project and the results obtained. The first section introduces the topic developed in the following parts and presents the purpose of the handbook to the public entities who are the target group. The second chapter provides insights on the present status of BIM adoption in the public sector, through literature research, interviews and an on-line survey. The third and fourth sections represent the core of the document. The third chapter presents the developed cost-benefit analysis (CBA) tool, describing the approach and methodology used to create it and a step-by-step guide to learn how to simulate a cost-benefit analysis using the tool. The fourth section is a practical implementation of the CBA tool in six case studies, representing various types of projects (small-scale infrastructures and buildings with differing budgets and covering diverse phases of the life cycle), in order to show validation of the model. The last chapter includes the conclusions of all the work performed.



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Croatia	Arhitektura minimal d.o.o. Arhitektonski studio Helman i Jukić Baldinistudio d.o.o. Croatian Chamber of Chartered Geodetic Engineers (HKOIG) Faculty of Architecture, University of Zagreb Institute IGH jsc State Geodetic Administration	Greece	BIM Design Hub CERTH/ITI (Information Technologies Institute at the Centre for Research and Technology-Hellas) Dektis Consultant Engineers S.A. HELLASCO (The Hellenic Association of Consulting Firms) IsZEB (Intelligent Solutions for Zero and Positive Energy Buildings - DIH CNPC) Ministry of Environment and Energy - General Secretariat of Spatial Planning and Urban Environment PEDMEDE (Panhellenic Association of Engineers) Technical Chamber of Greece (TCG)
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		Norway	Norwegian Mapping Authority BaneNOR Statsbygg
		Poland	Politechnika Poznańska (University of Poznań)
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Executive summary

Construction is a strategic sector for the development of the European economy, and governments and public players are its largest client base. However, there are some commonly recognised problems that could affect the construction process: levels of collaboration, under-investment in technology and R&D and poor information management.

Implementing Building Information Modelling (BIM) could both solve these issues and bring further benefits to public and private stakeholders, although the method of effectively evaluating these benefits remains to be worked out. For this reason, EISMEA, under the powers delegated by DG GROW, announced a tender to develop a methodology for

cost-benefit analysis for the use of BIM in public tenders. RINA Consulting S.p.A., together with its subcontractor, B1P Group S.r.l., were awarded this project that entered into force on 1 September 2020 and lasted for nine months. The implementation of the contract, funded by the COSME programme of the European Union, was supervised by an ad hoc 'advisory board' composed of representatives from the European Commission, EISMEA and the EU BIM Task Group (EUBIMTG).

The aim of the project was to develop a model which enables EU public clients to measure the costs and benefits of using BIM in their public construction projects. The project addressed three main objectives:



COST-BENEFIT MODEL DEVELOPMENT



MODEL VALIDATION AND CASE STUDIES



HANDBOOK CREATION



OBJ 1 - Cost-Benefit Model development

The model for measuring the costs and benefits (both monetary and non-monetary) of using BIM in public construction projects enables EU public clients to assess the estimated advantages for their specific projects on their own. The consolidated cost-benefit analysis model is tailored to the needs and challenges of stakeholders involved in BIM adoption at various levels.

The model:

- leverages on extensive desk research aimed at obtaining a comprehensive overview of the actual cost-benefit models developed and applied for measuring the impacts of BIM adoption in private and public projects;
- is based on the identification and quantification of BIM-associated costs and benefits, properly weighted, by means of an online survey addressed to 122 stakeholders (mainly public entities at various administrative levels). This helped to understand the main challenges in the adoption of BIM and what the authorities consider as (monetary and non-monetary) costs and benefits;
- relies on validation of the desk research findings through 40 structured interviews;
- considers both financial and economic analyses which drive the users to the evaluation of the benefit-cost ratio to measure the value for money of using BIM, thus calculating the eventual profitability of using BIM in public projects;
- allows the performance of a sensitivity analysis to verify the robustness of the model, the risk grade deriving from critical variables in the project and the measurement of their impacts on the sustainability of the project.



OBJ 2 - Model Validation & Case Studies

The practical usage and relevance of the cost-benefit methodology was demonstrated with its application to several representative types of projects. It focused on small-scale infrastructures and buildings of various budgets and covered various phases of the life cycle (e.g., design, planning, construction and operation).

The new model was developed for its potential application throughout the entire European Union territory and for various framework conditions, as demonstrated through the analysis of the six case studies.

Each case study, representing various BIM maturity levels for specific types of assets and project life cycle phases, was analysed to estimate how the costs and benefits may

differ when progressing from BIM level 0 to 1 and from BIM level 1 to 2.

The case studies are not strictly linked to a specific EU country or a specific project, but are valid for all EU Member States and applicable to various asset categories. The purpose is to show that the CBA model can be applied throughout the entire European Union territory, and to various framework conditions.

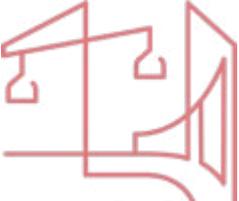
The intended outcome of the project is to provide the main beneficiaries of the model (e.g., public entities, policy makers, European Commission) with quantitative and qualitative arguments for using BIM for public construction works.



OBJ 3 - Handbook creation

The third objective was to compile this handbook, an easy-to-read and illustrated document to serve as a guideline for the EU public entities wishing to learn about the BIM cost-benefit analysis and use it.

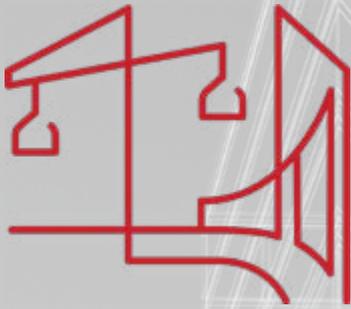
The handbook includes the problem definition as the lack of clear costs and benefits associated with BIM and the approach used for identifying and measuring these. Furthermore, it presents the model developed to simulate the costs and benefits of adopting BIM in public projects and the case studies that can guide the users in understanding better and utilising the model.



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1 Introduction

- 1.1 AEC Sector, Sustainability and BIM**
- 1.2 Purpose of this handbook**
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- 1.4 Target groups**



1.1 AEC Sector, Sustainability and BIM

Digitalisation in the construction sector and its related monetary and non-monetary benefits is considered a key action for the improvement of the architecture, engineering and construction (AEC) industry productivity. Subsequently, the overall development of the European economy would also be boosted considerably by digitalisation.

The construction sector is strategic because of its capability to generate incomes not only from the creation of new services and jobs but also from the delivery and maintenance of the built environment. In addition, the improved productivity of the AEC sector through the digitalisation of its processes could also generate high savings leading to economic upturn, especially at public level. The Government and public sector clients represent the construction industry's single biggest client. Therefore, the investment in improving the construction process at public level, represented by BIM methodology, is fundamental in helping ensure the success of digitalisation in the construction sector.

The construction industry, especially in the public sector, faces some commonly recognized issues such as low levels of collaboration, under-investment in technology and research and development (R&D), as well as poor information management. These issues then create a chain of problems which end up affecting the construction framework, resulting in poor value for money, unpredictable cost overruns, late delivery of projects and more project changes than are necessary.

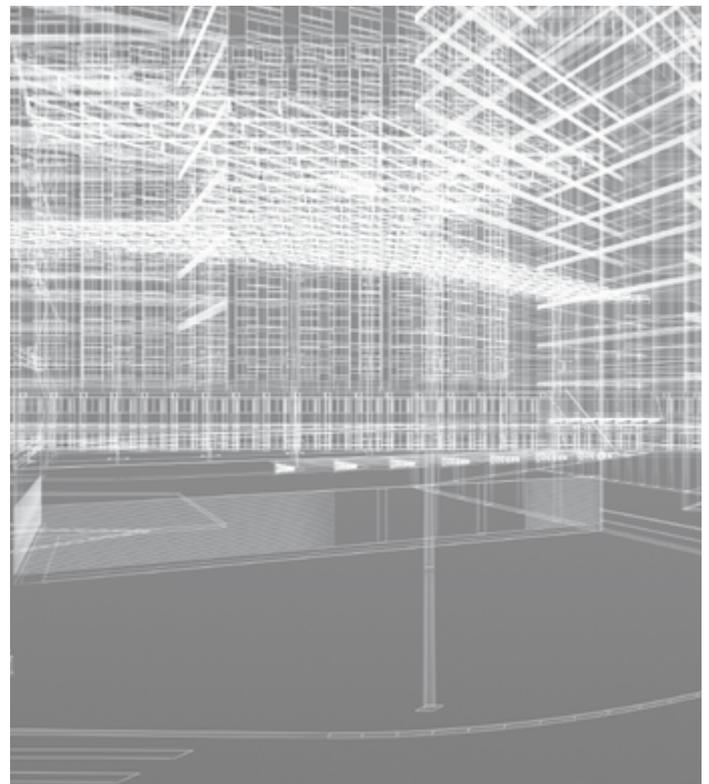
It is widely understood that positive returns on investment can be achieved with Building Information Modelling (BIM) implementation. There are two popular BIM maturity evaluation systems: the BIM maturity and the BIM maturity index levels (levels of initial/ad hoc, defined, managed, integrated and optimised). However, most organisations which are not familiar with BIM implementation or which are at the low maturity level refrain from adopting such comprehensive approaches, unaware of the related benefits of BIM process and how to evaluate them.

BIM, also known as n-D modelling, virtual model or virtual prototyping technology, can be defined as a collaborative process to produce, communicate and analyse construction projects using a digital information model throughout the project construction life cycle^{1,2}.

BIM is at the centre of a digital transformation of the

construction sector and the built environment. Governments and public procurers across Europe and around the world are recognising the value of BIM as a strategic enabler for cost, quality and policy goals. Many are taking proactive steps to foster the use of BIM in their construction sectors and public asset delivery and operations to secure these economic, environmental and social benefits.

The Government and public sector clients represent the construction industry's single biggest client. Therefore, the investment in improving the construction process at public level, represented by BIM methodology, is fundamental in helping ensure the success of digitalisation in the construction sector.



¹Azhar S, Khalfan M, Maqsood T. Building Information Modeling (BIM): now and beyond. Australas J Constr Econ Build 2012;12(4):15-28.

²Eastman C, Teicholz P, Sacks R, Liston K. BIM handbook A: a guide to building information modeling for owners, managers, designers, engineers, and contractors. 2011.

³Volk, R., J., Stengel and F., Shultmann (2014) Building Information Modelling (BIM) for existing Buildings - Literature Review and future Needs. Automation in Construction 38: 109-127

⁴Yalcinkaya & Singh (2014) Building Information Modelling (BIM) for Facility Management – Literature Review and Future Needs. Product Lifecycle management for a Global Market: 1-10

Benefits related to BIM have to be framed within the overall sustainability and environmental goals set for the AEC sector.

There has been a large number of studies elaborating the benefits of using BIM in the construction industry. In less than ten years, more than 900 studies on BIM utilisation have been published as academic papers, and most of these illustrate how BIM could change the construction industry, increasing its productivity^{3,4}).

Various studies have shown how effective BIM is and considerable effort has been put into identifying the benefits and obstacles of using it^{5,6}. The main recognised benefits that BIM technology can provide can be found in the life cycle cost control, in the effective construction process, design and quality improvement, decision-making support and risk management. Some of these benefits have a greater impact in specific projects (e.g., facility management) than others. Further benefits are also claimed in the ability to share information, in the reduction of construction and design errors, faster working environments, enhancing efficiency, operational efficiency, and so on⁷.

Therefore, with its three-dimensional ability combined with the versatility to control vast amounts of associated data, BIM is supported by many industry professionals as an effective tool for improving the construction industry.

The main recognised benefits that BIM technology can provide can be found in the life cycle cost control, in the effective construction process, design and quality improvement, decision-making support and risk management.



³ Li J., L. Hou, J. Wang and X. Wang (2014) A Project Based Quantification of BIM Benefits. *International Journal of Advanced Robotic Systems*, 11(1):1

⁴ Dakhil A., J. Underwood, & M. Al Shawi (2016) BIM benefits-maturity relationship awareness among UK construction clients. Conference: Proceedings of the First International Conference of the BIM Academic Forum Held at Glasgow Caledonian University, Glasgow, September 13-15, 2016 (ISBN – 9781905866816)

⁷ Ho Shin M., H. Kyung Lee and H. Yong Kim (2018) Benefit–Cost Analysis of Building Information Modeling (BIM) in a Railway Site. *Sustainability* 2018, 10(11), 4303



1.2 Purpose of this handbook

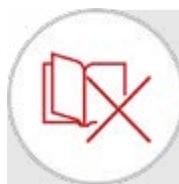
This handbook will prepare the reader to apply the model developed for evaluating the costs and benefits of using Building Information Modelling (BIM) in public tenders without the need for any additional resources.

This informative, easy-to-read and illustrative handbook is aimed at public stakeholders who want to learn about BIM cost-benefit analysis and who wish to implement recommendations for the introduction of BIM as part of a wider change programme.



What the handbook IS:

- a document that clearly describes the new BIM cost-benefit methodology, and develops a theoretical map of how those benefits could drive public stakeholders toward BIM adoption and implementation
- a guideline for the identification of the costs and benefits of BIM, covering some aspects that, at the moment, are not so clear (e.g. cost-benefit ratio)
- a collection of strategic recommendations for widening BIM usage in the public construction sector
- a practical guide to replicate the proposed costs-benefit analysis (CBA) methodology and assess BIM process viability for any public tender



What the handbook IS NOT:

- a technical introduction to BIM (which is covered widely in other literature) or a development of standards that could 'compete' with documents produced by standards bodies, academia and industry association

The handbook includes:

- Problem definition (i.e., BIM can be beneficial although its cost-benefit ratio is not clear)
- The approach used for identifying and measuring the potential costs and benefits
- The model that public organisations can use to simulate the costs and benefits of their projects
- Case studies which could guide the model users in the methodology application and results interpretation



1.3 How to use this handbook

EU public authorities, for whom this handbook has been written, can use it to:



promote the introduction of Building Information Modelling (BIM) in the public construction sector, one of the least digitalised industries. Many researchers have highlighted awareness of BIM implementation and its benefits as important aspects to encourage its adoption by industry as a new method of delivering projects. However, some aspects of BIM adoption still remain unanswered, for example, the method for working out the cost-benefit ratio; this handbook intends to address this issue



define a clear new cost-benefit analysis (CBA) BIM methodology for identifying and measuring potential costs and benefits



provide a practical and easy-to-understand model which can directly simulate costs and benefits in any construction project



describe practical case studies, to be considered as reference examples on how to use the CBA model



bring the current understanding of the AEC sector closer to the costs and benefits (both monetary and non-monetary) of using BIM in public tenders



stimulate, through a wider introduction of BIM and implementation of a new BIM cost-benefit methodology, competitiveness and economic growth while delivering value for public money



encourage greater dialogue across the public and private sectors for further collective actions, accelerating growth and fostering competitiveness in the construction sector, especially in the Small and Medium Size Enterprises (SMEs)



provide support to enable Governments and public sector clients to transition construction to the digital era



1.4 Target groups

Public entities at various administrative levels (national, regional, local) are the main target groups of this handbook. However, the EU BIM Task Group has also identified the following target groups:



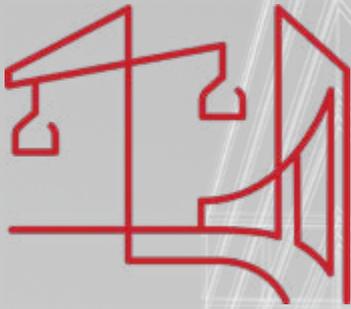
Public policy makers involved in the development of policy for infrastructure or construction sectors



National or local public clients/procurers primarily concerned with service procurement



Operators responsible for the ongoing management and operation of the built asset or environment



2 Where are we now? Background analysis

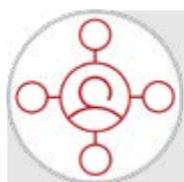
- 2.1 BIM and public sector stakeholder needs**
- 2.2 Literature review**
- 2.3 On-site data collection: interviews and online survey results**



2.1 BIM and public sector stakeholder needs

Building Information Modelling (BIM) methodology is recognised as a strategic process for achieving digitalisation in the architecture, engineering and construction (AEC) industry, especially in the public sector.

