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## The World Exhibition EXPO-2010 (Shanghai, China)

### Transportation System of the "second level" based on the "String Transport Unitsky" technologies



Moscow 2007

One of the themes of Russia's participation in the World Exhibition EXPO-2010 (Shanghai, China) arranged under the motto "Better Cities — Better Life" is focused on the innovation processes and new technologies aimed at city development. One of such technologies includes a new transportation system — "String Transport Unitsky — STU".

Application and use of a STU system could have a great significance for the development of the world cities including its use at EXPO-2010.

STU will make it possible to mobilize the hidden resources, to considerably outpace a car, bus, trolley-bus and tram in terms of its safety, economic efficiency, environmental impact and comfort and to leave behind the metro in terms of some indices.

Safety is characterized first of all by the 100-fold and 10-fold margin of safety of the double-rail micro-, mini- or macroSTU and the single-rail light, medium-size or heavy monoSTU, respectively.

STU is the all-weather operational transport. Neither rain or hurricane wind, snow drifts, ice or floods could affect the traffic schedule of the rolling stock.

The large-scale heavy powerful buses, trolley-buses and trams are the major sources of noise in the cities and in terms of its hazardous impact on human health noise takes the first place.

STU unlike other modes of transportation does not generate soil vibration that is hazardous for people, buildings and facilities, and it does not cause radio interferences and electro-magnetic pollution of urban environment. It is responsible for lower air pollution with combustion products and lower electric energy consumption.

STU routes could be laid along the built-up areas, squares, parks and other urban lands unsuitable for the construction of tram or trolley-bus lines. If necessary, they could pass through the residential and office buildings, shopping centres and other urban facilities.

In terms of the ticket tariffs STU will be at the level of existing urban transport.

STU as the second level transportation (with its track structure elevated above the ground) is associated with considerably lower land allocations.

Laying of a STU route through the city area does not require construction of bridges, overpasses, multi-level exchanges which construction costs often exceed the cost of roads themselves.

Circulation of STU is facilitated without intersections and traffic signals that in the existing urban transportation are mostly responsible for the over-consumption of fuel, air pollution and smog and are the main sources of the “traffic jams” and noise in the city streets.

STU structure enables location of communication lines and nodes and various types and facilities of urban infrastructure.

STU has a number of other advantages.

This project proposal is focused on the development of a continuously operating transportation system of the “second level” to serve the visitors of EXPO-2010 (Shanghai, China) with a prospect of its further expansion and integration into the citywide transportation system. Therefore the project proposal has the aim to solve the following subsequent problems:

1. Practical demonstration of STU transportation technologies.
2. Provision of the transportation services to the visitors of EXPO-2010 (Shanghai, China).
3. Promotion of urban transportation projects based on the STU technologies.

A new transportation system will be developed on the basis of the “String Transport Unitsky — STU” technologies having the world novelty and international patent protection. STU technologies having the relatively low investment cost make it possible to develop the transportation systems characterized by the high carrying capacity comparable with that of the underground (up to 70 million pass./year and more) and the high travel speed (up to 350 km/hour and more). In this case the STU transportation systems considerably differ from traditional transportation systems by their lower energy consumption, insufficient operation costs and minimal environmental impact.

It is envisaged that the transportation problems of EXPO-2010 (Shanghai, China) could be solved with the use of two basic types of STU — a double-rail miniSTU and a single-rail monoSTU.

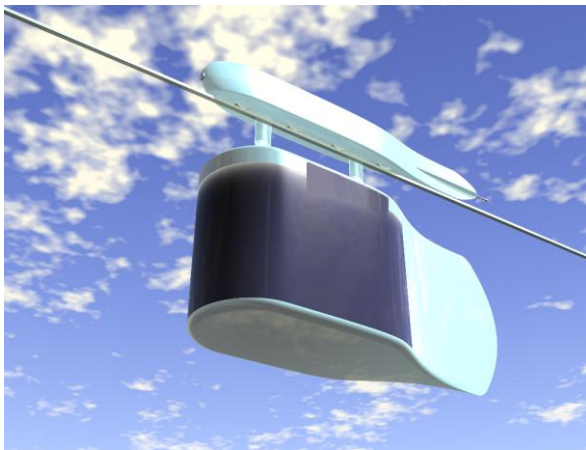
Attachment: Proposal for the World Exhibition EXPO-2010 (Shanghai, China) aimed at the organization and construction of a “second level” transportation system based on “String Transport Unitsky” technologies — 19 sheets.



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## **Project Proposal for EXPO "Shanghai-2010"**

Development of a "second level" transportation system based on  
"String Transport Unitsky" technologies



## List of the key executives of STU Ltd.

Chief Executive,  
General Director, General Designer

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Executive Director

Denis Unitsky

Deputy-General Director  
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## Introduction

This project proposal is focused on the development of a continuously operating transportation system of the “second level” intended to serve the visitors of EXPO “Shanghai-2010” with a prospect of its further expansion and integration into the citywide transportation system.

Therefore the project proposal has the aim to solve the following subsequent tasks:

1. Practical demonstration of STU transportation technologies.
2. Provision of the transportation services for the visitors of EXPO “Shanghai-2010”.
3. Promotion of urban transportation projects based on the STU technologies.

Development of a new transportation system is based on the use of “String Transport Unitsky” technologies (STU) having the world novelty and the international patent protection. Relatively low investment cost of the STU technologies makes it possible to create transportation systems of the high carrying capacity comparable to that of the underground (up to 70 million passengers per year and more) and the high travel speed (up to 350 km/hour and more). In this case the STU transportation systems considerably differ from the conventional transportation systems by their low energy consumption, insufficient operation costs and minimal environmental impact.

It is proposed that solution of the transportation problems for EXPO “Shanghai-2010” could be facilitated through the use of the following two basic types of STU — a double-rail miniSTU and a single-rail monoSTU.

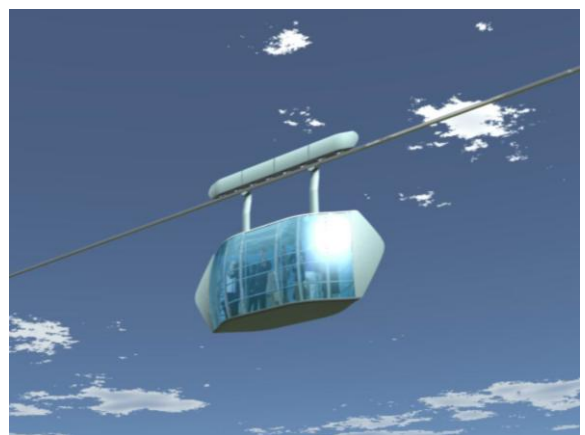


## STU technologies

**MiniSTU** is a double-rail transportation system including self-propelled wheeled vehicles with carrying capacity up to 20 passengers moving with a speed up to 120 km/hour along the two string-rails stretched between the anchor supports—stations rested on the intermediate supporting legs with the height of 4—6 m and more having the spans of 30—40 m.



