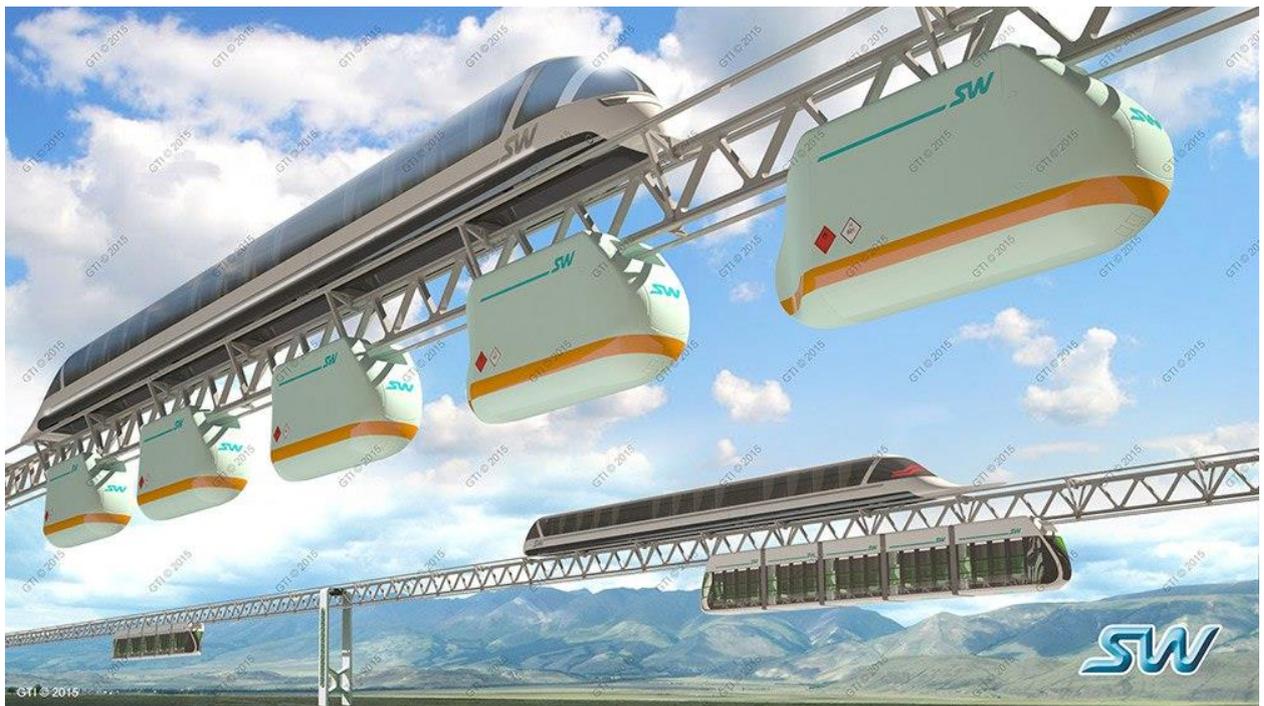


## Transport Complex SkyWay in Questions and Answers

# 100 Questions — 100 Answers



**2016**

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## Introduction

The year 2016 marked the 127<sup>th</sup> anniversary of Igor Sikorsky's birth. He was an aircraft designer, who created in Russia the first in the world multi-engine bomber, and in America – the first helicopter. After his emigration to the USA, which saved his life, Sikorsky had the last 20 USD left. Being in Chicago, he invested his last money in a very lucky way – he bought a ticket to the Sergey Rakhmaninov concert. After the concert, they started to talk... Rakhmaninov asked how much money the design engineer needed to start his own business. The answer was: 500 USD. Rakhmaninov put his hand in the pocket, got out a thick bundle of banknotes – his entire fee for the concert – and offered to Sikorsky. There was 5,000 USD, big money at that time...

Nobody in America believed in Sikorsky's helicopter. Moreover, in the 30ies of the XX<sup>th</sup> century, 30 years after his first successful experiments with the helicopter prototype in Kiev, the majority of engineers considered that his design diagram with one lift rotor and one steering rotor would never work. Sikorsky managed to prove a negative – and starting from the middle of the last century, 90% of all helicopters have been flying based on this diagram, which was later called a classical one all over the world.

Conclusions of experts concerning something new are always wrong – but that is because it is new! Otherwise, they would be the most successful and wealthiest people, as they would know what would happen tomorrow and they would understand where to invest their energy and money so as to become successful and earn more. The whole historical experience testifies to the contrary – only those people earn much and become successful, who invest in such projects, which neither “experts” nor “specialists” would dare to invest a dime in. In fact, only the Author and Creator of a new thing can be its genuine expert and specialist.

In order to make sure of the above said, it is enough to read some of the most interesting predictions specified below made by so-called “experts” and “specialists” for the last 150 years. No, they did not mean to suspend the technological progress, they sincerely believed they were right.

### Predictions:

- Computers in the future may weigh no more than 1.5 tons (Popular Mechanics, 1949).
- I think there is a world market for maybe five computers (Thomas Watson – CEO of IBM, 1943).
- I have traveled the length and breadth of this country and talked with the best people, and I can assure you that data processing is a fad that won't last out the year (Editor of Prentice Hall publisher, 1957).
- But what... is it good for? (Engineer at the Advanced Computing Systems Division of IBM commenting on the microchip, 1968).
- There is no reason anyone would want a computer in their home (Ken Olson – founder and president of Digital Equipment Corp., 1977).
- This ‘telephone’ has too many shortcomings to be seriously considered as a means of communication. The device is inherently of no value to us (Western Union internal memo, 1876).
- The wireless music box has no imaginable commercial value. Who would pay for a message sent to nobody in particular? (David Sarnoff's associates, in response to his urging for investment in the radio, 1920).
- Who the hell wants to hear actors talk? (Reaction of H.M. Warner - Warner Brothers on the use of sound in cinema, 1927).
- We do not like their sound and, in general, the guitar – it's yesterday. (Decca Recording Co., rejecting a record album of The Beatles, 1962).

- Heavier-than-air flying machines are impossible! (Lord Kelvin – president of the British Royal Society, 1895).
- Professor Goddard does not know the relation between action and reaction and the need to have something better than a vacuum against which to react. He seems to lack the basic knowledge ladled out daily in high schools. (New York Times editorial about Robert Goddard’s revolutionary rocket work, 1921).
- You mean drill into the ground to try and find oil? You’re crazy! (Associates of Edwin L. Drake refusing his suggestion to drill for oil, 1859).
- Airplanes are interesting toys but of no military value (Marechal Ferdinand Foch, Professor of strategy, Ecole Superieure de Guerre).
- Everything that can be invented has been invented (Charles H. Duell – Commissioner, US Patent Office, 1899).
- Louis Pasteur’s theory of germs is ridiculous fiction. (Pierre Pachet – Professor of Physiology at Toulouse, 1872).
- The abdomen, the chest, and the brain will forever be shut from the intrusion of the wise and humane surgeon. (Sir John Eric Ericksen – British surgeon, appointed Surgeon–Extraordinary to Queen Victoria, 1873).
- 640K ought to be enough for anybody. (Bill Gates, 1981).
- 100 million dollars is way too much to pay for Microsoft. (IBM, 1982).

Transport complex SkyWay (Unitsky String Transport) is not a historical exception. There have been made thousands of emotional “conclusions”, where “experts” have been analyzing during all 39 years of work on SkyWay not the essence of string transport, but, generally, their own ignorance on a rather difficult, comprehensive and branch-forming solution. There can be singled out just a few of them that can be truly considered expert opinions. These are the conclusions that have analyzed not only the term “string transport” and mental abilities of the developer, but SkyWay technical content itself in its optimal (not extreme) design, considering developer’s know-how. These are the conclusions that excluded assumptions of experts – obviously, competent and educated, but only in that sphere of knowledge where they are real specialists.

However, numerous potential investors, customers, officials of all kinds listened to and heard not the Developer of the new technology, not genuine Experts, but those whom they knew and trusted. It is easier that way. It is known that buried treasure is easier to look for under a lamp as it is lighter with it, rather than in a dark impassable forest. After all, London municipality believed a little over 100 years ago, at the time when the first automobiles already appeared in the streets, the specially created committee, who carried out an ordered analysis of transport development prospects and stated as follows: “...In 100 years (*i.e. in our days*), there will be 2 million people and 4 million horses in London. There will be more stables than residential houses. All neighbouring lands will be planted with grass and oat, but despite this, there will not be enough land and fodder for horses. And the layer of dung in some places will be half a meter thick...”

Predictions of today for the period of 50–100 years ahead are much the same, if in this analysis we replace the terms “horse” with “automobile”, “stable” with “garage”, “oat” with “gasoline”, “land” with “asphalt” and “dung” with “exhaust fumes”. Specialists and experts have at all times made the same mistake – 100 years back nobody “noticed” the first simple and unimpressive automobile, which then changed the world in the XX<sup>th</sup> century likewise today nobody “notices” the first simple and unimpressive SkyWay concept, built in Moscow region, town of Ozyory, in 2001, which will change the world in the XXI<sup>st</sup> century even more by making it safer, more eco-friendly and comfortable.

Thousands of people – presidents of countries, prime ministers, ministers, ambassadors, governors, academicians, doctors and candidates of sciences, students, pupils and ordinary people



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have asked the author, who has grown over the years to become general designer, numerous questions. This document presents answers to 100 most frequently asked questions.

Sincerely yours,  
Anatoly Yunitskiy  
Minsk, 2015

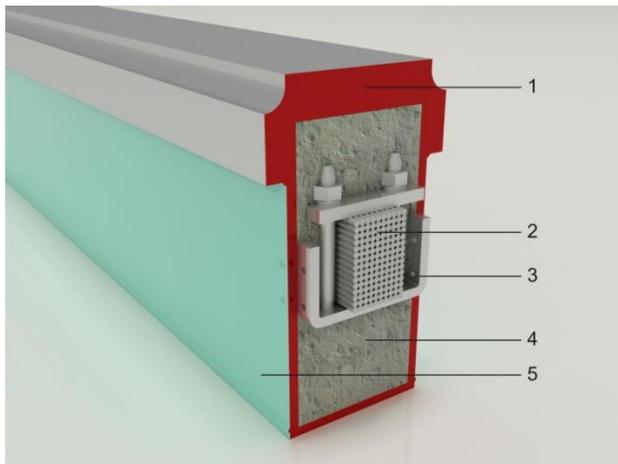
## 1. What is SkyWay?

Transport complex SkyWay (Unitasky String Transport) is a special automobile on steel wheels (passenger – unibus, cargo – unitruck, light vehicle with a bicycle drive – unibike), located on string rails mounted on supports (Fig. 1–14). The complex also includes infrastructure – stations, terminals, repair workshops, turnout switches, automated system of control, safety, power supply and communications. Due to high evenness and rigidity of rail-string track structure SkyWay, it is possible to develop motion speeds of up to 500 km/h.

Rail-string tracks can be single- and multi-lanes, with track structures located on joint and free-standing supports, as well as mounted (when a rail automobile is mounted above onto two string rails) and suspended (when a rail automobile is suspended below one or two string rails).

As to transport system carrying capacity and rolling stock passenger (cargo) capacity, SkyWay is divided into the following classes: ultra-lightweight, lightweight, medium-weight, heavyweight and super-heavyweight. As to speed limits, SkyWay can be low-speed (up to 100 km/h), fast (up to 200 km/h), high-speed (up to 300 km/h), super high-speed (up to 400 km/h) and hyper-speed (up to 500 km/h). High motion speeds place extremely strict requirements on evenness and rigidity of the track. Therefore, the higher the design speed is, the more expensive SkyWay track will be.

