UNITED NATIONS CENTRE FOR HUMAN SETTLEMENTS
(HABITAT)

STATE COMMITTEE OF THE RUSSIAN FEDERATION FOR
CONSTRUCTION, HOUSING AND MUNICIPAL ECONOMY
(GOSSTROY OF RUSSIA)

REGIONAL PUBLIC FUND TO ASSIST IN THE DEVELOPMENT
OF A LINEAR TRANSPORTATION SYSTEM

SUSTAINABLE DEVELOPMENT OF HUMAN SETTLEMENTS AND IMPROVEMENT OF THEIR COMMUNICATION INFRASTRUCTURE THROUGH THE USE OF A STRING TRANSPORTATION SYSTEM

Final Report on the UN Centre for Human Settlements (Habitat) project: FS-RUS-98-S01

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Introduction

Materials presented in the Final Report cover the project activities carried out within the framework of the international project of the United Nations Centre for Human Settlements (Habitat) on theme: "Sustainable Development of Human Settlements and Improvement of their Communication Infrastructure through the Use of a String Transportation System", FS-RUS-98-S01 during the 1999-2000 period by the professional team of the Regional Public Fund to Assist in the Development of a Linear Transportation System (Moscow).

The project activities were carried out in compliance with the Project Document of the UN Centre for Human Settlements (Habitat) and the Government of the Russian Federation signed on 24 September 1998 by Dr. K. Toepfer, Under Secretary-General, Executive Director of the UNCHS (Habitat) and Mr. I.A.Yuzhanov, Minister of the Russian Federation for Land Policy, Construction, Housing and Municipal Economy.

The aforementioned Project Document was prepared in accordance with the Programme of Cooperation between the UN Centre for Human Settlements (Habitat) and State Committee of the Russian Federation for Housing and Construction Policy for the 1998-1999 period and in pursuance of the "Federal Comprehensive Programme for the Development of Medium-size and Smaller Towns of the Russian Federation under the Economic Reform" approved by the Resolution of the Russian Federation Government of 28.06.1996 No. 762 and Federal Target Programme: "Socio-economic Development of Resort City of Sochi up to the Year 2010" approved by the Resolution of the Russian Federation Government of 30.04.1997 No. 511.

Upon the Instruction of Gosstroy of Russia responsibility for the Project management was placed on the President of the Regional Public Fund to Assist in the Development of a Linear Transportation System (hereinafter as "Fund"), author and patent holder of a principal "String Transportation System" scheme, Academician of the Russian Academy of Natural Sciences Mr. A.E. Yunitsky.

The coordinating activities connected with the project implementation on the territory of the Russian Federation were carried out by Habitat Executive Bureau in Moscow. The project activities were performed by the working team including the staff of the Fund with the involvement of professionals from "Yunitran" Research Centre (city of Gomel, Republic of Belarus), Centre for the Development of Mountainous and Climatic Resort "Krasnaya Polyana" (city of Sochi, Russian Federation), "Yunitran-Sochi" Fund to assist in the development of string transportation and a number of specialised agencies of Moscow, Sochi (Russia), Minsk (Republic of Belarus), Simferopol (Ukraine).

Project Goal and Objectives

The goal of the Project is to provide an alternative to the mass-scale motorisation of human settlements as the key factor contributing to their sustainable development and to formulate the basic criteria for the promotion of the proposed string transportation system (STS) under conditions of intensive transportation flows both to serve the needs of urban settlements with 100,000…200,000 populations and to handle interurban and interregional freight and passenger trips of 100,000 passenger/day and 100,000 tonnes/day intensity under difficult geographic and climatic conditions. In this case it was proposed to identify the ways for STS testing in terms of its economic, environmental and technical components, travel comfort and safety and to develop and test building technologies for different high-speed route alternatives (for a city, sea, mountains).

Furthermore, the Project tasks included evaluation of the Project in terms of its investment attractiveness, optimisation of costs entailed in a track structure, supports and transportation modules production and estimation of material consumption necessary to build 100 km of a STS route.

The Project further envisaged analysis of transportation communications development trends and generalisation of the relevant available national and international experience to be used as a basis for the formulation of strategy, priorities and mechanisms enabling practical realisation of environmentally sound high-speed STS transportation both in the city of Sochi and in other regions having similar geographic and climatic conditions and facing similar transportation problems.

The Project activities will make it possible to collect the initial data (socio-economic, transportation including transportation alternatives and indicators, and land use data) and to prepare a feasibility study. High investment attractiveness of the Project and a detailed feasibility study are factors contributing to the implementation of the next stages of the Project which envisage construction of a high-speed transportation infrastructure in the city of Sochi with the financial support provided from the resources of national and international investors.

To carry out the Project activities a site located in Sochi Region within the Black Sea coastal zone of Caucasus was selected. Its communication infrastructure experienced a serious environmental crisis caused by heavy transportation pressures. The Region of Sochi is served by the airport, marine passenger port with 10 port facilities, 9 railway stations and numerous motor transportation enterprises. In addition, the city area is crossed by the national transit highway Novorossyisk - Batumi - the major motorway arterial on the coast.

Sochi airport is capable to handle the total of 0.7 million passengers per year. Annually more than 3 million passengers make use of railway stations and additional more than 100,000 passengers are travelling by the long-distance buses served by bus terminals. Taking into account the fact that the city of Sochi is a large recreation zone of Russia its intra-city motor transportation carries more than 150 million passengers every year (with the city population being less than 400,000 residents).

Existing city transportation modes and first of all cars are the major source of noise and air pollution in Sochi. One of the ways to address transportation problems of the city is associated with the construction of a high-speed string transportation system to be capable to carry passengers and freights to any destination along a 95 km route "Sochi - Adler - Krasnaya Polyana - Engelmanovy Polyany" within short travel times of 20…25 minutes which will contribute to the development of Sochi as an international centre of tourism, recreation and sports.

The Project strategy will be of actual assistance for the City Administration in the preparation of "Transportation" section within the "Federal Programme for City Development up to the Year 2010" and formulation of Plan of Actions. It will also give recommendations on how to promote and put into practice environmentally sound high-speed transportation communications in other countries.

In compliance with the Project Document the following actual outcomes were produced in the course of the Project performance:

1. The sphere of a STS application was investigated and formulated with due regard to geographic and climatic conditions.
2. Working meeting was arranged with the participation of Habitat representative and interested organizations with its major focus on the project expertise, discussion of problems related to the construction of a principally new high-speed transportation system and negotiation of joint actions of partners.
3. Plan of future actions to promote practical implementation of the project was negotiated with the City Administration of Sochi.
4. Computerised data bank and information supply system was formed to support all project participants.
5. Comprehensive set of the key urban transportation indicators for the city of Sochi was proposed and alternative transportation solutions were evaluated.
6. Methodological guidelines were formulated to facilitate implementation of the programme focused on sustainable development of transportation communications through the use of a STS in the city of Sochi and other relevant regions of Russia and other countries.

As far as no actual experience in the development of a string transportation infrastructure have been available either in Russia or in other countries of the world, the project outcomes could be of practical use in the formulation of guidelines for the promotion of a STS in other regions of Russia and in other countries. For this purpose the city of Sochi was taken as an example to collect the initial data for a feasibility study and design works, to analyse various layout alternatives with a high-speed track coming within the city boundaries, along the sea and mountains and to choose an optimal alternative. A feasibility study will make it possible to evaluate technical, economic, environmental and other STS advantages as compared with other existing and future high-speed systems and to identify the sphere of the Project application taking into account geographic, climatic, demographic and social factors.

Part 1. Organisation of the project activities

In order to facilitate the Project performance the following agreements were signed:

- Grant Agreement between the UN Centre for Human Settlements (Habitat) of December 18, 1998 and the Fund (Appendix 2).
- Agreement on Share Investment of the Habitat Project FS-RUS-98-S01 of July 1, 1999 with the City Administration of Sochi (Appendix 3).

Financial support to the Project by the UNCHS (Habitat) has been effected since January 19, 1999. Actually, the first payment specified by the Agreement as the starting condition for the project activities was received by the Fund on January 28, 1999, which means that until that time all works for the Project were paid exclusively from the Russian resources.

In November 1998 Habitat Executive Bureau in Moscow organised a meeting to discuss the Project with the invited representatives of City Administration of Sochi, Department of Transportation and Communications of Moscow, Gosstroy of Russia and research institutions of Moscow and Minsk. The Meeting made the following recommendations: to hold an international seminar in the city of Sochi in March-April 1999 with the participation of a representative from the Habitat Headquarters and to formulate the project strategy with its subsequent expertise to be made by the relevant UN subdivisions. It also gave recommendations on how to arrange negotiations with the city authorities in Sochi in order to provide the necessary premises, equipment, technical and administrative assistance and financial support to the Project from the Russian side.

The project activities for the investment project "String Transportation System (STS)" in the city of Sochi were started in 1997 when the City Administration of Sochi issued its resolution of September 10, 1997 No. 628 "On Inclusion of Investment Programme 'String Transportation Systems (STS) of A.E.Yunitsky' in the Federal Target Programme 'Socio-economic Development of Resort City of Sochi up to the Year 2010". The Resolution noted important advantages of a large-scale application of a principally new high-speed STS for the economic and social sphere and planetary ecology as compared with conventional modes of transportation. Therefore, "Yunitran-Sochi" Fund was recommended to act as a contractor in the preparation of a pilot STS project for the route "Sochi - Adler - Krasnaya Polyana - Engelmanovy Polyany". Upon a pilot project completion, Department for Architecture and Town Planning under the City Administration was requested to prepare the relevant legal documents to support a STS design and construction.

In its letter of October 16, 1998 No. 02-35,2-7599 addressed to Under Secretary-General Dr. K. Toepfer the City Administration of Sochi confirmed its commitments for the project financing during 1998-2000 (together with Habitat) in the amount equivalent to USD 135,000. It was also indicated that the city of Sochi had already made its partial contribution to the project works including: choice, topographic survey and marking of STS routes, provision of other materials for the pilot project, salary for professionals of budgetary sphere, provision of motor vehicles, helicopter, working premises for researchers, designers, logistics. Furthermore, according to the resolution of City Administration of Sochi No. 628 of September 10, 1997 a land plot was allocated for a STS route of 99 km length including infrastructure which is considered as financial security and share participation of the City Administration in the given programme.

At the preparatory stage of the Project the following tasks were completed: negotiations with the key actors involved in the project for sustainable human settlements development; analysis of possibilities and ways for the project implementation and application under concrete conditions; formulation of activities to be carried out at the preparatory and initial stage of the project; distribution of roles among the local project participants and evaluation of resource requirements; estimation of possibilities and amounts of international support to the organisation and implementation of the project activities.

From 20 to 22 April, 1999 the UNCHS (Habitat) mission to Russia took place including: Mr. Braian Williams, Expert of Building Infrastructure and Technology Division, Mr. V.K.Storchevus, Director of Habitat Executive Bureau in Moscow. Working Meeting arranged in the city of Sochi discussed the issues related to the Project performance and its future promotion. The Working Group meeting was attended by the Project managing staff, representatives of Sochi and Krasnodar Region Administration, senior officials of research and scientific institutes from Moscow, Nizhny Novgorod, Minsk, Simferopol, Sochi, representatives of wide public and mass media. Among the Meeting participants there were also 10 design and research institutes, 12 design firms, 8 public non-commercial organizations.

The Meeting discussed the outcomes obtained at the first stage of the Project and investigated the possibilities for attracting potential investors. On the whole the first stage was positively evaluated. Also discussed were prospects for a STS testing ground construction "Sochi - Adler - Krasnaya Polyana -Engelmanovy Polyany".

It was noted that the Project orientation, objectives and implementation instruments are of practical interest not only for Russia but for other countries in which high growth rates in the number of cars and other transportation means could produce a negative environmental impact. The Project Manager was also recommended to attract additional sources of external aid including organizations within the UN system such as UNIDO, UNEP, World Bank.

The Project staff took as a guiding principle one of the initiatives proposed by the UN Centre for Human Settlements (Habitat) which proceeds from the Habitat Agenda and envisages continuous monitoring to promote efficient planning for sustainable development and wide use of Internet and other information tools for management purposes.

During the whole period of the Project performance the project staff maintained regular working relations with the representatives of the UN Centre for Human Settlements (Habitat), received from the Centre methodological guidelines and advice which was of great help for the working team.

Progress reports on the project activities were submitted to the UNCHS (Habitat) quarterly. Final Report for the year 1999 was submitted in January 2000.

In the course of the project performance the following information was collected and analysed: background information on the condition of ground transportation complex in the industrially developed and developing countries; development prospects of high-speed transportation modes (such as high-speed railways and trains on a magnet suspension); impact of transportation on environmental quality and sustainable development of human settlements.

Data collected for the city of Sochi included: statistics and transportation indicators reflecting environmental quality, economic and social processes and their dynamics during the last decade. As a result, the information collected was used to form computerised data bank.

The Project activities were carried out in close cooperation with population and authorities of the city of Sochi and Krasnodar Region.

Their ideas, assessments and critics of shortcomings were analysed and summarised to be included in the relevant sections of the work plan and Programme of sustainable socio-economic development of the resort city of Sochi implying the use of a string transportation system. In many respects they were used as a basis to propose future steps towards the implementation of the long-term sustainable development policy of human settlements.

It should be noted that as a result of systematic active collaboration of the Project staff with the public and officials of Sochi during the whole performance period it was possible to outline a number of concrete projects that are discussed in the final section of the Report.

The Project staff is grateful to all active participants of the project activities for their assistance without which it would not be possible to fulfil the project tasks at the required level.

The Project staff expresses its special thanks to the staff members of the UN Centre for Human Settlements (Habitat) Executive Bureau in Moscow and its Director Mr. V.K.Storchevus for the efficient and useful guidance of the project activities.

Part 2. Role of transportation in socio-economic development of human settlements

2.1. Globalisation and urbanisation

It was only less than one hundred years ago that as little as 5% of the total population of the globe lived in cities (2% of them – in large cities with more than 100,000 residents) and only one city – London – had more than 1 million inhabitants. Today one in two citizens of the Planet is an urban resident (75...80% of urban population is concentrated in the most highly industrialised countries such as England, FRG, the Nertherlands, USA), ¼ of urban residents is concentrated in large cities; the number of million-cities is more than 300 (against 12 in 1900, 43 in 1940 and 88 in 1960). In the recent time urban population was growing at the rates which were twice as high as the growth rates of the Earth's population as a whole.

Current urbanisation processes are characterised not only by the quantitative growth of cities but rather by their qualitative transformations which result in the emergence of giant metropolitan areas or clusters of cities with numerous populations in various parts of the world. They are sprawling over many thousands of square km to absorb neighbouring settlements and to form giant urban agglomerations and urbanised areas that in certain cases are stretching for 1,000 km and more. Thus, a vast urbanised zone was formed on the Atlantic coast of the USA (as a result of amalgamation of agglomerations of Boston, New York, Philadelphia, Baltimore and Washington). It covers an area of 150,000 sq. km and has 40,000,000 population. At the end of the century the USA formed three giant urbanised areas: Boswash (Boston-Washington), Chipits (Chicago-Pittsburgh) and Sansan (San Francisco-San Diego) with 80, 40 and 20 million population, respectively. One of the largest world conurbations – Tokkaido – is under formation on the Pacific coast of Japan as a result of amalgamation of agglomerations of Tokyo, Yokohama, Kyoto, Nagoya, Osaka and Kobe which concentrates 60 million population (half of the total national population). Enormous multi-million agglomerations were formed in FRG (Ruhr), England (London and Birmingham) and the Netherlands (Randstad Holland), etc.

Researchers who study current urbanisation processes note the growing role of integrative factors and a wide-scale sprawl of urbanisation formerly limited by city area to spread over rural areas and society as a whole. The most important material product of modern urbanisation is a large urban agglomeration, a cluster of urban settlements linked by a variety of intensive links to form a complicated dynamic system. It is expected that as a result of further widespread of scientific and technical revolution an urbanised area could grow into one of the most advanced type of future population distribution pattern, a kind of agglomeration of agglomerations.

Urbanisation structures of the highest territorial level – urban agglomerations, urbanised areas, group urban settlement forms are characterised by general strengthening and deepening of interactions between the settlement pattern and natural environment. Since in our days the area covered by these nature/urban environment interactions is very large the growing urbanisation process gives rise not only to their further strengthening but rather to the involvement of vast inter-settlement areas in this process including recreation zones, engineering and technical corridors, etc. Emergence of group population distribution patterns manifests a new stage of urban/nature relationships. Local forms of urban/natural environment interaction typical for autonomous cities, as a rule, led to the spot-like deterioration of environment and degradation of a relatively small marginal natural belt around the cities. Group settlement patterns widely spread in the 20th century and especially in its second half are characterised by different forms of interaction with natural environment, in particular, local forms gave way to the regional patterns which brought about deep changes in the natural environment under the impact of heavy man-induced loads concentrated and spread over vast areas.

Urban agglomerations and urbanised regions are areas in which natural environment is exposed to deep transformations caused by man-induced activity including intensive replacement of natural biocenoses by urbo- and agro-cenoses. Diversified human activities aimed at nature transformation go far beyond the limits of the built-up area itself to affect all natural environment components. Thus, the impact of physico-geological transformations of soil, ground water and other lithogenous components is felt within 25...30 km radius depending on concrete conditions whereas the impact of biogeochemical environmental transformation is spread over larger areas. As seen from the research data the influence zone of large cities and especially urban agglomerations in terms of their environmental impact exceeds their own radius by 50 times. Urbanised environment produces the heaviest impact on soils, water bodies and vegetation cover. It was also noted that in addition to the so-called natural extreme zones (Arctic, Antarctic, etc.) modern economic activities and urbanisation give rise to the generation of a sort of artificial extreme zones, first of all large cities and agglomerations.

The most general criteria used to evaluate the scale of man-induced pressure on natural environment within the urbanised zones include: size of a city or agglomeration, residential and development density, economic profile (mix of industries, development of sanitary and resort functions, etc.). Naturally, an urbanised area is characterised by worse environmental qualities if agglomeration cores are located close to each other to result in the "overlapping" impact of man-induced pressures whereas in case of one agglomeration there will be a single impact.

All the above said shows that urbanised communities act as very powerful sources of nature disturbance and degradation. Great man-induced loads concentrated in the large cities and urban agglomerations, irreversible disturbance of their water and land regime, primitive and negligible scope of biological productivity of urbo-biocenoses result in the situation when even in the settlements well provided with the necessary improvements and greenery the rate and pace of man-induced impact will be always higher than the natural environment ability to adapt to the above impacts.

In order to prevent a wide-spread penetration of this negative effect it is necessary to bring into balance all natural environment components and environment as a whole, i.e. to facilitate regeneration of clean water, air, soil and vegetation cover, individual landscapes, ecosystems and biocenoses.

At the same time in a wide sense urbanised and natural environment are opposite but not mutually exclusive notions that share one important common feature defined by the social essence of a man – "large city and virgin nature" are two poles of modern biosphere equally necessary for a man. However, in spite of this fair statement under the current progressive growth of population and production there is a variety of polar approaches and interpretations of the role of urbanisation in biosphere evolution and urban/nature relationship.

Firstly, it is a widespread negative attitude to urbanisation as a process hostile to live nature. This approach reflects position of environmentalists-"alarmists" who see no other way to save the natural environment but to curtail production, to stop the growth of large cities and stabilise population number, etc.

Secondly, there is another less known and diametrically opposite opinion that urbanisation is rather an instrument to safeguard nature than to destroy it. In this case urbanisation is regarded as a progressive process aimed at the overall development of society and nature; urbanisation potentials are highly evaluated; excessive urbanisation and search for the ways to neutralise urbanisation consequences in the ecological sphere are regarded as evil thoughts.

Both positions seem to be too straightforward reflection of professional interests and could not be used as a comprehensive approach to the solution of the problems in town planning sphere.

A new approach is necessary with its focus on the provision of conditions enabling promotion of non-traditional development patterns and aimed as much as possible to reduce pressures on the natural environment. This could be achieved through the development of advanced technical instruments, first of all, in the field of communications and in this case a string transportation system (STS) could provide this possibility.

2.2. Role of transportation in city development

Cities are the global financial, industrial and communication centers which concentrate a variety of cultural values, political life, enormous production, creative and innovation potential and they will retain their role in future. At the same time cities became great sources of poverty, violence, overloaded communications and constantly deteriorating environment. Densely populated urban areas are characterised by unstable consumption patterns, high concentration of industries, intensive economic activities, great number of cars and inefficient system of wastes disposal and recycling. All these factors provide the evidence that the major problems of the future will be posed by cities because it will be the cities that will concentrate the main problems in the field of ecology, raw material, energy and demography.

The main reason why cities came into existence was the need in transportation accessibility. Access to places of employment, educational, health and cultural centres, mass public recreation and entertainment facilities, development of physical contacts between people were the motives which brought together in one place at first thousands and then millions of people. That was the way cities were started. Spatial image of early cities was formed by a pedestrian, then in the course of centuries it was replaced by transportation vehicles – at first horse-driven, then in the 20^{th} century – railways (including tram and underground) and cars (including bus and trolley-bus). Historically, it was transportation communications and their infrastructure that formed the spatial image and spatial framework of modern cities and megalopolises.

It was the need in transportation accessibility that gave rise to the super high concentration of residential and industrial developments, people and their related material and energy flows, heat and gas exchange in the present day urban areas. It resulted in deterioration of natural plant communities, impoverishment of fauna, transformation of micro-climatic, geological and hydro-geological characteristics of lands, absolute numerical domination of man and maximum man-induced transformations of indigenous landscapes. Already today up to 50% of all population diseases in the urban areas could be referred to "city-generating" causes. First of all they include diseases resulting from congested living conditions, air and water pollution, noise, vibration and electromagnetic radiation.

On the other hand, unsatisfactory condition of a transportation network leads to the disturbances in the normal economic performance, production decline in the related sectors of economy, unjustified crop losses, limited access to raw resources, reduced job opportunities, increased prices of goods and services, lower quality of life, lower possibilities for education and cultural development, environment degradation, difficulties in disaster mitigation, restrictions for the development of foreign trade and tourism, increased death rates of population.

Taking into account an important role the transportation communications play in the life of future generations of citizens it is necessary to form the spatial image of future cities on the basis of new transportation technologies and urban development concepts.

2.3. Existing and future modes of transportation

In the course of the Project performance comparative analyses of the existing transportation modes was made with a view to evaluate their advantages and shortcomings.

1. Railway transportation. From the time of its emergence in the 18^{th} century more then 1 million km of railways were build all over the world. Under the present conditions the cost of 1 km of a railroad is estimated at USD 3…5 million and more, the cost of 1 passenger carriage – USD 1 million, and the cost of electric locomotive – USD 10 million. Railways construction is very material intensive including metal, reinforced concrete, gravel requirements. The volume of earth excavation works amounts on the average to about 50,000 cub.m/km. Land requirements are estimated at more than 5 ha/km. Under difficult geographic conditions there is a need in unique structures such as bridges, viaducts, elevated roads and tunnels which results in the increased construction costs and negative environmental impact.

In addition to noise, vibration and other types of pollution it makes its contribution in hydrosphere contamination (washing of equipment, rolling stock and its nodes in the course of operation and repair). Polluted water contains petroleum products, alkalis, detergents, phenols, salts of heavy metals, fertilisers, toxic chemicals and many other organic and inorganic substances. In Russia railway transportation consumes more than 1 billion cub. m of water every year. The volume of wastewater generated by railway transportation enterprises ranges from 200 to 4,000 cub. m per 24 hours.

2. Motor transportation. There are more than 10,000,000 km of roads built all over the world and more than 1 billion cars manufactured. The cost of a modern highway is USD 3…5 million/km and more; land requirements amount to more than 5 ha/km; the volume of earth excavation works is more than 50,000 cub. m/km. The cost of an average statistic car is about USD 15,000, the average weighted speed – 60…80 km/hour. Motor transportation became the major source of pollution in cities and urban agglomerations. Its exhausts contain more than 10 carcinogenic chemicals and more than 100 toxic substances. The source of environmental pollution and depletion is associated both with auto transportation itself and its road and engineering structures, service facilities, especially storage facilities for petroleum products, filling and technical service stations, washing and other facilities giving rise to environment degradation within the adjacent areas.

Construction and operation of embankments and depressions of highways result in the degradation of woodlands caused by swamping or dehydration of neighbouring lands.

According to the data of the World Health Organisation (WHO) more than 900,000 people are killed annually through road accidents, several millions become handicapped and more than 10,000,000 are injured. Research proved that super motorisation would bring modern cities to a deadlock.

3. Aviation. It is the most environmentally hazardous and energy consuming mode of transportation. In terms of its toxicity a modern jet liner could be comparable with 5,000…8,000 cars and its oxygen consumption for fuel combustion is equal to that necessary for breathing of more than 200,000 people. Regeneration of the equal amount of atmospheric oxygen will require several thousands hectares of pine forests or even a larger ocean plankton area. Summary atmospheric emissions of modern jets reach 30…40 kg/100 passenger/km. The bulk of aircraft emissions is concentrated within the area of airports, i.e. in the vicinity of large cities when the planes are flying at small heights and re-heat their engines. At low and medium heights (up to 5,000…6,000 m) nitrogen and carbon oxides remain in the atmosphere for several days after which they are washed away as acid rains. At upper heights aviation constitutes the only source of pollution. Noxious substances remain in the stratosphere much longer for about one year. The cost of a modern airliner is as high as USD 100 million, while construction costs for a large-scale international airport exceed USD 10 billion.

4. High-speed railways (HSR). Maximum travel speed is 400 km/hour, average operating speed - 180…200 km/hour. HSR is an ordinary railway road provided with improved and reinforced track structure (rails, sleepers) and cushion (special reinforced embankment and ballast foundation) and special high-speed rolling stock. The cost of 1 km of road is USD10…20 million, the cost of 1 coach - USD 2…3 million. Their environmental impact is heavier than that of conventional railways.

HSR requires noise screening facilities and special enclosures to prevent penetration of cattle and wild animals to the railway tracks which could result in the derailment of trains. HSR embankment creates an insurmountable obstacle for wild animals, surface and ground waters.

5. Trains on a magnet suspension.

5.1 "*Transrapid*" (Germany) with an electric magnet suspension using traditional conductors. For a coach length of 25 m the clearance between the rolling stock and the road structure should not exceed 10 mm, otherwise suspension would not work. Such roads place very high and difficult requirements for their construction and operation. The cost of a road is USD 20…30 million/km, the cost of 1 coach is USD 6…8 million. Construction is associated with high building material consumption (reinforced concrete and steel). Travel speed is up to 500 km/hour. It is characterised by heavy noise at high travel speeds. Energy efficiency coefficient is very low – 13.6%, i.e. slightly higher than that of a steam-engine.

5.2 "*Maglev*" (Japan) - super-conductive magneto-levitating railway road. Coaches are equipped with super powerful and environmentally hazardous super-conductive coils with their magnet field capable to provide suspension at the height of 10…20 cm. Travel speed is up to 500 km/hour. Coils located in a passenger coach are cooled by three cryogenic circuits of liquefied and gaseous helium and liquefied nitrogen. Jump-type losses in super-conductivity could result in coil explosion equivalent to that of several kilograms of trotyl. The cost of 1 km of road is USD 20…30, the cost of 1 coach is more than USD 10 million.

6. Monorail. A wheel cabin is moving along a beam (ALVEG) or under a beam (SAFEGE) which should have a large cross section in order to ensure the cabin steadiness. A system is characterised by high material consumption for span structures and supports. Suspension system results in unfavourable vibration dynamics of a coach and poor aerodynamic qualities. Therefore, monorails are low-speed roads which fail to reach travel speed of 200 km/hour. The cost of 1 km of monorail road is USD 4…10 million.

7. Trolley-bus is used as an urban mode of transportation. It is one of the most environmentally clean transportation modes. It requires hard surface roads and a special infrastructure provided with a feeder line. The cost of a modern trolley-bus is about USD 500,000.

8. High-speed tram. In the recent years is was widespread in the USA, Canada, Europe, South East Asia, Russia, Ukraine. Travel speed is up to 120 km/hour. The cost of routes is USD 3…5. The cost of 1 tram is about USD 1 million.

All the above mentioned modes of transportation have their alternatives. However, analysis shows that existing and future modes of transportation are associated with high costs and environmental hazard, as well as with large land allocations. None of the existing modes of transportation is capable to cope with noise requirements whereas noise protection measures would entail increased costs for high-speed road improvements.

Part 3. Problems of transportation provision for sustainable development of human settlements

3.1. Role and place of transportation in sustainable development of human settlements

High urbanisation rates, concentration of urban population in large cities, urban sprawl and rapidly growing megalopolises are factors which characterise the most important transformations of the image of human settlements. In the 21^{st} century urban areas will have an important role to play in the life of people all over the world to the effect that urban and rural populations become even more inter-dependent in terms of their economic, ecological and social well-being.

Development of communication technologies could have a strong impact on the economic activity and structure of human settlements.

Transportation and communication systems are of the key significance for the circulation of goods and population, information and knowledge exchange, access to the markets, provision of job opportunities, education and other services and land uses both within the boundaries of individual cities and between cities, rural settlements and other remote areas. The lack of convenient, accessible, safe and efficient systems of public transportation has an adverse impact especially on the poorest population groups, women, youth, elder citizens and invalids.

Non-motorised vehicles become the main means of transportation for poor and disadvantaged population groups. One of the structural countermeasures to prevent marginalisation of these groups is to encourage their mobility through the promotion of convenient, efficient and energy-saving modes of transportation.

Within the general context of the present day urban science aimed to solve the problems related to the formation of artificial living environment there is a distinctive sector of activity focused on the human settlements ecology. Transportation sector is one of the major consumers of non-renewable energy and land resources and one of the major sources of pollution, congestion and road and traffic accidents. Unfavourable impact of transportation systems currently in use could be reduced through the implementation of comprehensive transportation and land-use policy and planning. Environmental improvement measures are to be taken with due regard to the negative impact of all modes of transportation and especially car transportation which has been rapidly developing in many industrially developed countries of the world. Interest in the ecological aspect of motorisation demonstrated in Russia is closely related to the accumulated world experience and ever-increasing motorisation rates.

Automobile is capable to respond flexibly to any demand fluctuations for transportation services in various spheres of human activity. Advantages of automobilisation at the present stage of scientific and technological progress are obvious. However, simultaneously adverse environmental impact of automobile becomes more and more evident to grow to the global scale.

Search of ways for the development of automobilisation is closely connected with the need in the in-depth study of its impact on various natural environment components. Environmental impact of cars is the most evident in the urbanised areas. Cities become indicators of favourable or unfavourable car/nature interactions to take upon themselves all negative consequences of automobilisation. Car usage in urbanised areas is accompanied by the atmospheric air pollution, noise, higher morbidity rates of population. Concentration and intensive development of industries create unfavourable background for automobilisation in large cities and industrial centres. Conflicts between environmental quality and automobilisation in industrial zones and their surrounding areas require constant attention to the problems of automobilisation including their growth rates and environmental impact in the course of evaluation and planning for urban development.

In the process of its operation motor transportation generates toxic substances contained in its exhausts, high noise levels, soil and water contamination as a result of fuel and lubricant leakage, dust and other noxious substances which produces an adverse impact on natural environment and human beings.

Sufficient reduction of the atmospheric air pollution with carbon monoxide could be achieved through the improvement of regeneration capacity of urban environment. In this respect one of the main town planning tools to improve regeneration qualities of the natural environment implies expansion of the area of urban lands free from any developments and enrichment of their biomass. However, the town planning practice shows that as motor transportation is further developing it becomes one of the major consumers of vacant urban lands. In the USA annually more than 400,000 ha of non-built lands are allocated for different motor transportation needs including construction of overpasses, roads, garages and parking lots and other road and transportation facilities. In many developed countries automobilisation resulted in non-rational use of urban land resources which hinders biomass development and has a negative impact on its productivity.

One of the reasons of rapidly growing scale of land development is attributed to inefficient development of mass-scale passenger transportation. In particular, the average urban land requirements for various transportation modes per 1 passenger are as follows: 0.9 sq. m – for tram, 1.1 sq. m – for bus, more than 20 sq. m – for car transportation. Therefore, wide-scale impact of public transportation in the cities could provide a reliable basis for the optimisation of urban land use pattern in terms of environmental criteria.

Priority attention is to be given to the reduction of unnecessary trips through the promotion of adequate land-use and communication policy; formulation of transportation policy based not so much on a car usage but rather on its alternatives; development of alternative transportation modes and fuels; improvement of environmental qualities of existing transportation means; implementation of adequate price-formation and other policy and regulations.

Analysis of the use of traditional passenger transportation modes and qualitatively new trends of passenger flow-generation under the influence of motorisation showed that a new approach to traffic organisation is necessary in order to promote its efficient operation. In this respect a module principle seems to be very promising which in the Western literature is known as Personal Rapid Transit (PRT). The essence of the module principle is automatised control of the rolling stock (module) beginning from the request for a transportation service to the moment when the module is free from active operation and removed to its storage place. As passenger flows are growing the modules are automatically combined to make a train. It is possible to use a module principle of traffic organisation within an isolated track structure.

Analysis of practical application of new modes of the high-speed passenger transportation (NMHSPT) showed that the key system parameters (carrying capacity, travel speed, capacity of coaches, etc.) were formed under the influence of concrete application conditions which in some cases resulted in a wide variety of contradicting technical and economic indices. Investigation of wheel-based and contactless systems showed that none of the existing NMHSPT alternatives is capable to meet in full value the necessary requirements.

3.2. Peculiar nature of transportation service in human settlements of resort zones

Under high motorisation rates the growing travel demand for recreation trips to the coastal zones results in the intensive flows of passenger cars to these areas which has a negative environmental impact on the recreation qualities of health resort, recreation and tourist zones. Regulation of environmental pressure caused by motor transportation requires a wide range of town planning, organisational and engineering measures to be taken at the national, regional and local levels with a view, in particular, to slowdown seasonal car usage within the resort zones through the increased competitiveness of mass passenger transportation.

Unique combination of favourable climatic conditions, valuable natural landscapes, historic and architectural heritage are factors contributing to the further increase in holiday-maker flows to the coastal resorts. Location of sea health resorts within the total national settlement system proves their future competitiveness as compared with continental resorts.

Analysis of trip distribution pattern showed that in contrast to the widespread form of auto-tourism accepted in Russia and abroad when the whole origin-destination route of a multi-purpose trip is chosen by a driver in advance in this case the overwhelming majority of drivers coming to resorts from other cities use their cars as a means of transportation to the zone of their long-term recreation. Such holiday-makers stay in the recreation zone during the whole vacation period making intra-zone trips for everyday service, cultural or tourist purposes.

It was assumed that the inflow of recreation car trips was spontaneously generated under favourable development conditions following the established regularities of its qualitative and quantitaive change. Saturation process was regarded as non-regulated with possible self-regulation at certain generation stages.

It was estimated that under the persistence of spontaneously established trends the total annual flow of motorists to certain resort zones could increase by 4…6 times which in terms of recreation zones potentially suitable for rest means that the future car density index (number of cars available simultaneously within a fixed area) will be growing.

Concentration of cars within the coastal zone attracted by its natural landscapes could result in 20...30 times increase in car densities against dispersed motorisation pattern.

Growing motorisation rates and their environmental pressure could result in the disturbance of ecological balance and irreversible environmental processes. Deterioration of adaptation and regeneration capacities of biocenoses and natural landscapes could result in the lower efficiency of the proposed recreation programmes and economic performance of resort zone as a whole.

The survey showed that out of the total 4,295 km of the coastal zone stretching along the warm seas only 109 km are suitable for recreation purposes.

In 1980 dispersed simultaneous load on the coast of warm seas suitable for motorists' rest amounted to 0.423 cars per 1 m of coast. If the same inflow rates persist, the load could increase from 2.629 cars (1990) to 4.576 (2000) cars per 1 m of coast.

In addition to the number of cars coming to the health resort zone from other cities during the "peak" season to stay for a long time there are motorists who live within 2-hour travel distance from the sea and come for recreation (70% in 1990 and 80% in 2000) who were also included in the estimates.

In order to propose a system for the regulation of environmental pressure of cars in health resort areas it is necessary to investigate their specific contaminating impact within the recreation zones because the knowledge so far available is not sufficient.

Growing motorisation rates lead to the growing number of new recreation areas involved in the recreation sphere of motorists. This process is the most evident in southern coastal zones which turned to be unprepared to cope with the rapidly increasing numbers of motorists in terms of their economic structure and recreation facilities which were formed under low motorisation rates. As a result, many sites within the health resort zones of the Crimea, Caucasus, Black Sea coast, Odessa region and Azov Sea are spontaneously developed by motorists for recreation purposes.

Tent camps are constantly re-located from one place to another in the Black Sea coastal zone to increase environmental impact of cars on natural surroundings.

A network of very simple camps established during the "peak" season is capable to meet only 8…11% of motorists' recreation needs. A great supply-demand lag gives rise to the uncontrolled concentration of cars within the coastal zones, woodlands, residential zones of resort settlements and cities. In its turn, it results in environmental pollution, including atmospheric air pollution and increased noise levels, anti-sanitary conditions, higher risks of road accidents. Conflict situations occur in the traditionally established resort and recreation economy of coastal zones. The lack of coordination in the organisation and planning of various recreation sectors leads to the overloading of existing network of cultural and everyday service facilities, provision of basic and other services.

Practical implementation of planning and design solutions aimed at the development of recreation economic activities within the coastal zones is hindered by the difficulty to bring into harmony motorists' needs and the recreation profile specified for the site by medical zoning. The situation is aggravated by a contradiction in the evaluation of the role and place of motorists' recreation facilities within the Black Sea coastal zone. The lack of a scientifically-based approach to practical organisation of motorists' rest gives rise to growing conflict between motorisation and recreation environment of resorts.

Analysis of regional schemes and master plans of individual resorts shows that whereas the project documents give a full picture of territorial and recreation resources of recreation and tourist zones, they make no provisions for a gradual transition from the existing built-up environment to the future economic and recreation development scheme of the coastal zone including the estimated investment requirements for new recreation facilities for motorists. No proposals are either made to promote the development of new coastal areas and optimal use of recreation resources. As a result the following situations occur: a detailed or master plan envisages comprehensive development of a resort zone, however, higher motorists' demand for recreation necessitates uncontrolled construction of recreation facilities for motorists (for example, in settlements of Yevpatoria, Saki, Planerskoye, Rybachye, Solnechnogorskoye, etc.).

Uneven development, lack of scientifically grounded concept to integrate a land use zone proposed for motorists' recreation and a recreation profile of the site, uncontrolled construction of recreation facilities are factors responsible for the negative environmental impact, including:

- lower adaptation and regeneration capacity of natural resort complexes involved in the sphere of active motor transportation impact including: deterioration of vegetation cover, trample of grass, destruction of root system of plants, contamination of natural environment with inadequately utilised garbage, car wastes, salts, slime, etc.;
- atmospheric air pollution with waste gases of cars producing a negative impact on biocenoses and recreation qualities of resort zones as well as on human beings as the major component of natural environment;
- acoustic pollution as a result of growing car flows which comes into conflict with the recreation processes in the resort zones;
- dissonance in the operation of health resort economic activities caused by seasonal inflow of cars resulting in sharp increase in seasonal load on service facilities,

increased risks for transportation and pedestrian movement within the recreation zones, obstacles in visual perception of natural landscapes caused by parking lots and roads.

At the same time there are good examples of town planning and ecological organisation of motorists' rest in other countries with coastal recreation regions which managed to provide wide recreation opportunities for motorists.

In this respect it is interesting to note planning and design experience of France with its wide coastal network of recreation facilities for motorists (Languedoc - Roussillion and Aquitania). The basic principle used for the project design was to regulate the planning pattern through spatial distribution of a network of highways and parking facilities. As opposed to the hinterland the road network of a coastal zone has a linear-stripe configuration following the distribution pattern of resorts and adjacent agricultural lands along the sea coast.

The main arterial is laid, as a rule, parallel to the coastal line with a number of coastal towns and settlements strung on it to link them with a network of continental roads and recreation facilities in the form of "a glove" or "a rake". The main road is used mostly for economic and everyday service needs and partially for recreation trips which has an impact on its spatial distribution in relation to the coast. Thus, in case of Languedoc - Roussillion the road was laid 2…15 km away from the sea shore and in Lion bay it was 20…30 km away from the sea. The difference in the road layout was first of all attributed to the different ratio of economic/everyday service and recreation trips. For areas with predominantly industrial and agricultural traffic hinterland distribution of roads is typical whereas in areas with predominatly recreation trips the roads are laid close to the shore line.

Cross-axial road links and their carrying capacity are planned to "filter" traffic flows coming to the resort and recreation zones so that only car flows for recreation purposes were admitted.

Growing motorisation rates pose serious problems in the field of practical planning and design for motorists' recreation and first of all the need to consider the ecological aspect of the problem.

International experience in spatial planning of recreation networks for motorists shows that very often planners come across the need to eliminate noxious environmental impact of cars coming to the recreation zones. Alongside with the need to reduce local impact of cars on the natural environment (such as tramping of grass, destruction of root system of trees, contamination of meadows and beaches of lakes and seas, atmospheric air pollution and deterioration of natural values caused by dynamic intervention of man) it is necessary to address the problem as a whole because motorisation of recreation zones often results in deterioration of biological balance.

Feasibility and efficiency of methods aimed at the regulation of negative environmental impact of cars, as a rule, depend on a possibility to propose the ways for rational use of recreation resources. In this case maximum permissible concentration of cars (MPCC) within a concrete recreation area estimated as the number of cars per 1 ha of land was taken as a criterion to measure the scale of resource use and the degree of environmental impact of cars.

Search for a MPCC implies analysis of a natural complex in terms of its resistance to the impact of cars. No similar research have been done in recreation aspect, therefore, it is only possible to provide general evcluation of favourable or unfavourable biosystems of a resort zone.

Favourable biosystem is characterised by adaptation and regeneration qualities, i.e. capability to regenerate its resources which is especially important for recreation landscapes. For such systems a MPCC index will be always in dynamics. An ideal situation implies growing adaptation qualities and capacity of a biosystem under the maximum load dynamics.

Favourable biosystem should meet the following requirements:

- stable capacity to maintain the recreation qualities of resourt resources. It could be achieved through flora/fauna balance (not including "technological" production) which implies a great number of recreation (oxigen, ozon, heavy ions, iod, etc.) and biomass components and their synthesis in the proportions favourable for human health recovery. Participation of "technological" component including motor transportation processes is to be very tactful so that not to disturb adaptive capacity of biocenoses and to maintain stable possibility for recreation;
- stable capacity to maintain the recreation qualities under high productivity, i.e. stable recreation efficiency. It creates prerequisites for a quick compensation of recreation losses under the impact of cars within the whole range of other impacts. Compensation capacities of southern and northern coastal resorts would be different;
- high stability of recreation qualities under a wide-scale impact of motor transportation on the resort structure as a whole and on its individual components. In other words, ecosystem of a resort zone is characterised by a high degree of "interference-suppressing", on the one hand, and stable recreation qualities in the process of adaptation, on the other hand. Dynamic balance of biocenoses provides the best opportunities for maintaining favourable hydrological regimes of lands, gaseous composition of atmosphere, etc.;
- ability to remove motor transportation contaminating components during the natural recovery cycle;
- high "reserve activity", i.e. highly stable recreation efficiency and stability of ecosystem which contributes to maintaining optimal biocenoses condition under motor transportation impact.

Estimates show that in the nearest future a seasonal component of passenger flows coming from the hinterland to the coastal resorts will be constantly growing. It could come into a more serious contradiction with the existing organisation of traffic within the mass recreation zones on the coast. The use of traditional transportation modes with electric traction under seasonal operation conditions becomes inefficient. Transportation practice of resort zones shows that when the "peak" of recreation trips is going down and the rolling stock is relieved from operation there is a problem of drivers' re-orientation and placing in a job in other sectors of economy.

Indirectly, organisation of recreation is related to the rational land use and environment management within the recreation areas. In town planning terms the problem could be solved through spatial segregation of resort and residential land uses and removal of human settlements from coastal zone to the hinterland regions. This, in its turn, will result in the increased travel distances of population commuter and cultural and everyday trips. For example, in the Crimea the length of population trips could increase to 40 km and more. Conversion of traditional transportation modes to the high-speed operation regime will make it possible to increase this distance maximum to 14.5 km within 45-minute transportation accessibility which does not meet in full value population distribution requirements of resort zones.

Comprehensive study of problems related to the use of traditional modes of transportation in the Crimea made it possible to identify specific conditions for the use of high-speed transportation on the key recreation traffic directions. It was also estimated that under the established passenger transportation tariffs additional subsidies will be necessary to serve all these trips. The basic conditions are as follows:

- town planning: rational spatial gaps between resort and residential zones; maneuverability while laying the routes under difficult geographic and ground conditions; optimal land-use within the recreation areas;
- transportation: rational operation of the national economic complex of coastal zones under intensive development of recreation sector; flexible response to changing transportation demand; safety of transportation and pedestrian movement; comfort of travel;
- economic: minimisation of capital investments in transportation construction; minimisation of operational costs;
- environmental: conservation of recreation qualities of coastal zones; minimal adverse environmental impact; minimal permissible negative human impact.