**MonoSTU** is a high-level single-rail string transportation system including self-propelled hanging vehicles with carrying capacity up to 20 passengers moving with a speed of 120 km/hour along one string-rail stretched between the high-rise buildings—stations (supports) at the height of 50—100 m and more having the spans of 200—2,000 m.



Note: This project proposal envisages construction of the double-track STU systems enabling the full-value circulation of the rolling stock in two directions.

## 1. Organization of passenger traffic

According to the scheme (fig. 1) a miniSTU transportation system with the length of 6 km and carrying capacity of 200,000 passengers per 24 hours will be able to solve the problem of local visitors’ trips between the exhibition pavilions with the stops located every 300—500 m.

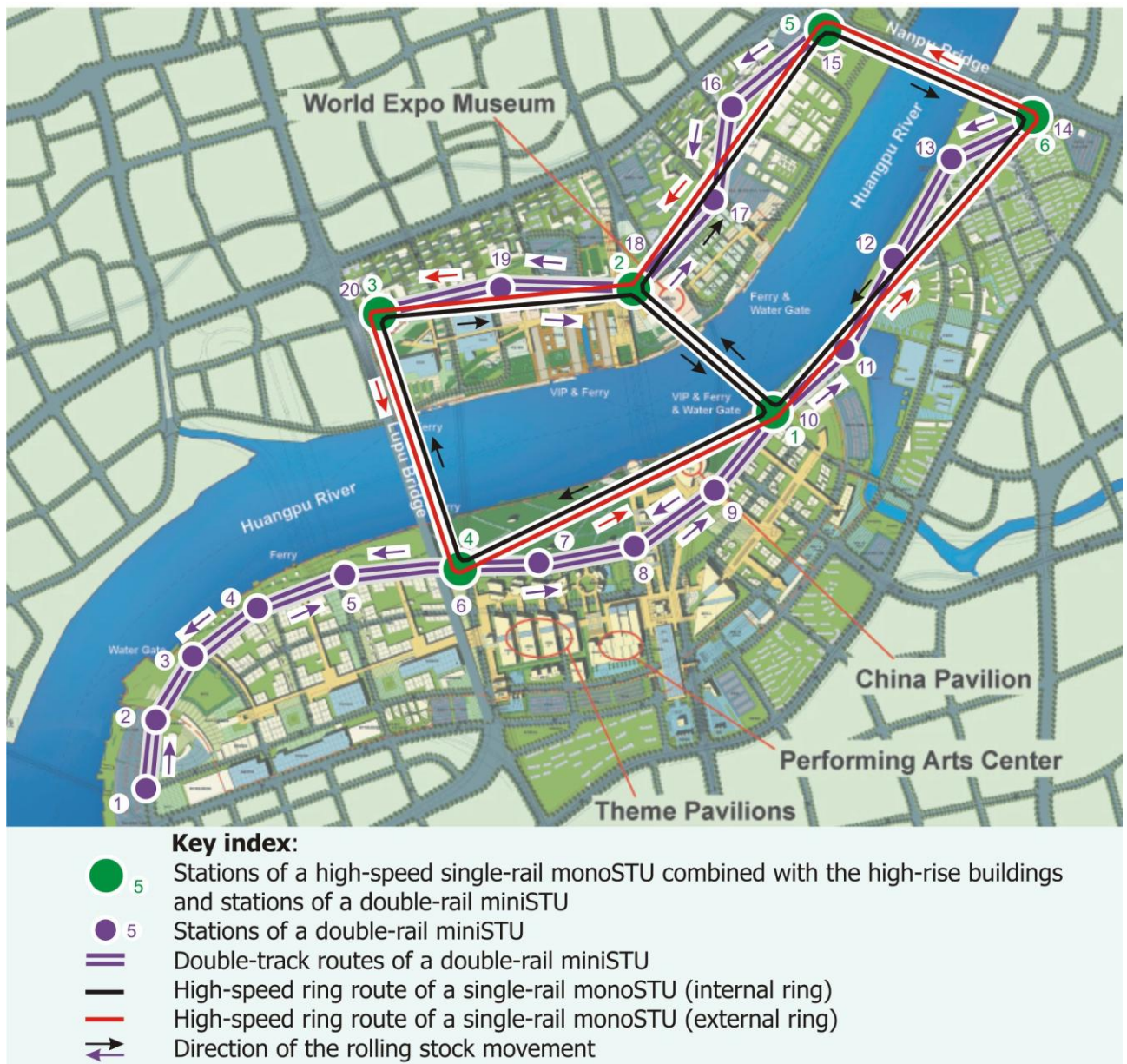


Fig. 1. Organizational scheme of passenger traffic at EXPO “Shanghai-2010”

The high-level monoSTU transportation system with the length of 6 km and carrying capacity of 150,000 passengers per 24 hours will be able to solve the problem of the high-speed movement of EXPO visitors between the exhibition districts located on the left and right bank of the river to form three transportation crossings over the Huangpu River (fig. 2).



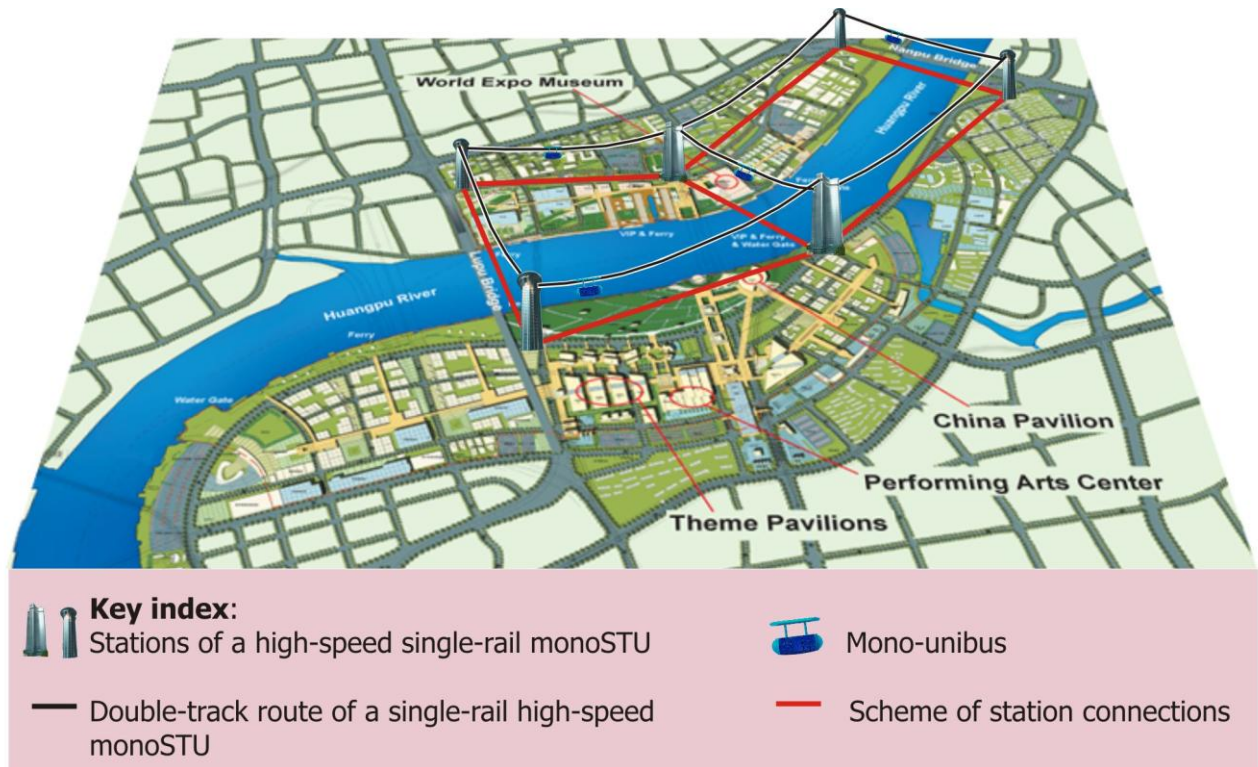


Fig. 2 Location scheme of a monoSTU transportation system between the high-rise buildings-stations