## 2. What is a string rail?



**Fig. 1. Rail-string of mounted SkyWay:**  
**1 – railhead; 2 – string (bunch of steel wires);**  
**3 – component for fastening string to rail body;**  
**4 – filler (special concrete); 5 – rail body**

String rail is a conventional unsplit (along the whole length) steel, reinforced concrete or steel-reinforced concrete beam or truss, equipped with a railhead and additionally reinforced with pre-stressed (stretched) strings (see Fig. 1, 13 and 14). Maximal string tension per one rail (depending on span length, speed motion limits and design mass of unibus or unitruck) is 10–1,000 tons and more (at design temperature of assembly – +20 °C). It combines the qualities of a flexible thread (at a large span between supports) and a rigid beam (at a small span under a wheel of a rail automobile and above the support). Therefore, under the impact of concentrated wheel load, the deflection (curvature) radius of a string-rail is 1,000 m and more (the higher the design speed is, the

more this radius must be). Due to this, wheel rolling of a rail automobile will be smooth, bumpless both in the middle of the span and above the support. A string rail is characterized by high strength, rigidity, evenness, manufacturability and ease of assembly, low material consumption (steel: 10–100 kg/m, concrete or other filler: 0.005–0.1 cu m/m), a wide range of working temperatures (from +70° C to –70° C). It provides an ideally smooth track for wheels movement as it has no technological or temperature joints along its whole length (railhead is welded as a single weaving). The cost of the assembled string-rail is estimated from USD 10,000 per 1 km, which is less than that of the assembled railway rail.



**Track structure SKYWAY** is cheaper than railway, monorail and automobile overpasses by 30–40 mln USD/km.

At a speed of 350 km/h, **unibus** will be more cost effective than high-speed railway by 6–8 times, than sports car – by 15–20 times.

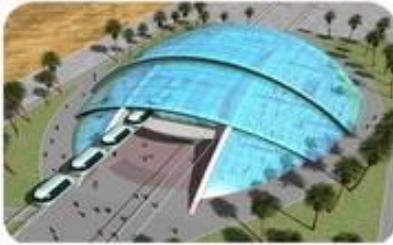


**String technologies** is an entirely Russian development, which happened in the history of transport development in the country for the first time. Russia has a unique opportunity to occupy a fundamentally new transport niche in the world economy based on innovative Russian technologies.



**Savings** per 1 km of the track (during construction):

- steel – 500–1,000 t (compared to monorail);
- reinforced concrete – 15,000–20,000 cu m (compared to fast railway overpass);
- land acquisition – 5 ha and volume of earthwork – 20,000–30,000 cu m (compared to railway and highways)



**Patents** – about 50 patents for inventions obtained, including abroad. A repeated expert evaluation undergone, dozens of positive opinions obtained, including from the Ministry of Economic Development and Trade, State Committee for Construction of Russia, the Academy of Transport and Solomenko Institute of Transport Problems of the Russian Academy of Sciences.



**Awards:**

- “Project of the Year of Transport Industry of Russia” – diploma of National Public Prize “Golden Chariot” (2009)
- Two UN grants (1998 and 2002)
- Three gold quality marks “Russian Brand” of the national program aimed to promote the best goods, services and technologies (2001)



**Project infrastructure** – creation of transport infrastructure, tele-, radio- and multimedia communications, electrification, nano-industrial technology; export of Russian goods and technologies, development of scientific school, change of world logistics and state of mind of society.



**Fig. 2. Different types and classes SkyWay**



**Fig. 3. Double-track SkyWay in a city, speed – up to 150 km/h**



**Fig. 4. Medium-speed single-track SkyWay, speed – up to 250 km/h**



**Fig. 5. High-speed track at a foothill, speed – up to 400 km/h**



**Fig. 6. Super high-speed track, speed – up to 450 km/h**



**Fig. 7. SkyWay at big height in a city**



**Fig. 8. Urban suspended unibus**



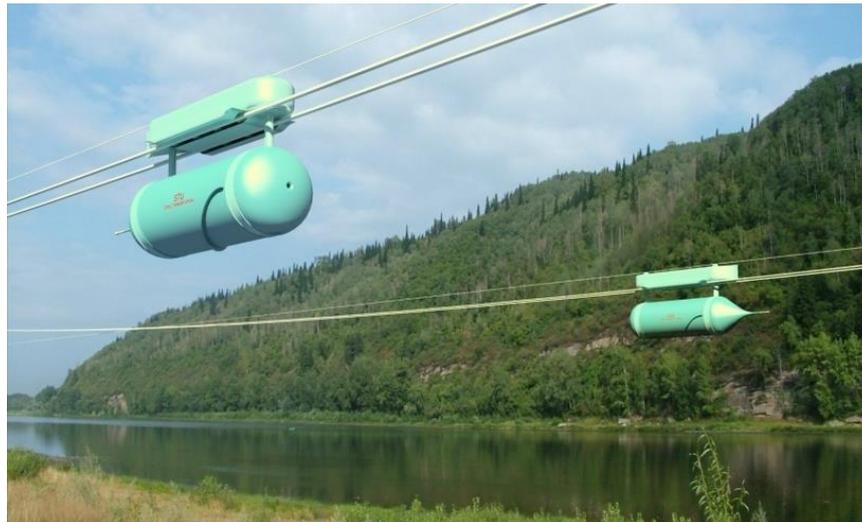
**Fig. 9. Bus on rail-string track structure**



**Fig. 10. Urban bus on a string rail built in asphalt**



**Fig. 11. Single-track high-speed SkyWay on a plain**



**Fig. 12. Cargo SkyWay for bulk and liquid cargo transportation**

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

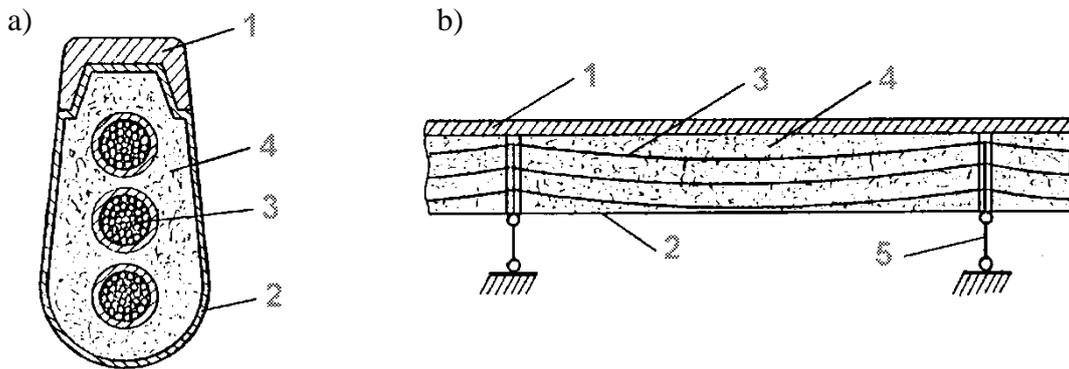
Its closest analogue is a pre-stressed reinforced concrete beam of a bridge made of rigid components (reinforced concrete structure) and flexible bunches of steel wires and cables stressed to about 100 kgf/mm<sup>2</sup> tension and put in special channels inside the beam. The beam and wire bunches are fixed with solidifying mixture, for example, cement solution or epoxy resin filled in the channels to make a single structure.

Another analogue is a hanging bridge that has a rigidity beam supported by a cable, which has a sag. The beam and cable are fixed with a suspension to make a single structure. The principal distinction that distinguishes hanging bridges from the string-rail is the fact that a cable of a hanging bridge is located beyond the rigidity beam while a cable of the string-rail is installed inside the hollow rail body filled with solidifying mixture that acts as a suspension, and in combination with a body – as a rigidity beam.

### **4. What is the principal distinction of a string-rail from other structures?**

A string rail in all classes of mounted SkyWay is designed so that construction sags of a string (twisted or untwisted cable), with sags of 20–50 m, make 10–150 mm. A string with such sag is easily placed inside the structure of small transverse dimensions (see Fig. 1 and 13). This will ensure high evenness of the track. To ensure even higher evenness, the rail at each sag can be

made with a camber – upward bending, – which is equal to the dynamic deformation of the sag with rail automobile moving.

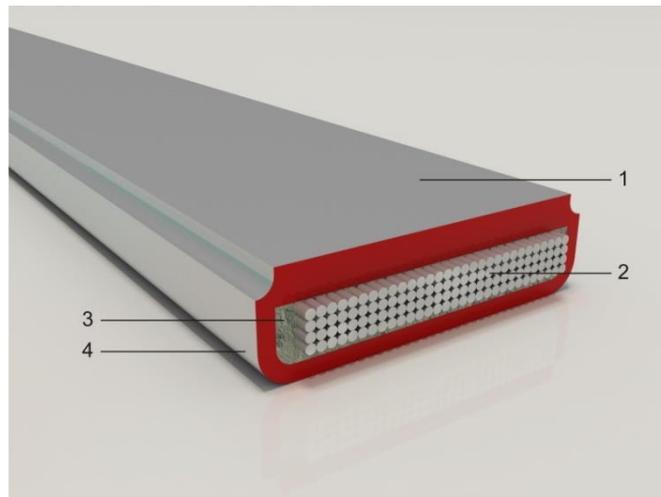


**Fig. 13. One of alternative designs of string-rail for mounted SkyWay:**  
**a) cross section; b) longitudinal section;**  
**b) 1 – railhead; 2 – rail body; 3 – string (twisted or untwisted rope);**  
**4 – filler; 5 – support**

In some design variants of suspended SkyWay, both rail and string are placed with a sag at the span (the longer the span is – the more the sag is, see Fig. 16). Such design variant is the most efficient in urban SkyWay, when between stations on the “second level”, there will be no supports, i.e. the span distance in it will be equal to the distance between the neighbouring stations.

Such SkyWay will be the most energy efficient, as after leaving a station and going downhill, the unibus will be accelerated up to the design speed not due to an engine, but due to gravity force (the so-called gravity engine). When entering a station and going uphill, it will be braked not by brakes, but again by gravity (the so-called gravity brake). In this case, there will be realized the most efficient energy recuperator of all those possible, with the efficiency factor of 100%. The reason is that the unibus will operate using not some mechanism with all its drawbacks, but the laws of physics, according to which potential energy of the unibus from the station, where it stands still, will be transformed into kinetic energy when moving at the section with the maximal speed in the middle of the span, to then be transformed into potential energy again at the next station.

Maximal motion speed here can be set based on the construction level difference between the station and the middle of the span, and engine power – based on the value of aerodynamic losses and losses to overcome unibus wheels rolling resistance when moving at the section. Designed variants of urban suspended SkyWay, for example, a 20-seat unibus at the span of 1,000 m requires an engine of only 5 kW, or 0.25 kW/passenger to reach the maximal speed of 100 km/h. None of known and advanced urban transport systems with stops every 1,000 m and motion speed of 100 km/h at the section can have or will have such efficiency. For doing so, the level difference between stations and the middle of the span must be about 35 m. With level difference of 20 m, the optimal speed will be about 70 km/h.



**Fig. 14. One of alternative designs of string-rail for suspended SkyWay:  
1 – head; 2 – string (bunch of steel wires); 3 – filler; 4 – body**

## **5. What are the transverse dimensions and mass of a string-rail?**

A string-rail is characterized by the following maximal transverse dimensions: width – 120 mm, height – 350 mm (for super-heavyweight high-speed mounted SkyWay). The minimal dimensions are the following: width – 30 mm, height – 9 mm (for ultra-lightweight low-speed suspended SkyWay).

Mass of a running meter is 3–120 kg, out of which steel makes 50–90%.

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

Steel of one modern heavy railway rail (considering baseplate, bolt clamps, etc.) is enough to manufacture the track structure (two rail-strings) for a single-track mounted SkyWay of middle class of the same length (steel consumption is 60–100 kg per 1 running meter of track structure), or double-track suspended SkyWay of middle class. In this case, it is necessary to remember that a railway rail has a span of just 0.5–0.6 m (distance between neighbouring sleepers), and that of SkyWay ranges from 30–35 m to 2–3 km.

