JOURNAL OF MULTIDISCIPLINARY SCIENCES AND INNOVATIONS

VOLUME 04, ISSUE 08
MOPNTHLY JOURNALS

ISSN NUMBER: 2751-4390
IMPACT FACTOR: 9,08

MINIMIZING ENVIRONMENTAL IMPACT IN TRANSPORT INFRASTRUCTURE: INTERNATIONAL APPROACHES IN BRIDGE AND TUNNEL CONSTRUCTION.

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Annotation: This article examines the problem of increasing environmental impact in transport infrastructure, particularly in bridge and tunnel construction. The aim of the study is to analyze environmentally efficient construction approaches applied in different countries. Within this framework, the experiences of Japan, Germany, the Netherlands, and Sweden are explored, with a focus on methods to reduce waste, improve energy efficiency, and minimize the environmental impact of construction processes. The results highlight the possibilities of applying these practices in the context of Uzbekistan.

Keywords: Bridge, tunnel, environmental impact, sustainable construction, waste, EIA, environmental protection.

In recent years, the rapid development of large cities and transport infrastructure has led to the large-scale construction of bridges and tunnels. However, this process has also intensified environmental problems. First of all, in the production of construction materials such as cement, concrete, metal, sand, and gravel, a large amount of natural resources is consumed. As a result, rocks and underground resources are being depleted at a fast pace. In particular, the production of cement, which is the main component of concrete, requires a significant amount of energy and emits carbon dioxide (CO_2). For example, in 2010, the cement industry accounted for 36% of the 7.7 gigatons of CO_2 emissions produced by the construction sector, which is almost 8% of global emissions. Therefore, reducing the ecological footprint of concrete structures is one of the most urgent tasks facing the construction sector today.

In addition to the production of materials, their practical application also has negative effects. Heavy machinery used in bridge and tunnel construction—such as excavators, bulldozers, concrete mixers, and transport vehicles—consumes large amounts of diesel and gasoline fuel. As a result, CO_2, nitrogen oxides (NOx), sulfur compounds, and dust particles are released into the atmosphere. These emissions significantly reduce air quality, negatively affecting nearby residents as well as construction workers. In particular, in enclosed areas such as tunnels, the air becomes polluted quickly, making breathing difficult and intensifying illnesses such as allergies and respiratory inflammations. Moreover, excessive CO_2 emissions further contribute to the worsening of global climate change.

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1- picture. Underground Structure Excavation

This picture illustrates the step-by-step excavation and structural preparation process of an underground structure.

Along with harmful substances in the atmosphere, water resources are also under serious threat. If treatment facilities at construction sites, major cities, or factories do not function effectively, wastewater containing various chemicals, plastics, and heavy metals flows into rivers and lakes. This leads to the disruption of aquatic ecosystems, the disappearance of fish and water plants, and ultimately the breakdown of the food chain. As a result, the supply of drinking water becomes more difficult, and the quality of irrigation water for agriculture deteriorates. Thus, water pollution is not only an environmental problem but also a socio-economic challenge.

Water pollution and improper earthworks during construction also intensify the process of soil erosion. The exposure of slopes, the destruction of the fertile topsoil layer, and the movement of heavy machinery lead to the loss of soil structure stability. This accelerates water runoff, causes the formation of gullies, and results in large amounts of sediment being carried downward into water bodies. Wind erosion, on the other hand, increases dust dispersion in dried areas, posing risks not only to the environment but also to human health. The loss of the fertile layer slows down vegetation recovery and ensures the continuity of the erosion process.

Another link in the chain of environmental problems is noise pollution. During construction, pile driving, drilling, blasting, and the operation of cranes and excavators serve as constant sources of high-level noise. Such noise disrupts bird nesting, breeding, and navigation, while underwater it creates stress for fish and affects their natural migration. For humans, it causes sleep disturbances, stress, reduced concentration, and a decline in quality of life. When construction continues for long periods, this noise becomes a permanent “background,” forcing wild animals to migrate entirely to other areas.

In various countries around the world, innovative methods are being developed to reduce environmental problems in bridge and tunnel construction. Some of their practical applications are presented below.