Proposed application sphere of new high-speed modes of passenger transportation aimed to cope with seasonal component of intra-resort traffic and to create regulated motor transportation zones should meet the following transportation requirements:

- to satisfy transportation needs within the future spatial distribution network of human settlements and resorts located in the southern coastal zone it is necessary to have transportation capable to provide a standard travel distance of 40…45 minutes in serving commuter trips of local residents. For this purpose its technical speed should be 150 km/hour;
- in technical terms transportation is to be capable to overpass the slopes within the range of 50…350% under difficult relief conditions of the Crimea. Minimal horizontal and vertical curve radius is 15 m and 20 m, respectively;
- all transportation system components and their operation conditions should meet the existing and future environmental safety requirements including travel safety and protection of recreation qualities of coastal areas. Summary atmospheric air pollution should not exceed maximum permissible level, internal (in a saloon) and external noise should not exceed the level of 30 dbA and 40 dbA, respectively; vibration load – 3 Hz, land consumption per 1 km of road – 500 sq. m;
- traffic organisation should flexibly respond to passenger flow fluctuations within the range of 1 to 40,000 passengers per 1 hour and to maintain considerably high travel comfort. In this case the cost of 1 km of road in its standard design should not exceed 1 million roubles (not more than 50,000 roubles for tunnel design not including finishing). Operation costs per 1 km should not be more than 50,000 roubles per year;
- all constituting components including a transportation vehicle and its track structure should meet the present day architectural and aesthetic requirements of resorts.

3.3. Analysis of existing communication infrastructure in the resort city of Sochi

Efficient transportation service is of vital importance for the attraction of holiday-makers and, consequently, for the economic development of Sochi as a resort. Furthermore, in the recent years existing transportation node of the region acquired additional significance as a conveniently and closely located centre for handling intensive cargo flows coming to Russia from various foreign countries including Turkey, Syria, Egypt, etc. In the nearest 10 years formation of a counter-flow of exported freights from Russia is expected.

Sochi Region has all basic modes of arterial and urban public transportation. Their operation indices are given in Table 1.

Table 1

Mode of transportation	Unit of measurement	Year 1985	1990	1991	1992	1993	1994	1995
Volumes of passenger traffic in Sochi Region								
Road transportation, including intracity	Mln. pass.	189.7	228.8	214.7	144.7	141.0	127.0	125.0
Railway*	Mln. pass.	2.6	4.0	3.3	3.1	3.6	3.3	2.8
Air	Mln. pass.	1.9	2.3	2.0	1.3	0.2	0.7	0.6
Sea	Mln. pass.	1.9	1.6	1.2	0.2	0.2	0.1	0.1
Volume of transported freights in Sochi Region								
Road transportation	Mln. ton.	6.4	8.1	7.0	4.0	2.3	1.4	1.2
Railway*, including:	Mln. ton	1.9	2.1	1.9	1.5	1.3	0.9	0.9
Unloading	Mln. ton.	1.9	2.1	1.8	1.4	1.2	0.8	0.8
Loading	Mln. ton	0.02	0.03	0.08	0.09	0.1	0.08	0.08
Air, total, including:	Thous. ton.	17.3	19.0	20.9	16.5	13.1	18.2	19.5
Unloading	Thous. ton.	15.2	16.5	17.9	13.0	9.9	15.0	16.0
Loading	Thous. ton.	2.1	3.0	3.1	3.5	3.2	3.2	3.5
Sea, total, including:	Thous. ton.	308	293	20	124	80	70	95
Unloading	Thous. ton.	308	293	20	124	80	70	95
Loading	Thous. ton.	0.01	0.01	0.01	0.01	0.01	0.01	0.01

*The figures given refer only to Sochi station

Transportation problems of Sochi are conditioned by a specific pattern of passenger and freight trip-generation in the resort zone. During pre-crisis years the peak volumes of passengers carried by arterial roads were 2.5…3 times larger than the annual average volumes. One-time population during the summer months increased by 2.5…3 times against the number of permanent residents. Seasonal irregularities in the distribution of traffic volumes required reserve capacities to handle in- and out-flows of passengers, orientation of city public transportation to the development of a flexible (in terms of the number of the rolling stock) component – bus service. In this respect difficult ground features of the site contributed to the development of bus transportation. The greatest volumes of holiday-makers are carried by the nationwide transportation modes including railways (78%) and aircraft (17%). A certain share of passenger trips is handled by motor transportation, in particular, individual cars, and sea vessels (5%).

During pre-crisis years the key transportation development tasks in Sochi Region were focused on the construction of air terminal facilities in the airport of Sochi; reconstruction of nation-wide highways; maintenance of operational efficiency of motor transportation and its provision with new rolling stock; sea port renewal.

Construction of two runways in Adler airport made it appropriate practically for all types of aircraft including "aerobuses". However, the estimated carrying capacity of the air terminal (0.5 million passengers) was not enough to handle the annual flows of 2…2.3 million passengers and first of all the growing seasonal loads. Therefore, in 1988 construction of a new airport complex was started in Sochi airport estimated for the carrying capacity of 2,500 passenger/hour. 90% of the project was completed, however, during the last 3 years its construction rates were very low because of the lack of finances.

Problems arising in the course of road construction are associated with mountain relief of the site. The only highway in the South Caucasus - "Djubga - Adler" is passing through the city centre of Sochi and in the presence of transit flows to Georgia and Armenia it could give rise to unfavourable transportation and environmental situation. Federal motor road service of Russia is taking further steps for the construction of by-pass roads in Sochi and Adler and construction and renewal of "Adler - Krasnaya Polyana" highway. Though this transit flow is currently absent, Ministry for Motor Roads started construction of the first stage of a by-pass road and preparations for the reconstruction of Dagomys - Tuapse highway with the financial support provided by Federal Road Foundation. Road construction costs in this region are 3-4 times higher than on the plain.

Citywide passenger transportation of Sochi includes only one mode – bus. The number of the rolling stock per 1,000 population is twice as large as the Russian average. However, most buses are in need of replacement or withdrawal from operation during the coming 2…3 years.

The lowest flow of holiday-makers was registered in 1995 which was 1.9 times less than in 1990. During the next years the volume of intra-city traffic was growing to reach 144 million passengers per year (during the last 4 years the growth amounted to 12%). At the same time the volume of intra-city freight traffic was going down. For example, in 1999 it was estimated at 570,000 tonnes which was 2.1 and 12.3 times less than in 1994 and 1990, respectively.

The city of Sochi has no large-scale industries, therefore, in spite of considerable drop in the volume of intra-city traffic the level of atmospheric air pollution was mainly attributed to motor transportation emissions. According to the data of City Transportation Department of Sochi its motor transportation is responsible for 97% of carbon monoxide and 92% of nitrogen oxide emissions in the summary pollution. Contribution of car transportation in noise and soil contamination amounts to 90…95%.

Federal Target Programme "Socio-economic Development of the City of Sochi up to the Year 2010" envisages the growth in the tourist flow from 2.3 million in 2000 to 3.2 million and 4.2 million persons in 2005 and 2010, respectively, with the city population estimated at 380,000 inhabitants. The programme further envisages development of a mountain-climatic centre "Krasnaya Polyana" located on the mountainous plateau at the altitude of 600…2,400 m and at 40…50 km distance from Sochi airport and railway station. Ski routes, tourist and excursion paths of Krasnaya Polyana are estimated for carrying capacity of 20,000 visitors per day or 30,000…60,000 visitors (maximum 100,000) during the large-scale competition events. In this case taking into account unique natural and climatic conditions of the region comparable to those of the mountainous resorts in Switzerland, France or Austria and their environment vulnerability access of freight traffic to the resort area will be restricted and passenger cars will be prohibited. Existing highway Adler - Krasnaya Polyana is proposed to handle a passenger flow up to 2,000 passengers per 24 hours and a fright traffic flow of 300,000 tonnes per year. It is expected that during the construction period (5 years) the volume of freight traffic will amount to about 2 million tonnes per year.

Reconstruction of a sea trade port of Sochi was started in the late 1980s. It is proposed to expand passenger service space, to repair and extend mooring wall. This project completed for about 90% was stopped in the recent 3 years because of the lack of finances.

In the Region of Greater Sochi there are practically no freight-absorbing and freight-generating industries except the city infrastructure, building and food industry and public catering facilities.

Drop in the number of visitors coming to the city of Sochi for recreation in 1995 resulted in the reduced volumes of passenger flows carried by railway and air transportation by 1.5 and 3.8 times, respectively, against the 1990 levels. Consequently, the volume of freight traffic carried by motor and railway transportation dropped by 6.8 and 2.5 times, respectively.

The region location close to Turkey, Syria, Egypt and availability of all modes of transportation were factors contributing to the emergence of a new transit flow of freights and passengers. In spite of stable growth trends observed in 1995 it was possible to compensate as little as 5% of 1990 traffic losses. At the same time air transportation managed to maintain its freight traffic efficiency at the 1990 level.

Sea port and airport are not actually provided with appropriate freight loading and unloading capacities, special equipment, storage and other freight handling facilities.

Thus, it is possible to single out the following key problems related to transportation system financing in the region of Sochi:

- availability of capital-intensive unfinished projects intended for the provision of seasonal recreation trips;
- deteriorated rolling stock and first of all for motor transportation registered in the Region;
- unpreparedness of the transportation system to cope with a transit flow Turkey – Georgia – Russia, in particular, loading and unloading of freights by air transportation;
- environmental damage caused by automobile transportation.

Part 4. String Transportation System (STS)

4.1. Condition of the Russian transportation network and development of a STS

Transportation system of Russia includes more than 600,000 km of highways with hard surface, more than 160,000 km of railways, more than 210,000 km of gas pipes and about 100,000 oil pipelines. According to the estimates in order to meet the national economic requirements and to solve social problems it is necessary to have at least 2 million km of roads which means that Russia is in need of about 1 million km of roads.

Under conditions of Russia with its Siberian frosts, heavy snowfalls, marshlands, permafrost, taiga, tundra, mountains and other problems the use of conventional methods of road construction, repair and maintenance to fill the gap in 1 million km seems practically unrealistic because all these works require colossal material and financial resources and not less than 100 years for their implementation.

Thus, a principally new transportation is necessary which will be characterised by the lower costs and material consumption and will be easily integrated in difficult climatic and geographic conditions. It will be possible to build a more extensive network of transportation communications at the same material and financial expenditures.

4.2. Principal STS scheme

Fig. 1. Single-track STS route.

STS is a pre-stressed linear cable and beam structure along which special electric modules of 5,000 kg freight or 20-passenger carrying capacity are moving (Fig.1). Electricity supply is effected through the wheels which are in contact with the current-carrying heads of special rails. In case an autonomous power supply system is used the rail head and, consequently, the track structure as a whole will be dead.

The basis of each transportation system is a transportation line along which freight and passenger transportation modules are circulating. As a rule, such structure is very material-consuming (for example, a motor road bed, rail track, bridge, tunnel, earth embankment, etc.) and its construction costs identify the total cost of the whole system. Therefore, it is important to ensure efficient use of physical and mechanical qualities of materials used for the transportation structure.

A scheme was calculated in which all elements being in shear are characterised by unique qualities: under the tensile strength load the structure is capable to bear additional load whilst remaining unbroken.

A string turned over two blocks and loaded to the ultimate strength by stress T (Fig. 2,a) is not destroyed even under an additional load in the middle of a span $P < 2T$ thanks to a deflection Y_c (Fig. 2,b).

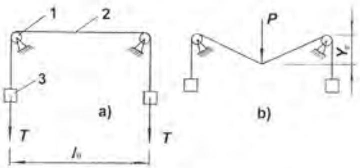

Fig. 2. String block system:
a) without external load; b) with a load; 1 - block; 2 – string;3 – load.

It is possible to transform this structure to get a linear scheme stretched to a longer distance (Fig. 3) in which moving supports *3* will function as blocks and instead of the loads of weight *T* a string is stretched by stress *T* and fixed in rigid supports *4*.

Analysis of the above schemes shows that at $P < 0.03T$ stresses in a fastened string (Fig. 3,b) will be only by 1% higher than in a block-operating string (Fig. 2,b) even if there is one load P in each span (as in the first case). The difference will be even less if the load on a string is lower. In the engineering calculations this difference can be neglected and both schemes could be regarded as identical. At $P < 0.01T$ the difference becomes negligibly small – less than 0.1%.

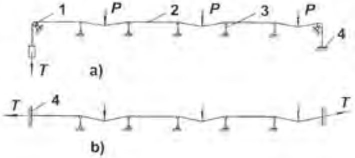

Fig. 3. String linear scheme:
a) with a block at the end of a string; b) with a string sealed off; 1 – block; 2 – string; 3 – swing support; 4 – fixing (anchor).

The scheme can be used as a basis for designing new transportation lines (STS transportation) and modernisation of conventional bridges and overpasses (highway and railway bridges).

A string transportation system is a long-stretched structure extending for thousands of km. Its characteristics such as safety, durability, maximum travel speed, construction and operation costs, etc. will depend not only on the design of its individual components but rather on their linear layout. Fig. 4 shows the most typical layout alternatives for a track coming along a plain, mountain and sea site.

A string track structure *1* is placed on the supports subdivided into three types: intermediate (supporting) mast *2*, anchor *3* and breaking *4* support. Supports are installed at distances of l_0 = 10…200 m, l_a = 1…5 km, l_m = 0.2…1 km, respectively. The distance between the supports depends on building technology, relief of the site, materials used for load-bearing construction elements and, especially, a string, operation conditions, mass and estimated travel speed of a transportation module, tensile strength of a string and other factors.

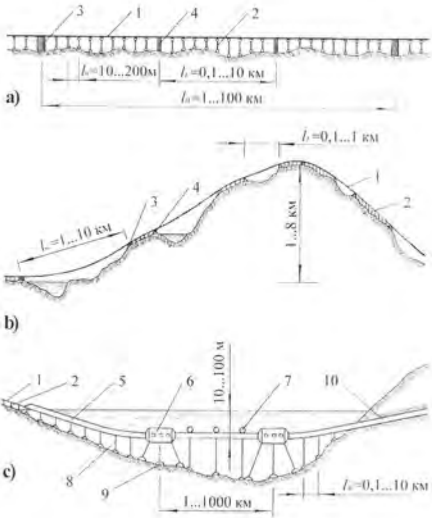

Fig 4. Linear STS scheme:

a) plane section; b) mountain section; c) marine section; 1 – string track structure; 2 – intermediate (supporting) mast; 3 – anchor support; 4 – braking support; 5 – pipe-tunnel; 6 – underwater float station; 7 – supporting pontoon; 8 – anchor thrust; 9 – anchor, 10 – underground tunnel.

On the main sections of a STS, i.e. sections between the supporting masts with l_o length, a track structure has no deflections because a static deflection Y_c of a string *3* is placed ("concealed") inside the structure. The load including the weight of a track structure and a transportation module is transmitted to a string through a layer *4*, the height of which is changed from zero (above the support) to a maximum value Y_c (in the middle of a span). Therefore, in a static condition a rail head *5* along which the wheels of transportation modules are moving has an even surface without any deflections or joints. It is possible to design a STS with a working surface of a rail head in the form of a wavy line (Fig. 5,b). Its shape is a mirror image of a straight line *8* of a dynamic deflection U_d of a track structure at the moment when a transportation module is passing. As a result, a span structure is descending to line *8* and in each instant a module trajectory is a straight line.

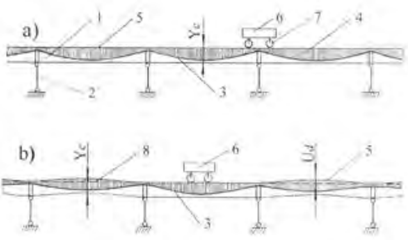

Fig. 5. Longitudinal section scheme of a string track structure:
a) track structure without deflections; b) track structure with anti-deflection; 1 – track structure; 2 – intermediate support; 3 – string; 4 – filler of variable height; 5 – rail head; 6 – transportation module; 7– wheel; 8 – straight line.

4.3. Engineering, technological and operational aspects of a STS

The basis of a STS track structure is provided by strings made of high-strength steel wires each of 1...5 mm diameter; wires are assembled in a bunch and put with a deflection inside a hollow rail (Fig. 6). Instead of wire it is possible to use a high-strength steel band.

A rail is installed in such a way that after the strings have been fixed by filling a rail cavity with solidifier (based on cement, bitumen or epoxy resin) a rail head remains ideally smooth. Therefore, a head along which a wheel of a transportation module is moving has neither deflections or joints along its whole length. Strings and rails are rigidly fastened on anchor supports. Under the structure weight a string deflection, for example, at 5 mm is possible in the following cases: tensile strength – 100...500 tonnes, span length – 25...50 m, mass of a rail track – 50...150 kg per 1 running meter. Such deflections are easily concealed ("enclosed") inside a hollow rail of 15...20 cm height.

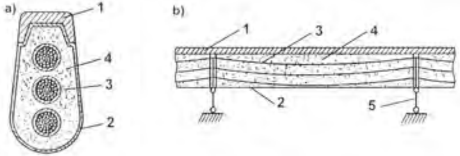

Fig 6. Design of a rail-string:
a) cross section; b) longitudinal section; 1 – head; 2 – body; 3 – string; 4 – filler; 5 – supporting mast.

STS design envisages that intermediate supports are exposed to a predominantly vertical and insufficient load of 25 tonnes for a span of 50 m. It is similar to a load on the supports of a high-voltage electricity transmission line which makes both structures close in terms of their design and material consumption (Fig. 7).

Fig 7. STS route on high supports (about 100 m)

Along the whole length of a track only two terminal anchor supports are exposed to maximum horizontal loads (one-way load) in the amount of 1,000 and 500 tonnes for a dual- and one-way track, respectively. Out of the total number of anchor supports 90% are intermediate (or technological) anchor supports. They are not exposed to great horizontal loads in the process of operation because both loads are counterbalanced.

Fig. 8-9 shows design alternatives of a low-rise support (10…20 m height).

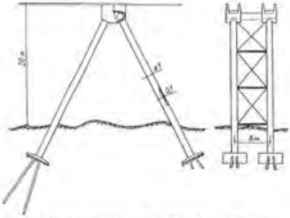

Fig 8. Anchor support of a dual-track STS route.

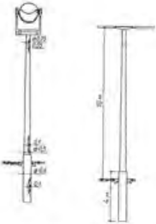

Fig 9. Intermediate support of a small-height single-track STS route.

String and rail have no deformation joints along the whole length and their operation scheme under temperature change is similar to that of a telephone cable, electricity transmission line or hanging bridge installed on the supports with deflection and stretching without joints for many kilometers. Rail is made as a dismountable-assembled structure. The estimated temperature drop is 100 °C which occurs once in 100 years in countries with sharp continental climate (and, in particular, in Siberia and Far East of Russia) or in the mountains. For sub-tropic and tropic zones the estimated temperature drop is by 20…50 degrees lower.

Wire used for a STS string is manufactured by the present day industries for steel cables (with maximum strength of 250 kgf/sq. mm) of pre-stressed reinforced structures and guy rope and hanging bridges. Steel used for rails of railway roads in terms of its physical and mechanical qualities is suitable for a rail-string head. STS is designed as a very rigid track structure. For example, at 50m span an absolute static deflection of a track under the load of 5,000 kg concentrated in the middle of a span will be as little as 12.5 mm or 1/4000 of a span length. For comparison: modern bridges including those for the high-speed railways are estimated for a permissible relative deflection of 1/400, i.e. tenfold higher. Dynamic deflection of a STS track under a moving load will be lower – up to 5 mm or 1/10000 of a span. Such track will be more even for a wheel of a transportation module than, for example, a bottom of a salt lake where, as you know, at the end of the 20^{th} century a car for the first time reached a sonic speed of 1,200 km/hour.

Speed limitation in a STS is associated rather with aerodynamic qualities than with the evenness and dynamics of a track and "wheel + rail" friction contact. Therefore, special attention in a STS was given to its aerodynamic qualities. It was possible to get unique results having no analogues in modern high-speed transportation including aviation. Aerodynamic resistance coefficient of a model passenger vehicle (scale 1:5) measured in a wind tunnel amounted to C_x=0.075 (Fig. 10).

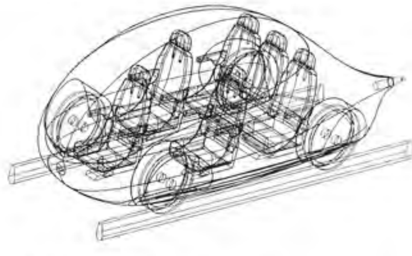

Fig. 10. Design alternative of a high-speed 6-passenger vehicle

Appropriate measures were proposed to reduce this coefficient to C_x=0.05…0.06. Low aerodynamic resistance makes it possible for a 20-passenger vehicle to reach the travel speed of 250…300 km/hour, 400…450 km/hour and 500…550 km/hour with the engine power of 80 kWt, 200 kWt and 400 kWt, respectively. In this case mechanical and electromechanical losses will be insufficient thanks to a high efficiency coefficient of a steel wheel and a motor wheel as a whole amounting to 99% and 92%, respectively.

It is known that as the travel speed increases the wheel-rail cohesion is diminishing. To reach the travel speeds of 300…350 km/hour and 400…450 km/hour a friction coefficient of "a wheel-rail" pair in a STS is to be not less than 0.04 and 0.07 (for 100 and 180 kgf thrust), respectively, which is easily reachable. Cohesion problems arise only at the travel speeds of 500 km/hour and more which require more than 300 kgf thrust. However, this problem is also easily solved. For instance, a principally new scheme was designed for a rubber-covered traction motor-wheel of 100 kWt power which is capable to provide the required cohesion and thrust. However, in the foreseeable future such high travel speeds will not be needed and the most optimal range of STS travel speed within 300…400 km/hour will be enough. In this case it will be easier to ensure higher safety of travel and to reduce energy costs which to a considerable extent affect the cost of travel by any mode of high-speed transportation including a STS. A STS module can be equipped with various types of driving gear implying some alternatives without wheel drive (Fig. 11).

Fig. 11. Transportation module with various drive unit types:
a), d) rotation wheel and propeller drive, respectively; b) motor vehicle; c) linear electric engine; e) gas turbine.

The given classification shows that only one type of driving gear, i.e. linear electric motor can be referred to a purely electric type. In all other cases non-electric drive is possible the use of which will be defined proceeding from environmental, economic or other considerations. For example, in undeveloped or underdeveloped areas (desert, tundra, taiga, permafrost, mountains, etc.) it will be more economically efficient to use transportation modules with internal combustion or diesel engine instead of laying out new power transmission lines to supply a STS.

Availability of two rims (flanges) and an independent ("automobile") suspension at each wheel will considerably lower the risk of derailment for a transportation module which is, for example, the main cause of road and railway accidents.

Module derailment as a result of aerodynamic forces or gusts of side wind is fully excluded which was proved by the wind tunnel tests.

A STS is resistant to the risk of fog, rain, thunder storm, snow, hail (under heavy hail the travel speed can be reduced to avoid damages in a nose part of a module; however, in areas of hail hazard armoured modules can be used), glaze of ice, sand and dust storms, hurricane wind.

STS is more than any other transportation system resistant to natural disasters such as earthquakes, land slides, heavy rains, floods, high water, attack of desert sands. STS routes are not critical to difficult geographic and climatic conditions, they are easy to build in large marshy areas, jungles, permafrost, deserts with drift sands, mountains, sea shelf. For example, at sea depths under 50 m, for example, a STS route put on the supports installed in the sea bottom will pass at 25…50 m height and more on the shelf above the water surface (depending on building requirements).

At greater depths a string track structure can be put in a tunnel (pipe) of 2.5…3 m diameter installed either in the sea bottom (at 500 m depth) or in the water at 50 m depth (Fig.12).

Fig. 12. Design alternative of a marine section of a STS route

In the latter case tunnels have zero buoyancy (or to be more precise – excessive buoyancy) and require anchoring every 1…2 km in the sea bottom. Small module weight (under 5,000 kg) and low circulation frequency (on the average every 1,000 m) prevent tunnel submergence. High deflection rigidity and special tunnel design contribute to the high evenness and rigidity of a string track structure under various travel speeds irrespective of the sea (ocean) depth.

As far as the structural safety of a STS track and supports is concerned it could be comparable with that of hanging or guy bridges as they are very close in terms of design, however, strings of a STS are much better protected from climatic or mechanical impacts than bridge cables.

Key nodes of electric modules (running gear, suspension, drive) and electronic control systems meet the existing requirements set for aviation and high-speed railways. Therefore, on the whole there are no barriers hindering promotion of a STS as the most environmentally friendly, safe and reliable mode of ground transportation capable to comply with noo-sphere approach to transportation system development.

Building technology used for a STS route construction is much simpler than that used for a bridge with a similar span (Fig. 13 - 16).

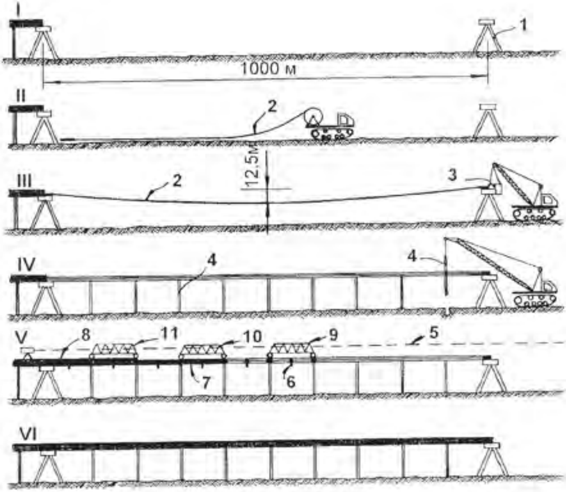

Fig. 13. STS building technology.

1 – anchor support; 2 – cable (string component); 3 – cable adjusting mechanism; 4 – intermediate support; 5 – sight line; 6 – cross plate; 7 – rail envelope; 8 – rail head; 9,10,11 – technological platforms to install cross plates, rail envelope and rail head, respectively; I – installation of anchor supports; II – laying of string cables; III – string adjusting and anchoring; IV – installation of intermediate supports; V – assembly of rail components and track structure; VI – ready track section.

Fig. 14. String tightening on anchor support.

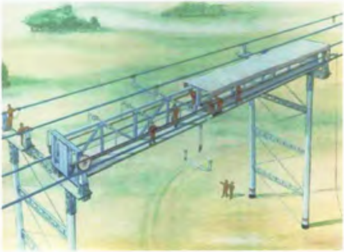

Fig. 15. Installation of intermediate support.

Fig. 16. Technological platform to assemble a string track structure.

Prefabricated string is adjusted to the assigned length with the help of technological devices (with tensile strength used as a control parameter) and fixed rigidly, for example, by welding with anchor supports (in this case not wire itself but its special cap at the end of a string is welded).

Intermediate supports are preliminary installed either in the process of string adjustment or strengthening. When intermediate supports and strings are put in place they are tested by a technological platform capable to move independently and to fix its location against the supports.

Moving from span to span a platform is to specify the whole rail envelope, to fix its designed position, put the filler, set a rail head, cross plates and do other works necessary for track installation. All the above works are easy for mechanisation and automatisation and can be carried out irrespective of weather conditions. All this contributes to higher flow-line construction rates (about 1,000 m per 24 hours), lower labour intensity and net cost.

To eliminate micro-unevenness and micro-waviness of working surfaces of the assembled rail head and its cross gap-free joints they can be grinded away along the whole length. A special combine can be also used to fix a STS string and other stressed rail components which moving along the track on its walking support-legs is to install assembled intermediate supports.

4.4. Technical and economic indices of a STS

Thanks to its low material consumption and high technology a STS route will be cheaper than conventional (3…20 times) and high-speed railways (8…10 times), motorways (3…4 times), monorail (2…3 times), train on a magnet suspension (15…20 times) and, consequently, the cost of travel by a STS will be the lowest amounting to USD 5…10 per 1,000 passenger/km and up to USD 3…5 per 1,000 tonne/km.

Maximum carrying capacity of a dual-way track is 500,000 passengers per 24 hours (about 200 million passengers per year) and 500,000 tonnes of freight (about 200 million tonnes per year).

A STS would provoke a strong price competition with other transportation systems of similar carrying capacity, comfort level and travel speed, etc. The cost of competitive transportation routes built in a plain is as follows: USD 10…15 million/km – for a high-speed railway; USD 20…30 million/km – for "Transrapid" system (train on a magnet suspension, FRG); USD 3…10 million/km – for a motorway; USD 4…8 million/km – for a mono-rail road.

A STS is much cheaper (3…20 times) than other known transportation systems which is attributed to its very low material consumption (including its track structure and supports); and no need in construction of elevated roads, bridges, viaducts, overpasses and other high-cost structures.

Passenger fare is lower compared with other high-speed systems being at the level of a railway ticket in an open-plan carriage. Net cost will depend on a number of factors such as the track cost (amortization costs), maintenance costs, cost of electric energy, intensity of passenger and freight flows, cost of the rolling stock, estimated travel speed, etc.

Average travel cost for passengers (reduced costs minus profit) carried by a STS on a plain at 1,000 distance with the average speed of 300 km/hour is as follows: USD 15…20 (for dual-way passenger flow of 20,000 pass./24 hours), USD 10…15 (50,000 pass./24 hours) and USD 5…10 (100,000 pass./24 hours and more) – Table 2 (with "Moscow - London" STS route taken as an example).

Net cost of freight transportation is low compared with other modes of transportation, though the average running speed accepted for calculations is rather high – 300 km/hour.

Average net cost per 1 tonne of freight to be carried on a plain at 1,000 km distance will be as follows: USD 5…6 (for a dual-way freight flow of 50,000 t/24 hours), USD 4…5 (100,000 t/24 hours) and USD 3…4 (200,000 t/24 hours).

In terms of its design a transportation module is simpler than a passenger car, therefore, under serial production the cost of a module will be at the level of a mini-bus – USD 20,000…40,000 or USD 1,000…2,000 per 1 seat (for a 20-seat electric car).

For comparison, we give the relative cost of the rolling stock in other high-speed systems: aircraft - 100,000…200,000 USD/seat, train on a magnet suspension - 100,000…200,000 USD/seat, high-speed railway - 20,000…30,000 USD/seat.

Distribution of costs in the net cost of transportation is as follows (for travel speed of 300 km/hour):

a) Passenger traffic - track and rolling stock amortization – 65…80%, operational costs - 10…20%, electric power - 5…10%.
b) Freight traffic - track and rolling stock amortization – 45…65%, operational costs - 10…20%, electric power - 25…45%.

Table 2

Proposed travel costs within a STS system:
"Moscow - London (Paris)" - at 2,830 km section ("Moscow - London")

Indicator	Passenger traffic, thousand pass./24 hours			Freight traffic, thousand tonnes/24 hours		
	20	50	100	50	100	200
1. Reduced costs (at 2,830 km section)						
- USD/pass.	72.60	32.71	19.43	-	-	-
- USD/tonne of freight	-	-	-	19.99	16.66	15.01
Including:						
1.1. Total transportation costs, including:	66.47	26.58	13.30	6.65	3.32	1.67
- amortization allocations	25.48	10.19	5.10	2.55	1.27	0.64
- maintenance costs	15.51	6.20	3.10	1.55	0.78	0.39
- profit allocations	25.48	10.19	5.10	2.55	1.27	0.64
1.2. Rolling stock costs:	6.13	6.13	6.13	13.34	13.34	13.34
- amortization allocations;	0.63	0.63	0.63	1.05	1.05	1.05
- maintenance costs;	0.63	0.63	0.63	1.05	1.05	1.05
- profit allocations;	0.63	0.63	0.63	1.05	1.05	1.05
- cost of electric energy	4.24	4.24	4.24	10.19	10.19	10.19
2. Number of vehicles to serve the whole route (at average travel distance of 1,000 km), number of units	1530	3820	7650	19100	38200	76400
3. Cost of the rolling stock, USD million	45.9	114.6	229.5	191.0	382.0	764.0
4. Average distance between the neighbouring vehicles in a transportation flow (single vehicles in one line):						
- Time frequency, sec.	86.4	34.6	17.3	6.9	3.5	1.7
- Distance, km	9.60	3.84	1.92	0.77	0.38	0.19

STS cost differs depending on a number of factors such as: one- or two-way track; on a plain, mountains, sea shelf, tundra, desert; low or high supports, etc. The cost is also strongly related to the infrastructure development (number of terminals, stations, depots, freight terminals, etc.).

The cost of 1 km of an average, well-equipped two-way STS route of serial production will be as follows: USD 1...2 million – on a plain; USD 2...4 million – in the mountains; USD 2...4 on sea shelf above water and USD 5...10 million – in a tube (afloat in the water, on or under sea bottom). In this case the cost of a two-way string transportation line itself (track structure and supports) will be considerably lower amounting to: USD 0.8...1.2 million -on a plain (for average support height of 15...25 m); USD 1.5...2 million – on sea shelf and mountains (for average support height of 35...50 m) and USD 0.5...0.8 million – in a tube. One-way track will be 30...40% cheaper than a two-way road. Tables below show the average material consumption and cost per 1 km (not including the cost of terminals and infrastructure).

Table 3

Approximate average material consumption and cost per 1 km of a two-way STS route laid on a plain (with "Berlin - Moscow" STS route taken as example)

Structural component	Material	Material consumption per 1 km		Approximate cost, thousand USD/km
		Mass, tonnes	Volume, cub. m	
1. Rail-string, total, including:				450
1.1. Rail head	Steel	96	-	190
1.2. Rail envelope	Aluminium sheet	5	-	25
1.3. String	Steel wire	79	-	160
1.4. Filler	Composite	-	45	20
1.5. Glue mastic	Composite	1	-	10
1.6. Protective string envelope	Polymer	4	-	20
1.7. String hydrofuge insulation	Polymer	1	-	10
1.8. Other		-	-	15
2. Cross plates		-	-	20
3. Intermediate supports (15 m height), total, including:		-	-	190
3.1. Poles	Reinforced concrete	-	96	70
3.2. Straight arch and brace	Reinforced concrete	-	46	35
3.3. Metal structures	Steel	10	-	20
3.4. Pile foundation	Reinforced concrete	-	48	48
3.5. Other		-	-	17
4. Anchor supports (15 m height), total, including:		-	-	105
4.1. Support body	Reinforced concrete	-	52	38
4.2. Pile foundation	Reinforced concrete	-	36	36
4.3. Metal structures	Steel	2	-	5
4.4. Anchor fixing	Steel	2	-	10
4.5. Other		-	-	16
5. Excavation and earth moving		-	-	20

Structural component	Material	Material consumption per 1 km		Approximate cost, thousand USD/km
		Mass, tonnes	Volume, cub. m	
6. Rail power supply		-	-	40
7. Control system of supports and track condition		-	-	10
8. Control system of traffic flow		-	-	20
9. Emergency power supply system		-	-	20
10. Traffic flow regulation system		-	-	30
11. Emergency stop platform		-	-	20
12. Design/survey works		-	-	50
13. Cost of land allocation and development		-	-	50
14. Other works		-	-	25
15. Unforeseen expenditures		-	-	50
TOTAL:				1100

Table 4

Average material consumption and cost per 1 km of a two-way sea (above-water) STS route (with "Sochi - Adler" STS route coming along the Black Sea shelf taken as example)

Structural component	Material	Material consumption per 1 km		Approximate cost, thousand USD/km
		Mass, tonnes	Volume, cub. m	
1. Rail-string, total, including:				400
Rail head	Steel	96	-	144
1.2. Envelope	Aluminium sheet	5	-	25
1.3. String	Steel wire	79	-	120
1.4. Filler	Composite	-	45	20
1.5. Glue mastic	Composite	1	-	5
1.6. Protective string envelope	Polymer	4	-	20
1.7. String hydrofuge insulation	Polymer	2	-	10
1.8. Other		-	-	40
2. Cross plates		-	-	40
3. Supporting cable	Steel wire	79	-	160
4. Supporting structure	Steel	32	-	50
5. Intermediate supports (35 m height), total, including:		-	-	380
5.1.Poles	Reinforced concrete	-	94	47
5.2. Straight arch and brace	Steel	34	-	51
5.3. Top structure	Steel	8	-	16

Structural component	Material	Material consumption per 1 km		Approximate cost, thousand USD/km
		Mass, tonnes	Volume, cub. m	
5.4. Underwater support section and foundation	Reinforced concrete	-	175	88
	Concrete	-	259	52
	Steel	24	-	36
5.5. Hydrofuge insulation of underwater support section	Composite	5	-	15
5.6. Painting of above-water structures	Paint	4	-	36
5.7. Dielectrics	Composite	-	-	26
5.8. Other				
6. Anchor supports (35 m height), total, including:		-	-	270
6.1. Support body	Reinforced concrete	-	102	51
6.2. Underwater section of support and foundation	Reinforced concrete	-	92	46
	Concrete	-	204	41
	Steel	26	-	39
6.3. Hydrofuge insulation and painting of structures	Composite	3	-	9
6.4. Metal structures	Steel	12	-	18
6.5. Anchor fixing	Steel	4	-	20
6.6. Dielectrics	Composite	-	-	18
6.7. Other		-	-	28
7. Excavation and earth moving works		-	-	20
8. Rail power supply system		-	-	40
9. Control system of supports and track condition		-	-	20
10. Control system of traffic flow		-	-	20
11. Emergency power supply system		-	-	20
12. Traffic flow regulation system		-	-	30
13. Emergency stop platform		-	-	20
14. Design/survey works		-	-	50
15. Cost of land allocation and development		-	-	10
16. Other works		-	-	50
17. Unforeseen expenditures		-	-	70
TOTAL:				1650

A STS complex includes: stationary facilities (terminals, stations, depot, freight terminals, repair garages, sub-stations, control system, signaling, communication, switching devices) which account for 30…50% of the total expenditures. The share of a track structure and supports amounts to 25…35% (including 15…25% - a track structure and 10…15% - supports). Other costs include: design, adaptation of research and pilot design results including a pilot track section – 5…10%, rolling stock – 5…10%, other expenditures – 10…15%.

Compared with other high-speed transportation systems a STS is characterised by a very low net cost of travel, thus, the fare should be increased to ensure a profitability of 100…200% (which will make it possible to pay back the expenditures during 3…5 years).

The cost of transportation lines is not strongly dependent on the ground features of the site, therefore, it is reasonable to use a STS to develop difficult of access areas such as deserts, marshlands, permafrost, taiga, tundra, jungles, ocean shelf, mountains, etc. For example, if the ground features of a ragged or mountain site require increase in the average support height from 15m for a plain to 50 m on a rugged terrain, the track cost will be increased only by 20…25% because the share of supports in the total system cost is small (10…15%). Cost increase will be approximately the same for a string route passing across marshland area, desert, permafrost, etc, resulting from the need in additional strengthening of supports and piles under conditions of a thick boggy bottom, deep-seated tight layers of sand in a desert, below defrosting ground layer (requiring special pile design).

Key average weighted (for various countries) technical and economic indices of a STS as compared with the existing transportation systems are given in Table 5.

Table 5

Key average weighted (for various countries) indices of transportation systems (passenger flow - more than 1,000 passenger/hour, freight flow – more than 1,000 tonnes/hour)

Mode of transportation	Technical and economic indices			
	Cost of a route including infrastructure, USD mln./km	Relative cost of the rolling stock, USD thous. per 1 seat	Net cost of travel	
			Passenger trips USD/100 pass./km	Freight trips USD/100 tonne/km
1. Railways (up to 100 km/hour):				
• Arterial	2-5	10-50	2-4	1-2
• Local	2 – 5	5-10	2-4	1-2
• city-wide:				
- underground	50-100	5-10	2-4	1-2
- tram	2-5	5-20	2-4	1-2
2. Motor transportation (100 km/hour):				
• individual car:				
- within the city limits (average load of 1.6 passengers)	3-5	1-5	3-5	5-20
- beyond the city limits (average load of 3.5 passengers)	2-5	1-5	3-5	5-20
• bus				
- within the city limits	3-5		2-4	10-20
- beyond the city limits	3-5	5-10	2-3	10-20

Mode of transportation	Technical and economic indices			
	Cost of a route including infrastructure, USD mln./km	Relative cost of the rolling stock, USD thous. per 1 seat	Net cost of travel	
			Passenger trips USD/100 pass./km	Freight trips USD/100 tonne/km
• trolley-bus	3-5	5-10	2-3	10-20
3. Air transportation				
• long-distance (900 km/hour)	0.5-1	100-200	10-20	15-40
• local (400 km/hour)	0.1-0.5	50-100	5-10	20-50
4. Sea transportation (50 km/hour)	0.1-0.5	20-50	2-5	1-2
5. River transportation (50 km/hour)	0.1-0.2	10-20	2-5	1-2
6. Oil pipelines (10 km/hour)	1-3	-	-	0.5-1
7. Gas pipelines (10 km/hour)	1-3	-	-	0.5-1
8. Conveyer transportation (10 km/hour)	2-5	-	-	1-2
9. Hydro-transportation (10 km/hour)	0.5-1	-	-	0.5-1
10. Cable-rope roads (10 km/hour)	1-2	1-2	5-10	2-5
11. Train on a magnet suspension (400 km/hour)	20-50	100-200	2-5	1-2
12. High-speed railway (300 km/hour)	10-20	20-50	10-20	10-20
13. Monorail (100 km/hour)	4-10	20-50	10-20	10-20
14.String transportation**** (passenger - 10 seats; freight - 5 tonnes of freight) at the speed of:				
- 100 km/hour (15 kWt engine power)	1-2	1-2	0.5-2	0.2-0.8
- 200 km/hour (35 kWt engine power)	--//--	--//--	--//--	--//--
- 300 km/hour (90 kWt engine power)	--//--	--//--	--//--	--//--
- 400 km/hour (200 kWt engine power)	--//--	--//--	--//--	--//--
- 500 km/hour (400 kWt engine power)	--//--	--//--	--//--	--//--

* estimated for 1 liter of gasoline=8.78 kWt x hour of electric energy

** route including infrastructure

*** overflow of oil or petroleum products, emission of natural gas, etc.

**** comparison evaluation against other modes of transportation

4.5. Ecological indices of a STS

Key average weighted (for various countries) ecological indices of a STS as compared with the existing transportation systems are given in Table 6.

Table 6

Key average weighted (for various countries) indices of transportation systems (passenger flow - more than 1,000 passenger/hour, freight flow – more than 1,000 tonnes/hour)

Mode of transportation	Environmental indices			
	Specific energy-resource consumption (litres of gasoline per 100 pass./km or tonnes/km)		Noxious emissions kg/100 passenger/km (or 100 tonnes/km)	Land requirements** ha/100 km
	Passenger traffic	Freight traffic		
1. Railways (up to 100 km/hour):				
• Arterial	1.1 – 1.4*	0.7 - 1.0*	Over 0.1	300 – 400
• Local	1.2 – 1.5*	0.9 - 1.4*	--//--	--//--
• city-wide:				
- underground	1.3 – 1.7*	-	--//--	-
- tram	1.9 – 2.1*	-	--//--	50 - 100
2. Motor transportation (100 km/hour):				
• individual car:				
- within the city limits (average load of 1.6 passengers)	4.7 - 6.3	6.6 - 11.1	over 1	200 - 300
- beyond the city limits (average load of 3.5 passengers)	1.5 - 1.7	5.1 - 9.2	--//--	300 - 500
• bus				
- within the city limits	2.1 - 2.3	-	--//--	200 - 300
- beyond the city limits	1.4 - 1.7	-	--//--	300 - 500
• trolley-bus	1.9 – 2.5*	-	over 0.1	200 - 300
3. Air transportation				
• long-distance (900 km/hour)	4.7 - 9.2	51 - 73	over 10	20 - 50
• local (400 km/hour)	14 – 19	152 - 202	over 50	10 - 20
4. Sea transportation (50 km/hour)	17 – 19	0.38 - 0.95	over 10	5 - 10
5. River transportation (50 km/hour)	14 – 17	0.57 - 1.4	--//--	2 - 3
6. Oil pipelines (10 km/hour)	-	0.51 - 0.57	over 1***	50 - 100
7. Gas pipelines (10 km/hour)	-	5.7 - 6.1	over 1***	--//--
8. Conveyer transportation (10 km/hour)	-	4.7 - 9.2*	over 1	--//--

Mode of transportation	Environmental indices			
	Specific energy-resource consumption (litres of gasoline per 100 pass./km or tonnes/km)		Noxious emissions kg/100 passenger/km (or 100 tonnes/km)	Land requirements** ha/100 km
	Passenger traffic	Freight traffic		
9. Hydro-transportation (10 km/hour)	-	2.3 - 4.7*	over 0.1	50 - 100
10. Cable-rope roads (10 km/hour)	0.3 – 0.5*	0.95 - 1.9*	--//--	20 - 30
11. Train on a magnet suspension (400 km/hour)	3.5 – 4.5*	-	--//--	100 - 200
12. High-speed railway (300 km/hour)	2.5 – 3.5*	-	--//--	300 - 500
13. Monorail (100 km/hour)	1.5 – 2.5*	-	--//--	50 - 100
14.String transportation**** (passenger - 10 seats; freight - 5 tonnes of freight) at the speed of:				
- 100 km/hour (15 kWt engine power)	0.17*	0.17*	below 0.01	10 - 20
- 200 km/hour (35 kWt engine power)	0.20*	0.20*	--//--	--//--
- 300 km/hour (90 kWt engine power)	0.34*	0.34*	--//--	--//--
- 400 km/hour (200 kWt engine power)	0.57*	0.57*	--//--	--//--
- 500 km/hour (400 kWt engine power)	0.91*	0.91*	--//--	--//--

* estimated for 1 litre of gasoline = 8.78 kWt/hour of electric power;
** route including infrastructure;
*** overflow of oil or petroleum products, natural gas emissions;
**** estimated by analogy with other modes of transportation.

Therefore, proposed mode of transportation seems to be very attractive in terms of its environmental qualities, in particular:

1. Construction of STS routes does nor require large land allocations (which is 150…200 times less than for highway or railway construction);

2. There is no need in building embankments, depressions or tunnels, cutting of forests, demolition of buildings; a STS is easily integrated into urban infrastructure and environment and is easy for construction under difficult natural conditions with environmentally-sensitive ecosystems including permafrost, mountains, marshlands, desert, water barriers (rivers, lakes, straits and ocean shelf, etc.); in this case operation costs will be lower than at highways or railways;

3. Communication system is characterised by a higher resistance to natural disasters (earthquakes, land slides, flooding, hurricanes), and unfavourable climatic conditions (fog, rain, icing, snow drifts, sand storms, severe heat and cold, etc.).

