THE BENEFITS OF COST-BENEFIT ANALYSIS IN CONSTRUCTION PROJECTS

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ABSTRACT
The European Union’s (EU) main goal, as stated in the EU Green Deal, is to achieve climate neutrality by 2050, and the construction sector plays a significant role in this achievement through efforts to make infrastructure, commercial, and private projects more sustainable. For many years, Cost-Benefit Analysis (CBA) has been used to evaluate and make decisions on co-financing large infrastructure projects funded by the EU. As a result, the EU has incorporated the CBA into its cohesion policies, major initiative objectives, major sectoral policies, and common links, such as climate change and resource efficiency. However, in order to achieve ambitious European goals, the CBA has found a much broader application and is now used for the evaluation of circular economy projects, alternative materials in construction projects, in waste management and sustainable design, or to prove the efficiency of information processes or corporate governance. This paper will give an overview of the use of CBA in assessing various construction projects, as well as categorize identified benefits that were monetized in each group of projects. Finally, the general advantages and disadvantages of using CBA when evaluating and selecting projects from various construction areas will be summarized.

KEYWORDS
Cost-benefit analysis, CBA, Construction projects, European financing, Benefits.
1. INTRODUCTION

In the past two decades, the Cost Benefit Analysis (CBA) has emerged as a main tool for evaluating large infrastructure and other projects in both academic literature and business practice. Now, the CBA becomes one of the most effective pruning techniques in the world, and it is widely used in the evaluation of infrastructure projects (Nickel et al., 2009). CBA is a technique for evaluating public projects that was developed in response to the shortcomings of financial analyses performed in private investment projects, and it allows for the assessment of the net socioeconomic impacts of public projects. In its most basic form, CBA determines whether the total benefit of a project to society outweighs the total cost. CBA has traditionally been used on clearly defined projects with relatively limited spillover effects, either with private or public money effectively guaranteed by the public sector (Vickerman, 2007).

It is more crucial than ever to employ a specific technique in the context of the European Green Deal and Europe's commitments to addressing climate change. These should provide a broader view than simply examining financial cash flows between stakeholders of EU projects and policies, such as assessing and monetizing the effects on stakeholders who are indirectly affected by these policies (EC, 2021). The European Union's (EU) main goal is to achieve climate neutrality by 2050, and the construction industry contributes significantly to this achievement by working to make infrastructure, commercial, and private projects more sustainable. Another strategic document released by the EU is the EU Taxonomy, which is the initial set of climate-friendly economic activity standards (EU, 2020) that will be funded in the future. Because the concept of sustainable financing was developed to encourage companies and institutions to make significant long-term investments in various economic sectors, directing financial flows towards a green, low-carbon and climate-resilient economy makes sense (Lovrenčić Butković and Omazić, 2022).

The more widespread use of CBA began when the European Commission (EC) began funding projects through cohesion programs and specifically proposed CBA as an appropriate assessment tool. When the EC issued the first "Guide to Cost Benefit Analysis of Major Projects" in 1994, CBA was used much more in practice for evaluating profitability and selecting investment projects. The first edition had only 28 pages, whereas the fifth edition, published in 2014, had 364 pages. The guides are published at the start of each European Union (EU) investment period. The Economic Appraisal Vademecum for the 2021-2027 programming period, which is based on the Guide for 2014-2020, is currently in effect. The EC (2014) even gave recommendations in its guides for creating CBA based on individual sectors, so the projects are divided into transport, environment, energy, broadband, and research, development, and innovation sectors.

CBA became an academic research topic about ten years ago, when researchers attempted to identify the costs and benefits associated with specific areas and projects using case studies. Despite the fact that the EC has defined sectors in its guides for analyzing investment projects, academic articles on the use of CBA in construction projects have mostly focused on transportation, and more recently, information systems, with the introduction of BIM. So,
this paper will provide an overview of the use of CBA in assessing various construction projects, as well as categorize identified benefits that were monetized in each group of projects.