In future after the termination of EXPO “Shanghai-2010” monoSTU could be used to develop the new city transportation corridors (see fig. 3) enabling the full-scale integration of the newly-built transportation system into the existing city transportation system of Shanghai.

Further development of the STU transportation system and its integration into the city infrastructure could be achieved through the extension of both mono- and miniSTU routes.

**Development of monoSTU routes** will make it possible for the Government of Shanghai to initiate a system-based high-rise city development integrated into the new transportation monoSTU system. For the purposes of EXPO “Shanghai-2010” it is possible to build a monoSTU section to link EXPO with the international airport “Pudong” including 5—8 high-rise (30—40-storey) hotel buildings. The height of a monoSTU route will depend on the conditions of its passing over the Huangpu River and the need to pass above the existing buildings.

Furthermore, as far as monoSTU is a high-speed mode of transportation construction of new transportation systems creates a real opportunity to remove new construction to the city outskirts beyond the limits of the high-dense built-up areas without increasing the travel time of passenger trips to get to the city centre.

**Development of miniSTU routes** (lower cost modern alternative of the elevated metro) will make the public transport of Shanghai more accessible for the population at relatively lower investment costs.

STU transportation systems with equal carrying capacity are higher-speed, more comfortable and environmentally friendly as compared with the traditional systems, thus they are easily integrated into the city infrastructure and have a minimal impact on the city environment and its architectural image.

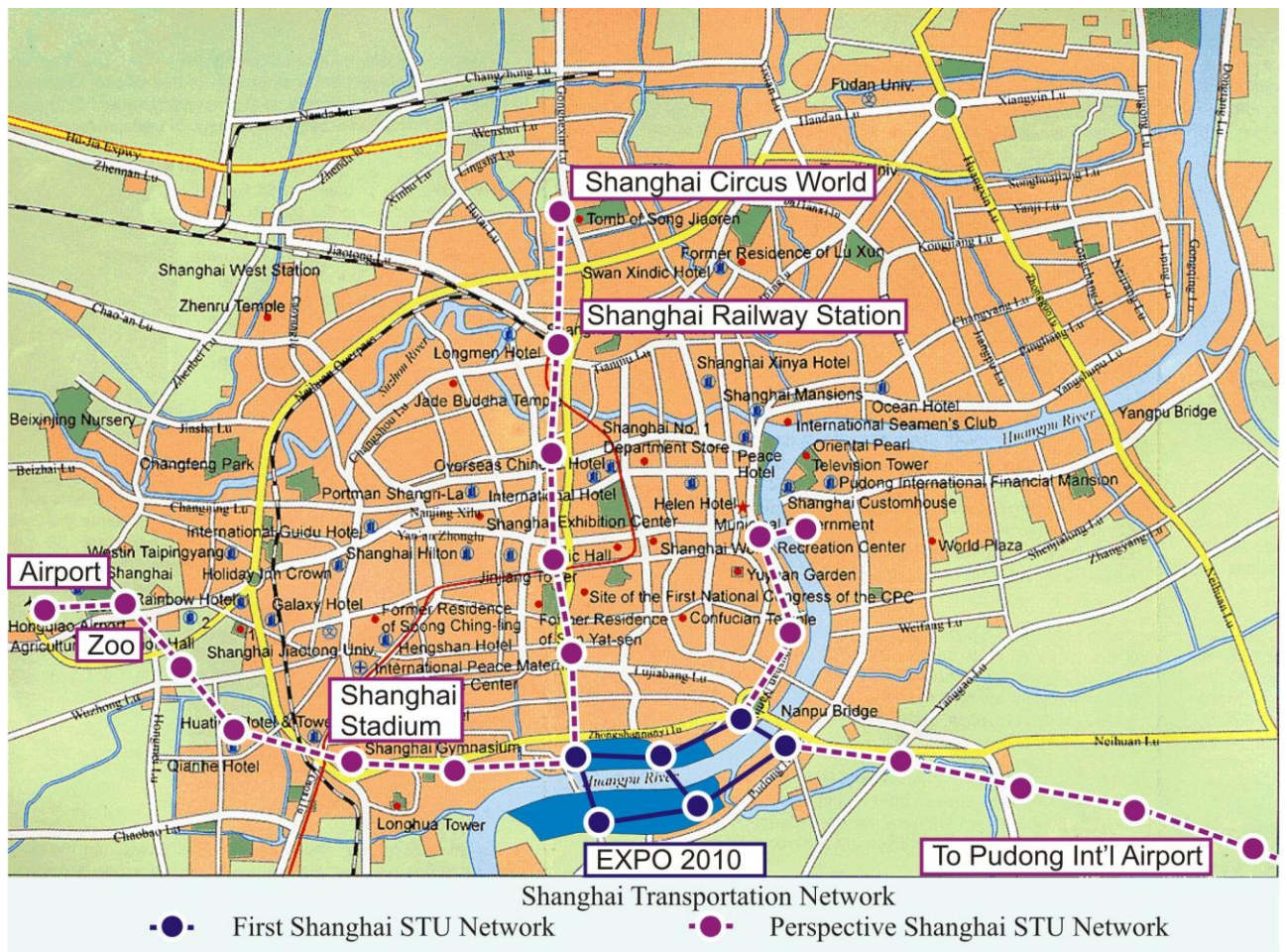


Fig. 3. Perspective development scheme of STU systems in Shanghai

## 2. Development plan of EXPO "Shanghai-2010" transportation system

STU Ltd. is ready to build for EXPO "Shanghai-2010" monoSTU (6 km) and miniSTU (6 km) transportation systems with the total length of 12 km and to put them into operation at the beginning of 2010. Their implementation could be facilitated on the basis of the following timetable of activities:

### Year 2007

June — October	— pre-project works and approval procedures
November — December	— preparation of the Terms of Reference for the general construction works

### Year 2008

January — December	— project and design works
July — December	— signing of contracts for equipment supply

### Year 2009

January — December	— manufacturing of the rolling stock
March — October	— construction of a track structure
October — December	— assembly of control and operation systems

**Year 2010**

January – February

— launching and adjustment works and tests

March – April

— pilot operation and personnel training

**3. The cost of STU projects for EXPO “Shanghai-2010”**

The cost of contracts for the development of the proposed STU transportation systems is given in the table.