Only in its outward appearance a STS track structure reminds an elevated road for monorail transportation, highway and railway roads, trains on a magnet suspension. A span of the elevated road is exposed to bending strain. It is designed as a beam structure with the bearing capacity equal to its own weight because the weight of a moving load amounts to 10% of the total mass of the structure. A STS track structure is designed as a rigid thread which combines the qualities of a rigid beam and a flexible cable which contributes to considerable lower material consumption. For example, the mass of a span of a modern reinforced concrete bridge or an overpass of 100 m length is estimated at several thousands tonnes whereas the mass of a dual-way string system of similar length is not more than 30 tonnes. Consequently, loads on the intermediate supports will be lower, thus, it is possible to make them more tracery and to reduce material consumption by tenfold.

Low material consumption results not only in the reduced volume and lower estimated cost of construction works but, what is more important, contributes to the reduced environmental pressure at the stage of transportation system construction.

Construction of a modern multi-lane highway requires more than 10,000 tonnes of asphalt cement per 1 km of road which is to be brought and paved. Each asphalt cement component follows a similar technological chain beginning from the extraction of raw resources to their transportation at thousands kilometers to asphalt cement plants. Each kilometer of a road further entails removal of tens of thousands tonnes of ground with partial or total destruction of tonnes of planted lands. Gravel and sand requirements are estimated at about 10,000 tonnes per 1 km of a motor road. In this case extraction of mineral resources and their transportation at long distances for processing result in the disturbance of natural balance in sites of minerals extraction, routes of their transportation, places of processing and construction of transportation communications.

High energy efficiency coefficient of a STS module (more than 90%), minimal mechanical and aerodynamic losses (aerodynamic drag coefficient C_x=0.08) make it possible to facilitate high-speed, safe and comfort transportation of passengers and freights with energy consumption by 5…10 times less than by a car. For example, fuel consumption (electric energy on conversion to gasoline) by a module of 35 kWt power at travel speed of 200 km/hour is estimated at 0.1…0.15 liter per 100 passenger/km. It is possible to integrate compact stations and terminals in the upper floors or roofs of city buildings which does not require additional land allocations.

Small cross sectional dimensions of a rail-string (100x200 mm) with enclosed energy and information communications including environmentally sound fibre optic lines capable to transmit hundreds of TV programmes and millions of telephone calls contribute to the elimination of other non-conventional pollution impacts such as shadow and visual intrusion of a track.

Low power and electric voltage (about 1,000 V) and the lack of sliding electric contacts make a STS a less powerful source of electromagnetic pollution than a trolley-bus. Damage to nature caused by the proposed communication system will be minimal during the whole lifetime cycle including construction, operation and dismantling after 100 years – an estimated service life for a STS.

Consumption of non-renewable energy carriers (oil, petroleum products, coal, gas), nonmetalliferous, ferrous and non-ferrous metals will be reduced as a result of the following factors:

- very low material consumption for a STS track and supports;
- no need in embankments, depressions, overpasses, viaducts, bridges and other resource-consuming structures.

Environment pollution will be reduced as a result of:

- use of the most clean type of energy – electric energy;
- low specific energy consumption (5…10 times less than by a car);

- cautious attitude to the development of environmentally-vulnerable ecosystems (tundra, permafrost, jungles, marshlands, etc.);
- possible use of alternative environmentally friendly types of energy (wind, solar, etc.).

Withdrawal of valuable lands from agricultural uses will be reduced because string roads do not require large land allocations (less than 0.1 ha/km), construction of tunnels, cutting of forests and demolition of buildings.

Noxious emissions of motor transportation and high-speed railways amount on the average to more than 10 g/pass.-km and approximately 0.6 g/pass.-km, respectively.

Noxious exhausts of a STS are less that 0.1 g per 1 pass./km, i.e. lower than emissions from a high-speed railway, which results from the lack of dust-generating embankments and gravel cushion and lower deterioration of STS rail, wheels and brake shoes.

A high-speed motorway (including segregation lanes, numerous traffic exchanges in various levels such as "clover leaf", acceleration and deceleration lanes, recreation parking facilities, filling stations, etc.) requires land allocation in the amount of 5…8 hectares per 1 km of the road. High-speed railway requires special enclosure on both sides and noise protection screens (which also poses an insurmountable obstacle for wild and domestic animals, agricultural machines, etc.). On the whole these roads require land allocations in the amount of 3…4 ha/km (data of Germany).

Land allocation for modern airports is comparable with the right-of-ways for high-speed railways, however, in this case more valuable lands located in the immediate vicinity of cities are used.

At the same time a STS does not require embankments, tunnels bridges, overpasses and other similar facilities which cover large land areas. One supporting mast and one anchor support require about 1 sq. m and 10 sq. m of land, respectively, thus, alienation area per 1 km of a STS track will be less than 100 sq. m, i.e. 0.01 ha and the width of a conditional right-of-way will be within 10 cm.

STS vehicles will be designed as air-tight, provided with vacuum or chemical toilets to exclude environmental pollution with human vital activity products, garbage and various technological wastes which is to be removed in special garbage collectors in depots. At the same time as seen from the experience a stripe of land along the highways and railways is exposed to heaviest contamination with passengers' wastes.

STS freight containers are designed to exclude leakage of liquid goods (they have no pumps, breech mechanisms, seals, etc. which could be a source of leakage) and spilling of friable freights. Crash could result in derailment of only one vehicle (extreme braking distance of the next vehicle will be less than the distance between two vehicles) with small freight and in this case a parachute is capable to reduce container speed to prevent it from destruction when falling to the ground.

At the same time railway accidents result in the heaviest environmental pollution with tonnes of transported chemical products. Accidents at oil and petroleum product pipelines are often accompanied by atmospheric emissions of thousands tonnes of oil and petroleum products, especially in resource extracting northern regions of Russia characterised by very sensitive eco-system.

A string transportation system (STS) is characterised by environmental safety not only in the course of its operation but at the stage of construction as well. Special technological equipment (technological platforms and building combines) used for its construction does not require access roads as all necessary building materials and components will be delivered to the construction site along already-completed track sections.

Furthermore, piled foundation of supports fully eliminates the need in excavation and earth moving works which could damage the layer of soil with its humus accumulated during millions of years. It is possible to lay a STS along any terrain without any embankments or land excavation whereas, for example, a modern highway or railway requires earth removal in the amount of 10,000…50,000 cub. m per 1 km or 100,000 cub. m per 1 km when passing along a rugged or mountain site. STS is not critical to a span length, therefore, there is no need in cutting either forests or free standing trees as any support can be displaced to one or another side, if necessary.

STS is characterised by very low material consumption for its construction which makes it most environmentally clean in technological terms.

A STS module has no projecting parts except its narrow wheels extended for 10 cm from the body; it does not require windshield wipers and headlights (as it is driverless) which at high speeds could be a source of noise. A vehicle body has a perfect aerodynamic shape (aerodynamic drag coefficient C_x=0.075), flow-around is symmetrical without side or tilting forces or air flow turbulence (that are especially noisy). Wheels can be made of light metal alloys (with 500…1,500 kgf load per 1 wheel) with the total mass of about 20…30 kg.

Therefore, mass of a STS vehicle will be, for example, by hundreds of times less than that of a train, its length – by tens of times shorter, and track evenness much higher. Thus, compared with a high-speed train a STS vehicle is a much weaker source of noise and soil vibration. A system of internal and support dampers capable to reduce low- and high-frequency track vibrations will also contribute to lower noise impact of a STS track structure.

STS is a low-voltage line (of 1,000 V voltage), thus, it does not generate electromagnetic pollution and can pass at large heights (up to 100 m) above housing estates, agricultural lands, natural reserves and parks. The lack of sliding electric contacts in a "vehicle-contact network" pair, low (by tens of times as compared with a railway) electric capacity of the rolling stock exclude environmental pollution with radio noise. A STS system is free of specific impacts such as powerful electromagnetic pollution of radar and radiation in aviation (during a many-hour flight each passenger is exposed to additional radiation caused by natural cosmic gamma-radiation reaching 300…400 micro-roentgen/hour against 20mr/h being a standard).

4.6. Socio-economic expectations of a STS introduction

At the present moment the degree of a STS development is such that there is no doubt in the system validity in terms of its efficient operation and practicable implementation. The main reason why a STS programme has not been put into practice so far is associated with the lack of finances. The only actual support in the form of a grant was provided by the UN Centre for Human Settlements (Habitat) in January 1999.

Given below data refer to the historic and economic aspects of a string transportation system including its practical implementation and use for regional traffic with due regard to the specific interests of individual countries.

A number of STS alternatives were considered and analysed including, in particular, an alternative for the 2nd Crete transportation corridor - "Paris - Moscow". International Conference devoted to the given transportation corridor which took place in the city of Minsk in October 1997 and brought together experts from 14 countries recommended the European Union to consider a STS as a high-speed component of Crete transportation corridors. In 1998 the Government of Belarus applied to the City Government of Moscow with a similar proposal. In this respect it should be noted that the EU Council of Ministers decided to allocate more than USD 100 billion for 9 Crete corridors up to the year 2010.

If financing of a "Paris - Moscow" STS route is opened in 2001 it is likely that a route will be put into service in 2006. One building team will be able to build more than 300 km of road per year, thus, 8 teams working simultaneously at different sections will be able to build the whole route during 1 year – 2005.

In 2001 it is proposed to invite international tenders to design a motor block, undercarriage and saloon for a transportation module and electronic control and safety systems for a STS. Presumably, its participants could be the largest corporations such as "General Electric", "Dymler Benz" "Microsoft", "Intel", "Mitsubishi", etc., firstly, because the work will be paid and, secondly, because a STS represents a new and very capital-intensive market (according to the experts' estimates the world market for a STS exceeds USD 1trillion) which is highly attractive for the aforementioned and other corporations. It is proposed that design of STS components submitted to a tender should be finalised during 3 years, i.e. by the year 2004. In 2004 all the above systems as well as alternative systems designed by internal efforts will be tested and optimised on a pilot section of a route planned for design in 2001 and construction in Russia in 2002.

The total cost of a STS route "Paris (London) - Moscow" (with the total length of 3,110 km) is estimated at USD 5.7 billion including USD 5.2 billion - the cost of a track and infrastructure and USD 0.5 billion - the cost of the rolling stock.

Cost distribution by year will be as follows: USD 20 million – in 2001; USD 180 million - in 2002; USD 500 million - in 2003, USD 1.1 billion - in 2004; USD 3.5 billion - in 2005, USD 400 million - in 2006.

A route put into operation will start to recoup itself in 2006 and the total costs will be repaid during the year 2009. In this case the net cost of travel from Moscow to Paris will be USD 32/passenger, and travel time -7 hours 10 minutes (with a travel distance of 2,770 km and estimated travel speed of 400 km/hour). Beginning from the year 2010 the average net profit of a string route will be estimated at about USD 2 billion per year to reach the total of USD 20 billion by the year 2020. That is why a STS programme will be very attractive for investors and could be in full-value effected from the resources of non-state investors and joint stock capital.

Construction of a high-speed road network in Russia will require minimal state resources. For example, it is possible to build a STS route network: "Lisbon (London) - Moscow - Lake Baikal - Peking (Seoul -Tokyo) - Delhi - El Kuwait" with the total length of about 30,000 km during the nearest decade with the financial support provided by international investments in the Programme "Live Water of Russia".

The programme is based on the use of non-conventional renewable resources of Siberia (drinking natural water of Lakes Baikal and Taimyr and food ice generated as a result of water freezing by winter frost) that have considerably higher export potential than, for example, non-renewable resources such as oil, natural gas and coal taken in aggregate.

Recoupment period of a STS system depends on the following main factors: loading (volume of passenger and freight traffic), normative operation profitability (and related ticket price), maintenance costs and the cost of electric energy. For example, recoupment period for a concrete track – "Berlin-Moscow" (1,830 km), ticket price – USD 40/pass. (140% profitability) and passenger flow of 50,000 pass./24 hours – will be 8 years. In this case the annual profit will amount to USD 480 million (the cost of a track including infrastructure and the rolling stock is USD 3.9 million). For passenger flow of 100,000 pass./24 hours the track expenses will be paid back during 3.5 years (profit – USD 1.1 billion/year). Travel time to come from the centre of Berlin to the centre of Moscow by a STS even at relatively low average travel speed of 300 kmph will be approximately the same as by plane (about 6 hours) but more safe and comfortable. Therefore, it is appropriate to compare a STS fare with air fare to show that USD 60/pass. is not a high price for a ticket (at 260% profitability). Then, the annual profit of a track will be USD 800 million and USD 1.6 billion for passenger flows of 50,000 and 100,000 pass./24 hours and recoupment period of 4.8 and 2.4 years, respectively.

Financial risks will be minimal because it is a financially sustainable project. Even at 20% loading of the target traffic volume the route will not be unprofitable to give but a small profit. In all our examples the cost of electric energy was taken as USD 0.05 kWt/hour.

Part 5. Application of a String Transportation System

5.1. Provision of an alternative to the mass-scale motorisation of human settlements as the key factor of their sustainable development

By the end of the 20th century half of the world population will be living in urban areas.

The UN Conference on Human Settlements in Istanbul noted that during the next three decades the number of citizens residing in urban areas will be twice as large as the number of rural residents and the total number of residents living in the cities will be by 2...3 billion more than the present day population. All these people will need housing, infrastructure, jobs and living conditions adequate to the 21st century requirements.

Research carried out by the leading transportation experts of the world showed that improvement of conventional modes of transportation in terms of their environmental qualities could not provide an alternative to the mass-scale super-motorisation of cities, thus, it is necessary to promote the search for non-conventional transportation alternatives. For example, in the early 1980s a special survey was carried out by Dr. V.N.Ivanov and Ph.D. V.K.Storchevus and its outcomes were published in a monograph "Ecology and Automobilisation" which substantiated the feasibility for urbanised zones to shift to environmentally clean transportation systems passing at the second level.

Today more than 300 modes of transportation are known in the form of projects, ideas or pilot lines, each of them having its own advantages. Out of them the following ten criteria were chosen which, in our opinion, are important for the future urban transportation system to meet the 21st century requirements:

1. higher environmental safety than a trolley-bus (in terms of its specific environmental impact, i.e. noxious emissions do not exceed 10 g/100 pass.-km) and an electric car (in terms of noise impact);
2. relative energy consumption for a high-speed movement (200 km/hour) will be 5...10 times less than for a passenger car (in conversion to gasoline – 0.2 liter/100 pass.-km);
3. low land requirements estimated at not more than 0.1 ha per 1 km of a route including infrastructure;
4. no need in the construction of embankments, depressions, tunnels, large-scale elevated roads, overpasses and viaducts which disturb natural landscapes and biocenoses and are characterised by poor resistance to natural disasters (earthquakes, floods, landslides, etc.);
5. low net cost of travel being at the level of modern suburban trains – USD 1...1.5 per 100 pass.-km;
6. low cost of a route including infrastructure not exceeding the cost of a cable road – USD 1.5...2 million/km; at the same time resource consumption for a transportation system (building materials, structures, earth excavation works, consumption of ferrous and non-ferrous metals, etc.) will be comparable with that for a cable road;
7. high level of comfort for passengers (comparable to that of a modern aerobus) and low cost under serial production (comparable to that of a passenger car – USD 1,000...2,000 per 1 seat);
8. safety of travel at the level of aircraft transportation;
9. high carrying capacity of a route –more than 100,000 pass./24 hours and 100,000 tonnes of freight per 24 hours;

10. multi-purpose communication system – including additional transmission of electric power and electronic information along the track structure.

Realisation of the above communication concept will require a principally new transportation of the 21st century and a string transportation system (STS) is likely to cope with the above requirements.

5.2. Experimental and industrial testing of a STS - basic condition for its introduction

The key stage of practical implementation of a principally new high-speed transportation system implies construction of a pilot testing ground to carry out its full-scale pilot industrial testing.

Research and testing will be carried out both at specially built laboratory stands and at a pilot 2-3 km section of a STS track.

A testing ground includes scientific research complex with a laboratory building, design bureau, assembly unit, autonomous power supply block, storage and other facilities and a pilot STS track. Within the framework of the Habitat project a number of proposals were made (and first of all on the allocation of land plots) to facilitate construction of testing grounds in Russia (resort city of Sochi) and Ukraine (city of Djankoi, Crimea).

Construction of a pilot STS track implies the following stages:

1. First, one span (of 1,000 m length) between anchor supports will be built with 20-25 intermediate supports (with their height ranging from 1 to 20 m) installed in between with spans ranging from 10 to 100 m. This section will be used to test building technology of intermediate and anchor supports, strain adjustment and anchoring, formation of a rail-string and track structure and checking of technical equipment. A track structure and supports will be also exposed to static tests to investigate movement dynamics and behaviour of a transportation module.
2. Once the tests were a success, the necessary corrections will be made in the transportation line, module and track design and the track will be extended by 2 km to reach the total length of 3 km. It will make it possible to gain the speed of 250 km/hour and to start testing of the high-speed (more than 200 km/hour) acceleration/deceleration regimes, control systems and non-standard operation conditions.
3. The final stage envisages extension of the track length to 15 km with its terminal sections designed as rings of about 1,000 m diameter including switching devices which will make it possible to reach the maximum travel speeds of 500-550 km/hour. Also tested will be high-speed travel regimes, turns and basic infrastructure components (switching devices and stations).

Approximate cost of the first two stages is estimated at USD 25 million, implementation period – 2.5-3 years. The third stage will be associated with approximately the same cost and time requirements.

Examination and tests of separate units, aggregates and components of the transportation line, module and infrastructure will be also carried out at specially designed laboratory stands.

After a STS has been exposed to a pilot industrial test on a testing ground, standardised and certified it is possible to recommend a high-speed transportation system of a new type for use both in developed and developing countries.

5.3. Main problems to be solved in the course of a STS testing

Construction of a testing ground for pilot industrial testing of a STS and full-scale tests of its separate parts and mechanisms including electric module and a track structure to be carried out under real geographic conditions are focused on the solution of the following tasks:

1. String track structure is not referred to beam or cable structures, therefore, the world experience in construction and operation of bridges and overpasses, mono-rail and cable roads and other transportation is not appropriate for a STS. Thus, a rail-string being the basis of a STS track structure is to be optimised experimentally (rail rigidity, tensile strength of a string, optimal span length, choice of filler and its physical and mechanical qualities, etc.) and tested at low (under 200 km/hour), medium (200-300 km/hour) and high (300-500 km/hour) travel speeds of a transportation module.
2. A STS electric module has four steel wheels with "an automobile" (independent) suspension, each of them with two rims (flanges) which makes a STS rolling stock principally different from that of railway, highway and mono-rail roads. Furthermore, a module is moving along the two pre-stressed rigid threads (rail-strings) of great length, rested upon rigid (anchor) and flexible (intermediate) supports. It is a principally new scheme of a high-speed track structure for the world experience with its moving dynamic not experimentally studied so far. So vibration frequency and amplitude of a rail-string, wheel suspension, module body supports as well as the generation of resonance frequencies in the track components, module and supports are to be further investigated.
3. High-speed movement of small-size modules at 20-30 m height above the ground requires a special approach to their aerodynamic qualities, optimisation of their body shape and impact of climatic factors such as wind, rain, snow, icing, high and low temperatures, etc.
4. STS supports and their components (anchor, intermediate, brake) differ from the supports of bridges, elevated and cable roads, power transmission lines both in terms of their design, static and dynamic loads and specific requirements. All this necessitates experimental study.
5. New track and rolling stock solutions require non-traditional approaches to the infrastructure design which is also to be exposed to experimental testing (including switching devices, terminal components, stations, freight terminals, etc.).
6. New transportation concept is associated with new approaches to its design standards (shape and geometrical dimensions of a rail head and supporting part of a two-rimmed wheel, track width, distance between two contra-flow lines, dimensions of a transportation module, etc.); electro-technical standards (voltage and type of current – direct or alternating, etc.), technological, operational and other standards.

5.4. Sphere of a STS application

Development of communications has been always of crucial importance for the social progress providing links between nations and contributing to strengthening of their trade and business relations.

Communications or transportation as exchange (transportation) of material and human resources is an indispensable condition of personal and public well-being; means of communication between people in territorial and intellectual space; way of life and one of the fundamental cultural values, indicator of the level of civilisation of the country.

Proposed string transportation system is called to address all the above problems.

In the course of the project performance the working team recognised the need in conceptual investigation of the future prospects for a STS application for urban and suburban transportation, inter-urban (inter-settlement), national and international communication. It is especially important for a STS which represents a principally new transportation system. The first pilot STS route in the city of Sochi will be used to specify the key parameters of its applicability:

- travel speed of intra-city traffic;
- carrying capacity of lines and stations;
- distance between stations;
- main directions of city-wide routes and other STS parameters.

Therefore, it is important to ensure that already the first line is reasonably universal and system-oriented to be applicable for transportation purposes at all the above-mentioned levels of communication.

Proceeding from the above said, it is possible to formulate the key STS parameters of passenger and freight alternatives which should meet the following requirements: a possibility to design and locate STS routes under urban conditions within the building lines, high-speed motorways and city arterial roads for uninterrupted non-regulated traffic flows.

Under conditions of historic cores and historic built-up environment of cities formed before the city arterial roads and streets were built the following STS layout alternative could be proposed: STS lines are located along the main directions of passenger and freight traffic flows at 50…100 m height and built in the form of high-rise tower buildings of strengthened bearing capacity with their upper floors (or roofs) used for stopping places. Such tower buildings with reinforced concrete framework of 10x10 cm cross section combined with shafts of the high-speed elevators will function as anchor supports of a STS line estimated for a horizontal strength of 1,000 tonnes. In this case in addition to automobile, trolley-bus and tram transportation the vertical lifts of high-rise buildings will serve for delivery purposes.

Thus, taking into account technical layout requirements for string routes within the urban areas it is possible to arrange a network of stopping places to provide a 500 meter walking distance of places of employment and residence against 1,500…2,000 meter accessibility accepted for underground stations.

In the authors' opinion of the STS project the use of automatically-controlled traffic regulation system within the city built-up areas will provide access to places of employment and residence within a 300-meter walking distance and reduce the intervals between stops to 1,000 m. In this case buses and trolley-buses will retain their transportation role.

Therefore, conventionally a network of STS routes in the central part of the city will have a square layout of 1 km x 1 km dimensions with the square side increasing to 1.5…3 km in the periphery zones.

Thus, in large cities a STS could provide a full-value alternative to individual vehicles, buses and freight transportation and partially to tram, high-speed tram and underground.

As to suburban transportation it is currently oriented to commuter railways, outfly high-speed tram routes and individual transportation. Analysis of the spheres of their application showed that STS as a transportation of the second level could create unlimited possibilities for territorial and spatial layout of transportation links to cope with the specific suburban settlement distribution patterns including villages and their location in relation to the city centre. Thus, for example, in Moscow Region a STS could pass within the limits of a large transportation ring which links Moscow satellite-towns of Serpukhov - Stupino - Kolomna - Orekhovo Zuyevo - Sergiev Posad - Dmitrov - Klin - Volokolamsk -Mozhaisk -

Obninsk at 45…60 km distance from the centre of Moscow, or to link a number of regional towns which form a transportation ring: Kaluga - Tula - Ryazan - Vladimir - Tver - Gagarin within 150…300 km radius. In this case circulation of freight and passenger traffic could be arranged along the above mentioned rings and between the regional towns.

Proposed layout scheme will make it possible to organise high-speed communication between the regional towns and the centre of Moscow in the automatically-controlled operation regime enabling "soft" combination of suburban and urban traffic, i.e. solution of the problem currently unsolved: to integrate commuter railways and underground transportation.

STS provides a new vision of inter-settlement (freight and passenger) transportation. To all appearances, the basic routes should pass along the strategic directions including the nation-wide and other strategic routes. In this case STS will contribute to "soft" integration of international, national and inter-city communications with suburban freight and passenger traffic.

Obviously, the given problem requires serious investigation and technical and economic developments.

At the same time already today it is possible to state that development of inter-city communications could be channelled along the key directions of Crete corridors. Thus, for example, organisation of transportation corridor No.2 "Ekaterinburg - Moscow - Minsk - Warsaw - Berlin - Brussels - Paris (London)" is possible.

Construction of a testing ground in the city of Sochi and the first STS section to link the city centre and Adler could serve as a social, economic and technical "spur" to include a STS in a multi-level transportation corridor "Gransk - Warsaw - Zhitomir - Nikolayev - Djankoi - Kerch - Novorossyisk -Sochi - Trabzon - Ankara".

Countries of the Black Sea Economic Community are interested to have a high-speed road of the 21st century passing around the Black Sea. The road will link all Black Sea resorts and contribute to the increased flow of tourists and holiday-makers, their growing activity and mobility, strengthening business and trade relations between Russia, Ukraine, Romania, Bulgaria, Turkey, Georgia and Abkhazia.

Maximum carrying capacity of a dual-way route is 500,000 passengers per 24 hours (or about 2 million passengers per year) and 500,000 tonnes of freights per 24 hours (about 200 million tonnes per year).

These characteristics meet the requirements for passenger and freight flows, suburban, inter-city, national and international communication.

STS could be built as technological or special-purpose roads to carry garbage beyond the boundaries of megalopolises; to bring ore from quarries to concentration plants; to transport coal to heat power stations and oil to oil refinery plants; to transport timber, sand and gravel; to deliver large volumes (about 100 million tonnes per year) of the high quality natural drinking water to densely populated regions of the world at 5,000…10,000 km distance, etc. The lack of rigid requirements set for the high-speed transportation and lower travel safety requirements in the absence of passengers will reduce the cost of a special-purpose STS by 1.5…2 times as compared with other high-speed string routes. It is possible to design string roads as freight, passenger (including tourist purposes) and freight/passenger routes.

STS routes will contribute to the development of cultural and information exchange between countries and drawing closer various religious confessions. Thanks to the high-speed and low-cost of STS routes it is possible to widen the range of interests and information of population.

STS tracks are easily integrated with electric power transmission lines, wind and solar power plants, communication lines including fibre-optic communications.

Part 6. Project activities and outcomes

6.1. International Seminar in the city of Sochi

International seminar: "Sustainable Development of Human Settlements and Improvement of their Communication Infrastructure through the Use of a String Transportation System" took place in the city of Sochi on 20-21 April, 2000.

The Seminar was organised by Habitat Executive Bureau in Moscow, City Administration of Sochi, Regional Public Fund to Assist in the Development of a String Transportation System (Moscow), "Yunitran" research Centre (Belarus), Academy of New Thought (Moscow), Sochi State University, "Krasnaya Polyana" Centre (Sochi).

The Seminar Agenda envisaged discussion of the problems directly related to the realisation and experimental industrial testing of a string transportation system (STS), in particular: sphere of a STS application under various town planning conditions including cities in developing countries; role of a STS in the Federal Target Programme: "Socio-economic Development of Resort City of Sochi up to the Year 2010" with a route "Sochi - Adler - Krasnaya Polyana - Engelmanovy Polyany" taken as an example; organisational and economic mechanisms to facilitate construction and investment of a pilot STS project under the current economic conditions; construction of a testing ground and attraction of a wide range of professionals, advocates of a STS to form positive attitude to the advanced alternative modes of transportation.

Participants of the Seminar were 49 Russian experts from Moscow, Nizhny Novgorod, Sochi; 6 international experts from Republic of Belarus (4), Ukraine (1) and UNCHS (Habitat) Headquarters, Kenya (1); representatives of 10 scientific research and design institutions, 12 industrial, building, consulting and trading firms engaged in construction and industrial production, 1 higher educational institution, 8 public and non-commercial organizations.

The Seminar participants outlined it as a priority task the formulation a regional sustainable development programme for the city of Sochi with the use of a string transportation system. It was recommended that the City Administration of Sochi together with other interested organisations set up the working team with its main focus on practical implementation of the high-speed STS transportation system: "Sochi - Adler - Krasnaya Polyana - Engelmanovy Polyany" and analysis of the existing base for building industry at the local level and within Krasnodar Region as a whole to be mobilised for the high-speed road construction.

Project Manager was recommended to conduct negotiations with the legislative and executive bodies of the city of Sochi with the aim to promote the following initiatives:

1. To create favourable conditions for the Project implementation, in particular, to fulfil guarantees of the Project support by the Russian side; to solve the problem of land allocation for the construction of a track and a testing ground; to grant target tax exemptions in the form of tax credits based on the goal-oriented and market-related approaches before the Project could bring a fair return;
2. To strengthen the integration between the STS Programme and the Master Plan and Development Programme for the resort city of Sochi with a special focus on freight and passenger traffic flows;
3. To adopt Resolution of the City Assembly establishing a special taxation regime and extra-budgetary investment guarantees;
4. To provide a possibility for the attraction of scientific, industrial and financial potential of other partners (including cities of Nizhny Novgorod, Moscow,

Republic of Belarus, Crimea, etc.) to the Project implementation on the basis of economic cooperation agreements;

5. To establish local free zone within the boundaries of a STS route;
6. To provide the necessary consultations and legal protection of intellectual property and "know-how" within the framework of the Project implementation. The Seminar participants made a special emphasis on the importance of a feasibility study (business-plan) and investment programme for potential investors.

The Seminar participants expressed their support to the initiative of the Regional Administration of Krasnodar envisaging possible extension of a STS application zone to link Sochi and Krasnodar as an alternative to highway and railway transportation service with due consideration given to the conservation of the national park and nature reserves and improvement of regional transportation links.

The Seminar applied to the Habitat Headquarters with the request to promote their collaboration within the framework of the Project. For this purpose it is intended to conduct negotiations with the officials of UNDP, UNIDO and Global Environmental Fund (GEF) and to discuss a possibility of initiating a joint pilot project focused on the introduction of a STS in other regions of Russia and other interested countries.

6.2. Operational STS model

A model passenger STS electric vehicle at 1:15 scale (for 10 and 15 passengers) and a freight module at 1:10 scale (for large-scale cargo including passenger cars) were designed, manufactured and tested. In terms of their mechanical and kinematic qualities both modules of the operational STS model fully comply with a real-life electric car (designed as a frame structure to carry a fixed body envelope; wheels equipped with independent suspensions and electric drive; opening and closing devices of a saloon; current collectors; automatically controlled systems including radio control, etc.).

Models were designed for various power supply alternatives:

a) external power supply network with constant-voltage (12 V) current supply through the chain "rail/string-wheel-electric brush-electric drive" – for a passenger vehicle;
b) autonomous power supply from a 6V voltage-accumulator envisaging automatic recharge at stopping points – for a freight vehicle.

Principally different design alternatives were proposed for a "mollusk shell"-type opening system of a vehicle saloon. In a freight vehicle a nasal part is opened which makes it possible to load it very quickly. In a passenger module it is a tail part which contributes to the comfort of passenger loading and unloading thanks to the sufficient height (2.2 m) of the parting section within the loading zone.

Furthermore, a physical model of a STS track was designed, manufactured and tested including a rail-string, anchor and intermediate supports, fixing nodes, power supply system of a rail, infrastructure components, etc.

The following model characteristics were examined:

- aerodynamic qualities of various shape alternatives of a STS transportation module. Design solution was proposed and optimised for a vehicle body which has no analogues in other high-speed ground transportation modes. For example, aerodynamic drag coefficient of a 20-seat STS vehicle is C_x=0.075, therefore, to gain the speed of 250...300 km/hour it is enough to have the engine power as little as 60...90 kWt which is equal to the power of a modern middle-class passenger car. It makes a STS environmentally clean transportation because it is high fuel consumption which, as a rule, gives rise to all environmental problems and, consequently, unsustainable development of human settlements. In terms of energy resource consumption (electric energy in conversion to gasoline) a STS is more efficient than a passenger car (by 5…10 times and more). At the STS travel speed of 250 km/hour its fuel consumption is 0.3 liter of gasoline per 100 pass.-km against 1.5…2 liter and 5…8 liter per 100 pass.-km consumed by a passenger car to gain the speed of 100 km/hour and 250 km/hour, respectively.

- various electric drive alternatives – each wheel provided with an independent drive (passenger module) and all wheels supplied from one electric motor through the system of reductors and differentials (freight module);
- rigidity of a track structure (as a ratio between track deflection under the load and the span length) depending on a string tensile force. Tensile force of each rail varied from 75…200 kg in a model to 150…400 kg in a track structure. These loads were transmitted through the cantilever anchor supports to dismountable-assembled strength beam imitating a track foundation;
- effect of falling down (destruction) of an intermediate support which will result in the span doubling. Tests showed that the track remains operational, however, at the reduced travel speeds of its modules.
- anchor console-type supports (model height – 1.2 m or 12…18 m for a full-scale alternative);
- intermediate support in the form of a column or a girder. To provide equal cross-sectional (horizontal plane) rigidity of a track the required tensile force of strings will be by 1.5…2 times more for supports designed as isolated columns than for supports designed as spatial girders.
- behaviour of a two-rimmed wheel under the changed track width. At low speeds movement of a two-rimmed wheel does not depend on the track width within the limits of its suspension capacity to respond to horizontal shifting.

Furthermore, the working drawings were prepared for an operational model at 1:5 scale and a string track of 100 m length. However, manufacturing of this large-scale route goes beyond the budget limits of the given project and requires additional fund raising.

6.3. Testing results

The major STS outcomes received before the initiation of the given project were presented and discussed at a number of international congresses and conferences including, in particular, the international conference devoted to the second Crete transportation corridor "Paris – Berlin – Warsaw – Minsk – Moscow" (Minsk, Belarus, 1997) which was attended by representatives from 14 countries. It was a STS that was included in the Conference decision and recommended for the European Community as a possible high-speed transportation component of the proposed Crete corridors.

It seems most reasonable to carry out testing of a string system in Ukraine or Russia in order to develop a pilot STS model with the financial support in the form of investments or credits to be provided by one of the interested countries which will be the first to build a new-type high-speed transportation line.

If the appropriate financial support is given for finalising scientific research and experimental design works and construction of a testing ground for experimental industrial testing of a STS, construction of the first string roads could be started in 3-4 years. Thus, if financing of a testing ground project is opened in the early 2000 it will be possible to start construction of the first STS high-speed routes in 2004.

6.4. Preliminary feasibility study

Preliminary feasibility study was prepared with the use of a computerised model UNIDO COMFAR 2.1.

The feasibility study included evaluation of the key technical, technological, marketing, financial and economic aspects of a STS construction project at the section: Sochi-Adler - Krasnaya Polyana - Engelmanovy Polyany. Construction of the route will provide a comprehensive solution of transportation and environmental problems including integration of the high-speed mass-scale passenger and freight transportation under difficult geographic conditions (sea, mountains) and conservation of unique mountain landscapes, climatic, health resort and recreation qualities of the site.

Feasibility study consists of the following four main sections: 1. History and main idea of the project; 2. Analysis of transportation service market; 3. Engineering design and technology; 4. Economic assessment and financial analysis.

Given below are only economic aspects and financial evaluation of the project.

A STS section from Sochi to Engelmanovy Polyany consists of the following two parts. Section Sochi- Adler will pass along the Black Sea shelf at 100…500 m distance from the shore. Section Adler - Engelmanovy Polyany will pass along Mzymta river bed. Its total length is 92 km including 26 km in the sea and 66 km in the mountains.

Three building alternatives were discussed including: one-way, combined (one-way for a sea section and two-way for mountains) and two-way track.

Approximate number of service staff – 406 persons to be chosen among the local population and trained accordingly in the course of a STS launching and adjusting.

Maximum travel speed of vehicles adopted for a track is 200 km/hour.

Along the track it is proposed to locate 4 terminals, 7 intermediate stations, 3 freight terminals, 1 depot and 1 dispatcher unit.

Table 7 below gives the initial technical and economic data used for the estimation of financial and economic indices.

Table 7

Item	Unit of measurement	Track alternatives		
		One-way	Combined	Two-way
Cost of the project	USD million	97.7	135.4	154.3
Time of putting into operation beginning from the starting date of financing	Years	3	3	3
Sources of financing:				
Internal resources (joint-stock capital)	USD million	34.3	7.4	54.5
Borrowed resources	USD million	63.4	98.0	99.8
Share of the joint stock capital in the total cost of the project	%	35%	28%	35%
Terms of borrowed funds provision:				
Annual interest rate	%	6	6	6
Duration	years	10	10	10
Grace repayment period	years	3.5 years (0.5 year from the date of putting into operation of the 1st stage)		
Frequency of payment		Equal payments every ½ year		
Track length	km	92	92	92

Item	Unit of measurement	Track alternatives		
		One-way	Combined	Two-way
Cost of travel from Sochi to Engelmanovy Polyany (92km)	USD	3.5	3.5	3.5
Estimation horizon	years	15	15	15
Discount coefficient	%	10%	10%	10%
Maximum annual carrying capacity	Million persons	5.9	20.3	23
Annual passenger flow accepted for the estimates	Million passengers	2.1	7.2	8.1

Though the cost of a two-way project is by 1.57 and 1.14 times higher than that of a one-way and combined track, respectively, in terms of its structure of capital investments it is more favourable because in the total cost of the project the net share of costs entailed in the license, scientific research and experimental design works, construction of a pilot section, design and survey works and infrastructure is much less.

Moreover, the average annual volume of capital investments effected in a two-way track amounts to USD 51.4 million (154.3:3) which is more than in other construction alternatives. At approximately equal specific share of annual passenger turnover of 0.355 the annual passenger flow carried by a two-way track operating at its maximum annual capacity will be by 3.9 and 1.13 times more than by a one-way or combined track, respectively (Table 7).

Cost of travel for passengers (USD 3.5) and its differentiation by track sections was estimated based on the following grounds:

- the need to pay back capital investments within reasonable time limits;
- purchasing capacity of population;
- competitive advantages of a STS fare against motor transportation at section Sochi-Adler;
- length of the route;
- access to human settlements located along the mountain section.

Structure of expenditures for a two-way route: electric energy – 3.15%, salary – 4.3%, spare parts, maintenance and repair –1.7%, taxes included in net cost – 10.1%, administrative overhead costs – 6.5%, amortisation of a track, rolling stock and non-material assets – 74.2%.

A great share of amortisation expenditures in the total structure of maintenance costs is attributed to the high rate of annual amortisation charges established in Russia as a standard in the amount of 5% of the total cost of basic facilities. Amount of amortisation charges is legally fixed for a long period, thus, possible reduction of the net cost of freight and passenger transportation will be defined by the amount of capital investments in the construction of supports, a track structure and infrastructure which account for 61% in the total structure of capital investments.

Amortisation costs define to a considerable degree the net cost of transportation which would be the lowest in a two-way alternative.

Table 8 gives the key financial and economic indices for three track alternatives during 15 years of operation, i.e. time limit accepted for estimation purposes.

Table 8

Item	Unit of measurement	Track alternatives		
		One-way	Combined	Two-way
Net cost of passenger transportation	USD/100 pass.-km	2.06	0.92	0.91
Net cost of freight transportation	USD/100 t-km	2.54	1.11	1.10
Recoupment period	year	More than 15	6.1	6.3
Dynamic recoupment period	year	More than 15	10.7	11.1
Index of investment profitability		0.47	1.24	1.22
Net discount profit	USD million	-43.3	27.3	29.8
Internal profit rate	%	1.1	13.7	13.6
Level of without loss operation in the 5th year of a track operation	%	-	-	22
Accumulated net profit	USD million	14.2	221.2	244.9
Taxes in budgetary and extra-budgetary funds during 15 years from putting into operation of the 1st stage, including:	USD million	61.1	235.7	270.9
Federal budget	USD million	22.0	104.3	119.6
Regional budget	USD million	6.9	12.9	14.7
Local budget	USD million	29.3	115.5	133.7
Extra-budgetary funds	USD million	2.9	2.9	2.9

As seen from the table data the level of without loss operation in the 5th year of the track operation amounts to 22% which is the evidence of the project sustainability and low risks of losses in the course of its operation. This figure will be more sensitive rather to the changes in passenger and freight services provision than to the changed costs which is also true with regard to the internal profit rate within the range of -/+10%.

The risk of non-reimbursement of credit resources (the main debt and interests) is closely related to the debt repayment index which will be less than 1 for a one-way track and 1.0 and 1.63 – for other two alternatives, i.e. it is rather stable.

Construction of a one-way track alternative is not efficient in terms of capital investments. Net discount profit has a negative value, investment profitability index is less than 1, project recoupment period is beyond the estimated time limits. Annual earnings fail to meet the debt service commitments which proves financial insolvency of the given project alternative. Maximum carrying capacity of the track is not enough to meet the region's requirements for passenger and freight transportation.

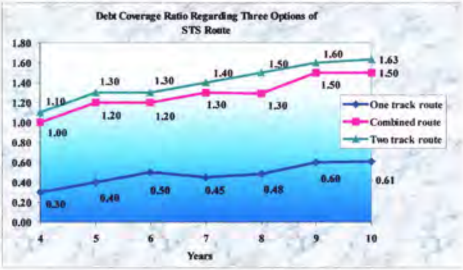

Fig. 17. Debt repayment coefficient for three STS alternatives: single-track, combined and double-track route.

Combined and two-way alternatives are close in terms of their technical, financial and economic indices. However, a two-way track seems more preferable as it could produce higher net discount income and accumulated net profit within a relatively short recoupment period of capital investments. A two-way alternative is also more attractive for investors.

As a result of a two-way track construction it will be possible to create more than 400 new jobs. During a 15-year operation period a STS will bring more than USD 270 million of tax revenues to the budget and extra-budgetary funds. Furthermore, the project will have a multiple effect in building and research sector and create more than 1,000 additional job opportunities.

STS is a low capital-intensive system which entails low maintenance costs and could be successfully used in the regions characterised by underdevelopment of their road network, high residential densities and difficult environmental situation.

Part 7. Use of the Project outcomes

7.1. Use of the Project outcomes by the City Administration of Sochi

Taking into account advantages of a STS the City Administration of Sochi made a decision to revise "Transportation" Section within the framework of the Federal Target Programme and to replace a monorail which was originally planned for construction by a STS.

Over the reported period the following tasks were implemented:

- a land plot was chosen and approved by the Administrations of Sochi and Krasnodar Region to initiate the first stage of a high-speed STS route in the city of Sochi; it implies construction of a testing ground and a pilot 3 km section of a string road;
- issues related to a STS route construction were submitted for consideration to the City Duma (Parliament) and Transportation Commission under the City Administration; only those proposals were approved which eliminated additional burden on the city budget placed by the development of the first in the world STS track;
- STS was included in the development plan of a mountainous climatic centre "Krasnaya Polyana" to replace a monorail for handling tourist trips from the city of Sochi.

Work is going on for the formulation of proposals for the regional sustainable development programme of the city of Sochi aimed to promote the use of a STS at the regional (Administrations of Sochi and Krasnodar Region) and federal (Government of Russia, State Duma and Council of the Russian Federation) levels.

7.2. Factors affecting the use of the Project outcomes

The most important factor contributing to the project implementation is associated with the STS advantages against other transportation systems in terms of its environmental, economic, land-use, safety, resource-consumption and other qualities.

Factors hindering the Project performance are as follows:

- novelty of a STS technical idea;
- lack of practical experience including experimental and industrial testing and development at the testing ground;
- conservatism of approaches to the transportation problem solution demonstrated by the governmental bodies including federal and regional authorities;
- inertness and competition of traditional transportation modes;
- negative public attitude to all kinds of innovations.

7.3. Work with professionals and wide public

A mathematical dynamic STS model was developed by the joint efforts of mathematicians from Belarus State University, St.Petersburg State Transportation University, Voronezh Polytechnic Academy, Academy of Sciences in Byelarus and Ukraine. The major research outcomes are discussed in the author's monograph: "String Transportation Systems: in the Earth and Space" (the city of Gomel, Belarus, 1995).

During the implementation of the project there was prepared the brochure "String Transportation System (STS) in Questions, Answers and Projects" which may be used for information of the wide public and potential investors (Appendix 5).

The operational STS model was exhibited at Leipzig Fair (Germany, 1995) and Hanover Industrial Fair (Germany, 1996); and at a number of exhibitions including the Exhibitions of Achievements of Belarus Academy of Sciences (1995, 1996, 1997); "Innovations-98", Moscow (1st Degree Diploma); "Spectransport-99" and "Road-99", Moscow, 2000 Global Environmental Forum in Malmo, Sweden.

Presentation of a string transportation system was also made in the course of the World Conference on the Future of Cities – URBAN-21 which took place in Berlin on 4-6 July, 2000.

7.4. Some prospects for the development of future STS projects

Construction of a high-speed transportation system makes it possible to attract to the country financial resources because a new market will be attractive for the Western firms manufacturing electronic equipment and various transportation vehicle components and firms involved in innovation activities and developments which ensure high profitability of commercial projects.

As an example let us take a project for the delivery to Europe and Asia of the high quality drinking water from Lake Baikal or food ice of Lake Taimyr located beyond the North Polar Circle in Taimyr peninsula.

Today the cost of the high quality food natural ice at the world market is USD 3,000, i.e. higher than that of copper and aluminum. At the same time melted water is more useful for human health as it is capable to preserve its liquid crystal structure for a long time period.

It will be reasonable to deliver the Russian drinking water to the European and Asian (India, China, etc.) markets in the form of ice to be stored in special terminals - refrigerators. Baikal water brought from the depth of 500 m will be frozen at the special plants using the natural winter frost.

To realise the Programme "Live Water of Russia" it will be necessary to build about 25,000 km of STS routes "Lisbon - Paris (London) - Moscow - Lake Baikal (Lake Taimyr) - Ulan Bator - Peking (Seoul -Tokyo) - Delhi - El Kuwait" with the total cost of about USD 40 billion (including infrastructure).

Construction could be carried out on a stage-by-stage basis to pay back the costs at the expense of freight and passenger traffic.