2. THE MAIN PRINCIPLES OF CBA

According to the Guide (EC, 2014), CBA is an analytical tool used to assess the welfare change attributable to an investment decision and, as a result, its contribution to EU cohesion policy objectives. CBA seeks to improve resource allocation efficiency by demonstrating the superiority of one intervention over alternatives. It is relatively easy to calculate the benefits and overall profitability of private projects, but for public projects that do not generate income, it is necessary to be able to monetize the benefits that will be achieved by implementing such projects. In this sense, the CBA is based on several assumptions, including opportunity costs, a long-term perspective, the monetary computation of economic success indicators, the discounting method, a microeconomic approach, and an incremental approach.

After describing the social, economic, political, and institutional environment in which the project will be carried out, identifying the project's effects, and verifying the project's relevance, demand and options analysis must be performed, taking into account environmental and climate change considerations, as well as project costs. All of this is the most challenging feature of conducting the analysis, because the obtained data represent inputs into the cost-benefit analysis. So, the old adage "if you put garbage in, you'll get garbage out" could be applied here. The quality of the data used and the assumptions made, have a significant impact on CBA results and must be interpreted carefully and nuancedly to be used correctly (EC, 2021: 51).

Given that the CBA's goal is to demonstrate the project's financial viability with external financing, it facilitates decision-making on non-reimbursable public funds, whether European, national, or from a third party. Following the collection of all inputs, the next step is to create a financial analysis that should answer two questions: is the project financially profitable and financially sustainable? A project is considered financially viable when there is no risk of it running out of funds during the implementation and operation phases. It is determined whether cash inflows exceed cash outflows over the life of the project by analyzing financial sustainability. If the project is found to be financially viable, the profitability of the investment is calculated, determining how profitable the project is for the investors. The project's financial profitability is calculated using two indicators: financial net present value - FNPV - and financial rate of return - FRR. Figure 1 depicts the entire structure of financial analysis.
An economic analysis must be performed after a financial analysis to determine contribution of the project to well-being. The goal of economic analysis is to provide evidence for a project's socioeconomic benefits. It is presumed that a given project provides economic benefits to society in exchange for public funding of Capital Expenditures (CAPEX) and possibly the incremental change in Operating Expenditures (OPEX), even if it does not result in financial gain for the beneficiary (EC, 2021: 73). The financial study considers how the project will benefit the owners, whereas the economic analysis looks at how the project will affect society. In this context, it is critical to identify all the societal benefits that the project can provide and to monetize these benefits in a specific way. Several methodologies have been developed to date in an attempt to monetize the economic, social, and environmental impacts of infrastructure projects, the most well-known of which is Willingness to Pay (Shen et al., 2019; Becker et al., 2020). According to international practice, the standard approach in economic analysis converts prices from financial analysis into social values. As a result, the following adjustments and corrections are required: phase 1. fiscal corrections (to exclude indirect taxes from the economic analysis), phase 2. conversion of market prices into accounting prices, and phase 3. external effects correction.

Following the economic costs and benefits definition, three parameters are used to present the results of the economic analysis: Economic Net Present Value - ENPV, Economic Rate of Return - ERR, and the Benefits Costs ratio - B/C. In order for the project to be economically justified, the ENPV must be greater than zero, the ERR must be positive and higher than the socioeconomic discount rate, and the B/C must be higher than one. Figure 2 depicts the process of conducting an economic analysis as part of a CBA.
Given the difficulty of accurately and completely covering all economic benefits when it comes to public projects for which the CBA analysis is performed, the following is an overview of the benefits used and identified in various sectors thus far.

3. METHODOLOGY AND FINDINGS

3.1 Research methodology

We chose the Web of Science database for our research methodology in order to demonstrate a broad application of CBA techniques for the evaluation and profitability of projects from various sectors. The literature search was carried out using a variety of keywords, including: “CBA, construction projects+ transport; CBA, construction projects+ water management; CBA, construction projects+ waste management; CBA, construction projects+ health and safety; CBA, construction projects+ BIM” etc. In total, 308 scholarly papers from 2008 to 2022 were discovered using our search strategy. The duplicated papers with redundant information were checked in the following step, and 246 papers remained. Following this, we evaluated publications based on their titles and abstracts, removing irrelevant papers until only 156 potentially related papers remained. Table 1 shows that the majority of the analyzed papers are about transportation projects, with 54 research items out of 156 in total (around 41%), which is likely because investments in that part of the infrastructure have been a priority for years. Furthermore, in the context of all sustainability initiatives, transportation projects should support the fight against climate change, whether through mitigation or adaptation strategies, while also taking into account the needs of the most vulnerable users.

