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ABDURAXMON ASIMOVICH ISHANXODJAYEV TAVALLUDINING 85 YILLIGIGA BAG‘ISHLANGAN "TRANSPORT INSHOOTLARI: ZAMONAVIY TEXNOLOGIYALAR, SEYSMIK BARQARORLIK" MAVZUSIDAGI XALQARO ILMIY-AMALIY KONFERENSIYASI ILMIY ISHLARI TO‘PLAMI

Toshkent davlat transport universiteti texnika fanlari doktori, professor, transport qurilishi sohasida taniqli olim, fan va texnika sohasidagi Abu Rayhon Beruniy nomli O‘zbekiston Davlat mukofoti laureati, "Shuxrat belgisi" ordeni, "Sharafli mehnati uchun" medali, "Oliy talim fidoiysi", Oliy talim alochisi", "SSSR ixtirochisi", "Yo‘l ustalarning ustozi", "Seysmik xavfsizlik sohasi alochisi" ko‘krak nishonlari sohibi **Abduraxmon Asimovich Ishanxodjayev tavalludining 85 yilligiga** bag‘ishlangan **"Transport inshootlari: zamonaviy texnologiyalar, seysmik barqarorlik"** mavzusidagi xalqaro ilmiy-amaliy konferensiya ilmiy ishlari to‘plami chop etildi.

Abduraxmon Asimovich 100 dan ortiq ilmiy asarlar, shu jumladan, 2 ta monografiya, 2 ta darslik, 18 ta chet elda chop etilgan ilmiy maqola va ishlab chiqarishga tadbiq etilgan 6 ta ixtiroga berilgan guvohnoma va patentlar muallifidir. Uning ilmiy maslahatchiligi va ilmiy rahbarligida 2 ta doktorlik, 8 ta nomzodlik va 4 ta texnika fanlari bo‘yicha falsafa doktori (PhD) ilmiy darajalariga dissertatsiyalar yoqlandi, ko‘p sonli ilmiy-tadqiqot mavzulari – fundamental va amaliy Ilmiy grantlar, yo‘l-ko‘prik qurilishi bo‘yicha Respublika va soha me’yoriy hujjatlari yaratganlar.

Ishanxodjayev Abduraxmon Asimovich 1962 yilda Toshkent temir yo‘l muhandislari institutini "Sanoat va fuqaro qurilishi" mutaxassisligi bo‘yicha tugatib, bir yil O‘zbekiston suv xo‘jaligi Davlat loyiha instituti muhandisi, to‘rt yil "Toshshaxarqurilish Bosh Boshqarmasi" qurilish tashkilotlarida qurilish ustasi va ish bajaruvchi lavozimlarida ishladi. Shu davrda u hozirgi Respublika Prezidenti devoni binosi qurilishida ishtirok etdi, Toshkent viloyati Bo‘stonliq rayoni "Chimyon" dam olish zonasida tiklanayotgan "Quyoshli" pioner lager qurilishiga rahbarlik qildi. Nihoyat, u 5-yillik loyiha va ishlab chiqarish tajribasiga ega mutaxassis sifatida 1967-yil dekabrida O‘zbekiston Fanlar Akademiyasi mexanika va inshootlar seysmik mustaxkamligi institutiga, ushbu institut direktori, o‘sha paytda fan nomzodi, keyinchalik akademik Tursunboy Rashidov ilmiy rahbarligida aspiranturaga kiradi va keyingi 20-yil davomida kichik va katta ilmiy hodim, laboratoriya mudiri lavozimlarida faoliyat ko‘rsatdi.

Shu davrda uning bevosita rahbarligi va ishtirokida O‘zbekiston Fanlar Akademiyasi mexanika va inshootlar seysmik mustahkamligi institutida dunyoda yagona "Metropolitenlar zilzilabardoshligi" laboratoriyasi tashkil etildi. Ushbu laboratoriya Toshkent metropoliteni Chilonzor metro yo‘lini noqulay grunt sharoitlari va yuqori seysmik zonada loyihalash va qurishda, metro qurilishi tajribasida birinchi bo‘lib yirik yig‘ma temirbeton elementlardan tiklanadigan yurish va bekat tonnellarining yangi, zilzilabardosh konstruksiyalari yaratish va tadbiq etishda faol qatnashdi. Toshkent metrosi Chilonzor yo‘lining qurilgan bo‘laklarida ulkan eksperimental tadqiqotlar o‘tkazildi, metro tajribasida birinchi bo‘lib muhandis-seysmometrik kuzatuvlar tashkil qilindi. Laboratoriya ilmiy xodimlari va izlanuvchlaridan 10 dan ortiq kishi nomzodlik va doktorlik dissertatsiyalari yoqladilar. Kafedrada bajarilgan ilmiy-tadqiqotlar natijalarining ishlab chiqarishga tadbiqidan hosil bo‘lgan katta miqdordagi iqtisodiy samara institut va O‘zbekiston Fanlar Akademiyasi hisobotlarida qayd etildi.