N o.	Activity	Cost, million USD	
		MonoSTU (6 km)	MiniSTU (6 km)
1.	Pre-project activities and approval procedures	0.9	0.9
2.	Preparation of the Terms of Reference for the general construction works	0.7	0.7
3.	Project and design works	2.1	2.3
4.	Signing of contracts for equipment supply	2.4	1.9
5.	Manufacturing of the rolling stock	7.2	6.0
6.	Construction of a track structure	9.0	14.4
7.	Assembling of control and operation systems	1.5	2.1
8.	Launching and adjustment works and tests	0.7	0.9
9.	Pilot operation and personnel training	0.6	0.7
	Total cost of each contract:	<b>25.1</b>	<b>29.0</b>
	Total cost of two contracts with 10% discount <sup>1</sup>	<b>49.5</b>	

The total cost of STU projects for EXPO “Shanghai-2010” not including the cost of contracts includes the following additional costs:

- import duties for materials, equipment and the rolling stock;
- the cost of transportation from the border of the Russian Federation to Shanghai;
- construction cost of high-rise buildings (for monoSTU);
- construction cost of anchor and intermediate supports (for miniSTU);
- construction cost of station premises (for mono- and miniSTU).

In the course of the project development and expansion the cost of STU routes could be reduced by 20—30% through the organization in China of the production of the track structure components, equipment and the rolling stock.

<sup>1</sup> If two and more contracts are signed simultaneously a 10% discount is used due to the reduced volume of organizational and approval activities.



# MiniSTU

**The lower-cost transportation system of the "second level"**

Double-track route (not including infrastructure and the rolling stock):

- 2.4—2.7 million USD/km in flatland;
- 3.5—5.1 million USD/km in cities and mountains.

**The most economically efficient transportation system of the "second level"**

Energy consumption by a mini-unibus at the travel speed of 100 km/hour:

- 0.6—0.8 kWt·hour/100 pass.·km;
- 0.15—0.2 liter of fuel/100 pass.·km.

**The most environmentally friendly transportation system of the "second level"**

Land allocations:

- 50—90 sq. m/km;
- 0.005—0.009 ha/km.

**The most accessible transportation system of the "second level"**

Net cost of passenger travel:

- 0.5—0.8 USD/100 pass.·km  
(cost recovery period of a system — 2—3 years).

**The lower-cost high-speed rail car**

The cost of a 18-passenger mini-unibus:

- 50,000—80,000 USD — serial production;
- 150,000—200,000 USD — small-serial production;
- 300,000—500,000 USD — individual order.



**MiniSTU** is an alternative String Transport Unit with the average gage width of 2 m (approximately by 0.5 m wider than that of a modern high-speed railway). It is intended for the circulation of mini-unibuses of medium carrying capacity (7—20 passengers) and small freight carrying capacity (up to 1.5 tons) for the travel speeds ranging from 50 to 500 km/hour. Carrying capacity of a double-track route is up to 70 million passengers per year or 7 million tons of freight per year. It has three design alternatives: 1) electrified route with power supplied to the electric unibuses through the wheels from the current-carrying string-rails; 2) mini-unibuses using internal combustion engine; 3) mini-unibuses with power accumulators charged during the stops (during 20—30 seconds) at the stations of the “second level”.

**Sphere of application** — passenger and small-tonnage freight transportation in the cities (speed — 50—120 km/hour), between cities (120—350 km/hour), between regions and countries (350—500 km/hour).

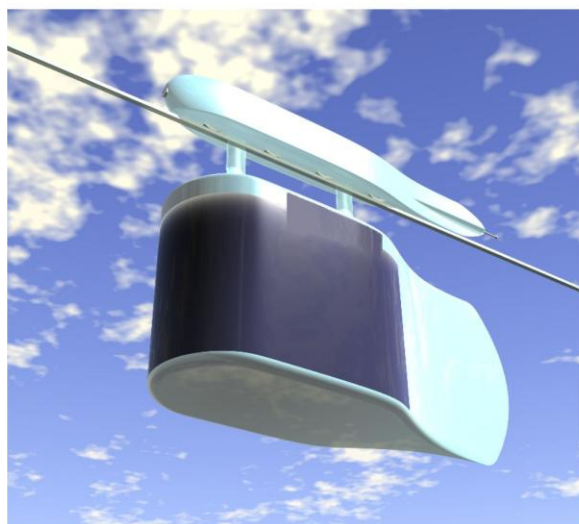
Advantages of miniSTU as compared with other known transportation systems are attributed to its design and technological peculiarities protected by 41 patents:

- **String-rail** is designed and assembled according to the standards applied to hanging and guying bridges; it has the service lifetime of 100 years and does not require certification (like bridges it requires only expertise and testing in the course of putting into operation). It has a steel head installed on the body with the strings stretched inside. Assembled strings (with a sag of 15—30 mm in the centre of a span) and the body having an upward bend (construction camber of 25—50 mm in the centre of a span) are fixed together with special concrete to form a rigid structure. In the electrified alternative a string-rail is installed on electric insulators (the rails are insulated from each other and from the supports). Separate string-rail components are manufactured by the Russian industry and have the quality certificates. Standard designs of a string-rail are available for various natural and climatic conditions, span lengths and design travel speeds.
- **String** is made of the high-strength wires, each of 3—5 mm diameters. The wire which is industrially produced in large volumes is made of the carbon steel of 65—85 mark and has the tensile strength of 190—220 kgs/mm<sup>2</sup>. The summary strain of strings per 1 rail of a miniSTU is 100—150 tons (at +20 °C).
- **String span structure** — two string-rails installed on the supports. In terms of their rigidity, smoothness, strength and durability they meet the requirements imposed on the elevated mono-rail roads, high-speed railways and trains on a magnet suspension. It has switch devices and a minimal curvature radius of 10 m.
- **Supports** are subdivided into anchor supports exposed to the horizontal load of strings (installed every 1—5 km according to the length of the high-strength wire) and supporting masts exposed to the vertical load (installed every 20—30 m and more). They are made either of the reinforced concrete (prefabricated or monolithic) or of steel or aluminum components (welded or dismountable assembled). Standard designs of supports are available for various heights, soil types and span lengths.
- **Mini-unibus** is made of materials, complete units and equipment produced by the leading world manufacturers. It is simple to design and manufacture. Steel wheels provided with two anti-derailment side rolls ensure more reliable and safe movement along the rails as compared with railways. Each of the four wheels has its own suspension. The gear which is industrially produced and certified has the power of 30—180 kWt (depending on the design travel speed). The mass (without passengers) is 900—1,800 kg. Mini-unibuses are operated by a driver or could be additionally provided with an automatic control system (autopilot).



**The lowest-cost suspended transportation vehicle**

- The cost of a 20-seat mono-unibus:
- 50,000—70,000 USD serial production;
  - 150,000—200,000 USD small-serial production;
  - 300,000—400,000 USD individual order.