Table 1. Distribution papers according to application sectors

<table>
<thead>
<tr>
<th>Application sectors</th>
<th>Number of papers</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport</td>
<td>64</td>
<td>41,02</td>
</tr>
<tr>
<td>Water management</td>
<td>26</td>
<td>16,67</td>
</tr>
<tr>
<td>Waste management</td>
<td>18</td>
<td>11,54</td>
</tr>
<tr>
<td>Health &amp; Safety</td>
<td>6</td>
<td>3,85</td>
</tr>
<tr>
<td>Building Information Modeling</td>
<td>42</td>
<td>26,92</td>
</tr>
<tr>
<td>Total</td>
<td>156</td>
<td>100,00</td>
</tr>
</tbody>
</table>
3.2 Findings based on application sector

3.2.1 CBA & Transport Projects

The transportation sector has long been recognized as a driver of economic growth and social inclusion, and it represents a major investment opportunity for every country. The most significant infrastructure projects have been completed in the field of transportation infrastructure, including railways, highways, and high-speed rails etc. Transport projects improve people's lives all over the world, and they help to ensure a clean, green, inclusive, resilient, and safe environment now more than ever. Investments in such projects are very high and require significant financial resources; but however, the benefits derived from them far outweigh the financial expenses, and the task of CBA is to demonstrate this.

Researchers contend that large transportation projects, when combined with appropriate policies, can create additional benefits above and beyond the user benefits calculated using the traditional CBA method (Wang et al., 2019). Tudela et al. (2006) stated that CBA is the most commonly used assessment technique in transportation projects because it assesses the project's expected social and economic impacts. Transport projects aim to improve the quality of transportation infrastructure through investing in new infrastructure and utilizing existing infrastructure more effectively to improve accessibility, mobility, and safety while also matching transportation demand (EC, 2014). Furthermore, transportation investments must be tightly linked to the needs identified in national transportation strategies, which must be based on a thorough evaluation of transportation demand (both for passengers and for freight). As a result, it is not surprising that the majority of infrastructure-related works are focused on transportation projects (Vierth, 2013; Salling and Leleur, 2015; Wang et al., 2019).

The EC (2014) emphasizes Green House Gas (GHG) emissions reduction as the most important impact of transportation projects. Transportation's effects on GHG reduction are most attainable at the strategic level, where there is more potential to influence vehicle unit emissions and shifts to lower emission mechanisms. The Vademecum (2021) summarizes the social and economic impacts of GHG reduction projects that can be considered during project evaluation. This includes perceived passenger time, freight time, vehicle operating costs, safety, emissions/local health, climate change, noise, other environment issues, and broader economic benefits.

Earlier academic works on this topic mostly dealt with the analysis of potential economic and social impacts of transportation policies (Geurs et al, 2009; Musso et al., 2009; Bristow and Nellthorp, 2000), whereas recent works have focused on identifying the aforementioned impacts on concrete case studies. One study conducted in the United Kingdom (UK Department for Transport, 2005; Venables, 2016) discovered a number of potential broader economic benefits, such as changes in output in imperfectly competitive markets, agglomeration effects, and the tax consequences of a shift to more productive jobs. Belal et al. (2020) used CBA in their study to investigate the proposed high-speed rail line's economic viability. This project had a positive NPV due to the identified primary benefits, such as
shortened travel time from door to door, as well as other desirable characteristics other than speed, such as comfort, dependability, and safety. Wang et al. (2019) used CBA to develop an integrated model for calculating wider economic impact, which they tested on a metro line project. The majority of the benefits and impacts, according to the research, can be summed up to: time savings, urban renewal, safety, air pollution savings, GHG emissions savings, and traffic noise reduction.

3.2.2 CBA & Water Management

Today's major efforts in meeting the EU's ambitious climate and energy goals are focused on protecting water and marine environments, resources, and ecosystems from pollution, overuse, and structural changes. On the other hand, because of the ageing process and high population expansion in urban areas, it is required to update existing water and wastewater treatment plants as well as construct new ones, as the majority of water and wastewater infrastructure is inadequate and nearing the end of its useful life (Feghaly et al., 2021). The vast majority of water/wastewater projects are carried out within the operations of integrated water utility operators and are classified as compliance or efficiency projects (EC, 2021). Many projects in practice combine elements of both, with the first resulting in higher operating costs and the second having the potential to reduce such costs and thus the impact.