The adoption of BIM enables the cost, quality and policy goals to be met through its coordinated approach and the interoperability between all the disciplines involved in a building project.



The public sector can benefit from the adoption of BIM in three distinct stakeholder roles:

- Public procurer or an infrastructure and estate owner concerned with the project phase (i.e., delivery of built assets)
- Public infrastructure and estate owner concerned with the operations and maintenance phase (i.e., use of public built assets)
- Policymaker concerned with the development of legislation, policy, regulations or standards for improving performance of the sector or built environment (i.e., sector focus)

The analysis performed during the project highlighted a heterogeneous status of BIM implementation and thus various levels of BIM maturity in the public sector across Europe. Even though most of the organisations displayed good knowledge of BIM processes, the perception is that this could be considered a fairly new methodology, not yet fully consolidated.

It is generally agreed that BIM could reduce the overall costs of a project during its life cycle, solving the collaboration issues and lowering the number of unexpected changes. Nevertheless, the lack of short-term benefits, together with a long payback period are listed as the main negative factors slowing down the uptake of BIM methodology. Cultural resistance to changes in the traditional procedures plus the lack of a legislative framework and an incentives system are seen as the main barriers to the development of BIM in the public sector.

However, on the positive side, several benefits are achieved from the adoption and use of BIM in a public organisation. These benefits include improved management of a construction project throughout its life cycle, reduced times when compared with the traditional processes and the achievement of a higher quality product. Indeed, the use of BIM processes allows storage of large amounts of data, cutting down on errors and unforeseen changes and collaboration and interaction with various disciplines.

The majority of public organisations which have adopted or are willing to implement BIM do so not only to produce Employer and Organisation Informative Requirements (EIR and OIR), but also to check the models and verify their compliance with the tendered specifications. The final goal is to improve the coordination activities, during the construction phase and the management and maintenance of the public asset, by having all the necessary information stored.

The lack of short-term benefits, together with a long payback period are listed as the main negative factors slowing down BIM adoption.

¹Azhar S, Khalfan M, Maqsood T. Building Information Modeling (BIM): now and beyond. *Australas J Constr Econ Build* 2012;12(4):15-28

²Eastman C, Teicholz P, Sacks R, Liston K. *BIM handbook A: a guide to building information modeling for owners, managers, designers, engineers, and contractors*, 2011



2.2 Literature review

Literature review has been a preliminary essential step in identifying costs and benefits of using BIM in public tenders. Five main scientific papers were selected to provide valuable information on other past cost-benefit analysis experiences. The information collected refers to the approaches used for measuring costs and benefits associated with BIM adoption. It was useful to evaluate how those methodologies were tested and validated through case studies and understand the main challenges faced by researchers. The information analysed also highlights the critical risks to be addressed during the design of the methodology. Seven additional literature sources

were carefully examined in order to define a suitable list of indicators for capturing the most significant costs and benefits for the adoption of BIM in public tenders.

The key elements which emerged from the analysis of each resource were fundamental for the identification of indicators that a consistent cost-benefit analysis (CBA) should involve. The most significant costs and benefits reflecting the point of view of the public clients are summarised in the following table. It is worth highlighting that the literature review results have been reinterpreted considering the public clients' perspectives.



BENEFITS

INDICATOR	MEASURABILITY AND COMMENTS
Savings related to early clash detection	These items are related to the reduction of costs from the creation of a high-quality model which enables the detection of interferences and errors during the design phase, preventing expensive changes during the construction stage of a project
Savings related to prevention of changes in construction phase	
Savings associated with schedule reduction	These values are associated with the quantification of the time saved using BIM for a project
Savings associated with accuracy in quantity take-offs	This benefit is associated with more accurate estimates of the required material and the connected activities
Environmental benefits	The environmental benefit is associated with a reduction in the quantity of material wasted and so with the overall CO ₂ emissions of the project
Savings associated with lower risks (enhanced certainty)	This value is an advantage for the enhanced certainty in expenses. After careful consideration, this benefit was excluded from the CBA as it does not reflect the condition of a large set of public clients across Europe
Savings realized in FM and maintenance activities	Savings made through BIM adoption in the operations phase (once the asset has been completed) are often referred to as those largest in size and being realised over a longer period of time
Savings associated with lower number of litigations	These last two items are event-related benefits whose quantification is strictly dependent upon the occurrence of an event, e.g., a litigation, a claim or an accident, and the associated costs of settling the individual negative issue
Savings related to better H&S	
Enhanced communication and collaboration	These are the most mentioned benefits connected to BIM adoption and cited in the majority of literature sources reviewed. This indicator was excluded from the CBA, as a credible universal estimate of this advantage in monetary terms could not be calculated, especially considering the 'ex-ante' nature of the analysis provided by the CBA methodology



COSTS

INDICATOR	MEASURABILITY AND COMMENTS
Hardware related investments	These three investment items were mentioned in various resources as the most relevant expenses associated to BIM adoption
Software related investments	
Training related expenses	
Design phase cost/ BIM model creation	This cost is associated with the BIM model creation expenses which are charged to the public entity
Consulting costs	This expense appears to be significant (especially in the early stages of BIM adoption)

Besides the costs and benefits, several limitations and challenges which dealt with the employment of BIM in the construction industry were also reported by various authors. The research underlined that both a comprehensive database of BIM adoption experiences and a common baseline for evaluating BIM implementation impact are still missing. In this framework, the various costs and benefits have so far been quantified using diverse approaches, based on differing assumptions, reflecting the perspectives of diverse stakeholders and employing case-specific data.

The research underlined that both a comprehensive database of BIM adoption experiences and a common baseline for evaluating BIM implementation impact are still missing.

Main Reference methodology/study

- **The Economics of BIM and added Value of BIM to Construction Sector and Society**, Schultz, A., U. M. Essiet, D. V. Souza de Souza, G. Kapogiannis and L. Ruddock (2013)
- **BIM Level 2 Benefits Measurement (the full report)**, PWC (2018)
- **Benefit-Cost Analysis of Building Information Modeling (BIM) in a Railway Site**, Shin, M. H., H. K. Lee and H. Y. Kim (2018),
- **The Potential Cost Implications and Benefits from Building Information Modeling in Malaysian Construction Industry**, Chai, C. S., C. S. Tana, E. Aminudina, S. C. Loob, K. C. Gohc, M. C. Theongd, X. S. Leed, L. W. Chin (2017)
- **Building Information Modelling: Evaluating Tools for Maturity and Benefits Measurement**, M. Kassem, J. Li et al., (2020)
- **Cost-benefit analysis of Building Information Modeling implementation in building projects through demystification of time-effort distribution curves**, W. Lu, A. Fung, Y. Peng, C. Liang, S. Rowlinson (2014)
- **The project benefits of Building Information Modelling (BIM)**,
- D. Bryde, M. Broquetas, J. M. Volm (2012)
- **How to Measure the Benefits of BIM, A Case Study Approach**, K. Barlish (2011)
- **Cost Benefit Analysis of implementing Building Information Modeling (BIM) for construction management of the Sports Arena of University of Alaska Anchorage**, C. C. McConnell (2014)
- **A Project-based Quantification of BIM Benefits**, J. Li, L. Hou, X. Wang, J. Wang, J. Guo, S. Zhang and Y. Jiao (2014)
- **The key performance indicators of the BIM implementation process**, P. Coates, Y. Arayici, L. Koskela, M. Kagioglou, C. Usher and K. O'Reilly (2010)
- **Creation of Formula to Predict Time and Cost Benefit by Using 5D BIM Rather than Traditional Method of Construction**, A. Khan and A. Muneeb (2019)



2.3 On-site data collection: interviews and online survey results

With the aim of accurately quantifying the indicators assessed through the literature review, an online survey was distributed to a list of public contractors and telephone interviews were conducted with selected stakeholders. This activity enabled the measurement, in practice, of the effects associated with the implementation of Building Information Modelling (BIM) in the public construction sector, through ad hoc questions and relying on the direct experience of public stakeholders.

Interviews results

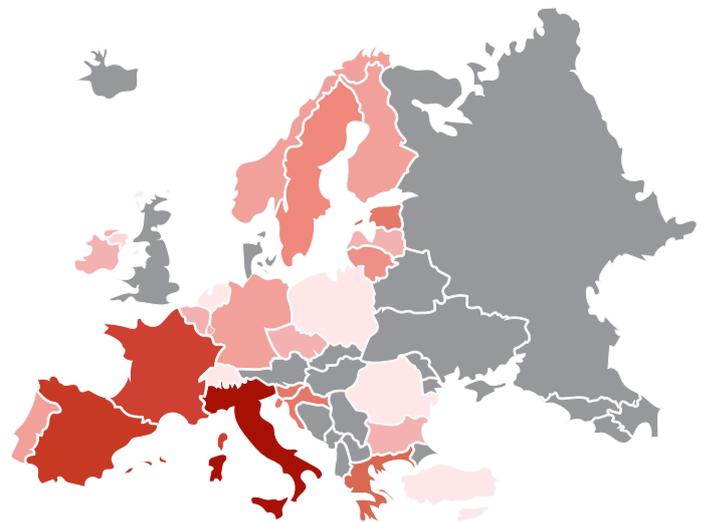
40 stakeholders from various European countries were interviewed. They were able to provide helpful perspectives on BIM implementation in a public framework. Amongst these were public authorities, national companies, research institutes and universities. All participants supplied very interesting information based on their unique experience with BIM, not only from its direct adoption but also in their support for organisations which are implementing BIM.

The interviews were individual and semi-structured; the questions were focused on identifying the main costs and benefits and strengths and weaknesses of using BIM. The information which was collected and analysed further emphasised that BIM adoption in public procurements is a very long and complex process, more related to a deep cultural change towards digital thinking rather than simply the introduction of new software and hardware to support the regular work.

Two main topics emerged from the interviews:

- the main benefits, weaknesses, opportunities and threats found in the processes which lead a public administration to adopt and regularly use BIM in public procurements
- the costs associated with the integration of BIM methodology in the common procedures within a public organisation

A SWOT analysis was set up in order to present the results obtained in terms of strengths and weaknesses directly associated with the implementation of BIM. Threats and opportunities were also identified as barriers which could slow down the process or as vehicles to foster it.



Countries involved in the surveys and interviews

BIM adoption in public procurements is a very long and complex process, more related to a deep cultural change towards digital thinking rather than simply the introduction of new software and hardware to support the regular work.

BIM ADOPTION IN PUBLIC TENDERS	STRENGTHS	WEAKNESSES
	Improvement in management and coordination	Few or no benefits at the beginning
	Improvement in maintenance activities - operation phase	Low productivity and additional effort required
	Reduction of contingencies through improvement of clash detection and quality check	Specific knowledge and expertise required
	Improved time management and efficiency in time scheduling	High costs of adoption
	Improvement in costs estimation and information management	Complexity and lack of flexibility
	Reduction of total projects' costs	Interoperability issues
	Improvement in projects' quality	

BIM ADOPTION IN PUBLIC TENDERS	OPPORTUNITIES	THREATS
	Regularisation and streamlining of the national AEC procedures	Lack of a clear regulatory framework and incentives for adoption
	Digitalisation of the aec sector	Cultural and procedural obstacles
	Specific studies on and analyses of costs and benefits associated with BIM	Monopoly of certain software companies
Development of a clear regulatory frameworks and introduction of incentives	High costs of adoption	

Regarding the costs associated with the use of BIM, the main outcome of the interviews is that the initial costs of starting to use BIM methodologies are higher than the immediate benefits gained. These costs refer in particular to the necessary training for the staff and to the required software and hardware. It is commonly agreed that an estimate of the return of the investment associated with BIM adoption can be assessed only after several years

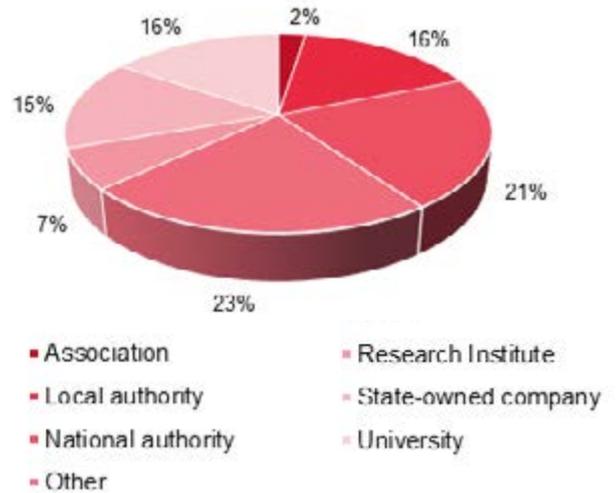
from its implementation. However, after those initial expenditures, no more extra costs are identified and all the expenditures are completely absorbed by the projects' costs. In this context, it is worth recalling that the point of view used to develop the methodology corresponds to the one of the public client/procurer and not to architectural or engineering firms' nor to contractors'.

AVERAGE COSTS FOR BIM ADOPTION			
Training costs (cost/person)	Software licenses costs - modelling & verification (person/year)	Hardware costs (cost/person)	Total costs (cost/person considering the first year of adoption)
5 - 8 k€	8 – 10 k€	2 - 3 k€	15-20 k€

Survey results

The invitation to complete the online survey was sent to more than 500 potential respondents in European countries and 122 of these complied. This sample is made up of respondents from various public and private entities categorised as: 'national authority', 'local authority', 'state-owned company', 'university', 'association', 'research institute' and 'other' comprising organisations which cannot be included in the previous categories (e.g., architectural firms, engineering firms, companies which are only partially state-owned, chambers of commerce and NGOs).

Each respondent was required to self-assess the BIM maturity level of their entity based on the descriptions contained in the table below, based on Bew's and Richards' study³:

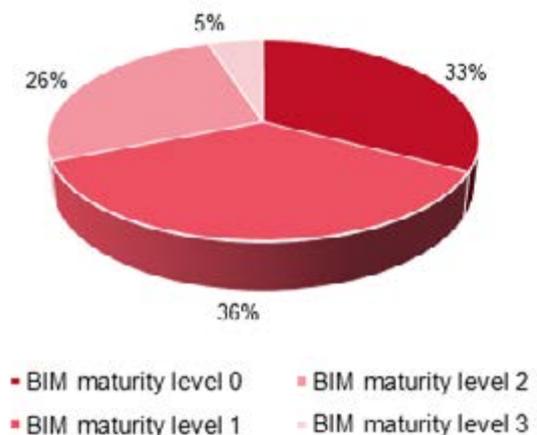


Sample distribution of survey participants divided per category

BIM Maturity levels description (extracted from the survey)

BIM Maturity Level	Description
Level 0	There is very little collaboration among stakeholders and 2D CAD drafting is employed - BIM is not adopted
Level 1	Both 2D and 3D CAD drafting is employed and information on the project are shared among stakeholders through a Common Data Environment
Level 2	Each stakeholder works on its own 3D model, but a federated model exists, time-management and cost-management information are shared among stakeholders
Level 3	All project stakeholders are working on a single shared 3D model and the model is employed also to carry out facility management and maintenance

Almost 70% of respondents indicated that their organisation belongs to BIM maturity level 0 or 1. 26% belongs to BIM Maturity Level 2 while only 5% declared to be at BIM maturity level 3. (See Figure below) No statistically significant pattern was identified correlating the geographical location with a particular BIM maturity level.