**The lowest-cost transportation system of the "second level"**

- Double-track route (not including infrastructure and the rolling stock):
- 1.5—2.4 million USD/km in flatland;
  - 2.6—3.5 million USD/km in cities and mountains.

**The most economically efficient transportation system of the "second level"**

- Energy consumption by a mono-unibus at the travel speed of 100 km/hour:
- 0.6—0.8 kWt·hour/100 pass·km;
  - 0.15—0.2 liter of fuel/100 pass·km.

**The most environmentally friendly transportation system of the "second level"**

- Land allocations:
- 20—50 sq. m/km;
  - 0.002—0.005 ha/km.

**The most accessible transportation system of the "second level"**

- Net cost of passenger travel:
- 0.4—0.6 USD/100 pass·km (cost recovery period of a system — 3—4 years).



## **MonoSTU — a new sight on the rail transportation in the 21<sup>st</sup> century**

In the 21<sup>st</sup> century a new sight on the rail transport is needed to mobilize its hidden resources and to leave behind an automobile in terms of its safety, economic efficiency, environmental impact and comfort.

A steel wheel has serious advantages over a rubber wheel. Its rolling resistance is 20—30 times lower therefore the engine power is proportionally reduced to ensure its movement with the design speed. A rubber wheel compresses snow and does not destroy ice therefore highway roads are in need of constant cleaning in winter time. Whereas a steel wheel is capable of breaking ice which like snow has no impact on the wheel-rail cohesion therefore making this transport all-weather operational.

Urban transport is characterized by frequent stops necessitated by the need to brake before the traffic lights and to stop at the stopping grounds. Therefore fuel in urban motor transport and electric energy in electrified transportation modes is used not for the useful work but rather to intensively accelerate heavy vehicles not always fully loaded by passengers which dry mass considerably exceeds the mass of passengers. During the braking this energy is lost therefore existing urban transport is not economically efficient and, consequently, non-effective. The known ways of energy recuperation are associated with a considerable rise in price of the rolling stock and are not very efficient.

Public transport requires large allocations of the high-cost lands and electrified transport additionally requires a contact network which is expensive in itself and does not contribute to the improvement of the city image. Numerous supporting masts, bracing wires, electric insulators hanging above the streets create visual intrusions into the city built-up environment and alongside with the powerful electro-magnetic all-penetrating contamination of environment create visual discomfort for the city residents. Buses, trolley-buses, trams, mini-buses are the sources of additional accidents, traffic jams, smog and lead to the rapid destruction of the road carriageways, creating intensive noise which in terms of its hazardous impact on human health takes the lead among other types of hazardous impacts.

The aforementioned disadvantages are absent in the underground however its maintenance costs excessively increase the total cost of the system (up to 100 million USD/km) and it has a negative impact on passengers' health forced to spend in closed space under the ground several hours every day exposed to the intensive noise and vibration. Underground also has a hazardous impact on the city located above to result in caving in of soil and constant vibration of city buildings and facilities and their foundations.

All the above disadvantages are absent in the STU string transport alternative which was given the name of a gravitation mono-rail STU or monoSTU. Its transportation module is accelerated and decelerated by the gravitation therefore it does not need an engine to reach the speeds of 80—120 km/hour irrespective of its mass and dimensions. An engine is needed just to compensate the aerodynamic resistance and energy losses in the rolling wheel. A steel wheel and a rail reduce the rolling resistance to a minimum and the unibus body (passenger STU vehicle) optimized as a result of numerous tests in the wind tunnel has a lower aerodynamic resistance as compared with a bus (by 6—8 times) or sports car (3—4 times). Therefore a mono-unibus for 15—20 passengers requires an engine with a power as small as 2—3 kWt which contributes to considerable energy savings. For example, during its service life (100 years) a mono-unibus operating at a 10-km route section with 10 stops (every 1 km) with passenger flow of 50,000 pass./day (18 million pass./year) will be able to save about 200,000 tons of fuel with the total cost of USD 100 million as compared with a city bus (the average fuel consumption is 2.2 liters per 100 pass.×km). The savings will be

approximately similar as compared with a trolley-bus (if we convert electric energy into fuel a trolley-bus will consume on the average 2.1 liter/100 pass.×km), and will amount to more than USD 200 million as compared with a car (average fuel consumption is 5 l/100 pass.×km). As compared with underground (1.5 liter/100 pass.×km) and tram (2 liter/100 pass.×km) the fuel savings at a 10-km section of an urban monoSTU route during 100 years will be about USD 100 million.

MonoSTU is designed as a string-rail freely hanging on the spans of 500—2,000 m and more (assigned construction sag is 10—50 m and more) with a suspended many-wheeled mono-unibus provided with an autonomous electric drive. Supports combined with the stops have the height of 50—100 m and more depending on the height of a string-rail above the ground and its construction sag. The more the sag the higher speed could be achieved by a unibus accelerated by the gravitation at the links between the stations. For example, at the sags of 10 m and 50 m the maximal speeds will be 50 km/hour and 110 km/hour, respectively. In this case the tension of strings in the rail of a medium monoSTU will be 75—110 tons for a 2—3-ton mono-unibus.

It would be most reasonable to combine monoSTU supports with buildings such as residential houses, offices, shops, industrial buildings, multi-storey garages, etc. These buildings will have their independent purposes being self-sufficient and self-repayable therefore their cost should not be included in the total cost of the route. The load-bearing framework of these buildings will be designed with due regard to the horizontal loads up to 75—110 tons and 150—220 tons for a single- and double-track track STU routes, respectively. As far as this loads amount to as little as 1—2% of the total weight of buildings it will not lead to the increase in their cost as compared with traditional structures. Design of such buildings with the height up to 200 stories has been developed and patented. The cost of routes should include only additional lifts to serve STU passengers and the cost of equipment for a station occupying a part of the building floor. Taking into account the above expenditures the total cost of a single- and double-track monoSTU will be 2—3 USD million/km and USD 4—6 million/km, respectively. The cost of building-stations depending on their purposes and height will range from USD 1 million (1,000 sq. m of useful floor area) to USD 50 million (50,000 sq. m) at the net cost of 1 sq. m of useful floor space amounting to USD 1,000.

Carrying capacity of a monoSTU route with 20-seat mono-unibuses circulating with 15-second frequency in both directions will be 9,600 pass./hour or 200,000 pass./24 hours (21 hours of operation per day) or 73 million pass./year. The travel time between stations (1 km) will be 1—1.5 min.

With a ticket cost of 0.1 USD/km and the average trip length of 5 km a 5-km monoSTU route could achieve the cost recovery during 4—5 years and 2—3 years for passenger flows of 20,000 pass./24 hours and 50,000 pass./24 hours, respectively.

MonoSTU routes will be the most economically efficient, reliable, safe, environmentally friendly and comfortable ground (off-street) transportation system. In contrast to the cable roads its strings are protected in the rail against mechanical damage and corrosion with a high-strength body and special composite. To destroy a string-rail the cross-sectional stress should be more than 100 tons therefore even tornado with its maximal speed of 500 km/hour is unable to do it. Steel wheels of a mono-unibus are protected against derailment in case of emergency situation therefore it will provide the safest mode of ground transportation capable to save millions of human lives in the 21<sup>st</sup> century (for example, at the present time more than 1.2 million people are killed annually as a result of road accidents, more than 50 million are injured and become invalids and cripples).