As is stated in the Vademecum (2021), the primary economic benefits associated with water and wastewater projects include: (i) increased accessibility to water and wastewater services; (ii) improved quality of drinking water; (iii) improved water source reliability and security of water supply service; (iv) minimised variability in GHG emissions because of the changes in energy use and the efficiency of wastewater collection and treatment systems, including sludge management; (v) impacts on health; (vi) reduction in uncontrolled raw wastewater discharge/exfiltration; (vii) avoided costs of local flooding caused by the inefficient sewers and/or storm water systems; (viii) improved environmental quality of the water bodies and preservations of ecosystem services; (ix) benefits from recreational use of the water bodies; (x) avoided opportunity cost of water, such as the abstraction charge.

There are very few academic articles that deal with the identification of benefits, i.e. the implementation of CBA on the examples of water projects (Fan and Matsumoto, 2019; Andary et al., 2019; Becker et al., 2020; Brown et al., 2009). So far, CBA has mostly been used to compare projects in this sector (Feghaly et al., 2021), but given the importance of the problem and potential future prospects, it is to be expected that a larger number of researchers will begin to address this topic.

3.2.3 CBA & Waste Management

Waste management is the global problem with increased negative impact on every segment of life or business. More than a third of total waste produced in the EU is Construction and Demolition Waste (CDW) (EC, 2018), and it contains a diverse range of materials including bricks, concrete, metals, wood, plastic and glass. Construction sector generated 36.0% of total waste generation in the European Union in 2018 (Eurostat, 2020). As a result, efforts to solve this problem, as well as investments in waste-related projects, are desirable. The
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negative effects of CDW on the environment are numerous, with one of the most significant being the use of a significant amount of land resource for waste landfill disposal (Yuan et al., 2011). The implementation of the circular economy concept is intrinsically tied to waste issues and the trend toward implementing circular projects in the construction industry. Lovrencic Butkovic et al. (2021) examined current evaluation tools for circular economy projects in the construction industry, and it was discovered that the majority of papers published in this field fall under the waste management category. According to Tu et al. (2022), reduction of construction waste sources is a critical strategy for addressing the construction industry's sustainability issue, and the economic benefit is an important factor in project decision-makers' decision to implement this strategy. Their findings reveal that the net benefit of reducing CW sources is positive, and the three most effective techniques for increasing economic advantages of reducing CW sources are BIM implementation, design for standard material size, as well as storage of material. The primary economic implications of waste management initiatives include the decrease of GHG emissions, pollution of air and water, use of land and pollution of soil, and health hazards and nuisance effects (e.g., noise, odour, litter, dust, and vermin) (EC, 2021). The following are examples of typical social benefits (costs) for waste management investments: (i) avoided waste to landfill; (ii) recovery of recyclable materials and compost production; (iii) energy recovery; (iv) visual disamenities, noise, and odors; (v) variation in GHG emissions; or (vi) health and environmental hazardsc (EC, 2014).

3.2.4 CBA & Health & Safety

Construction industry is well known for its staggering accident statistics with workers in the AEC industry being on average three times more likely to be fatally injured in the workplace. Construction Health & Safety (H&S) is not simple to achieve and requires both financial and organizational effort. If the management can see the value-added of additional investment in H&S, they would more gladly implement more safety measures and put an even higher focus on the well-being of construction workers. One such method to show the ratio of costs and associated benefits is the Cost-benefit analysis. Surprisingly, there is a paucity of research dealing with the advantages and disadvantages of investing in H&S, in light of the overall significance of the topic of construction H&S and its prevalence in the literature. It must, however, also be said that it is difficult to quantify the exact costs of both the accidents and implemented safety measures and even more difficult to quantify the benefits.

Additionally, further investment in safety does not guarantee that accidents will no longer happen, it only reduces the possibility of an accident occurring, or reduces the gravity of the accident if does occur. Since it is a game of probabilities, the exact measurements are difficult. Having all this in mind, it is of no surprise that calculating the cost-benefit ratio of safety investment is a daunting task, one that researchers seldom take on, and not a lot of publications were found dealing specifically with this topic.