BIM maturity level distribution of the sample

³ Bew, M., & Richards, M., 2008, BIM Maturity Model. Paper presented at the Construct IT Autumn 2008 Members' Meeting. Brighton, UK.

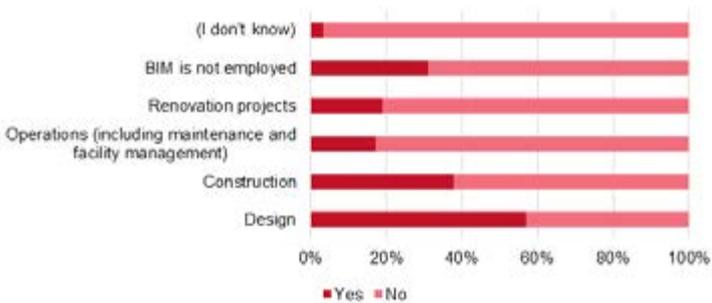
The main results obtained from the survey show the current state of BIM adoption in the public construction sector: the project phases in which BIM is employed and the most common costs and benefits associated with each phase.

As indicated in the following graphs, it appears that most public procurers tend to adopt BIM in the design phase. The highest expenses, however, were found in the renovation projects, design and operations phases.

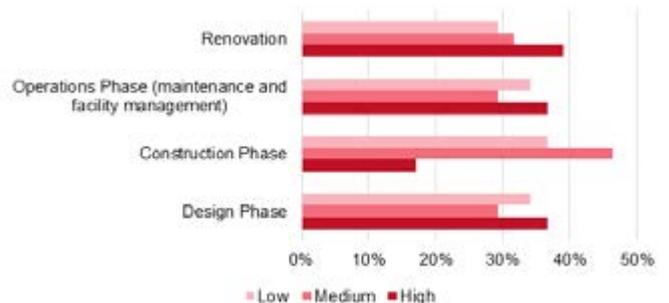
With regard to BIM associated benefits (and savings), most of the stakeholders agreed that BIM can generate a substantially positive impact during the operations phase (including facility management and maintenance activities).

This result is extremely interesting when combined with the fact that, as highlighted above, only a small percentage of respondents' organisations (less than 20%) are employing BIM during this phase. Hence, it appears that the majority of public procurers expect to obtain substantial benefits from the BIM model used for facility management and maintenance activities

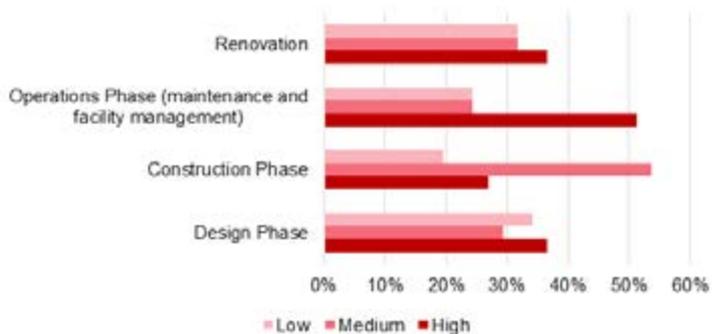
The majority of public procurers expect to obtain substantial benefits from the BIM model used for facility management and maintenance activities.



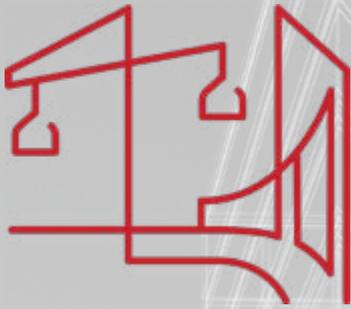
Project phases in which BIM is mostly employed by public procurers



BIM adoption associated costs for each phase



BIM adoption associated benefits for each phase



3 Is BIM cost-effective for public entities? Development of Cost-Benefit Analysis tool

- 3.1 Approach: CBA, BIM and public authorities
- 3.2 Methodology: model for identifying and measuring potential costs and benefits
- 3.3 Guide: step-by-step procedure to simulate cost-benefit analysis



3.1 Approach: CBA, BIM and public authorities

The need to produce such a cost-benefit analysis (CBA) tool relates to the fact that Building Information Modelling (BIM) is a critical driver in the digitalisation of the construction sector in Europe. Despite the many advantages that are often attributed to its employment, a consistent and replicable methodology for estimating BIM's concrete impact on public tenders appears necessary to foster its adoption further. The tool enables EU public clients to assess the costs and advantages of adopting BIM in their specific projects. It was developed following a consolidated cost-benefit analysis methodology tailored to the needs of and challenges faced by public stakeholders.

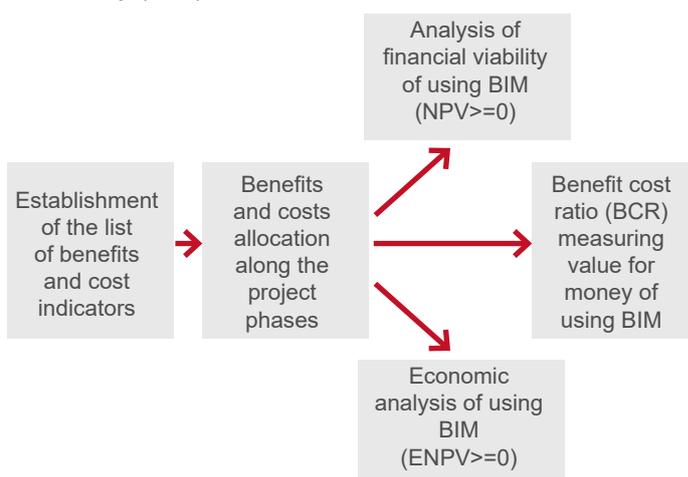
The cost-benefit analysis tool was designed for ease-of-use by people with varying degrees of knowledge and experience of BIM.

The steps followed to reach this aim are reported below and are expanded upon in the previous and following chapters:

- Literature review and identification of main BIM cost-benefits
- Validation of the literature research through the on-site consultation phase: online surveys and telephone interviews
- Definition of the tool
- Application of the tool in practical case studies, representing various types of projects (small-scale infrastructures and buildings with differing budgets and covering diverse phases of the life cycle), in order to refine and validate the model

The definition of the tool followed the process described in the block diagram, starting with the monetary and non-monetary cost-benefit indicators identified and selected in the previous phases of this study. Next, it was assumed that each project follows a three-phase process, starting with 'Planning and design', then 'Construction' and, finally, 'Operation and maintenance'. Ad hoc formulas were established for the computation of each indicator whose value was set to be automatically allocated over a time-period reflecting the project specifications. The difference between benefits and costs related to BIM adoption over the period enabled the computation of the project-related cashflow. In this context, benefits consist of savings arising from BIM adoption in the project, while costs relate to additional expenses associated with BIM implementation in the project and a share of the investments necessary for its adoption. The cashflow obtained, once discounted,

led to the computation of the Net Present Value (NPV). Two versions of this indicator were considered: the NPV, addressing solely the financial viability of adopting BIM in the project, and the ENPV (Economic Net Present Value) which incorporates positive environmental and 'social' externalities in the analysis. When the value of these two indicators is positive ($NPV \geq 0$ and $ENPV \geq 0$), the implementation of BIM in the project is considered a sustainable solution. By analysing benefits and costs separately, it is possible to measure how much benefits exceed costs and how many euros are gained for each euro invested in BIM. This value is given by the Benefits-Costs Ratio (BCR) and is a measure of the so-called Value for Money (VfM).



The methodology was built to carry out an ex-ante assessment of the use of BIM in a public procurement process. In this framework the results cannot capture and reflect the information that could be easily collected through an ex-post analysis. Therefore, the tool relies heavily on preliminary established values in order to limit the amount and complexity of information required by the user. These values ensure that the tool can be used to assess the sustainability of adopting BIM in various investment projects, providing estimates of related costs and benefits.

By analysing benefits and costs separately, it is possible to measure how much benefits exceed costs and how many euros are gained for each euro invested in BIM.



3.2 Methodology: model for identifying and measuring potential costs and benefits

The work carried out during the project led to the creation of the CBA tool for estimating the costs and benefits of employing BIM in a construction project.

As described in the previous chapters of this handbook, the study began with the review of several existing research projects and methodologies to measure benefits and costs

associated with BIM adoption. The findings of the literature review process were combined with the results of the online survey, and discussed further during the interviews conducted throughout the study. These steps led to the definition of the list of cost and benefit indicators reported below.



COSTS

Public entity personnel labour cost increase during pre-tendering phase	Costs related to lower productivity and additional effort required
Public entity personnel labour cost increase during tendering phase	
Public entity personnel labour cost increase during post-award phase	
Increased cost for consulting services to the public procurement process	
BIM modelling activity cost	
Public entity hardware upgrade investment	BIM related investment costs - share allocated to the specific project
Public entity annual software license fee	
Personnel training costs	
BIM coordination cost	



BENEFITS

Cost reduction due to early clashes and errors detection with subsequent reduction of changes necessary during construction phase
Cost reduction associated to more precise quantity take-offs
Cost reduction related to lower costs for claims/litigations
Time savings in design and construction phases and associated project duration reduction
Public entity personnel labour cost reduction due to faster document analysis for facility management and maintenance
Cost reduction associated with more efficient annual maintenance
Cost reduction attributable to the government/society due to better Health & Safety
CO ₂ emission reduction due to reduced material wasted

THE WORK BEHIND THE CBA TOOL

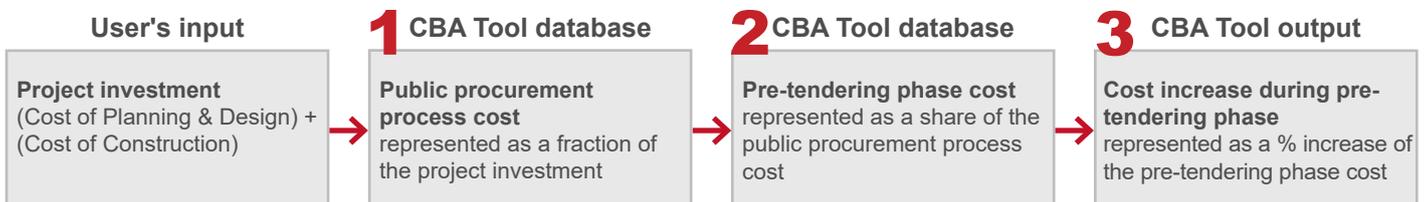
Background computations

The CBA tool calculates most of the indicator values relying on a database created using the data collected in the online questionnaire. The computations of the cost and benefit indicators follow various approaches which were adopted to capture and reflect the specificities of each possible project assessed using the CBA tool. The value of a set of those indicators varies depending on the BIM maturity level considered; both level 1 and 2 scenarios are provided for each project.

As an example of how the CBA tool calculates the values of the costs, three diverse approaches are presented.

Approach 1 used to obtain the values of the following indicators

- Public entity personnel labour cost increase during pre-tendering phase
- Public entity personnel labour cost increase during tendering phase
- Public entity personnel labour cost increase during post-award phase
- Increased cost for consulting services to the public procurement process



At the same time, the BIM-related cost increase is dependent upon a set of additional variables which affect the related percentage used in each scenario. In particular, concerning the cost increase involving the pre-tendering and tendering phases of a procurement process, the additional variables impacting the computation are:

- The BIM maturity level of the scenario which is being considered (1 or 2)
- The level of experience of the public client with BIM (some or no experience)
- The 'Project category' ('New asset construction' or 'Work on an existing asset')

These factors increase or decrease the related expense item by pre-fixed percentages which were established following both discussions with stakeholders and experts and internal assumptions.

When the investment cost of a project is indicated as an input, the method for calculating the values of these indicators can be described in three phases:

1. Computation of the public procurement process cost. From the survey results, an average percentage (whose value is dependent upon the investment value) was extracted. This percentage represents the public procurement process cost connected to the specific project investment in a scenario where BIM is not adopted. For example, for investments between 1 and 5 million euros, the public procurement process cost is represented by about 8.5% of the total investment value
2. Extraction of four expense items (e.g., Public entity personnel labour cost) from the resulting cost of the procurement process (once again related to a baseline scenario without BIM). Each item represents a share of the procurement process value (the value of each share is once again obtained from the analysis of the survey results)
3. Application of a percentage increase representing additional costs, efforts and/or productivity reduction related to the use of BIM in the project.

Approach 2 used to obtain the value of BIM modelling activity cost

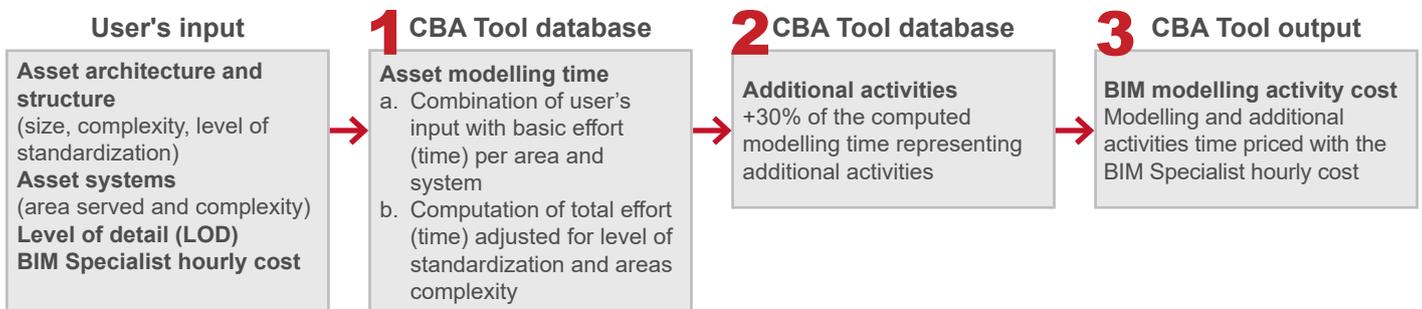
The 'BIM modelling activity cost' computation follows a completely different process that was established on the analysis of six real case studies. In particular, it was possible to produce an ad hoc database in order to estimate the time necessary for 3D modelling an asset.

The assets of the case studies were modelled following the specifications of the relative tender documentation and recording the actual time necessary for this activity. Furthermore, the time required to perform additional activities such as the quantity take-off extraction was also recorded. These data were analysed and, after several tests and discussions, they were used to establish the basic effort time necessary to model different areas and MEP systems of individual assets.

In this framework, two slightly similar approaches were developed in order to differentiate the cases in which the asset under study can be categorised as "Building", "Infrastructure" or as a "Mixed" asset (an infrastructural asset with building(s) included in its area).