Ustozimiz 30 yildan ortiq muddatda rahbarlik qilgan Toshkent avtomobil-yo‘llar instituti “Ko‘priklar va transport tonnellari” kafedrasi O‘zbekiston Respublikasi, shuningdek, Osiyo, Afrika va Lotin Amerikasi mamlakatlari uchun ko‘priksozlik bo‘yicha oliy malumotli kadrlar tayyorladilar. Shuni qayd etish lozimki, professor Ishanxodjaev Abduraxmon Asimovich turli yillarda Tojikiston va Qirg‘iziston Respublikalari hududlarida, Armaniston Respublikasining Spitak shahrida ro‘y bergan kuchli zilzilalar oqibatlarini o‘rganish va tahlil qilishda, sobiq Ittifoq Fanlar Akademiyasi prezidiumi qoshidagi seysmologiya va zilzilabardosh qurilish bo‘yicha idoralararo kengash azosi sifatida faol ishtirok etdi. Keyingi yillarda u Toshkent shahri va Respublikada qurilayotgan ulkan transport inshootlari konstruksiyalari, shu jumladan Toshkent metropoliteni yer usti xalqa yo‘li konstruksiyalarini ekspertiza qilish jarayonlarida ham bevosita ishtirok etdi.

Ishanxodjayev Abduraxmon Asimovich 50 yildan ortiq davrda ilmiy darajalar beruvchi ixtisoslashgan va ilmiy kengashlarning raisi, ilmiy kotibi, a’zosi va ushbu kengashlar qoshidagi ilmiy seminar raisi sifatida 300 dan ortiq mutaxassislarning doktorlik, nomzodlik va falsafa doktori ilmiy darajasini olish jarayonida qatnashdi. Hozirda u Toshkent Davlat Transport Universiteti huzuridagi doktorlik dissertatsiyalari himoyasi bo‘yicha ilmiy kengash a’zosi va ushbu ilmiy kengash qoshidagi ilmiy seminar raisi, O‘zbekiston mexaniklar jamiyatining kengashi a’zosi, Sharof Rashidov nomli Samarqand Davlat universiteti va O‘zbekiston Fanlar Akademiyasi seysmologiya instituti qoshidagi doktorlik dissertatsiyalari himoyasi bo‘yicha ilmiy kengashlar a’zosi sifatida ilmiy darajadagi mutaxassislar tayyorlashda faol ishtirok etmoqdalar.

Mazkur ilmiy-amaliy konferensiyaning maqsadi transport qurilishi sohasida olib borilayotgan zamonaviy ilmiy tadqiqotlar yo‘nalishlarini muhokama qilish, jumladan ko‘priklar va tunnellar qurilishi, metropolitenlar, yuqori seysmik hududlarda transport obyektlarining ishonchliligi va seysmik mustahkamligi, zamonaviy hisoblash va loyihalash usullari, hamda innovatsion muhandislik yechimlari bo‘yicha ilmiy natijalar almashuvini ta’minlashdan iboratdir.

Konferensiyada O‘zbekiston Respublikasi hamda xorijiy mamlakatlarning oliy o‘quv yurtlari va ilmiy-tadqiqot institutlari olimlari, shuningdek, muhim ilmiy tadqiqot natijalariga ega bo‘lgan ishlab chiqarish vakillari o‘z ilmiy ishlari bilan ishtirok etdilar.

