International Seminar within the framework of the UN Centre for Human Settlements (Habitat) Project No. FS-RUS-98-SO1-A "Sustainable Development of Human Settlements and Improvement of their Communication Infrastructure through the Use of a String Transportation System"
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A. Yunitsky, Progect Manager
General Designer of STS

On the Progress of the Habitat Project "Sustainable Development of Human Settlements and Improvement of their Communication Infrastructure through the Use of a String Transportation System"

Dear ladies and gentlemen, participants of the Seminar!

The Habitat Project "Sustainable Development of Human Settlements and Improvement of their Communication Infrastructure through the Use of a String Transportation System (STS)" was initiated in Russia in January 1999.

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 the STS realisation;
- to identify the ways of the STS testing with regard to 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 the investment attractiveness of the STS, to formulate a strategy, priorities and mechanisms facilitating practical implementation of the Project in the city of Sochi and in other regions.

Taking into account the fact that the Project put forward a principally new transportation system considerable attention in it is focused 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 of trading and business relations. The history of mankind knows a number of examples of the great trading ways such as "from Varangians to Greeks" of "Great Silk Track".

Roads provide an indispensable condition of the well-being of individual persons and society as a whole, means of human communication in territorial and intellectual space; the way of life and one of the fundamental cultural values, indicator of the level of civilisation; finally, it is the way of life that we choose and that chooses us. I am sure that this approach gives us a clue to the sustainable development, on the one hand, and to the optimal solution of the global road transportation problems, on the other hand.

Let us consider, for example, the state of the transportation network in Russia. It includes more than 600,000 km of motorways with hard surface, more than 160,000 km of railway roads, more than 210,000 km of gas-pipes and about 100,000 km of oil pipelines. At the same time according to the estimates in order to meet the economic requirements of the country and to cope with the social problems the total length of the transportation network should be at least 2,000,000 km. In other words, Russia is wanting about 1,000,000 km of roads. For comparison: with its total area of the USA being by 1.8 times less than that of Russia it has more than 6,000,000 km of roads. Undoubtedly, it is the evidence of power and prosperity of the United States of America.

Unsatisfactory condition of the road network leads to the disturbances in the normal economic performance, drop in the production rates in the related national economic sectors, unjustified losses , limited access to the raw resources, reduced job opportunities, higher cost of goods and services, decline in the living standard of population and lower possibilities for the development of education and culture, 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 an attempt to analyse practically all existing and future transportation modes. Which mode of transportation will the mankind take to enter the new millennium?

1. Railway transportation. In its modern meaning it takes the origin at the beginning of the 19th 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 road is US $ 3…5 million, the cost of one passenger coach - US $1 million, electric locomotive - US $10 million. Road construction is associated with high costs in terms of resource consumption such as metal (steel, copper), reinforced concrete, gravel, large-scale excavation works the average volume of which is about 50,000 cub.m/km, and high land requirements - about 3 ha per 1 km. Under the difficult geographic conditions construction of unique structures such as bridges, viaducts, elevated roads, tunnels is necessary which results in the increased cost of the system and the growing negative environmental impact. The average weighted travel speed is 100…120 kmph.

2. Automobile transportation. It emerged at the end of the last century. Over the past period more than 10,000,000 km of roads were built and about 1 billion of cars were produced. The cost of a modern highway is US $5…10 million and it requires about 5 ha/km of land to be withdrawn from other land uses. The volume of excavation works exceeds 50,000 cub.m/km. The cost of an average statistics car is about US $15,000, the average weighted travel speed is 60…80 kmph. Automobile became one of the main sources of air pollution in the cities. Automobile emissions contain more than 10 cancer-generating substances and more than 100 toxic compounds. The source of environmental pollution and deterioration is associated with the motor transportation itself and with its road infrastructure and engineering and service facilities, especially storage tanks for petroleum products, filling , technical service and car washing stations, etc. which leads to the transformation of the natural environment within the adjacent areas.

Areas immediately adjoining the roads are exposed to the heaviest pollution with the width of the contaminated stripe reaching 300 m and more.

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.

During the last decade automobile became the main instrument of murder of human beings. According to the data of the World Health Organisation more than 900,000 people all over the world are killed annually in the roads 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: on the average about 500,000 people of the planet are killed in military conflicts.