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

No, it does not. All materials required for its manufacturing are produced today by industries of any developed country, including Russia. For example, a railhead, along which a SkyWay vehicle actually moves, could be made of steel used for railway rails or bridge structures. Therefore, a railhead can be rolled using conventional rolling mills, only equipped with more simple accessories. The reason is that a string railhead profile is much simpler than that of a railway rail and its mass per unit length is significantly lower: 3–25 kg/m.

SkyWay string is made as a twisted or untwisted cable consisting of high-strength steel wires of 1–5 mm diameter. This wire with a tensile strength of 90–350 kgf/mm<sup>2</sup> is industrially produced in many countries to be used for cables and ropes in hanging and cable-stayed bridges, in pre-stressed reinforced structures, steel cord of automobile tires, etc. Dozens of steel grades produced by large-serial manufacturers are suitable for this string, therefore there is no need to enumerate them. A ribbon, band, rod, tube, etc. made of steel or other high-strength materials, including composites and polymers, could also be used as a string.

The same is true for other string-rail components, track structure, supports and SkyWay rail automobile – all these components are either produced by industry, or initiation of their

production would not be a problem.

As solidifying materials to consolidate (to make monolithic) the string and rail body, it is possible to use cement mortars with admixture of plasticizers and corrosion inhibitors, composition materials based on epoxide or silicone resins, bitumen and other industrially produced bond materials.

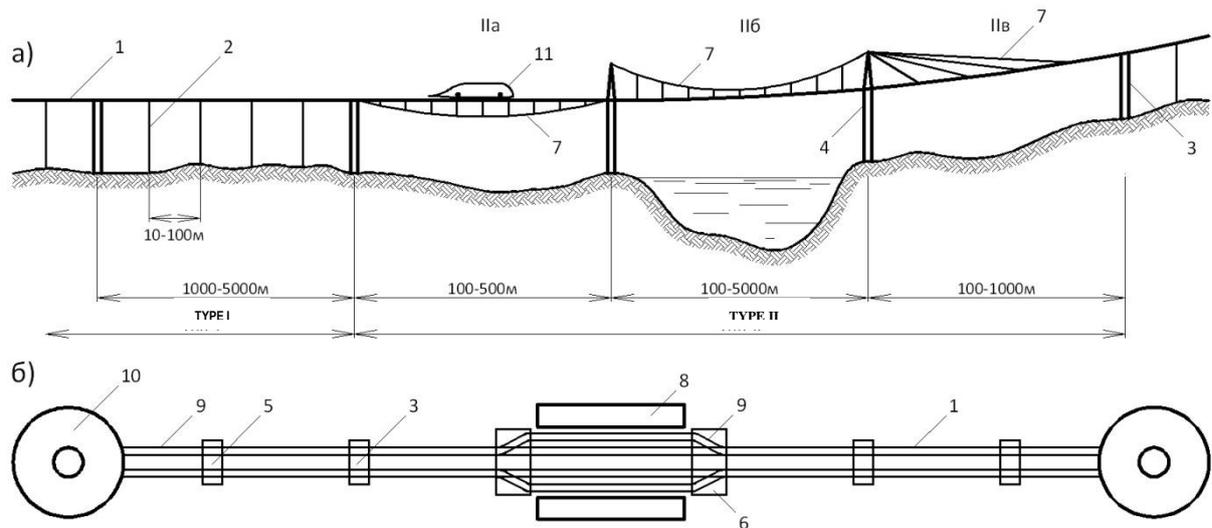
## 8. What is the linear track scheme?

The linear track scheme of mounted SkyWay (variants), when a rail automobile is located above string rails, is shown in Fig. 15; of suspended SkyWay (rail automobile is located under string rails) – in Fig. 16.

Depending on span length, the following two specific types of SkyWay track structures are recognized:

- 1 – conventional design (span up to 50 m);
- 2 – with additional supporting cable structure (span more than 50 m) with a cable installed:
  - a) at the bottom;
  - b) at the top – with a parabolic sag;
  - c) at the top – as cable stay.
- 3 – trussed structure, with a trussed string (span up to 500 m).

SkyWay supports are divided into two characteristic types: anchor (installed every 1,000–5,000 m and more) and supporting masts (installed every 10–1,000 m and more).

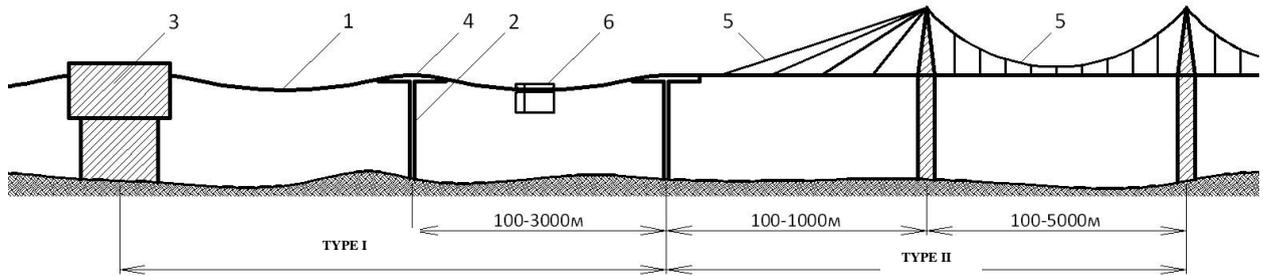


**Fig. 15. Linear track scheme for mounted SkyWay:**

a) side view; b) top view;

- 1 – rail-string track structure; 2 – support; 3, 4, 5, 6 – anchor supports, correspondingly: intermediate, pylon, terminal, with turnout switch; 7 – supporting cable; 8 – intermediate station; 9 – track section made of conventional rails (of railway type); 10 – ring terminal; 11 – mounted rail automobile

Suspended SkyWay also has several design variants, including with supporting cable (see Fig. 16).



**Fig. 16. Linear track scheme for suspended SkyWay:**

- 1 – rail-string track structure (one or two string rails per one track); 2 – support; 3 – anchor support combined with passenger station; 4 – saddle (provides smooth passing over intermediate support); 5 – supporting cable; 6 – suspended rail automobile**

## 9. What is the tension force of strings?

The average tension force per one rail-string for mounted SkyWay of middle class will make as follows: from 200–250 tons for low-speed and up to 1,000 tons and more for high-speed variants of the system. With design wire tension stress to break of 100 kgf/mm<sup>2</sup>, their total area of cross section in the first case will be 20–25 cm<sup>2</sup> per one rail, and mass – less than 20 kg/m. If a string is made, for example, as three twisted cables, the diameter of each cable will be about 35 mm. Minimal tension of ultra-lightweight low-speed suspended SkyWay is up to 10 tons, maximal tension of super-heavyweight mounted SkyWay is 1,500 tons and more.

For comparison: cables of existing hanging bridges reach 1,500 mm in diameter, and their tension stress – 200 thousand tons and more. By the way, SkyWay and a hanging bridge have approximately the same carrying capacity (for passenger and cargo traffic).

Design string tension in a rail string depends on the span length, unibus mass, its design motion speed and even on the suspension type – for a rigid wheel suspension and with a rigid damper in a designed unibus, a higher string tension is required in order to provide higher evenness of the track and comfortable smoothness of movement.

Therefore, SkyWay designing is more like designing a plane, where it is impossible to take arbitrary hull shape, wing area, takeoff weight, etc. rather than designing a railway. However, officials regularly send documentation for SkyWay expert evaluation to railway authorities, who, failing to find sleepers and wheel pairs, give negative opinions because of wrong, in their view, solutions. It is neither good, nor bad – these are just SkyWay peculiarities, which have to be taken into consideration.

Flexural rigidity of a rail body, i.e. its design peculiarities, also has a significant impact on the required value of pre-stressed string tension. In high-speed SkyWay, a string rail can be made with a very high flexural rigidity, which can exceed flexural rigidity of a conventional railway rail by 1,000 and more times (the way it is achieved is one of the numerous SkyWay know-how). This allows to reduce the required string tension manifold.

## 10. What is the maximal possible span?

Track structure spans of mounted SkyWay exceeding 50–100 m should be supported by a special cable (fixed on the top or bottom), i.e. they must be designed by type of a hanging or cable-stayed bridge. Taking into account the light weight of a track structure and rail automobiles, cables with diameter of 100 mm made of high-strength steel wire will ensure support of mounted SkyWay spans of up to 1,500 m long, of 200 mm – up to 3,000m.

The maximal span of suspended SkyWay with a sagging track structure, when using high-strength steel for rail and string manufacture, is 3,000 m.

Modern high-strength composite materials for a string will ensure the maximal span length

of 4,500–5,000 m.

## 11. How rigid is a rail-string track structure?

An important quality of a track is its relative rigidity: a ratio between the structure sag under the weight of the rolling stock, located in the middle (or in 1/4) of a span, and the span length. Modern bridges, including hanging bridges, are designed in Russia and abroad with the estimated relative deformation of 1/400–1/800. Mounted SkyWay is designed as a more rigid structure. For example, a sag of the rail-string structure with a 50 m span under the weight of a high-speed unibus will be less than 10 mm, or less than 1/5,000.

Therefore, a rail-string track for a moving wheel will be much smoother than, for example, a railway track of a high-speed network laid on a modern reinforced concrete or steel bridge.

Construction (assembly) deflections of various track structure components under the impact of their own weight are given in Table 1.

**String deflections of mounted SkyWay under its own weight**

Table 1

Span length, m	Static (assembly) deflection of structural element			
	strings inside a rail		of supporting cable	
	Absolute deflection, cm*	Relative deflection	Absolute deflection, m**	Relative deflection
25	1.6	1/1,600	–	–
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
1,000	–	–	25	1/40

\* string deflection is hidden (“wired”) inside the rail-string body; the rail is made without sagging, it is even, or with an upward bending;

\*\* cable deflection is located under the track structure or above it.

## 12. Will there be thermal deformation in a rail-string track structure?

There will be no longitudinal thermal deformation in a rail body or in a railhead, or in a string, as their length remains unchanged in summer and in winter. Neither rail nor string will have any thermal deformation joints along the whole length, similar to telephone wires or power transmission lines that are like strings in a rail fixed to supports with a sag and stretch without any joints for many kilometers. However, temperature change in the structure can cause changes in its stress-strain state.

SkyWay track structure is designed so that at any estimated temperature variations the rail and string are exposed only to tensile force. Therefore, the structure cannot lose stability, which could happen if these components were exposed to compression stress. For example, at maximal temperature difference of 100° C (from +60° C in summer in the sun to –40° C in winter), the maximal range of tensile stress variations in steel rail-string components will be about 2,400 kgf/cm<sup>2</sup>: for a string – from 7,600 kgf/cm<sup>2</sup> (in summer) to 10,000 kgf/cm<sup>2</sup> (in winter); for rail body and railhead – from 0 to 2,400 kgf/cm<sup>2</sup>, respectively. With the reduced temperature difference, a strain-stress state will be proportionally reduced.

### 13. Will temperature variations of string tension result in track deflection?

With temperature variations, there can be observed track deflection in a string sag plane (i.e. in a vertical plane), which will be proportional to its initial sag and relative tension variation. At temperature variation of  $100^{\circ}\text{C}$  (or a more neutral value of  $50^{\circ}\text{C}$ ), maximum vertical track deflection at a 30 m span will make about 2 mm, or 1/10,000. In this case, the track will have a 2 mm upward deflection in winter and the same 2 mm downward deflection in summer.

Such micro-roughness is easily compensated by a wheel suspension and will not affect the smooth motion of a unibus moving at speeds of up to 500 km/h. Furthermore, as thermal deflections have a pre-designed and known-in-advance character at this air temperature, the track profile will be automatically adjusted by a computer-controlled wheel suspension, if necessary.

In addition, there are design and technological know-how, which will exclude track deflection at temperature variations.