In the economic terms the Programme seems to be very attractive. The net delivery cost of more than 100,000 tonnes of drinking water per day using a STS system will be USD3/1,000 km or USD20/t for a medium distance of 6,500 km. Taking into account the selling price of water, costs for water preparation and other costs (including freezing) its actual cost for consumers (for example in Delhi) will be USD 50/t (5 cents/liter). At the wholesale price of food ice of USD 250/t (25 cents/kg) its delivery in the amount of as little as 200 million tonnes per year or 0.2 kg/day per 1 potential consumer will be enough to pay back the costs for the whole STS network.

Under the appropriate support of the Government of the Russian Federation and success of a joint-stock activity it will be possible to finalise the programme by the year 2010. The first STU sections, for example, "Moscow - Minsk", "Moscow - Nizhny Novgorod", "Paris - Madrid", "Peking - Delhi", etc. can be built in 2004-2005 and they will be self-repaying in 3...4 years at the expense of passenger and freight traffic, thus, when the STU construction is finalised most of its costs will be paid back.

The European Community recognises the need in searching for new solutions in the field of high-speed transportation services. According to the experts' forecasts of the International Railway Union the total volume of traffic expected in Europe in the year 2010 will increase by 140 billion passenger/km out of which more than 50 billion passenger/km will be carried by the high-speed railways in addition to the existing volume. European Council of Ministers identified priority routes for the high-speed transportation (nine Crete corridors). Before the year 2010 it is planned to spend 250 billion ECU (about USD 300 billion) for this purpose. A certain portion of the resources (about USD 100 billion) will be channeled to the development of a high-speed railway network. At the existing specific capital expenditures for the high-speed railways amounting to about USD 10…20 million per 1 km the resources allocated will be enough to build a new high-speed railway network with the length of not less than 10,000 km.

One of the longest European routes (3,110 km) is the Second Crete Corridor Moscow-Minsk - Paris - London. European Community considers a possibility of building a transportation system on the basis of a STS as one of the alternatives.

As in any other transportation system availability of maximum possible potential traffic flows including passenger (more than 20,000 passenger per 24 hours) and freight (more than 50,000 t/24 hours) transportation is an important factor determining the choice of a concrete STS alternative. Only in this case it will be possible to ensure a reasonable recoupment period of 3…5 years and to attract investments, credit resources and joint-stock capital necessary to build a principally new communication network within the short time limits (during 5…10 years).

It seems feasible to start the first STS route (Sochi - Adler - Krasnaya Polyana - Engelmanovy Polyany) in the city of Sochi from the stage of design and survey works initiated in 2002, therefore, to make the proposed communication system simultaneously a pilot track for countries with sub-tropic or tropic climate, sea coast and mountains. The cost of this 92 km route is USD 150 million.

Simultaneously it is possible to start a STS route at Moscow - Minsk section to make it a pilot track for countries with continental climate. The cost of this 710 km route is USD 1.1 billion.

Furthermore, it is reasonable to start a STS route in Siberia at Tomsk - Krasnoyarsk section to make it a pilot track for countries and regions characterised by sharp continental climate, extensive marshland areas, taiga and long lasting, frosty winter with heavy snowfalls. The cost of this 510 km route is USD 750 million.

Parallel with the initiation of the aforementioned pilot (innovative) tracks in 2003 it is proposed to prepare a number of programmes focused on the development of STS-based communications in the 21st century for their subsequent submission to the Government of Russia, countries of Europe, in particular, EU countries (as a high-speed component of nine Crete transportation corridors), Asia (and first of all India, China, Malaysia, Indonesia), Arabian peninsula and Egypt, North and South America (first of all Canada, Brasilia, USA), Africa, Australia and Oceania. Programme of communication network of the 21st century to be developed at the global scale including both developing and industrially-developed countries will be offered to the UN bodies which since 1998 have been rendering their support to a STS programme (Habitat, UNDP, UNIDO, etc.). In the context of industrialised countries a STS could be regarded as an alternative to the mass-scale motorisation whereas for developing countries it could provide an environmentally friendly infrastructure basis for the growing cities and megalopolises, population distribution, development of extraction and processing sectors of national economy. If during the 2005-2030 period 1/3 of the newly-built cities and megalopolises (according to the UN forecasts the total urban population will increase by 2.5-3 billion) use a STS as their infrastructure basis they will require 2…3 million km of high-speed string roads.

Part 8. Conclusions and recommendations

The implemented project "Sustainable Development of Human Settlements and Improvement of their Infrastructure through the Use of a String Transportation System" is one of the first steps towards practical realisation of a high-speed transportation network capable to cope with the modern worldwide requirements and tasks aimed at the provision of adequate conditions for sustainable human settlements development.

In the course of the Project performance the following outcomes were achieved:

1. Sphere of a STS application was investigated and formulated with due regard to the specific geographic and climatic conditions of Sochi region.
2. Meeting/Seminar was arranged in the city of Sochi on 20-21 April, 1999 with the participation of Habitat representative, Russian and international experts in the field of transportation. Development of a regional sustainable development programme for the city of Sochi with the use of a high-speed STS system was recognised as a priority task.
3. Plan of future actions to promote practical implementation of the Project was negotiated with the City Administration of Sochi.
4. Computerised data bank was formed and a system of information support for the project participants was proposed.
5. Comprehensive set of the key urban transportation indicators for Sochi region was prepared including evaluation of various transportation solutions.
6. Provisional feasibility study was prepared for a STS route: Sochi-Adler-Krasnaya Polyana-Engelmanovy Polyany.
7. STS was evaluated in terms of its applicability in potential Russian transportation projects and in the solution of global transportation problems.

The Project outcomes could be used by:

- Federal authorities at all stages and levels of realisation of the General scheme of the settling on the territory of the Russian Federation adopted by the Government of the Russian Federation, minutes № 31 of 15 December 1994.
- Federal authorities to implement "Federal Comprehensive Development Programme for Medium-size and Smaller Towns of the Russian Federation under the Economic Reform" in compliance with the Resolution of the Government of the Russian Federation No. 762 of 28 June, 1996;
- local authorities of all levels as one of the ways to address transportation problems within the context of sustainable human settlements development tasks provided that the necessary financial support is available.

Comparative analysis of various transportation systems made it possible to identify advantages of a string transportation system and to formulate arguments in favour of its large-scale application.

The major socio-political advantages are as follows:

1. Increased communication capacity (business and personal contacts, tourist trips, excursions and recreation trips including long-term recreation and weekends, etc.).
2. Wider possibilities: to work further from home without changing habitual place of residence; to develop sustainable residential zones (housing estates) within the walking distance of STS; to build linear cities open to nature and located along STS routes; to provide urgent medical aid; not to interfere in human traditional habits in the sphere of transportation services (for example, a possibility to travel at longer distances with a personal car at reasonable prices).

3. Individualisation of travel: use of a STS transportation module as a personal mode of transportation at more affordable price than a car.
4. Reduced number of accidents at other transportation modes as a result of attraction of a certain part of passenger and freight traffic by a STS (annually about 990,000 people are killed in road accidents including after-injury deaths and millions of handicapped).
5. Better protection of transportation energy-supply and communication systems from natural disasters (such as flood, land slides, earthquakes, tsunami) and terrorist actions thanks to the interaction of STS control components.
6. Improved transportation qualities: all-weather operation (irrespective of fog, snow, glaze of ice, sand storm, etc. and other unfavourable weather conditions); universal use (including land and sea sections).
7. Contribution to the formation of integrated, interrelated and more safe global environment.

The major socio-economic advantages of a large-scale STS application are as follows:

1. Reduced share of financial resources necessary for the long-lasting construction projects: low capital intensity of a STS (considerably lower than for any other high-speed transportation system, for example, tens of times lower than for a train on a magnet suspension; shorter recoupment period (3…5 years).
2. Reduced cost of transportation service, higher accessibility and attractiveness for all population groups at higher service quality (speed, comfort, safety).
3. Accelerated and improved integration and cooperation economic links both at the national and international level.
4. Easy access to develop hard to reach areas such as deserts, marshlands, permafrost, taiga, tundra, jungles, ocean shelf, mountains, etc. as the cost of STS lines in not strongly dependent on the ground features of the site.
5. No need in construction of special power transmission and communication lines including fibro-optic ones that are easily integrated with STS.
6. Possibility to form a global high-speed STS infrastructure within short time limits (during 10…15 years) which will have a multiple effect in other industrial sectors.

The following recommendations were made focused on the promotion of efforts towards the STS improvement and practical integration of the new transportation system in the existing communication network in the interests of sustainable human settlements development:

1. To continue development and testing of individual STS components and the system as a whole within the framework of scientific research and experimental and design works under conditions of a research centre set up for the region of Sochi; as a result a pilot 95 km section: Sochi - Adler - Krasnaya Polyana - Engelmanovy Polyany will be built based on the analysis of the outcomes obtained in the course of the given project performance.
2. To continue negotiations with Crimea Administration towards provision of the legal framework for the development of a testing ground in the city of Djankoi and investigate the system performance under conditions close to industrial ones.
3. To continue efforts towards the mobilisation of financial resources including investments of international and national sources.
4. To continue efforts towards the promotion of a STS at the international market in order to attract attention of international corporations and companies interested in the investment of communication projects.

5. The project outcomes will be of practical importance for the success of future economic and social development of various regions of Russia.

Appendix 1

UNITED NATIONS CENTRE FOR HUMAN SETTLEMENTS
GOVERNMENT OF THE RUSSIAN FEDERATION

Project document

Project Title:	Sustainable development of human settlements and improvement of their communication infrastructure through the use of a string transportation system
Project number:	FS-RUS-98-S01
Duration:	18 months
Starting date:	October 1998
National Executive Agency:	Ministry of the Russian Federation for Land Policy, Construction, Housing and Municipal Economy
International Executive Agency:	UN Centre for Human Settlements (Habitat)
Input of Habitat:	$ US 45,000
Input of the Russian Federation:	900,000 roubles (equivalent of $ US 135,000)

Resume: Identification of the town planning aspects enabling the use of the string transportation system under the difficult geographic and climatic conditions: the case study of the city of Sochi.

Signed by:
On behalf of the UN Centre for Human Settlements (Habitat)
Under-Secretary-General
Executive Director of the UN Centre for Human Settlements (Habitat)

K. Topfer

Date: 24.09.1998

Signed by:
On behalf of the Government of the Russian Federation
Minister of the Russian Federation for Land Policy, Construction, Housing and Municipal Economy

I.A.Yuzhanov

Date: 24.09.1998

A. BACKGROUND INFORMATION

The present project document was prepared in compliance with the Programme of Co-operation between the UN Centre for Human Settlements (Habitat) and the State Committee of the Russian Federation for Housing and Construction Policy for the 1998-1999 period in pursuiance of the "Federal Comprehensive Programme for the Development of Smaller and Medium-size Cities of the Russian Federation under the Economic Reform", approved by the Resolution No. 762 of the Government of the Russian Federation of 28.06.1996, and the Federal Target Programme "Socio-economic Development of the Resort-City of Sochi for the period up to the Year 2010", approved by the resolution No. 511 of the Government of the Russian Federation of 30.04.1997.

Sustainable city development and environmental protection are the priority tasks of the urban development. In accordance with the project documents adopted by the UN Conference on Human Settlements in Istanbul in June 1996 the only possible way to solve these problems is associated with the use of a comprehensive approach taking into account the social, ecological, economic, engineering and technical aspects.

Russia is a country of the high urbanisation level (73%) and rates. In 1995 the cities and urban-type settlements had 108,000,000 population and the rural settlements - about 40,000,000 population.

The growth in the number of cities and their population was associated with the construction of the large-scale industrial enterprises and power facilities and exploitation of mineral resources. However, inattention to the environmental protection and inadequate control of noxious industrial wastes (especially that of transportation and, first of all, cars) in the cities resulted in the extreme antropogenic loads on the environment and the crisis ecological situation in many regions, and, in particular, in the large industrial centres. Environmental quality became one of the most important indicators showing to the deformations in the national economic structure, irrational distribution of the productive forces and outdated technologies used in the municipal economy and transportation communications.

The city of Sochi located in the Causacus coastal zone of the Black Sea was selected as a site to implement the proposed project. Its communication infrastructure is experiencing a serious ecological crisis caused by the intensive transportation loads. The Sochi Region is served by the airport, the sea passenger port with 10 landing piers, 9 railway stations and numerous bus transportation facilities. The state transit highway Novorossyisk-Batumi which is the main arterial road on the coast is crossing the whole city territory.

The total number of passengers carried by the Sochi airport amounts to 0.7 million persons per year. The total number of passengers using the railway stations is more than 3 million persons per year. More than 100,000 passengers are carried annually by the intercity bus transportation. Taking into account the fact that Sochi is the large recreation zone of Russia the annual number of passengers carried by the car transportation exceeds 150,000 persons (with the total city population being less than 400,000 inhabitants).

Thus, it is transportation and first of all car transportation which constitutes the main source of noise and air pollution in the city of Sochi.

One of the ways to solve the given problem implies construction of a high-speed string transportation system (STS)* which will make it possible to deliver passengers and freights to

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* Resolution of the Sochi City Administration No. 628 of 10.09.97 "On the inclusion of the investment programme "Yunitsky's String Transportation Systems" into the Federal Target Programme "Socio-economic development of the city of Sochi for the period up to the year 2010"

their destinations over a short period of time (20…25 minutes) using the highway "Sochi – Adler – Engelmanovy Polyany" (95 km) and to convert the city of Sochi into a real international tourist, recreation and sports centre.

STS is a special type of an electric car with its wheels moving along the special current-carrying isolated rails-strings. String elements of the rail-string structure are tightened to the summary tensile stress of 250 tons and are fixed toughly in the anchor piers set at the spacing of 1…2 km. Moreover, the road structure consisting of two rails is supported by the intermediate piers which depending on the ground features are located at the distance of 50-100 meters from each other. The STS with its rail string characterised by a high smoothness and dynamic hardness makes it possible to gain the speeds up to 200…300 and 300…400 km/h within the city boundaries and at the intercity roads, respectively.

It seems reasonable that the high-speed STS route is laid out along the shelf of the Black Sea and further to the mountains along the valley of the river Mzymta which is characterised by the difficult engineering, geological and geomorphologic conditions. Seismic activity in the area is fully conditioned by the processes going on in the mantel and is related to the regional breaks of the earth's crust. According to the provisional seismic zoning scheme the North Caucasus is evaluated at 7 points according to the Richter scale.

Under these difficult engineering, geological and climatic conditions (snow-drifts, avalanches, snow falls, mud flows) it is more preferable to build the transportation facilities in the form of the high (20…50 meters) elevated string roads having a point-type foundation supported by the deeply embedded piers. High piers will allow to smooth away the mountainous relief and to avoid felling of trees while laying out the road.

Thus, as a matter of fact, construction of a high-speed STS road will provide the main alternative for the car transportation which has been used on a mass-scale in the Greater Sochi and will contribute to the considerable improvement of the environmental conditions within this unique region of the Russian Federation.

B. OBJECTIVES

The goal of the Project is to provide an alternative for the mass-scale motorisation of the human settlements as the key factor hindering their sustainable development as well as to test the proposed string transportation system under conditions of the very intensive transportation flows to be used both for the urban settlements with 100,000…200,000 population and for the intercity and interregional freight and passenger trips with the traffic intensity of 100,000 pass. per 24 hours and 100,000 tons per 24 hours under the difficult geographic and climatic conditions. In this case it is intended to identify the ways for testing the STS system in terms of its economic, ecological and technical components as well as in terms of its comfort and travel safety, and to propose the building technologies for constructing a high-speed road coming across the city area, sea and mountain zone.

Moreover, it is proposed to identify the investment attractiveness of the Project, to optimise the cost indices of the communication structure, the piers and transportation modules as well as the materials requirements necessary to build 100 km of the STS route.

It is also intended within the framework of the Project and based on the analysis of the development trends of the transportation communications and generalisation of the available home and international experience to formulate the strategies, priorities and mechanisms to facilitate practical implementation of the environmentally sound STS transportation system for the city of Sochi and for other regions having the similar geographic and climatic conditions and transportation problems.

C. PROJECT BENEFICIARIES

The key users of the Project will be the local authorities, Chief Department of Architecture and Town Planning, construction, energy and tourist enterprises as well as the local population and tourists.

D. EVALUATION OF THE CONTROLLING FACTORS WHICH COULD AFFECT THE PROJECT IMPLEMENTATION

The essence of the technical design of the string transportation is a steel wheel moving along the special rail which was studied with a great degree of detail at the high-speed railway roads in Japan, France, Spain and other countries as well as at the test grounds with the moving speeds of 300…500 km/h. However, the distinctive feature of the STS is associated with its more optimal technical and economic indices. Thus, for example, the string road structure located on the piers at the height of 10…50 meters makes it unnecessary the use of the embankments, depressions, bridges and viaducts and, therefore, results in the reduced construction costs by 3…5 times and minimisation of the negative environmental impact in the course of construction of a high-speed transportation infrastructure. Communication STS structure is in fact a variety of an aerial bridge with a very small deflection (a few centimetres) located inside the hollow rail. The rich technical and industrial experience gained in the bridge construction was used to design this STS.

These and other outcomes as well as the world experience will be used to the full scale to implement the STS, however, they require optimisation of construction, technological and operational indices to be carried out both through the stand testing of the individual elements of the communication structure, piers and transportation modules and through the testing of certain sections of the road as a whole.*

Taking into account specific features of the STS which distinguish it from other transportation systems a detailed mathematics model was applied for a single transportation module and a flow of modules moving along the string road with the speeds ranging from 100 to 500 kmph and more using various structural and technological characteristics of the system. Specialists representing the mathematical schools of Russia, Byelorussia and Ukraune were involved in the work.

In all systems the transportation module constitutes the main source of environmental pollution as it is responsible for either noise pollution or emissions of the fuel combustion products. That is why the STS module was thoroughly tested in the large wind tunnel and the tests produced the unique results in terms of the module configuration which had no analogues in the world practice: the lift-drag ratio of the module was reduced to 0.075 against the ordinary car which had the lift-drag coefficient amounting to 0.2…0.3.

These experimental data make it possible to forecast that the STS will become the most environmentally pure type of the ground high-speed transportation as, for example, to gain the speed of 350 km/h for a 10-seat module it is enough for its electric motor to have the power as small as 80 kWt. Therefore, the STS module will be able to gain the transportation

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* It is planned that the Russian side will cover the costs for the experimental and industrial test of the STS at the proving ground. The test results will be used to implement the given Project. In compliance with the support provided to the STS Programme by the President of the Republic of Belarus A.G.Lukashenko it is proposed to involve in the Project the industrial and scientific potential of Belarus as well.

speeds close to those of an aircraft while having a motor similar to that of a middle-class car and its negative environmental impact will be at the level of the urban trolley-bus.

Reduced environmental impact from transportation emissions in terms of the green-house effect resulting from the use of the STS could be in compliance with the global actions undertaken within the framework of the UN Programme for Change of Climate.

The Project activities envisage evaluation of alternative modes of transportation in terms of their costs, economic safety and compliance with the urban development prospects including a scenario which does not imply any sufficient changes in the transportation system. A comprehensive set of urban transportation indicators will be used to make a comparable analysis of various transportation solutions.

Alongside with the STS it is proposed to analyse the following systems as the alternative transportation solutions: mono-rail road, motorway and motorway with a trolley-bus lane as well as a number of other transportation modes (such as high-speed railway, high-speed tram, magnet cable way).

In the course of the analysis of the transportation indicators a special emphasis will be placed on those which could produce the most heavy negative environmental and recreational impact on the Larger Sochi Region. In particular: emissions of noxious substances in the atmosphere; withdrawal of lands for road construction; volume of earth excavation works. Moreover, environmental impact of transportation, especially high-speed transportation modes (with the moving speed of 200 km/h and more) is caused by their specific characteristics: relative capacity of engine (kWt/passenger and kWt/ton of freight) and specific energy costs per 1 vehicle (kWt/hour/passenger and kWt/hour per ton/km). Therefore, considerable attention in the course of the Project performance will be given to the analysis of energy costs per 1 unit of transportation operation.

The project activity also envisages evaluation of the STS in terms of the solution of the problem of seasonal transportation services.

F. PROJECT STRATEGY

The work for the Project will allow to collect the initial data (such as socio-economic and transportation data including transportation alternatives and indicators as well as land-use data) and to prepare the feasibility study. High investment attractiveness of the STS and the detailed feasibility study will make it possible to carry out the following stages envisaging formation of a high-speed transportation infrastructure in the city of Sochi using the resources of the investors both national and international ones. The key investor will be the Russian Assembly of Investors (the city of Moscow) which has already set up the association of the International Transformation Investment Programme "Yunitsky's String Transportation Systems".

The Project strategy envisages provision of the actual assistance to the Administration of the city of Sochi in the formulation of the "Transportation" section within the "Federal Programme of the City Development for the Period up to the Year 2010" and in the preparation of the plan of actions as well as to advise on the measures to be taken to form the environmentally sound high-speed transportation communications in other countries.

G. OUTCOMES

In the course of the Project implementation it is proposed to achieve the following concrete results:

1. To identify and formulate the areas of the STS applicability taking into account the geographic and climatic conditions.
2. To hold a meeting of the working group with the representatives of Habitat as well as the interested organisations to implement the project expertise and to discuss the problems associated with the realisation of the principally new high-speed transportation system and co-ordination of the consistent joint efforts of the partners.
3. To co-ordinate the plan of future activities with the municipal authorities of the city of Sochi to promote the practical implementation of the Project.
4. To form a computerised data bank and to organise the information support system for all project participants.
5. To prepare a comprehensive set of the key urban transportation indicators for the Sochi Region implying evaluation of alternative transportation solutions.
6. To prepare the methodological recommendations to implement the programme for the sustainable transportation communications development using the STS in the city of Sochi and other similar regions of Russia and other countries as well.

I. PROJECT ACTIVITIES

As no experience is available either in Russia or in the world as a whole in the formation of the string transportation infrastructure the given project will be further used as a basis to advise on the development of the STS in other countries. For this purpose the city of Sochi will be taken as an example to collect the initial data necessary to prepare the feasibility study and design as well as to analyse various alternatives for the construction of a high-speed road passing within the city boundaries, along the coastal zone and in the mountains in order to choose the optimal alternative. The feasibility study will make it possible to identify the technical, economic, ecological and other advantages of the STS as compared with other existing or proposed high-speed systems and to identify the applicability of the project taking into account the geographic, climatic, demographic and social factors.

Arrangement of the international expertise and experts' meeting involving the interested home and international agencies will provide for the formulation of the recommendations aimed at the attraction of the investments to implement all the subsequent stages of the practical implementation of the programme using the investors' resources. In this case the high investment attractiveness of the Project, its technical, economic, ecological and other advantages will contribute to its implementation over a short period of time. It will produce a multiplied effect in many national economic sectors, in particular, through the improved sustainability of the human settlements and formation of a new type of cities linked by the STS into a single transportation-communication system which is more suitable for human life, work and rest and capable to meet more fully the 21-th century requirements.

J.OUTPUTS

1. National output

"The International Transformation Investments Programme "Yunitsky's String Transportation System" as an executive agency formed within the framework of the Russian

Assembly of Investors will be responsible for a considerable input into the Project activities. Part of this contribution will be provided "in kind", for example, rent of premises, personnel involved in the project and its salary, equipment and other costs will be considered as the input of the Russian side into the project implementation.

a) Project personnel 396,000 roubles

Project co-ordinator, professional and technical staff involved in the Project will be paid by the Russian side.

b) Sub-contract 229,500 roubles

It is proposed to involve sub-contractors to collect the initial data (including geological, climatic, geodesic, demographic, socio-economic, transportation and land-use data, etc.) for the region, to conduct negotiations and arrange meetings with the professionals and the municipal authorities of the city of Sochi as well as to make the operational STS model.

c) Premises, equipment, materials 210,000 roubles

The national executive agency is responsible for the provision of the appropriate premises for the project staff for the implementation period as well as furniture, expendable equipment, electric energy supply, telephone and telegraph communication, protection.

d) Miscellaneous 64,500 roubles

Mission costs for the trips within Russia, maintenance costs for the equipment and premises, local telephone calls, etc.

2. Input of the UN Centre for Human Settlements (Habitat)

Input of the UN Centre for Human Settlements is provided from the external part of the project budget which is co-ordinated by the international executive agency - Habitat.

a) Project personnel $ US 26,000

It is proposed to recruit the Project Manager, one international consultant, and national consultants with their salary to be paid from the external part of the project budget.

The external part of the budget will be also used to provide the administrative support to the Project by the UN Centre for Human Settlements as well as to cover the mission costs.

b) Sub-contracts $ US 2,000

It is planned to use the external part of the budget to pay to the sub-contractors for the preparation of the background materials for the Project.

c) Working Group Meeting $ US 10,000

Holding of meetings with the participation of professionals involved in the Project preparations will be paid from the external part of the budget.

d) Equipment $ US 5,000

External part of the budget will be also used for purchasing a computer and other equipment necessary to form the data bank and to carry out the technical and economic calculations.

e) Miscellaneous $ US 2,000

External part of the budget will be also used to pay for the translation and printing of documents.

PROJECT BUDGET PROVIDED BY THE GOVERNMENT OF THE RUSSIAN FEDERATION*

	Total		1998		1999		2000	
	man/ month	thous. roubl.	man/ month.	thous. roubl.	man/ month.	thous. roubl.	man/ month.	thous. roubl.
10. Project personnel								
12.01 Project Co-ordinator	18	54	3	9	12	36	3	9
12.02 Professional staff	108	216	18	36	72	144	18	36
12. Technical staff	126	126	21	21	84	84	21	21
19.00 COMPONENT TOTAL		**396**		**66**		**264**		**66**
20. Sub-contract								
21.02 National sub-contract		229,5		79,5		120		30
29.00 COMPONENT TOTAL		**229,5**		**79,5**		**120**		**30**
40. Equipment and premises								
45.00 Premises		80		10		60		10
42.00 Equipment		130		20		110		-
49.00 COMPONENT TOTAL		**210**		**30**		**170**		**10**
50. Miscellaneous								
53.00 Miscellaneous		64,5		10		40		14,5
59.00 COMPONENT TOTAL		**64,5**		**10**		**40**		**14,5**
99.00 BUDGET TOTAL		**900,0**		**185,5**		**594**		**120,5**

* $ US 1 is equal to 6,3 roubles as of the end of July 1998.

BUDGET PROVIDED BY THE UN CENTRE FOR HUMAN SETTLEMENTS

	Total		1998		1999		2000	
	man/ month	US$	man/ month	US$	man/ month	US$	man/ month	US$
10. Project personnel								
11.01 Project Manager	18	12,600	3	2,100	12	8,400	3	2,100
11.03 International consultant	1	8,000	0,5	4,000	0,5	4,000	-	-
17.02 Project Secretary	18	3,600	3	600	12	2,400	3	600
COMPONENT TOTAL		**24,200**		**6,400**		**14,800**		**2,700**
16. Mission costs								
16.01 Mission costs		1,800		-		1,800		-
16.99 COMPONENT TOTAL		**1,800**		**-**		**1,800**		**-**
20. Sub-contracts								
21.02 National sub-contracts		2,000		500		1,000		500
29.00 COMPONENT TOTAL		**2,000**		**500**		**1,000**		**500**
30. Meetings, workshops, study tours								
31.00 Working Group Meeting		10,000		10,000		-		-
39.00 COMPONENT TOTAL		**10,000**		**10,000**		**-**		**-**
40. Equipment								
42.00 Non-expendable equipment		5,000		3,000		2,000		-
49.00 COMPONENT TOTAL		**5,000**		**3,000**		**2,000**		**-**
50. Miscellaneous								
52.00 Reports, printing		2,000		500		500		1,000
59.00 COMPONENT TOTAL		**2,000**		**500**		**500**		**1,000**
99.00 BUDGET TOTAL		**45,000**		**20,700**		**20,100**		**4,200**

Schedule of the Project activities

Activity	Starting date	Completion date
1998		
1. Collection and analysis of the initial data, research papers and publications necessary to investigate the possibility of using the STS in the southern regions of the Russian Federation with the city of Sochi taken as an example	October	November
2. Study and generalisation of the practical experience in the transportation infrastructure development using the high-speed transportation in Japan, Germany, France, Spain, etc.	November	December
3. Holding of the Working Group Meeting with the participation of the interested agencies (including a representative of the UN Centre for Human Settlements (Habitat)	-	November
4. Development of measures and mechanisms for their implementation to launch a high-speed STS road in the city of Sochi	October	December
5. Design of an operational STS model (scale 1:5)	October	December
6. Submission of the progress report for 1998	-	December
1999		
7. Translation of the project materials into the computerised format (computerised data bank)	January	June
8. Making an operational STS model including the key infrastructure elements (scale 1:5)	January	August
9. Preparation of a comprehensive set of the key urban transportation indicators for the Region	January	June
10. Development of the regional sustainable development programme for the city of Sochi using the high-speed STS system	February	September
11. Preparation of the Feasibility study for the Project	April	October
12. Formulation of proposals for the potential investors	August	October
13. Expertise of the project at the home agencies and organisations within the UN system	October	December
14. Submission of quarterly progress reports and the annual 1999 progress report		November
2000		
15. Preparation of methodological recommendations	January	March
16. Submission of the final report	-	March

Appendix 2

GRANT AGREEMENT

between the UN Centre for Human Settlements (Habitat) and the Regional Public Foundation to Assist in the Promotion of a Linear Transportation System (Foundation), Moscow, Russia

Article 1 – Purpose

The overall purpose of this Grant Agreement is to support the implementation of the Habitat project "Sustainable Development of Human Settlements and Improvement of their Communication Infrastructure through the Use of a String Transportation System", FS-RUS-98-S01-A within the Russian Federation. Specific purposes of the given Grant Agreement are as follows:

- To facilitate involvement of the local professionals and international consultants in the Project preparation and implementation;
- To sign contract and to set up a Working group for the project preparation and implementation;
- To formulate a strategy, to identify priorities and mechanisms for the practical implementation of the environmentally sound high-speed string transportation system (STS) for the city of Sochi and for other regions of Russia having the similar town planning and climatic conditions;
- To specify the investment policy for the Project, to propose the ways to test the STS from the point of view of its economic efficiency, and ecological and technical qualities as well as taking into account comfort and traffic safety; to specify building technologies for the construction of a high-speed road under the conditions of a city, sea or mountains;
- To prepare a feasibility study, business-plan and investment programme in compliance with the international requirements in order to attract the investments necessary to realise the STS.

Article 2 - General Framework

Implementation period of the project "Sustainable Development of Human Settlements and Improvement of their Communication Infrastructure through the Use of a String Transportation System" is 18 months. Its financing is provided with the support of the UN Centre for Human Settlements (Habitat). The Regional Public Foundation to Assist in the Promotion of a Linear Transportation System is responsible for the Project implementation which will contribute to the formulation of priorities of sustainable human settlements development and improvement of their communication infrastructure through the use of a STS. The Project recommendations will facilitate to identify the town planning aspects appropriate for the use of a STS under the difficult geographical and climatic conditions.

Article 3 – Obligations

a) Obligations of the Regional Public Foundation to Assist in the Promotion of a Linear Transportation System are given in Annex A of this Grant Agreement.
b) Obligations of the UN Centre for Human Settlements (Habitat).

Subject to fulfillment by the Foundation of its obligations specified by item "A" of this Article, the UN Centre for Human Settlements (Habitat) will pay a total grant of US$ 45,000. The payments will be effected in accordance with the schedule specified by item 5 of the Grant Agreement.

The UN Centre for Human Settlements (Habitat) and its Executive Bureau in Moscow will provide overall guidance to the project activities during its performance period. The UNCHS (Habitat) will arrange a consultancy mission to Russia for its representative to render assistance in the Project implementation and to take part in the meeting of the Working group proposed within the framework of the Project.

Article 4 - Entry into force and duration of the Agreement

The Agreement will enter into force upon its signing by the two parties provided that the project activities be completed in 18 months beginning from the date when the project financing is started.

Article 5 - Payment Schedule

The total grant of US $ 45,000 will be paid as follows:

First payment (15%) - upon signing of the Agreement;

Second payment (40%) - upon completion of the 1st phase of the project and submission of the progress report (see Annex 2, Calendar Timetable for the Project Activities);

Third payment (35%) - upon the completion of the 2nd phase and submission of the progress report;

Fourth and the last payment (10%) - upon completion of the Project and submission of the final report to the UN Centre for Human Settlements (Habitat).

Mr. Daniel Biau
O.I.C.,
UNCHS (Habitat),
Nairobi, Kenya

Date: 18.12.1998

Mr. Anatoly E. Yunitsky,
President,
Regional Public Foundation to Assist in the Promotion of a Linear Transportation System
Moscow, Russia

Date: 18.12.1998

This Grant Agreement consists of the present document in five articles and two annexes attached to it.

ANNEX A

Obligations of the Regional Public Foundation to Assist in the Promotion of a Linear Transportation System (Foundation) for the Project: "Sustainable Development of Human Settlements and Improvement of their Communication Infrastructure through the Use of a String Transportation System", FS-RUS-98-S01-A

The Regional Public Foundation to Assist in the Promotion of a Linear Transportation System takes upon itself the following obligations:

- overall responsibility for the project implementation and performance of the project activities as specified by its project document;
- collection of initial data necessary for the project performance;
- formulation of the key urban transportation indicators for the Sochi Region to be used for the assessment of various transportation solutions;
- identification and formulation of the spheres of application for the STS taking into account town planning, geographical and climatic conditions;
- preparation of methodological recommendations to implement the programme for the sustainable development of the transportation communications with the use of a STS for the city of Sochi and other similar regions of Russia;
- holding a working group meeting with the participation of a Habitat representative and interested agencies to discuss the project expertise and the problems related to the implementation of a principally new high-speed transportation system and to coordinate the joint actions of the participants;
- preparation of a feasibility study, business-plan and investment programme in compliance with the international requirements in order to attract investments necessary for the STS system implementation;
- submission of quarterly progress reports to the Habitat HQ as well as the financial reports as specified in the calendar timetable;
- preparation of a final report to be submitted to Habitat in 18 months after the project financing was started.

ANNEX B

Calendar Timetable for the Project Activities: "Sustainable Development of Human Settlements and Improvement of their Communication Infrastructure through the Use of a String Transportation System", FS-RUS-98-SO1. (December 1998 - May 2000)

Project Activities	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Phase 1 (1 December 1998 - 31 January 1999)																		
To collect and analyze the initial data, research projects and publications necessary to investigate a possibility for the use of a STS in the southern regions of the Russian Federation with the city of Sochi taken as an example	X	X																
To study and generalize the experience in designing a transportation infrastructure using high-speed transportation of Japan, Germany, France, Spain, etc.		X	X															
To hold a meeting of the Working group involving the interested organizations (and a representative of the UNCHS (Habitat)		X	X															
Phase 2 (1 February - 31 August 1999)																		
To propose measures and implementation mechanisms to build a high-speed STS route in the city of Sochi	X	X	X															
To design an operative STS model (scale 1:5)	X	X	X															
To translate the project materials into a computerized data bank				X	X	X	X	X	X									
To make an operative STS model including the key infrastructure elements (scale 1:5)				X	X	X	X	X	X	X	X							
To formulate a comprehensive set of the key urban transportation indicators for the region				X	X	X	X	X	X									
Phase 3 (1 September - 31 December 1999)																		
To prepare a regional sustainable development programme for the city of Sochi using a high-speed STS system					X	X	X	X	X	X	X	X						
To prepare a feasibility study, business-plan and investment programme							X	X	X	X	X	X	X					
To make proposals for potential investors											X	X	X					
Expertise of the project in the home and UN organizations													X	X	X			
To submit a progress report for 1999													X					
Phase 4 (1 January - 31 May 2000)																		
To prepare a final report and to translate it into English																X	X	X
To submit the final report																		X

Appendix 3

Agreement
of Share Investment in the UN Centre for Human Settlements (Habitat) Project No. FS-RUS-98-SO1: "Sustainable Development of Human Settlements and Improvement of their Communication Infrastructure through the Use of a String Transportation System"

City of Sochi July 1, 1999

City Administration of Sochi (hereinafter referred to as "Investor-1") in the name of the Administration Head Mr. Latyshev V.V., acting with the authority of the City Charter of Sochi, on the one hand, and the Regional Public Fund to Assist in the Development of a Linear Transportation System (hereinafter referred to as "Investor-2") in the name of President A.E.Yunitsky acting with the authority of the Charter, on the other hand, in the joint name hereinafter referred to as "Investors" signed the present Agreement to agree as follows:

1. Subject of the Agreement

1.1. Investors commit themselves to pool their inputs and to organise the joint venture for the implementation of the UN Centre for Human Settlements (Habitat) project FS-RUS-98-SO1: "Sustainable Development of Human Settlements and Improvement of their Communication Infrastructure through the Use of a String Transportation System" (hereinafter referred to as "Project").

The Agreement is fulfilled in compliance with the Habitat Project Document No. FS-RUS-98-SO1 signed on September 24, 1998 by Under Secretary-General, Executive Director of the UN Centre for Human Settlements (Habitat) and the Russian Federation Government with the aim of investigating the town planning aspects of using a string transportation system (STS) under difficult geographic and climatic conditions with the city of Sochi taken as an example.

Upon the Agreement between the UN and Investor-2 signed on December 18, 1998 in Nairobi (Kenya) responsibility for the Project implementation is placed on Investor-2 authorised as its general executive.

1.2. Concrete tasks of the present Agreement to be carried out with the financial support of the UN:

- participatory, in partnership with the UN, involvement in the Project performance;
- formulation of strategies, priorities and mechanisms for practical implementation of an environmentally sound high-speed STS for the city of Sochi;
- preparation of a feasibility study, business-plan and investment programme in accordance with the international requirements in order to attract investments for practical realisation of a STS in the city of Sochi;
- involvement of local and international partners in the Project development and implementation.

2. Obligations of the Parties

2.1. Investor-2 assumes the following obligations:

2.1.1. To invest available (without additional financing) know-how, technical, engineering and other knowledge and experience, inventions and industrial samples, research, experimental and calculations results, etc. in the Project performance in accordance with p. 1.2 of the present Agreement and a calendar timetable of the project activities.

2.1.2. Within its competence and resources and with the appropriate support provided by the UN Centre for Human Settlements (Habitat) to perform the services specified by the calendar plan of works.

2.1.3. To suspend the work by the appropriate 10 days' notice given to Investor-1 in the event inevitably negative results or inexpediency of further actions have been revealed in the process of the Project performance. In this case the Parties are obliged to consider a feasibility of further actions and their orientation within 10 days.

2.2. Investor-1 assumes the following obligations:

2.2.1. To effect share investment in the Project in accordance with p. 4.1. of the present Agreement in the amount and within the time limits specified by the present Agreement.

3. Term of Agreement

3.1. Investor-2 shall fulfil the services envisaged by p. 1 of the present Agreement within the time limits specified by the calendar plan of the Project activities approved by the UN.

3.2. Investor-1 shall fulfil its investment obligations before August 1, 1999 (Stage 1) and before November 1, 1999 (Stage 2).

4. Terms of Investment

4.1. Proposed non-financial investment in the amount equivalent to not less than USD 135,000 (one hundred thirty five thousand US dollars) in the form of office and residential premises provided for the staff members of the Project Working Group; payment of telephone calls and fax service charges; allocation of land plots for the construction of a pilot testing ground, infrastructure and service and residential premises in the city of Sochi and other non-financial investments contributing to the implementation of the Project.

Allocation of land plots and their assessment will be made in compliance with the procedures and norms specified by the efficient Civil, Urban and Land Codes of the Russian Federation and other normative and legal acts regulating the legal land relations.

4.2. Works and services shall be evaluated by the parties on the basis of calculations, accounting documents, acts, etc.

4.3. Upon the Resolution of the City Administration of Sochi of 10.09.1997 No. 628 "On Inclusion of Investment Programme 'String Transportation Systems (STS) of A.E.Yunitsky' in the Federal Target Programme 'Socio-economic Development of Resort City of Sochi up to the Year 2010" the proposed non-financial investment is considered as a share of the City Administration of Sochi in the profit of the STS Programme.

5. Force Majeure

5.1. Either Party shall bear responsibility to other Party for the delay or non-fulfillment of obligations within the framework of the present Agreement owing to force majeure circumstances outside their control that are impossible to foresee or avoid including declared or actual war, civil disturbances, epidemic, blockade, embargo, earthquakes, floods, fires and other natural disasters.

5.2. Certificate issued by a relevant Chamber of Commerce or other competent body is sufficient to confirm existence and validity period of force majeure circumstances.

5.3. Either Party that fails to fulfil its obligations shall be obliged to give a notice to the other Party about the reason hindering fulfillment of its obligations in accordance with the Agreement.

5.4. In the event of persistence of force majeure circumstances during 3 (three) successive months without any signs of ceasing the present Agreement is subject to termination by Investor-1 and Incvestor-2 by giving appropriate notice to the other Party.

6. Arbitration

6.1. Any dispute or disagreement between the Parties arising out of or in connection with this Agreement shall be settled by negotiations between the Parties.

6.2. In the event an attempt to settle disagreement by negotiations will have failed it shall be submitted to arbitration for settlement upon the established legal procedures.

7. Special Conditions

7.1. Any amendments or supplements to the present Agreement shall be valid provided they were submitted in written form and signed by both Parties.

7.2. Early termination of Agreement is possible by common consent of both Parties or in accordance with the provisions of Civil Law efficient in the Russian Federation.

7.3 Either Party shall be entitled to terminate the Agreement by written notice given to other Party.

7.4. The given Agreement was made in two copies, each of them legally valid, one copy to either Party.

8. Legal addresses and payment requisites of the Parties

Investor-1:
Mr. V.V.Latyshev, Head of City Administration of Sochi. Address: City of Sochi, Sovetskaya str., 26, tel 92-27-66, clearance account No. 40206810400000310017 at RKC Bank, identification code 040396000, identification No. 2320037148, OKONKH, 97600, OKPO 04019640.

Investor-2:
Mr. A.E.Yunitsky, President, Regional Public Fund to Assist in the Development of Linear Transportation System. Address: 115035, Moscow, Pyatnitskaya str., 7, build.1, clearance account No. 40703810600000001112 at Vneshtorgbank of Moscow, correspondence account No. 30101810700000000187, Division 1 under Chief Department of CB of the RF in Moscow, identification code No. 044583187, identification No. 7702070139, identification No. of the Fund 7701189766, code OKPO 18432303.

Memorandum of Agreement
about negotiated price of scientific research product
Share Investment in the UN Centre for Human Settlements (Habitat) Project No. FS-RUS-98-S01: "Sustainable Development of Human Settlements and Improvement of their Communication Infrastructure through the Use of a String Transportation System"

The undersigned N.I.Karpov, City Head of Sochi, in the name of Contractor (Investor-I), on the one hand, and A.E.Yunitsky, President, Regional Public Fund to Assist in the Development of Linear Transportation System, on the other hand, certify that the Parties have reached an agreement about the negotiated price of the produced (or transferred) scientific research product in the amount equivalent to USD 135,000 (one hundred thirty five thousand US dollars)*.

Including distribution of this amount by stages:

Stage 1 - the sum equivalent to USD 30,000 (thirty thousand US dollars) in the form of financial resources;

Stage 2 - the sum equivalent to USD 40,000 (forty thousand US dollars) in the form of financial resources;

Stage 3 - non-financial investments in the amount of USD 65,000 (sixty five thousand US dollars).

The present Memorandum provides the legal grounds for settling mutual accounts and payments between Executive and Customer.

For Executive:
A.E.Yunitsky, President,
Regional Public Fund to Assist
in the Development of Linear
Transportation System

For Customer:
N.I.Karpov, City Head, Sochi

* Negotiated price is given in USD following the UN requirements and taking into account the international nature of the Project activities (in the given Project No. FS-RUS-98-SO1 the UN acts as Investor-3)

Appendix 4

KRASNODAR REGION
CITY ADMINISTRATION OF SOCHI

354061, Sochi, Sovetskaya str., 26, tel. 92-20-37

RESOLUTION

10.09.97 No.628

On inclusion of investment programme
"String Transportation Systems (STS)"
of A.E.Yunitsky in the Federal Target
Programme: "Socio-economic Development
of Resort City of Sochi up to the Year 2010"

In order to implement the Resolution of the Russian Federation Government of 30.04.97 No.511 "On Federal Target Programme "Socio-economic Development of Resort City of Sochi up to the Year 2010" and, in particular, its transportation component and taken into account considerable advantages of a principally new high-speed string transportation system (STS) against conventional modes of transportation in terms of its wide-scale use in the economic, and social sphere and planetary ecology it was DECIDED:

1. To include investment programme "String Transportation Systems" in the Federal Target Programme "Socio-economic Development of Resort City of Sochi up to the Year 2010" as a transportation component complying with the relevant master development plan for resort city of Sochi.
2. To approve establishment of "Yunitran-Sochi" Fund in accordance with Memorandum of Intentions of 05.08.97 and entrust it with the responsibility to solve organisational and financial issues related to the programme performance on the basis of advanced and socially-oriented market mechanisms and mobilisation of credit resources from various sources including international ones.
3. To authorise "Yunitran Fund" to act as a contractor for a pilot project "String Transportation Systems" for the route "Sochi-Adler-Krasnaya Polyana-Engelmanovy Polyany".
4. To authorise Chief Department for Architecture and Town Planning under the City Administration in association with City Committee for Land Resources and Land Management to prepare the necessary legal documents to support design and construction of a STS route on the basis of the outcomes of the pilot project "String Transportation Systems" "Sochi-Adler-Krasnaya Polyana-Engelmanovy Polyany".
5. To consider allocation of land plots for a STS route and infrastructure as a share of the City Administration in the profit of the Programme.