3. Aviation has a 100-year history. It is the most environmentally hazardous and energy-consuming mode of transportation. The summary atmospheric emissions of noxious substances from the modern aircraft reaches 30…40 kg/100 passenger-km. The major bulk of aircraft emissions is concentrated within the area of airports, i.e. in the vicinity of the large cities, which is the result of flying at low heights with reheating of engine. 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. Duration of noxious substances presence in the stratosphere is much longer - about 1 year. Air transportation is the most expensive one. The cost of a modern airliner is as high as US $100 million, while construction costs for a large-scale international airport exceed US $10 billion.

4. High-speed railways (HSR). Their construction was started in the last quarter of our century. Maximum travel speed is 400 kmph, average operating speed - 180…200 kmph. The cost of 1 km of road is US $10…20 million, the cost of 1 coach - US $ 2…3. They produce environmental impact that is heavier than that of conventional railways. For example, according to the environmentalsts' estimates the environmental impact of the construction of a high-speed railway "St-Petersburg-Moscow" will be equal to that of Chernobyl. In this case the net cost of travel will be US $123 per 1 passenger (with the total length of the route being 660 km). Another example - experts estimated that if in the 21st century a densely populated country such as China with its limited and vulnerable agricultural lands orients towards the HSR construction, in 20…30 years it will be in the face of a nation-wide famine the scale of which will be equal 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.

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 US $ 25…50 million/km, the cost of 1 coach is US $6…8 million. For example, according to the business-plan of the German “Siemens” Company submitted to the Government of Moscow, the cost of a “Transrapid” route - “Airport Sheremetyevo - Centre of Moscow” with the total length of 29 km will be US $1.5 billion (not including the cost of land and demolition costs for buildings and structures).

Its travel speed is up to 500 kmph. At high travel speeds it produces a heavy noise because the coach shell totally encloses the bearing beam (on top, bottom and on both sides) and the air is sucked in the clearance at high speed. It has a very low energetic efficiency: substation efficiency is 34% (substation modulates an alternating current frequency to form a travelling magnetic field along the road structure), 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, their magnetic field provides suspension at the height of 10…20 cm. Travel speed is up to 500 kmph. 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 the coils explosion equivalent to that of several kilograms of trotyl. The cost of 1 km of road is US $20…30, the cost of 1 coach is more than US $10 million.

6. Monorail - is widely used in the USA, Canada, France and other countries. A wheel cabin is moving along a beam with a large cross section which ensures the cabin steadiness. Cabin is characterised by the unfavourable vibration dynamics and poor aerodymanics qualities resulting from the suspension system; therefore, monorail roads fail to provide high travel speeds, for instance, at the level of 200 kmph. The cost of 1 km of monorail road is US $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 US $500,000.

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

9. Rail bus - a variety of a tram which uses a diesel instead of an electric motor. Germany started their production in 1995. The cost of 1 rail bus is US $2 million.

10. Cable roads. Canada, USA and Germany have already put into operation an overhead transportation system designed by Swiss engineer G. Muller with passenger coaches moving along the cables hanging on the light metal supports. This is quite a low-cost structure (US $1.5-2 million/km), however, the maximum travel speed would not exceed 50 kmph.

Discussed above were the main modes of transportation, each of them having a number of alternatives. For example, screen-jet as an alternative to an air-plane, electric car as 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 are the most exotic ones such as routes for aircraft with shortened wings intended for flights in the underground tunnel of 50 m diameter (Japan) or a flying saucer which creates a vacuum ahead of a bow of an aircraft (Russia).

Therefore, the existing and future modes of transportation are associated with the extremely high costs and environmental hazard, they require alienation of large areas of valuable lands for their construction. None of the transportation modes except a bicycle could cope with noise requirements while noise control measures would entail higher costs in order to provide the high-speed roads with necessary noise protection devices.