“Transport inshootlari: zamonaviy texnologiyalar, seysmik barqarorlik” mavzusidagi xalqaro ilmiy-amaliy konferensiyaning asosiy yo‘nalishlari quyidagilardan iborat:

1. Transport inshootlari uchun zamonaviy konstruktiv yechimlar va materiallar;
2. Ko‘priklar hamda yo‘l o‘tkazgichlarni diagnostika qilish, ta’mirlash va mustahkamlash texnologiyalari;
3. Seysmik hududlarda transport inshootlarini loyihalash va ekspluatatsiya qilishdagi dolzarb masalalar;
4. Ilg‘or xorijiy tajriba, innovatsion yondashuvlar va amaliy tavsiyalar.

Ushbu ilmiy-ma’rifiy to‘plam Abduraxmon Asimovich Ishanxodjayevning tabarruk 85 yoshga to‘lishi munosabati bilan nashr etilib, unda transport qurilishi sohasida faoliyat yuritayotgan yetakchi olimlar, professor-o‘qituvchilar va malakali mutaxassislarning ilmiy izlanishlari jamlangan. To‘plamda transport qurilishining dolzarb muammolari, zamonaviy muhandislik yechimlari, ilmiy-nazariy va amaliy tadqiqot natijalari yoritilib, ushbu sohaning bugungi holati va istiqboldagi rivojlanish yo‘nalishlari aks ettirilgan. Mazkur nashr Abduraxmon Asimovichning transport qurilishi faniga qo‘shgan ulkan hissasiga nisbatan chuqur hurmat va e’tirof ramzi sifatida tayyorlangan.

Methodology for Assessing Embodied Carbon in Bridge Structures

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Abstract: This study introduces a methodology for evaluating the embodied carbon of building materials and structural elements. The approach includes relevant formulas and step-by-step procedures to systematically assess carbon emissions associated with material production and construction processes. While actual numerical results are not presented in this work, the methodology provides a framework for applying these calculations in practice. Operational carbon is not considered in this study but is identified as a topic for future research. Overall, the proposed methodology offers a structured approach to analyzing embodied carbon, supporting further studies and adaptations in construction projects aimed at sustainable development.

Keywords: Bridge sustainability, Embodied carbon, Operational carbon, Life Cycle Assessment, Environmental impact, Infrastructure in Uzbekistan

1. Introduction

The relationship between humanity and nature has deep and ancient philosophical roots. As expressed in a well-known proverb: “Treat the Earth well: it was not given to you by your parents, it was loaned to you by your children.” This ancient Native American proverb, spoken centuries ago, resonates even more strongly in today’s society. It implies that every action harming the Earth and its natural systems is ultimately an action taken against the future of coming generations. For this reason, growing concern regarding greenhouse gas (GHG) emissions has become an imperative issue for professionals across all disciplines.

On a global scale, GHG emissions are the primary anthropogenic drivers of climate change. According to the United States Environmental Protection Agency (EPA), the transportation sector including road, rail, air, and maritime transport together with buildings accounts for approximately 21% of global GHG emissions. When focusing on developed countries such as the United States, this proportion is even higher: in 2012, the transportation and building sectors represented about 38% of total national emissions, exceeding one third of the overall contribution.

Within the field of civil engineering, the objective is not limited to the development of residential and commercial buildings, but also encompasses critical infrastructure such as roads, bridges, and tunnels. In recent decades, numerous sustainability rating systems and assessment frameworks have been developed to evaluate and improve the environmental performance of buildings. However, in contrast to buildings, infrastructure systems and bridges in particular have received comparatively limited attention in sustainability-related research.

As mentioned previously, several studies and rating systems exist to measure the sustainability of buildings, raising the question of why bridges differ so significantly from buildings in this context.