V.V.Latyshev,
First Deputy of City Head,
Head of City Administration

KRASNODAR REGION
CITY ADMINISTRATION OF SOCHI

354061, Sochi, Sovetskaya str., 26, tel. 92-20-37

16.10.98 No. 02-35, 2-7599
On share participation in financing of activities within the framework of the Habitat project

Dr. K. Toepfer,
UN Under Secretary-General

c.c.: Mr.V.K.Storchevus,
Director,
UNCHS (Habitat) Executive Bureau
in Moscow

Dear Mr. K. Toepfer,

City Administration of Sochi guarantees its participation in financing of the project "Sustainable Development of Human Settlements and Improvement of their Infrastructure through the Use of a String Transportation System" in the amount equivalent to USD 135,000 during the 1998-2000 period.

The City of Sochi has already provided finance for the pilot project including: choice, topography survey, marking of STS routes and preparation of other materials, salary for the budgetary professional staff, provision of motor vehicles, helicopter, working premises for researchers and designers, logistics, etc.

Upon the Resolution of City Administration of Sochi No. 628 of 10.09.1997 the given project was included in the transportation scheme as its component in compliance with the master plan for city development and in the Federal Target Programme "Socio-economic Development of Resort City of Sochi up to the Year 2010".

The given Resolution authorised allocation of land for a 99 km STS route and its infrastructure which is also considered as a financial security and share participation of the City Administration in the proposed Programme performance.

City Administration is ready to assist as much as possible in further promotion of a STS Project in partnership with Habitat within the required scale.

N.I.Karpov,
Head of the City of Sochi

Appendix 5

Summary of Expert Reviews

During the process of implementation of the Habitat project FS-RUS-98-S01 as well as after its completion Habitat Executive Bureau in Moscow received the expert reviews of the string transportation system from Russian and foreign experts as follows:

1. Academician N.K. Baibakov, former Chairman of Gosplan of the USSR, in his letter to Mr. N.E. Aksenenko, Minister, Ministry of Railways of the Russian Federation, attaches special attention to the ecological safety as well as to the convenience of running of the string transportation system in comparison with other high-speed transportation means.

2. Mr. V.I.Sevastianov, Chairman of the Mandate commission, Gos douma, flyer-cosmonaut of the USSR, in his review of 5 July 1999 to Mr. L.V. Romashev, Director, Central territorial agency of the Moscow municipal property, noted that «this project was approved by the leading experts of Russia and western countries. It represents a safe, ecologically sound, high-speed and economically attractive type of transport, which will add to the image of the capitol and help to a great extent solve its transportation problem».

3. After consideration of information on the string transportation system the Permanent Commission on industry, construction, transport, communication services, fuel and energy complex of the Parliament of the Autonomous Republic of the Crimea under the leadership of its Chairman Mr. G. Babenko adopted its resolution No 12-34 of 12 March 1999 entitled «On the concept of application of the modern type of transport - the string transportation system (STS) by A.E. Yunitsky under the conditions of the Autonomous Republic of the Crimea», which noted that «the construction of the high-speed transportation route (STS) has great social and economic importance for the Crimea».

4. The Executive Commission of the Krasnoperekop City Council, Autonomous Republic of the Crimea, adopted the resolution No 121 of 30 July 1999 signed by Mayor A.V. Sautin to start preparation of normative documents and business plan for consideration of the Council of Ministers of the Autonomous Republic of the Crimea with the purpose of including the Yunitsky string transport as a high-speed component into the transport corridor «Gdansk - Kerch».

5. Within the framework of the project there was convened a meeting of the Commission of the Academic Council of the Petersburg State Railway University (PSRWU) under the chairmanship of Professor L.N. Pavlov, Pro-Rector on scientific research. The meeting was attended by prominent scientists in the transportation field. The members of the Commission noted originality and practical advisability of realization of the STS project under geographic and climatic conditions of the North-Western part of Russia, technical and economic efficiency of the project based on transition from the flat railway system to the spatial system. The participants confirmed the necessity of construction of an experimental section with the purpose of identifying major construction parameters and technical indices of the STS.

6. On 2 February 1999 there was held a meeting of the economic section of the Public and Economic Council at the Mayor of the city of Sochi devoted to the subject of the Yunitsky's transportation system. The participants of the meeting noted novelty in principal of the transportation system proposed by the author, its originality in technical, designing and technological solutions as well as great technical and economic efficiency of the STS under the conditions of the city of Sochi with its complicated geological and geomorphological situation for the engineering works.

7. Mr. S.S. Ling, Prime Minister, Republic of Belarus, sent a letter to Mr.Luzhkov, Mayor of Moscow, on the possibility of realization of a project on the setting-up of the string transportation system. Special attention in the letter is attached to the advantages of the STS construction within the boundaries of Moscow which could be the first experimental proving ground for this new transportation system.

8. Mr.S.A. Sibiryakov, Director, Department of interregional cooperation, Ministry of Federal and National Affairs of the Russian Federation, in his expert review of 12 November 1999 to Mr. S.K. Shoygu, Minister, Ministry of civil defense, emergencies and disaster relief, briefly described the string transportation system, terms of its construction and running, economic and ecological indices of the proposed type of transportation as well as a scheme of attracting investments in realization of this project with the assistance of the programme «Live Water of Russia».

9. A proposal on the possibility of practical use of the string transportation system was considered by the Government of the Republic of Karelia. In particular, the Ministry of industries, transport, communications and trade and the Ministry of external relations responded by their suggestions to construct STS routes in the frontier areas with Finland where stable freight and passenger currents are available. As a share of their participation in the project the Ministries offered land lots required for designing and construction of the STS and its infrastructure.

10. On 10 December 1999 Mr. S.I. Kruglik, State Secretary, First Deputy of Chairman, State Committee of the Russian Federation for construction, Housing and Municipal Economy (Gosstroy of Russia) sent a letter to Mr. S.A. Ordzhonikidze, Deputy Minister of Foreign Affairs of the Russian Federation, Chairman of the Joint Commission of the Russian Federation on cooperation with UNIDO whereby it is stated that «the received results signify that the development of this type of transport is prospective from both viewpoints, i.e. protection of environment and efficiency of freight and passenger transportation in comparison with that in use at the present time». In accordance with this conclusion Gosstroy of Russia requests the Commission to consider the possibility of setting-up the second phase of the international project on the territory of the Russian Federation with participation of the UN Centre for Human Settlements (Habitat).

11. The STS project was considered and approved by the Committee on city economy, municipal and private property, privatization, agriculture and foodstuffs, land use and construction (architecture), industry, transport, energy and communication of the city of Sochi for introduction in the process of development of transportation infrastructure of the resort city of Sochi.

12. The Government of the Krasnodar region considered the conclusion of its joint commission on distribution of productive forces made with regard to the Declaration of Intent on the setting-up of a scientific and research centre and an experimental route of the string transportation system by the Foundation «Yunitran-Sochi». The centre will be set-up on a land plot of an approximate size of 6 ha belonging to the Adler poultry association in the city of Sochi. Based on this conclusion a letter of agreement to accommodate the scientific and research complex on the mentioned land plot was signed by Mrs. N.I. Khvorostina, Deputy Chairman of the Government of the Krasnodar region, and sent to the Administration of the city of Sochi.

13. On 10 February 2000 Mr. S.I. Kruglik, State Secretary, First Deputy Chairman, State Committee of the Russian Federation for Construction, Housing and Municipal Economy (Gosstroy of Russia), signed the letter No SK-494/I addressed to Mr. E.D. Kasantsev, Deputy Minister of Railways of the Russian Federation which contained information on the steps taken by Gosstroy of Russia and Habitat Executive Bureau in

Moscow in direction of promoting the project through the international organizations UNIDO and Habitat. It was noted in the letter the global significance of STS introduction in Russia and in other interested countries.

14. Within the framework of the project activities on 18 November 1999 Mr. A. Sh. Shamusafarov, Chairman of the State Committee of the Russian Federation for Construction, Housing and Municipal Economy (Gosstroy of Russia), sent a letter to Mr. Carlos Magarinos, Director General, United Nations Industrial Development Organization (UNIDO), Vienna, Austria whereby it was noted that «the received results signify that this type of transport development is prospective for the conditions of Russia and other countries». It was requested in the letter to consider the issues of economic advisability to design and build the string transportation system, to determine spheres of its application, possibilities of carrying out model and bench testing as well as finding potential investors interested in providing financial support to this project.

15. In November 1999 the negotiations took place in Vienna between Mr. V.K. Storchevus, Director, Habitat Executive Bureau in Moscow, and Mr. Yo Maruno, Deputy to the Director General, UNIDO, and Mr. D.I. Piskunov, Special advisor to the Director General, UNIDO, on the subject of UNIDO participation in the project of Gosstroy of Russia and Habitat «Development and construction of a high-speed ecologically sound string transportation system to ensure urban and inter-settlements freight and passenger transportation». The parties discussed the details of cooperation in this joint project. It was decided that the contacts regarding developing constructive proposals on how to implement the project would be continued.

16. On 14 February 2000, within the framework of the project, Gosstroy of Russia sent a letter to Dr. C. Toepfer, Executive Director, UN Centre for Human Settlements (Habitat), about its agreement to present the string transportation system (STS) at the Global Ministerial Environment Forum to be held on 29-31 May 2000, Malmo, Sweden. The presentation of the STS working model was visited by more than 300 participants and visitors of the Forum.

In his report on the participation in the Forum Mr.V.K. Storchevus, Director, Habitat Executive Bureau in Moscow, indicated that «presentation of a working STS model in the course of the Global Ministerial Environment Forum in many respects proved that it is feasible to further promote and test a STS to bring it to industrial sample. The STS could become an efficient full-value environmental and economic alternative to motor transportation in urban areas appropriate for the use for a wide range of passenger and freight traffic. Deep interest in further search for transportation alternatives and their wider introduction expressed by professional environmentalists proved the need in launching the second stage of the Habitat project (in collaboration with UNEP) implying design and survey works and construction of a proving ground equipped with appropriate labs and infrastructure and located within the land plot allocated by City Administration of Sochi. Participation in the Global Ministerial Environment Forum under the auspices of UNEP demonstrated achievements of Russia in the field of new transportation technologies and proved that similar events are fruitful for the attraction of potential foreign investors and fund raising to facilitate development and introduction of knowledge-intensive technologies in the national urban economic practice».

17. On 22 March 2000 the Ministry of Federal and National Affairs, National and Migration Policy of the Russian Federation sent a letter to Mr. S.A. Ordzhonikidze, Deputy Minister, Ministry of Foreign Affairs of the Russian Federation, Chairman of the Joint Commission of the Russian Federation on cooperation with UNIDO whereby it was

suggested, given UNIDO recommendation, to include the project of STS development in the programme of financial support.

18. Mr. Anatoly E. Yunitsky, Project Manager of this project submitted an international application to the International Bureau of the World organization on intellectual property. The application PCT/IB94/00065 was published in accordance with the Agreement on patent cooperation (PCT).

Appendix 6

UN Centre for Human Settlements (Habitat)
Habitat Executive Bureau in Moscow

Project FS-RUS-98-S01

STRING TRANSPORTATION SYSTEM IN QUESTIONS, ANSWERS AND PROJECTS

Moscow 2000

Author: A.E.Yunitsky

A.E.Yunitsky - President of "Yunitran" Fund for the promotion of string transportation and General Designer of Research "Yunitran" Centre. Author of about 100 inventions including a principal STS scheme, with 22 of them used in construction, machine-building, electronic and chemical industries, scientific research projects of the Russian Federation, Republic of Belarus and other CIS countries. Acting Member (Academician) of the Russian Academy of Natural Sciences, Academician of the Russian Academy and Vice-President of Academy of New Thought. Project Manager of the UN Centre for Human Settlements (Habitat) project FS-RUS-98-SO1 "Sustainable Development of Human Settlements and Improvement of their Communication Infrastructure through the Use of a String Transportation System".

String transportation system (STS) in questions, answers and projects
Moscow, 2000

Given is the general data on STS and answers to 100 questions asked in the course of the Habitat project (FS-RUS-98-S01) performance to the author by opponents, sceptics and advocates of a STS as well as testing results of various scale models with relevant proposals for a testing ground construction and practical application of a STS.

"Yunitran" Fund: 115487, Moscow, Sadovniki str., 2,
tel./fax: (7-095) 118-02-38
Internet http://www.mtu-net.ru/yunitran
e-mail: yunitran@mtu-net.ru

Contents

Part 1. Background information about transportation and STS

Since January 1999 the UN Centre for Human Settlements (Habitat) Project FS-RUS-98-SO1 "Sustainable Development of Human Settlements and Improvement of their Communication Infrastructure through the Use of a String Transportation System (STS)" has been underway in Russia [1].

The key goals and objectives of the Project are as follows:

- to create an alternative to the mass-scale automobilisation of human settlements as a major factor contributing to their sustainable development and to specify the basic conditions providing for a STS realisation;
- to identify the ways for a STS testing in terms of its economic, environmental and technical components as well as in terms of its comfort and travel safety;
- to generalise the available national and international experience, to identify investment attractiveness of a STS, to formulate a strategy, priorities and mechanisms facilitating practical implementation of the Project both in Russia and in other countries.

Taking into account the fact that the Project proposes a principally new transportation system its major focus is on the interpretation of the role and place of transportation in the life of man, country, society and civilisation.

Development of communications always was of a fundamental importance for the social progress contributing to the development of links between different nations, and strengthening their trading and business relations.

Communications or transportation as exchange (circulation) of material and human resources is an indispensable condition for the well-being of individual persons and society as a whole, means of human communication in physical and intellectual space; the way of life and one of the basic cultural values and indicator of civilisation level.

Unsatisfactory condition of a transportation network leads to the disturbances in the normal economic performance, drop in the production rates in the related national economic sectors, unjustified losses in agricultural yield, limited access to the raw resources, reduced job opportunities, higher cost of goods and services, decline in the living standard of population and reduced educational and cultural opportunities, deterioration of environmental quality, difficulties in the elimination of consequences under emergency situations, decline in the national defence preparedness, restricting of foreign trade and tourism, higher death rate of population.

The Project made a comparative analysis of the main existing and future transportation modes and a STS and investigated a possibility to use a STS under conditions of the city of Sochi, Russia.

Which mode of transportation will be chosen by the mankind to enter the new millennium?

1. Railway transportation. In its modern meaning it takes the origin at the beginning of the 19^{th} century though the first track roads already existed in the Ancient Rome. The total length of railways built all over the world is more than 1,000,000 km.

Under the present conditions the cost of 1 km of a two-way road including infrastructure is USD 3…5 million, the cost of one passenger coach - USD 1 million, electric locomotive – about USD10 million. Road construction is very cost-intensive including: resource consumption such as metal (steel, copper), reinforced concrete, gravel; large-scale excavation works amounting on the average to 50,000 cub.m/km; and high land requirements-more than 5 ha/km or 10 ha/km including infrastructure.

Difficult geographic conditions necessitate construction of unique structures such as bridges, viaducts, elevated roads, tunnels which results in the increased total cost of the whole system and growing negative environmental impact. The average weighted travel speed is 100…120 km/h.

Wildlife habitat and living environment of the human settlements adjacent to the railway roads is exposed to noise impact, vibration, heat and electromagnetic radiation generated by the moving trains. The total amount of wastes generated by passenger trains during one year amounts to 12 tonnes including 250 kg of feces which is scattered along the road and its right of way over 1 km distance.

Railway transportation is characterised by very high water consumption and heavy water pollution. For example, the total water consumption by railway transportation facilities of Russia alone amounts to about 1 billion cub. m per year whereas wastewater of transportation enterprises contains petroleum products, phenol, creosol, resin, salts of heavy metals. Effluents discharged to water reservoirs give rise to the deterioration of water quality and living conditions of organisms inhabiting water bodies with 1 g of petroleum products contained in the water capable to make 2 tonnes of water unsuitable for drinking purposes.

Every year about 1,000 people and millions of animals are killed in Russia under the wheels of trains.

2. Automobile transportation. It emerged at the end of the last century. Over the past period more than 10 million km of roads were built and about 1 billion of cars were produced.

The cost of a modern highway is USD 5…10 million and its land requirements are estimated at more than 5 ha/km or 10 ha/km including infrastructure. The volume of excavation works exceeds 50,000 cub.m/km. The cost of an average statistics car is about USD 15,000, the average weighted travel speed is 60…80 km/h.

Automobile became one of the main sources of noise and air pollution in the cities. Automobile emissions contain about 20 cancer-generating substances and more than 120 toxic compounds. The source of environmental pollution and deterioration is associated with motor transportation itself and its relevant road infrastructure and engineering and service facilities, especially storage tanks for petroleum products, as well as filling, technical service and car washing stations, etc. which is the cause of natural environment transformation within the adjacent areas.

Noxious components contained in motor transportation exhausts and petroleum evaporation products is a source of air pollution and soil and surface water contamination. Contaminating substances are carried by rain and melted waters to the ground water and more deep-seated water-bearing tables. As a consequence, air, soil and water pollution gives rise to the degradation of vegetation cover. The major pollutants generated in the course of road construction and operation include dust, exhausts, petroleum products, wear products of tires, brake shoes and gears, asphalt and concrete pavements, de-icing salts and sand. Areas immediately adjacent to the highways are exposed to the heaviest pollution which is spread over a stripe of 300 m width and more.

It is also necessary to add the negative impact of various accompanying systems which serve motor transportation such as oil wells and pipelines, oil refinery and asphalt concrete plants, etc.

Embankments and depressions entailed in the highway construction give rise to the degradation of forests as a result of swamping or dehydration of the adjacent areas.

Highways and their infrastructure deprived the mankind of more than 50 million hectares of lands (which is the total area of highways in FRG and Great Britain) and, what is more important, these lands are not of the worst quality.

During the last decade automobile became the main man-made instrument of killing. According to the data of the World Health Organisation more than 900,000 people all over the world are killed annually in the road accidents (including those died as a result of after-accident injuries), millions of them become invalids, and more than 10 million are injured. For comparison: the average number of people killed on the planet every year in military conflicts is about 500,000.

Negative impact of motor transportation on the living environment and human health caused by the high concentration of cars in the cities and super-motorisation of urbanised zones made it necessary to start a search for the new alternatives [2]. As a result of the negative environmental impact of motor transportation and other sources of pollution a number of cities and their agglomerations were put under extreme environmental conditions which hinder their sustainable development and require cardinal measures to improve their communication infrastructure.

3. Aviation has a 100-year history.

It is the most environmentally hazardous and energy-consuming mode of transportation. The summary amount of noxious atmospheric emissions from modern aircraft reaches 30…40 kg/100 passenger/km. The bulk of emissions is concentrated within the area of airports, i.e. in the vicinity of large cities, in the course of flight at small heights and engine reheating. At low and medium heights (up to 5,000…6,000 m) nitrogen and carbon oxides remain in the atmosphere for several days after which they are washed away as acid rains. At upper heights aviation constitutes the only source of pollution. Noxious substances remain in the stratosphere much longer for about one year.

A modern jet liner in terms of its toxicity is equal to 5,000…8,000 cars and the amount of oxygen consumed for fuel combustion is equal to that consumed by more than 200,000 people for breathing. Regeneration of the equal amount of atmospheric oxygen will require several thousands hectares of pine forests or even a larger ocean plankton area.

During a many-hour flight every passenger is exposed to additional irradiation as a result of cosmic natural gamma-radiation and in the aircraft saloon an exposure dose is equal to 300…400 microroentgen/hour against 20 microroentgen/hour which is a standard.

Another important factor entailed in airport construction is related to land allocation. In terms of space requirements it is comparable with railway and highway construction however, lands allocated for airports are located in the immediate vicinity of cities, thus, their value is much higher.

Aviation produces a heavy noise impact, especially within the area of air-ports, and considerable electromagnetic pollution generated by radar facilities.

Air transportation is the most expensive one. The cost of a modern airliner is as high as USD100 million, while construction costs for a large-scale international airport exceed USD10 billion.

4. High-speed railways (HSR). Their construction was started in the last quarter of our century. Maximum travel speed is 400 km/h, average operating speed - 180…200 km/h.

HSR is an ordinary railway road provided with improved and reinforced track structure (rails, sleepers) and cushion (special reinforced embankment and ballast foundation) and special high-speed rolling stock.

The cost of 1 km of road is USD10…20 million, the cost of 1 coach - USD 2…3 million. Their environmental impact is heavier than that of conventional railways. For example, according to the environmentalists' estimates the environmental impact of the construction of a high-speed railway "St-Petersburg - Moscow" will be equal to that of Chernobyl accident. In this case the net cost of travel will be USD 123 per 1 passenger (with the total length of the route being 660 km). Another example - experts estimated that if in the

21[st] century development of a densely populated country such as China with its limited and vulnerable agricultural lands is oriented towards HSR construction, in 20…30 years it will be in the face of a nation-wide famine and its scale will be comparable to that of the period of cultural revolution when about 30 million Chinese died of hunger.

HSR requires noise screening facilities and special enclosures to prevent penetration of cattle and wild animals to the railway tracks which could result in the derailment of trains. HSR embankment creates an insurmountable obstacle for wild animals, surface and ground waters.

By the year 2000 as little as 3,100 km of HSR has been built in Europe.

5. Trains on a magnet suspension.

5.1. "Transrapid" (Germany) with an electric magnet suspension using traditional conductors. For a coach length of 25 m the clearance between the rolling stock and the road structure should not exceed 10 mm, otherwise suspension would not work. Such roads place very high and difficult requirements for their construction and operation.

The cost of a road is USD 25…50 million/km, the cost of 1 coach is USD 6…8 million. For example, business-plan of the German "Siemens" Company submitted to the Government of Moscow specified the cost of a "Transrapid" route - "Airport Sheremetyevo - Centre of Moscow" with the total length of 29 km as USD 1.5 billion (not including the cost of land and costs for building and structure demolition). Construction is associated with high building material costs including reinforced concrete and steel for the span beams which are to be massive (though the span length is only 24 m) and supports (to eliminate any displacement under the load, even at portions of 1 mm).

Its travel speed is up to 500 km/h. It is characterised by heavy noise at high travel speeds produced by the bearing beam totally enclosed (on top, bottom and on both sides) by a coach shell and the air sucked in the clearance at high speed. It has a very low energetic efficiency: substation efficiency is 34% (alternating current frequency modulated by a substation is used to form a magnetic field running along the track), efficiency of a linear electric motor is 40%. As a result of multiplication we get a total efficiency of 13.6% which is somewhat higher than that of a locomotive.

5.2. "Maglev" (Japan) - super-conductive magneto-levitating railway road. Coaches are equipped with super-conductive coils and the power of their magnetic field is so high (no similar magnetic field has ever been found in nature either in our Planet or in the solar system and the Galaxy, therefore, imagine how hazard it could be for all live things) that it is capable to provide suspension at the height of 10…20 cm. Travel speed is up to 500 km/h. Coils located in a passenger coach are cooled by three cryogenic circuits of liquefied and gaseous helium and liquefied nitrogen. Jump-type losses in super-conductivity could result in coil explosion equivalent to that of several kilograms of trotyl.

The cost of 1 km of road is USD 20…30, the cost of 1 coach is more than USD 10 million.

6. Monorail is widely spread in the USA, Canada, France. A wheel cabin is moving along a beam (ALVEG) or under a beam (SAFEGE) which should have a large cross section in order to ensure the cabin steadiness. A system is characterised by high material consumption for span structures and supports. Because of the unfavourable vibration dynamics of a suspension system and poor aerodymanics qualities of a cabin monorail roads have low travel speeds failing to reach 200 km/h. The cost of 1 km of monorail road is USD 4…10 million.

7. Trolley-bus is used as an urban mode of transportation. It is one of the most clean transportation modes in terms of its environmental impact. It requires hard surface roads and a special infrastructure provided with a feeder line. Therefore, trolley-bus routes are usually more expensive than traditional highways. The cost of a modern trolley-bus is about USD 500,000.

8. High-speed tram. In the recent years was widely developed in the USA, Canada, Europe, South East Asia, Russia, Ukraine. Travel speed is up to 120 km/h. The cost of routes is USD 6...12 per 1 km. The cost of 1 tram is about USD 1 million.

9. Rail bus – is a variety of a tram which uses a diesel instead of an electric motor. Its production was started in Germany in 1995. The cost of 1 rail bus is USD 2 million.

10. Cable roads. Aerial transportation system designed by a Swiss engineer G. Muller has been already put into service in Canada, USA and Germany. It consists of passenger coaches that are moving along the cables hanged on the light metal supports. It is a relatively low-cost structure (USD 1.5...2 million/km), however, it fails to reach a speed more than 50 km/h.

Discussed above were the main modes of transportation, each of them having a number of alternatives. For example, screen-jet is an alternative of an air-plane, electric car is that of a motor car. These and other modes of transportation the total number of which is more than 200 are the object of research in many countries of the world. Among them is a route for air planes with shortened wings coming through the underground tunnel of 50 m diameter (Japan) or a flying plate which creates vacuum in front of a nasal part of an aircraft (Russia) which in the author's opinion could be regarded as exotic ones.

Analysis shows that existing and future modes of transportation are associated with high costs and environmental hazard, their construction requires alienation of large areas of valuable lands. None of the transportation modes except a bicycle is capable to cope with noise requirements whereas noise control measures to provide the high-speed roads with necessary noise protection devices would entail higher costs.

The system analysis shows that in the 21st century a road transportation system could take the lead among other transportation modes in terms of its environmental, economic, communication, land-use and safety qualities which is capable to provide the travel speed of 300...500 km/h and comply with the following requirements:

1) the cost of a route including infrastructure is not higher than that of a cable road amounting to about USD 1.5...2 million; in this case resource-consumption for a transportation system (including requirements for building materials and structures, the volume of earth works, consumption of ferrous and non-ferrous metals, etc.) is to be compatible to that for a cable road;
2) transportation passenger module in terms of its comfort is at the level of a modern airliner and its cost is not higher than that of a passenger car;
3) the net travel cost is at the level of local electric trains in Russia - not higher than USD 1...2 per 100 passenger/km (or 10...20 USD/1,000 passenger/km);
4) land requirements are not more than 0.1 ha of land per 1 km of road including infrastructure;
5) does not require construction of embankments, depressions, tunnels, powerful elevated roads, viaducts resulting in the deterioration of landscapes and biocenosis and characterised by poor resistance to the natural disasters (such as earthquakes, flooding, land slips, etc.)
6) in terms of its specific environmental impact the module is less hazardous than a trolley-bus or an electric car with its noxious atmospheric emissions being not more than 10 g per 100 passenger/km;
7) energy costs (fuel consumption) for a high-speed movement will be 5...10 times less than for a modern passenger car (in terms of gasoline consumption - up to 0.5 liter per 100 passenger/km);

8) traffic safety is at the level of aircraft passenger transportation;
9) carrying capacity per 1 route is more than 100,000 passengers and 100,000 tonnes of freight per day;
10) operates as a multi-purpose communication system providing a high-speed circulation of passengers and freights and transmission of electric energy and electronic information.

The given analysis strengthened the author's opinion that none of the existing or future transportation systems could cope with the above mentioned requirements of the 21st century.

This fact inspired the author to design a principally new communication system which eliminates the shortcomings of the existing systems and incorporates the advantages of the future transportation systems. In this case the search for a solution was based on the following requirements: no exotic in terms of engineering and scientific proposals such as magnet suspensions, superconductivity, levitation, anti-gravitation, etc. A system should be based on the well-tested materials, technologies and engineering solutions.

Idea of a string transportation system (STS) was suggested by the author in 1982 when his first publications appeared in the journals "Inventor and Rationalisator" and "Technika Molodezhi" devoted to a planetary non-rocket-borne transportation means to open up near outer space. Based on this idea a STS was developed as an independent project.

It took more than ten years to develop a theoretical scheme and to find engineering, technological and design solutions as well as to optimise environmental, economic and engineering components and to analyse the system advantages and shortcomings. First information about a STS (without details about its engineering essence) was published as late as in 1993 in one of the Belorussian journals. Three more years were spent to get a patent for a principally new STS scheme in the leading world countries through the application to the World Intellectual Property Organisation. The last years were spent to prepare working drawings for a rail-string, supporting structures, infrastructure components, major units of a transportation module, research of aerodynamics, dynamics of a high-speed movement using a hard string (a rail-string) and manufacturing of operating models.

Thus, though so far actually not 1 km of a string road has been built it is possible to draw up its key technical and economic specifications.

STS is a pre-stressed stretched cable-and-beam structure which is fixed on the supports to carry special electric module cars with the total load-carrying capacity of 20 passengers or 5,000 kg of freight [3, 4, 5]. Power supply is provided by special current-carrying rail heads contacting with the cabin wheels. In case electric cars are supplied from an autonomous power system the rail-head and the track as a whole will be cut off current.

The basis of a STS is formed by a beam of high-strength steel wires each of 1…5 mm diameter installed with a dip inside a hollow rail. Instead of wire it is possible to use a high-strength steel strip. The rail is assembled in such a way as to maintain its head ideally smooth after the hollow rail has been filled with solidifying filler, for example, using cement, bitumen or epoxy resin to fix the strings. Therefore, it is possible to eliminate dips or junctions on the whole length of a rail head along which a transportation module wheel is moving. Strings and rails are rigidly fixed on anchor supports located at the intervals of 1…2 km. String dips of 50 mm under the structure weight are observable in the following cases: tension force of 100…500 tonnes, span length of 25…50 m, a rail track mass of 50…150 kg per 1 running meter. It is easy to hide, "to enclose" these dips inside a hollow rail of 15…20 m height.

There is also a great number of intermediate supports installed at 25…100 m intervals with 20…50 intermediate structures per 1 anchor support which will define the total cost of a supporting part. The STS design implies that intermediate supports are exposed predominantly to a vertical load which is light amounting to 25 tonnes at 50m span. It is approximately equal to the load carried by the high-voltage power transmission lines, which makes these both structures close in terms of their design and material consumption. Along the whole length of the route only two terminal anchor supports are exposed to maximum horizontal loads of 1,000 and 500 tonnes for a dual- and one-way track, respectively. More than 90% of the total number of anchor supports are intermediate (or technological) anchor supports which will not be exposed to heavy horizontal loads in the course of operation because the loads on the supports from both sides are counterbalanced.

String and rail have no deformation welds along the whole length and under changed temperature conditions their operating scheme would be similar to that of a telephone cable, a wire of a power transmission line or a cable of a hanging bridge fixed on the supporting structures with a dip and stretching for many kilometres without junctions. The rail is designed as an assembly structure. The estimated temperature gradient is accepted at 100 °C. Such temperature gradient is registered once in 100 years in countries with sharp continental climate or in the mountains; in sub-tropic or tropic zones it will be 20…30 °C lower.

A STS string is made of a wire manufactured today for steel cables (with its ultimate strength up to 200 kgf/mm^2) or pre-stressed reinforced structures and cables of hanging or guying bridges. For a rail-string head it is appropriate to use steel used for railroad rails which in terms of its physical and mechanical qualities is suitable for the purpose. STS is designed as a very rigid track. For instance, with a span of 50m the absolute statistical track deflection caused by a load of 5,000 kg concentrated in the middle of a span will amount to as little as 12.5 mm or 1/4000 of a span length. For comparison: modern bridges including those for the high-speed railways are designed for a permissible relative deflection of 1/400 which is 10 times higher. Dynamic deflection of a STS track under the moving load will be lower - up to 5 mm or 1/10000 of a span. This track will be smoother for the wheels of a transportation module than, for example, the bottom of a salt lake where, as you know, at the end of the 20th century for the first time an automobile managed to exceed the sonic speed - 1,200 km/h.

Factors limiting a maximum STS speed are associated rather with its aerodynamic qualities than with a track smoothness or vibration and "wheel-rail" friction contact. That is why special emphasis in a STS design is laid on its aerodynamic qualities. It was possible to obtain unique results having no analogues in modern high-speed transportation including aviation. Aerodynamic resistance coefficient of a model passenger vehicle measured in a wind tunnel amounted to $C_x = 0.075$. Measures are proposed to reduce this coefficient to $C_x = 0.05…0.06$. Low aerodynamic resistance makes it possible for a 20-passenger vehicle with the engine capacities of 80 kW, 200 kW and 400 kW to reach the speeds of 250…300 km/h, 400…450km/h and 500…550 km/h, respectively. In this case mechanical and electromechanical losses will be insufficient thanks to a high efficiency coefficient of a steel wheel and a motor wheel as a whole amounting to 99% and 92%, respectively.

It is known that as the speed increases the wheel-rail cohesion is diminishing. To reach the travel speeds of 300…350 km/h (with a thrust of 100 kg) and 400…450 km/h (with a thrust of 180 kg) "a wheel-rail" pair in a STS is to have a friction coefficient not less than 0.04 and 0.07, respectively which is easily reachable. Cohesion problems arise only at the travel speeds of 500 km/h and more which require a thrust of more than 300 kgf. However, this problem is also easily solved with the help of a STS. For instance, we designed a principally new scheme for a rubber-covered thrust motor-wheel of 100 kW capacity which is capable to provide the required cohesion and thrust. However, in the foreseeable future such high travel speeds will not be needed and it will be enough to use the most optimal STS speed in the range of 300…400 km/h . In this case it will be easier to ensure higher safety of travel and to reduce energy costs which to a considerable extent affect the cost of travel by high-speed transportation modes including a STS.

Availability of two rims (flanges) and an independent ("automobile") suspension at each wheel will considerably lower the risk of derailment for a transportation module which is, for example, the main cause of road and railway accidents. Module derailment as a result of aerodynamics forces or gusts of side wind is fully excluded which was proved by the wind tunnel tests.

In construction terms the safety of a STS track structure and supports is similar to that of a hanging or guy rope bridge because they are very close in terms of their design, however, in our case the STS strings are much better protected from climatic and mechanical impacts than the bridge cables.

The key elements of an electric car (running gear, suspension, gear transmission) and the systems of electronic control meet the existing requirements for aircraft and high-speed railways. Therefore, on the whole we do not see any obstacles for a STS to become the most safe and reliable mode of land transportation in the future.

It should be noted that in the economic terms the cost of a fully-equipped serial-produced dual-way STS route including infrastructure (terminals, stations, freight terminals, depots, etc.) to be located in various ground feature conditions will be as follows (in million USD): 1.0…1.5 - in the plane; 1.5…2.5 - in the mountains; 1.5…2.5 - above the sea; 5…8 - in the underwater or underground pipe-tunnel.

In design terms a transportation module is simpler than a passenger car, therefore, the cost of a serial-produced module will be at the level of a mini-bus – USD 20,000…40,000 or USD 1,000…2,000 per 1 seat (for a 20-seat electric car). For comparison, we give the relative cost of the rolling stock in other high-speed systems: aircraft - 100,000…200,000 USD/seat, train on a magnet suspension - 100,000…200,000 USD/seat, high-speed railway - 20,000…30,000 USD/seat.

Net cost of a STS passenger or freight transportation will depend on many factors and first of all on the intensity of a passenger- and freight flow (for the travel speed of 300 km/h), including:

a) passenger traffic, USD/1,000 pass./km: 20…25 (10,000 pass./24 hours); 10…15 (20,000 pass./24 hours); 5…10 (50,000 pass./24 hours);
b) freight traffic, USD/1,000 tonnes/km:6…8 (20,000 tonnes/24 hours); 4…5 (50,000 tonnes/24 hours); 2…3 (100,000 tonnes/24 hours).

Structure of travel costs (for the travel speed of 300 km/h):

a) passenger traffic - track and rolling stock amortization – 65…80%, operation costs - 10…20%, electric power - 5…10%.
b) freight traffic - track and rolling stock amortization – 45…65%, operation costs - 10…20%, electric power - 25…45%.

STS can be designed as technological or specialised routes to be used for various purposes such as: to remove garbage beyond the boundaries of megalopolises; to deliver ore from quarries to the processing plants; to transport coal to heat power stations or oil from oil deposits to refinery plants; to supply large volumes (about 100 million tonnes per year) of a high quality drinking water to the densely populated regions of the world at distances of 5,000…10,000 km, etc. String roads can be also used as freight, passenger (including those for tourist purposes) and freight-passenger routes.

Therefore, technical, economic and environmental qualities of the proposed mode of transportation seem to be very attractive, in particular:

1) construction of STS routes does nor require large land allocations (which is 150…200 times less than for highway or railway construction);
2) STS routes do not require construction of embankments, depressions or tunnels, cutting of forests, demolition of buildings; a STS is easily integrated into an urban

environment and is easy for construction under difficult natural conditions such as permafrost, mountains, marshlands, desert, water barriers (rivers, lakes, straits and ocean shelf, etc.);

3) communication system is characterised by a higher resistance to natural disasters (earthquakes, land slides, flooding, hurricanes), and unfavourable climatic conditions (fog, rain, icing, snow drifts, sand storms, severe heat and cold, etc.);
4) thanks to its low material consumption and high technological qualities the cost of a STS route will be lower than that of conventional modes of transportation (by 2…3 times), high-speed railways (by 8…10 times) and highways (by 3…4 times); monorail roads (by 2…3 times), trains on a magnet suspension (by 15…20 times), therefore, its travel cost will be also the lowest one amounting to 5…8 USD/1,000 passenger/km and 2…5 USD/1,000 tonnes/km.

STS routes are easily matched with electric transmission lines, wind and solar electric power plants, communication lines including fibro-optical ones, therefore, they are likely to serve not only as the high-speed roads but as communication systems as well.

Maximum carrying capacity of a dual-way track is 500,000 passengers (about 200 million passengers per year) and 500,000 tonnes of freight per day (about 200 million tonnes per year).

At the present moment neither a STS developer or experts have any doubt in the system validity in terms of its efficient operation and practicable implementation. The main reason why a STS programme has not been put into practice so far is associated with the lack of finances. For more than 20 years all works for a string transportation system have been carried out thanks to the personal support and enthusiasm of its author which is naturally not enough to further promote it. In fact, no state support has been provided either, though President of Belarus Alexander Lukashenko expressed his personal interest and support of the proposed system. The only actual support in the form of a grant was provided by the UN Centre for Human Settlements (Habitat) in January 1999 and add to it some small private investments.

A mathematical dynamic STS model was developed by the joint efforts of mathematicians from Belarus State University, Petersburg State Transportation University, Voronezh Polytechnic Academy, Academy of Sciences in Byelarus and Ukraine. The major research outcomes are discussed in the author's monograph: "String Transportation Systems: in the Earth and Space" (the city of Gomel, Belarus, 1995). The operational STS model was exhibited at Leipzig Fair (Germany, 1995) and Hanover Industrial Fair (Germany, 1996); and at a number of exhibitions including the Exhibitions of Achievements of Belarus Academy of Sciences (1995, 1996, 1997); "Innovations-98", Moscow (1st Degree Diploma); "Spectransport-99" and "Road-99", Moscow. Everywhere the STS was highly evaluated by the professionals.

How long will it take to put a string system into practice?

A number of STS alternatives were considered and analysed including, in particular, an alternative for the 2nd Crete transportation corridor - "Paris - Moscow". International Conference devoted to the given transportation corridor which took place in the city of Minsk in October 1997 and brought together experts from 14 countries recommended the European Union to consider a STS as a high-speed component of Crete transportation corridors [9]. In 1998 the Government of Belarus applied to the City Government of Moscow with a similar proposal. In this respect it should be noted that the EU Council of Ministers decided to allocate USD 400 billion for 9 Crete corridors up to the year 2010.

Thus, for example, if financing of a "Paris - Moscow" STS route is opened in 2001 it is likely that a route will be put into service in 2006. One building team will be able to build more than 300 km of road per year, thus, 8 teams working simultaneously at different sections will be able to build the whole route during 1 year – 2005.

In 2001 it is proposed to invite international tenders to design a motor block, undercarriage and saloon for a transportation module and electronic control and safety systems for a STS. Presumably, its participants could be the largest corporations such as "General Electric", "Microsoft", "Intel", "Mitsubishi", etc., firstly, because the work will be paid and, secondly, because a STS represents a new and very capital-intensive market (according to the experts' estimates the world market for a STS exceeds USD 1trillion) which is highly attractive for the aforementioned and other corporations. It is proposed that design of STS components submitted to a tender should be finalised during 3 years, i.e. by the year 2004. In 2004 all the above systems as well as alternative systems designed by internal efforts will be tested and optimised on a pilot section of a route planned for design in 2001 and construction in Russia in 2002.

The total cost of a STS route "Paris (London) – Moscow" (with the total length of 3,110 km) is estimated at USD 5.7 billion including USD 5.2 billion - the cost of a track and infrastructure and USD 0.5 billion - the cost of the rolling stock.

Cost distribution by year will be as follows: USD 10 million – in 2001; USD 100 million – in 2002; USD 500 million – in 2003, USD 1 billion – in 2004; USD 4.1 billion – in 2005.

A route put into operation will start to recoup itself in 2006 and the total costs will be repaid during the year 2009. In this case the net cost of travel from Moscow to Paris will be USD 32/passenger, and travel time - 7 hours 10 minutes (with a travel distance of 2,770 km and estimated travel speed of 400 km/h). Beginning from the year 2010 the average net profit of a string route will be estimated at about USD 2 billion per year to reach the total of USD 20 billion by the year 2020. That is why a STS programme will be very attractive for investors and resources of non-state investors and joint stock capital will be enough to implement it in full-value.

Construction of a high-speed road network in Russia will require minimal state resources. For example, it is possible to build a STS route network: "Lisbon (London) - Moscow - Lake Baikal - Peking (Seoul - Tokyo) - Delhi - El Kuwait" with the total length of about 30,000 km during the nearest decade with the financial support provided by international investments in the Programme "Live Water of Russia" and the programme will bring the total annual income of USD 100-200 billion enough to pay back construction costs during one year. One more project which is not less attractive for Russia in terms of its currency earnings is focused on Siberia and northern regions with their frosts serving as a sort of natural refrigerator. Today the cost of a high quality food natural ice at the world market is USD 7,000 against USD 500…1,000 – the cost of high quality natural drinking water, which is higher than that of copper and aluminium and 50 times higher than that of oil. At the same time today the total human demand for the high quality bottled drinking water is estimated at 10 billion tonnes per year (for comparison: the annual oil and coal consumption amounts to about 2 and 3.5 billion tonnes, respectively), whereas one half of the world resources is concentrated in Russia (Lakes Baikal, Taimyr, Onega, etc.). Therefore, the programme could be realised only on the basis of a STS which is capable, for example, to deliver water and food ice from Baikal to Madrid at the net price of USD 0.05/liter and USD 0.1/kg, respectively or from Baikal to Moscow at the price of USD 0.03 and 0.07, respectively.

Half of resources earned only by the above STS programme and re-invested in other projects will be enough during the next 40-50 years to build 1 million km of roads so necessary for Russia. And what is more important, these roads will have the lifetime of 100 years, they will not be in need of snow or ice removal and the use of sand and anti-icing salts in winter, they will not be destroyed during 2…3 winter seasons; they will not be drowned in bogs or permafrost, it will not be necessary to patch them every year.

For Russia this task will not be much more difficult, for example, than problems solved by the USA in the 20th century which had to build more than 5 million km of roads to ensure normal vital activity for its 250 million population. Road construction was associated with higher costs and environmental hazard; roads intended for the low-speed motor transportation entailed appropriate infrastructure provision; they gave rise to the promotion of automobile industry with the annual production rates of 1 million cars.

STS, for example, will make it possible to link Europe and Asia with America by a land route "London (Paris) – Moscow – Lake Baikal – Yakutsk – Bering Strait – Calgary – New York". The route with the total length of 21,000 km and the total cost of about USD 40 billion will be able to pay back its construction costs during 4…5 years.

There are dozens of other string route alternatives which have strategic and geopolitical significance practically for all continents and countries of the world.

Part 2. 100 Questions to the Author

Technical aspects

1. What is it a string transportation system (STS)?

One-way STS track consists of two special current-carrying rail-strings (isolated from each other and from the supports) along which a four-wheel high-speed electric module is moving. In case an autonomous power supply system is used a track structure will be dead. High smoothness and rigidity of a string track structure makes it possible to easily reach the travel speeds of 250...300 km/h which in the future could be increased to 500...600 km/h. It is possible to design a STS route as a multiple-track structure with its tracks located either on common or free standing supports.

2. What is it a rail-string?

A rail-string (in terms of building machinery) is a rigid string consisting of a beam (a specially designed hollow rail) with a number of high-strength steel cables put inside it with a dip and fastened to a summary strength estimated at hundreds of tonnes. A rail and cables are tied with each other to form a single structure. In terms of its qualities a rail-string is a combination of a flexible string and a rigid beam.

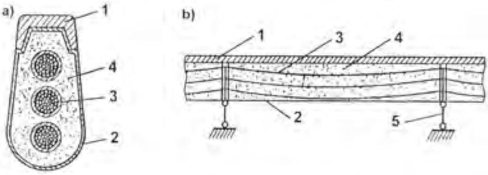
3. Are there any analogues of a rail-string among other building structures?

Its closest analogue is a reinforced concrete bridge beam made of rigid components (reinforced concrete structure) with flexible bunches of steel wires stressed to 100...150 kgf/mm2 tension and put in special channels inside the beam. Beam and bunches of wires are fixed with solidification mixture, for example, cement solution or epoxy resin filled in the channels to make a single structure.

Another analogue is a hanging bridge consisting of a rigidity beam supported by a cable and fixed with a dip. Beam and cable are fixed with suspension to make a single structure.

4. Then what is a principal rail-string distinction?

Design of a rail-string envisages that at spans of 10...100 m the dips of a string (cable) would be equal to 1...10 cm. In this case it is easy to place a string inside a small diameter structure (see fig.).



Design of a rail-string:
a) cross section; b) longitudinal section; 1 - head; 2 - body; 3 - string; 4 - filler; 5 - supporting mast.

5. Longitudinal dimensions and weight of a rail-string?

A rail-string is characterised by the following maximum longitudinal dimensions: width – 10 cm, height – 20 cm. Mass of a running meter is 50…75 kg out of which steel makes 50…75%.

6. Is a rail-string lighter than a railway rail?

Yes, it is. In terms of material consumption a track structure (including two rail-strings) for a one-way STS route is comparable to one modern heavy railway rail (including blocking, bolt fixtures, etc.) of the same length.