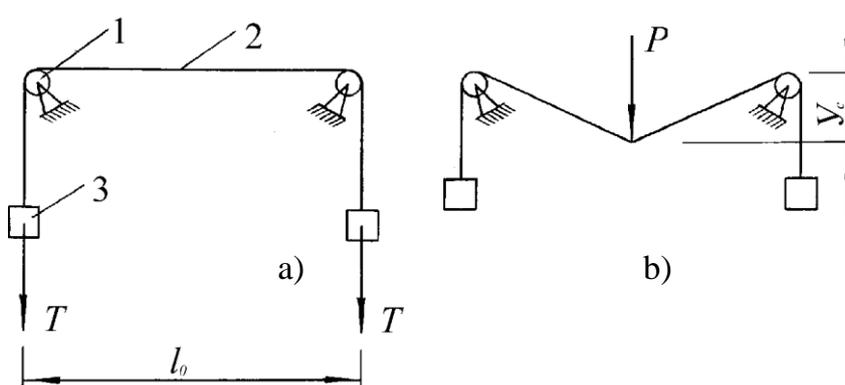
### 14. Will the rolling stock change string tension when in motion?

It will, but not much, just within 1%. It is explained by peculiarities of a kinematic scheme for the rail-string track structure. Fig. 17 shows a string block system, string tension in which (and, consequently, strain) does not depend on external load  $P$  but rather on tensile force  $T$  only.

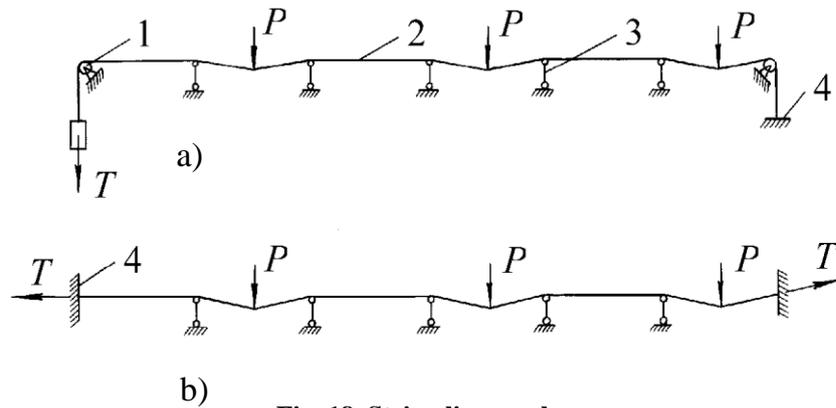
Such structure can be transformed into a linear scheme of a greater length (Fig. 18).

The analysis showed that at  $P < 0.02 T$  (which is observed in SkyWay), the strain-stress state of structures, shown in Fig. 17 and 18, differ from each other by not more than 1% (more precisely – 0.1—0.5%). In engineering estimates, this difference can be neglected and structures can be considered identical.

This considerably distinguishes SkyWay from other building structures, for example, bridges and overpasses. The latter are exposed to millions of loading cycles in the course of their operation and each time the stress in various structural components, for example, reinforced beams, increases by 2 and more times. All this results in the development of fatigue phenomena in the structure and, therefore, reduced service life of structures and growing maintenance and repair costs.



**Fig. 17. String block system:**  
a) without external load; b) with load; 1 – block; 2 – string; 3 – load



**Fig. 18. String linear scheme:**  
 a) with block at the end of string; b) with string sealed off; 1 – block; 2 – string;  
 3 – swing support; 4 – fixing (anchor)

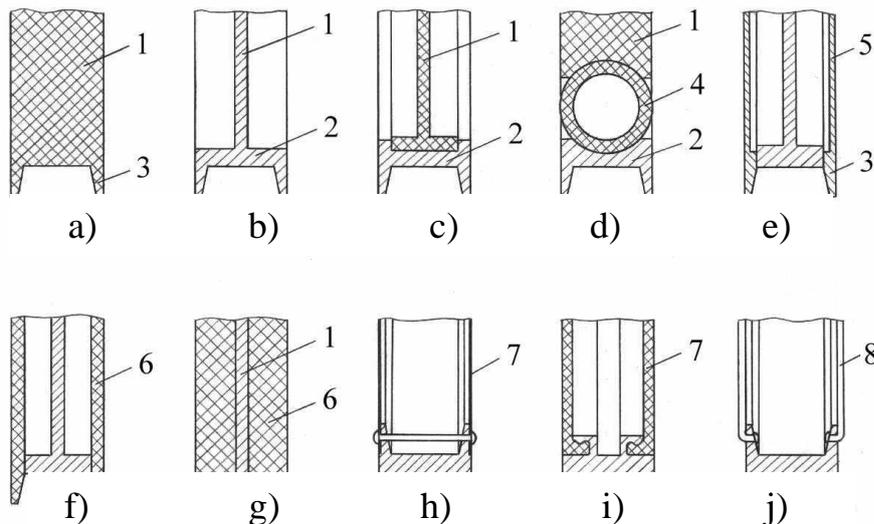
As SkyWay strain-stress state remains practically unchanged during the whole period of its operation irrespective of the number of loads, such string-rail track structure will have increased total durability.

### 15. How accurately are track gauge parameters observed?

Left and right string rails will be linked with each other every 10–20 m with special cross bulkheads that fix a gauge like sleepers of a railway. The side force in the interval between them, for example, under the impact of a hurricane side wind of 100–150 kgf per one wheel, will change the gauge width by 1–2 mm as a result of rail-string deflection, which will not pose any danger to the unibus rolling wheel moving at speeds of up to 500 km/h.

### 16. What will happen to a rail vehicle if rails slide apart?

This risk exists at railways, including high-speed railways, when numerous train derailments happen due to this reason. It happens because the train wheel has one flange. In a SkyWay module, each unibus wheel has two flanges (by one flange on the left and right side of the railhead, see Fig. 19) and an independent suspension.



**Fig. 19. Design of 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

Therefore, a rail vehicle will not be critical to the gauge width. For example, a wheel suspension can be designed in such a way that variation of gauge width by 10 mm will not result in derailment, but rather will be a regular operation mode. In the light of the above, coming off the track is more typical of cars that are kept on road surface only by friction force and often fall down to the side ditch, especially under icy conditions, whereas the rims available on a wheel pair of trains keep them stable on a track.

Moreover, rail vehicles are equipped with an additional anti-derailment system – side rollers, which bear against side rolling surface of a rail. Therefore, they will also maintain the designed gauge width.

### **17. As a rule, structures use twisted cables. Why are straight wires more reasonable for a SkyWay string?**

A SkyWay string is used for a completely different purpose compared to a crane cable, which is constantly winding on (or unwinding from) its drum and gets folded by its numerous pulleys. In addition to its strength, the main feature of a twisted cable is its flexibility, which is achieved thanks to intertwisting of wires. Moreover, a twisted cable is wired in a solid whole, therefore it does not get fluffy in case its separate wires are broken. However, in case some of the wires are broken, their load is re-distributed due to friction forces to expose the rest of intact wires to overstrain.

Overstrain is also caused by intertwisting of wires, as within their contact zone, there is increased contact stress and abrasive wear. Ultimately, it can result in cable breaking, therefore it is very important to check the wholeness of each wire. Furthermore, wires in a twisted cable are located at an angle to the longitudinal axis (and to longitudinal load action), therefore their carrying capacity is reduced. The cable elasticity module is also reduced:  $(1.5-1.8) \times 10^6$  kgf/cm<sup>2</sup> against  $E = (2-2.1) \times 10^6$  kgf/cm<sup>2</sup> for steel.

A SkyWay string is a stationary component, which does not require either elasticity or other abovementioned shortcomings typical of a twisted cable. Instead, it has the following important advantages of a string made of a bunch of direct wires, i.e. in the form of an untwisted cable:

1. In case some wires are broken, their length is reduced (a string can be put in a protective envelope filled with special anticorrosive mixture like solid oil) and their stress is therefore not transmitted to other wires; the structure becomes non-critical to the number of wire breaks.
2. There are no high contact stresses between wires in a string and, consequently, there is no local wear, wire defects, overstrain zones, etc.
3. Elasticity module of a string will be equal to that of steel –  $(2-2.1) \times 10^6$  kgf/cm<sup>2</sup>.
4. Absence of elasticity requirements makes it possible to use a wire of larger diameters (3–8 mm), thus, the total surface of a string will be smaller and, therefore, it will be characterized by higher corrosion and mechanical resistance and durability.

All the above qualities will contribute to higher structure durability and reduced consumption of high-strength steel for a string by 1.2–1.5 times compared to a twisted cable.

### **18. What is a probability of string breakage?**

Each string consists of dozens and even hundreds of high-strength wires and is put in a protective envelope, which is filled with anticorrosive mixture. All this is placed inside a hollow steel high-strength rail body filled with solidified filler (for example, based on epoxy resin). On the top, the structure is covered by a railhead, which ensures reliable protection of a string from external atmospheric and mechanical impacts.

Before its assembly, each high-strength wire is subject to marginal checking. Furthermore, a linear SkyWay scheme envisages that under a moving load in a span, the tensile stress of a string

is varied (increased) by as little as 0.1–0.5% (see Fig. 18). Therefore, during the whole service life of SkyWay track, the strain-stress state of its most important component – a string – will be practically invariable (static). This will also contribute to the increased lifetime of the system due to the lack of fatigue accumulation.

All this makes it possible to forecast a longer SkyWay service life as compared to its closest analogue – a hanging bridge, and is estimated to exceed 100 years. In this case, with each string wire working independently of the rest (they are not twisted and placed in parallel to each other in a string), any wire breakage, and even breakage of 50% of wires, would not result in structure collapse. The structure will be supported by wires that remain intact; in addition, their tensile stress will remain the same (variations will be within 1%). Furthermore, as the total tensile force of a string will drop, then its sag on a span will proportionally increase. For example, with 5% of wires broken, the string sag on a span will be 31.5 mm instead of 30 mm (see Fig. 13). The occurred additional unevenness equal to  $31.5 - 30.0 = 1.5$  mm at the span of 30 m (relative unevenness of  $1/20,000$ ) will not affect SkyWay operation.

In comparison, existing cableways have none of the abovementioned advantages – their steel cables are exposed to the aggressive aerial environment impact. They get worn out, especially wires of upper (external) layers, they constantly get broken by rope pulleys, experiencing millions of cycles during their operating life, they are vulnerable to external mechanical impacts such as gun fire, etc. Nevertheless, breakage of cableway ropes with their spans reaching a record distance of 3,000 m is a very rare occurrence.

## **19. What will happen if a track is fully broken?**

It is technically very difficult to simultaneously break (cut off) hundreds of wires that are mechanically protected in the left and right rails and located at the distance of over a meter from each other, including with simultaneous destruction of two rails. Its probability is close to zero. It is easier to blow up a plane; however, they have always flown and will go on flying. It is even more difficult to blow up a rail-string – one needs to try hard to succeed – nevertheless, it is possible. Therefore, let us consider the consequences of this.

The average distance on a track, for example, between high-speed unibuses will be more than 3,000 m. Therefore, a possibility of a unibus being located on a damaged span 30 m long at the moment of track breakage, will be less than  $1/100$ . Moreover, a probability of derailment will occur only if a track is broken in front of the wheels, not behind them – otherwise a unibus will be able to escape the emergency span.

Thus, a probability of emergency situation for one of unibuses is less than  $1/100$ , even if a track is fully destroyed. Other rail automobiles located in front of a damaged section will be stopped in emergency service and sent in the opposite direction, or to the oncoming line, which will be switched to a single-track operation mode.

## **20. What is the reason for high smoothness of string-rail track?**

First of all, what can be smoother than a high-tensioned string? Even originally being unsmooth and curved, it will straighten under tension. All longitudinal members of the track (string, railhead, rail body) always have a stretched out condition, both in winter and in summer.

Secondly, the railhead will be polished to a high precision along its whole length. In this case, any macro-roughness (above 1 mm) will be removed by means of track adjustment, and micro-roughness (under 1 mm) — will be polished.

Thirdly, all loaded components of the track – railhead, rail body, string, support, support foundation – will operate in normal operating modes only at an elasticity stage, without any plastic deformations, which tend to accumulate and reach critical values.