The overall approach can be summarised in three phases:

1. Once the inputs related to the asset are inserted in the CBA tool, the resulting number of hours necessary for the 3D modelling activities are calculated based both on this information and on the internal database. The modelling time is established in relation to the level of detail of the model, the size of the areas to be modelled, their average level of complexity and the level of standardisation. The latter refers to the extent to which an area already modelled could be replicated in order to obtain other parts of the same building. A similar approach was also adopted for the systems whose modelling time depends on their complexity and the size of the area served
2. The modelling time is then increased by a percentage which represents the activities to be developed after the modelling process. These activities can be summarised as follows: initial documentation analysis, production of 2D drawings from the 3D model, quantity take-off extraction and other activities foreseen by the tender specifications or by the public authority
3. The resulting number of hours is subsequently priced in line with the national hourly cost of a BIM Specialist in the country where the asset is located

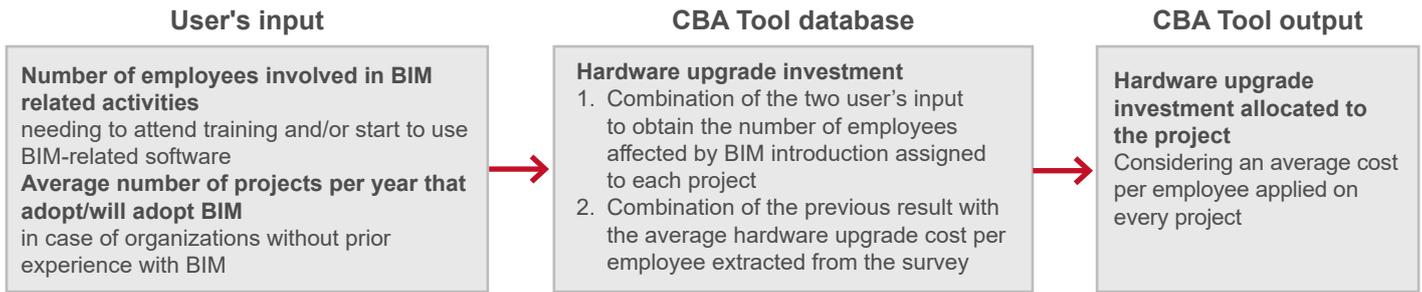


The BIM coordination cost in the case of a scenario with BIM maturity level 1 is proportional to the modelling time and adjusted according to the complexity of the asset architecture, structure and systems.

Approach 3 used to obtain the value of BIM related investment costs

For the computation of BIM-related investment costs, the approach can be explained directly through an example: the 'Public entity hardware upgrade investment'. The methodology employs once again an average value extracted from the survey: the hardware upgrade cost per employee of the public organisation. In the context of

this indicator computation, this average value is directly multiplied by the ratio of the number of employees involved in BIM-related activities (whose daily work is affected by the introduction of BIM in the organisation, who either need to start using new software and/or attend trainings) and the average number of projects using BIM in a year. It is a simple approach which enables the user to account for a limited share of the overall hardware upgrade investment in each organisation project.



For each cost and benefit included in the methodology, the tool allows the user to select whether he/she is willing to exclude the specific indicator from the computation. This option was included to encompass scenarios where not all cost savings and cost increases occur simultaneously in the project. For example, a public organisation might want to avoid accounting for hardware-related investments while assessing the use of BIM in a project. It might also be willing to exclude the possibility that any reduction in the project schedule might occur in relation to BIM adoption.

With regard to benefits, computations are generally more straightforward as, for most of these, an average percentage extracted from the survey is directly applied to the estimated project-related investment. Once again, additional factors like those affecting the BIM impact on the procurement process cost, reported above, affect the computation. For example, the benefit related to early clashes and error detection is computed on the project construction investment, but its value is adjusted depending on:

- The level of detail (LOD) of the model (200, 350 or 450/500)
- The 'Project category' ('New asset construction' or 'Work on an existing asset')

Another example is represented by the 'Cost reduction attributable to the government/society due to better Health & Safety' for which an average number of accidents avoided per construction project was established and priced, based on an estimated average societal cost of work-related injuries and illnesses (per case) in Europe.

For each cost and benefit included in the methodology, the tool allows the user to select whether he/she is willing to exclude the specific indicator from the computation, in order to encompass scenarios where not all cost savings and cost increases occur simultaneously in the project.

Allocation of the indicators along the project phases

Once the basic value of each cost and benefit is established, it is allocated over the project period, depending on the duration of each phase. The 'Planning and design' phase duration varies between 1 and 5 years, the 'Construction' stage duration ranges between 1 and 10 years while the 'Operation and maintenance' is set at 20 years. Each indicator is allocated using one of the approaches indicated in the following examples:

1. 'Cost reduction associated to more precise quantity take-offs' is set to be allocated on the first year of each project construction phase
2. 'Cost reduction associated to more efficient annual maintenance' reduces the annual maintenance cost of the asset and it is allocated on each year of the operation and maintenance phase.
3. The initial amount of the 'Cost reduction related to lower costs for claims/litigations' is divided by the number of years of 'Planning and design' and 'Construction' phases. The annual share of the indicator value is then allocated during the two phases and its yearly share values are adjusted for inflation.

The allocation of cost and benefit values throughout the project period enables the final computation of the main tool outputs: the financial and economic indicators measuring the profitability and the value for money of adopting BIM in a specific project. With this regard, the Net Present Value and the Economic Net Present Value as well as the Benefit-Cost Ratio and the Economic B/C Ratio are computed. Moreover, the ENPV and the Economic Benefit-Cost Ratio are calculated for each of the three phases of a construction project which are assessed in the analysis.

A final interesting feature of the CBA tool is the possibility, thanks to a sensitivity analysis, to assess three potential scenarios for each project, leading to three diverse results for each estimate:

- Baseline Estimate
- Optimistic Estimate
- Pessimistic Estimate

The scenarios are obtained through the variation in the values of eight critical variables (four associated with the computation of costs of adopting BIM in construction projects and four connected to the calculation of the related benefits). These are:

CRITICAL VARIABLES	
investment reduction percentage associated with enhanced accuracy of BIM-based quantity take-off	Values associated with the computation of costs of adopting BIM in public construction projects
investment reduction percentage associated with early clashes and error detection.	
investment reduction percentage associated with time savings during the design and construction phases of a project	
reduction percentage associated with the operations phase related to enhanced efficiency in asset maintenance activities	
Value of the public organisation procurement process cost	Values associated with the calculation of the related benefits
Value of the annual BIM-related software investment allocated to the project	
Value of the BIM-related investment in training allocated to the project	
BIM modelling and coordination costs (the modelling activity cost refers solely to BIM maturity level 1)	



3.3 Guide: step-by-step procedure to simulate cost-benefit analysis

This section will guide you through the different steps required to create the tool for calculating the costs and benefits of adopting BIM in public tenders by public organisations.

INPUTS REQUIRED

Inputs

The following list of questions is expected to capture a set of information that are necessary to compute the costs and benefits of adopting BIM in public tenders, by public organisations. The information collected refers to features of the public organisation involved in the construction project and of the project under analysis. The questions have been designed so that organisations with different levels of experience with BIM (even those with no experience) can employ this tool and obtain the necessary insights on costs and benefits.

Please answer to the following questions entering what requested in the blank spaces (please DO NOT FILL IN grey cells). All questions are mandatory if not otherwise stated.

1 Please indicate the information required below describing your organization experience with BIM

1.1 Does your organization have previous experience with BIM (it has started any pilot project or completed one adopting BIM)?

1.2 In how many projects BIM is adopted, every year, on average?

Clear cells content

General rules for the Inputs page:

- The information required must be entered in the white spaces
- When cells are grey, the user should not type in any information
- Unless otherwise stated, all white cells must be completed
- Numerical information required might refer to specific values (such as the number of years), the selection of options ('1', '2', '3', etc.), monetary amounts (expressed in €), surface areas (expressed in m²) and percentages

1

Preliminary General Information (questions 1 to 11)

2

BIM Model Creation Information (questions 12 to 14)

3

Category of Asset Information (questions 15 to 26)

1

Preliminary General Information (questions 1 to 11)

Here you are required to answer a set of questions which serve to acquire general information on the use of BIM in the public organisation involved in the project, and on the characteristics of the projects where BIM is or might be adopted.

The user is required to provide information on:

- the organisation's experience with BIM
- the number of tenders in which BIM is or is expected to be used every year
- the project costs and timing
- internal employees
- other specific data necessary for defining the main features of the project

PRELIMINARY GENERAL INFORMATION	3.1	Cost of planning (including design)	<input type="text"/>	€	
	3.2	Cost of construction	<input type="text"/>	€	
	4.1	Please select the planned number of years of the construction phase of the project, from the drop down menu. In case the actual phase period refers to fractions of years, please select the number of years that is the closest to the actual period.	<input type="text"/>		
	4.2	Please select the number of years from the start of the project planning activities to the completion of the design activities and the subsequent start of the construction phase, from the drop down menu. In case the actual phase period refers to fractions of years, please select the number of years that is the closest to the actual period.	<input type="text"/>		
	5.1	What is the number of employees of your organisation that are involved in BIM related activities? (Those that needed and/or will need BIM training, and/or work with BIM software, technicians, architects, engineers, procurement specialists, etc.).	<input type="text"/>		
	5.2	What is the number of employees of your organisation that might be involved in BIM related activities in case BIM is implemented in projects? (Those that might need BIM training, those that will employ BIM software, architects, technicians, engineers, procurement specialists, etc.).	<input type="text"/>		
	6	Please indicate the Gross Floor Area of the project asset (in m ²) in case the project refers to a building or to an infrastructural asset that includes buildings in its perimeter, otherwise, please leave the space blank. The Gross Floor Area (GFA) is the sum of the floor areas of all the spaces within the building, with no exclusions; it essentially corresponds to the total area within the perimeter of the outside walls.	<input type="text"/> m ²		
7	Please indicate the value of the annual maintenance costs for the project asset. In case you do not have this information and cannot estimate it, please, do not type any value in the cell. In this case, the tool will not estimate the costs and benefits of adopting BIM during the "Operation & Maintenance" phase.	<input type="text"/>			

2

BIM Model Creation Information (questions 12 to 14)

This section is made up of three questions respectively on:

- the level of detail (LOD) of the model needed in the tender
- the asset category ('Building', 'Infrastructure' and 'Mixed')
- the average cost of a BIM specialist in the country (for enabling the tool to adapt costs computations to the national context of the user)

Depending on the answer to the second of these questions, you will be required to fill in one, two or all subsequent sections as explained in the following point.

BIM MODEL CREATION INFORMATION	12	Please indicate the level of details/development required in the tender, among the options below (select from the available options the LOD referring to the corresponding option number, between 1 and 3).	<ul style="list-style-type: none"> 1 - BASIC DESIGN - LOD 200 2 - DETAILED DESIGN - LOD 300 3 - DIGITAL TWIN - LOD 450 / 500 <input type="text"/>	
	13	Please indicate, referring to the tender, the category of asset involved, among the options below (select the corresponding category number, either 1, 2 or 3).	<ul style="list-style-type: none"> 1 - INFRASTRUCTURE 2 - BUILDING 3 - MIXED (an infrastructure including also buildings in its area that must be modelled) <input type="text"/>	
	14	Please indicate the average national hourly cost for a BIM specialist (€).	<input type="text"/>	

3

Category of Asset Information (questions 15 to 26)

- If the asset category indicated is 'BUILDING', you should complete the sections:
 - Architecture and Structure (questions 15 to 17): information on surface size, average level of complexity and the level of standardization based on the scales provided in the tool interface
 - MEP design (questions 18 to 21): information on the four systems (if present in the project) and as foreseen by the tool: heating, ventilation and air conditioning; refrigeration; piping; electrical and lighting and special systems

The screenshot shows two sections of the tool interface for a 'BUILDING' asset category.

ARCHITECTURE AND STRUCTURE

Area surface category	Choose: Yes / No	Indicate the level of complexity for each existing area category
Surface < 25 m ²	<input type="checkbox"/>	<input type="checkbox"/>
25 m ² < Surface < 100 m ²	<input type="checkbox"/>	<input type="checkbox"/>
100 m ² < Surface < 500 m ²	<input type="checkbox"/>	<input type="checkbox"/>
Surface > 500 m ²	<input type="checkbox"/>	<input type="checkbox"/>

16 Please, indicate the number of areas of each surface category.

Surface < 25 m ²	Number of areas
<input type="text"/>	<input type="text"/>

MEP DESIGN

1 - 400 m ² < Surface < 1000 m ²	<input type="checkbox"/>
2 - 1000 m ² < Surface < 2000 m ²	<input type="checkbox"/>
4 - 3000 m ² < Surface < 5000 m ²	<input type="checkbox"/>
5 - Surface > 5000 m ²	<input type="checkbox"/>

20 Electrical and lighting system

- If the category of the asset indicated in question 13 is 'INFRASTRUCTURE', you should complete the section:
 - Infrastructure Surface and Systems (questions 22 to 26): information on surface size, systems and their level of complexity (based on the provided scales)

The screenshot shows the 'INFRASTRUCTURE SURFACE AND SYSTEMS' section of the tool interface.

INFRASTRUCTURE SURFACE AND SYSTEMS

Please indicate the size of the surface served by the mechanical system (m²).

m²

23 Piping system

Please select the level of complexity of the piping system. (1)

Please indicate the size of the surface served by the piping system (m²).

m²

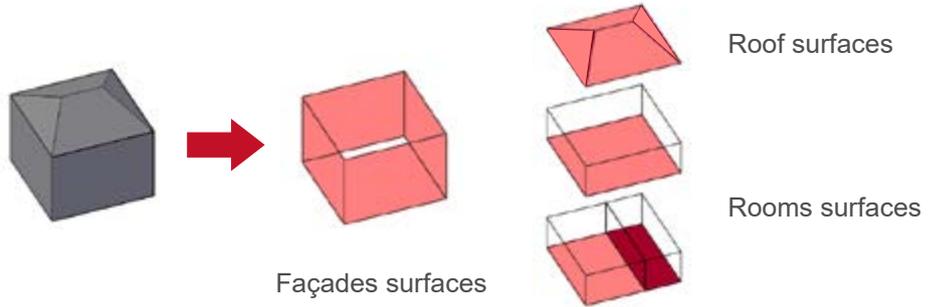
- If the asset category indicated is 'MIXED', you should complete all the three sections described above.

FOCUS ON CATEGORY OF ASSET INFORMATION

The data required in the “category of asset information” are explained through the following examples.