Most of the research was conducted by Ipke in his PhD thesis (2009) and reported in accompanying journal and conference papers (Ikpe et al. 2007b; Ikpe et al. 2007a; Ikpe et
Ikpe et al. (2008; Ikpe et al. 2011a, 2011b; Ikpe et al. 2012). Ikpe et al. (2011b) approached the issue of CBA for H&S by conducting a quantitative survey amongst small, medium and large contractors in order to determine the impact of total accident prevention costs on accident prevention benefits. Contractors were requested to estimate how much they spend on H&S measures, how much do the accidents cost and to estimate benefits of those preventive measures. The results have shown that for approximately 1 GBP spent on accident prevention 3 GBP are gained as a benefit. In another paper (Ikpe et al. 2011a), the authors go further in detail about the individual impact of benefits in investing in specific H&S measures (Personal safety equipment, safety promotion, training,...), and safety training and safety personnel are the two most effective accident prevention measures. The third paper (Ikpe et al. 2007b) presents a “willingness to pay” approach to determine cost-effectiveness, which is not a CBA approach, but rather a monetary value on the border of profitability. Other papers (Ikpe et al. 2007a; Ikpe et al. 2008; Ikpe et al. 2011b) are quite similar in topic and methods and do not require additional mention.

Lowe et al. (2020) have had a different approach. They examined 153 case studies of equipment purchases on H&S of construction workers and determined the profitability of various equipment types. This research, while useful and impactful to the issue of cost-effectiveness for H&S only deals with a specific issue. The third set of authors that have conducted research on the use of CBA for H&S are Panopoulos and Booth (2007). Their paper provides a wealth of information on CBA in the context of construction H&S but deals with the theoretical application and does not present a numerical case of costs and benefits of H&S improvements.

What is clear from the previous paragraphs is that not one of the research has actually dealt with CBA in practice, but rather only with a ratio of invested/gained which cannot be called Cost-Benefit Analysis. This has been identified as a major research gap that needs to be researched quantitatively to determine actual values of cost savings and other benefits with regard to the costs of implementation of safety measures.

3.2.5 CBA & Building Information Modeling

Undoubtedly, the potential advantages of Building Information Modeling (BIM) on project success and management have become a popular topic of scientific discussion due to its expanding range and impact. At the same time, the practice is partly skeptical and enamored with actual measurements of this impact on projects. CBA is indispensable here. By nature and focus, there are several vital categories regarding BIM and CBA integration: design phase, integration of design and construction, coordination, and visualization. Before 2007, there was almost no work on this topic. In other words, it has been scientifically present for fifteen years (Chahrour et al., 2020; Olugboyea, Olukemi Windapo, 2019). Li et al. (2009) investigated construction plan rehearsal in the designing phase and optimization in the execution phase, investigating timely error detection and usage areas. According to a study conducted by Sacks and Barak in 2008, implementing BIM in structural engineering design has resulted in a notable boost in productivity. Specifically, the use of BIM has led to
efficiency gains of between 15% and 41% in the drawing phase of reinforced concrete
constructions cast in location.

Interestingly, the same authors started the research in the construction phase just before they
turned to the design phase. Sacks et al. (2005) demonstrated that precast concrete companies'
adoptions of BIM technology resulted in increased labor productivity and cost savings.
Specifically, their findings showed that precast concrete companies could save between
2.3% and 4.2% of total project costs. In those years, increased the quality of engineering
design (for example, error-free drawings) was observed, which must be considered in CBA
in BIM projects (Kaner et al., 2008). CIIF's (2007) study highlights numerous advantages
of utilizing BIM for construction projects. These benefits include eliminating unexpected
changes in the budget, achieving greater accuracy in cost estimation, reducing the time
required to generate cost estimates, saving money on the contract, shortening project
timelines, reducing the occurrence of unbudgeted changes by up to 40%, attaining cost
estimation accuracy within 3%, reducing the time taken to generate cost estimates by up to
80%, achieving up to 10% savings on the contract value, and reducing project duration by
up to 7%. Research conducted by Azhar and colleagues in 2013 examines the performance
of BIM projects over time, highlighting various advantages, such as improved quality, on-
time completion, increased units per person-hour, cost savings, and reduced risk of potential
delays. Research development goes in the direction of a holistic approach to the project.
Therefore, it is not surprising that the recent research is on improved resiliency for the project
(Rad et al., 2021)