Therefore, SkyWay transport system does not require such operations as packing of sleepers, re-fastening of rails, filling of pot holes in earth banks (as on rail roads) or elimination of track pits and potholes, filling of ruts, breakdowns of the roadbed, heat cracks, etc. (as on auto-

roads). In addition, the railhead in SkyWay transport system will not have a single joint along the whole length of the track during the whole operating life. To be more precise, there will be joints, but they will have no clearances or height drops. In the process of construction, these joints will be welded and then – polished. It will be virtually a “velvet track”.

## **21. What will be the string rail wear?**

Thanks to lower contact tension in the “wheel – rail” pair (15–20 kgf/mm<sup>2</sup> against 100–120 kgf/mm<sup>2</sup> for railways, which is explained by a different, more favourable configuration of wheel support), railhead wear in SkyWay transport system will be less intensive compared to railway transport. It is necessary to point out that rail height wear will be 0.1–0.5 mm after being exposed to 100 mln tons of train load. Apart from that, railhead wear will be reduced due to the following factors: lower wheel loads; more favourable dynamics within a “wheel – rail” contact zone (instead of support “bevel wheel – cylindrical railhead”, there is implemented an assembly “cylindrical wheel – flat railhead” in SkyWay technologies; it not only reduces contact tension, but also significantly lowers wheel rolling resistance); absence of rail breaking stress (under the wheel); high buffer action of all string-rail elements, which excludes any peak dynamic loads, etc. The railhead thickness is designed for the whole operating life of SkyWay transport system (50–100 years). For example, in order to provide the total transportation volume of 2–3 bln tons, the railhead thickness of 20–25 mm is enough.

Moreover, a string rail, or more precisely its head, will be made up of technologically convenient sections along its length (without any clearances). They can be, for example, 20 m long. A worn out or defective part of railhead can be replaced at any time.

## **22. It is known that high mechanical stresses cause material relaxation. Does it pose any danger in SkyWay transport system?**

Indeed, any system, including mechanical one, tends towards thermodynamic balance with time. For example, tensile force in a strained wire under invariable elongation decreases with time. With design stress in a steel string of 100 kgf/mm<sup>2</sup> and the distance between anchor supports of 3,000 m, the initial elongation (tension) of wires in a string will make about 15 m, or 1/200 of its initial length.

Similar initial tension and relative elongation are observed in pre-stressed high-strength wire in reinforced concrete structures, for example, bridge components, as well as in ropes of hanging and cable-stayed bridges, ropes of Ostankino TV tower, bow springs of vehicles, springs in various mechanisms, etc. Pre-stressed wire in pre-stressed reinforced concrete structures is the closest analogue of SkyWay string. It is also straight (in many engineering structures, twisted pre-stressing strands and plies are used, relaxation in which is a result of multi-wire rope squeezing and decrease in its diameter rather than steel relaxation processes) and fixed to form a monolithic whole with the rest of the structure.

Bridge operation experience during many decades showed that relaxation of high-strength steel wire is insignificant and does not pose any danger. In this case, it is necessary to remember that pre-squeezed concrete has a higher degree of relaxation in traditional reinforced concrete structures (unlike in SkyWay transport system). Moreover, beams of traditional bridges are exposed to bending strain, considering that beam height is dozens of times smaller than its length. Therefore, even insignificant additional deformations of a stretched reinforced component (in a stretched zone) or compressed concrete (in a compressed zone of the beam) result in many-fold, much higher beam deflection under load.

In SkyWay transport system, the string, being in fact a pre-stressed reinforcement, is stressed not for concrete but for anchor supports. Therefore, in order for strain in a string to drop, the distance between neighbouring anchor supports shall decrease. Considerable changes will

arise, when drop in pre-stressing makes 10%, i.e. if stresses drop from 100 to 90 kgf/mm<sup>2</sup>. But for this, one of supports shall move for 1.5 m (i.e. by 10% from 15 m), which is unreal. Especially since on the other side of the same support, in this case, the distance to the other anchor support shall increase for the same 1.5 m, which will result in string strain increase at the same section. This, consequently, will prevent the support from any displacement.

In view of the above said, high-strength steel of SkyWay string has more favourable operating conditions. Its minor relaxation, permissible during quite a long time, will be 1–2 orders less dangerous than relaxation of the same reinforced structure in traditional pre-stressed reinforced concrete structures designed for service life of at least 50 years. Therefore, it is possible to conclude that SkyWay system will survive for at least 100 years (like Eiffel Tower, the steel of which is also exposed to relaxation) without any problems.

### **23. What are the intervals between supports?**

SkyWay supports are divided into two characteristic types:

- a) anchor supports, where string anchoring is carried out (Fig. 20);
- b) intermediate (supporting), which carry the track structure in the intervals between anchor supports (Fig. 21).

Depending on local topography and track requirements, the following span dimensions for SkyWay supports are used: 1) in mounted SkyWay transport: anchor supports – every 2–3 km (if necessary – up to 10 km), intermediate – every 25–50 m (if necessary – up to 1,000 m and more); 2) in suspended SkyWay transport: anchor – every 2–3 km (if necessary – up to 10 km), intermediate – every 200–300 m (if necessary – up to 1,000 m and more).

### **24. Will there be any turns along the route?**

Considering, that local topography does not affect SkyWay technologies, it is possible to design the track in a straight line – to make the shortest route. However, if necessary, the track structure can have a curve both in vertical and horizontal planes (Fig. 22 and 23).

To provide travel comfort (passengers should not feel over-loads at curved sections), the curvature radii of the track shall be at least 10 km for travel speed of 300 km/h, at least 15 km – for 400 km/h, 20 km – for 500 km/h. Steep turns shall be provided if turn radii of horizontal curves are lower. Curvatures can have a smaller radius, about 1,000 m and less, but in this case the travel speed on such sections of the track shall not exceed 100–150 km/h.

A minimal curvature radius is 10 m (at stations, terminals, depots, i.e. in places, where the speed of rail automobiles is minimal). In this case, a rail on curved sections of the track with the radius of less than 100 m will be made without strings (like railway rails). They will be supported by beam or trussed span structures of a usual or a string-type design.

An anchor support can be combined with turns at the station (see Fig. 22) or it can be joint for two track structures at the turn (see Fig. 23).

### **25. Will supports experience heavy loads?**

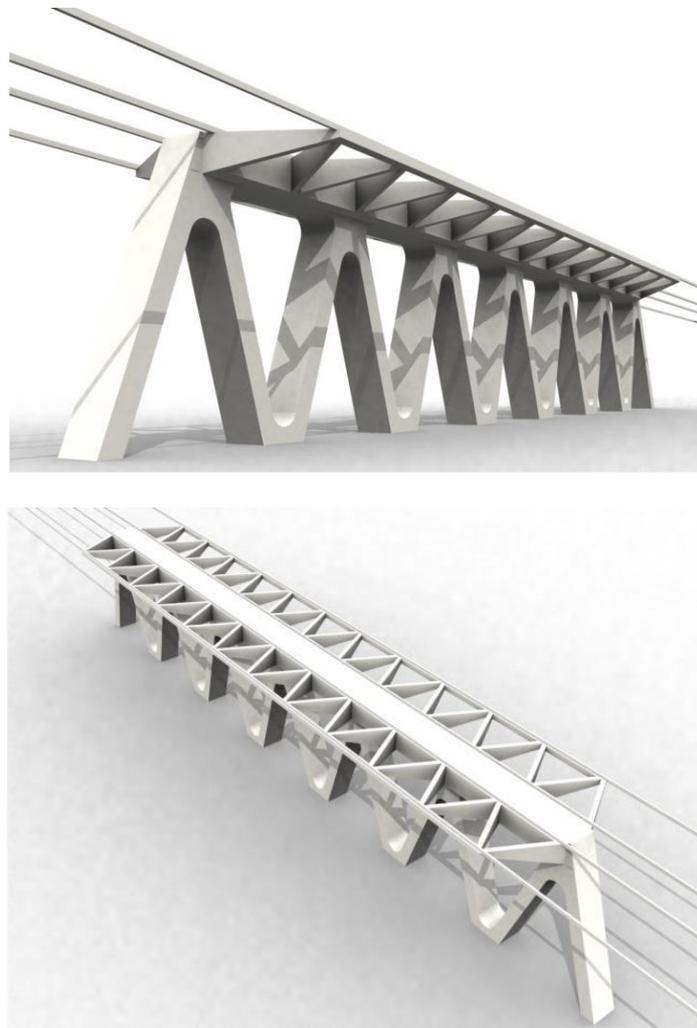
In terms of their structure and loads, SkyWay supports are similar to supports of high-voltage transmission lines, which, as is known, experience the loads that are by several orders lower than, for example, supports of existing highway and railway bridges.

The minimal vertical load on an intermediate support of a single-track SkyWay (considering moving load) is 10 tons (a 40-meter span); the maximal one is 50 tons (a 500-meter span). Anchor supports are designed for horizontal load of a pre-stressed string and rail body. In this case, only terminal anchor supports are exposed to load, whereas intermediate ones, i.e. technological supports (their number is more than 90% of the total number of anchor supports) are

not exposed to horizontal loads in the course of track operation as the string strain is counterbalanced from both sides of the support.

Therefore, the estimated horizontal (longitudinal) stress of, for example, 250 tons per 1 rail and 500 tons per anchor support of a single-track road will be regarded as emergency (in case all strings of the track structure are broken on one side of the support) and technological (in the process of assembly, when the given anchor support is terminal, as the track is not built further). Under normal operating conditions of the track, anchor supports (except for two terminal supports, which are more powerful) will not experience any horizontal stress.

With the increase of rail automobile weight, span length and design speed, loads on supports will increase. However, these loads compared to loads on conventional bridge supports will be insignificant. Supports will also experience additional loads, which are considered when being designed: vertical ones – from snow and ice weight (within 10 kgf per one running meter of the track, or 300 kgf for a span 30 m long); horizontal: a) longitudinal – from acceleration and braking of rail automobiles (loads are distributed onto many supports, including onto, primarily, anchor supports; one intermediate support experiences not more than 100–200 kgf); b) transverse – from wind load affecting rail automobiles, track structure and supports (due to low wind resistance and good aerodynamic streamlining of all specified SkyWay elements, wind loads will be relatively small).



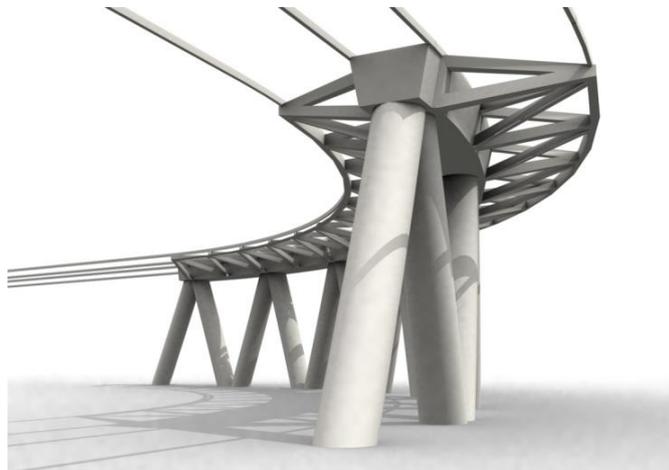
**Fig. 20. Anchor support of double-track mounted SkyWay (variant)**



**Fig. 21. Low-height intermediate support of single-track mounted SkyWay (variant)**

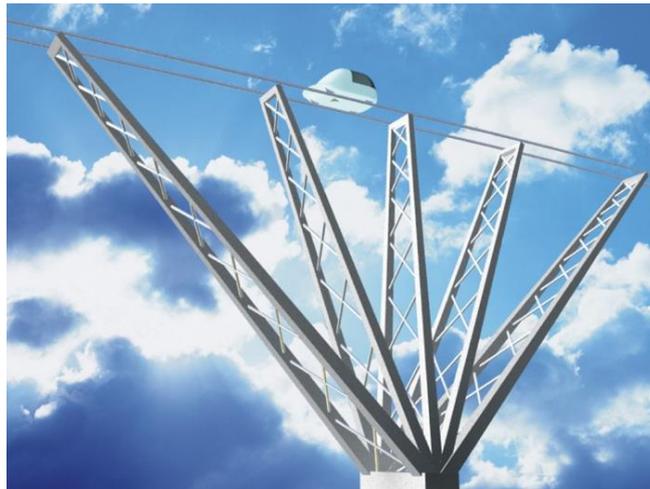


**Fig. 22. Reversal anchor support of mounted SkyWay combined with passenger station**



**Fig. 23. Reversal anchor support of double-track mounted SkyWay (variant)**

## 26. What is the height of supports?



**Fig. 24. High-rise support combined with a long radius vertical curve (variant)**

The minimal height of supports required for safe passage of agricultural machinery, wild and domestic animals under the SkyWay track structure is 3–4 meters. In some cases, the height of supports can be equal to zero, when the railhead is located on the ground level (Fig. 10), and the track structure is installed on a special sleeper framework built in asphalt or in the ground (foundation). The maximal height of supports is only limited by the economic feasibility and can reach the values of 100 m and more (Fig. 24).