Area surface category

Surface < 25 m²
 25 m² < Surface > 150 m²
 150 m² < Surface < 300 m²
 Surface > 300 m²



- Surface < 25 m²: n°1
- 25 m² < Surface < 150 m²: n°7

Level of complexity

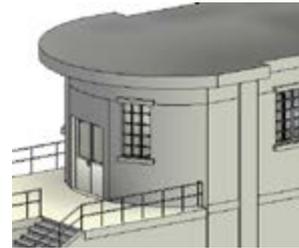
LOW

E.g. a façade made up of a wall of a small number of simple windows and few architectural details



HIGH

E.g. a façade made up of a curved wall with a large number of architectural details typical of a historical building



Level of standardisation

HIGH

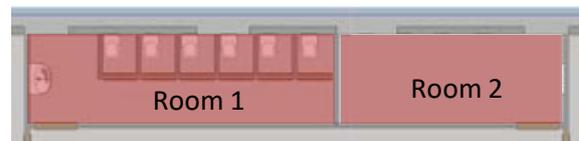
Very similar areas that can be duplicated with few adjustments



Area served by MEP systems

BUILDING

Sum the gross floor areas of all the rooms (e.g. area Room1+area Room2) served by a system and repeat it for each MEP system present in these rooms

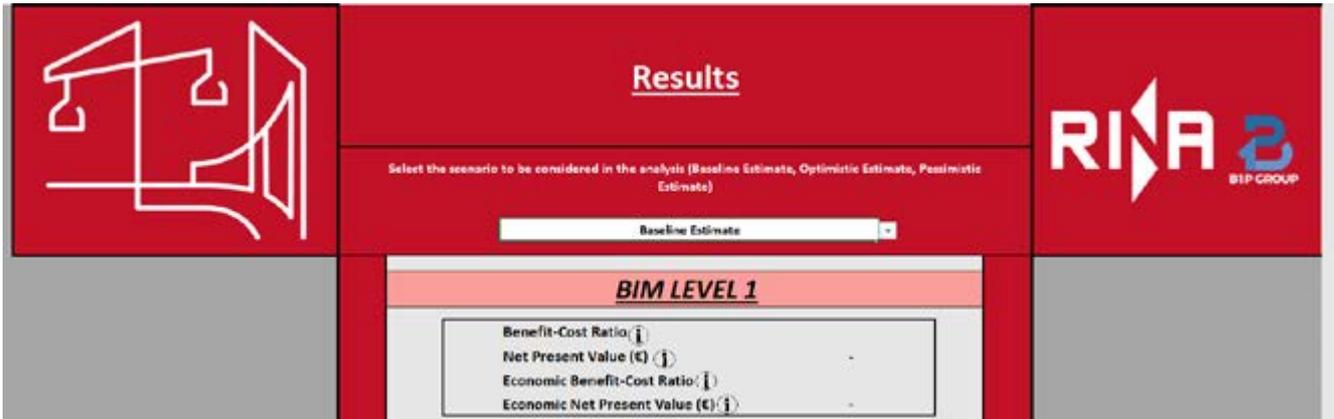


INFRASTRUCTURE

Calculate the area served by MEP systems as a rectangular projection (only for the specific zones where there are systems) and repeat it for all the systems present



OUTPUTS OBTAINED



Results sheet

The 'Results' sheet shows the overall results of the application of the cost-benefit analysis on the adoption of BIM in your project both for BIM maturity level 1 and 2.

The five indicators that are computed according to the level of BIM maturity are:

- the Benefit-Cost Ratio
- the Net Present Value (NPV)
- the Economic Benefit-Cost Ratio
- the Economic Net Present Value (ENPV)

Additionally, the BIM direct expenses (model costs and coordination costs) are displayed along with the Economic Benefit-Cost Ratio and the Economic Net Present Value (ENPV) associated with each phase of the project (planning & design, construction, and operational and maintenance).

It must be highlighted that in the BIM level 2 section, there is no cost associated to the modelling activity.

Benefit Cost Ratio / Economic Benefit Cost Ratio



These indicators describe the relationship between the benefits and the costs associated to the adoption of BIM in the project.

When their values are higher than 1, it means that the advantages (expressed in monetary terms) of using BIM in the project outweigh the cost of its implementation.

Net Present Value / Economic Net Present Value



These indicators are used to evaluate the profitability of an investment over a period of time. In the case of BIM, the profitability is expressed as achieved savings.

The higher are these indicators values, the more "profitable" (in terms of financial savings and socio-economic benefits) is the adoption of BIM in the project. The ENPV includes in its computation social and environmental benefits while the NPV does not.

CBA - BIM level 1 and CBA - BIM Level 2 sheets

All phases		1	2	3	4
Maturity level 1		Planning and Design			
Benefits		Year 1	Year 2	Year 3	Year 4
On	Cost reduction due to early clashes and errors detection and subsequent reduction of changes necessary in construction phase				
On	Cost reduction associated to more precise quantity take-offs				
On	Cost reduction related to lower costs for claims/litigations				
On	Time savings in design and construction phases and associated project duration reduction				
On	Public entity personnel labour cost reduction due to faster document analysis for facility management and maintenance				
On	Cost reduction associated to more efficient annual maintenance				
On	Cost reduction attributable to the government/society due to better Health & Safety				
On	CO2 emission reduction due to reduced material wasted				
Tot. benefits					
Tot. benefits (adjusted for formula)					
Total benefits for actualization					
Costs					
On	Public entity personnel labour cost increase during pre-tendering phase				

For each BIM maturity level, the tool performs a cost-benefit analysis on the use of BIM for the specific project (for which the user has provided information on the Inputs sheet).

For each BIM maturity level, there exists a sheet where eight benefits and nine costs are listed. Both costs and benefits are entered for the three typical project phases:

- the design and planning (up to 5 years)
- the Construction (up to 10 years after the design phase)
- the Operation and Maintenance phase (20 years after the construction phase)

The values included in the CBA are automatically computed and allocated starting from the information entered in the Input sheet.

On the top left of the page, the user can select which phases should be displayed ('Planning and Design', 'Construction', 'Operation and Maintenance' or 'All phases').

Subsequently, you can find the Free Cashflow that the tool computes and on the basis of which the following indicators are calculated:

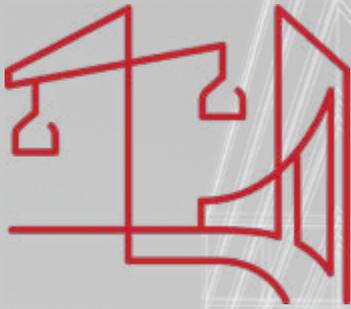
- Economic Net Present Value
- Actualized Economic Benefits
- Actualized Economic Costs (Actualized Costs)
- Economic Benefit-Cost Ratio
- Yield

NOTICE that the **Discount Rate**, set at the standard value of 4%, is the **unique value** that **the user can change in the excel sheet**, according to the characteristics of the project.

- By scrolling down the page, you will see displayed the ENPV, the Economic B/C Ratio and the associated Free Cashflow for each of the three phases
- By scrolling down even further, you will see displayed the financial aspects inherent to the three phases of the project

Tot. costs
Tot. costs (adjusted for formula)
Total costs for actualization
Net "Income"
Free Cash Flows
Cash Flow per ENPV
Discount rate
Economic Net Present Value
Actualized Economic Benefits
Actualized Economic Costs (Actualized Costs)
Economic B/C Ratio
Yield

Financial benefits	Year
	Benefits (financial only)
	Benefits adjusted for cashflow (financial only)
	Benefits adjusted along years (financial only)
Financial costs	Year
	Costs (financial only)
	Costs adjusted along years (financial only)
	Actualized cost (financial only)
Financial NPV	Year
	Net Income
	Free cashflow
	Free cashflow adjusted along years
	Net Present Value (financial only)
	B/C Ratio



4 How to practice the CBA tool? Validation through case studies

- 4.1 Case study 1 - Conversion of an old building in a sport centre**
- 4.2 Case study 2 - Maintenance and renovation project of a road**
- 4.3 Case study 3 - New port construction project**
- 4.4 Case study 4 - Renovation project for a public building**
- 4.5 Case study 5 - BIM verification project**
- 4.6 Case study 6 - New residential building construction project**



4.1 CASE STUDY 1

Conversion of an old building in a sport centre

MAIN PROJECT CHARACTERISTICS

TIPOLOGY		BUILDING <i>conversion</i>
SIZE		1680 m ²
BUDGET		1.174.800 €
LEVEL		DETAILED DESIGN



DESCRIPTION

The building is an old and disused one-floor factory (around 8 metres high) on the edge of the city. The two longest façades are made from metal plates, which give an industrial look to the building, while the other two are brick walls with a simpler aspect.

PURPOSE OF THE PROJECT AND PLANNED INTERVENTIONS

The project destination is a sports centre for the community, composed of two different parts: a large ice rink and a small office and locker room with showers. All the rooms are situated in front of the ice rink area, where the grandstand for the events is located.

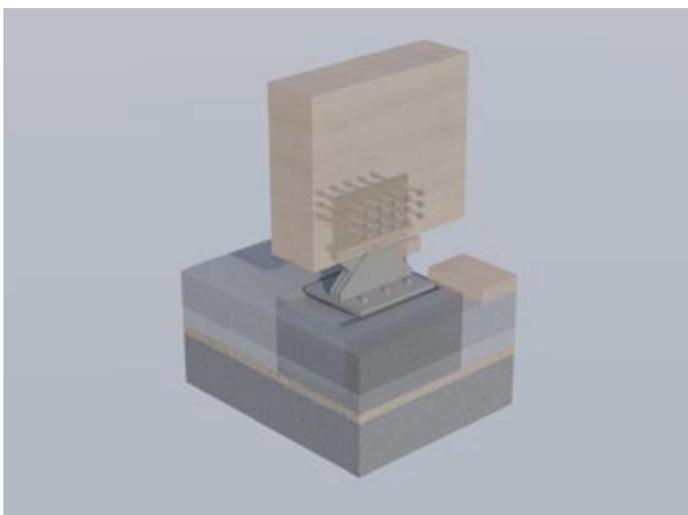
The interventions required are summarised as:

- demolition of the interior of the building
- creation of the space for the ice rink including all service mechanical, electrical, plumbing and special systems
- construction of two rooms and the permanent grandstand

Tender requirements

The tender requires the detailed design for the interventions described for the renovation project.

No particularly relevant solutions are foreseen from a technological, architectural or structural point of view. The creation of a BIM model is required in order to extract the drawings and the Quantity take-offs (QTO) from it.



Example of 3D BIM model required: detailed design representation of structural element

PRELIMINARY GENERAL INFORMATION	Does your organisation have previous experience with BIM?	No
	In how many projects per year, on average, might BIM be adopted?	6
	Project category (New asset construction / Work on an existing asset)	Work on an existing asset (No BIM model available)
	Cost of planning (including design) (€)	106800
	Cost of construction (€)	1068000
	Number of years for construction	2
	Number of years for planning and design	1
	Number of employees that might be involved in BIM activities in case BIM is implemented in projects	12
	Gross Floor Area (m ²)	1680
	Value of the annual maintenance costs of the project asset	32172 €
	BIM coordination is carried out internally/externally?	Externally
	Average annual salary of an employee of your organisation (€)	15781
	Is a Common Data Environment (CDE) going to be employed in the project?	Yes
	Indicate the inflation rate for the project period (%)	2
BIM MODEL CREATION	LOD Required in the tender (200/350/450/500)	2 (350)
	Asset Category (Infrastructure/Building/Mixed)	2 (Building)
	BIM Specialist national hourly cost (€/h)	13

ARCHITECTURE AND STRUCTURE	Area surface category	Yes/No	Level of complexity (1/2/3)	Number of areas per category	Level of standardization (1/2/3)
	Surface < 25 m ²	Yes	2	4	1
	25 m ² < Surface < 150 m ²	Yes	2	4	
	150 m ² < Surface < 300 m ²	No	-	-	
	Surface > 300 m ²	Yes	1	6	

MEP DESIGN	System	Yes/No	Level of complexity (1/2/3)	Area served by the system
	Mechanical (e.g. HVAC)	Yes	1	400 m ² < Surface < 1500 m ²
	Piping	Yes	2	1500 m ² < Surface < 3000 m ²
	Electrical and lighting	Yes	1	400 m ² < Surface < 1500 m ²
	Special (e.g. safety systems)	Yes	1	Surface < 400 m ²

NOTES

- The hourly cost of a BIM Specialist has been estimated starting from the data indicated in “BIM Salary Report” (2020 Edition), published by BIM Corner. It has been considered the average annual gross salary of a “BIM Technician/BIM Modeler” working in Poland. The hourly wage has been estimated and increased by 50%, assumed it as the company mark-up for the hourly rate charged to the public client
- The average annual salary of employees of the public organisation has been extracted from the report (Ms Excel file) available at: https://stat.gov.pl/files/gfx/portalinformacyjny/en/defaultaktualnosci/3292/1/44/1/employment_wages_and_salaries_in_national_economy_in_2019.xlsx. The data employed refers to “Public administration and defence; compulsory social security”

OUTPUTS FROM THE TOOL

BIM MATURITY LEVEL 1

ECONOMIC IMPACT

Project General Indicators:



Net Present Value (NPV)

40.414 €



Benefit-Cost Ratio

1,46

BIM direct expenses:



BIM Model Cost

4.945 €



BIM Coordination Cost

1.775 €

Phase Focus:



Operation and Maintenance

ENPV: -10.127 € - EBC Ratio: 0,81

Most Relevant Economic Indicator:



Efficient maintenance

54.575 €



BIM based Quantity Take-Off (QTO)

37.268 €

ENVIRONMENTAL IMPACT



CO₂ Emissions Reduction

533 €



Economic Net Present Value (ENPV)

158.506 €

CONSIDERATIONS

- Despite the negative ENPV of the Operation and Maintenance phase, the overall project NPV is positive and the associated B/C Ratio is slightly higher than 1: the adoption of BIM in this case study is expected to be advantageous and sustainable
- The most relevant indicators chosen for this case study are the benefits associated to enhanced accuracy of the quantity take off and improved efficiency in maintenance activities. The latter, despite presenting a substantial value, does not offset the cost associated with a BIM modelling software license, hence the ENPV of the maintenance phase appears to be negative

TIPS

Each cost and benefit indicator could be switched off if its calculation is considered not consistent with the project. In this case study, the full list of benefits and costs are calculated, so no indicator has been switched off.

OUTPUTS FROM THE TOOL

BIM MATURITY LEVEL 2

ECONOMIC IMPACT

Project General Indicators:



Net Present Value (NPV)

103.239 €



Benefit-Cost Ratio

2,15

BIM direct expenses:



BIM Coordination Cost

3.301 €

Phase Focus:



Operation and Maintenance

ENPV: 39.100 € - EBC Ratio: 1,73

Most Relevant Economic Indicator:



Efficient maintenance

124.431 €



BIM based Quantity Take-Off (QTO)

37.268 €

ENVIRONMENTAL IMPACT



CO₂ Emissions Reduction

533 €



Economic Net Present Value (ENPV)

221.330 €

CONSIDERATIONS

- In this scenario, both the NPV and the B/C Ratio of the project are higher with respect to BIM maturity level 1
- The values of the two most relevant indicators grew if compared to the BIM maturity level 1. In BIM maturity level 2 scenario, in fact, the benefit associated with enhanced efficiency in maintenance grew to such an extent that the operations and maintenance related ENPV is not anymore negative

TIPS

In this scenario the full list of benefits and costs are calculated, so no indicator has been switched off.



4.2 CASE STUDY 2

Maintenance and renovation project of a road

MAIN PROJECT CHARACTERISTICS

TIPOLOGY  **INFRASTRUCTURE**
renovation and maintenance

SIZE  **34850 m²**

BUDGET  **11.052.564 €**

LEVEL  **DIGITAL TWIN**



DESCRIPTION

The project involves renovation and maintenance interventions aimed at repairing and resurfacing substandard street pavements, providing new safety routes for citizens in several streets throughout the city.

PURPOSE OF THE PROJECT AND PLANNED INTERVENTIONS

The project includes various types of interventions such as maintenance and new installations. The main works involve the replacement of deteriorated road sections and the implementation of new traffic lights and road signs. Particular focus is placed on the underground sub-services, such as the MEP systems like sewers and electrical conduits, which must be connected to the existing network currently in use.

