



## Environmental Impacts of Warehouse Complexes: Analysis of their Influence on Landscape and the Environment

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### Abstract

This article analyzes the environmental impacts arising from the construction and operation of warehouse complexes and their effects on the landscape and the environment. Warehouse complexes are a key component of the logistics chain in modern industry, but their construction and operation can significantly negatively affect the surrounding environment. The article examines various aspects of these impacts, including land occupation, changes in landscape, emissions, and waste management. It discusses options for prevention, elimination, and compensation of negative effects, as well as current legislative and methodological approaches to assessing the environmental impact of warehouse complexes. The aim of the article is to provide a comprehensive view of the issue and identify potential measures to mitigate the environmental impacts of warehouse complexes.

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### Introduction

The construction of warehouse complexes represents an essential part of the logistics chain in modern industry. These complexes play a crucial role in the efficient management and distribution of goods, but they also bring significant challenges in terms of environmental protection. Implementing measures designed to prevent, eliminate, or compensate for negative environmental impacts can significantly minimize their effects, but complete avoidance of adverse effects is not always possible.

Currently, legislative prescribed methodological procedures are often used to assess the magnitude and specifics of the impact of warehouse complexes on the environment. These procedures are necessary for evaluating most large construction projects even before obtaining building permits. The environmental impact of constructions is subject to assessment according to legislation, such as Act No. 100/2001 Coll. on Environmental Impact Assessment (EIA) [1]. Additionally, these impacts can also be evaluated using other methodologies, such as Life Cycle Assessment (LCA), environmental audits, or environmental risk assessment.

The construction of warehouse complexes often affects the natural environment in the landscape, whether through the occupation of large land areas or changes in the landscape. Therefore, it is essential to carefully consider their environmental impact [2].

### Warehouse Complex

A warehouse complex consists of one or more warehouse buildings that provide various related functions, including gatehouses, administration offices, technical, and hygiene facilities for employees. A warehouse facility can be defined as a building, covered space, or uncovered hardened area designed for storage or related activities.

In the case of a warehouse complex comprising multiple buildings, it is necessary to calculate their total built-up area. This area includes the built-up area of connected or related garages, administrative buildings, hardened areas designated for storage and handling, as well as surface parking lots. Unhardened areas within the warehouse complex are not included in this area. Areas of construction site facilities, where materials necessary for project implementation may be temporarily stored during construction, are not considered warehouse facilities.

Warehouse complexes may also include halls, typically located in industrial zones, intended for the construction of empty halls that the investor plans to subsequently lease. Such halls provide flexible space for various storage and logistics needs and are often tailored to the specific requirements of tenants.

An important aspect in assessing warehouse complexes is their environmental impact, which includes

not only the occupation of large land areas but also changes in the landscape, emissions, and waste management. Therefore, it is essential for the construction and operation of these complexes to comply with legislative and methodological procedures to minimize negative impacts on the environment [3].

### Consequences of Construction Activities

Construction activity, essential for societal development and modernization, has a significant impact on the environment, often unnoticed by regular users of buildings. Among the primary negative consequences of construction activity are the consumption of natural resources, energy usage, waste generation, and pollution, significantly burdening ecosystems.

One of the most significant environmental impacts is waste generation, which includes construction materials, remnants of concrete, bricks, wood, and other building components. This waste often ends up in landfills, where it can contaminate soil and groundwater. During construction, air pollution occurs due to dust, chemicals, and emissions from construction machinery, negatively affecting air quality and human health [3].

In addition to ecological impacts, construction activity also has social and cultural implications. Large construction projects can lead to the displacement of communities and changes in traditional ways of life. Urbanization and industrialization can alter cultural landscapes and traditional societal values. Working conditions in construction can often be demanding and hazardous, negatively impacting the health and social well-being of workers.

One of the most serious consequences of construction activity is its contribution to the greenhouse effect and global warming. Greenhouse gas emissions, such as carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>), produced during the production of construction materials, operation of construction machinery, and transportation, contribute to rising Earth temperatures. These climate changes can have catastrophic consequences for humanity and nature, including extreme weather events, rising sea levels, and ecosystem changes.

Overall, construction activity significantly contributes to ecosystem pollution. Chemicals used in construction, such as paints, solvents, and adhesives, can contaminate

water bodies and soil. Air pollution from particulate matter and toxic substances has serious health implications for the population and contributes to environmental problems on a global scale. It is therefore crucial to seek ways to minimize these negative impacts through sustainable construction practices and technologies [4].