The optimal height of supports on a flat and moderate terrain is 5–6 meters. Such height will allow to cross over practically any forest without significant clearings (under the track there will be low-growing plants – shrubs, berry crops, etc.), highways and railways, small and mid-size rivers. In this case, the environment will be exposed to minimal damage. The average height of supports at a rugged terrain will be 10–20 m and more.

## 27. What is the material consumption for supports?

Not much. Supports can be made of reinforced concrete or steel. In the first case, at average supports height of 6 m, reinforced concrete consumption for their construction per one kilometer of SkyWay double-line track will amount to about 200 m<sup>3</sup>. For comparison: reinforced concrete consumption for double-sided fencing of railway mainline alone reaches 750 m<sup>3</sup>/km. Thus, SkyWay supports will be more cost-effective and less material-intensive than, for example, the fencing of high-speed railway (without this fencing, it is impossible to ensure 100% safety, as even a moose, a wild boar or a cow going out on the track will cause derailment).

Comparison of reinforced concrete consumption for SkyWay supports and material intensity of reinforced concrete railway sleepers shows that 1/3 part of railway sleepers is enough to manufacture supports for SkyWay track of the same length. When manufacturing steel supports, steel consumption will not be high, either – about 50 tons/km for a single-line track. It means that steel consumption will be significantly less than the mass of one modern heavy railway sleeper of the same length (per 1 km of the track).

## 28. Are supports subject to swinging? If yes, how could it affect track evenness and travel safety?

SkyWay track structure rests on the superstructure of supports, which can be displaced in three main directions: along the track, across the track and downward. For example, with the support height of 10 m, displacement of the support top in the direction of unibus movement (along

the track) even for 100 mm will result in track bed lowering by as little as 0.5 mm. Thus, it will practically not affect evenness of the track (or with its displacement for 10 mm, such lowering will be only 0.005 mm).

Downward displacement of supports under the structure and rolling stock weight will depend on the structure compression rigidity and carrying capacity of the foundation and the ground. Piled foundation at the depth of 10 m eliminates ground shifts, if a standard pile driven in to the limit of 100 tons is exposed to the estimated load of 20 tons (for pile displacement, it has to be washed out for the depth of over 3 m, which is hardly possible even in case of a flood). Therefore, the estimated vertical displacement of the support top under the most unfavourable combinations of external loads will be within 1 mm; in addition, this displacement will be in its elastic stage, without accumulation of plastic deformations.

Transverse displacements of the support top pose the greatest danger, as they could lead to the side track deformation. In this case, deflection within 5 mm at a distance of 50 m is considered safe, which will provide safe and comfortable movement at travel speeds up to 500 km/h. Therefore, intermediate supports are designed with a higher rigidity in transverse direction than in a longitudinal direction, which under the most unfavourable external impacts (such as gusty hurricane wind, side wheel load, etc.) will cause transverse vibrations of the support within the permissible limits.

To eliminate the consequences of unforeseen displacements of supports (for example, as a result of an earthquake or landslides, etc.), each support is equipped with a system of track adjustment to ensure accuracy of 1 mm.

## **29. What will happen if a support is destroyed, for example, as a result of a terrorist attack?**

It will not result in the accident on the line. The reason is that the track, including the load-bearing string, is uninterrupted. Support failure (each support is fixed to the track structure by a special unfastening device like a lizard tail) will only result in doubling of a span and, correspondingly, in some increased track deformation. As a result, it will affect wheel suspension, but not passengers. Therefore, in case several supports in a row are blown up in a terrorist attack, the track will not be put out of operation. SkyWay transport system is characterized by high survivability, it is equally resistant to terrorist attacks and natural disasters, such as earthquakes, storms, severe landslides, floods, etc.

Even if all intermediate supports are blown up in a row, the track structure between anchor supports will lie on the ground, and it will be possible to move at low speeds on that pre-stressed (strained) structure, lying even on a soft ground.

## **30. What will happen if an anchor support is blown up?**

Taking into account its strength and solidness, not less than 100 kg of tritone and thorough preparations would be required to blow up an anchor support. Nevertheless, it is practically impossible as SkyWay will have a ramified security system, including electronic control for all track and rolling stock components, and visual control such as track observation from a specially equipped helicopter. Security service is capable to promptly trace terrorists' preparations, carry out the required measures to ensure safety, for example by stopping the movement on a dangerous track section.

However, even if an anchor support is destroyed, a SkyWay track will remain operative, as anchoring of strings is arranged in such a way that force transmission to the next track section will be carried out bypassing the support body, through a special steel structural element. It means that even if an anchor support body is broken, continuity of a rail-string track will not be interrupted.

### **31. How safe will be driverless unibuses?**

It is actually a man (or the so-called "human factor"), who is the weakest, most vulnerable and unsafest link in traffic flow control, especially what concerns high-speed transport, where there are dozens and even thousands of participants. The Japanese were one of the first to understand and show it to the world community: over the last 30 years, high-speed railways in Japan have carried more than 5 billion passengers and none of them was killed. Such trains are driverless, they are controlled by electronic devices (for passengers' comfort, models of machine operators were put in cabins in the first years of train operation). This experience was taken into account in SkyWay.

On the first SkyWay tracks, rail automobiles can be operated by drivers, as creation of automatically controlled system can be extremely expensive and not feasible from the economic point of view at small-scale production. Later, with the development of SkyWay track network, they will be transferred to driverless operation.

### **32. How high is the probability of unibus collision on the line?**

This probability is close to zero. Unibuses moving on one line are not expected to catch up with or, let alone, outrun one another: they will move at the invariable speed and distance between them, which exceeds the braking length required for emergency stop.

SkyWay envisages the following 2 braking modes: service braking (acceleration – up to 1 m/sec<sup>2</sup>, braking length at 300 km/h speed – more than 3,500 m) and emergency braking (2.5 m/sec<sup>2</sup>, braking length – 1,400 m). If neighbouring unibuses move in a high-speed traffic flow even at a minimal distance of, for example, 200 m from each other and one of them starts braking with acceleration of 1 m/sec<sup>2</sup> (for which, it is required to engage all its brakes), the following unibus will reach it at a relative speed of 72 km/h in 20 seconds. This time will be more than enough for an adequate response of the control system to an emergency situation, both in manual and automated control modes.

Similar collisions observed, for example, on highways (for reference: every year, about 1.5 mln people die and more than 10 mln become handicapped as a result of road accidents) could be attributed to the following factors:

1. Every car is driven individually, without coordination with and consideration of actions of other road users (overtaking, turns, cars getting too close to each other, driving to the contra-flow lane, etc.).
2. The distance between cars in a flow is insufficient (10–50 m), which is often less than the braking length required for a vehicle stop.
3. Delayed and often inadequate driver's response to an emergency situation on the road, etc.

There are no such reasons for collision in SkyWay system: movement will be controlled from the single center and repeatedly duplicated by linear (located on the track) and on-board computers integrated into the network. Therefore, there is no need to have a driver. In this case, all manoeuvres (stops, drive in or off the track, speed change, etc.) will be coordinated by all traffic users with due regard to the real conditions of the track state, unibus and current weather conditions (wind, rain, snow, etc.). Thanks to this, SkyWay accident rate will be lower than that of existing railway transport and in aviation, where at least 1,000 people die annually as a result of accidents. It means that SkyWay will be several thousand times safer than automobile transport.

### **33. What is the dynamic rigidity of the track?**

For SkyWay, like for any other high-speed transport system, dynamic rigidity is more important than static one. There have been investigated and determined design features of SkyWay track structure, as well as unibus movement modes, where resonance phenomena in a string-rail were not detected (for speeds up to 400–500 km/h). Moreover, track vibrations would arise and be

left behind a moving unibus. They would be damped over 0.1–0.5 sec. to enable the following unibus to move along the undisturbed, ideally even track.

The principles used here are similar to those applied for design of hanging bridges: any component must damp structure vibrations within its frequency range. In this way, all possible structure vibrations will be damped: from low- to high-frequency ones, including from the impact of single unbuses and their flow, wind (including gusty wind), etc. In this case, due to inertness and high strength of high-speed rail-string track, attributed to both string tension and bending stiffness of rail itself, dynamic amplitude of structure vibrations will insignificantly differ from static one, i.e. it will be less than 1/5,000. For comparison: highway roadbed is considered even, if the clearance between a 3-meter rod and road surface will be not more than 10 mm, i.e. such a roadbed has relative unevenness of about 1/300.

At low travel speed (up to 100 km/h), string-rail relative rigidity at a span will be sufficient if it is within 1/1,000.

### **34. Will a unibus moving along the string produce a wave-like motion?**

Firstly, a unibus will move not along the string, but along the rail, which is characterized by higher bending stiffness than that of, for example, a R-75 railway rail, by 1,000 and more times in some cases (when a string rail is designed in the form of a trussed string). Therefore, under a unibus wheel, a string rail will behave rather as a rigid beam than as a flexible thread – under the impact of concentrated load from a wheel, the local curvature (bend) radius of a string-rail will be 1 km and more. Thanks to it, rail automobile wheel rolling will be smooth and shockless, both in the middle of the span and above supports.

Secondly, a modern car or a railway rolling stock, including a high-speed one, can move in a wave-like manner when their track structure is designed as an elevated road installed on supports. As a result of a compromise between the requirements to reduce material consumption for span structures and to achieve maximally high values of track structure rigidity under the impact of designed moving load, there was internationally accepted the normative relative rigidity for spans of bridges and overpasses at the level of 1/400–1/1,000. For example, for high-speed railways it is 1/1,000–1/2,000. Therefore, a wheel of a high-speed train moving along the bridge with a span of, for example, 30 m, will have a sine curve and an amplitude of 15–30 mm and the wave length of 30 m. In this case, a wheel pair of a train is very heavy (its mass is about 1 ton) and a suspension is rather rigid. Nevertheless, travel on a high-speed railway is very comfortable for passengers, without vibration or noise, and is even more comfortable compared to, for example, traveling by bus.

The rail-string track structure is designed based on the norms that are currently used to design bridges, overpasses, elevated roads, viaducts and other transportation facilities installed on supports. Therefore, SkyWay track rigidity will be similar to that of bridges or overpasses for high-speed railways. In addition, rail automobile wheel rolling will be smoother and more silent due to its smaller mass of 40–60 kg. Each wheel will be equipped with an independent and rather soft “automobile” suspension and two flanges, and the wheel rim and hub will be separated by a damper – an elastic polymer cushion.

Furthermore, a string-rail head will have a camber in each span, i.e. upward bending in relation to supports, which in the middle of the span will be 10–15 mm, equal to the value of track deformation under the impact of designed load. Thus, each rail-string span, deformed under the weight of a rail automobile, is flattened to form a straight line, and the wheel will move on an ideally even way.