Tender requirements

In the tender documents, the public authority provides detailed design sheets of 2D drawings with the Bill of Quantities (BoQ) for each requested work. During the construction the BIM 3D - Digital Twin model is required including all the works to be carried out and each new element to be implemented for approval. The BIM team must use all the standards indicated by the public contractor's BIM Manager in a Common Data Environment (CDE) provided by the public authority.



Example of 3D BIM model required: Digital Twin representation of a road portion

PRELIMINARY GENERAL INFORMATION	Does your organisation have previous experience with BIM?	No
	In how many projects per year, on average, might BIM be adopted?	17
	Project category (New asset construction / Work on an existing asset)	Work on an existing asset (No BIM model available)
	Cost of planning (including design) (€)	1004779
	Cost of construction (€)	10047785
	Number of years for construction	1
	Number of years for planning and design	1
	Number of employees that might be involved in BIM activities in case BIM is implemented in projects	38
	Gross Floor Area (m ²)	-
	Value of the annual maintenance costs of the project asset	2686 €
	BIM coordination is carried out internally/externally?	Externally
	Average annual salary of an employee of your organisation (€)	29004
	Is a Common Data Environment (CDE) going to be employed in the project?	Yes
	Indicate the inflation rate for the project period (%)	2
BIM MODEL CREATION	LOD Required in the tender (200/350/450/500)	3 (450/500)
	Asset Category (Infrastructure/Building/Mixed)	1 (Infrastructure)
	BIM Specialist national hourly cost (€/h)	23

INFRASTRUCTURE SURFACE AND SYSTEMS	Total surface	Level of complexity (1/2/3)	System	Yes/No	Level of complexity (1/2/3)	Area served by the system
	34850 m ²	3	Mechanical	No	-	-
			Piping	Yes	2	21250 m ²
			Electrical and lighting	Yes	2	21250 m ²
			Special	Yes	2	21250 m ²

NOTES

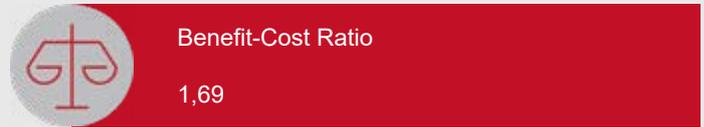
- The hourly cost of a BIM Specialist has been estimated starting from the data indicated in "BIM Salary Report" (2020 Edition), published by BIM Corner. It has been considered the average annual gross salary of a "BIM Technician/BIM Modeler" working in France. The hourly wage has been estimated and increased by 50%, assumed it as the company mark-up for the hourly rate charged to the public client
- The average annual salary of employees of the public organisation has been extracted from the report available at: <https://www.insee.fr/fr/statistiques/4647813#graphique-figure1>. The data employed refers to employees from the "Fonction publique territoriale"

OUTPUTS FROM THE TOOL

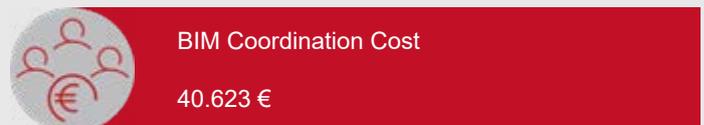
BIM MATURITY LEVEL 1

ECONOMIC IMPACT

Project General Indicators:



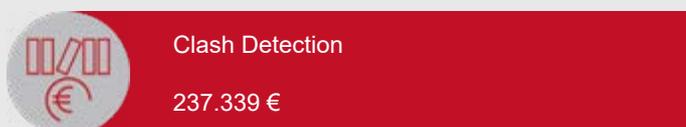
BIM direct expenses:



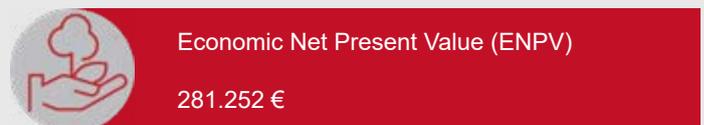
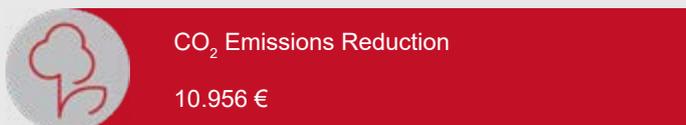
Phase Focus:



Most Relevant Economic Indicator:



ENVIRONMENTAL IMPACT



CONSIDERATIONS

- Despite the large costs represented by the BIM modelling and coordination activities, and the absence of BIM related benefits during the design phase, the overall project NPV is positive and the associated B/C ratio is slightly higher than 1. In this sense, the use of BIM in this project can potentially be sustainable and lead to savings
- The clash detection related benefit is the largest benefit achievable during the construction phase where the BIM model is used to obtain approvals before each construction step. This step, despite the allocation of BIM direct expenses still shows a positive ENPV

TIPS

- In this case study it is required the provision of a Digital Twin to be developed during the construction phase, so the benefit associated to the quantity take-off has been switched off as the design phase is assumed to be carried out without BIM
- Considering the limited time-period in which the project is expected to be completed, the benefit related to the time saving has been deactivated. At the same time, assuming that the public organisation does not need any hardware upgrade, the corresponding cost item has been switched off

OUTPUTS FROM THE TOOL

BIM MATURITY LEVEL 2

ECONOMIC IMPACT

Project General Indicators:



Net Present Value (NPV)

595.306 €



Benefit-Cost Ratio

5,31

BIM direct expenses:



BIM Coordination Cost

30.746 €

Phase Focus:



Construction

751.394 € - EBC Ratio: 16,47

Most Relevant Economic Indicator:



Clash Detection

237.339 €



BIM based Quantity Take-Off (QTO)

350.615 €

ENVIRONMENTAL IMPACT



CO₂ Emissions Reduction

10.956 €



Economic Net Present Value (ENPV)

724.571 €

CONSIDERATIONS

- The overall project NPV and B/C ratios improved significantly from BIM maturity level 1 to level 2
- The benefit related to the quantity take-off is considered in this scenario and it contributes significantly in improving the Construction phase Economic B/C Ratio value

TIPS

- Differently from BIM maturity level 1 scenario, BIM is expected to be employed in all phases of a construction project, that is why, at BIM maturity level 2, also the quantity take-off related benefit is active
- As for BIM maturity level 1 scenario, the hardware upgrade cost item and the benefit capturing time-savings are switched off

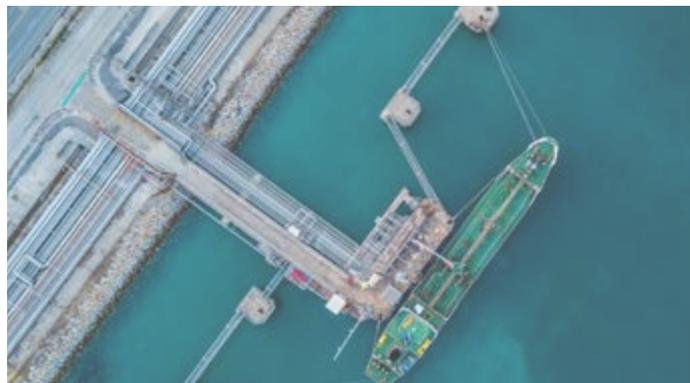


4.3 CASE STUDY 3

New port construction project

MAIN PROJECT CHARACTERISTICS

TIPOLOGY		INFRASTRUCTURE <i>new construction</i>
SIZE		7203 m ²
BUDGET		5.148.000 €
LEVEL		BASIC DESIGN



DESCRIPTION

The port is located on the inland coast of the country, overlooking one of the busiest stretches of sea in the region. It is developed for about three kilometres, parallel to the coastline, and the service structures are extended for over a kilometre on flat territory. The docks are uniformly constructed with a homogeneous structure and there are two buildings serving the mooring area for each dock.

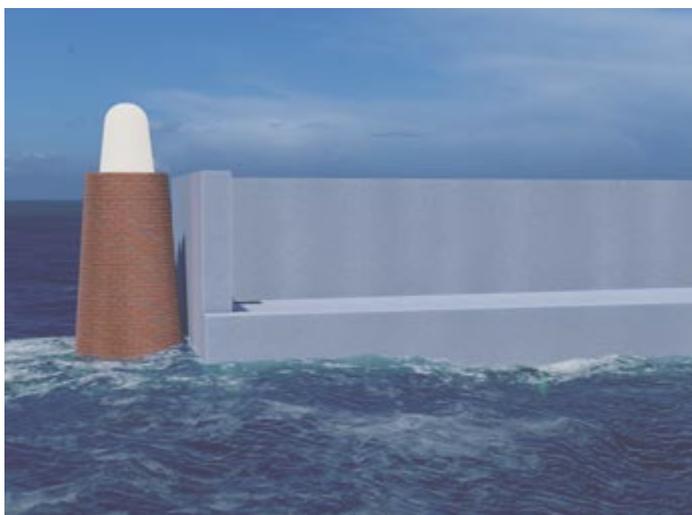
PURPOSE OF THE PROJECT AND PLANNED INTERVENTIONS

The project focuses on the northernmost part of the lagoon, a bare area of land which separates the harbour from the sea where there a beach is situated a short distance from the current shoreline.

The construction of new docks and two buildings are the main interventions required by the project.

Tender requirements

No particularly relevant solutions are foreseen from a technological, architectural or structural point of view. The creation of a BIM model is required in order to extract the drawings and the QTO from it.



Example of 3D BIM model basic design detail required: dock's structure

PRELIMINARY GENERAL INFORMATION	Does your organisation have previous experience with BIM?	No
	In how many projects per year, on average, might BIM be adopted?	3
	Project category (New asset construction / Work on an existing asset)	New asset construction
	Cost of planning (including design) (€)	468000
	Cost of construction (€)	4680000
	Number of years for construction	2
	Number of years for planning and design	1
	Number of employees that might be involved in BIM activities in case BIM is implemented in projects	10
	Gross Floor Area (m ²)	313
	Value of the annual maintenance costs of the project asset	23400 €
	BIM coordination is carried out internally/externally?	Externally
	Average annual salary of an employee of your organisation (€)	36430
	Is a Common Data Environment (CDE) going to be employed in the project?	Yes
	Indicate the inflation rate for the project period (%)	2
BIM MODEL CREATION	LOD Required in the tender (200/350/450/500)	1 (200)
	Asset Category (Infrastructure/Building/Mixed)	3 (Mixed)
	BIM Specialist national hourly cost (€/h)	25

ARCHITECTURE AND STRUCTURE	Area surface category	Yes/No	Level of complexity (1/2/3)	Number of areas per category	Level of standardization (1/2/3)
	Surface < 25 m ²	Yes	2	30	2
	25 m ² < Surface < 150 m ²	Yes	2	8	
	150 m ² < Surface < 300 m ²	Yes	1	2	
	Surface > 300 m ²	No	-	-	

MEP DESIGN	System	Yes/No	Level of complexity (1/2/3)	Area served by the system
	Mechanical (e.g. HVAC)	Yes	2	400 m ² < Surface < 1500 m ²
	Piping	Yes	2	400 m ² < Surface < 1500 m ²
	Electrical and lighting	Yes	2	400 m ² < Surface < 1500 m ²
	Special (e.g. safety systems)	No	-	-

INFRASTRUCTURE SURFACE AND SYSTEMS	Total surface	Level of complexity (1/2/3)	System	Yes/No	Level of complexity (1/2/3)	Area served by the system
	6890 m ²	1	Mechanical	No	-	-
			Piping	Yes	2	5200 m ²
			Electrical and lighting	Yes	2	5200 m ²
			Special	No	-	-

OUTPUTS FROM THE TOOL

BIM MATURITY LEVEL 1

ECONOMIC IMPACT

Project General Indicators:



Net Present Value (NPV)

211.164 €



Benefit-Cost Ratio

2,72

BIM direct expenses:



BIM Model Cost

10.329 €



BIM Coordination Cost

4.537 €

Phase Focus:



Planning&Design

ENPV: -38.372 € - EBC Ratio: 0,35

Most Relevant Economic Indicator:



Efficient Maintenance

39.695 €



BIM based Quantity Take-Off (QTO)

163.307 €

ENVIRONMENTAL IMPACT



CO₂ Emissions Reduction

4.575 €



Economic Net Present Value (ENPV)

333.065 €

CONSIDERATIONS

- Although the costs associated to BIM adoption during the planning & design phase are exceeding benefits, the overall project NPV and B/C Ratio are still indicating that the use of BIM might still be advantageous in this case study
- The value of the benefit associated with savings connected to more efficient maintenance activities, despite being referred to a 20 years' time-period, appears to be limited

TIPS

- Considering the limited time-period required for the design and construction phases of the project, no substantial time-savings are expected for this case study, so the corresponding benefit has been deactivated
- It is assumed that no additional consulting services supporting the public procurement process are necessary (the corresponding cost item has been switched off)

OUTPUTS FROM THE TOOL

BIM MATURITY LEVEL 2

ECONOMIC IMPACT

Project General Indicators:



Net Present Value (NPV)

248.079 €



Benefit-Cost Ratio

2,96

BIM direct expenses:



BIM Coordination Cost

14.464 €

Phase Focus:



Planning&Design

ENPV: -26.331 € - EBC Ratio: 0,47

Most Relevant Economic Indicator:



Efficient Maintenance

90.504 €



BIM based Quantity Take-Off (QTO)

163.307 €

ENVIRONMENTAL IMPACT



CO₂ Emissions Reduction

4.575 €



Economic Net Present Value (ENPV)

369.980 €

CONSIDERATIONS

- In this case study, it appears that the shift from BIM maturity level 1 to level 2 does not bring a large improvement to the NPV and the B/C Ratio
- At BIM maturity level 2, the situation of the planning & design phase is slightly improving its ENPV, even if it remains negative as for BIM maturity level 1
- The savings generated through enhanced efficiency in maintenance activities is instead significantly increasing at BIM maturity level 2



4.4 CASE STUDY 4

Renovation project for a public building

MAIN PROJECT CHARACTERISTICS

TIPOLOGY		BUILDING <i>renovation</i>
SIZE		4000 m ²
BUDGET		13.090.000 €
LEVEL		DIGITAL TWIN



DESCRIPTION

The building is an existing five-storey school located in the centre of a metropolis. The structure is made of concrete and masonry elements.

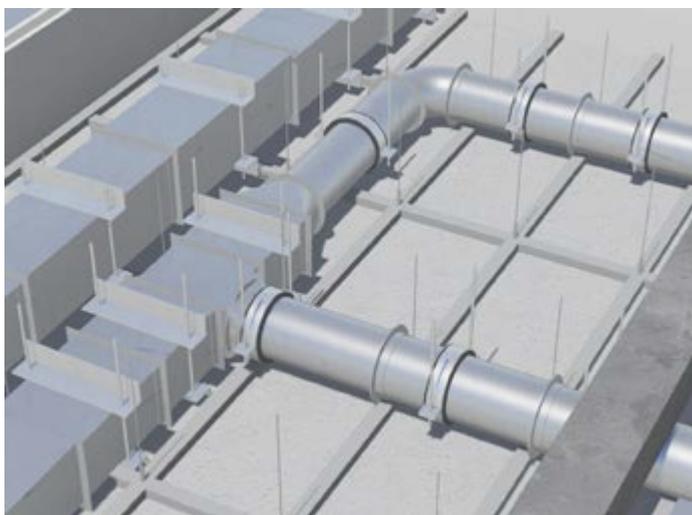
PURPOSE OF THE PROJECT AND PLANNED INTERVENTIONS

The main objective of the project is the interior renovation of the building, including the reconfiguration of the existing walls and floors, to accommodate new classrooms such as art classrooms, performing arts, gymnasium and widened hallways. The construction of new wheelchair-accessible restrooms is also planned, together with high-end MEP systems improvements, including all the electrical, mechanical and plumbing systems. No interventions are foreseen for the external parts of the building, but the courtyard with the existing asphalt playing field must be demolished together with the fencing and netting, and proper disposal of all demolished materials must be considered. The new project includes the construction of a basketball court using high-end materials.