Today transportation fatigue begins to dominate over the stress situations for urban residents who are already tired before coming to their jobs. MonoSTU instead of the transportation fatigue could offer its passengers rest at the bird's fly height in the course of their traveling to and from work. It will also offer them “de luxe” type service.

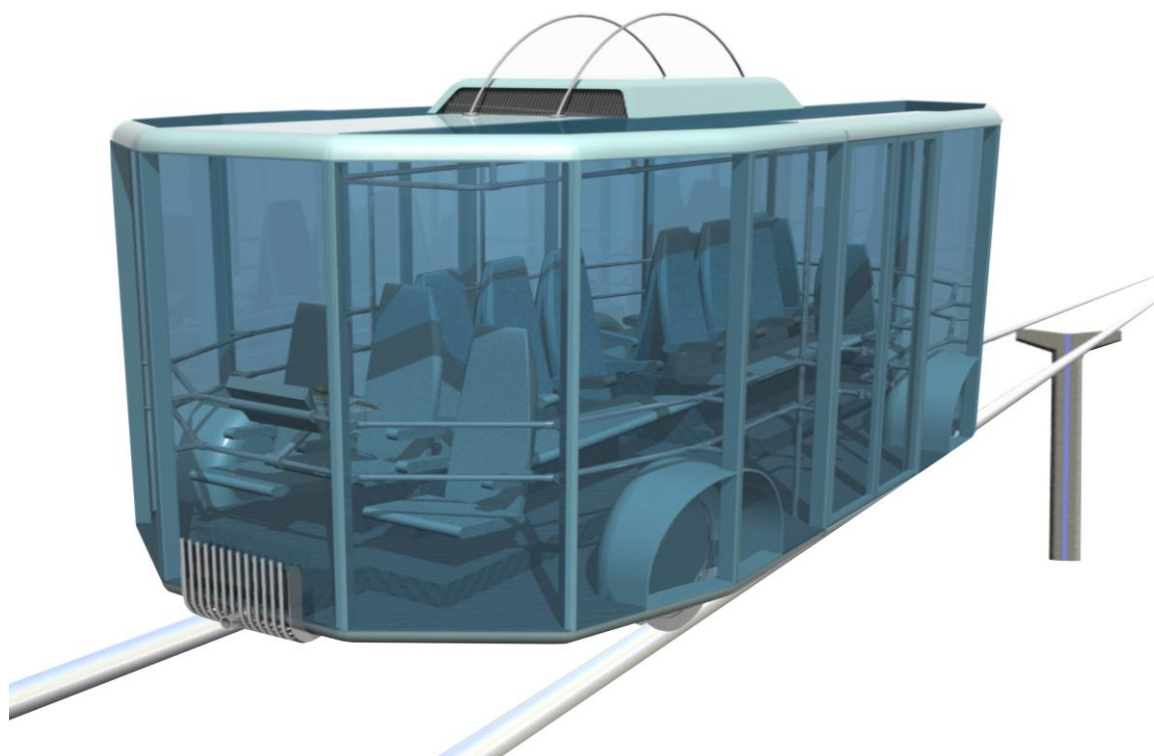


## Advantages of STU Systems

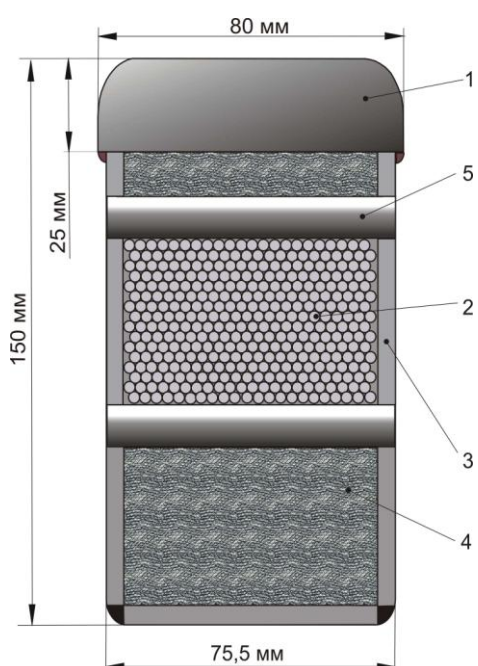
### Key components of STU systems

#### Double-rail macro- (mini-, micro-) STU

#### Unibus



#### String-rail



Cross-section of a macroSTU string-rail for a span of 36 m (scale 1:2):

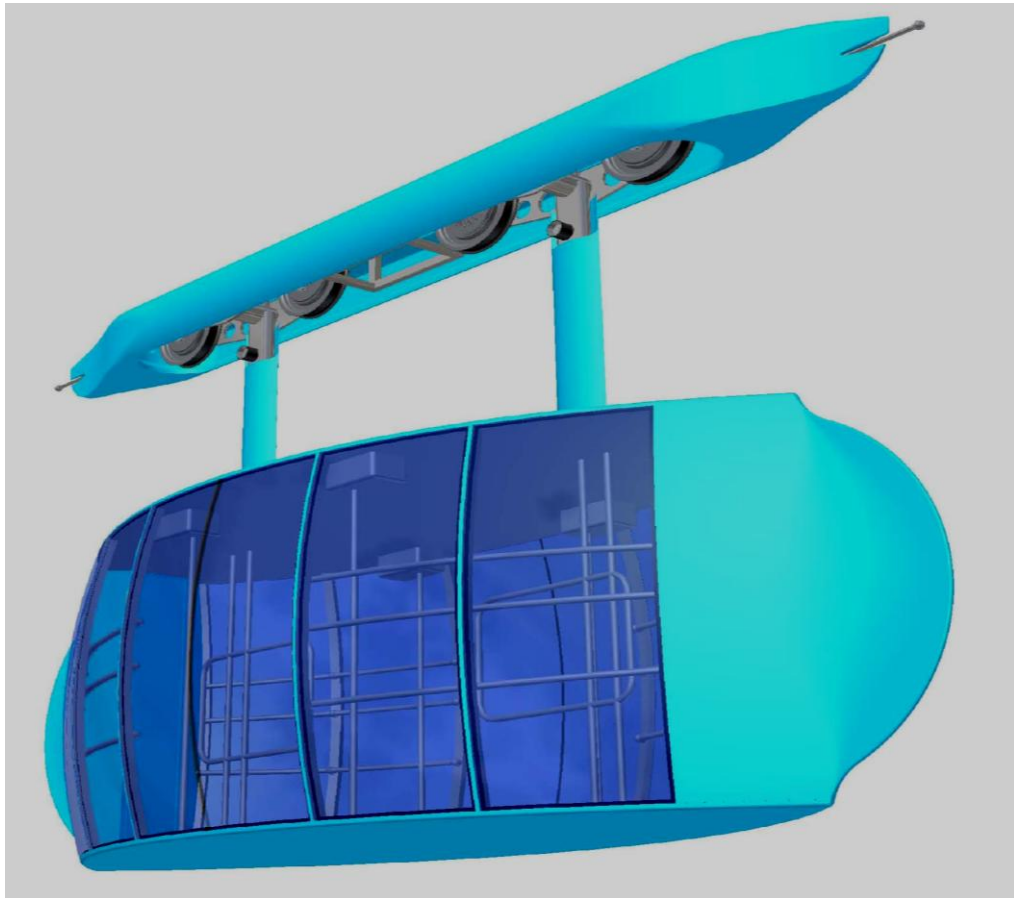
- 1 — rail head;
- 2 — string (352 high-strength wires each of 3 mm diameter);
- 3 — steel body;
- 4 — composite (high-strength concrete with addition of plasticizer, inhibitor of corrosion, etc.);
- 5 — string fixer (every 3 m).