7. Does a rail-string require unique materials for its manufacturing?

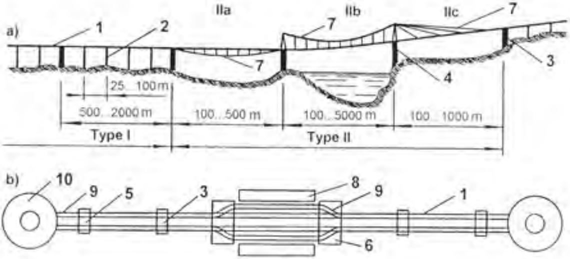
No, it does not. All materials necessary for its manufacturing are produced today by industries of any developed country including Russia. For example, a rail head along which a STS vehicle is moving is made of steel used for railway rails. It can be manufactured at the same rolling mills but equipped with more simple instrumentation because a head profile is simpler than that of a railway rail (it is closer to a channel and its linear mass is much less than that of a rail amounting to 15…30 kg/m).

A STS string is a non-twisted cable made of high-strength steel wires of 1…5 mm diameter. Wire with a tensile strength of 90…350kgf/mm^2 is industrially produced to be used for cables and ropes in hanging and guy rope bridges, reinforced structures, steel cord of automobile tires, etc. Dozens of steel marks produced by the large-serial manufacturers are suitable for a string, therefore, there is no need to list them.

The same is true for other rail-string components, track structure, supports and STS transportation module – all these components are either produced by industry or it is not a problem to master their production.

8. Linear track scheme?

Given below is a linear track scheme.



Linear track scheme.

a) side view; b) top view; 1 – two-way track structure; 2 – supporting mast; 3, 4, 5, 6, - anchor supports including: intermediate, pylon, terminal, switch ones, respectively; 7 – supporting cable; 8 – intermediate station; 9 – track section made of conventional rails (of railway type); 10 – ring terminal.

The following two types of a STS track structure are recognised depending on a span length: I – conventional design (with a span under 100 m); II –including additional supporting cable structure (with a span more than 100 m) with cable fixed: a) at the bottom; b) on the top with a parabolic dip; c) on the top in the form of guy ropes. STS supports are sub-divided into the following three typical categories: anchor (fixed at 500…2,000 m distance and more), brake (at 200…500 m distance and more) and supporting masts (at 10…500 m distance).

9. What is a tension strain of a string?

A tension strain on one rail-string will be equal to 250 tonnes (at the estimated tensile strength of wire being 100 kgf/mm^2 its summary cross sectional area will be 25 sq. cm and the mass - about 20 kg/m; if a string is made of three cables then each cable should be of about 35 mm diameter).

For comparison: cross section of a modern hanging bridge reaches 1,500 mm and its tensile strength is 100,000 tonnes and more. By the way, carrying capacity (including passenger and freight traffic flows) of a STS and a hanging bridge is the same. The ratio between the tension strain of a rail-string and the length of a span will be as follows: 250 tf - 100 m; 500 tf – under 1,000 m; 1,000 tf – under 2,000 m.

10. Maximum possible span?

To support a STS track structure with spans exceeding 100 m in length it is necessary to use a special cable (fixed on the top or bottom) designed like a hanging or guy rope bridge. Light-weight track structure and STS modules make it possible to use cables of 10 cm or 20 cm diameter made of high-strength steel wire sufficient to support spans of 2,000 m and 4,000 m, respectively. Modern composition materials will ensure a maximum span length of 5,000…6,000 m.

11. How rigid is a track structure?

An important quality of a track is its relative rigidity: ratio between the structure deflection under the weight of the estimated load located in the middle (or ¼) of a span and the span length. Modern bridges, including hanging bridges, are designed in Russia for the estimated relative deformation of 1/400. Estimated rigidity of a STS is by one order higher: deflection of a string structure with a 50 m span under the weight of a transportation module amounting to 5,000 kgf will be equal to about 10mm or 1/5000. Therefore, the smoothness of a string track for a moving wheel will be by one order higher than, for example, that of a high-speed railway road laid on a modern reinforced concrete or steel bridge.

Construction (assembly) deflections of various track components under their own weight are given in the Table below.

Table

Deflection of the STS Structure under their own weight

Span, m	Static (erection) deflection of structural elements			
	string in rail		guy cable	
	Absolute deflection, cm	Relative deflection	Absolute deflection, m	Relative deflection
25	1.6	1/1600	-	-
50	6.3	1/800	-	-
75	14.1	1/530	-	-
100	25	1/400	0.25	1/400
250	-	-	1.56	1/160
500	-	-	6.25	1/80
750	-	-	14.1	1/53
1000	-	-	25	1/40

12. What about thermal strain?

Neither a rail or a string are exposed to any longitudinal deformation (stretch) with their length being invariable in summer and in winter. Like the wires of telephone or electric transmission lines that are fixed by supporting masts to stretch for many kilometres without any joints a rail and string system is not exposed to thermal strain. However, temperature drop could change its stressed strained state.

Design of a STS track provides for its structure rigidity under the estimated temperature variations. For example, at maximum temperature drop of 100 °C (from +60 °C in summer to –40 °C in winter) the maximum tensile force will range from 7500 kgf/sq.cm (in summer) to 10000 kgf/sq.cm (in winter) and from 0 to 2500 kgf/sq.cm for a string and rail, respectively. Under reduced temperature drop a deformed stress will be proportionally reducing.

13. Temperature variations in a string tension will result in track deflection. Is it dangerous?

In fact, track deflection is observable in a vertical plane which will be proportional to its initial dip and relative variation of tension. At 100 °C temperature drop (or 50 °C more neutral value) a maximum vertical deflection of a track with a 50 m span will amount to about 5 mm or 1/10000. In this case 5 mm upward and downward deflection of a track will be observed in winter and in summer, respectively. This micro-unevenness which is easily compensated by a wheel suspension would not affect smoothness of a vehicle moving at speeds of 500…600 km/h. Furthermore, as far as thermal deflections have an assigned and pre-determined nature a wheel suspension controlled by a computer will correct the travel profile automatically.

14. What is the rolling stock impact on a string tension?

Variations of a string tension will be of about 1% which is attributed to the kinematic qualities of a string track structure. Fig. 18 shows a string block system in which a string tension does not depend on external load *P*. This structure is easily transformed in a linear scheme of a greater length (Fig. 19).

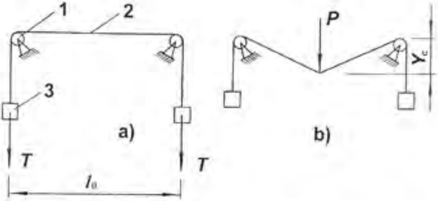


Fig. 18. String block system:
a) without external load; b) with a load; 1 - block; 2 - string; 3 - load.

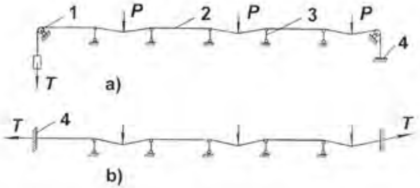


Fig. 19. String linear scheme:
a) with a block at the end of a string; b) with a string sealed off; 1 – block; 2 – string; 3 – wing support; 4 – fixing (anchor).

Analysis showed that at $P < 0{,}01T$ (which is observed in STS) the difference between deformed stress values of structures shown in fig. 18 and 19 does not exceed 1% (more precisely 0.1…0.5%). In engineering estimates this difference could be neglected and the structures could be considered identical. It considerably distinguishes a STS from other building structures, for example, bridges or overpasses. The latter are exposed to millions of loading cycles in the course of their operation and in each case the stress of various components such as reinforced beams increases by 2 and more times. All this results in the development of fatigue and, therefore, reduced lifetime of a structure and growing maintenance and repair costs.

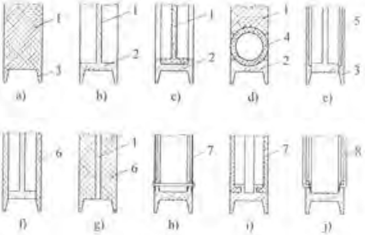
As far as the deformed stress of a STS remains practically invariable during the whole period of its operation irrespective of the number of loads a string transportation system would be characterised by longer durability.

15. How accurate are the track parameters?

Left and right rail-strings will be linked with each other every 5…10 m with special cross cleats which fix a gauge like sleepers of a railway. Side thrust in the interspace, for example, caused by hurricane side wind of 100…150 kgf per 1 wheel will change the gauge width by 1…2 mm as a result of a rail deflection which will not be dangerous for a vehicle moving at speeds up to 500…600 km/h.

16. In case of sliding apart rails how it can affect a vehicle, is it going to fall down?

This risk exists at the railway roads including the high-speed ones which became the cause of many cases of derailment resulting from the fact that the train wheels have one flange. In a STS module each wheel has two flanges (on the left and right side of a rail head, see Fig.) and an independent suspension. Therefore, a transportation module would be non-critical to the gauge width. For example, a wheel suspension can be designed in such a way that the variation of a gauge width by 10 mm would result rather not in derailment but in regular travel conditions. In this respect coming off the track is more typical for cars which are kept from falling to a side ditch, especially under icy condition of roads, only by a frictional force, whereas trains which have rims on their wheel pair are more stable.



Structure of a supporting part of a wheel:
a), b) – solid (monolithic) wheel; c), d), h), I), j) - combined with a moving rim; e), f), g) - combined with moving flanges; 1 – wheel body; 2 – rim; 3 – flange; 4 – elastic toroidal component; 5 – flexible plate; 6 – flexible disk; 7 – membrane; 8 – spoke.

17. As a rule, twisted cable (rope) is used for similar structures. Why a STS string is made of straight wires?

Unlike a crane with its cable constantly winding and unwinding on its drum and folding by its numerous pulleys a STS string is used for a different purpose. In addition to its strength twisted cable is very flexible which is reached thanks to wire intertwisting. Moreover, twisted cable squeezed in a solid whole is not getting fluffy when its separate wires are broken. However, in case some of the wires are broken the total load is re-distributed to expose intact wires to overstrain.

Overstrain also gives rise to wire intertwisting caused by very high contact stress and abrasive wear and as a result, break of cable. Wires of a twisted cable located at an angle to the longitudinal axis (and, therefore, to the longitudinal load) are characterised by a lower carrying capacity and lower elasticity module of a cable: $(1.5\ldots1.8)\cdot10^6$ kgf/sq.cm against $E=(2\ldots2.1)\cdot10^6$ kgf/sq.cm for steel.

A STS string is a stationary component which does not require either elasticity or other above mentioned shortcomings of a twisted cable. Instead, it has the following important advantages:

a) in case some wires are broken their length is reduced (a string is put in a protective envelope filled with special anticorrosive mixture like lubricant grease) and their stress is not transmitted to other wires; the structure becomes non-critical to the number of wire breaks;
b) contact stress is absent, therefore, there is no local wear, wire defects, overstrain zones, etc.
c) elasticity module of a strain will be equal to that of steel – $(2\ldots2.1)\cdot10^6$ kgf/sq.cm;
d) the lack of elasticity requirements makes it possible to use wire of larger diameters (3…5 mm), thus, a string will have a smaller summary surface and, therefore, it will be characterised by higher corrosion and mechanical resistance and durability.

All the above qualities will contribute to the higher structure durability and lower material consumption, in particular, high-strength steel consumption for a string will be 1.2…1.5 times less than for a twisted cable.

18. What is a string break probability?

Each string consists of several hundreds of high-strength wires put in a protective envelope which is filled with anticorrosive mixture. It is placed in a hollow rail body filled with solidified filler (for example, on the base of epoxy resin). On the top the structure is closed by a rail head which protects a string from external atmospheric and mechanical impacts.

Each high-strength wire is subject to marginal checking before it is installed. Furthermore, a linear STS scheme envisages that under a moving load in the span the tensile stress of a string is varied (increased) by as little as 0.1…0.5%. Therefore, during the whole performance period deformed stress of the most important system component – a string – will be practically invariable (static) which will also contribute to the increased lifetime of a system due to the lack of fatigue accumulation.

Thus, it is possible to forecast that a STS will have a longer lifetime period than that of its closest analogue – a hanging bridge, to be estimated at more than 100 years. In this case, with each wire of a string working independent (all of them are twisted and placed parallel to each other in a string) any wire break (up to 50% of wires) would not result in the falling down of a structure which will be supported by the intact wires the tensile stress of which will be also intact remaining at the level of 1%.

Existing cableways are deprived of the above mentioned advantages: their steel cables are open to the aggressive aerial impact, their wires, especially in the upper external layers, are worn out and broken by rope pulleys, they are vulnerable to external mechanical impacts such as gun fire, etc. Nevertheless, break of cableway ropes with their spans reaching a record distance of 3,000 m is a very rare occurrence.

19. What if a track is fully broken?

Simultaneous breaking of hundreds of wires that are mechanically protected and located at several meters from each other and destruction of two rails simultaneously is very difficult in technical terms. Its probability is close to zero.

The average distance between the vehicles on a track will be more than 1,000 m, therefore, location of a vehicle within a damage span of 50 m length at the moment of break will have less than 1/20 probability. Moreover, only a track broken in front of wheels creates a derailment probability, otherwise a vehicle will be able to escape a damage section.

Therefore, a probability of emergency situation for one of the modules is less than 1/40, even if a track is fully destroyed. Other modules located in front of the damage section will be stopped and send in the opposite direction or to the counter line switched to one-way operation regime.

As soon as a contact between all four wheels of a derailed vehicle and the rails is broken, a flare cartridge of a one-time parachute and air cushions of safety installed in each vehicle will be automatically switched on. Parachute will reduce the high travel speed of a module designed as a high-strength mono-block to prevent its destruction during the landing. Therefore, a probability of human death under the described situation will be much lower than, for example, that under a similar situation of "Formula –1".

20. What makes a string route so even?

First of all, is there anything more straight than a string strained to a high stress, no matter how uneven or curved it could initially be? All cross sectional track components (a string, rail head and body) are kept in a stretched out condition all time, in winter and in summer.

Secondly, a rail head is polished with a high degree of accuracy along its whole length. In this case any macro-unevenness (above 1 mm or under 1 mm) will be removed either by the track adjustment or abrasion.

Thirdly, regular performance regime of all loaded components (a rail, string, support, piled foundation) is possible only under their elasticity stage without plastic deformations which tend to accumulate and reach critical values.

Therefore, STS does not need a number of works necessary for the normal railway or highway operation such as: packing of sleepers, re-fastening of rails, filling of washouts, pits, pot holes and annealing cracks, etc. A STS rail head which does not have a single joint along the whole length of its track (or to be more precise, there are some joints but without any clearances or height drop) provides for very smooth operation during the whole period to make it really a velvet track.

21. And what about rail deterioration?

A rail, or, more precisely, its head, will be made up of technologically convenient sections, for example, of 10 m length, without any clearances. Deteriorated or defected section of a rail could be replaced, if required. At the same time a STS rail has a longer lifetime period than a rail of a high-speed railway estimated at dozens of years which could be attributed to the following factors: lower (by one order) wheel loads, more favourable dynamics within a "wheel-rail" contact zone, no breaking stress and higher buffer action of all rail-string components which eliminate peak dynamic loads, etc.

22. High mechanical stress is known to result in material relaxation. Is it dangerous?

In fact, mechanical system as any other system tends towards thermodynamic balance. For example, tensile force of a strain wire under invariable elongation will be reducing. For the estimated string strain of 100 kgf/mm^2 and 1,000 m distance between the anchor supports initial wire elongation (tension) will amount to approximately 500 cm or 1/200 of its original length.

Approximately similar initial tension and specific elongation is observed in pre-stressed high-strength wire of various reinforced structures such as bridge components, hanging or guy rope bridges, cables of Ostankino TV tower, springs of transportation vehicles, etc. Pre-pressed wire of reinforced structures is the closest analogue of a STS string which is also straight (in many cases twisted ropes are used and their relaxation is the result of rather a cable squeezing than steel relaxation processes) and fixed to form a solid whole with the structure.

Bridge operation experience gained during many decades showed that relaxation of high-strength steel wire is insufficient and does not pose any hazard. However, it should be remembered that pre-squeezed concrete is characterised by a higher degree of relaxation in reinforced structures than in a STS. Moreover, bridge beams are exposed to bending strain and in this case a beam height is tens of times less than its length, therefore, even insufficient additional tensile strain of a reinforced component or cement will result in the beam deflection under the load which is dozens of times larger.

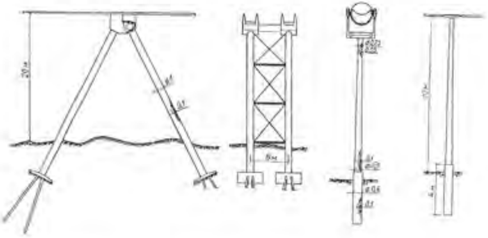
Thus, a strain of a STS rail is characterised by more favourable performance regime and its relaxation is 1…2 orders less hazardous than that of reinforced concrete structures. Therefore, it is possible to conclude that a STS system will survive for at least 100 years (like Eiffel Tower made of steel which is exposed to relaxation as well) without any problem.

23. What is the distance between supports?

Two types of supports are used:

a) anchor supports with strain anchoring;

b) supporting (intermediate) masts to support a track structure in the interval between the anchor supports (see Fig.).



Anchor support of a dual-way STS route

Intermediate support of small height for a one-way STS route

The following span dimensions are used depending on the ground features and track requirements: 500…2,000 m (up to 10 km, if necessary) for anchor supports; 20…100 m (up to 500 m, if necessary) – for intermediate supports.

24. Is it a straight or a winding track?

As far as a STS is non-critical to the ground features of the site it is possible to design it as a straight line to make the shortest path. If necessary, curves in vertical or horizontal plane are possible. To provide travel comfort for passengers (to reduce G-force impact on curved sections) a radius of curvature is to be not less than 10,000 m, 15,000 m and 20,000 m for the travel speeds of 300 km/h, 400 km/h and 500 km/h, respectively. Under the less curvature radii in a horizontal plane a system will be designed to include turns. Under a radius of curvature less than 1,000 m the travel speed should be reduced to 100…150 km/h.

25. How heavy are the loads on the supports?

In terms of their structure and loads STS supports are close to the high-voltage transmission lines which, as it is known, are exposed to the loads that are by several orders lower than, for example, the loads on modern highway and railway bridges.

Intermediate support of a one-way STS track is exposed to a minimal vertical load of 20 tf (including movable load at 50 m span) and maximum emergency load of 250 tf (at 500 m span).

Anchor supports are estimated for horizontal load of a string. In this case only terminal anchor supports are exposed to the load whereas intermediate, i.e. technological supports (which amount to more than 90% of the total number of anchor supports) are not exposed to horizontal loads in the course of the route operation because the string strain is counterbalanced from both sides of the support.

Therefore, the estimated horizontal stress of 250 tf per 1 rail and 500 tf per an anchor support of a one-way track will be regarded as emergency (in case all strings of the track structure are broken on one side of the support) or technological (in the process of assembly when the given anchor support is terminal because the track is not further extended). Under the regular performance regime anchor supports (except two terminal supports being the most powerful ones) are not exposed to horizontal stress.

26. What is the support height?

Minimal height of supports is 5 m which is necessitated by safe passage of agricultural machinery, wild and domestic animals under the STS track structure. Maximum height of supports which is limited only by the economic feasibility could reach the values of 100 m and more. Optimal height of supports on the plain or slightly rugged terrain is 20…30 m which makes it possible to cross any forest without cutting through, as well as highways and railways, small and medium rivers with minimal environmental impact. At heavily rugged terrain the average height of supports could reach 30…40 m.

27. Is support manufacturing associated with high material consumption?

No, it is not. Reinforced concrete or steel supports are used. Reinforced concrete consumption for supports with the average height of 25 m per 1 km of a dual-way track is about 300 cub. m (for comparison: reinforced concrete consumption for a two-sided enclosure of a high-speed railway reaches 750 cub. m/km). Therefore, STS supports are associated with lower cost and material comsumption than, for example, enclosure of a high-speed railway (without which it is not possible to ensure its 100% safety, because even a moose getting into a track could be a cause of derailment).

Comparison of reinforced concrete consumption for STS supports and railway sleepers shows that material requirements for STS supports would be equal to that for ½ of the total number of sleepers for a track of similar length. In case of steel supports steel consumption is not high either amounting to about 100 t/km for a one-way track which is slightly higher than for a modern heavy railway rail of a similar length (1,000 m).

28. Are supports subject to swinging and if so, how it can affect the track evenness and safety?

A STS track is based on the superstructure of supports exposed to displacement in three main directions: axial, side and downward. For a support of 25 m height displacement of its top in the direction of a vehicle movement (along the track) even at 50 cm (!) will result in the bed lowering of as little as 5 mm, or for a 50 m span the track evenness will be practically intack (for 10 cm displacement the lowering will amount to 0.2 mm).

Downward displacement of supports under the weight of the structure and the rolling stock will depend on the structure compression rigidity and carrying capacity of the foundation and the ground. Piled foundation piled to the depth of 10 m eliminates ground shifts, for example, for a standard pile driven in to the limit of 100 tf exposed to the estimated load of 20 tf (for its displacement a pile is to be washed out for the depth of more than 5 m which is hardly possible even under the flood). Therefore, under the most unfavourable combimations of external loads the estimated vertical displacement of the upper part of a support will be within the limit of 1 mm.

Side displacement of the support top poses the greatest hazard which could lead to the lateral track deflection. In this case deflection within 5 mm limit at a distance of 100 m is considered safe which will provide for the travel safety and comfort at travel speeds of 500 km/h and more. Therefore, intermediate supports are estimated for the high cross-sectional rigidity which under the most unfavourable impacts (such as gusty hurricane wind, side wheel stress, etc.) will result in the cross-sectional vibrations of the support within the permissible limits.

To eliminate the consequences of unforeseeable displacements (for example, as a result of earthquake or land slides, etc.) each support is provided with a system of track adjustment to ensure an accuracy of 0.1 mm.

29. What if a support is destroyed as a result of a terrorist action?

It will not result in the line break, the track will remain uninterrupted. Falling down of a support (each support is fixed to a track structure by a special unfastening device like a lizard tail) will result in doubling of a span and, correspondingly, increased track deformation which will affect wheel suspension but not passengers. Therefore, if several supports are blown up as a result of terrorist actions the track will not be put out of operation. STS is characterised by a high survival probability, equally resistant both to terrorist actions and natural disasters such as earthquakes, storms, severe land slides, floods, etc.

30. What if an anchor support is blown up?

Taking into account a support strength its blowing up will require not less than 10 kg of trotyl and thorough preparations (STS is provided with a ramified security system including electronic control of all track components and vehicles and visual control such as track observation from a specially equipped helicopter). Security service is capable to trace terrorists' preparations and to stop the movement on a dangerous section. Even if an anchor support is destroyed a STS will remain operative because a fixing system provides for power transmission to the next section of a track by-passing a support body. It means that even if an anchor support is broken continuity of a string route will not be interrupted.

31. Driverless vehicle - is it dangerous?

On the contrary. A man (the so-called "human factor") is the weakest, most vulnerable and unsafe link of a traffic flow regulation, especially of a high-speed flow estimated by dozens or sometimes thousands of actors. The Japaneses who were one of the first to understand it showed to the world that over the last two decades high-speed railways in Japan carried more than 5 billion passengers and none of them was killed. They use driverless trains controlled by electronic devices (to calm their passengers at the beginning they put molds of machine operators in the cabins). This experience was taken into account in a STS.

32. How high is a vehicle collision probability?

Its probability is close to zero. Vehicles moving along one line are not expected to catch up with or outrun one another: they are intended to move with invariable speed and distance between them to exceed a braking length necessary for emergency stopping.

STS envisages the following 4 braking regimes: operating (acceleration – 1 m/s^2 braking length – more than 3,500 m at 300 km/h travel speed), urgent (acceleration – 2.5 m/s^2 braking length – 1,400 m), emergency (10 m/s^2 - 350 m) and extreme (50 m/s^2 - 70 m).

Emergency and extreme braking envisages the use of all braking systems including special parachutes and electromagnetic braking systems. It implies simultaneous switching of a flare cartridge to eject a parachute and life-saving air cushions in a passenger saloon to eliminate death injury of passengers (maximum overloading for passengers will be approximately the same as that of a passenger car hit against immovable barrier at the speed of 25 km/h).

Collisions observed, for example, in the motor ways can be attributed to the following factors:

a) each car is driven individually without coordination and consideration of actions of other actors (by-passes, turns, excessive drawing together, driving in counter-flow lane, etc.);
b) the distance between cars in a flow is insufficient (10…50 m) which is often less than a braking length necessary for a vehicle stopping;
c) delayed and often inadequate driver's response to a road accident, etc.

These factors are absent in a STS: movement is controlled from a single centre and duplicated many times by linear (on-line) and on-board computers that are integrated to make a network and, therefore, there is no need in a driver. In this case all manoeuvres (stops, drive in or off the route, changed speeds, etc.) will be adjusted to all road sections with regard to the real conditions of the track, transportation module and weather (wind, rain, snow, etc.).

33. What is a dynamic track rigidity?

Dynamic, rather than static, rigidity is more important for a STS like for any other high-speed transportation system. Investigation of specific structural features of a track and vehicle movement regimes showed that resonance phenomena were absent in a rail-string (for speeds up to 500…600 km/h). Moreover, track vibration observed behind a moving vehicle will be damped over 0.1…0.5 sec. and the next vehicles will be moving along an undisturbed, ideally even track.

The principles used were similar to those applied for a hanging bridge design: any component is to damp the structure vibrations within its own frequence range. Therefore, it is possible to damp all kinds of possible structure vibrations from the low- to high-frequency ones, including the impact of single modules and their flows, wind (including gusty wind), etc. In this case inertion and high strength of a track will contribute to lower dynamic amplitude of structural vibrations amounting to not less than 1/5000 which is less than statical. (For comparison: road bed of a highway is considered even if a clearance between a 3-meter rod and the road surface will be not more than 10 mm, i.e. its relative unevenness does not exceed 1/300).

34. Is the economic efficiency a STS vehicle higher than that of a passenger car?

In comparison with a 5-seat high-speed passenger car a STS vehicle proved to be by approximately 20 times more economically efficient (on conversion to 1 passenger) which is the result of the following factors: improved aerodynamic qualities (3 times); increased electric motor efficiency (more than by 90% against 30% of a real internal-combustion engine efficiency), increased (doubled) holding capacity, reduced (1.2 times) mechanical losses especially in a "wheel-road surface" pair ("steel-steel" for a STS and "rubber-asphalt" for a motor car). Specific electric energy consumption of a STS is as follows: 0.016 kW · hour/t · km and 0.014 kW · hour/pass. · km for freight and passenger traffic, respectively, at the travel speed of 300 km/h; and 0.031 kW · hour/t · km and 0.025 kW · hour/pass · km for the travel speed of 400 km/h, respectively. The given data refer to the transportation modules of 4,000 kg carrying capacity and 20-seat passenger vehicles with their engine power being 40 and 80 kW (for the speed of 300 km/h) and 100 and 200 kW (for the speed of 400 km/h), respectively. (It is easy to recalculate electric energy consumption on conversion to combustible fuel consumption to get: 1 liter of gasoline = 8.78 kW hour of electric energy).

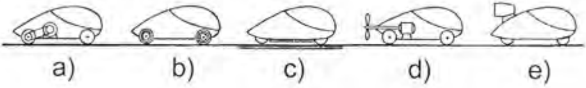
35. What is a module wheel rotation speed?

A transportation module wheel with 50…70 cm diameter has the following rotation speeds depending on its travel speed: 1,500…2,100 rot./min. at 200 km/h; 2,300…3,200 – at 300 km/h; 3,000…4,200 – at 400 km/h; 3,800…5,300 at 500 km/h.

Therefore, even at high travel speeds of a transportation module rotation speed of its wheels and their rotating engines will be ordinary for the modern technical equipment (for example, rotation speed of turbines of a turborjet engine reaches the values of 20,000…30,000 rot./min. and in this case turbine blades are exposed to super-high loads and very high thermal impact).

36. What sort of drive is appropriate for a transportation module?

Figure below shows drive unit alternatives.



Transportation module with various drive unit types:
a), d) – rotation wheel and propeller drive, respectively; b) - motor-wheel; c) - linear electric engine; e) – gas turbine.

It is more reasonable to use motor-wheel (for speeds under 500 km/h) and pusher propeller drive put directly on motor shaft for travel speeds above 500 km/h. Modern wide-blade fan-type propellers are noiseless and have 90% efficiency.

37. How much noise is produced by rattling wheels, moreover that they are made of steel?

No rattle noise at all, even at high travel speeds which is comparable with a high-speed railway having no rail interruption at 1 km length. A rail-string head is dismountable, i.e. easy to replace, if necessary; it has no clearances along the whole route length while any micro- or macro-unevenness are easily grinded off with a special polishing machine.

Therefore, the lack of clearances in the rail joints, improved track evenness, lower wheel mass (a wheel mass is 20...30 kg against almost 1,000 kg of a train wheel pair), automobile (i.e. independent) suspension of each vehicle wheel (compare with a train wheel pair in which vibrations of one wheel give rise to vibrations of the other) are factors which contribute to extremely quiet and smooth movement of a wheel though it is made of steel.

38. Is there any shock when a wheel is over-passing a support?

No, it is not. Firstly, because a rail-string has no joints on the support and there is no difference between this and other sections of the track. Secondly, coming closer to a support a rail deflection (with a relative value of 1/5000) is smoothly reducing to reach zero (at the moment when it passes a support). Thirdly, dynamic deflection of a track under the impact of wheels will be observed behind the wheels at travel speeds above 200 km/h, therefore, no bending is observed when a wheel is passing over a support.

39. Is it possible for a module to be blown off by the side wind?

No, it is not. It was proved by wind-tunnel tests of a transportation module (at scale 1:5). For example, at the travel speed of 250 km/h and hurricane side wind (with 100 km/hour velocity) the tilting effort will be within the limit of 100 kgf which for a module mass of more than 2,000 kg is not associated with any risk of a wheel-rail contact breakage. Derailment implies not only a wheel-rail contact breakage but also important is the break scale which is to exceed suspension move and the height of a wheel flange.

40. Is it possible for a vehicle to fly up at high travel speeds?

This risk exists for a transportation vehicle moving in the immediate vicinity of the ground surface which results from screening effect. For example, tilting effort observed in a high-speed car is attributed to uneven flow-around in the clearance between the car bottom and the road and above the car. Therefore, anti-wing is installed. At 10...20 m height above the ground a screening effect disappears which is attributed to small vehicle dimensions and a STS module body design which provides for symmetrical flow-around eliminating any cross or tilting efforts at any travel speeds.

41. Is a vehicle damaged possible so that it fails to continue its movement?

In this case it will be taken in tow by a transportation module going ahead or behind which is equipped with a special joint.

42. Why the transportation modules are so small?

Indeed, carrying capacity of a passenger (up to 20 seats) and freight (up to 5,000 kg) module contradicts to the advanced development trends including motor, railway and air transportation focused on the increased carrying capacity and overall dimension of transportation vehicles. All this requirements are dictated by the existing problems associated with travel costs and safety of traffic. However, consequences of recent traffic accidents and especially air crashes are shocking in terms of the number of simultaneous human losses caused by the large carrying capacity of transportation units.

The only mode of transportation not affected by the above trend is a passenger car. It has the same carrying capacity and overall dimension as 100 years ago and it is its main advantage which made it an individual, family-type and the most spread mass-scale transportation means (it is difficult to imagine a passenger car, for example, for 100 seats). STS is going to fill the same niche as a passenger car: its passenger will not be bound with a schedule served by a personal or public module (analogue of a taxi). Carrying capacity would depend rather on traffic organisation than on load-carrying capacity of a transportation vehicle – it is known that a sea is made up and evaporated drop by drop.

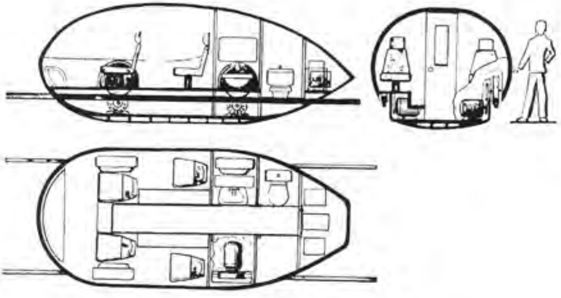
43. A passenger car is not known to be notable for its comfort. And what about a STS?

Most people are used to spend their active time in closed and dense space. Ergonomic qualities of conventional transportation modes make it possible for their passengers to view only the ground surface, road, etc.

STS gives an opportunity to combine efficient solution of its basic functional task – to provide comfortable and quick carrying of passengers to their destinations – and performance of aesthetic functions. Large glazed areas, comfort seats, soft velvet track make an ordinary road pleasant for travellers who have a chance to have a bird's-eye view of surrounding natural landscapes. Each vehicle is equipped with air conditioning devices supplied with initially clean air taken at 20…30 m heights and lacking the smell of fuel and lubrication, sun-heated asphalt, exhausts of car flows, etc. typical for highways.

Passengers are offered a wide range of additional services such as multi-canal musical and TV programmes, inter-city telephone communication, special services for businessmen, passengers with children and invalids. STS which in terms of its dimensions is close to a mini-van is hermetic, equipped with a system of vacuum or chemical toilets which exclude waste disposal on the track.

Upon passengers' desire a vehicle can be stopped at any of the intermediate stations, i.e. every 10…20 minutes or at any of the anchor supports, i.e. every 1…2 km (every 15…30 seconds).



Four-wheel long-distance vehicle

44. What about glaze of ice, is it dangerous?

No, it is not, as it is not for a railway road: contact mechanical stress under a steel wheel exceeding 1,000 kgf/sq.cm provides for ice crumbling and blowing off the rail, thus, making it self-cleaning. By the way, a greater hazard for a railway is associated rather with deep snow than glaze of ice to the effect that the train wheels fail to reach a rail and a train is put on its "belly". Both snow and ice pose a hazard for a car which rubber wheels characterised by very small contact stress of 5 kgf/sq.cm result in ice crushing and snow compressing. A motorway not provided with a self-cleaning capacity requires special machines to remove ice and snow from its surface. On the contrary, snow drifts are not so dangerous for a STS, even in the sites of heavy snowfalls, because the snow depth would not exceed 5 m which is lower than STS supports.

45. Maximum travel speed: its limitations and required engine power?

One of the most important advantages of a STS is associated with the fact that it does not use the now fashionable but low-efficient, energy-consuming, not safe and not reliable exotic systems such as magnet suspension including super-conductivity, air cushion, screening effect (screen flyer), turbine, jet engine, etc.

A wheel has not exhausted its possibilities which was proved by a recent (1997) record when for the first time an automobile managed to overcome sonic speed (1,200 km/h). For example, energy efficiency of a steel electric motor-wheel of a STS is more than 90% whereas the total energy efficiency of a train on a magnet suspension ("Transrapid" (Germany) is less than 15%, i.e. at the level of a steam-engine locomotive.

Problems arising at high travel speeds are caused not by a wheel but rather by track unevenness, therefore, bottoms of dried salt lakes are chosen for record routes. A string route will be even more smooth for the wheels of an electric module which is not in need of setting up records because super-high travel speeds in aerial environment are inefficient, non-economical and not harmless for people and nature. STS speed will be limited by aerodynamic qualities rather than by its wheel, track smoothness, vibration dynamics, "wheel-rail" friction contact. Therefore, special attention in a STS is focused on its aerodynamic features.

We managed to obtain unique results having no analogues in the modern high-speed transportation including aviation. Aerodynamic drag coefficient of a model passenger vehicle measured in a wind tunnel amounted to $C_x = 0.075$. Measures are proposed to reduce this coefficient to $C_x = 0.05...0.06$.

Low aerodynamic drag makes it possible for a 20-passenger vehicle with the engine capacity of 80 kW, 200 kW and 400 kW to reach the travel speeds of 300...350 km/h, 400...450 km/h and 500...550 km/h, respectively. (It should be noted that at high travel speeds in aerial environment required engine power is growing proportionally to cubic speed with 90...95% and more of its power used to overcome aerodynamic drag). It is known that as the travel speed increases the wheel-rail cohesion is going down. To reach the travel speeds of 300...350 km/h and 400...450 km/h a friction coefficient of a "wheel-rail" pair of a STS with four driving wheels is to be not less than 0.04 (to provide 100 kgf thrust) and 0.07 (to provide 180 kgf thrust), respectively, which is easily reachable.

Cohesion problems arise only at the travel speeds of 500 km/h and more which require more than 300 kgf thrust. However, this problem is also easily solved in a STS. For instance, a principally new scheme designed for a rubber-covered thrust engine-wheel of 100 kW power is capable to provide required cohesion and thrust. At travel speeds exceeding 500 km/h it is reasonable to use the thrust of a propeller put on a shaft of electromotor. Modern propellers are noiseless (noise is generated rather by an engine than a propeller) and reach 90% efficiency. At more than 600 km/h travel speeds an evacuated tube is more appropriate with its air pumped out to 10% of atmospheric pressure. However, it is a faraway future task. Today, it is quite sufficient to have travel speeds of 300…400 km/h.

46. Is everybody ready to take a risk of travelling along the strings at 20…50 m height?

It is purely psychological risk which will be easily eliminated in the future. It was time when people were afraid to travel by trains, cars, then fly by aircraft. Strange as it is, but passenger feels most safe sitting in a car, whereas a car is one of the most efficient man-made killing instruments: the annual number of people killed in road accidents (or died of after-accident injures) all over the world amounts to 990,000 and about 10 million become invalids or disabled (according to the data of the World Health Organisation; their statistics also show that the annual number of death as a result of war injures is much less – 502,000).

Car is even more dangerous for the wildlife being the cause of death of billions of animals (especially small ones) killed not as a result of accidents but by chance. It is not surprising that highways are characterised by high accident rates caused by pedestrians crossing the road at red light signal, or a moose coming in a driveway; glaze of ice, spilled machine oil, snow drift, puncture of tires especially of front running wheels; alcohol intoxication or bad general state, mood or absent-mindedness of a driver; pot holes or outside objects; uncoordinated drivers' actions, especially in the course of maneuvering at turns, by-passes, intersections, etc.

None of the above mentioned causes is attributed either to a STS or to aviation. Therefore, it is not surprising that the number of people killed in air crashes is the lowest (in absolute and relative values). However, factors resulting in aircraft crash are absent in a STS, in particular, a bird does not pose a hazard for a module whereas even a dove coming in a turbine of a plane could be a cause of a catastrophe; a STS module is not subject to a risk of icing, engine stop, shortage or cutting off fuel; bump, thunder storm clouds, lightning; it has no inflammable materials whereas fuel of aircraft tanks tend to explode or inflame when a plane is falling down, etc. Thus, a STS has all prerequisites to become the most safe mode of transportation which could be appreciated by a passenger making a choice of a travel mode.

47. What if supply current is cut off?

Each transportation module has an accumulator battery with constant compensating charge from the network. In case a line is dead currency supply is automatically switched on accumulators. Their energy reserve is enough for a module to get to the nearest station or to the next not de-energized section of the track.

48. What if a track fails to continue its operation and there is nobody to help (war, earthquake, etc.)?

Each module has an emergency hatch in its bottom part and each passenger seat is equipped with a rescue rope and seat belt to help a passenger to descend on the ground.

49. What is a maximum angle of elevation?

On a plain a STS is moving at high speeds with its seats resting upon their supporting part like seats of a conventional train. However, a STS wheel has its peculiarity – it has two (not one) rims which provides for a different wheel-rail supporting pattern within the mountainous sections of a track, i.e. through its rims like a V-belt drive. It makes it possible to increase the frictional force in a "wheel-rail" friction contact by many times and to get a maximum angle of elevation of 45…60°. Naturally, design of a rail on mountainous sections of the route will differ from that on a plain which is also true for a transportation module, its running gear and wheels. In this case a more powerful engine is also required. However, all this makes it possible to cross the mountains and mountainous passes straightforward, eliminating hairpin turns or tunnels.

50. How are terminals and stations designed?

Terminals have a ring-shaped design with a moving (rotating) platform or floor (see Fig. 20 and 21).

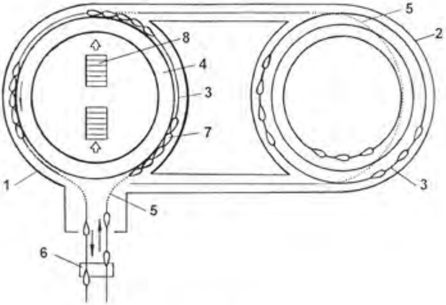


Fig. 20. Terminal scheme.

1 – terminal building; 2 – depot building; 3 – ring track; 4 – ring-shaped moving platform; 5 – switch; 6 – terminal anchor support; 7 – vehicle; 8 – entrance (exit) to the terminal.

Fig. 21. Freight-passenger terminal

Terminal has about 60 m diameter which can be extended to 100 m and more depending on the intensity of passenger flows (for more than 100,000 passengers per 24 hours). Intermediate stations with intensive passenger flows will be equipped with switching devices and sheds which makes it possible to organise circulation of vehicles independent on the general traffic schedule. Stations with small passenger flows are designed as open platforms located on the route. Loading (unloading) of passengers is facilitated in the course of braking of single not fully-loaded vehicles.

51. How loading and unloading of passengers is arranged in the terminal?

Passengers entering the terminal hall make notice of a luminescent table which accompanies each vehicle (a table is fixed on a vehicle or on the wall in the form of a running line) to indicate the station name, for example, "Terminal". If a passenger fails to find the necessary station he can get in a vacant vehicle and to press "Terminal" button on a control panel (inside a vehicle). At 0.5 m/sec. travel speed of a moving platform (with a vehicle joined to it) and 50 m diameter of a ring track passenger will have 0.5…2.5 minutes to board a vehicle.

When the saloon is closed (automatically or manually) a vehicle is detached from the moving platform and switched to the line. If for this or that reason a vehicle saloon was not closed or there were no passengers a vehicle returns to the second ring. In a similar way but in a reverse order passengers are unloaded at the destinations. In its general form a scheme reminds a luggage delivery scheme at circular transporters of modern airports. If necessary, some vehicles are sent to a depot located either in a separate building or on the other floor of the terminal.

52. How are freight terminals operating?

Freight terminals intended for automatised loading and unloading of freight modules have a ring-shaped design, like passenger terminals. They are characterised by compactness and high carrying capacity which is achieved through the original technology of loading/unloading operations and the use of specially designed containers for liquid, friable and piece freights. For example, a terminal with about 100 m diameter will have a carrying capacity of about 100,000 tonnes of oil per 24 hours (36.5 million tonnes per year) which is considerably smaller in size than, for example, a sea port of similar carrying capacity.

53. What is a maximum carrying capacity of a track?

For the rolling stock consisting of ten 10-seat vehicles (with 100 m distance between them), travel speed of 300 km/h and circulation frequency of 30 seconds during the peak hours carrying capacity of one line and the route as a whole (two lines in two directions) will be 12,000 pass./hour and 24,000 pass./hour (567,000 pass./24 hours or 210 million pass./year), respectively. In this case a track has a reserve to increase its carrying capacity without construction of additional lines.

Minimal on-line distance between freight modules will be 50 m (one module on one span; 50…100 m – minimal extreme braking distance with a deceleration parachute), therefore, maximum carrying capacity of one line is 24,000 tonnes/hour or 576,000 tonnes/24 hours (210 million t/year) or 48,000 t/hour, 1.15 million t/24 hours, 420 million t/year for a dual-way route, respectively. Actual volume of freight and passenger traffic will be by one order lower, therefore, STS routes will be operating with 10% capacity which, in the end, will contribute to their higher reliability and safety.

54. Is a STS carrying capacity higher than that of an oil pipeline?

Its carrying capacity (in one direction) is up to 210 million tonnes per year, net cost of oil transportation is 1.5…2 times lower than that of an oil pipeline. In this case it is possible to use airtight return containers of 5,000 kg capacity, equipped with an electronic information map to indicate oil composition, extraction site, etc. which prevents mixing of oil extracted in various oil fields as it occurs nowadays and facilitates isolation of light, high-sulphurous and parafin-base oil in the course of refining. Whereas a pipeline is used to transport oil only in one direction, a STS is capable to carry a variety of other goods, alongside with petrol products (such as gasoline, diesel fuel, etc), in both directions, including: ore, coal, sawn timber and other raw materials; food products, building materials, equipment; as well as shift workers, etc.

Moreover, the cost of a STS will be lower than that of an oil pipeline of a similar carrying capacity. Loading and unloading of containers will be arranged on an automatic basis in the small-scale freight terminals of about 100 m diameter.

55. What kind of freights will be carried by a STS?

STS is capable to carry any freights of 4,000…5,000 kg – at high travel speeds; freights of 10…20 tonnes at reduced travel speeds (under 100 km/h), freights of 30…40 tonnes – at special many-wheel platform. Therefore, a STS is appropriate for 99.9% of the mass-scale freights such as: oil and petrol products, coal, ore, food products, furniture, metal-rolling, building materials and structures, chemical products, special freights (liquified gases and cryogen liquids, radioactive and explosive substances, weapon), etc.

Special containers are designed for liquid, friable, piece and special cargo to be fixed with seaport, railway and automobile containers. Containers for perishable goods, for example, food products are provided with temperature control devices (in winter) and air conditioning (in summer); containers for environmentally hazardous freights will have a multi-layer high-strength envelope, etc.

56. Is there a risk of leaf falling caused by a vehicle rushing above the forest?

No, there is not. You even do not feel any air vibration standing at 10…15 m distance from a vehicle rushing at 350 km/h speed which could be attributed to its high aerodynamic qualities (aerodynamic drag coefficient – C_x=0.075) and low module energetics (engine power – 80 kW). In physics terms any transportation system has a zero efficiency coefficient and a STS is not an exception because it has zero useful transportation work: with zero cargo speed at origin and destination and approximately invariable height. In the end, all energy supplied to the vehicle engine is ejected in the form of track and ground vibrations, noise, rattle of wheels, air gusts, etc. in the environment, ultimately converted into heat.

