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Island Megalopolises: Tunnel Systems as a Critical Alternative in Solving Transport Problems



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ABSTRACT

A principal difficulty with island megalopolises is the transport problem, which results from limited surface land on an already developed island, on which roads and car parking can be placed. This limitation leads to traffic jams on the small number of roads and to intrusive car parking in any available surface location, resulting in safety issues. The city of Vladivostok is located on the Muravyov-Amursky Peninsula in the Russia Far East region (the Primorsky Krai). This city is essentially the third capital of Russia because of its important geopolitical location. To address the car traffic problems in Vladivostok, and because of the absence of places to build new roads, the city administration has proposed the usage of the beaches and waterfronts along the sea coast in this regard. This decision is in sharp conflict with Vladivostok's ecological and social aspirations to be recognized as a world-class city. It also neglects the lessons that have been learned in many other waterfront cities around the world, as such cities have first built aboveground waterfront highways and later decided to remove them at great expense, in order to allow their citizens to properly enjoy the environmental and historical assets of their waterfronts. A key alternative would be to create an independent tunneled transport system along with added underground parking so that the transport problems can be addressed in a manner that enhances the ecology and livability of the city. A comparison of the two alternatives for solving the transport problem, that is, underground versus aboveground, shows the significant advantages of the independent tunnel system. Complex efficiency criteria have been developed in order to quantify the estimation of the alternative variants of the Vladivostok transport system. It was determined that the underground project is almost 1.8 times more advantageous than the aboveground alternative.

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1. Introduction

In terms of the number of cars per 1000 inhabitants, the city of Vladivostok strongly holds the first place in Russia, with numbers at 520–560 cars, according to different estimations [1]. The restricted carrying capacity of existing highways demands the development of a new road network. Another problem is the lack of parking spaces for motor transport, which results in spontaneous parking on existing highways, and which aggravates the transport problem even more.

During recent years, much has been made of the traffic improvements that took place in connection with the preparation for hosting the Asia-Pacific Economic Cooperation (APEC) summit; at that time, the basic route from the city center to

Vladivostok International Airport was reconstructed and two giant cable-stayed bridges were built. These constructions reduced the stream of cars on the central street, Svetlanskaya Street, and reduced traffic congestion around Lugovaya Square—the most problematic sections of the highway network of the city. However, the improvements that were carried out only partially eased the existing problems.

The transport specificity of the city—that is, its narrow roads, which are not capable of providing the necessary carrying capacity—becomes more complicated by its mountainous relief and its position as an urban territory bounded by an area of surrounding gulfs. In conditions of such dense urban building surface use, the construction of new roads often appears to be impossible. Projects are beginning to appear that make use of the water area of the gulfs; this sharply reduces the infrastructural attractiveness of the territory, depriving the townspeople of places of recreation. All these listed factors demand the creation of new transport

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highways underground by building a system of road tunnels with connected underground parking lots (Fig. 1).

2. Criteria of transport system efficiency

In order to assess the feasibility of accepted designs regarding the disposal of installations that are a part of the urban infrastructure, it is necessary to not only take into account the costs involved, but also the efficiency of the solution with regards to the other priorities of a megacity, such as ecological issues, health and safety, living comforts, and infrastructural attractiveness [2,3].

To estimate the ecological efficiency of tunnel building, it is necessary to analyze the quantity of emissions of harmful substances into the air from motor transport on the city roads in Vladivostok, and to analyze the noise levels of motor transport on city roads.

2.1. Criterion of ecological safety

It is obligatory for the state structures of management and the consideration of economic activities that the state standards regarding the safety of products, works, and services reflect an encompassing view of the life and health of a region [4,5]. We observe the state of the environment in Vladivostok from this position.

2.1.1. Estimation of quantity of harmful atmospheric emissions

Motor transport is the main source of the harmful emissions that are polluting the city's atmosphere. The meteorological agency reports that in the case of Vladivostok, the specific parameters of the dispersion of harmful emissions from motor transport are an additional factor toward the city's environmental decline [6]. This problem is now at an acute level in the main parts of the city.

Emissions from motor transport were 2.015×10^5 t in 2011 (i.e., 47.25% of the total volume of emissions in the region) [7]. The concentration of exhaust fumes at traffic signals and in residential areas is especially high. At peak times at locations such as crossroads, traffic jams form, cars consume oxygen, and the atmosphere is saturated with exhaust fumes. In the city of Vladivostok, rush hours occur in the morning, when adults leave for work and take their children to school or daycare, and in the evening, when they return home.



Fig. 1. The radial-ring circuit project for a road tunnel system in the city of Vladivostok. (1) Tunnels; (2) underground parking lots.

The monitoring of air pollution, as recorded by the city administration of Vladivostok in 2010, is presented in Table 1 [8]. There is a mid-year concentration of nitrogen dioxide and dust that exceeds the maximum concentration limit by 1.5–2 times.

According to the relevant research, the air basin of the city of Vladivostok is dangerously polluted by nitrogen dioxide, which irritates and frequently attacks the mucous membranes of eyes and lungs. This gas can cause a considerable deterioration in existing diseases of the respiratory system, such as bronchitis and asthma, and can cause infections of respiratory airways to be more easily and quickly spread. Nitrogen dioxide can be seen as a serious health hazard to the population [9]. This situation was dramatically worsened after the road construction for the APEC summit (Table 2).

A feature of harmful emissions underground that distinguishes them from emissions on the surface is that they can be “regulated.” That is, the volatile exhaust gases from cars on the surface are widely distributed, making “catching” them impossible. Regarding gases in a tunnel, their distribution is limited by the tunnel walls, so they can feasibly be captured because forced air circulation is necessary for normal functioning of the underground structure. On being delivered to the surface, return air will pass through a ventilating fan and can also be directed through air scrubbers, thereby allowing the air to be cleaned and the harmful gases to be neutralized. The quantity of harmful emissions thus decreases.

Another advantage of the road tunnel system is that its use will lead to a sharp decrease in the time spent in a motor vehicle, resulting in a reduction in traffic congestion and increased fuel economy. By a tentative estimation, the quantity of harmful emissions in the atmosphere after the building of a network of road tunnels will be reduced by 8–10 times.

If the degree to which the maximum air pollution concentration levels were met was to be measured both before and after the building of a road tunnel system, a 10-point scale can be applied to understand the tunnel system effectiveness. In this case, 10

Table 1

The general emission of contaminants by vehicular traffic in residential areas of the Primorsky Region in 2010.

Types of transport facilities	Fuel types	Quantity of vehicles	Contaminants (tons)
Cars	Gasoline	479 888	61 562
Trucks and buses with a full weight less than 3500 kg	Gasoline	38 133	31 413
	Diesel	10 895	1 381
Trucks greater than 3500 kg	Gasoline	25 273	54 653
	Diesel	56 864	18 477
Buses with a full weight greater than 3500 kg	Gasoline	1 484	7 723
	Diesel	2 444	1 576
Total		614 981	176 785

1 ton = 907.18474 kg.

Table 2

The general emission of contaminants by vehicular traffic in residential areas of Primorsky Region in 2013.

Types of transport facilities	Fuel types	Quantity of vehicles	Contaminants (tons)
Cars	Gasoline	736 811	94 522
Trucks and buses in full weight less than 3500 kg	Gasoline	29 147	24 011
	Diesel fuel	8 097	1 027
Trucks greater than 3500 kg	Gasoline	17 618	38 100
	Diesel fuel	39 641	12 880
Buses in full weight greater than 3500 kg	Gasoline	1 982	10 316
	Diesel fuel	3 264	2 106
Total		836 560	182 962

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