#### Key characteristics of a string-rail:

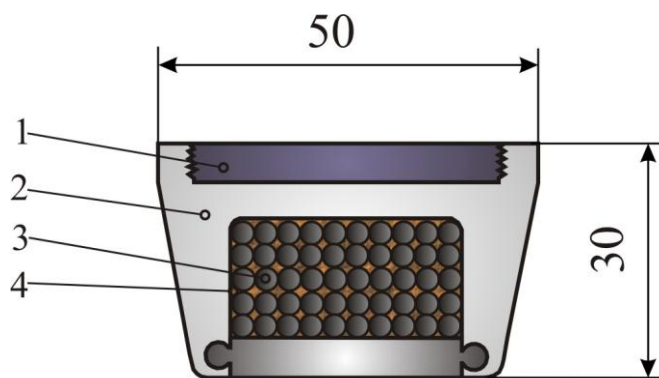
- steel consumption — 41.8 kg/m;
- total mass — 56.1 kg/m;
- summary pre-stressed tension of strings, body and rail head — 292 ts (at +20 °C).

## Single-rail light (medium-size, heavy) monoSTU

### Mono-unibus



### String-rail



Cross-section of a string-rail  
of a passenger medium-size monoSTU  
for a span up to 2,000 m (scale 1:1):

- 1 — steel rail head;
- 2 — body of the high-strength aluminum alloy  
(with a pressed-in steel head);
- 3 — string (50 high-strength steel wires each of 3  
mm diameter);
- 4 — composite (on the basis of epoxy resin).

Key characteristics of a string-rail:

- steel consumption — 4.4 kg/m; 2.1 kg/m —  
high-strength aluminum alloy;
- total mass — 6,7 kg/m;
- summary pre-stressed tension of strings, body  
and rail head — 75 ts (at +20 °C).

## **Comfort**

Alongside with a comfortable solution of its key functional task — fast and safe carrying of passengers — STU contributes to the solution of aesthetic tasks. Large glazed surfaces, comfortable seats and a smooth velvet track will make a trip along an ordinary road a pleasure of having a bird's eye view of the surrounding landscape. Each transportation module will be provided with climate-control devices and it should be stressed that the initial air taken at the height of 6—10 m and more will be clean (not as in existing urban transport at the asphalt surface). In contrast to highways the smell of lubricants, asphalt heated in the sun or car exhausts, etc. is absent.

Movement of the rail cars along the string-rail track does not depend on weather or road conditions (wind, rain, snow, fog, icing, etc.), the route has no traffic signals and one-level intersections with other modes of transportation and pedestrians therefore the average travel speed of STU will be higher than that of existing ground modes of transportation. It contributes to its growing comfort for passengers who will be offered a rapid, safer and more comfortable transportation service.

Small dimensions of the rolling stock and its lower capacity (as compared with a bus, trolley-bus or tram) make it possible for the rail STU cars to enable a high-frequency circulation (every 2—3 minutes and 1—2 minutes and less during the peak-hours). Therefore passengers do not need to stand long at the stations waiting for transportation which is especially important under the extreme weather conditions (severe frost, wind, shower rain, hot weather, etc.) as well as for older people, children, people with weak health.

Buses, trolley-buses and trams due to their large dimensions considerably contribute to the generation of “traffic jams” in the city streets which creates discomfort not only for their passengers but also for users of other modes of public transport as well as for private cars and taxis.

Electric network of the existing electrified urban transportation is its weak point due to frequent failures such as current cutting off, breaks of copper wire, destruction of electric insulators, shorting, etc. which disturbs the traffic schedules and creates discomfort for passengers.

## **Safety**

Today no other transportation techniques are characterized by the margin of safety equal to that of STU (100-fold for double-rail micro-, mini- or macroSTU and 10-fold for single-rail light, medium or heavy monoSTU) which is achieved thanks to its special cinematic scheme of external (cross-sectional) loads on a string inherent only to a string system. String break is possible only if a more than 200—600-ton vehicle on a double-rail STU or a 20—60-ton vehicle on a single-rail STU is used instead of the design 2—6-ton module; or if the wind speed will exceed 1,000 km/hour or the frost is below  $-200\text{ }^{\circ}\text{C}$  which is unreal.

A rail STU car is characterized by the high movement stability on the track which could be attributed to its steel wheels provided with anti-derailment side rolls, an independent suspension and high aerodynamic qualities of its body. Various emergency situations were modeled for the operational models at scales 1:15, 1:10 and 1:5 as well as for a pilot STU section in the town of Ozyory of Moscow Region. For example, destruction of two intermediate supports, availability of the outside metal objects with the height of 3 m on both rails, strong side wind and earthquake of 10-magnitude by Richter scale affecting simultaneously could not result in the rail car derailment at low travel speeds (up to 80 km/hour).

The STU rolling stock could be operational at hurricane wind. For example, in order to throw a rail car down from the track the pressure of the side wind should exceed the module weight which means that the wind speed should be more than 600 km/hour which is unreal.

Strings in the rail are protected against mechanical damage by a steel armored body and special high-quality concrete or composite based on polymeric resins. It is more difficult to destroy such multi-layer structure made of the high-strength materials than a mono-structure, for example, a rail of a railway. Therefore a string track structure is more stable to terrorist acts than a railway structure including a tram track.

Even the destruction of several intermediate supports at a time that perform only a supporting function will result just in the reduced travel speeds of unibuses at this section of the road due to the increased deformation of the track. In this case a string track structure is not destroyed. If we remove a number of sleepers of a railway (which is much easier than to explode a number of more stable intermediate supports in a STU) it will lead to the breakdown of a rail and derailment.

Unibus has a relatively small carrying capacity which makes it less attractive for terrorists than many-seat buses, trolley-buses, trams, suburban trains, metro, railways or aircraft. Less attractive will be also the STU stations with their small dimensions and small concentrations of passengers as opposed to the modern airports, railway or underground stations. A terrorist explosion in a unibus will not lead to the destruction of a string track as an explosive wave will be absorbed and damped by the strong multi-layer floor and a steel framed roof to direct an explosive wave to the less stable side structures.