Tender requirements

In the tender documents, the public authority provides the basic design sheets of 2D drawings and requires a 3D BIM model during each work stage required.

During construction, the 3D BIM - Digital Twin model is required. This includes all the works to be carried out and each new element to be implemented for approval. The BIM team must use all the standards indicated by the public contractor's BIM Manager in a Common Data Environment (CDE) provided by the public authority.



Example of 3D BIM model required: Digital Twin representation of MEP system portion

PRELIMINARY GENERAL INFORMATION	Does your organisation have previous experience with BIM?	Yes
	In how many projects is BIM adopted, every year, on average?	14
	Project category (New asset construction / Work on an existing asset)	Work on an existing asset (No BIM model available)
	Cost of planning (including design) (€)	1190000
	Cost of construction (€)	11900000
	Number of years for construction	3
	Number of years for planning and design	1
	Number of employees of your organisation that are involved in BIM related activities?	42
	Gross Floor Area (m ²)	4000
	Value of the annual maintenance costs of the project asset	65497 €
	BIM coordination is carried out internally/externally?	Externally
	Average annual salary of an employee of your organisation (€)	52464
	Is a Common Data Environment (CDE) going to be employed in the project?	Yes
	Indicate the inflation rate for the project period (%)	2
BIM MODEL CREATION	LOD Required in the tender (200/350/450/500)	3 (450/500)
	Asset Category (Infrastructure/Building/Mixed)	2 (Building)
	BIM Specialist national hourly cost (€/h)	23

ARCHITECTURE AND STRUCTURE	Area surface category	Yes/No	Level of complexity (1/2/3)	Number of areas per category	Level of standardization (1/2/3)
	Surface < 25 m ²	Yes	2	85	2
	25 m ² < Surface < 150 m ²	Yes	2	43	
	150 m ² < Surface < 300 m ²	Yes	2	3	
	Surface > 300 m ²	Yes	2	5	

MEP DESIGN	System	Yes/No	Level of complexity (1/2/3)	Area served by the system
	Mechanical (e.g. HVAC)	Yes	2	3000 m ² < Surface < 5000 m ²
	Piping	Yes	2	400 m ² < Surface < 1500 m ²
	Electrical and lighting	Yes	2	1500 m ² < Surface < 3000 m ²
	Special (e.g. safety systems)	No	-	-

NOTES

- The hourly cost of a BIM Specialist has been estimated starting from the data indicated in “BIM Salary Report” (2020 Edition), published by BIM Corner. In this case study, it has been considered the average annual gross salary of a “BIM Technician/ BIM Modeler” working in Belgium (prudentially slightly increased to be aligned with the values considered for the other case studies). The hourly wage has been estimated and increased by 50%, assumed it as the company mark-up for the hourly rate charged to the public client
- The average annual salary of employees of the public organisation involved in this project, has been extracted from the report of Statbel (Ms Excel file) available at: https://statbel.fgov.be/sites/default/files/files/documents/Werk%20%26%20opleiding/9.1%20Lonen%20en%20arbeidskosten/9.12.%20Gemiddelde%20bruto%20maandlonen/SES2016_FR.xls. Data employed refers to “Architectes, urbanistes et géomètres”

OUTPUTS FROM THE TOOL

BIM MATURITY LEVEL 1

ECONOMIC IMPACT

Project General Indicators:



Net Present Value (NPV)

403.327 €



Benefit-Cost Ratio

3,44

BIM direct expenses:



BIM Model Cost

41.411 €



BIM Coordination Cost

21.237 €

Phase Focus:



Construction

ENPV: 545.814 € - EBC Ratio: 7,70

Most Relevant Economic Indicator:



Efficient Maintenance

113.328 €



Time-Savings

238.361 €

ENVIRONMENTAL IMPACT



CO₂ Emissions Reduction

1.283 €



Economic Net Present Value (ENPV)

520.975 €

CONSIDERATIONS

- The NPV and the B/C ratio highlight the profitability, expressed as savings, of the investment in BIM and its subsequent use in the project. In this scenario a Digital Twin is required, so the modelling activity cost is allocated during the construction phase, as 3D models are used for review and approval before each construction stage
- The two most relevant indicators reported for this case study refer to the savings generated by an increased efficiency in the asset maintenance activities as well as the time-savings obtained during the three years of the construction stage of the project

TIPS

- In this case study three indicators have been switched off as they are not considered consistent with the project of this scenario:
 - the savings associated with the reduction of the number of claims and litigations
 - the savings related to the enhanced accuracy of the quantity take-off, as BIM has not been employed during the design phase
 - regarding costs, no increase in effort is required during the post-award phase due to the adoption of BIM

OUTPUTS FROM THE TOOL

BIM MATURITY LEVEL 2

ECONOMIC IMPACT

Project General Indicators:



Net Present Value (NPV)

1.130.822 €



Benefit-Cost Ratio

8,53

BIM direct expenses:



BIM Coordination Cost

37.147 €

Phase Focus:



Construction

ENPV: 1.097.797 € - EBC Ratio: 19,51

Most Relevant Economic Indicator:



Efficient Maintenance

258.388 €



Time-Savings

472.079 €

ENVIRONMENTAL IMPACT



CO₂ Emissions Reduction

1.283 €



Economic Net Present Value (ENPV)

1.248.470 €

CONSIDERATIONS

- The NPV and the Benefit-Cost ratio are showing that the use of BIM in the project is advantageous, with even larger potential benefits with respect to maturity level 1 scenario
- The NPV of the construction phase almost doubles its value from the maturity level 1 to the level 2
- The values of the two most relevant indicators are higher in this scenario than in BIM maturity level 1. The CBA tool in fact foresees an increase of these two benefits at the maturity level 2

TIPS

- The indicators related to savings associated with a reduction in expenses for claims and litigations and the labor cost increase during the post-award phase are both switched off
- Differently from the previous scenario, the indicator representing savings arising from the enhanced accuracy of the quantity take-off is active as, in case of BIM maturity level 2, BIM is employed in all phases of the project life-cycle



4.5 CASE STUDY 5

BIM verification project

MAIN PROJECT CHARACTERISTICS

TIPOLOGY		BUILDING verification
SIZE		4000 m ²
BUDGET		26.880.000 €
LEVEL		DETAILED DESIGN



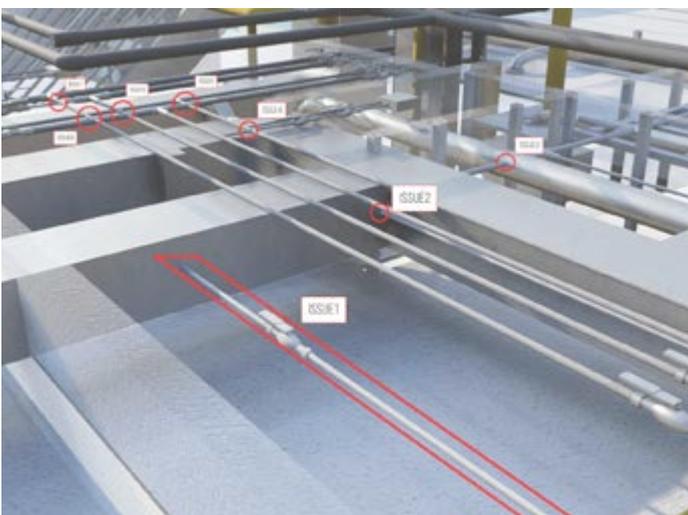
DESCRIPTION

The building is a new built, highly specialised state hospital. The public authority is the main stakeholder of the construction which has been designed by international architects and structural engineers using high-end technical and design solutions. The contracting authority prepared all the design activities, using a highly specialised and controlled BIM process, through consolidated contract documents shared with the key design stakeholders. There are currently multi-disciplinary coordinated BIM models, where each element is listed and can be found with the same name, in the QtO and construction schedule documents.

PURPOSE OF THE PROJECT AND TENDER REQUIREMENTS

The contracting authority requires the verification of the BIM process implementation by considering the following activities:

- study of the documentation related to the design phase, in particular both the contractual documents concerning the BIM process and the documents produced after the analysis of the entire procedure, which led to the production of each design content
- verification of the BIM models produced during the design phase, checking the correspondence of the information in the models with those required by the contractual documents.
- open discussion between the designers and the contracting authority to settle any unresolved points and problems encountered



Example of 3D BIM coordinated model to be verified: portion of MEP systems and architectural elements

PRELIMINARY GENERAL INFORMATION	Does your organisation have previous experience with BIM?	Yes
	In how many projects is BIM adopted, every year, on average?	8
	Project category (New asset construction / Work on an existing asset)	New asset construction
	Cost of planning (including design) (€)	3600000
	Cost of construction (€)	23280000
	Number of years for construction	4
	Number of years for planning and design	2
	Number of employees of your organisation that are involved in BIM related activities?	28
	Gross Floor Area (m ²)	4000
	Cost of annual maintenance of the completed asset	219.708 €
	BIM coordination is carried out internally/externally?	Externally
	Average annual salary of an employee of your organisation (€)	50837
	Is a Common Data Environment (CDE) going to be employed in the project?	Yes
	Indicate the inflation rate for the project period (%)	2
BIM MODEL CREATION	LOD Required in the tender (200/350/450/500)	2 (350)
	Asset Category (Infrastructure/Building/Mixed)	2 (Building)
	BIM Specialist national hourly cost (€/h)	43

ARCHITECTURE AND STRUCTURE	Area surface category	Yes/No	Level of complexity (1/2/3)	Number of areas per category	Level of standardization (1/2/3)
	Surface < 25 m ²	Yes	2	61	2
	25 m ² < Surface < 150 m ²	Yes	2	46	
	150 m ² < Surface < 300 m ²	No	-	-	
	Surface > 300 m ²	Yes	1	5	

MEP DESIGN	System	Yes/No	Level of complexity (1/2/3)	Area served by the system
	Mechanical (e.g. HVAC)	Yes	3	1500 m ² < Surface < 3000 m ²
	Piping	Yes	3	1500 m ² < Surface < 3000 m ²
	Electrical and lighting	Yes	3	3000 m ² < Surface < 5000 m ²
	Special (e.g. safety systems)	Yes	3	1500 m ² < Surface < 3000 m ²

NOTES

- The hourly cost of a BIM Specialist has been estimated starting from the data indicated in “BIM Salary Report” (2020 Edition), published by BIM Corner. In this case study, it has been considered the average annual gross salary of a “BIM Technician/BIM Modeler” working in Germany. The hourly wage has been estimated and increased by 50%, assumed it as the company mark-up for the hourly rate charged to the public client
- The average annual salary of employees of the public organisation has been extracted from the report available at: <https://www.destatis.de/EN/Themes/Labour/Earnings/Earnings-Earnings-Differences/Tables/yearly-gross-earnings.html>. The data employed refers to “Public administration and defence; compulsory social security”

OUTPUTS FROM THE TOOL

BIM MATURITY LEVEL 1

ECONOMIC IMPACT

Project General Indicators:



Net Present Value (NPV)

1.633.533 €



Benefit-Cost Ratio

10,0

BIM direct expenses:



BIM Model Cost

33.626 €



BIM Coordination Cost

22.992 €

Phase Focus:



Operation and Maintenance

ENPV: 234.894 € - EBC Ratio: 5,15

Most Relevant Economic Indicator:



Efficient Maintenance

395.515 €



Clash Detection

577.948 €

ENVIRONMENTAL IMPACT



CO₂ Emissions Reduction

2.643 €



Economic Net Present Value (ENPV)

1.748.967 €

CONSIDERATIONS

- The positive ENPV estimated for the operation and maintenance phase is contributing to the potential substantially high NPV result for the overall project. A very high B/C Ratio is estimated to be achievable during the project life-cycle. In this framework the adoption of BIM for this scenario is expected to be advantageous and sustainable
- The most relevant indicator in this case study refers to the enhanced efficiency in maintenance, where the value reported is the sum of the annual savings realized over a period of 20 years. The other relevant benefit is associated with the clash detection allocated along the construction phase

TIPS

- The indicators representing the decreased productivity during the pre-tendering and tendering phases of the project have been switched off assuming that the public organisation involved in the project has already extensive experience with BIM and so no lowered productivity is foreseen. At the same time, also the benefit representing time-savings has been switched off in this scenario

OUTPUTS FROM THE TOOL

BIM MATURITY LEVEL 2

ECONOMIC IMPACT

Project General Indicators:



Net Present Value (NPV)

1.930.283 €



Benefit-Cost Ratio

10,60

BIM direct expenses:



BIM Coordination Cost

74.871 €

Phase Focus:



Operation and Maintenance

ENPV: 587.393 € - EBC Ratio: 11,39

Most Relevant Economic Indicator:



Efficient Maintenance

901.773 €



Clash Detection

577.948 €

ENVIRONMENTAL IMPACT



CO₂ Emissions Reduction

2.643 €



Economic Net Present Value (ENPV)

2.045.718 €

CONSIDERATIONS

- The overall project NPV and B/C ratio are suggesting that the adoption of BIM in the project is expected to be potentially highly advantageous. No negative ENPV are expected in any phase
- The indicator representing savings from an improved efficiency in maintenance activities is expected to increase its value from maturity level 1 to maturity level 2. At the same time, the benefit connected to clash detection is assumed to be independent from the BIM maturity level

TIPS

The same economic indicators switched off in the BIM maturity level 1 scenario have not been considered here either, as they are identified as not consistent with the project



4.6 CASE STUDY 6

New residential building construction project

MAIN PROJECT CHARACTERISTICS

TIPOLOGY		BUILDING <i>new construction</i>
SIZE		1800 m ²
BUDGET		2.307.780 €
LEVEL		BASIC DESIGN



DESCRIPTION

The project is the construction of a new residential building in the suburbs of a metropolis.

PURPOSE OF THE PROJECT AND PLANNED INTERVENTIONS

The new building must be a rectangular residential building with three floors connected by an internal staircase and an elevator. The functional characteristics and the distribution of the various floors must comply with the following requirements:

- the ground floor must consist of 10 standard housing units, a technical room, an entrance hall, and a distribution staircase with an elevator
- the entrance hall must be accessible from the main doors and must be connected to a central corridor with the entrance to the housing units
- each flat, which must be big enough to house four people or a small family unit, will consist of an entrance area in front of the living room, two bedrooms each with a balcony, a small kitchen and a toilet designed for disabled people
- the balconies in the bedrooms must be designed to respect the privacy of the other flats so the tenderer must use shades or different architectural elements to achieve this
- the stairway/elevator connecting the three floors must have windows on the external facades to allow adequate lighting and natural ventilation
- two external steel safety stairs must be located on the sides of the building

Tender requirements

The public tender requires the basic design for the interventions described in the new construction project. The creation of a BIM model is required in order to extract the drawings and the QTO from it.