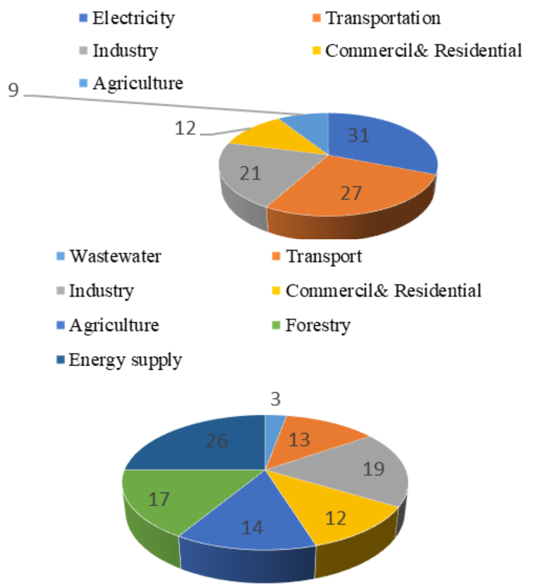

Fig. 1. Global Greenhouse Gas Emission by sourse

One major distinction lies in the identity of the client. While buildings are most often commissioned by private companies or investors, bridges are typically initiated and funded by governments or public administrations at the municipal, regional, or national level. This difference has direct implications for project budgets, which are generally more constrained in the public sector than in private developments. Furthermore, because bridges serve to shorten travel distances and improve mobility, expectations regarding their environmental performance are often secondary. Bridge users tend to focus more on the financial cost borne by their city, state, or country indirectly funded through taxation than on the sustainability of the structure itself.

In contrast, when private companies develop buildings, obtaining sustainability certifications often enhances corporate image and demonstrates environmental

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responsibility, which can provide tangible benefits to the company. Another fundamental difference concerns the purpose of the structure. Most buildings are designed primarily for residential or office use, where architectural expression and façade design are secondary to functional requirements. For bridges, the primary objective is to connect different parts of a city or region and to create shorter and more efficient transportation routes. At the same time, bridges play a significant social and cultural role: they reduce travel time, enhance connectivity, and frequently become iconic elements that define the identity of a city, often being perceived as works of engineering art.

Sustainability, as defined by the EPA, is based on the principle that everything necessary for human survival and well-being depends, directly or indirectly, on the natural environment. Similarly, the Brundtland Report defines sustainable development as development that meets present needs without compromising the ability of future generations to meet their own.

In this context, this study aims to address existing gaps in bridge sustainability research by analyzing carbon emissions throughout the bridge life cycle, expanding life cycle cost assessment (LCCA) methodologies to carbon-based evaluations, and contributing to the development of a more comprehensive framework for sustainable bridge design.

Although this study is based on international databases and case studies mainly from European and North American contexts, the proposed methodology is not geographically limited. The framework developed in this research can serve as a foundation for future applications in other regions, including Uzbekistan. By adapting material emission coefficients, traffic data, and maintenance practices to local conditions, this approach could support the assessment of embodied and operational carbon emissions of bridge infrastructure at a national level. Such future applications would contribute to more informed decision-making in infrastructure planning and promote the development of sustainable bridge design practices in Uzbekistan.

2. Research methodology

Despite growing interest in sustainable construction, a significant knowledge gap remains in the field of sustainable bridge design. In particular, limited information is available regarding the environmental implications of material selection, structural dimensions, and, most importantly, the maintenance and operational phases of bridges. Existing studies rarely address how maintenance activities affect bridge functionality over time. For instance, during maintenance periods, it is often unclear whether a bridge remains open to traffic, how many lanes remain operational compared to full service conditions, or which alternative routes are implemented when full or partial closures occur. These aspects play a crucial role in understanding the overall sustainability performance of bridge infrastructure.

Current research related to bridge maintenance and operation is predominantly grounded in economic analyses. For certain bridges, Life Cycle Cost Analysis (LCCA) has been applied to evaluate costs associated with traffic flow, toll systems, and other infrastructure-related factors. While LCCA provides valuable insights into economic efficiency, it does not explicitly account for greenhouse gas (GHG) emissions generated during the operation and maintenance phases of a bridge's life cycle. Extending this methodology to incorporate carbon emissions represents a critical research opportunity.

The primary objective of this study is to establish a benchmark for embodied carbon in bridge structures, considering both road bridges and pedestrian bridges. In addition, this research aims to develop an integrated methodology that accounts for maintenance and operational impacts by expanding conventional LCCA frameworks to include carbon-based assessments. By addressing these gaps, this study seeks to support a more comprehensive evaluation of bridge sustainability and contribute to the development of improved strategies for the design and management of sustainable bridge infrastructure.

Sustainability is commonly defined as a fundamental principle recognizing that human survival and well-being are inherently dependent, both directly and indirectly, on the natural environment. According to the United States Environmental Protection Agency (EPA), sustainability involves creating and maintaining conditions in which human societies and natural systems can coexist in a productive and balanced manner, while fulfilling social, economic, and environmental needs for both present and future generations.

This concept is closely aligned with the definition presented in the Brundtland Report, which describes sustainable development as development that satisfies current needs without undermining the capacity of future generations to meet their own. In this sense, sustainability extends beyond immediate outcomes and requires a long-term perspective that accounts for the lasting impacts of human actions.