In case of a failure in a standard drive a unibus could use an emergency starting electric drive operating on accumulators that is available in each wheel to get to the nearest station. In case an emergency drive is out of order the damaged module could be tugged to the nearest station by one of the nearest modules (in front of it or behind) using an automatic butt-jointing device. In case the whole rolling stock is out of operation passengers could use a rope ladder available in each module to come down to the ground. A helicopter will be used to evacuate passengers if it is not possible to come down to the ground, for example, at water sections. The major difference from a plane or helicopter in distress is that all passengers will be alive.

Servicing personnel and passengers of electrified urban transport are exposed to a risk of affection by the high-voltage electricity.

### **All-weather operation**

STU is an all-weather transport. Neither showers or hurricane winds or snow drifts in the streets are able to affect the STU circulation schedule. STU remains operational even during the floods when the ground urban transport is paralyzed or during earthquakes and other natural disasters. De-energizing of cities (as a result of natural disasters or failures in power plants or electricity networks) will not affect the operation of STU either.

In winter there is no need to remove snow or ice from the STU tracks whereas the costs for maintaining the city roads in normal condition during the long winter with heavy snowfalls are estimated at USD 10,000—20,000 per year per 1 km (including alongside with wages for the servicing staff the cost of snow-removing vehicles and dumpers, lubricant materials, deterioration of road-and-transportation conditions and increased number of road accidents resulting in the damage of vehicles, injuries and deaths of people, inactivity of public and private transportation, delays with getting to work as a result of traffic jams, consumption of deicers, etc.). During its

lifetime (100 years) STU could enable the savings in the city budget in the amount of more than 2 million USD/km which exceeds construction costs of 1 km of STU route.

### **Environmentally friendly system**

Large-scale, heavy and powerful buses, trolley-buses and trams are the major sources of noise in the cities while in terms of its hazardous impact of human health urban noise takes the first place among other impacts. The major noise in trams is produced by the rail joints, large unsprung mass of steel wheels, wheel cart and tram itself, uneven track laid on a ballast cushion, current collector. In a trolley-bus it is a powerful engine with a redactor, tire protector and current collector. In the STU these sources of noise are absent.

Existing urban transport is a source of soil vibration which has a negative impact not only on population but also on urban buildings and facilities.

STU will not generate soil vibration thanks to its very smooth track, the lack of rail joints (rails are welded as one weaver), damped wheels, string-rail and reinforced concrete supports, small unsprung mass of steel wheels and small mass of a module.

Contact network of a trolley-bus and a tram often sparks and generates radio interferences and strong electro-magnetic contamination of urban environment (for example, the life expectancy of trolley-bus and tram drivers all day working in the alternating electro-magnetic field is considerably lower than the national average).

Due to the large mass of the rolling stock in the existing modes of urban transport in relation to one passenger and its high resistance (aerodynamic, rolling, resistance in the current collector) they need excessive power engines, namely: 3—4 kWt and more per 1 passenger in buses, trolley-buses and trams (or 10—15 kWt/pass. at low loads that are typical), 5—6 kWt/pass. and more in mini-buses, 20—50 kWt/pass. and more in taxi and private cars. For example, miniSTU (dry weight is about 1.5 tons with carrying capacity of 20—25 passengers) needs an engine of 1—1.5 kWt/pass. which means that at similar transportation work in terms of energy consumption the STU will be more environmentally sound, in particular, by 1—1.5 times than public transportation and 10—20 times and more than passenger cars.

STU is the most environmentally clean transport among other known modes of transportation (including trolley-bus and tram) due to its steel wheel and steel rail (rolling resistance of a steel wheel is 20—30 times lower than that of a rubber wheel of a trolley-bus), high aerodynamic quality of its body (for example, aerodynamic quality of the high-speed mini-unibus is by 5—6 times better than that of a trolley-bus or tram), lower material-consumption of the rolling stock acceleration and deceleration of which is associated with the major energy consumption (80—100 kg of dry weight per 1 passenger against 150—300 kg/pass. of a tram and trolley-bus). Consequently, at similar transportation work the STU will be responsible for the smallest share in the city air pollution with fuel-burning products (with an internal combustion engine) and the lowest electric energy consumption (for an electrified alternative).

It is planned that a diesel of the STU transportation module (non-electrified alternative) will use dimethyl ether as its fuel — synthetic gasoline which synthesis from methane could be easily initiated in any city (for example, it is produced in Moscow using a simplest plant). Its combustion products (water and carbon dioxide) are similar to those of methane and natural gas and are environmentally clean. This fuel is 1.5—2 times cheaper than traditional diesel fuel and is ideal — a motor is started at any frost, its resource is increased by 1.5—2 times, combustion products do not contain carbon black and noxious substances (lead, sulfur, etc.).

## **Accessibility**

STU routes could pass through the built-up districts, squares, parks and other city areas where construction of tram or trolley-bus lines is not possible. In some cases STU routes could pass through the residential and office buildings, shopping centres and other city buildings and facilities, i.e. in the immediate vicinity of passenger flow generators. These possibilities of the second-level transport are currently used in the course of the mono-rail road construction in various cities of the world. Therefore, in terms of the walking accessibility STU will be more preferable than ground modes of urban transportation.

In terms of the ticket costs STU will be at the level of existing urban tariffs for public transportation which makes it affordable for all population groups including the low-income residents.

## **Other economic and non-economic factors**

Construction of STU routes within the city area does not require bridges, overpasses, underground and above the ground pedestrian crossings, multi-level exchanges which construction costs often exceed the cost of traditional urban roads.

STU is the second-level transport with its track structure elevated above the ground on the supports. It contributes to the reduced land allocations for the road construction: 15—20 sq. m of land for the intermediate supports for 1 km of a double-track route and 40—50 sq. m for anchor supports. For comparison: trolley-bus, bus and tram transportation requires the allocation of 0.7 ha/km (7,000 sq. m/km) of valuable urban lands (its cost is estimated at 0.5 million USD/ha and more).

Circulation of STU does not require intersections and traffic lights that are mostly responsible for over-consumption of fuel by the existing urban transport, air pollution and smog as well as for the traffic jams and noise in the city streets.

STU string-rail could be used to accommodate the city communication lines (wire and fibro optical) and its anchor supports — to incorporate the nodes of radio relay and cellular communications.

Each anchor support of STU combined with a stop could be used to locate one- or many-level (including underground) car parking facilities and garages, shops, public catering and service facilities (shops, exchange offices, etc.), recreation and entertainment facilities, etc., thus, anchor supports and stations will be able to pay back the costs independently.

Buses and trolley-buses are mostly responsible for the destruction of asphalt and concrete pavement of city streets (due to heavy loads on axis, often braking at traffic lights and stops and high temperature of tires in summer with asphalt melted by the sun), generation of ruts and asphalt swellings at public transportation stops.

A tram track worsens the evenness of city streets, deteriorates the road surface and its sections with sleepers laid on the dismountable-assembled reinforced concrete slabs are the sources of the increased noise generated by passing-by motor transport.

Unlike trolley-bus and tram lines the STU does not require the high-cost contact network made of deficient copper (which is in need of periodical replacement) with its supporting masts, bracing wires, electric insulators, power cables, power sub-stations.