Example of 3D BIM model required: basic design representation of the external safety stair

PRELIMINARY GENERAL INFORMATION	Does your organisation have previous experience with BIM?	No
	In how many projects per year, on average, might BIM be adopted?	15
	Project category (New asset construction / Work on an existing asset)	New asset construction
	Cost of planning (including design) (€)	69000
	Cost of construction (€)	2238780
	Number of years for construction	1
	Number of years for planning and design	1
	Number of employees that might be involved in BIM activities in case BIM is implemented in projects	39
	Gross Floor Area (m ²)	1800
	Value of the annual maintenance costs of the project asset	29874 €
	BIM coordination is carried out internally/externally?	Externally
	Average annual salary of an employee of your organisation (€)	36430
	Is a Common Data Environment (CDE) going to be employed in the project?	Yes
	Indicate the inflation rate for the project period (%)	2
BIM MODEL CREATION	LOD Required in the tender (200/350/450/500)	1 (200)
	Asset Category (Infrastructure/Building/Mixed)	2 (Building)
	BIM Specialist national hourly cost (€/h)	25

ARCHITECTURE AND STRUCTURE	Area surface category	Yes/No	Level of complexity (1/2/3)	Number of areas per category	Level of standardization (1/2/3)
	Surface < 25 m ²	Yes	2	125	3
	25 m ² < Surface < 150 m ²	Yes	2	5	
	150 m ² < Surface < 300 m ²	Yes	1	4	
	Surface > 300 m ²	Yes	1	1	

MEP DESIGN	System	Yes/No	Level of complexity (1/2/3)	Area served by the system
	Mechanical (e.g. HVAC)	Yes	1	400 m ² < Surface < 1500 m ²
	Piping	Yes	1	Surface < 400 m ²
	Electrical and lighting	Yes	1	1500 m ² < Surface < 3000 m ²
	Special (e.g. safety systems)	Yes	1	400 m ² < Surface < 1500 m ²

NOTES

- The hourly cost of a BIM Specialist has been estimated starting from the data indicated in “BIM Salary Report” (2020 Edition), published by BIM Corner. It has been considered the average annual gross salary of a “BIM Technician/BIM Modeler” working in Italy. This data has been increased by 50%, assumed it as the company mark-up for the hourly rate charged to the public client
- The average annual salary of employees of the public organisation has been extracted from the report (Ms Excel file) available at: https://www.istat.it/it/files//2021/03/Tavole_ses2018.xlsx. The data employed refers to “Public control”

OUTPUTS FROM THE TOOL

BIM MATURITY LEVEL 1

ECONOMIC IMPACT

Project General Indicators:



Net Present Value (NPV)

58.758 €



Benefit-Cost Ratio

1,60

BIM direct expenses:



BIM Model Cost

7.883 €



BIM Coordination Cost

2.223 €

Phase Focus:



Planning&Design

ENPV: -39.813 € - EBC Ratio: -

Most Relevant Economic Indicator:



Clash Detection

39.662 €



BIM based Quantity Take-Off (QTO):

78.122 €

ENVIRONMENTAL IMPACT



CO₂ Emissions Reduction

1.132 €



Economic Net Present Value (ENPV)

178.576 €

CONSIDERATIONS

- The overall project Benefit-Cost Ratio is higher than 1 and the associated Net Present Value resulting estimate is positive: the adoption of BIM in this case study is expected to be advantageous and sustainable
- This positive potential result is obtained despite the negative ENPV of the Planning and Design phase, that is expected to be offset by a high value during the year of construction
- The values of the most relevant economic indicators reported are those adjusted for inflations set at 2% and allocated over the Construction phase

TIPS

In this case studio the hardware upgrade investment has not been considered and the related cost has been switched off, as it has been assumed that the current hardware of the public organisation involved in the project is already enabling a smooth adoption of BIM. The benefit representing the savings through the reduction of claims and litigations and the benefit related to the time-savings have been both switched off.

OUTPUTS FROM THE TOOL

BIM MATURITY LEVEL 2

ECONOMIC IMPACT

Project General Indicators:



Net Present Value (NPV)

100.715 €



Benefit-Cost Ratio

2,02

BIM direct expenses:



BIM Coordination Cost

6.851 €

Phase Focus:



Planning&Design

ENPV: -34.649 € - EBC Ratio: -

Most Relevant Economic Indicator:



Clash Detection

39.662 €



BIM based Quantity Take-Off (QTO):

78.122 €

ENVIRONMENTAL IMPACT



CO₂ Emissions Reduction

1.132 €



Economic Net Present Value (ENPV)

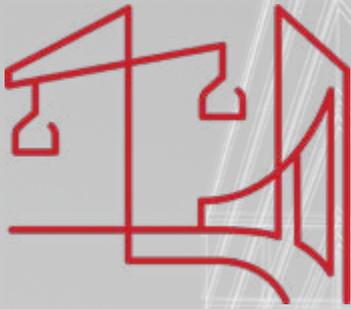
220.533 €

CONSIDERATIONS

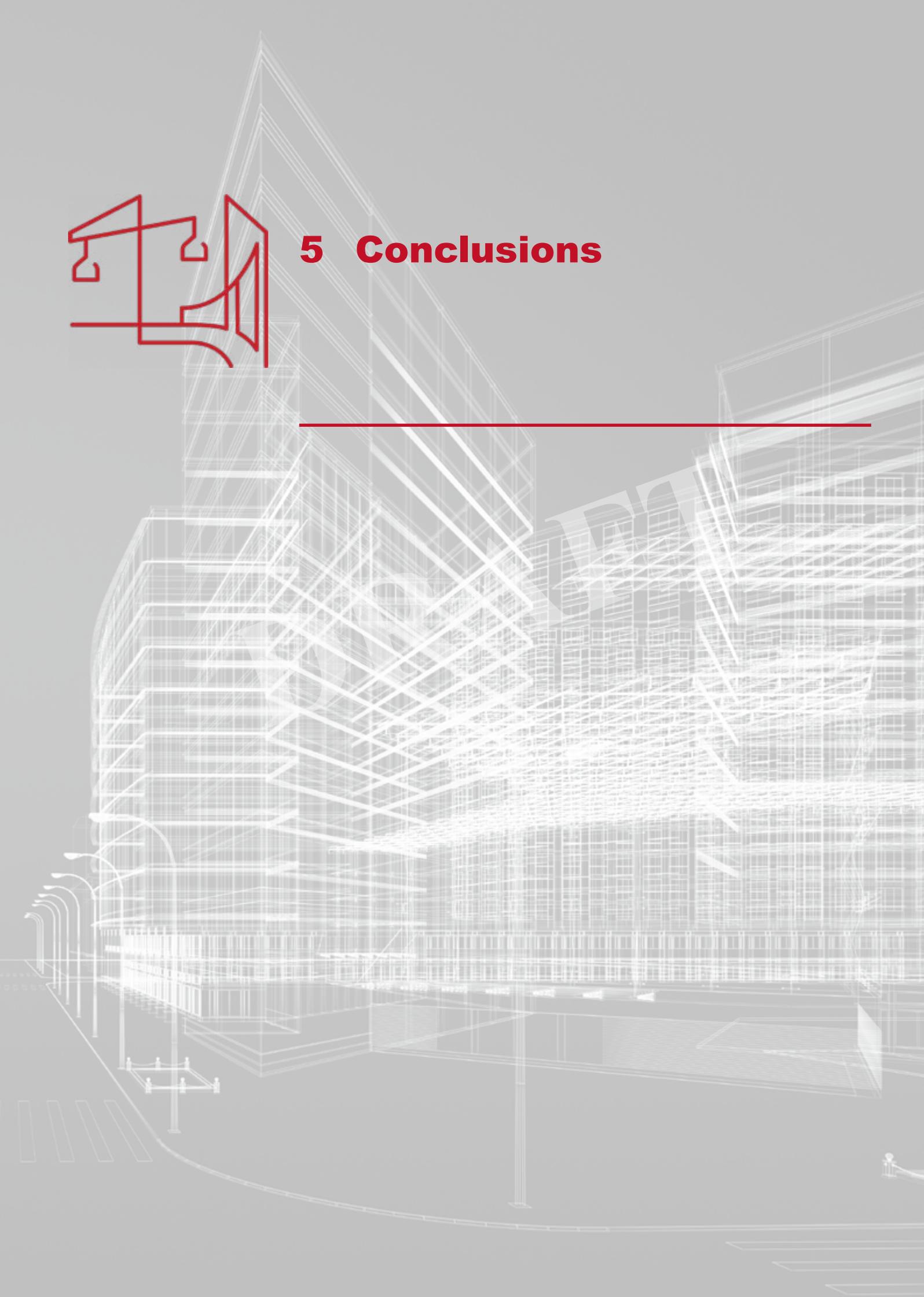
- The NPV and the Cost-Benefit ratio are suggesting that the adoption of BIM in the project is expected to be sustainable. In addition, considering the same phase as for BIM maturity level 1, the planning and design ENPV is not anymore negative
- The values of the two most relevant indicators are equal to that for BIM maturity level 1. The CBA tool, in fact, does not foresee any increase of these two benefits shifting from one maturity level to the other. One of the reasons leading to this result relates to the fact that BIM maturity level 2 entails that, as a standard practice, the design activity is carried out using BIM, that is why no cost associated with this activity is charged to the public client

TIPS

The same economic indicators switched off in the BIM maturity level 1 scenario have not been considered here either, as they are identified as not consistent with the project.



5 Conclusions





5 Conclusions

Fostering BIM adoption in the construction industry, starting from its use in public tendering, is a key issue to address in order to improve the industry performance and pave the way toward digitalization.

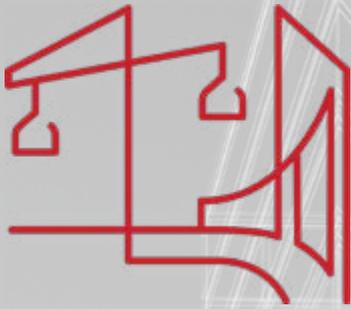
However, this study showed a lack of awareness by public procurers about the benefits of using BIM and how these benefits could in part, or totally, compensate the costs of its adoption.

Thus, this study and the developed cost-benefit analysis tool (CBA) for the use of BIM in public tenders aim to educate public procurers and enable them to estimate, ex-ante, the benefit-cost ratio of the adoption/decision for a specific foreseen investment.

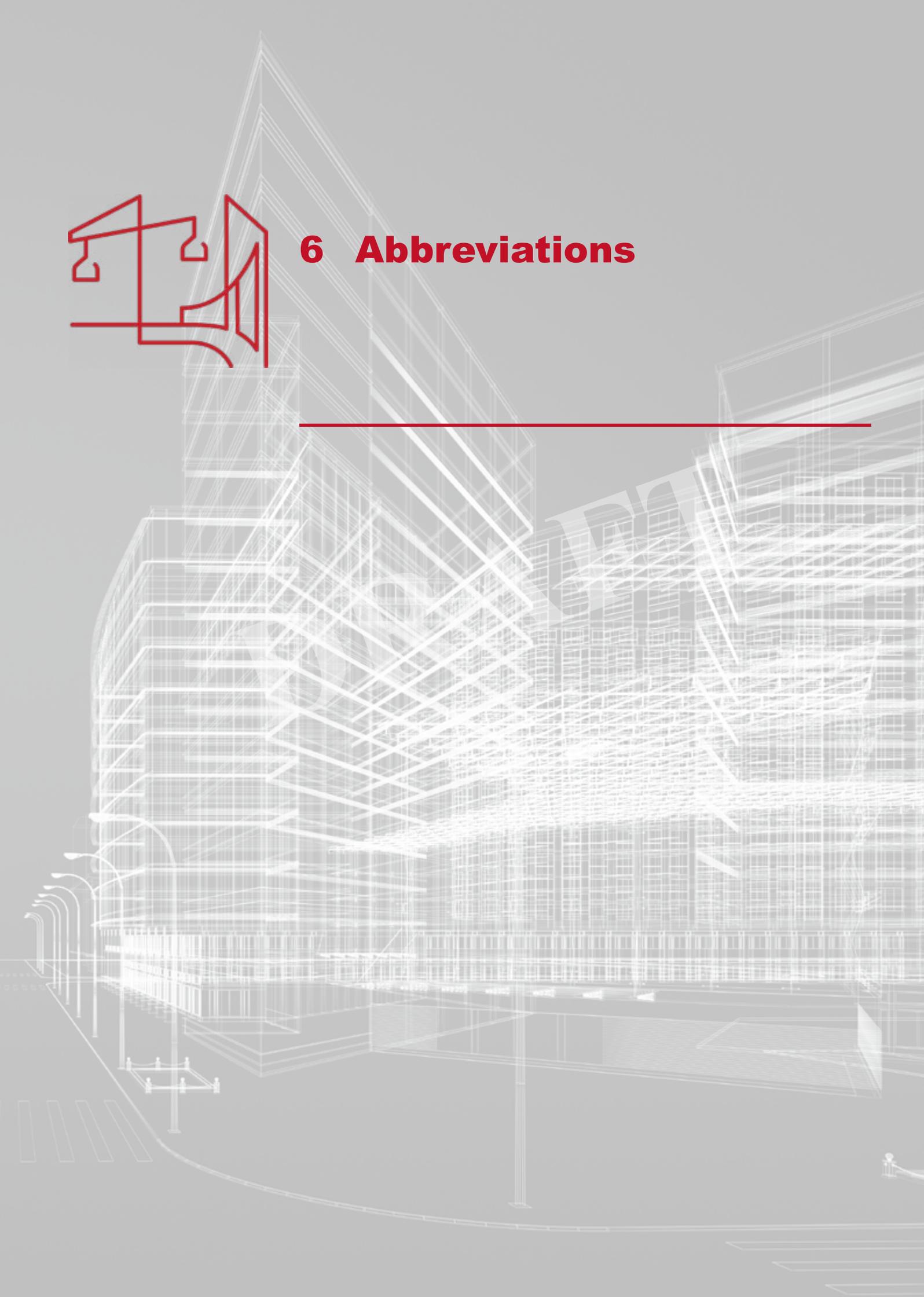
The tool presented in this handbook, in fact, provides an investment-specific CBA which supports public decision-making case by case.

It is worth emphasizing that the focus on public tenders has led to the need for measuring not only the financial benefits (for example, savings due to precise quantity take-offs) but also economic benefits more related to the socio-environmental field (for example, reduction of wastes and CO₂ emissions). For this reason, two clusters of performance indicators have been created to measure the viability of using BIM in an investment project: NPV and BC ratio, from a financial point of view, ENPV and EBC ratio, from the economic one.

The testing of the tool on six case studies has provided robust results, however, users' feedback could lead to further improvements in the future.



6 Abbreviations





6 Abbreviations

AEC	Architecture, Engineering and Construction
BCR	Benefit-Cost Ratio
B/C	Benefit-Cost
BIM	Building Information Modelling
BoQ	Bill of Quantities
CBA	Cost-Benefit Analysis
CDE	Common Data Environment
COSME	EU programme for the Competitiveness of Enterprises and Small and Medium-sized Enterprises
DG GROW	The Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs
EASME	Executive Agency for Small and Medium Enterprises
EBC	Economic Benefit-Cost
EIR	Employer's Information Requirement
EISMEA	European Innovation Council and SMEs Executive Agency
ENPV	Economic Net Present Value
EU	European Union
EUBIMTG	EU BIM Task Group
IRR	Internal Rate of Return
LOD	Level of Detail
MEP	Mechanical, Electrical, Plumbing
NPV	Net Present Value
QTO	Quantity Take Off
R&D	Research and Development
VfM	Value for Money

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