Sustainable development therefore represents a comprehensive way of thinking, in which the direct and indirect consequences of decisions are carefully considered. These consequences may manifest over short or extended time horizons ranging from months to decades or even centuries yet their existence and influence remain significant. Ensuring that such impacts do not irreversibly damage natural systems is central to the pursuit of sustainable development.

Greenhouse gas (GHG) emissions represent the primary anthropogenic driver of global warming. Among these gases, carbon dioxide (CO_2) is the most significant contributor, as shown in Figure 1-6. In addition to CO_2, other gases such as methane (CH_4), nitrous oxide (N_2O), and fluorinated gases also play a role in intensifying climate change and degrading the ozone layer. Although fluorinated gases are released in relatively small quantities, they have a disproportionately high impact on the Earth's climate due to their high Global Warming Potential (GWP) and are therefore classified as High Global Warming Potential gases (EPA, 2012).

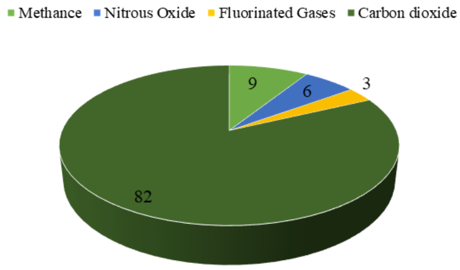

Fig. 2. Greenhouse Gases

Since the Industrial Revolution, the concentration of greenhouse gases in the Earth's atmosphere has increased considerably as a result of various human activities. These activities include energy production, transportation, industrial processes, and construction-related operations. A summary of the main anthropogenic sources contributing to greenhouse gas emissions is presented in Table 1-1.

Table 1

Greenhouse Gases Source of Emissions

Green house Gases	Source
Carbon dioxide CO_2	Burning fossil fuels
	Burning solid waste
	Burning trees and wood products
	Certain chemical reactions
Methane CH_4	Production, transport of coal
	Production, transport of natural gas
	Production, transport of oil
	Livestock and other agricultural practice
Nitrous oxide N_2O	Agricultural and industrial activities
	Combustion of fossils fuels
	Combustion of solid waste
Fluorinated gases	Variety of industrial process

Global Warming Potential (GWP) is an index used to evaluate and compare the capacity of different greenhouse gases to trap heat in the atmosphere over a defined period, typically 100 years. This indicator expresses how much energy a specific gas absorbs relative to carbon dioxide during the same timeframe (EPA, 2012). Carbon dioxide is assigned a GWP value of 1, as it serves as the reference gas for comparison.

Other greenhouse gases exhibit significantly higher GWP values, indicating a stronger warming effect per unit mass. For instance, methane and nitrous oxide have substantially higher GWP values than carbon dioxide, as illustrated in Table 1-2, highlighting their greater contribution to climate change despite lower emission quantities.

Table 2

Global Warming Potential of some Greenhouse Gases

Green house gases	GWP (100 years)
Methane CH_4	21
Nitrouse oxide N_2O	310

Life Cycle Assessment (LCA) is a systematic methodology used to assess the environmental impacts associated with a product, process, or system throughout its entire life span, from raw material extraction to end-of-life disposal (UNEP, 1996). This approach enables a comprehensive evaluation of environmental burdens by considering all stages of a product's existence.

As illustrated in Figure 1-7, the LCA framework is structured into four main phases:

1. Goal and Scope Definition, which establishes the purpose of the study, system boundaries, and assumptions;
2. Life Cycle Inventory (LCI), involving the collection and quantification of inputs such as materials and energy, as well as outputs including emissions and waste;
3. Life Cycle Impact Assessment, where the potential environmental impacts are evaluated based on inventory data;
4. Interpretation, which involves analyzing the results, identifying key contributors, and drawing conclusions to support decision-making.