The system analysis carried out within the framework of the Project showed that in order to safeguard the environmental, economic, communication, land-use and safety interests the leading position among other transportation modes in the 21st century should be given to a road transportation system capable to provide the travel speed of 300…500 kmph and comply with the following requirements:

1. cost of a route including its infrastructure is not higher than that of a cable road - up to US $1.5-2 million;

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. net cost of travel is at the level of the local electric trains - in Russia it is up to US $2 per 100 passenger/km;

4. requires not more than 0.1 ha of land per 1 km of road (not including infrastructure) to be alienated from other land uses;

5. does not require construction of embankments, depressions, tunnels, powerful elevated roads, viaducts resulting in biocenosis disturbances ;

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 at the level of aircraft passenger transportation;

9. carrying capacity per 1 route - up to 1 million passengers or 1 million 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 our opinion that none of the existing or future transportation system could cope with the above mentioned requirements of the 21st century.

It inspired the author to design a principally new communication system lacking the shortcomings of the existing systems and integrating the advantages of the advanced transportation systems. In this case the search for a solution was based on the following requirements: no engineering or scientific exotics - magnet suspensions, superconductivity, levitating, anti-gravitation, etc. The system is to be based on the existing Russian materials, technologies and engineering solutions.

Idea of a string transportation system arose in 1982 and then the first publications appeared in the journals “ Izobretatel and Ratsionalisator” and “Technika Molodezhi”.

It took 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. Three years were spent on patenting in the leading world countries through the application to the World Intellectual Property Organisation. The last five years were focused on the preparation of the 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.

Now we are able to demonstrate a physical model of a STS route and a transportation module at the scale of 1:15 including anchor fixture of high-strength steel wires and strips which are actually the strings.

Thus, though so far not a km of a string road has been built it is possible to present some of the key technical and economic indices of the proposed STS.

STS is a pre-stressed stretched cable-and-beam structure to carry special electric cars for 20 passengers with the total load-carrying capacity of 5,000 kg. Power supply is provided by special current-carrying rail heads contacting with the cabin wheels. 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 installed in such a way that its head remains ideally smooth after the strings have been fixed by filling in the hollow rail with a solidifying filler, for example, an epoxy resin. Therefore, a rail head along which the wheel of a transportation module is moving has no dips or junctions on its whole length. Strings and rails are rigidly fixed on anchor supports located at the intervals of 1…2 km.

There is also a great number of intermediate supports installed at 25…100 m intervals, 20…50 structures per 1 anchor support which should define the cost of a supporting part. The STS design implies that intermediate supports are exposed predominantly to a vertical load which is very small - 25 tonnes at 50m span. This load is similar to that of the high- voltage power transmission lines, that is why both structures are so close in terms of their design and material consumption.

There are no deformation welds on the whole length of a string or rail, their operating scheme under the changed temperature conditions is similar to that of a telephone cable, a wire of a power transmission line or a cable of a hanging bridge which are also fixed on the supporting structures with a dip stretching for many kilometres without any junctions. The rail is designed as a assembly structure. The estimated temperature gradient is assumed at 100°C (once in 100 years from +60°C in summer sun to -40°C in winter).

For a STS string it is suitable to use a wire manufactured today for steel cables (with its ultimate strength up to 350 kgs/mm^2) or pre-stressed reinforced structures and cables of hanging or guying bridges. In terms of its physical and mechanical qualities steel used for railroad rails is also appropriate for a rail-string head. 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 kgs 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 model than, for example, the bottom of a salt lake where, as you know, two years ago an automobile managed to exceed the sonic speed - 1,200 kmph.

The maximum STS speed will be limited rather by its aerodynamics than by the smoothness or vibrations of the track and problems of “wheel-rail” speed drive. That is why special emphasis in STS design is laid on its aerodynamic qualities. We managed to obtain unique results having no analogues in the 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 ten-passenger vehicle with the engine capacity of 80 kWt to reach a speed of 300…350 kmph, or 400…450 and 500…550 kmph for the engine capacity of 200 and 400 kWt, respectively. Taking into account a short length of a Sochi road (92 km) it will be sufficient to have a travel speed of 200 kmph and the engine capacity of 35kWt (30 kWt for aerodynamics and 5 kWt - for mechanical losses), efficiency of a steel module wheel - 99%, motor-wheel as a whole - 92%.