Unevenness of the track will only arise if a unibus mass is not strictly specified (for example, mass variation in a 20-seat module will reach 2,000 kg as it can move on the track with full load or without load). Another reason is differences observed in string and rail body tension (in winter and in summer this difference can reach 50–100 tons). As a result, during certain periods (strong heat or severe frosts), unevenness of 3–5 mm for some unbuses (over-loaded or empty) could be observed in the middle of spans, with the relative value of 1/5,000–1/10,000. During

some other periods, track unevenness for unibuses with a normative load will be 1/10,000—1/15,000, which is significantly more even than that of a high-speed railway track in overpass design.

### 35. Is a SkyWay rail automobile more economically efficient than a passenger car?

Compared to a 5-seat high-speed passenger car, an electrified unibus SkyWay is characterized by higher economic efficiency (in terms of 1 passenger for the same travel speed) by approximately 20 times: by 3–5 times due to improved aerodynamic qualities, by 2–3 times due to increased engine efficiency (electric engine efficiency is more than 90% compared to real internal combustion engine efficiency of about 30%), by 2–3 times due to increased carrying capacity and by 1.5–2 times due to reduced mechanical losses (especially in a "wheel – road bed" pair: "steel – steel" in SkyWay against "rubber – asphalt" in a motor car).

Specific electric energy consumption of SkyWay in one of design variants is as follows: at a speed of 300 km/h – 0.2–0.3 kW×hour/t×km for freight transportation and 0.015–0.25 kW×hour/t×km for passenger one; at a speed of 400 km/h, respectively – 0.04–0.05 kW×hour/t×km and 0.035–0.045 kW×hour/t×km. The given data refer to rail automobiles with carrying capacity of 4,000 kg and 20-seat passenger unibuses equipped with engines of 60 and 120 kW power (for the speed of 300 km/h), or 150 and 300 kW (for the speed of 400 km/h), respectively. If necessary, it is easy to recalculate electric energy consumption in terms of fuel consumption based on: 1 kW×hour of electric energy = 0.3 liters of petrol.

High-speed rail automobile SkyWay is the most economically efficient vehicle among all known. Its super high economic efficiency is especially visible at low speeds, such as 100 km/h, typical of automobile transport. At stable motion at a horizontal track section, a 40-seat unibus with a 10-ton weight travelling at the specified speed requires the engine power of 9 kW (of which 6.6 kW is required for aerodynamic resistance of the body; 1.5 kW – for wheel rolling resistance; 0.9 kW – transmission losses). Fuel consumption in case of using a diesel engine will be only 2.7 liters per 100 km of the track (or 0.054 l/100 pass.×km, or 0.54 l/1,000 pass.×km). Fuel consumption of the best 4-seat passenger cars is 20–30 times higher – 1–1.5 l/pass.×km.

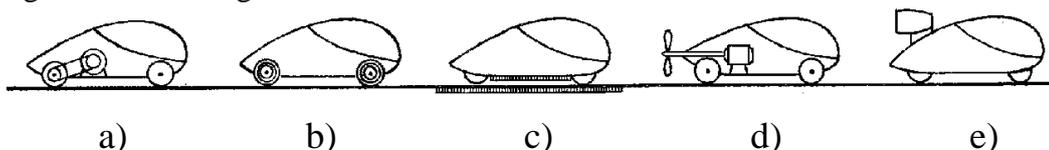
### 36. What are the unibus wheel revolutions?

A wheel diameter of a high-speed unibus will make 50–70 cm, therefore it will have the following revolution speed: at the speed of 200 km/h – 1,500–2,100 rev/min; at 300 km/h – 2,300–3,200 rev/min; at 400 km/h – 3,000–4,200 rev/min; at 500 km/h – 3,800–5,300 rev/min.

Thus, even at high travel speeds of a rail automobile, revolution speed of wheels and their rotating engines will be ordinary for modern technical equipment. For example, revolution speed of turbojet engine turbines reaches the values of 20,000–30,000 rev/min; in this case, turbine blades are exposed to super-high loads and very high thermal impact.

### 37. What types of drives can be used in a unibus?

Fig. 25 shows design variants of unibus drive unit.



**Fig. 25. Rail automobile with various types of drive unit:**  
a), d) – rotation engine with wheel and propeller drive, respectively;  
b) – in-wheel motor; c) – linear electric engine; e) – gas turbine

A SkyWay rail automobile is a variety of a conventional car put on steel wheels. Like a conventional automobile, it can use a diesel, gasoline engine, turbine or combined drive – for example, "diesel – electric generator – energy accumulator – electric engine". If necessary, its engine can work on natural gas, methane, hydrogen, spirit and other ecologically clean types of fuel. Furthermore, SkyWay can be electrified using an external source of electric energy (like a trolleybus, tram or metro). It is also possible to use an autonomous power source — on-board accumulators, energy accumulators of a condenser, molecule or other type, fuel batteries, etc.

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

As a rail automobile drive, there can also be used an external drive – for example, traction cable, which will provide overcoming of slopes at 45–60 degrees at some track sections with particularly rough terrain and in the mountains.

### **38. How intense will be rattling sounds of wheels in motion considering they are made of steel?**

There will be no rattle noise at all, even at high travel speeds as it is the case with modern high-speed railways, where rails are laid down without interruption for the length of over 1 km. A rail-string head is dismountable, i.e. easy to replace, if necessary; it will be laid with no clearances along the whole track length in the form of one continuous string while any micro- or macro-irregularities could be then easily ground off with a special polishing machine.

Thus, absence of clearances in rail joints, improved track evenness, availability of inner and support dampers, a lower wheel mass (springless part of the wheel will have a mass of 30–50 kg against almost 1,000 kg for a train wheel pair on the railway), automobile (i.e. independent) suspension of each unibus wheel (against a train wheel pair, where any vibrations of one wheel give rise to vibrations of the other) are factors, which contribute to extremely quiet and smooth wheel rolling even though it is made of steel. Rattling sound appears not as a result of rolling, but rather as a result of bumps, which follow each wheel separation from the rail head.

### **39. Will wheel bumps be felt when moving through a support?**

No, they will not.

Firstly, a rail-string has no joints on the support and there is no difference between this and other sections of the track. In other words, it will not have a bending point above the support (in contrast to conventional overpasses and bridges, where superstructures have an expansion joint above the support and, consequently, an inevitable bending point in a longitudinal track profile).

Secondly, coming closer to the support, a rail deflection (its relative value will be less than 1/2,000) will be smoothly reducing to zero (at the moment of its movement through a support). Moreover, as a string-rail under a unibus wheel works in bending like a rigid beam (or rather like a rigid thread), a string-rail curvature (bend) radius under the impact of concentrated load from the wheel above the support will be 1,000 m and more; at high-speed tracks, this value is 10,000 m and more. The curvature radius is also significantly influenced by tension force of the string.

Due to these properties, unibus wheel rolling will be smooth and shockless, both in the middle of the span and above the support. In addition, structural upward bending of the track on the span can be designed so that at the moment of unibus passing above the support, the track will not be buckled upward, but buckled inward, with the radius of at least 1,000 m. Therefore, all the more, there will not be any wheel bump when passing above the support.

### **40. Can a side wind blow a unibus off the rail track?**

No, it cannot.

It has been proved by numerous wind-tunnel tests of a unibus (at scale 1:5) carried out at the Central Scientific Research Institute named after Academician Krylov (St.-Petersburg). For example, at the travel speed of 250 km/h and a hurricane side wind (speed of 200 km/hour), the tilting effort will be not high – within 100 kgf – due to high aerodynamic properties of a unibus body. With a unibus mass of, for example, 5,000 kg, it will not pose any danger: such tilting effort cannot break a wheel-rail contact. For rail automobile derailment, it is required to not only bend it, but also tear the wheels from the rail from either of its sides. For doing so, this bend has to exceed suspension travel and the height of wheel flanges. Furthermore, practically all types of unbuses will be equipped with an anti-derailment system, thanks to which a rail automobile will not derail even if it is turned upside down (both the track and the unibus).

#### **41. Is it possible that a unibus flies up at high travel speeds?**

Such risk exists for a near the ground vehicle (moving in the immediate vicinity to the ground surface), which results from screening effect. For example, tilting effort observed in a high-speed sports car is attributed to uneven airflow in the clearance between the car bottom and the road, as well as above the car. In order to compensate this effect, an anti-wing (spoiler) is installed. At 5–10 m height above the ground, a screening effect disappears due to small transverse unibus dimensions; therefore, tilting effort disappears, too.

Furthermore, the body of a rail automobile SkyWay is designed in such a way as to ensure its symmetrical airflow from all sides eliminating any significant transverse forces, including tilting efforts at any standard travel speeds, as well as at a strong side wind.

#### **42. How can a unibus move further in case it broke down?**

In this case, it will be in a few minutes taken in tow by a unibus going behind – each of them is equipped with a special automatic docking device. One unibus, like a locomotive, can pull or push, if necessary, up to five broken rail automobiles.

At high travel speeds, a broken unibus (if it is not braked on purpose) will be slowly reducing its speed moving by inertia for more than 10 km. Therefore, it is quite easy to couple with it after a stop (or at any intermediate speed) – it will take a few minutes. In addition, every unibus is equipped with an emergency electric drive operating from an on-board accumulator. Therefore, it will be able, if necessary, to independently reach the nearest stop or station at a low speed, where it will be removed from the track and sent to repairs.

In extreme case, a special evacuation module will come to the emergency unibus on the same track (or on the counter track) to evacuate passengers and a broken unibus; in case it is impossible – it will lower the broken unibus to the ground. Specially equipped helicopters can also be used for emergency and rescue operations along the route.

Furthermore, evacuation of passengers to the ground can be facilitated with the use of special devices such as rescue chutes, folding (flexible) ladders, etc., which all unbuses are equipped with.

There have been specified a lot of security measures in case a passenger vehicle SkyWay – unibus – breaks down. Obviously, if some accident of this kind happens to a helicopter or a plane, it will be impossible to help them. It will be a disaster with minimal chances for passengers' survival. Therefore, those SkyWay opponents (and there are quite a few of them), who emotionally and even aggressively claim that string transport will become the most dangerous kind of transport, arouse nothing but perplexity. It is quite evident that SkyWay accident rate can be significantly reduced compared to modern world aviation, where at least 1,000 people die annually as a result of accidents. In contrast, what we subconsciously consider to be relatively safe (it will not happen to us!) – a passenger automobile – is in fact more dangerous than the Kalashnikov gun. It is widely known that about 1.5 mln people die and over 10 mln people become handicapped in road

accidents every year, whereas in wars, which are constantly having place on the planet, there are killed about 500 thousand people per year.

### 43. Why are unibuses so small?

In fact, indices of the optimal carrying capacity for high-speed passenger (up to 50 seats, Fig. 26) and high-speed cargo (up to 10,000 kg, Fig. 27) rail automobiles SkyWay contradict the tendencies of advanced transport development, whether it is motor, railway or air transport, which is focused on constant increase in their carrying capacity and overall dimension of vehicles. All this is dictated by the existing problems associated with the need to reduce travel costs and to improve traffic safety. However, consequences of recent traffic accidents, especially of air crashes, are shocking in terms of the number of simultaneous human losses caused in particular by the large carrying capacity of transportation units. At the same time, the cost of transportation is not reduced but, on the contrary, has a tendency to constantly grow on all kinds of transport.

The only kind of transport not affected by the above tendency is a passenger car. As 100 years ago, it has approximately the same carrying capacity and overall dimension. Its dimensions for 100 years have even become less – a passenger car has become lower in height. These are in fact its main advantages, which have made it an individual, family-type and the most mass-scale transportation means (it is difficult to imagine a passenger car of a tram size, for example, for 100 seats).

A unibus is going to occupy the same niche as a passenger car. Therefore, its passengers will not depend on the service timetable on the track – everybody can have their own unibus or can choose to use a public one (analogue of a taxi). Transport system carrying capacity will rather depend on traffic organization on the route than on load-carrying capacity of a vehicle – it is known that the sea is made up drop by drop, and evaporated drop by drop.