Regarding BIM coordination, Lu et al. (2013 and 2017) both claim that CBA has numerous
advantages, including but not limited to effective communication, improve in cost control
and management, increased profit margins, fast project delivery, higher quality of
information, competitive advantage, better team culture, and enabled e-procurement of
materials and components. According to various studies (Grilo and Goncalves, 2010; Baiden
and Price, 2011; Miettinen and Paavola, 2014; Ericksen, 2015; Liu et al., 2017;
Ghaffarianhoseini et al., 2017), adoption of BIM for design and construction integration can
lead to the following benefits: improved management of project schedules, enhanced
collaboration, provision of a time database, and a more professional attitude. Even
technically unimportant but essential for investors, visualization based on BIM application
can positively contribute to projects, which CBA must consider. Several benefits have been
observed from applying BIM in the construction industry. They include design review, clash
detection, improved work quality, and reduced requests for information and order changes.
Other benefits also include higher client satisfaction and their increased participation, valued
and quick decision-making processes, reduced contractual claims and better marketing.
These observations have been reported by various studies such as Staub-French and
Khanzode (2007), Jiang et al. (2013), Grilo and Goncalves (2010), and Ghaffarianhoseini et
al. (2017).

Integrating project life-cycle phases in BIM is one of the most widely researched BIM topics.
At the same time, this is one of the primary purposes of introducing BIM in concrete projects.
To summarize, the complete integration of BIM in construction projects provides various benefits, including improved energy performance, safety management, as well as waste elimination. It also offers an integrated and interactive database, enhanced data interoperability, increased transfer of knowledge and exchange of information. Other benefits include intelligent documentation, easy retrieval of building data, simulation of performance, improved prefabrication, deconstruction management, and effective management of supply chains.

Additionally, BIM improves facility operation and maintenance, enhances service quality, enables coordinated decision-making, and fosters trust and commitment. These benefits have been documented in several studies, including Baiden and Price (2011), Miettinen and Paavola (2014), Rahman et al. (2014), Erickson (2015), Cao et al. (2015), Ghaffarianhoseini et al. (2017), Liu et al. (2017) and Alreshidi et al. (2017). Researchers and practitioners are more likely to notice reduced productivity during the project's construction phase. Afterward, a deeper analysis shows the meaning of design in productivity for the complete project success.

4. CONCLUSION

We present a content overview of the available literature on the use of CBA in construction projects, with an emphasis on economic, social, and environmental benefits, in an attempt to clarify methodology and assist in the creation of an agenda for future research. A significant portion of the analyzed works deals with the implementation of CBA on examples of various construction projects; however, there is a scarcity of explicit results in the context of the economic and social benefits of the projects, particularly the method of monetization. According to this paper, following a thorough review of 156 identified papers, the majority of construction projects evaluated using CBA were in the transportation sector, followed by BIM, with water and waste management trailing behind. This review also discovered a significant increase in the number of papers published in this field, as well as an increase in the use of CBA as a construction project assessment method.

CBA is critical in evaluating both public and private projects, but this may be due to the fact that CBA is conditioned by the EC and elaborated in detail in its Guides. However, CBA is frequently used in conjunction with other assessment methods, such as Life Cycle Analysis - LCA (Ernst, 2019; Yuan et al. 2011; Doan and Chinda, 2016) or Multi Criteria Analysis - MCA (Tabatabaee et al., 2019,Darko et al., 2019; Khoshand et al., 2020). Although there are various criticisms of the use of CBA, such as insufficient consideration of project environmental benefits (Manzo et al., 2018), it is undeniable that there are qualitative significant benefits that should increasingly come to the fore in the future, particularly in the context of sustainable finance and investment.

Finally, the findings demonstrated that no future project will be able to analyze itself by individual sectors, but that various and combined aspects, such as the use of alternative materials, must unquestionably be taken into account (Del Ponte et al., 2017, Senaratne et al., 2016), waste management as a significant segment of every construction project (Perera
and Shandraseharan, 2021; Chen et al., 2018), and especially green building and design (Chen et al., 2018; Šuman et al., 2020).

REFERENCES


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