At the present time the STS is at the level of development which gives every reason for its developers and experts to believe in its feasibility and high operative efficiency. The main reason why the STS has not been put into practice so far, is attributed to the lack of financial support. For already 16 years all works for the string transportation design have been carried out thanks to the enthusiasm of its author and his own financial support which was, undoubtedly, insufficient. Actually, no state support is either provided, though, for example, President of Belarus Alexander Lukashenko supported the STS programme and expressed his personal interest in it. The STS has got a real support in the form of a grant extended by Habitat beginning from January 1999 and some small private investments.

How long will it take to realise a string system in practice?

I am not going to discuss the STS route in Sochi in detail. Firstly, because there is a special report of Mr. Lemesh, Director of the Institute of Independent Expertise, focused on its business-plan. Secondly, the route is too short to demonstrate the advantages of a high-speed circulation. Moreover, it is to be taken into account that the track will be laid under the difficult geographic conditions along the sea, mountains and the zone of seismic and landslide hazards, thus, it will be more difficult and expensive in terms of implementation and less profitable in terms of operation. Let me present just a few figures: the lengths of a route “Sochi - Engelmanovy Polyany” is 92 km, the cost is US $ 154 million, construction period - 4 years, recoupment period - 6 years, net cost of travel - US $0.25 and US $0.9 per 1 passenger at the link “Sochi - Adler” and “Sochi - Engelmanovy Polyany” , respectively.

Within the framework of the Project other STS alternatives were also considered and analysed including those built under the less difficult geographic conditions, in particular, coming thorough the 2nd Crete transportation corridor - “Paris - Moscow”. The International Conference devoted to the given transportation corridor held in the city of Minsk in October 1997 which brought together experts from 14 countries recommended the European Union to use the STS as a high-speed link in the Crete corridors. The Government of Belarus applied to the Government of Moscow with a similar proposal in 1998. In this respect, it is necessary to note that the EU Council of Ministers decided to allocate US $400 billion for the construction of 9 Crete corridors for a period up to the year 2010.

Currently negotiations are going on in Malaysia, Israel, China, Taiwan and a number of European countries to promote the work for the 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 having the most underdeveloped territory and the worst quality of roads. More than 100 years passed since the famous saying of the great Russian writer Nikolai Vassilyevich Gogol that poor roads and fools were the two main disasters in Russia, however, his words are still true. 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 the start will be given in the city of Sochi by the present Seminar which will be its reference point.

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 consumption of energy resources (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 kmph):				
• 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 kmph):				
• 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 kmph)	4.7 - 9.2	51 - 73	over 10	20 - 50
• local (400 kmph)	14 - 19	152 - 202	over 50	10 - 20
4. Sea transportation (50 kmph)	17 - 19	0.38 - 0.95	over 10	5 - 10
5. River transportation (50 kmph)	14 - 17	0.57 - 1.4	-#-	2 - 3
6. Oil pipelines (10 kmph)	-	0.51 - 0.57	over 1***	50 - 100
7. Gas pipelines (10 kmph)	-	5.7 - 6.1	over 1***	-#-
8. Conveyer transportation (10 kmph)	-	4.7 - 9.2*	over 1	-#-
9. Hydro-transportation (10 kmph)	-	2.3 - 4.7*	over 0.1	-#-
10. Cable-rope roads (10 kmph)	0.3 - 0.5*	0.95 - 1.9*	-#-	20 - 30
11. Train on a magnet suspension (400 kmph)	3.5 - 4.5*	-	-#-	100 - 200
12. High-speed railway (300 kmph)	2.5 - 3.5*	-	-#-	300 - 500
13. Monorail (100 kmph)	1.5 - 2.5*	-	-#-	50 - 100
14. String transportation**** (passenger - 10 seats; freight - 5 tonnes of freight) at the speed of:				
- 100 kmph (15 kWt motor power)	0.17*	0.17*	below 0.01	10 - 20
- 200 kmph (35 kWt motor power)	0.20*	0.20*	-#-	-#-
- 300 kmph (90 kWt motor power)	0.34*	0.34*	-#-	-#-
- 400 kmph (200 kWt motor power)	0.57*	0.57*	-#-	-#-
- 500 kmph (400 kWt motor power)	0.91*	0.91*	-#-	-#-

* estimated for 1 litre of gasoline = 8.78 kWt/hour of electric power;
** road including its infrastructure;
*** spilling of oil or petrol products, natural gas emission;
**** estimated by analogy with other modes of transportation.