### **Ecological Aspects of Warehouse Facilities**

Warehouse facilities are often perceived as disruptive elements in the landscape with a negative impact on the environment. Therefore, technical solutions in their design should emphasize minimizing these negative effects. The goal is to create buildings that not only meet all functional requirements but also minimize environmental impact and are capable of compensating for negative effects with suitable measures.

Warehouse complexes typically consist of large areas designated for storing various types of goods or materials, comprising multiple buildings or halls designed to accommodate and store large quantities of goods. These complexes are equipped with various elements such as racks, pallet racks, conveyor systems, and warehouse management systems, facilitating the organization and arrangement of goods. Thanks to these systems, it is possible to efficiently receive, store, and dispatch goods.

Modern warehouse complexes often utilize advanced technologies and automated systems that increase the efficiency of handling goods and reduce operating costs. These complexes may also be interconnected with other logistic systems such as ports, airports, and road and rail networks, enabling global distribution of goods.

Warehouse complexes vary in their location and size. Some are located near urban centers to enable rapid distribution of goods to local markets, while others are situated in more remote areas and serve as distribution centers for the entire country or even for international trade. The size of warehouse complexes can range from smaller operations covering a few thousand square meters to enormous complexes spanning several hectares.

With the development of new technologies and

logistic trends, new concepts of warehouse complexes emerge, such as so-called "dark stores." These facilities are specifically designed for online sales and direct delivery of goods to customers. Warehouse complexes are key elements in the field of logistics and are crucial for economic growth and prosperity worldwide. Although they may have negative impacts on the environment, properly designed and operated facilities can minimize these impacts and contribute to sustainable development.

To mitigate negative ecological impacts, it is essential to integrate sustainable practices into the design and operation of warehouse complexes. This includes the use of renewable energy sources, efficient waste management, the implementation of green roofs and facades, and the optimization of logistic processes to minimize emissions. Implementing such measures can significantly reduce the ecological footprint of warehouse facilities and support their integration into the natural and social environment [3].

### **Optimizing Storage Spaces for Efficient Operations**

Optimizing storage spaces is crucial for ensuring efficient operations and maximizing the utilization of available space. Each storage space is unique and often contains various architectural elements such as peaks, protruding walls, extensions, and columns. Proper space utilization requires correct segmentation based on the type of stored inventory and the use of suitable methods and warehouse operation concepts.

Efficiently dividing the warehouse into zones and selecting appropriate equipment for each area contributes to significant space and cost savings. Well-planned zoning allows for the efficient use of available space, improves the flow of goods, and increases overall warehouse efficiency. For example, zones can be divided into areas for receiving goods, storage, order picking, and dispatch. Each zone can be equipped with specific equipment such as racks, pallet racks, or automated systems that facilitate the handling and storage of goods.

Proper zoning also minimizes the need for excessive movement of employees and goods, leading to reduced operating costs and increased productivity. However, the more isolated areas exist in the warehouse, the more challenging navigation becomes for

for employees. Therefore, it is important to set the right proportions between different areas and ensure appropriate positioning among them. This approach includes analyzing the flow of goods, identifying key operations, and implementing logistic strategies that optimize the movement of goods and employees within the warehouse.

Another important aspect of optimization is the use of modern technologies, such as automated storage and retrieval systems (AS/RS), which can significantly increase warehouse capacity and efficiency. These systems allow for better utilization of vertical space and reduce the need for manual labor, thereby reducing errors and increasing operational accuracy.

Optimizing storage spaces also involves regularly assessing and adjusting warehouse operations based on current needs and trends. This continuous improvement is crucial for maintaining a high level of efficiency and the ability to respond to changing market demands.

By implementing these strategies, warehouse complexes can achieve significant improvements in efficiency, reduce operating costs, and increase overall customer satisfaction [5].

### Protection of Landscape Character and its Significance

Landscape character derives from the permanent ecosystem regimes and ecological conditions of a landscape, the fundamental natural properties of a given area. Within these frameworks, landscape character is shaped by natural processes (in the case of natural landscapes) or created by human activity and way of life (in the case of anthropically transformed landscapes). Each landscape has its unique landscape character, which is the result of a combination of natural and human factors.