In Japan, reducing environmental impact during bridge construction is especially important due to mountainous terrain, deep rivers, and densely populated areas. For this reason, the extradosed

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method is widely applied. This technique is a hybrid of cable-stayed and prestressed girder bridges, where the pylons are relatively shorter, and the cables support the bridge deck at a shallow angle. In this way, spans of 100–250 meters can be effectively covered. The method simplifies the construction process and minimizes harm to the natural environment. Fewer piers are required, which limits interference with soil and water, while saving materials ensures more efficient resource use. At the same time, the cables require regular inspection and maintenance, so this method may not be suitable for very long spans.

The first major example of this method was the Odawara Blueway Bridge (1994). Later, it was also applied in projects such as the Ibigawa and Kisogawa Bridges (2001), as well as the Fudo Bridge (2010) and the Okuibiko Bridge (2011). These bridges demonstrated the practical potential of the extradosed technology, making it one of the sustainable solutions in Japan.

2- picture. “ Odawara Blueway” bridge

In Japan, reducing environmental impact is largely achieved through the improvement of construction technologies, whereas in Germany, the main focus is on prefabrication methods. In this approach, elements are first manufactured in factory conditions and then quickly and accurately assembled on the construction site. This method reduces waste, eliminates construction inaccuracies, decreases noise and dust, and significantly saves working time. For example, prefabrication was extensively used in the reconstruction of the Rodenkirchen Bridge in Cologne, allowing work to proceed without disrupting traffic flow.

In recent years, significant research has also been conducted in Germany on carbon-fiber materials. In particular, carbon fiber and carbon-reinforced concrete (CRC) make it possible to build lighter, thinner, and more corrosion-resistant structures compared to traditional reinforcement. This not only helps conserve resources but also contributes to reducing CO_2 emissions in the long term.

From 2010 to 2024, the Technical University of Dresden and the C³ (Carbon Concrete Composite) consortium tested these materials in laboratories and demonstrated their practical application possibilities. For example, experimental bridges and small structures built on the university campus using CRC technology serve as an important basis for the future use of these new materials in construction.

In addition to modular assembly technologies, some countries pay special attention to the recycling of materials. For example, the Netherlands uses circular construction methods.

The Netherlands places great emphasis on environmental protection and the recycling of resources. At the initiative of the government and Rijkswaterstaat, the national infrastructure agency, systems such as the National Bridge Exchange and Bridge Bank have been established. In these systems, old steel and concrete elements are inventoried and stored for later reuse or application in other projects. This approach aims to reduce the demand for new raw materials, minimize waste, and achieve economic efficiency. Practical experiences conducted between 2020 and 2025 have shown that reusing existing elements can significantly reduce CO_2 emissions—by up to 60%. For example, old bridge components in the city of Nijmegen were successfully reused in the construction of new structures. Such experiences could also be relevant for Uzbekistan: systematically inventorying existing concrete and steel elements and developing a national strategy for their recycling or adaptation in suitable projects would make a substantial contribution to sustainable development.

While the Netherlands has established systems for inventorying and reusing bridge elements, other countries have also developed their own approaches to enhance ecological efficiency. For example, Switzerland has focused on material innovation and has widely adopted UHPFRC technology. UHPFRC (Ultra-High-Performance Fibre Reinforced Concrete) has been extensively used since 2003 in more than 280 bridge projects. For instance, UHPFRC pavements on the Morge and Dalvazza bridges addressed issues such as cracking and chloride ingress, while the Fruttli Bridge, built using a combination of timber and UHPFRC, achieved reduced weight and a lower carbon footprint. This technology is 3–5 times stronger than conventional concrete, reducing maintenance requirements and significantly lowering CO_2 emissions over the structure's life cycle.

Moreover, in recent years, energy efficiency has become a key focus, and Sweden's experience clearly demonstrates this.

Sweden is implementing a "fossil-free" approach on construction sites. In an experiment conducted in Stockholm in collaboration with Skanska and Volvo CE, electric models of excavators and other machinery were used, achieving up to a 50% transition to electric equipment. This not only reduced the carbon footprint but also decreased noise and local pollution..

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