Therefore, environmental impact is evaluated rather by the intensity of energy ejection per 1 unit of a track and energy nature, than by the travel speed. STS is characterised by the lowest energy ejection intensity per 1 unit of a track amounting to 800 J/m or 190 cal/m (against 4,000 and 20,000 J/m for "Mercedes-600" - closest to a STS in terms of its dimensions, and a high-speed train, respectively). Energy ejection is characterised by the most favourable conditions provided by a velvet, joint-free STS track, high damping, light-weight wheels which make it possible to eliminate rattle of wheels; and ideal shape of a vehicle body contributing to the elimination of aerodynamic noise (high-frequency fluctuations caused by turbulent air flows, etc.).

Ejected energy is in the form of added air mass movement and whereas the air mass is relatively large, air movement will be in the form of a slight wind with its velocity decreasing proportionally to the square of the distance from the vehicle. Furthermore, a STS route will be rather free than full of vehicles – immovable observer will see a vehicle passing by at high speed in portions of second with the next one coming only in 30…60 seconds (at the traffic intensity of 20,000…50,000 passengers per 24 hours). Therefore, the average energy ejection is very low amounting to 15…30 W/m · sec.

57. Are there any weather or other travel limitations?

There are none. A STS is not afraid of fog, rain, thunder storm, snow, hail (travel speed can be reduced under heavy hail to avoid damages in a nose part of a module; also armoured modules can be used in areas of hail hazard), glaze of ice, sand and dust storms, hurricane wind. A STS is likely to withstand a tornado waterspout which could be attributed to its high-strength construction, very low sailing effect and high flow-around qualities of building components and a transportation module (for example, tornado is beyond the capacity of modern building structures such as reinforced concrete bridges whereas STS structures are characterised by the higher specific strength, i.e. estimated per 1 unit of surface).

STS is more than any other transportation system resistant to natural disasters such as earthquakes, land slides, heavy rains, floods, high water, attack of desert sands. STS routes are not critical to difficult geographic and climatic conditions, they are easy to build in large marshy areas, jungles, permafrost, deserts with drift sands, mountains, sea shelf.

Figures below shows STS alternatives for various geographic conditions.

STS design alternatives for various geographic conditions

58. What is the traffic intensity?

The average distance (frequency) between two neighbouring 10-seat vehicles (50% loading of a 20-seat vehicle) moving at the speed of 300 km/h to carry two-way passenger flows will be as follows: 7.2 km (or 86 sec.) for the flow of 20,000 pass./24 hours; 2.9 km (35 seconds) – for the flow of 50,000 pass./24 hours; 1.4 km (17 seconds) – for the flow of 100,000 pass./24 hours. For a two-way freight traffic carried by the transportation modules of 4,000 kg carrying capacity the average distance will be as follows: 1,150 m (13.8 sec.), 580 m (6.9 sec.) and 290 m (3.4 sec.), respectively.

59. Is a track provided with accesses and switching devices?

A STS route is equipped with high-speed (for the travel speeds of 300…400 km/h), medium-speed (150…200 km/h) and low-speed (under 100 km/h) switching devices. For, example, high-speed switches will be installed at terminal accesses which will make it possible to arrange non-stop circulation of transit vehicles without deceleration, bypassing the terminal. Switches designed as elaborate engineering structures will have the length of more than 100 m.

Other sections of the track (including stations and stops) are provided with medium-speed switches to make vehicles slow down at their accesses. Traffic control system envisages special time and place for this manoeuvre which implies certain compression of a transportation flow ahead and behind a vehicle to give it 1…2 minutes for menoeuvring at several km distance from the nearest vehicles.

Low-speed switches characterised by the lowest cost and higher safety can be installed actually at each anchor support. It makes it possible for any vehicle to stop practically at any spot allocated for the purpose (information is to be given at least 5…10 minutes before the stop so that a control system could smoothly re-arrange the transportation flow).

In structural terms STS switches are close to the railway switching devices, though they have their peculiar features defined by the two-rim wheels and the need in electric insulation of rails, including a switch.

Furthermore, alongside with horizontal switches vertical devices are also possible as small weight of a transportation module makes them easy to remove to upper or lower level.

60. How to get out if a track height is, for example, 50 m?

It is much simpler and safer than in a plane flying at 10,000 m height which is unable to unload its passengers between the airports. A STS passenger can get out not only in the terminal or station, but in the interval, at any anchor support, i.e. every 1,000 m. Passenger getting in a vehicle gives a command to the on-board computer (by voice or digital code) about his destination. If passenger's choice is a support of 50 m height somewhere in the forest known for its mushrooms, he will have to use a convenient staircase located in a support body to descend to the ground (if it is a frequently visited site, it is possible to install an elevator or an escalator).

Getting off a passenger informs the traffic control system (using on-board computer) about his departure time and destination. There cannot be the slightest doubt that your order is neglected.

Loading and unloading of passengers at terminals and stations is much easier: you get in (or out) a vehicle coming to the terminal building (like modern bus stations). In this case the track height has no significance as it could go several km away from the terminal. High-speed accesses require acceleration (deceleration) lanes of more than 1,000 m length, therefore, switching devices are located several km away from the terminal to which passengers are brought by the branch lines which could enter the terminal building at the ground level.

61. Is it boring to see fragments of structures, trees, etc. swiftly flying before passenger's eyes in the window?

In a plain the highest point of a STS is its rail-string with a moving vehicle, therefore, there are no structural components before passenger's eyes (unlike railways or highways). One of the reasons why 20…30 m height was proposed for a STS route is associated with trees in order to keep them save and sound under the track, i.e. below the level of passenger's eyes and not to spoil a possibility to enjoy a bird's eye view of natural landscapes with a convenient observation sector of 100 m.

62. Are there any "rail-wheel" current collection problems entailed at high travel speeds?

No, there are not. No similar problems arise in the high-speed railways either that are provided with two (not one) current collectors installed on top (overhead) and bottom (rail) and all problems are related to current collection from immovable and flexible copper wire on the top. At high sliding speeds of current collector its trolley wire is sparking, burning, exposed to pitching and rolling as through a point contact moving at speeds of hundreds of km it has to transmit electric power estimated at hundreds and thousands of kilowatt.

At the same time a train wheel is moving (not sliding) along a rail, therefore, electric power is transmitted through a stationary contact (a wheel has zero speed within its contact zone with a rail) which has no clearances thanks to the high contact force between rigid wheel and rigid rail. This "wheel-rail" current collection scheme was used in a STS (left "wheel-rail"-right "wheel-rail") and in this case operation conditions are more favourable for a STS current collector which requires about 100 kW input power which is by one order less than for an electric train.

63. It is known that strong, especially gusty wind is capable to destroy power transmission lines. And what about a STS?

STS track structure and supports are characterised by higher strength than high-voltage power transmission lines at approximately equal sailing qualities. Taking into account lower sailing capacity of a STS structure and vehicles, the relative track deflection under side wind of 100 km/h velocity will be 1/10,000…1/5,000 which will not have a serious impact on the transportation system operation.

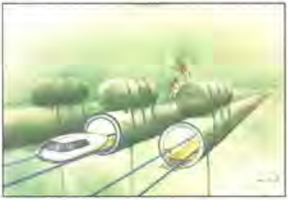
Design of a STS track and supports eliminates resonance effects under gusty wind which otherwise could result in their destruction caused by stalling flutter. In addition to the high-strength structure it could be attributed to the dip of strings which in a STS is estimated at several cm (against several meters in power transmission lines that are easy to shake like swing), strings are "enclosed" inside rigid beams (rails) that in their turn are cross-fixed to form a solid structure difficult to shake even by a hurricane, thus, it is possible to design a STS resistant to any wind, even tornado waterspout.

64. Where else is it possible to use a STS?

STS can be used as a low-speed (under 100 km/h) special purpose transportation: internal transportation to serve logging operations, slag refuse disposal, sand and gravel quarries, coal, ore, oil, gas and other deposits, garbage removal, etc. Lower transportation and traffic safety requirements of a special purpose STS in the absence of passengers will contribute to its lower (by 1.5…2 times and more) cost as compared with other high-speed string routes.

65. Is it possible to lay a STS route along the sea?

STS will become a universal mode of transportation capable to pass across the land and sea. At sea depths under 50 m, for example, a STS route put on the supports installed in the sea bottom will pass at 25…50 m height and more on the shelf above the water surface (depending on building requirements).



Design alternative for a sea STS section

At greater depths a STS track can be put in a tunnel (pipe) of 2.5…3 m diameter installed either in the sea bottom (for under 500 m depth) or in the water at 50 m depth (see Fig.).

In the latter case tunnels have zero buoyancy (or to be more precise – excessive buoyancy) and require anchoring every 1…2 km in the sea bottom. Small module weight (under 5,000 kg) and low circulation frequency (on the average every 1,000 m) prevent tunnel submergence. High deflection rigidity and special tunnel design contribute to the high evenness and rigidity of a string track structure under various travel speeds irrespective of the sea (ocean) depth.

66. Does a STS require elaborate building technology?

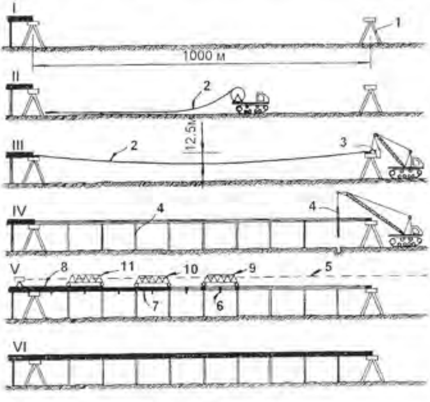
In technological terms it was possible to start STS construction in the last century when all necessary structural and building materials, mechanisms and equipment were already available. A STS route requires much simpler building technology than a bridge with a similar span (see Fig.).

Prefabricated string is adjusted to the assigned length with the help of technological devices (with tensile strength used as a control parameter) and fixed rigidly, for example, by welding with anchor supports (in this case not wire itself but its special cap at the end of a string is welded).

Intermediate supports are preliminary installed either in the process of string adjustment or strengthening. When intermediate supports and strings are put in place they are tested by a technological platform capable to move independently and to fix its location against the supports.

Moving from span to span a platform is to specify the whole rail envelope, to fix its designed position, put the filler, set a rail head, cross plates and do other works necessary for track installation. All the above works are easy for mechanisation and automatisation and can be carried out irrespective of weather conditions. All this contributes to higher flow-line construction rates (about 1,000 m per 24 hours), lower labour intensity and net cost.

To eliminate micro-unevenness and micro-waviness of working surfaces of the assembled rail head and its cross gap-free joints they can be grinded away along the whole length. A special combine can be also used to fix a STS string and other stressed rail components which is intended to install assembled intermediate supports moving along the track on its walking support-legs.



STS building technology.

1 – anchor support; 2 – cable (string component); 3 – cable adjusting mechanism; 4 – intermediate support; 5 – sight line; 6 – cross plate; 7 – rail envelope; 8 – rail head; 9, 10, 11 – technological platforms to install cross plates, rail envelope and rail head, respectively; I – installation of anchor supports; II – laying of string cables; III – string adjusting and anchoring; IV – installation of intermediate supports; V – assembly of rail components and track structure; VI – ready track section.

Economic aspects

67. Cost of a STS in comparison with other transportation systems?

A STS has the lowest cost among other transportation systems of similar carrying capacity, comfort level and travel speed, etc. The cost of competitive transportation routes built in a plain is as follows: USD 10…15 million/km – for a high-speed railway; USD 20…30 million/km – for "Transrapid" system (train on a magnet suspension, Germany); USD 3…10 million/km – for a motorway; USD 4…8 million/km – for a mono-rail road.

A STS route is many times (3…20 times) cheaper than other known transportation systems which is attributed to its low material consumption (including its track structure and supports); and no need in construction of elevated roads, bridges, viaducts, overpasses and other high-cost structures.

68. How much are the travel costs for passengers?

Passenger fare is lower compared with other high-speed systems being at the level of a railway ticket in an open-plan carriage. Net cost will depend on a number of factors such as the track cost (amortization costs), maintenance costs, cost of electric energy, passenger and freight flows, cost of the rolling stock, estimated travel speed, etc.

Average travel cost for passengers (given are costs minus profit) carried by a STS on a plain at 1,000 distance with the average speed of 300 km/h is as follows: USD15…20 (for dual-way passenger flow of 20,000 pass./24 hours) and USD 5…10 (for 100,000 pass./24 hours and more) – see Table below with "Moscow-London" STS route taken as example.

Table

Travel costs within a STS system: "Moscow - London (Paris)" at 2,830 km section ("Moscow - London")

Indicator	Traffic volume (in two directions)					
	Passenger traffic, thousand pass./24 hours			Freight traffic, thous. tonnes/24 hours		
	20	50	100	50	100	200
1. Given costs (at 2,830 km section):						
- USD/pass.	72,60	32,71	19,43	-	-	-
- USD/tonne of freight	-	-	-	19,99	16,66	15,01
Including:						
1.1. Total transportation costs, including:	66,47	26,58	13,30	6,65	3,32	1,67
- amortization allocations	25,48	10,19	5,10	2,55	1,27	0,64
- maintenance costs	15,51	6,20	3,10	1,55	0,78	0,39
- profit allocations	25,48	10,19	5,10	2,55	1,27	0,64
1.2. Rolling stock costs, total, including:	6,13	6,13	6,13	13,34	13,34	13,34
- amortization allocations	0,63	0,63	0,63	1,05	1,05	1,05
- maintenance costs	0,63	0,63	0,63	1,05	1,05	1,05
- profit allocations	0,63	0,63	0,63	1,05	1,05	1,05
- cost of electric energy	4,24	4,24	4,24	10,19	10,19	10,19

Indicator	Traffic volume (in two directions)					
	Passenger traffic, thousand pass./24 hours			Freight traffic, thous. tonnes/24 hours		
	20	50	100	50	100	200
2. Number of vehicles to serve the whole route (at average travel distance of 1,000 km), number of units	1530	3820	7650	19100	38200	76400
3. Cost of the rolling stock, USD million	45,9	114,6	229,5	191,0	382,0	764,0
4. Average distance between the neighbouring vehicles in a transportation flow (single vehicles in one line):						
- time frequency, sec.	86,4	34,6	17,3	6,9	3,5	1,7
- distance, km	9,60	3,84	1,92	0,77	0,38	0,19

69. Cost of freight transportation?

Net cost of freight transportation is low compared with other modes of transportation, though the average speed accepted for calculations is rather high – 300 km/h. Average net cost per 1 tonne of freight to be carried on a plain at 1,000 distance will be as follows: USD 5…6 (for a dual-way freight flow of 50,000 t/24 hours), USD 4…5 (100,000 t/24 hours) and USD 3…4 (200,000 t/24 hours).

70. Cost of 1 km of a STS route?

STS cost differs depending on a number of factors such as: one- or two-way track; on a plain, mountains, sea shelf, tundra, desert; low or high supports, etc. The cost is also strongly related to the infrastructure development (number of terminals, stations, depots, freight terminals, etc.).

The cost of 1 km of an average, well-equipped two-way STS route of serial production will be as follows: USD 1…2 million – on a plain; USD 2…4 million – in the mountains; USD 2…4 on sea shelf above water and USD 5…10 million – in a tube (afloat in the water, on or under sea bottom). In this case the cost of a two-way string transportation line itself (track structure and supports) will be considerably lower amounting to: USD 0.8…1.2 million - on a plain (for average support height of 15…25 m); USD 1.5…2 million – on sea shelf and mountains (for average support height of 35…50 m) and USD 0.5…0.8 million – in a tube. One-way track will be 30…40% cheaper than a two-way road. Tables below show the average material consumption and cost per 1 km (not including the cost of terminals and infrastructure).

Table

Average material consumption and cost per 1 km of a two-way STS route laid on a plain (with "Berlin - Moscow" STS route taken as example)

Structural component	Material	Material consumption per 1 km		Approximate cost, thousand USD/km
		mass, tonnes	volume, cub. m	
1. Rail-string, total, including:				450
1.1. Rail head	Steel	96	-	190
1.2. Rail envelope	Aluminium sheet	5	-	25
1.3. String	Steel wire	79	-	160
1.4. Filler	Composite	-	45	20
1.5. Glue mastic	Composite	1	-	10
1.6. Protective string envelope	Polymer	4	-	20
1.7. String hydrofuge insulation	Polymer	1	-	10
1.8. Other		-	-	15
2. Cross plates		-	-	20
3. Intermediate sup-ports (15 m height), total, including:		-	-	190
3.1. Poles	Reinforced concrete	-	96	70
3.2. Straight arch and brace	Reinforced concrete	-	46	35
3.3. Metal structures	Steel	10	-	20
3.4. Pile foundation	Reinforced concrete	-	48	48
3.5. Other		-	-	17
4. Anchor supports (15 m height), total, including:		-	-	105
4.1. Support body	Reinforced concrete	-	52	38
4.2. Pile foundation	Reinforced concrete	-	36	36
4.3. Metal structures	Steel	2	-	5
4.4. Anchor fixing	Steel	2	-	10
4.5. Other		-	-	16
5. Excavation and earth moving		-	-	20
6. Rail power supply		-	-	40
7. Control system of supports and track condition		-	-	10
8. Control system of traffic flow		-	-	20
9. Emergency power supply system		-	-	20
10. Traffic flow regulation system		-	-	30

Structural component	Material	Material consumption per 1 km		Approximate cost, thousand USD/km
		mass, tonnes	volume, cub. m	
11. Emergency stop platform		-	-	20
12. Design/survey works		-	-	50
13. Cost of land allocation and development		-	-	50
14. Other works		-	-	25
15. Unforeseen xpenditures		-	-	50
TOTAL:				1100

Table

Average material consumption and cost per 1 km of a two-way sea (above-water) STS route (with "Sochi - Adler" STS route coming along the Black Sea shelf taken as example)

Structural component	Material	Material consumption per 1 km		Approximate cost, thousand USD/km
		mass, tonnes	volume, cub. m	
1.Rail-string, total, including:				400
1.1. Rail head	Steel	96	-	144
1.2. Envelope	Aluminium sheet	5	-	25
1.3. String	Steel wire	79	-	120
1.4. Filler	Composite	-	45	20
1.5. Glue mastic	Composite	1	-	5
1.6. Protective string envelope	Polymer	4	-	20
1.7. String hydrofuge insulation	Polymer	2	-	10
1.8. Other		-	-	40
2. Cross plates		-	-	40
3. Supporting cable	Steel wire	79	-	160
4. Supporting structure	Steel	32	-	50
5. Intermediate supports (35 m height), total, including:		-	-	380
5.1.Poles	Reinforced concrete	-	94	47
5.2. Straight arch and brace	Steel	34	-	51
5.3. Top structure	Steel	8	-	16
5.4. Underwater support section and foundation	Reinforced concrete	-	175	88
	Concrete	-	259	52
	Steel	24	-	36

Structural component	Material	Material consumption per 1 km		Approximate cost, thousand USD/km
		mass, tonnes	volume, cub. m	
5.5. Hydrofuge insulation of underwater support section	Composite	5	-	15
5.6. Painting of above-water structures	Paint	4	-	12
5.7. Dielectrics	Composite	-	-	26
5.8. Other		-	-	37
6. Anchor supports (35 m height), total, including:		-	-	270
6.1. Support body	Reinforced concrete	-	102	51
6.2. Underwater section of support and foundation	Reinforced concrete	-	92	46
	Concrete	-	204	41
	Steel	26	-	39
6.3. Hydrofuge insulation and painting of structures	Composite	3	-	9
6.4. Metal structures	Steel	12	-	18
6.5. Anchor fixing	Steel	4	-	20
6.6. Dielectrics	Composite	-	-	18
6.7. Other		-	-	28
7. Excavation and earth moving works		-	-	20
8. Rail power supply system		-	-	40
9. Control system of supports and track condition		-	-	20
10. Control system of traffic flow		-	-	20
11. Emergency power supply system		-	-	20
12. Traffic flow regulation system		-	-	30
13. Emergency stop platform		-	-	20
14. Design/survey works		-	-	50
15. Cost of land allocation and development		-	-	10
16. Other works		-	-	50
17. Unforeseen expenditures		-	-	70
TOTAL:				1650

71. What is the structure of construction expenditures for a STS route?

A STS complex includes: stationary facilities (terminal, stations, depot, freight terminals, repair garages, sub-stations, control system, signalling, communication, switching devices) which require 30…50% of the total expenditures. The share of a track structure and supports amounts to 25…35% (with 15…25% for a track structure and 10…15% - for supports). Other costs include: design, adaptation of research and pilot design results including a pilot track section – 5…10%, rolling stock – 5…10%, other expenditures – 10…15%.

72. What defines the cost of passenger tickets?

Compared with other high-speed transportation systems a STS is characterised by a very low net travel cost, thus, the fare should be raised to ensure a profitability of 100…200% (which will make it possible to pay back the expenditures during 3…5 years).

The structure of expenditures (for 100% profitability) is as follows: balance profit – 50%, track and rolling stock amortization – 22%, maintenance costs – 16%, electric energy– 12% (for average vehicle speed of 300 km/h).

73. Cost structure of freight traffic at 100% profitability?

Balance profit – 50%, electric energy – 30% (for average vehicle speed of 300 km/h), track and rolling stock amortization – 11%, maintenance costs – 9%.

74. Cost of transportation will in many respects be defined by the cost of electric energy?

It should be remembered that a STS is a high-speed transportation associated with considerable power consumption (by the way, less than other high-speed transportation modes) to gain the necessary speed. At the same time the cost of a string route is very low, the share of amortization and maintenance costs is reduced and energy consumption is approximately invariable. It is especially true for the net cost of freight traffic with the share of energy costs amounting to 60% and 80% for the travel speeds of 300km/h and 400 km/h, respectively. For passenger traffic this share is lower amounting to 25% (travel speed – 300 km/h) and 30% (travel speed – 400 km/h).

75. Is the cost of oil transportation by a STS lower than by a pipeline?

The cost is by 1.5…2, or in some cases 2.5…3 times lower which will depend on price-formation policy. A STS route will be repaid not so much by oil transportation as by passenger and freight traffic including food products, building materials and structures, chemical and petroleum products, etc.

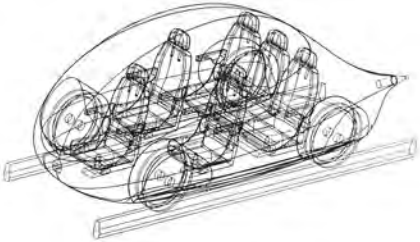
76. What cost of building materials and structures was assigned to calculate the cost of string routes?

The following integrated prices were used as a basis to specify the cost of structures: USD 1,500…5,000/t – assembled metal structures depending on their complexity and steel mark; USD 5,000/t – aluminium structures; USD 750…1,000/cub. m – assembled reinforced concrete structures and USD 500/cub. m – solid reinforced concrete; USD 200/cub. m – concrete. The cost of terminals and technological premises was estimated at USD 3,000/cub. m – terminal building (general construction works plus engineering and technological equipment), USD 1,500/cub. m – depots and garages and USD 1,000/cub. m – area of freight terminals provided with basic services.

77. What is the rolling stock cost?

The cost of a STS rolling stock can be evaluated against the cost of a passenger car which in terms of its dimensions and design is very close to a STS vehicle. The cost of electric engines for a STS of serial production with 25…50 kW power is 1.5…2 times lower than that of an internal-combustion engine of equal power; STS engines are characterised by higher reliability, durability and are easy for maintenance and service. A body of a STS transportation module is cheaper than that of a car of similar size which is attributed to its simple design (lack of radiator, doors, luggage carrier, hood, headlights, marker, braking and other lights, windshield wiper, window raiser, etc.).

Undercarriage and suspension of a STS vehicle is also simpler and of lower cost than in a car (no unreliable and high-cost rubber tires, wheel turning mechanisms, simpler operating mechanism for turning moment of nonrotatory wheels, no cross-country travel requirements, etc.).



High-speed 6-seat passenger vehicle alternative

The cost of rated engine speed and turning moment systems (control block in a STS and gear box, clutch, fuel supply, etc. in a car) is approximately the same in both transportation modes. Drive regulation system of a STS vehicle is much cheaper and simpler as the number of parameters is less: travel speed, distance to the nearest vehicles and on-line location (coordinates).

Driving a car is a complicated task which in spite of the progress of computerisation today is only solvable by driver's brain (driver's factor is very important not only for car driving but also for its cost: nowadays people all over the world – millions of people - spend many hours driving a car, though being very short of time). In a STS vehicle this problem is solved by a low-cost controller provided with appropriate software to be controlled and managed by linear computers integrated in a network. Control system of a car in addition to a driver and executive mechanisms (steering wheel and column, wheel turning mechanisms, clutch pedal, brakes, gear shift mechanism, etc.) includes a system of information visualisation necessary for driving control which is absent in a STS, in particular, windshield wiper in a wind screen to provide for its cleanliness and visibility, headlights and parking lights, marker lights, instrument panel, mirrors, horn signal, etc.

Interior design is approximately the same for a STS vehicle and a car and can be varied depending on customer desire. Furthermore, a number of components is absent in a STS vehicle and transportation system as a whole, for example: fuel tank (and, consequently, the whole chain of accompanying elements such as filling stations on a track, oil refinery plants to produce gasoline and diesel fuel, oil pipelines, oil wells); fuel feed system; exhaust outlet, silencing and combustion system (for example, more strict environmental requirements imposed in the recent years in a number of countries resulted in considerable growth in the cost of cars).

In view of the above said it will be appropriate to forecast that under serial production the cost of a STS vehicle will be 1.5...2 times lower than that of a passenger car or a mini-bus of similar carrying capacity and comfort and, therefore, it will be more accessible for individual use (in the future thanks to STS advantages it will be possible to develop an extensive network of string transportation similar to the existing highway network).

78. What was the estimated cost of a passenger vehicle and transportation module and how it affected the net cost of travel?

Estimated cost of USD 50,000 and USD 20,000 was takes for a 10-seat passenger vehicle and freight transportation module (5,000 kg carrying capacity), respectively. Obviously, these figures are overestimated. Nevertheless, the share of the rolling stock in the total travel cost (amortization and maintenance costs) amounts to as little as 2...6% and 10...20% for passenger and freight traffic, respectively. It means that the rolling stock is not critical to its loading, thus, it is possible to increase the share of 1...5-seat vehicles and to improve their comfort (to provide toilets, washroom, shower, bath).

Moreover, a number of vehicles can be arranged as a hotel single-room or office (to include furniture, computers, modern satellite communications, fax machines, etc.), thus, to be used not only as a means of transportation but as a place of work (especially during mission trips) or rest. Even if the cost of such vehicle is USD 100,000 its fare will be only by 20...30% higher than in other transportation modes.

79. Is it possible to take with you a passenger car and how much will it cost?

Passenger can register his personal car as like any other cargo under 5,000 kg. Taking into account the fact that a car is oversized cargo it will be transported in a specially equipped transportation modules with higher power engines. If a trip is not very long (0.5...1 hour; 150...300 km distance) passenger may stay in a car or to take a passenger vehicle. In this case a car will arrive in a destination simultaneously with its owner who can remove to it immediately. Net cost of a car (1,500 kg mass) transportation, for example, from Berlin to Moscow (distance – 1,830 km) will amount to USD 15...20.

80. How soon STS track expenditures will be paid back and how high are financial risks?

Recoupment period of a STS system depends on the following main factors: loading (volume of passenger and freight traffic), normative operation profitability (and related ticket price), maintenance costs and the cost of electric energy. For example, recoupment period for a concrete track – "Berlin - Moscow" (1,830 km), ticket price – USD 40/pass. (140% profitability) and passenger flow of 50,000 pass./24 hours – will be 8 years. In this case the annual profit will amount to USD 480 million (the cost of a track including infrastructure and the rolling stock is USD 3.9 million). For passenger flow of 100,000 pass./24 hours the track expenses will be paid back during 3.5 years (profit – USD 1.1 billion/year). Travel time to come from the centre of Berlin to the centre of Moscow by a STS even at relatively low average travel speed of 300 km/h will be approximately the same as by plane (about 6 hours) but more safe and comfortable. Therefore, it is appropriate to compare a STS fare with air fare to show that USD 60/pass. is not a high price for a ticket (at 260% profitability). Then, the annual profit of a track will be USD 800 million and USD 1.6 billion for passenger flows of 50,000 and 100,000 pass./24 hours and recoupment period of 4.8 and 2.4 years, respectively.

Financial risks will be minimal because it is a financially sustainable project. Even at 20% loading of the target traffic volume the route will not be unprofitable to give but a small profit. In all our examples the cost of electric energy was taken as USD 0.05 kW/hour.

81. What economic niche - in an individual country or in the world as a whole – is opened by a STS?

Almost 100 years ago Henry Ford with his automobilisation programme managed to make a revolution not only in the USA economy but in the world as a whole. Economic potential of a STS is not less. In its essence and scale a STS is comparable with Internet. Potential niche of a string transportation in the world economy exceeds USD trillion which, for example, is larger than a niche created 20 years ago by Bill Gates and his "Microsoft" Corporation, then unknown and now the richest man of a planet. Potential volume of orders on a STS in a number of countries such as Russia, China, India, USA exceeds USD 100 billion each.

82. How much a track cost depends on the ground features and relief of the site?

The cost of transportation lines is not strongly dependent on the ground features of the site, therefore, STS routes can be built in difficult of access areas such as deserts, marshlands, permafrost, taiga, tundra, jungles, ocean shelf, mountains, etc. For example, if ground features require increased height of supports (from 15m on a plain to 50 m on a rugged terrain), the track cost will be increased only by 20…25% because the share of supports in the total system cost is small (10…15%). Cost increase will be approximately the same for a string route passing across marshland area, desert, permafrost, etc. resulting from the need in additional strengthening of supports and piles.

Environmental aspects

83. What is a planetary environmental impact of a large-scale STS application?

Firstly, consumption of non-renewable energy carriers (such as oil and petroleum products, coal, gas), non-metalliferous materials, ferrous and non-ferrous metals will be reduced which results from the low material- and resource-consumption of a STS including its track and supports which do not require construction of embankments, depressions, overpasses, viaducts, bridges and other resource-consuming facilities.

Secondly, it contributes to lower environmental pollution as a result of: use of electric energy being the most clean energy type; low specific energy consumption (5…10 times less than a car); cautious attitude to vulnerable eco-systems (tundra, permafrost, jungles, marshlands, etc.); use of alternative environmentally sound energy types (wind, sun, etc.).

Thirdly, alienation of fertile agricultural lands for string routes will be reduced because STS routes do not require large land allocations (less than 0.1 ha/km, i.e. the same as for pedestrian or walking path), construction of tunnels, cutting of woods, demolition of buildings.

84. Noxious atmospheric emissions as compared with other transportation modes?

Average noxious atmospheric emissions from motor transportation and high-speed railways amount to 10 g per 1 pass./km and about 0.6 g per 1 pass./km, respectively.

Aviation is responsible for the greatest atmospheric pollution. Summary noxious atmospheric emissions from modern aircraft reach 300…400 g per 1 pass.km. The bulk of aircraft emissions is concentrated within the airport zones, i.e. in the vicinity of large cities, generated by aircraft flying at low heights and engine reheating. At low and medium heights (up to 5,000…6,000 m) nitrogen and carbon oxides remain in the atmosphere for several days after which they are washed away as acid rains. At upper heights aviation constitutes the only source of pollution with noxious substances capable to stay in the stratosphere much longer - about 1 year. Even conversion to hydrogen aircraft engines will not solve the problem. Exhaust products of engines harmless near the earth in the form of water vapor are converted into ice crystals at upper heights having a screening effect.

Noxious exhausts of a STS are less that 0.1 g per 1 pass./km, i.e. lower than emissions from a high-speed railway, which results from the lack of dust-generating embankments and gravel cushion and lower deterioration of STS rail, wheels and brake shoes.

Moreover, STS vehicles will be air-tight, provided with vacuum or chemical toilets to exclude environmental pollution with vital activity products, garbage and various technological wastes which is to be removed in special garbage collectors in depots. At the same time as seen from the experience a stripe of land along the highways and railways is exposed to heaviest contamination with passengers' wastes.

Design of freight STS containers excludes leakage of liquid goods (they have no pumps, breech mechanisms, seals, etc. which could be a source of leakage) and spilling of friable freights. Crash could result in derailment of only one vehicle (extreme braking distance of the next vehicle will be less than the distance between two vehicles) with small freight and in this case a parachute is capable to reduce container speed to prevent it from destruction when falling to the ground.

At the same time railway accidents result in the heaviest environmental pollution with tonnes of transported chemical products. Accidents at oil and petroleum product pipelines are often accompanied by atmospheric emissions of thousands tonnes of oil and petroleum products, especially in resource extracting northern regions of Russia characterised by very sensitive eco-system.

Noxious emissions and other key environmental indices are given in Table below.

Table

Key environmental characteristics of various transportation systems
(passenger flow - more than 1,000 passenger/hour, freight flow - 1,000 tonnes/hour)

Mode of transportation	Specific energy-resource consumption (litres of gasoline per 100 passenger/km or tonnes/km		Noxious emissions kg/100 passenger/km (or 100 tonnes/km)	Land requirements** ha/100 km
	Passenger traffic	Freight traffic		
1. Railways (up to 100 km/h):				
• arterial	1.1 - 1.4*	0.7 - 1.0*	Over 0.1	300 - 400
• local	1.2 - 1.5*	0.9 - 1.4*	-#-	-#-
• city-wide:				
- underground	1.3 - 1.7*	-	-#-	-
- tram	1.9 - 2.1*	-	-#-	50 - 100
2. Motor transportation (100 km/h):				
• individual car:				
- within the city limits (average load of 1.6 passengers)	4.7 - 6.3	6.6 - 11.1	over 1	200 - 300
- beyond the city limits (average load of 3.5 passengers)	1.5 - 1.7	5.1 - 9.2	-#-	300 - 500
• bus				
- within the city limits	2.1 - 2.3	-	-#-	200 - 300
- beyond the city limits	1.4 - 1.7	-	-#-	300 - 500
• trolley-bus	1.9 - 2.5*	-	over 0.1	200 - 300
3. Air transportation				
• long-distance (900 km/h)	4.7 - 9.2	51 - 73	over 10	20 - 50
• local (400 km/h)	14 – 19	152 - 202	over 50	10 - 20
4. Sea transportation (50 km/h)	17 – 19	0.38 - 0.95	over 10	5 - 10
5. River transportation (50 km/h)	14 – 17	0.57 - 1.4	-#-	2 - 3
6. Oil pipelines (10 km/h)	-	0.51 - 0.57	over 1***	50 - 100
7. Gas pipelines (10 km/h)	-	5.7 - 6.1	over 1***	-#-
8. Conveyer transportation (10 km/h)	-	4.7 - 9.2*	over 1	-#-
9. Hydro-transportation (10 km/h)	-	2.3 - 4.7*	over 0.1	-#-
10. Cable-rope roads (10 km/h)	0.3 - 0.5*	0.95 - 1.9*	-#-	20 - 30
11. Train on a magnet suspension (400 km/h)	3.5 - 4.5*	-	-#-	100 - 200
12. High-speed railway (300 km/h)	2.5 - 3.5*	-	-#-	300 - 500
13. Monorail (100 km/h)	1.5 - 2.5*	-	-#-	50 - 100
14.String transportation**** (passenger - 10 seats; freight - 5 tonnes of freight) at the speed of:				

Mode of transportation	Specific energy-resource consumption (litres of gasoline per 100 passenger/km or tonnes/km		Noxious emissions kg/100 passenger/km (or 100 tonnes/km)	Land requirements** ha/100 km
	Passenger traffic	Freight traffic		
- 100 km/h (15 kW engine power)	0.17*	0.17*	below 0.01	10 - 20
- 200 km/h (35 kW engine power)	0.20*	0.20*	-#-	-#-
- 300 km/h (90 kW engine power)	0.34*	0.34*	-#-	-#-
- 400 km/h (200 kW engine power)	0.57*	0.57*	-#-	-#-
- 500 km/h (400 kW engine power)	0.91*	0.91*	-#-	-#-

* estimated for 1 litre of gasoline = 8.78 kW/hour of electric power;
** road including infrastructure;
*** spilling of oil or petroleum products, natural gas emissions;
**** estimated by analogy with other modes of transportation.

85. Electric energy is harmless when consumed by a STS, however, it results in environmental pollution when generated by a power plant?

Hazard is associated no so much with environmental pollution as with concentration of noxious substances. Air, water and food products contain all chemical elements included in Mendeleyev's periodic table that are harmless under appropriate concentrations. Special survey showed a direct relationship between morbidity rate, especially among children, and degree of environmental pollution. For example, in experts' opinion this cause (environmental pollution) is attributive of the reduced life expectancy in Russia approximately by 3…5 years.

According to the estimates substandard water quality "is responsible" for the reduction of life expectancy by 2…3 years. Contribution of acute and chronic food intoxication in reduced life expectancy is estimated at not less than 1…2 years.

Transportation, especially in urban areas is the major source of air pollution caused by atmospheric exhausts immediately in the human living environment. To have a more clear picture let us make a theoretical experiment: let us take the lowest power transportation vehicle with internal-combustion engine - a moped - and electric appliance of similar power, for example, an iron. Both of them we switch on in our flat (their power is equal). In a minute we'll have the following three alternatives: 1) to use a gas mask not to die of dyspnea; 2) to switch off a moped and to use a bicycle; 3) to invent a transportation vehicle which provides for power consumption as safe as an iron and excludes the need in pushing pedals as a bicycle. We come across similar situations every day and not in theory but in real life, in the house we all live in which is something more than our flat, with thousands or even millions of moving vehicles and not mopeds but rather much more powerful and environmentally hazardous cars.

In fact, heat power plants give rise to environmental pollution but in terms of one unit of power this pollution is lower than that generated by cars and it is observed far from the population concentrations. There are also other, less hazardous or environmentally safe power plants such as hydro-power, nuclear, tidal, geothermal, wind and solar electric power stations.

Furthermore, STS will contribute to the promotion of autonomous energy supply systems based on renewable energy sources such as wind and sun. In terms of direct environmental impact wind energy is one of the most clean energy sources. It does not generate noxious atmospheric emissions and water contamination, does not result in the depletion of limited non-renewable mineral resources and transformation of water regime.

There are principal schemes of wind and solar power plants with vertical axis of rotation which could be combined with STS supports and track structure. It could result in a sharp reduction of capital costs for their construction and maintenance as they do not need any access roads, power transmission lines to supply energy users, etc.

For STS needs it is enough to have an energy source of 100…200 kW power or two wind power stations each of 50…100 kW installed at 1 km distance along the track with their maximum number corresponding to the number of supports, i.e. 10…20 units/km to generate a summary power of 500…2,000 kW/km (for a track characterised by moderate and strong winds). Therefore, the total power of wind power stations of a STS will amount to 0.5…2 million kW per each 1,000 km (at the average wind velocity of 10 m/sec.), the net cost of energy generation will be within USD 0.02/kW and the recoupment period of 6 years. Therefore, in addition to its autonomous energy supply source a STS could become a powerful electric power plant capable to meet the needs of surrounding areas. In this case it is not necessary to have high-cost and environmentally hazardous high-voltage power transmission lines as users' energy supply will be facilitated directly by a STS.

86. What are land requirements for a STS compared with other transportation land users?

A high-speed motorway (including segregation lanes, numerous traffic exchanges in various levels such as "clover leaf" , acceleration and deceleration lanes, recreation parking facilities, filling stations, etc.) requires land allocation in the amount of 5…8 hectares per 1 km of the road. High-speed railway requires special enclosure on both sides and noise protective screens (which also poses an insurmountable obstacle for wild and domestic animals, agricultural machines, etc.). On the whole these roads require land allocations in the amount of 3…4ha/km (Germany data).

Land allocation for modern airports is comparable with right-of-ways for the high-speed railway roads and for this purpose more valuable lands located in the immediate vicinity of cities are used.

As to a STS, it does not require embankments, tunnels bridges, overpasses and other similar facilities associated with large land requirements. Land requirements for one supporting mast and one anchor support amount to about 1 sq. m and 10 sq. m, respectively. Therefore, the total right-of-way along the whole length of a STS route will occupy less than 100 sq. m, i.e. 0.01 ha of land and its conditional width will be within 10 cm which is considerably smaller than land requirements for a pedestrian or walking path.

87. What damage could a STS construction cause to nature? What about other transportation systems?

A string transportation system is characterised by environmental safety not only in the course of its operation but at the stage of construction as well. Special technological equipment (technological platforms and building combines) used for its construction does not require access roads as all necessary building materials and components will be delivered to the construction site along the ready track sections.

Furthermore, its construction implying the use of piled foundation could fully eliminate excavation and earth moving works which could damage the layer of soil with its humus accumulated during millions of years. STS could pass through any terrain without any embankments or land excavation whereas, for example, a modern highway or railway construction is associated with earth removal in the amount of 10,000…50,000 cub. m and

100,000 cub. m for mountainous country. STS is not critical to a span length, therefore, there is no need in cutting of forests or even free standing trees as it is possible to displace any support, if required.

STS is characterised by very low material consumption for its construction which makes it most environmentally clean in technological terms. For example, material consumption for a one-way STS route will be the same as for two railway rails and ½ of the total number of sleepers for a road of similar length (and in this case railway will require additional ½ of sleepers, contact network with copper wire and supports, powerful gravel cushion, earth embankment, bridges, overpasses, viaducts, etc.)

Thus, a STS does not require a great number of blast furnaces, ore, mines (necessary for steel and copper production), cement plants and manufacturing of reinforced concrete products, sand, gravel quarries, intensive motor and railway traffic to deliver building materials, access roads, etc. which could produce additional, sometimes irreversible environmental impact.

88. How heavy is a STS module impact in terms of soil vibration and noise?

A STS module has no projecting parts except its narrow wheels extended for 10 cm from the body; it does not require windshield wipers and headlights (as it is driverless) which at high speeds could be a source of noise. A vehicle body has a perfect aerodynamic shape (aerodynamic drag coefficient C_x=0.075), flow-around is symmetrical not resulting in side or tilting forces, no air flow turbulence (that are especially noisy). Wheels can be made of light metal alloys (with 500…1,500 kgf load per 1 wheel) with the total mass of about 20…30 kg.

Therefore, mass of a STS vehicle will be, for example, by hundreds of times less than that of a train and its length – by tens of times shorter; mass of a spring-free part is tens of times less, track evenness much higher (is there anything more straight than a tight strained string?). Thus, compared with a high-speed train a STS vehicle is a much weaker source of noise and soil vibration. A system of internal and support dampers capable to reduce low- and high-frequency track vibrations will also contribute to lower noise impact of a STS track structure.

89. What are other (non-conventional) hazardous impacts of a STS, for example, electromagnetic radiation as compared with other transportation modes?

STS is a low-voltage line (of 1,000 V voltage), thus, it does not generate electromagnetic pollution and can pass at large heights (up to 100 m) above housing estates, agricultural lands, natural reserves and parks. The lack of sliding electric contacts in a "vehicle-contact network" pair , low (by tens of times as compared with a railway) electric capacity of the rolling stock exclude environmental pollution with radio noise. A STS system is free of specific impacts such as powerful electromagnetic pollution of radar and radiation in aviation (during a many-hour flight each passenger is exposed to additional radiation caused by natural cosmic gamma-radiation reaching 300…400 microroentgen/hour against 20mr/h being a standard).

Social and political aspects

90. What are socio-political advantages of a large-scale STS use?

The major socio-political advantages are as follows:

1. Increased communication capacity (business and personal contacts, tourist trips, excursions and recreation trips including long-term recreation and weekends, etc.).

2. Wider possibilities: to work further from home without changing habitual place of residence; to develop sustainable residential zones (housing estates) within the walking distance of STS; to build linear cities open to nature along STS routes; to provide urgent medical aid; not to interfere in human traditional habits in the sphere of transportation services (for example, a possibility to travel at longer distances with a personal car at reasonable prices).

3. Individualisation of travel with the use of a STS transportation module as a personal mode of transportation at more affordable price than a car.

4. Reduced number of accidents at other transportation modes as a result of attraction of a certain part of passenger and freight traffic by a STS (annually about 990,000 people are killed in road accidents including after-injury deaths and millions of handicapped).

5. Better protection of transportation-energy and communication systems from natural disasters (such as flood, land slides, earthquakes, tsunami) and terrorist actions thanks to the interaction of STS control components.

6. Improved transportation qualities: all-weather operation (irrespective of fog, snow, glaze of ice, sand storm, etc. and other unfavourable weather conditions); universal use (including land and sea sections).

7. Contribution to the formation of integrated, interrelated and more safe global environment.

91. Socio-economic advantages of a large-scale STS use?

The major socio-economic advantages are as follows:

1. Reduced share of financial resources necessary for the long-lasting construction projects: low capital intensity of a STS (considerably lower than for any other high-speed transportation system, for example, tens of times lower than for a train on a magnet suspension; shorter recoupment period (3…5 years).

2. Reduced cost of transportation service, higher accessibility and attractiveness for all population groups at higher service quality (speed, comfort, safety).

3. Accelerated and improved integration and cooperation economic links both at the national and international level.

4. Easy access to develop hard to reach areas such as deserts, marshlands, permafrost, taiga, tundra, jungles, ocean shelf, mountains, etc. as the cost of STS lines in not strongly dependent on the ground features of the site.

5. No need in construction of special power transmission and communication lines including fibro-optic ones that are easily integrated with STS.

6. Possibility to form a global high-speed STS infrastructure within short time limits (during 10…15 years) which will have a multiple effect in other industrial sectors.