However, not every landscape deserves the same level of protection. Landscape character, representing the natural, cultural, and historical characteristics of a particular place or area, is protected from activities that could diminish its aesthetic and natural value. Interventions in landscape character, especially the placement and permitting of buildings, must be carried out with regard to preserving significant landscape features, protected areas, cultural landmarks of

the landscape, harmonious scale, and relationships within the landscape.

Landscape character is the only legislative tool that can prevent the realization of buildings that, although do not damage protected areas in terms of nature conservation interests, harm the aesthetics of the landscape and its cultural values, negatively impacting observers and inhabitants. Therefore, consent from nature conservation authorities is necessary for the placement and permitting of buildings, as well as other activities that could change landscape character. These details of landscape character protection are determined by the Ministry of the Environment.

Protection of landscape character involves adhering to several principles. The first is the preservation of significant landscape features that contribute to the uniqueness of the landscape. These features may include natural formations, historical and cultural landmarks, as well as traditional agricultural and forestry elements that have shaped the landscape's appearance for centuries.

The second principle is the protection of protected areas and cultural landmarks that have historical and cultural significance. These areas and objects are carriers of historical memory and cultural identity, and their preservation contributes to maintaining continuity and uniqueness of the landscape.

The third principle involves maintaining harmonious scale and relationships within the landscape. This ensures that new buildings and interventions are in line with the existing character of the landscape and do not disrupt it. Harmony in the landscape is achieved through sensitive planning and design that respects existing natural and cultural elements.

Implementing these principles requires a multidisciplinary approach, involving collaboration among experts in ecology, urban planning, architecture, and cultural heritage. It is essential that decision-making regarding interventions in landscape character is based on thorough analyses and considers the long-term impacts on the natural and cultural values of the landscape [6].

## The Importance of Soil Protection and its Current Challenges

Soil is situated at the interface of all components of the environment and is constantly interacting with the lithosphere, water, air, and biota. These mutual influences can have both positive and negative consequences, manifested by changes in ecosystems and environmental problems. Soil protection is an integral part of individual and societal awareness in developed countries, where people realize that any soil pollution leads to loss of life and livelihoods [7].

Soil serves various functions, which can be divided into productive and non-productive, with soil's ecological functions referred to as environmental functions. Productive functions include crop cultivation and food production, while non-productive functions encompass water regulation, biodiversity maintenance, and nutrient cycling. Soil quality is an indicator of the sustainable state of the natural ecosystem. Unfortunately, current trends show alarming deterioration in soil quality.

Degradation processes have reached such intensity and extent that they have become one of the most serious environmental problems. Soil degradation represents reversible and irreversible changes, often caused by human activity, which reduce the soil's ability to fulfill its productive and ecological functions, including biomass production. This process may involve erosion, contamination, salinization, and soil compaction. Soil degradation, along with the effects of drought and floods, contributes to reducing potential incomes in agriculture and significantly affects the eco-social development of the landscape.

Degraded and contaminated soil directly affects the quality of life in residential and industrial areas, with a direct impact on the health status of the population. Soil pollution by chemicals, such as pesticides and heavy metals, can contaminate the food chain and threaten public health. These facts are becoming the subject of discussions at both national and international levels, raising questions regarding soil protection policies, legislative measures, and the implementation of sustainable agricultural and industrial practices.

The importance of soil protection lies in its ability to support life processes and maintain ecosystems,

which are the foundation for human survival and prosperity. Therefore, it is essential to focus on implementing effective strategies and measures to ensure soil protection and restoration. These include techniques such as agroforestry, soil conservation, proper soil resource management, and reducing emissions of polluting substances. These initiatives can contribute to mitigating the negative consequences of soil degradation and promote sustainable societal development [8].

## Soils of the First and Second Categories and Environmental Aspects

Soils of the first and second categories are designated for agricultural purposes and are divided based on their quality and suitability for agricultural production. Structures built on these soils are considered sensitive in terms of environmental and landscape aspects. The construction of such buildings should be carefully considered with regard to soil and landscape protection. Environmental impact studies may be required, and permits for construction may be contingent upon compliance with various measures and restrictions. Soils of the first category have high utility and are considered the best soils for agricultural production. These are typically soils with a deep layer of fertile humus, well-drained, and with sufficient nutrient supply.

Soils of the first category are used for cultivating demanding crops such as cereals, vegetables, fruits, and grapes. Soils of the second category have lower utility compared to those of the first category but are still suitable for agricultural production. These are usually soils with lower humus content and a smaller supply of nutrients. Soils of the second category are often used for growing grass and pastures [7].