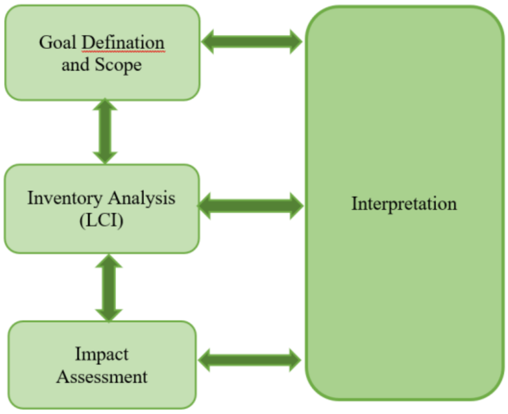

Fig. 3. Life Cycle assessment Framework

Embodied Carbon

Embodied energy represents the total energy required to produce a material, covering all stages from extraction to final manufacturing (Treloar, 1994). The associated embodied carbon quantifies the greenhouse gas (GHG) emissions resulting from this energy, measured in kilograms of CO_2 equivalent (De Wolf, 2014). In the context of bridges, embodied carbon is primarily considered during the construction phase, reflecting the emissions from material processing, transportation, and assembly. Unlike buildings, where maintenance and end-of-life stages are often included, bridge analysis generally focuses on construction-related emissions.

Operational carbon accounts for GHG emissions occurring throughout the bridge's service life, including maintenance activities and routine operation. Maintenance can temporarily obstruct traffic, causing additional emissions, which are therefore included in the operational carbon assessment. Furthermore, energy consumption from bridge lighting and other electrical systems contributes to operational emissions. Together, embodied and operational carbon provide a comprehensive picture of the bridge's carbon footprint, supporting more informed decisions for sustainable bridge design and management.

This study focuses on a selection of pedestrian and road bridges to analyze their embodied carbon during the construction phase. The same methodology is applied to both types of bridges, ensuring consistency in assessment. The steps of the methodology are as follows:

1. Determining Structural Material Quantities (SMQ)

The first step is to identify the quantities of structural materials used in each bridge. Accurate material quantities are crucial for calculating embodied carbon. While obtaining this data for existing bridges may be challenging, designers and engineers can apply the same approach during the design or immediately after construction. The quantity of structural material i is denoted as SMQ_i

2. Normalizing Material Quantities (NMQ)

To allow comparisons between bridges of different sizes, material quantities are normalized. The normalized quantity of structural material (NMQ_i) is calculated as the weight of material per unit area of the bridge deck:

$$NMQ_i\,[kg/m^2] = \frac{SMQi[kg]}{Length[m] \times Width[m]}$$

3. Calculating Embodied Carbon (EC)

The embodied carbon of each structural material is calculated by multiplying the normalized material quantity by its embodied carbon coefficient:

$$EC_i\ [kgCO_2e/m^2] = NMQ_i\ [kg/m^2] \times ECC_i[kgCO_2e/kg]$$

4. Global Warming Potential of the Bridge (GWP)

Finally, the total embodied carbon or global warming potential of the bridge is calculated as the sum of the embodied carbon of all materials:

$$GWP[kgCO_2e/m^2] = \Sigma EC_i\ [kgCO_2e/m^2]$$

This methodology provides a structured framework for evaluating the environmental impact of bridges during their construction stage and allows comparison across different bridge types.

3. Conclusion

This study presents a methodology for assessing the embodied and operational carbon of pedestrian and road bridges, aiming to establish a benchmark and evaluate their sustainability over the entire life cycle. The methodology consists of three main steps: first, collecting comprehensive data on bridges; second, calculating the embodied carbon based on structural material quantities; and third, adapting a Life Cycle Cost Assessment (LCCA) approach to estimate the operational carbon, including traffic impacts during maintenance and energy use for lighting.

The data collection includes bridge dimensions, material quantities, daily traffic volumes, lighting systems, and toll information. This ensures a thorough understanding of both the construction and operational characteristics of the bridges. Embodied carbon is calculated by normalizing material quantities and applying material-specific carbon coefficients to estimate the total global warming potential (GWP). Operational carbon considers emissions from maintenance, traffic delays, and electricity consumption, capturing both direct and indirect contributions to greenhouse gas emissions.

While actual numerical results are not presented in this study, the proposed methodology provides a structured and repeatable framework for evaluating bridge sustainability. Importantly, this framework can be adapted for Uzbekistan and other Central Asian contexts, taking into account local material production processes, operational practices, and emission factors. Such adaptation would allow more accurate national-level environmental assessments and support sustainable decision-making in bridge design and management.

In summary, this methodology offers a solid basis for designing and assessing sustainable bridge infrastructure, integrating functional, social, and environmental aspects while allowing future research to implement Uzbekistan-specific parameters.

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