92. How a STS could contribute to demographic problems solution?

Along STS routes characterised by environmentally sound infrastructure and noiseless vehicles it is possible to build linear cities located within the walking distance and harmoniously integrated in the natural environment. In this case it is not necessary to cut forests, to build highways, etc. resulting in the deterioration of biogeocenosis within the development zone. It will be easy to promote agriculture and environmentally friendly industries; to form the spots of rationally organised society. Construction of linear cities will be associated with lower capital investments than conventional development. Simply, it will give more benefits for a man because living in normal natural and social conditions will be more important than any material possessions. Thus, the first steps will be made towards a new future society built rather on harmony with nature than on opposition.

It should be remembered that land is the major resource used by the existing transportation (first of all high-speed) systems and what is more important – the most valuable resource. In Europe and especially in Western Europe the cost of 1 hectare of land is estimated at millions of dollars as it is either land withdrawn from agricultural use or allocated at the expense of reduced recreation zones or withdrawal from possible development which results in higher built-up densities and deteriorated living conditions of millions of population. For example, some Western experts forecast that if China orients its policy to the large-scale construction of high-speed roads which require allocation of more than 3 ha of land per 1 km, in the 1st quarter of the 21st century it will be in the face of famine that by its scale is comparable with that of the period of cultural revolution which took the lives of more than 30 million people.

STS supports require as little as 0.01 ha/km of land and if they are designed in the form of buildings which in their aggregate will make a linear city, there is no need in additional land allocations. Moreover, a linear city could be built on a so far undeveloped but suitable for living site, for example, a sea shelf located at 1…2 km distance away from the shore (see Fig.).

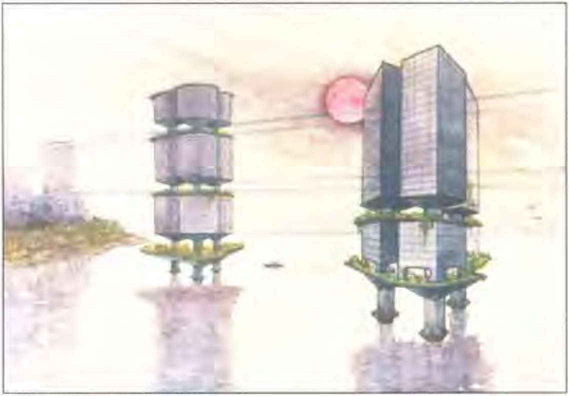


Fig. Linear city on a STS route along the sea shelf

Each STS anchor support could be easily integrated with unusual and architecturally impressive facilities such as a high-rise residential building, sea hotel, restaurant, sports and recreation complex with a filled-in beach around it in the form of an island, etc, with all of them linked with each other by a high-speed, all-weather, storm-resistant track. This solution could increase, for example, the area of Israel (by 300…500 sq. km – 30,000…50,000 ha) or Japan (by 10,000…20,000 sq. km – 1…2 million ha).

93. Is it possible to use a STS for military purposes?

Undoubtedly, like any other transportation system. For example, a motorized division with small arms (about 10,000) could be re-located at 1,000 km distance during 3.5…4 hours. Furthermore, continuous circulation of specially equipped modules containing mobile rocket units could be arranged difficult for detection by external observation aids.

94. How a STS can cross the borders between countries?

STS vehicles moving without stops at a height like aircraft do not need to cross the borders of states but rather need an air corridor. Passengers or freights are to pass through customs at origins and destinations.

For example, provisions of the Russian Constitution related to free circulation of goods and people are currently infringed in Kaliningrad Region which results from the need to cross three borders and to go through three customs in order to move from this region to any other region of Russia. STS helps eliminate this problem because Belarus, Lithuania and Poland (depending on a STS alternative) could provide an air corridor only to handle transit freight and passenger trips.

95. What advantages for Russia could give, for example, construction of a STS in a resource extracting region of the country?

About 80% of industrial potential of the RF is concentrated in the west from the Urals and 80% of its fuel resources is concentrated in the east which necessitates transportation of hundreds of millions of tonnes of fuel every year. It is obvious that until safe nuclear reactors for nuclear power plants are designed it is necessary to find additional energy sources for the region. One of them is Pechora coal basin – the largest one in the European part with its total resources almost twice as large as in Donbass. In addition, Pechora basin is characterised by higher thickness of coal seams, better mining conditions, higher labour efficiency and lower net cost of mining.

STS makes it possible to sharply increase the export of Pechora coal, especially cleaned coal, which high transportation costs to the users make it not competitive at the present day world market. For example, the cost of American caking coal in shipment ports is USD 47/t and the cost of energy coal delivered from SAR to the Netherlands is USD 30/t. The cost of coal transported by a STS from Pechora basin to Kaliningrad port could be by 20…30% lower. Where to sell Pechora coal? Naturally, to Scandinavian countries which today have to buy coal even in the far Columbia.

As it is known Sweden decided to stop construction of nuclear power plants and to replace then by heat power plants using gas and coal for their operation. It could be reasonable to invite Sweden which is a long-established and widely recognised supplier of mining equipment for collaboration with the Russian Federation to develop new areas of Pechora basin. Similar proposals could be made to Finland, Norway and other West European countries which will contribute to the development of Pechora basin to become the largest base of caking and fuel coal in Europe.

Practically, all mining industry of the Russian Federation is concentrated in hard to reach and underdeveloped northern areas the development of which is hardly possible without foreign investments. For example, the RF Government prepared a list of 250 relevant deposits with the total raw resources (oil, gas, coal, copper, silver, etc.) estimated at USD 12 trillion. Among gas and oil deposits Timan-Pechora deposit (situated between Archangelsk and North Urals with 2.4 billion tonnes of explored oil resources) is the largest one which in the future plans 75 million tonnes of oil per year for delivery to Europe.

Further in the east, immediately behind the North Urals there is one more promising oil basin: Priobsk oil field (with 2.4 billion tonnes of explored oil deposits) and neighbouring oil fields of Tyumen which is responsible for more than one half of the total Russian oil output. Development of Timan-Pechora oil fields entails development of Priobsky deposit and a STS communication infrastructure especially provided for the purpose will make it possible to promote development of a sea shelf of Arctic Ocean with even more extensive oil and gas resources.

On the whole, it is a possibility for the region rich in fuel resources to be integrated in the world economy so as to give rise to geopolitical transformations of planetary scale as a result of reduced or fully eliminated dependency of Europe and the West as a whole on Persian Gulf region. In experts' opinion those who control these fuel sources will control, for example, Germany as well.

Yamal peninsula is the youngest region among other vast sub-Arctic areas characterised by extremely vulnerable environment. In fact, it consists of a number of huge ice blocks of 50 m thickness, sort of run aground and overlapped with a layer of sea clay of 1...2 m width. Yamal is situated 20 m above the sea level. It is hardly possible to find any other place on the globe being so vulnerable in terms of modern spatial technology which had to be coloured rather as white covered with ice area than as green lowland.

According to experts' estimates more than 6 million ha of pasture lands in Yamal were damaged as a result of unwise mineral extraction solutions. Their reclamation will require allocation of gigantic financial resources estimated at USD 50...100 billion. Communication infrastructure based on the use of a STS will make it possible to minimise environmental implications of deposit exploitation in the northern regions of Russia and first of all in Yamal peninsula.

It should be emphasised that in future environmental impact will be the major factor to identify development costs of northern regions which is proved by international experience. For example, initial project cost of a gas pipeline in Alaska (USA) was estimated at USD 600 million, however, its construction was blocked as a result of protest made by the public and environmental associations. After the relevant nature conservation measures were taken which turned to be very expensive under permafrost conditions a pipeline was built but then its cost increased to USD 5 billion.

A key question of all without exception northern projects is how oil will be delivered from Russia to other countries of Europe, i.e. which region of Europe will be developing at fastest rates. Proposed STS alternative will make it possible to attract the major share of foreign investments to densely-populated regions of Russia which are going to accommodate a STS route including Kaliningrad region with its port. In future a STS route could be extended in north-east and south-west direction to deliver raw resources from the northern deposits of Russia to the West and to bring western industrial goods and food products to Russia.

STS programme is also in compliance with the future targets of oil delivery to Europe from Kazakhstan (50 million tonnes per year) and Azerbaijan (25 million tonnes per year) as all the above mentioned transportation communications are easily integrated through a STS within the area of city of Smolensk. This development concept of northern areas is interested not only for oil and gas companies of the RF (in particular, Gasprom), but for the Government of Russia (ministry of economy, environment, finances, etc.), local government bodies (that are currently facing serious environmental problems generated by oil and gas developers associated with tundra recovery which requires hundreds of years), as well as the Government of Belarus and western investors capable to evaluate their investment efficiency (expected total volume of investments – USD 200 billion). If a STS infrastructure has one owner (for example, Gasprom of the RF) it is possible to propose a price policy which will make delivery of the Russian raw resources to the West free, as all costs will be included in passenger fare. And in this case a STS fare will be lower than that for railway passengers. As a result Russian goods will be more competitive in the West and will bring additional profit.

Other questions

96. Most serious STS disadvantage?

The only serious STS disadvantage, unfortunately still not eliminated, is associated with the lack of already built at least 1 km of STS track. But, as it is known, this drawback was in its time inherent in highways and railways, aircraft and trains on a magnet suspension, electric cars and other inventions ever made by man.

Nowadays this shortcoming of a string transportation system is easy to eliminate as all basic STS components are available and efficiently operating in various technical fields. For example, one of the project distinctive features is associated with the need to provide an ideally even and very rigid track capable to carry a transportation module wheel which was achieved through the use of steel strings strained to high stress. However, this solution is very close to the design of hanging or guy rope bridges which relevant practical, experimental and theoretical potential gained during hundreds of years was in full value used in working for a STS project.

STS transportation module in its essence is a variety of a high-speed electric car which, in fact, is not supplied with accumulators but through its wheels is switched to the industrial electricity supply network which is regarded as one of its basic advantages. Electric car design experience of the leading world corporations was also used in the STS project. Moreover, poor aerodynamic qualities of a modern car do not allow to gain high travel speeds, therefore, a unique shape of a STS module was proposed having no analogues in the world including aviation with its aerodynamic drag coefficient amounting to C_x=0.075 (patented in a number of countries).

Current development of a STS is at the stage which does not arise any doubts in terms of its operative qualities and validity among its authors and developers as well as among experts and governmental bodies of Belarus, Russia and Ukraine.

97. Why a testing ground for a STS is necessary?

The key stage of practical implementation of a STS implies construction of a pilot testing ground to carry out full-scale pilot industrial testing of a string transportation system. A testing ground includes scientific research complex with a laboratory building, design bureau, assembly unit, autonomous power supply block, storage and other facilities and a pilot STS track.

Construction of a pilot STS track implies the following stages:

1. First, one span (of 1,000 m length) between anchor supports will be built with 20-25 intermediate supports (with their height ranging from 1 to 20 m) installed in between with spans ranging from 10 to 100 m. This section will be used to test building technology of intermediate and anchor supports, strain adjustment and anchoring, formation of a rail-string and track structure and checking of technical equipment. A track structure and supports will be also exposed to static tests to investigate movement dynamics and behaviour of a transportation module.

2. After that the necessary corrections will be made in the transportation line, module and track design and the track will be extended by 2 km to reach the total length of 3 km. It will make it possible to gain the speed of 250 km/h and to start testing of the high-speed (more than 200 km/h) acceleration/deceleration regimes, control systems and non-standard operation conditions.

3. The final stage envisages extension of the track length to 15 km with its terminal sections designed as rings of about 1,000 m diameter including switching devices which will make it possible to reach the maximum travel speeds of 500-550 km/h. Also tested will be

high-speed travel regimes, turns and basic infrastructure components (switching devices and stations).

Approximate cost of the first two stages is estimated at USD 25 million, implementation period – 2.5…3 years. The third stage will be associated with approximately the same cost and time requirements.

Examination and tests of separate units, aggregates and components of the transportation line, module and infrastructure will be also carried out at specially designed laboratory stands.

After a STS has been exposed to a pilot industrial test on a testing ground, standardised and certified it is possible to recommend a high-speed transportation system of a new type for use both in developed and developing countries. If the full-scale tests prove theoretical research and tests of a STS model track and its rolling stock carried out within the framework of the Habitat project a STS could be proposed for the world community as the most environmentally friendly, less capital- and resource-intensive and most economically efficient transportation system capable to cope with the requirements of the 21st century.

The tasks to be solved at the testing ground are as follows:

1) String track structure is not referred to beam or cable structures, therefore, the world experience in construction and operation of bridges and overpasses, mono-rail and cable roads and other transportation is not appropriate for a STS. Thus, a rail-string being the basis of a STS track structure is to be optimised experimentally (rail rigidity, tensile strength of a string, optimal span length, choice of filler and its physical and mechanical qualities, etc.) and tested at low (under 200 km/h), medium (200…300 km/h) and high (300…500 km/h) travel speeds of a transportation module.

2) A STS electric module has four steel wheels with "an automobile" (independent) suspension, each of them with two rims (flanges) which makes a STS rolling stock principally different from that of railway, highway and mono-rail roads. Furthermore, a module is moving along the two pre-stressed rigid threads (rail-strings) of great length, rested upon rigid (anchor) and flexible (intermediate) supports. It is a principally new scheme of a high-speed track structure for the world experience which moving dynamics is in need of further study. So vibration frequency and amplitude of a rail-string, wheel suspension, module body supports as well as the generation of resonance frequencies in the track components, module and supports are to be further investigated.

3) High-speed movement of small-size modules at 20…30 m height above the ground requires a special approach to their aerodynamic qualities, optimisation of their body shape and impact of climatic factors such as wind, rain, snow, icing, high and low temperatures, etc.

4) STS supports and their components (anchor, intermediate, brake) differ from the supports of bridges, elevated and cable roads, power transmission lines both in terms of their design and static and dynamic loads and specific requirements. All this necessitates experimental study.

5) New track and rolling stock solutions require non-traditional approaches to the infrastructure design which is also to be exposed to experimental testing (including switching devices, terminal components, stations, freight terminals, etc.).

6) New transportation concept is associated with new approaches to its design standards (shape and geometrical dimensions of a rail head and supporting part of a two-rimmed wheel, track width, distance between two contra-flow lines, dimensions of a transportation module, etc.); electro-technical standards (voltage and type of current – direct or alternating, etc.), technological, operational and other standards.

98. How many years has the author been involved in a STS project?

About 20 years, or even 25 years if we take its pre-history (project of a planetary transportation vehicle – a system for the future wide-scale development of near the ground cosmic space based on non-rocket principles which gave rise to a STS idea).

It could seem quite a long period, thought if we remember the history of engineering and automobile and railway transportation their pre-history was much longer. Trains on a magnet suspension required much more time for their development, though only FRG spent for them billions of DM which was not the case with a STS. The former USSR was also involved in magnet suspension projects and spent several billions of dollars during few decades, though not a km was built. Even more simple inventions such as photography required more than 100 years from the moment of its idea to implementation. Thus, inventor has a chance to see his invention with his own eyes, put into life only if he starts his project, especially a large-scale one like a STS, in a relatively young age.

It took the author many years (about 10 years) to formulate and develop his idea, to crystallize its essence, to make the estimates and technical and economic analysis. It took years to promote the calculations, feasibility study, relevant technical solutions, testing of major units and components, specification of STS inherent standards, etc. Several more years were spent to acquire a patent for a principal scheme of a string system in the leading world countries and in this case the major problem was associated rather not with a patent itself but with the lack of finances (which required about USD 100,000). However, in independent experts' opinion the cost of non-material assets created by the author during this period is evaluated at USD 1 billion.

The fact that a STS is still unrealised is attributed to the lack of financial support rather than to the shortcomings of a STS and its unsolved research and technical problems. All works during these 25 years have been carried out at the expense of the author himself, whose financial possibilities are very limited. Without patents (first of them were obtained as late as in 1997) attraction of investments to support the programme was out of the question. It will be only possible to start the fund raising only in the year 2000.

Unfortunately, the author was not lucky to meet in his life a person like S.V.Rakhmaninov. As it is known, famous composer, pianist and conductor who lived in the USA in emigration in the 1920s met another emigrant I.I.Sikorsky, then already known aircraft designer living in poverty. This man, being so far from technics, believed in the poor designer who was fully neglected and had no orders, gave him USD 5,000 (today it is equivalent to USD 500) and said: "I believe in you. Pay back if you can, if not, all right let it be so". Who knows if helicopter industry of the USA could come into existence without this support?

99. What differs investments in a STS programme and a specific STS route?

The same, for example, as in "Automobile" and "Automobile VAZ 2110" programmes. In the former case it is an automobile in general which could have hundreds of modifications (concrete marks), good or bad. Thanks to efficient technical and economic solutions "Automobile" programme has been flourishing for more than 100 years and will be a success further on until a new more efficient programme, for example a STS project, is proposed. As to "Automobile VAZ 2110" programme it could be not very successful and lose in competition with other programmes.

It is approximately the same with a STS. It is possible to build, for example, a STS track "Moscow - N.Novgorod" which for this or that reason could be non-profitable and investor will suffer losses. On the contrary, that who invested money in a STS programme is not going to meet losses. Negative experience is also experience. Then the next transportation line, for example, "Minsk - Moscow" will be built based on the obtained results to become profitable and eliminate possible risks and losses. According to the world statistics profit coefficient of investments in scientific research and experimental design and construction works at the final stage of a research programme will be 1:100 or even 1:1000.

100. What guarantees a STS programme success?

It is the programme itself with its powerful initial potential. It is not even concrete people (and its author as well) and concrete tasks and errors in the course of the programme implementation that identify its success. Let us remember firsts steps in aviation. They were accompanied with numerous errors, unwise solutions, failure to fly up, crashes. Air planes are still crashing and what of it? Aviation created the most powerful niche in the world economy and in not going to give it to somebody else. It started when nothing was actually known even for aircraft designer about aerodynamics which makes the basis of aviation.

Let us remember our recent past when the foundations of rocket construction and modern astronautics were laid. What most difficult problems their designers had to solve! Let us consider only two of them: rocket stability and fuel combustion in a jet engine. In stable state a rocket looks like a pencil put on its edge. Can you imagine something more unstable? Is it appropriate to speak about launch accuracy? Designers neglected these difficulties and today it is hardly possible to find any other system being more accurate than a rocket. A spaceship launched from the Earth at enormous speed is capable to land in the assigned spot of another planet moving at a distance measured by hundreds of millions kilometers. And how about a problem of fuel combustion when the heat power per 1 sq. m of a combustion chamber of a jet engine reaches 1 million kW? It seemed that there were no adequate materials to resist this power but designers managed to find a solution of this problem as well.

Or another example – a train on a magnet suspension – "Transrapid" (Germany), or more precisely, its suspension problems. An ordinary magnet put to a paper-clip, for example, will result in either:

1) a paper-clip remained still lying on the table; or

2) a paper-clip is jumping to stick to a magnet.

However, there is a third, fantastic alternative with a paper-clip hanging in the air not touching either a table or a magnet which was realised in a "Transrapid" project.

STS is free of similar difficult problems. A string system is based on simple mechanics, in figurative sense it is like "iron", known and tested long-long ago including its wheel, drive, rail, track, track structure and supports, control systems, etc. Estimations of a track and supports is the subject of structural mechanics used to design bridges, buildings and facilities; movement of a STS vehicle refers to structural dynamics including dynamics and aerodynamics of a four-wheel car.

The same is true for other STS problems which are either solved in modern engineering or are not difficult to solve based on the knowledge of theory and practice of building structures, railway, highway, aircraft construction, electric engineering and electronics, etc.

Questions about a STS were asked by[*]:

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Part 3. Practical implementation alternatives

3.1. STS as environmentally sound alternative of super-automobilisation

The end of the 20[th] century saw the urban revolution - for the first time in the human history half of the world population is living in the cities.

As it was stressed by the UN Conference on Human Settlements in Istanbul urban revolution will be going on for the next three decades to the effect that the number of urban residents will grow twice as much as that in the rural areas. Thus, population concentrated in the cities will be by 2.5...3 billion residents more than at the present time and all of them are not only to be housed but also to be provided with infrastructure and job opportunities adequate for the 21[st] century.

Though the present day and future cities will remain the global financial, industrial and communication centres, concentrations of the whole variety of cultural values, dynamic political life, enormous production, creative and innovation potential, at the same time they became the source of poverty, violence and overloaded communications. Unstable consumption patterns in the highly-dense cities, industry concentration, intensive economic activity, high concentrations of cars and inefficient systems of waste management are the factors showing that the main environmental problems of the future will be associated with the cities.

Let us consider a city from the point of view of its transportation infrastructure.

Streets and crossroads, squares and parking lots, bridges and viaducts, garages and gas stations and other facilities in modern cities are built just for cars. Cars subordinate cities more than people who built them and who (as biological creatures) are in need of other living conditions.

Cars in the city are a main source of air (to 80%) and noise (to 90%) pollution. Adjacent areas are polluted with fuel combustion products containing more than 100 cancer-producing and more than 100 toxic substances, tire and road friction products, de-icing salts, road dust and others. Gas filling and washing stations, car repair shops and other elements of transportation infrastructure are also sources of pollution. Land covered with roads does not breathe and its natural surface and ground water regime is changed. Land is withdrawn from a biospheric oxygen generation system and air cleaning by green plants in places of mass population concentrations.

Every day millions of people sit at wheel to stay in self-contained space of the small size in stress condition for hours, and breathe polluted air with fuel and lubricant steam, fuel combustion products and fumes of heated asphalt.

Every day cars kill thousands of people all over the world, make tens thousand of people cripples and invalids. Billions of people are exposed to negative effect.

Transportation mobility of urban population is constantly growing and in a number of megalopolises the total number of trips in 2000 will be more than by 3 times larger than in 1980. As s result of further urbanisation processes their 6 times increase is possible in the year 2025.

An example of such megalopolises is the city of Mexico, the largest city of the world with more than 20 million population living over 2,000 sq. km area. In total more than 30 million trips are made in Mexico every day using more than 3 million cars and public transportation modes.

It is also necessary to make note of daily resource consumption by these cities and the need to transport these resources to the users. Average drinking water and food consumption per 1 resident amounts to about 1,000 and 2,000 tonnes, respectively. In addition, 2,000 tonnes of wastes and 900 tonnes of environmentally noxious substances are generated. For example, in Mexico motor transportation is responsible for 100% of the total lead concentration and 82% of carbon oxide exhausts which result in considerable deterioration of the atmospheric air quality.

The main reason why cities, megalopolises and mass concentrations of population are formed is a need to guarantee transportation accessibility. Access to places of employment, educational, health and cultural centers, mass-scale recreation and entertainment places, provision of a possibility for physical contacts between people – are factors which brought together at first thousands and then millions of people. That was the way the cities grew and their image has been formed during centuries first by pedestrians, then – by horses that move transportation means, and in 20 century – by rail-road (including trams and underground) and cars (including buses and trolleys). Historically it was transportation communications that have formed the image and spatial pattern of modern cities and megalopolises.

Only the need in transportation access gave rise to the super-high concentrations of residential and industrial developments, population in modern cities and related flows of energy, heat and gas exchange. All this results in the deterioration of natural vegetation and fauna, changed micro-climatic, geological and hydro-geological conditions, absolute numerical domination of man and maximum man-induced transformations of indigenous landscapes. Already today up to 50% of all population diseases in the large cities can be referred to the "city-generating" causes. First of all, they include diseases associated with the overcrowding, air pollution, noise, vibration and electromagnetic radiation.

Time is a limited resource as the day still lasts for 24 hours and human life - approximately for 80 years. Gross national product per capita of population in the developed countries exceeds USD 20,000 at approximately 2,000 working hours per year. Therefore, very roughly 1 hour of civilised human life on the average can be evaluated at USD 10. Thus, in a civilised country daily saving of 1 hour of citizen's time per is more economically justified than saving of 10 liter of gasoline, 100 kg of coal or 10 kg of bread per 1 citizen. At the same time in many cities of the world commuter trips take almost one half of the working day. Travel costs ranging from 4 to 6 hours are considered usual for the Indonesian capital the city of Jakarta. The number of cars in the USA is often close to the maximum carrying capacity of roads. It was estimated that the cost of this problem for the country amounts to USD 1 billion per day including reduced productivity, time losses and deterioration of population health.

But if the role of transportation in the future will remain so great, why not to form the future image of our cities based on new transportation technologies and urban development concepts?

Imagine a chess-board with its squares being natural landscape and lines dividing the board into squares are linear cities of 500 m width, built-up predominantly with cottage buildings (Fig.22).

Along the city axis in the green stripe of 100 m width above the trees, i.e. at the height of 50 m and over there are high-speed "green" transportation communications. "Green" means that they are secure, they don't threaten to people lives and health (environmentally-friendly, noiseless, high-speed moving safety, etc.), they don't break the harmony of environment including landscape. If such city is 50 km long and the speed of moving is 200 km/h, it will take a person 15…20 minutes to get from one corner to another as a maximum, but as an average – 10…15 minutes. Offices and industrial and other buildings with mass concentrating of people will be also located in middle green area of a city, and everybody will be able to walk towards them. If they are located at 100…500 m distance, it will take a pedestrian not more than 3…5 minutes to get there. At the same time each building is provided with a transportation station located on its roof or top floors to which passengers could get by an escalator or high-speed elevator.

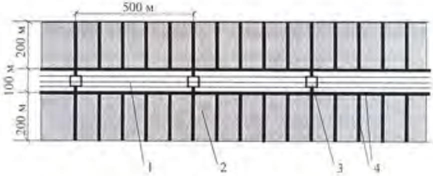

Fig. 22. Linear city:
1 – multi-way high-speed "green" routes (through, reverse, sidetracks); 2 - cottage building area; 3 – high-rise offices, industrial buildings and facilities, cultural, shopping, health and other centers; 4 – pedestrian paths.

At the residential density of 1 person per 1 linear meter (or 500 m^2 /person) such city will have the total 50,000 population where as a "chess-board" green megalopolis (Fig. 23) formed by 100 such crossing linear cities (50 at the each side, at 1 km distance from each other) could accommodate 5 million population living in comfort over the area of 2550 sq. km.

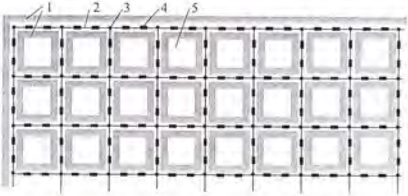

Fig. 23. Green (chess-board) megalopolis:
1 – linear city building area; 2 – "green" high-speed transportation communications; 3 – change stations; 4 – loading/unloading passenger stations; 5 – natural park.

You will be able to get from any point of such megalopolis to any another one just with one change. Maximum travel time (from one corner to another) is 35 minutes; average time is 15…20 minutes. Maximum carrying capacity of a transportation line is 500 thousand passengers and 100 thousand tonnes of freight per day, or over 2 million people (for the total communication network) during the rush hours to move within a megalopolises.

Population concentration (2000 man/km^2) in such city-village will be considerably less then in modern cities. It will be a really green megalopolises, not covered with asphalt and intended exclusively for pedestrian movements. And people will wake up in the mornings not because of car noise but because of birds' songs.

Do we need such cities? There are many other cities built everywhere. You know the city of Las Vegas built especially for entertainment in a desert. Why not to build cities for harmonious life? And for this purpose there are many more beautiful places in the world than a desert.

For realizing this concept a principally new transportation of the 21^{st} century is necessary. A String Transportation System fully complies with these requirements.

High energy efficiency of an electric gear and minimum mechanic and aerodynamic losses provide for the high-speed, safe and comfort passenger and freight trips with less energy consumption (5…10 times less than a car). Compact stations will be combined with upper floors and roofs of buildings and won't require additional land use.

Small cross sectional dimensions of a rail-string with energy and information service lines including environmentally sound optical fiber communications inside it (100 x 200 mm) except other non-traditional pollution: routes will not shadow and do visual intrusion.

Low power (to 50 kW for a vehicle by capacity 20 passengers and carrying capacity of 5 tons), low-level electric tension (about 1000 V) and absence of sliding electric contacts make the STS more faint source of electromagnetic pollution, than trolley-bus. Injury to the Nature during the whole living cycle of the STS will be minimal – during building and exploitation stages and dismantling.

The total length of a high-speed transportation network of the aforementioned chess-board megalopolis is 5,000 km and its cost – about USD 8 billion (i.e. approximately the same as a 660 km high-speed railway "St. Petersburg-Moscow" or a 300 km route "Berlin-Hamburg" of "Transrapid" train on a magnet suspension). During the peak hours a megalopolis could be served by 50,000 modules of the total cost of about USD 1 billion (for comparison: summary cost of 2…3 million cars in a modern megalopolis reaches USD 20 billion).

Thanks to the low cost of a communication system and its rolling stock, low energy consumption for the high-speed travel and low maintenance costs of a STS its net cost of travel will be lower than at any other known urban transportation mode amounting to about USD 0.1/pass. for the average 25 km trip.

Pedestrian linear cities are easily integrated in the existing urban system (Fig. 24).

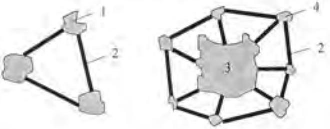

Fig. 24. Linear city in the urban network:
1 – real city;
2 – linear city;
3 – real megalopolis;
4 – city-satellite (airport).

For example, linear cities can concern little and middle cities located at the distance 50…150 km. Concerning cities-satellites and airports with each other and with the megalopolis will be also effective. Having such communication system a passenger from the megalopolis center can get to any city-satellite or airport within 20…25 minutes. It will cost him 0,5…1,5 USD.

It is possible to form a linear eco-polises with a radial-circular pattern of 50…80 m diameter to be located around the existing city or a megalopolises (Fig. 25). In the future it will contribute to the dispersal of large cities and formation of a "waste-free" settlement system providing for the preservation of existing natural landscapes and historic and cultural centres and bringing the processes of urban metabolism closer to the natural processes.

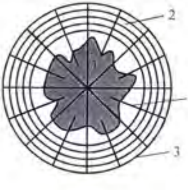

Fig. 25. Linear circular city.
1 – existing city;
2 – linear circular city;
3 – circular high-speed STS route;
4 – radial STS route.

So a STS provides a new urban development concept in the 21st century aimed at the formation of environmentally sound linear cities, in which housing estates, industrial, office, cultural and other buildings and facilities will be situated within a pedestrian distance from the high-speed environmentally-friendly and secure string routes. They will be in harmony with the Nature in all its variety: fields, shelf of the ocean, mountains, taiga, desert, jungle and any other places which God gave us.

If to think about the fate of 3 billion of potential urban residents and to provide at least 1 billion of them with decent conditions for life, work and rest in the 21st century it is necessary to have about 200 such chess-board type megalopolises and to build 2 million km of high-speed roads with 1 km to serve megalopolises themselves and the other 1 km to link them with each other and with other cities. This task can be solved by the efforts of the world community as, for example, over the last 100 years more than 5 million km of transportation communications were built only in the USA, however, they are characterised by higher cost and environmental hazard and lower speeds.

3.2. STS as a basis of consumer market of non-traditional renewable resources of Siberia

High quality drinking water constitutes an important component of the human life support system. It was estimated that minimum 10 billion tonnes of environmentally clean water is necessary to cover the total annual human requirements including manufacturing of food products, medicaments, beer and other drinks. However, water deficit is increasing annually in geometric progression. And it is not possible to make up this deficiency as water in the only consumer product which cannot be replaced with some other product.

Therefore, human demand for clean drinking water is 5 times higher, for instance, than that for oil (today about 2 billion tonnes of oil is extracted annually) or 3 times higher than for coal. Already today the cost of the high quality natural water is 6…8 times higher than the cost of oil (1 USD/liter against 0.15 USD/liter) and 20…30 times higher than the cost of coal. That is why the largest consumer market in the 21st century will be the market of ecologically clean drinking water.

According to the data of the World Health Organisation about 2 billion of the world population are suffering from the drinking water shortage. Only one out of 10 people in the world drinks natural water, the rest of them are using chemically treated, chlorinated or desalted water. For some regions this problem became even more acute than food or fuel supply. People living in the countries of Persian Gulf use desalted sea water; population of Algeria, Hong Kong, Singapore cannot do without imported water. For Arabian countries maintenance of water balance becomes a problem of vital importance, priority task of their national security. Experts do not exclude a possibility of war in the Near East at the beginning of the 21st century which aim will be to take hold rather of water than land.

Research of the recent years broadened our knowledge about the "water factor" and its impact on human morbidity and genofund and the results arouse a great concern. Up to 80% of diseases are associated with the use of polluted water. The quality of water we drink would affect the quality of health of many future generations.

Water makes up 65% of the total weight of an adult human being, it is found even in bones and tooth enamel. Nutriments and salts are absorbed in the blood only in dissolved form. Any chemical processes going on in a living cell are only possible in the presence of water. Brains activity is slowing down without liquid, however, four glasses of water taken with intervals during the day are capable to maintain and increase the vital energy. On the other hand, water is washing out from the human organism all which is not needed or is harmful to it. But it is important that water that we drink be clean and safe.

Water is a universal solvent. Even the most clean water contains more than 800 chemical substances. All of them are necessary for our organism provided that the whole complex of mineral substances is well-balanced and all of them are in the necessary concentrations. Otherwise, constant use of such water could make our life ten years shorter.

Today a fashionable idea is associated with the delivery of drinking water from icebergs which is not the best way to solve the water problem. Firstly, it is distilled ice and distilled water is equally hazardous as polluted water. Secondly, as a matter of fact, the ice is not clean. For example, one of the reasons why the strongest chemical poison DDT was prohibited was caused by the fact that it was found in the lever of pinguins. In nature evaporated water is migrating in the atmosphere clouds for months until it is precipitated in the form of snow in Arctic or Antarctic regions. Distilled water converted into ice already contains atmospheric dust, not always of man-induced nature. For example, in the pre-historic times it was the products of volcano eruption or dust storms and pathogenic micro-flora which, by the way, is still contained in frozen ice and in case of its melting could give rise to unknown diseases.

Homeopathy proves that water has a molecular memory. Million times diluted medicine is a cure. Thus, the question arises whether clean natural water can be replaced by filtered piped water initially contaminated with pesticides, herbicides, nitrates, phosphates, chlor-organic compounds (for example, dioxin, generated in the course of chlorinated water boiling is 68 times more poisonous that potassium cyanide), salts of heavy metals, etc. It is known that filters not only prevent water pollution (its efficiency is not more than 80…90%) but partially absorb the necessary mineral components thus deteriorating the natural mineral balance. In this case homeopathic memory of noxious substances coming through a filter is increased to poison our organism. Toxic effect of water is much more hazardous than that of food because water and dissolved substances and salts of heavy metals are involved in all biochemical processes of a human organism.

There is no other country in the world that has high quality natural drinking water resources as large as Russia, for example, its Lake Baikal.

Baikal is unique in terms of its water resources that are greater than those of the Baltic Sea. In terms of its hydro-chemical qualities its water has no analogues in the world. The Lake is a giant natural water reservoir containing 1/5 of the total global fresh water resources and ½ of the world clean drinking water resources, the best ones. Vital activity of its organic life is still operating irreproachably thanks to the living (endemic) filters. Water in many zones of the Lake is clean. However, aborigine organisms are capable to survive only in such environment and they are ruined coming to Angara the only river flowing from Baikal though its water is very difficult to distinguish from that in the lake.

For million years the natural "Baikal factory" has been generating 60 billion tonnes (60 cub. km) of invaluable liquid mineral brought every year by 300 rivers flowing into Baikal and after its purification flowing through Angara to the Arctic Ocean.

In the course of its purification which takes many years water is losing its molecular memory of the previous pollution. In this case the whole complex of micro-elements brought with rain and spring water is balanced. More than USD 1,000 trillion will be necessary to cover the costs for sea water desalting to get the fresh water in the amount equal to that of Baikal (fresh but not so rich with valuable micro-elements). For comparison: all gold currently extracted in the Earth is evaluated 1,000 times less. In economic terms the cost of Lake Baikal is much higher than that of an oil sea of equal volume which is by hundreds of times higher then the cost of the total global oil resources.

In the southern-west part of Lake Baikal there are deposits of "renewable" ultra-fresh water, its resources are enormous and practically inexhaustible. Baikal water does not require additional treatment, conservants or gassing because of its ecologically purity, slight mineralisation and oxygenation even at the bottom at the depth of about 1.5 km. Water at the depth of 500 m and lower was formed more than 100 years ago, i.e. during the "pre-industrial" period and it fully lacks any technogenic toxicants, salts of heavy metals, chlor-organic substances and pathogenic micro-flora.

Water in the other largest Russian reservoir - lake Taimyr located beyond the North Polar Circle - is even more clean.

Minor share of population is living in the northern zones and here people are in need of warm, whereas the majority living in the tropic or sub-tropic areas are in need of cold. People equally need cold and heat that is why they invented refrigerators and conditioners. It is much more difficult to get cold than heat. For example, the efficiency of a heat engine "energy - heat" can be close to 100% whereas that of the reverse process: "energy - cold" is much lower - 5…10% (the efficiency of a heat power plant is 30…40%, electric transmission line - 80…90%, refrigerator generating cold - 10…15%).

Today the cost of a high quality food natural ice at the world market is USD 3,000, i.e. higher than that of copper and aluminium. At the same time melted water is more useful as its liquid crystal structure and curative properties are preserved for a long time.

Russia is rich in the natural resources which could become its major export potential in the 21st century, in particular, a high quality ultra-fresh water and Siberian frost.

It is reasonable to deliver the Russian drinking water to the European and Asian (India, China, etc.) market in the form of ice to be stored in special terminals - refrigerators. Baikal water brought from the depth of 500 m will be frozen in winter with the use of natural frost at the special plants.

To realise this programme it is necessary to have a principally new transportation of the 21st century which is to be characterised by the following qualities: low cost - as the main consumer is located at the distance of 5,000…8,000 km from Lake Baikal and 6,000…10,000 km - from Taimyr; high-speed - as water will be spoilt during its long transportation and ice will be melted; ecological purity - as it goes to the densely-populated regions of Europe and Asia; high carrying capacity - as water supplies are estimated at hundreds of million and billion tonnes per year; feasible for the difficult geographic and climatic conditions - as the routes will pass through the zone of permafrost, marshlands, taiga and mountains. Only a STS is capable to meet these requirements.

To realise the Programme "Live Water of Russia" it will be necessary to build about 30,000 km of freaigt and passenger STS routes with the total cost of about USD 30 billion (including infrastructure).

Construction will be carried out on a stage-by-stage basis to facilitate gradual pay-back of expenditures at the expense of freight and passenger traffic.

In engineering terms this task is simpler than, for example, construction of railways in the period of their flourishing. For instance, USA built about 35,000 km of railways during a decade from 1850 to 1860 and more than 115,000 km during 1880-1890, with a pickaxe and spade as there were no bulldozers, excavators, cranes, trucks. It is much simpler to build a STS, especially at the beginning of the 21st century, having the most advanced technical devices, powerful and under-loaded industries and, in particular, building industry not only in Russia but in other interested countries of Europe and Asia.

The Programme is also attractive in the economic terms. The cost of delivery of more than 100,000 tonnes of drinking water per day using a STS system will be 3 USD/1,000 km or 20 USD/t for a medium distance of 6,500 km. Taking into account the selling price of water, costs for water preparation and other costs (including freezing) its actual cost for consumers (for example in Delhi) will be 50 USD/t (5 cents/liter). At the wholesale price of food ice of 250 USD/t (25 cents/kg) its delivery in the amount of as little as 200 million tonnes per year or 0.2 kg/day per 1 potential consumer will be enough to pay back the costs for the whole STS network.

As far as we are interested not only in the economic profit but rather in the health of billions of people in the 21st century it would be reasonable to arrange the marketing and management of the programme in such a way that each potential consumer of a high quality natural drinking water from Russia be its stock-holder. Thus, it will be possible to realise the whole programme at the expense of the joint-stock capital. In this case the programme expenditures will be approximately the same as for the European tunnel programme (a high-speed railway "London-Paris" with a tunnel under La Manche and infrastructure which was built predominantly at the expense of the shareholders' resources), however, in terms of its efficiency, acuteness and usefulness our system is much better.

A wide assortment of the Russian bottled natural water will be delivered to the world market including: artesian, lake, mineralised, ultra-fresh, curative-medical water, food ice, including relict one, etc. About 1 million of new highly paid jobs will be created in Russia and abroad. In a few years after STS construction it will be possible to increase the delivery of water to 1 billion tonnes per year to give the annual profit of about USD 200 billion. Delivery of water in the form of food ice would save the costs for the generation of the equal amount of artificial cold requiring burning of not less than 1 billion tonnes of coal at the electric power plants with the total capacity of 200 million kW and appropriate refrigerator capacity. Imagine how hazardous it would be for the planetary environment. As to the programme "Live Water of Russia" it is environmentally sound both in terms of its thermodynamics and its impact on the total thermal balance of the planet.

Under the appropriate support of the Government of the Russian Federation and success of a joint-stock activity it will be possible to finalise the programme to the year 2010. The first STS sections, for example, "Moscow - Minsk", "Moscow - Nizhny Novgorod", "Paris - Madrid", "Peking - Delhi", etc. can be built in 2005...2006 and they will be self-repaying in 3...4 years at the expense of passenger and freight traffic, thus, when the STS construction is finalised most of its costs will be paid back.

If half of resources earned with the help of a STS and its programme "Live Water of Russia", in particular, is re-invested it will be possible to build additional 1 million km of roads so necessary for Russia during 40...50 years. They will be high-speed roads with their lifetime estimated at 100 years; they will not be destroyed in 2…3 winters, capable to resist at permafrost or marshland conditions; roads that do not require snow and ice removal, use of sand or de-icing salts in winter, mending and repairing every season.

STS will make it possible to link Europe and Asia with America by a land freight/passenger high-speed route "London (Paris) - Moscow - Lake Baikal - Yakutsk - Bering Strait - Calgari - New York" with the total length of about 21,000 km and the cost of about USD 40 billion capable to pay back the expenditures for its construction during 3…4 years. The route could be used to transport food ice of Siberia alongside with the ice of Alaska (which is of lower quality attributed to its origin) to the American market which is much more extensive, for example, than a market of aerated drinks such as "Coca-Cola" with its total volume of sales during many decades estimated at more than 1 trillion dollars.

It is possible to propose dozens of STS alternatives both strategically and geopolitically significant practically for all continents and countries of the world. If Russia manages to organise serial STS production it will manage to occupy the key positions in the promotion of new global communication policy of the 21st century.

Currently negotiations are going on in Malaysia, Israel, China, Taiwan and a number of European countries to promote the work for a STS Programme. However, first of all it is Russia that is in need of this high-speed communication network of the 21st century, the greatest country of the world characterised by the most underdeveloped territory and the worst road quality. More than 100 years ago the great Russian writer Nikolai Vassilyevich Gogol said that the two greatest disasters for Russia are associated with poor roads and fools and this famous saying is still valid. Realisation of a STS will demonstrate to the world that in the new millennium Russia will have the best roads built by clever people. And a start can be given in Siberia.

Literature

1. Project of the UN Centre for Human Settlements (Habitat) FS-RUS-98-S01 "Sustainable Development of Human Settlements and Improvement of their Transportation Infrastructure trough the Use of a String Transportation System". - Nairobi - Moscow, 1998.

2. Ivanov V.N., Storchevus V.K. Ecology and Automobilisation. - Kiev, "Budzivelnik", 1983 - 88 p.

3. Yunitsky A.E. String Transportation Systems in Earth and Space. Gomel: "Infotribo". 1995. - 337 pages.

4. Yunitsky A.E. Linear Transportation System. International application for invention RST/IB94/00065 of 08.04.94. Applicant: "NTL Neue Transportlinien GmbH" (Germany) and Yunitsky A. E.

5. Yunitsky A. E. Linear Transportation System. Patent of the Russian Federation No. 2080268 IPC B61B 5/02, B61B 13/00, E01B 25/22. Priority 08.04.94, registered 27.05.97.

6. Yunitsky A.E., Savchuk V.P., Savenkov V.A., Varvilskaya O.N. Analysis of fluctuations of span structures in a string transportation system/ Theses of the reports at Byelorussian Congress on Theoretic and Applied Mechanics "Mechanics-95", Minsk, 1995, pp. 253-254.

7. Yunitsky A.E., Savchuk V.P., Savenkov V.A., Varvilskaya O.N. On the Dynamics of a string Transportation System/ Theses of the reports at Byelorussian Congress on Theoretic and Applied Mechanics "Mechanics-95", Minsk, 1995, pp. 253-254.

8. Yunitsky A. E. High-speed Road Transportation - STS/ Theses of the reports at the International Scientific and Practical Conference "Resource- and Energy-saving Technologies in Transportation and Construction Complex", Gomel, 1995, pp. 69-70.

9. Yunitsky A. E. Creation of a String Transportation System (STS) "Paris - Moscow"/ Proceedings of the International Conference on the Development of a Communication System Paris – Berlin – Warsaw – Minsk – Moscow. Minsk, 1998, pp. 81-84.

10. Yunitsky A.E. Transportation Means for String Transportation Sys-tems (2 alternatives). Patent of the Russian Federation for the application No. 97500229/49 (005129) of 18.10.96 ICIS 12-03. Patent holder - Yunitsky A.E.

11. Yunitsky A. E. Rail for String Transportation Systems. Patent of the Russian Federation for the application No. 97500230/49 (005130) of 18.10.96 ICIS 12-03, 25-01. Patent holder - Yunitsky A.E.

12. Anatoly E. Yunitsky. Linear transport system. Letters patent Republic of South Africa No. 95/2888,07,04,1995. International classification B65G.

13. Yunitsky A.E. Transportation of the Coming Century. Journal "logistics", No 2, 1999, pp. 10-11.

14. Resolution of City Administration of Sochi of 10.09.1997 No 628 "on Inclusion of Investment Programme "String Transportation Systems of Yunitsky A.E. in the Federal Target Programme "Socio-economic development of Resort City of Sochi up to the Year 2010". Sochi, 1997.