## Development of Warehouse Complexes on Brownfields

Developing warehouse complexes on brownfields is highly desirable from a sustainability perspective. Brownfield sites are areas that were previously used industrially or commercially but are now abandoned, degraded, or contaminated. These areas often pose a source of danger to public health and the environment but also offer an opportunity for revitalization and reuse. Warehouse complexes are essential for the efficient and safe storage of goods and materials transported in brownfield areas. Additionally, these

complexes can contribute to economic growth and job creation in the region.

However, when constructing warehouse complexes on brownfields, it's important to consider environmental factors. Brownfields may be contaminated with hazardous chemicals or toxic substances, posing health risks. Therefore, conducting thorough environmental assessments of the area is necessary to ensure that construction is safe and sustainable. Environmental assessments must identify all potential contaminants and propose methods for their removal or isolation. This process is crucial for reducing risks to public health and ensuring that new warehouse complexes do not have a negative impact on the environment.

In planning and constructing warehouse complexes on brownfields, other factors such as infrastructure, transportation accessibility, labor needs, and community relations must also be considered. Well-developed infrastructure and transportation accessibility are key to the efficient operation of warehouse complexes, while access to skilled labor ensures their long-term sustainability. Working with local authorities and the community is crucial for the successful and sustainable development of these projects. Collaboration with local authorities can ensure that construction is in line with local needs and environmental standards, and that projects contribute to the overall development of the region.

Developing warehouse complexes on brownfields presents an opportunity to revitalize abandoned areas and support economic growth while ensuring environmental protection and public health. Utilizing brownfield sites can significantly contribute to reducing pressure on green spaces and promote sustainable development through the regeneration of degraded areas. Given the potential economic and environmental benefits, brownfield revitalization is a strategic step for the future of warehouse complexes and sustainable urban development [6].

### **The Importance and Protection of Water Resources**

Water is one of the most important natural resources essential for the survival of all living organisms. Its availability and quality directly affect human health, the prosperity of ecosystems, and the sustainability

of environmental systems. Water pollution represents a serious problem with numerous negative consequences for the environment and human health.

Water pollution can be caused by various factors, such as industrial waste, the use of pesticides and herbicides in agriculture, the discharge of wastewater from cities, improper waste disposal, and the use of motor vehicles. These activities contribute to the deterioration of water quality and can cause significant damage to ecosystems and human health [3].

Groundwater is an important source of drinking water for many areas, and it is critical to ensure its protection from pollution. Contamination of groundwater can have particularly serious consequences, as these waters are often the main source of drinking water supply.

Surface waters are equally important, and their pollution has serious consequences for human health, plants, and animals. Pollution of rivers and lakes can lead to the death of aquatic organisms, disrupt ecosystems, and cause diseases in people who use these waters.

Therefore, it is essential to take measures to protect the water environment, including the regulation and control of industrial waste discharge, effective wastewater management, and the promotion of environmentally friendly practices. Each of us can contribute to the protection of water resources by minimizing the amount of pollutants that enter the water environment [8].

### **The Impact of Human Activities on Air Pollution and Measures to Reduce it**

Human activities significantly contribute to the formation of atmospheric pollutants, which have negative consequences for the environment and human health. Air pollution is a serious issue that manifests in various ways, such as acid rain, smog, the ozone hole, and climate change.

### **Consequences of Air Pollution:**

**Acid Rain:** Emissions of sulfur dioxide ( $\text{SO}_2$ ) and nitrogen oxides ( $\text{NO}_x$ ) from industrial processes and transportation enter the atmosphere, where they react with water vapor to form acids. These acids return to the ground as acid rain, which damages vegetation, water sources, and buildings.

**Smog:** A combination of pollutants, such as nitrogen oxides, volatile organic compounds, and particulate matter, forms smog, which deteriorates air quality and causes respiratory problems in people.

**Ozone Hole:** Emissions of chlorinated and fluorinated hydrocarbons (CFCs) contribute to the depletion of the ozone layer, which protects the Earth from harmful ultraviolet radiation. A thinner ozone layer increases the risk of skin diseases and eye damage.

**Climate Change:** Emissions of greenhouse gases, such as carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>), cause global warming and climate change, leading to extreme weather events, rising sea levels, and ecosystem disruption.

### Measures to Reduce Air Pollution:

Air pollution is a global problem that affects all of us. It is important to recognize its severity and work together to reduce our ecological footprint. Key steps to protect the environment and improve air quality for future generations include:

**Using Greener Energy Sources:** Transitioning to renewable energy sources like solar, wind, and hydroelectric power reduces reliance on fossil fuels and lowers emissions of harmful pollutants.

**Supporting Sustainable Transportation:** Encouraging the use of public transportation, cycling, walking, and electric vehicles can significantly reduce emissions from cars and trucks.

**Responsible Behavior:** Individuals can contribute by reducing energy consumption, recycling, and supporting policies and practices that promote environmental sustainability.

By adopting these measures, we can mitigate the impact of human activities on air pollution and contribute to a healthier environment [9].

### Emissions

Although warehouse complexes are not direct air polluters, they still contribute to the emissions of certain substances, primarily through the combustion of fuels and the movement of vehicles in parking lots and adjacent roads. During construction, warehouse complexes are a source of dust, and the amount of emissions can be difficult to determine accurately as it depends on various factors such as the construction

period, season, and weather conditions.

Another source of emissions is the temporary operation of construction machinery and freight transport. The transport service of the entire warehouse complex significantly impacts air quality, especially based on experiences from similar construction projects. Deliveries are often concentrated in the morning and afternoon hours, while customer arrivals typically occur during regular daytime hours from 8:00 AM to 8:00 PM.

It is clear that even though warehouse complexes are not primary sources of emissions, their operation and construction have a certain impact on air quality. Therefore, it is important to take measures to minimize these emissions and ensure that the operation of the complexes is as environmentally friendly and least burdensome to the environment as possible [6].

**The Waste Management Hierarchy and its Importance**  
Proper waste management is key to minimizing their negative impact on the environment and human health. The hierarchy of waste management, enshrined in the Waste Act, provides a systematic guide to waste management, emphasizing the preference for environmentally friendly solutions [3].

The first and most preferred option in the hierarchy is to prevent waste. Minimizing waste production includes reducing the consumption of raw materials and energy, recycling and reusing products. Proper storage and handling of materials also contribute to waste prevention. For example, using durable and reusable packaging can significantly reduce waste. The second option is the reuse of waste. Products that are no longer needed in their original form may still be usable. Reuse includes, for example, donating or selling old furniture, clothing or electronics, thereby extending the life of these products and reducing the need for new resources. The third option is recycling, which consists in processing waste into new products.

Recycling reduces the amount of waste ending up in landfills and saves natural resources. Recycled materials such as paper, plastic, glass and metal can be reused to make new products, contributing to a more sustainable economy.

The next option in the hierarchy is energy utilization

of waste. This process involves the use of waste as a source of energy through incineration or other technologies that enable the conversion of waste into heat, electricity or fuel. Energy recovery is suitable for waste that is not suitable for recycling or reuse [3].

The last option is landfilling, which should be considered as the last option for waste that cannot be treated otherwise. Landfilling waste is inefficient and can have negative environmental impacts, including soil and water contamination and the production of greenhouse gases. Compliance with the hierarchy of waste management is essential for efficient and environmentally responsible waste management. Waste prevention, reuse, recycling and energy recovery are preferred options that minimize the negative impact of waste on the environment and human health. Only waste that cannot be processed in any other way should end up in landfills. Implementing these principles can contribute to a more sustainable future [9].

## Conclusion

The construction of large structures, such as warehouse complexes, industrial zones and housing complexes, inevitably brings some negative impact on the environment. However, the implementation of measures designed to prevent, eliminate and compensate for these negative effects can minimize their impact. Nevertheless, it cannot be completely avoided. Currently, legislatively established methodological procedures are used to assess the impact of large constructions on the environment. These procedures are necessary to assess the magnitude and nature of the impact before construction begins. Buildings on lands of the first and second category are generally considered sensitive from the point of view of environmental and landscape aspects. Therefore, their implementation should be carefully considered with regard to soil and landscape protection.

In connection with the protection of agricultural production, a ban on the construction of logistics centers on these valuable lands is being considered. This emphasizes the importance of protecting land of the first and second category. Therefore, an environmental impact study is often required, and a construction permit may be subject to compliance with various measures and restrictions. Overall, it is essential that environmental protection is taken into account as a priority task in the development of infrastructure and large construction projects. Only in this way can we ensure the sustainable and harmonious development of our communities and countries for current and future generations [10].

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