**Fig. 26. Passenger high-speed unibus (capacity – 36 passengers, design travel speed – 360 km/h)**

Small SkyWay unibuses are capable to ensure higher carrying capacity of the transport system compared to that of, for example, large-scale and costly railway trains or airbuses, which cannot circulate with high frequency due to their large dimensions. For example, if at the travel speed of 360 km/h (100 m/s) rail automobiles for 20 passengers circulate on the route at a 1,000 m distance from each other (circulation frequency – 10 sec.), the total carrying capacity of the

route in two directions will be as follows: 14,400 passengers per 1 hour; 345,600 passengers per 24 hours; 126.1 million passengers per year. At present, there is no high-speed railway with such workload, although these tracks have been designed for trains with 300–500 passenger capacity.

Cargo carrying capacity of low-speed cargo trains SkyWay (speed up to 100 km/h) could amount to 1,000 tons and more, if necessary. In addition, their optimal wheel load is up to 5 tons as it is in cargo motor transport. The length of such trailer trains could reach 200 m and more. Therefore, cargo tracks SkyWay can be designed with capacity of 100 mln tons and more per year similar to, for example, tracks for ore transportation with heavy trains.



**Fig. 27. Cargo suspended rail automobile SkyWay (capacity – 10 ton, with traction cable)**

#### **44. What is unibus comfort level compared to that of a passenger car?**

Most people spend their active time in a closed and cramped space. Ergonomic qualities of conventional kinds of transport allow passengers to view only the ground surface, roadway, poles, etc.

SkyWay gives people an opportunity to combine an efficient solution of the main functional task – comfortable and quick passengers transportation to their destinations – and performance of aesthetic functions. Large glazed areas, comfortable seats, soft “velvet” track make an ordinary trip pleasant for travelers who have a chance to have a bird's-eye view of the surrounding natural landscapes. Every unibus is equipped with air conditioning system supplied with initially clean air taken at the height of 5–10 m and more, which is free from smell of fuel and lubrication materials, sun-heated asphalt, exhausts of combustion products from car flows, etc. typical of highways.

Passengers will be offered a wide range of additional services such as multi-channel music and TV broadcasting, inter-city telephone communication and Internet, special services for businessmen, passengers with children and people with disabilities. Even the smallest long-distance SkyWay unbuses, whose dimensions exceed those of minibuses, are hermetic and equipped with a system of vacuum or chemical toilets, which exclude waste disposal on the track (Fig. 28).

At passengers' option, expressed in advance, a unibus can be stopped at any of intermediate stations, i.e. every 5–10 minutes, or at any of anchor supports, i.e. every 2–3 km (every 15–30 seconds).

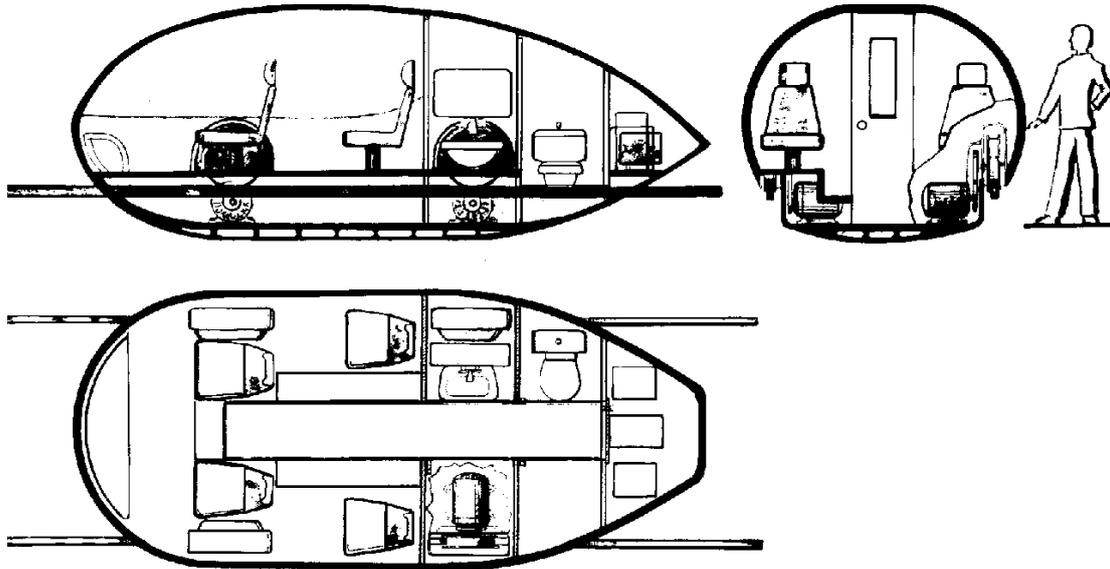


Fig. 28. Four-seat ("family-type") high-speed long-distance unibus

#### 45. Is glaze ice dangerous for SkyWay?

No, it is not, likewise it is not dangerous for railway: contact mechanical stress under a steel wheel exceeds  $1,000 \text{ kgf/cm}^2$ , which ensures ice crumbling and blowing off the railhead, thus, providing its self-cleaning.

By the way, a greater hazard for railway is associated with deep snow rather than with icy conditions, as train wheels fail to reach the rails and a train is put on its "belly". Both snow and glaze ice pose a hazard for a car, as its pneumatic-tire wheels are characterized by small contact stress of only  $5 \text{ kgf/cm}^2$ ; as a result, glaze ice is not crushed and snow is compressed. A motorway surface is not capable of self-cleaning and, therefore, requires special machinery to remove ice and snow.

In contrast, snowdrifts are not dangerous for SkyWay, as even in regions with heavy snowfalls the snow depth does not exceed 3 m, which is lower than supports of SkyWay rail-string tracks.

Tests carried out at a SkyWay test site in the town of Ozyory, Moscow region (see Fig. 46 and 47) proved that icy conditions do not pose any danger for SkyWay. A modified truck ZIL-131 put on steel wheels of 700 mm diameter easily climbed uphill (uphill gradient 1:10) in winter, with ice thickness of 50 mm on the railhead. Ice was specially frozen on, as after the first run of a front wheel it was thrown down off the rail.

#### 46. What is the unibus maximum travel speed and required engine power? What are they limited by?

One of the most important SkyWay advantages is associated with the fact that it does not use the now fashionable but low-efficient, energy-consuming, unsafe and unreliable systems such as magnetic suspension, including with the use of super-conductivity, air cushion, screening effect (aerodynamic ground-effect craft), turbine, jet engine, etc.

A wheel has not yet exhausted its potential, which was proved by a recent record (1997) when an automobile managed to overcome sonic speed (1,200 km/h) for the first time. For

example, energy efficiency of a steel electric SkyWay in-wheel motor is more than 95%, whereas the total energy efficiency of a magnet suspension train ("Transrapid", Germany) is less than 15%, i.e. at the level of a steam-engine locomotive. If we consider energy efficiency of SkyWay steel wheel alone (it is structurally and by its standards significantly improved compared to a railway wheel pair), i.e. if we evaluate only its rolling resistance on SkyWay rail string (which is structurally and by its standards significantly improved compared to a railway rail), then its value will be unapproachable for the systems with electromagnetic suspension of carriages even in the distant future – 99.8%.

Problems arising at high travel speeds are caused not by a wheel, but rather by track evenness; for this reason, bottoms of dried salt lakes are chosen for record routes. A string-rail track for unibus wheels will be even smoother. In addition, there is no need for SkyWay to set up records, as super-high travel speeds in aerial environment are inefficient, non-economical and not harmless for people and nature. Critical SkyWay speed will be limited by aerodynamic properties rather than by its wheel, track smoothness, vibration dynamics or "wheel – rail" friction contact. Therefore, special attention is paid to SkyWay aerodynamic features.

We have obtained unique results, which have no analogues in modern high-speed transport, including in aviation. The aerodynamic drag coefficient of a high-speed passenger unibus model, measured in a wind tunnel, amounted to  $C_x=0.075$ . When determining this coefficient, aerodynamic resistance was correlated to the mid-section – the maximal value of the unibus cross-section area. There have been proposed measures to reduce this coefficient to  $C_x=0.05-0.06$ .

Due to low aerodynamic resistance, an 80 kW engine can ensure a 20-seat unibus travel speed of 200–250 km/h, a 200 kW engine – 350–400 km/h, a 400 kW engine – 450–500 km/h. It should be noted that at high travel speeds in aerial environment, motion resistance power is growing proportionally to the velocity cube; in this case, 90–95% of engine power and more is used to overcome aerodynamic drag.

It is known that as travel speed increases, the wheel–rail cohesion is going down. To ensure the speed of 300–350 km/h, the coefficient of friction in SkyWay "wheel–rail" pair, with four driving wheels of a 10-seat unibus, must be at least 0.04 (the required traction is 100 kgf); to ensure the speed of 400–450 km/h – at least 0.07 (the required traction is 180 kgf), which is easy to reach.

Cohesion problems arise only at SkyWay travel speed of 500 km/h and more, which requires more than 300 kgf of traction. However, this problem is also easy to solve. At such travel speeds, it is reasonable to use the traction of an air pusher propeller put on an electromotor shaft. Modern propellers are noiseless (noise is generated by a plane engine rather than a propeller) and reach 90% of efficiency. At travel speeds more than 600 km/h, it is reasonable to use a vacuum tube, where the air is pumped out to 5–10% of the atmospheric pressure. However, it is a matter of a distant future. For the time being, the speed of 350–450 km/h is quite enough.

#### **47. Will passengers be afraid of traveling at a 5–10 m height?**

Most likely, they will not. This fright has a purely psychological nature, which means it can be overcome with time. There was time when people used to be afraid of traveling by trains, then by cars, and later – to fly by plane at the height of 10–12 km.

The height of unibus location above the ground is not so dangerous as its travel speed. When falling from the height of, for example, 10 m, a body will develop a vertical speed of 14 m/s (50 km/h) when hitting the ground, under the action of gravity. In order to develop a vertical speed of, for example, 450 km/h (125 m/s), it would be required to fall from the height of 796 meters. It is exactly what is happening with planes and helicopters from time to time.

Therefore, it is not important at what height a vehicle will fall from the track structure – it is more important at what speed it will fall. In this case, SkyWay unibus looks best of all, as it is located at about a 10 meter height and equipped with an anti-derailment system. In contrast, a high-speed railway train has significantly more chances to end up in a ditch – a disaster can be caused by a moose, cow or wild boar coming to the railway track out of a forest, let alone an

occasional tractor. Such situations happen quite often with transport systems located on the “first level” – on the ground surface – but impossible in SkyWay.

Strange as it may seem, passengers feel the safest sitting in a car, whereas a car is one of the most dangerous and efficient human inventions as an instrument to kill people. The annual number of people killed in road accidents all over the world (including those who die from after-accident injuries) amounts to about 1.5 million people, and over 10 million people become handicapped for the same reason (according to the data of the World Health Organization; their statistics also show that the annual number of people killed in wars is considerably less – about 500,000 people).

A car is even more dangerous for the wildlife being the cause of death for billions of animals. High accident rates observed in highways are not surprising and they are attributed to various reasons, such as: a pedestrian, who decided to run across the road, or a moose coming in a roadway; icy conditions, spilled machine oil or a snow drift; puncture of a pneumatic tire, especially of a front running wheel; alcohol intoxication or general unwellness, bad mood or absent-mindedness of a driver; pot holes or outside objects on the roadbed; uncoordinated actions of drivers when manoeuvring, especially at turns, by-passes, intersections, etc.

None of the abovementioned reasons of accidents is observed either in SkyWay or in aviation. Therefore, it is not surprising that the number of people killed in air crashes is the lowest (in absolute and relative values; for example, in 2008–2011, the total number of people killed in air crashes all over the world was less than 1,000 people per year). However, SkyWay has no those factors, which result in air crashes: in particular, a bird does not pose any danger for a unibus, whereas even a raven getting in a plane turbine could be a cause of a catastrophe. A unibus is not subject to icing, engine stop, lack of fuel or fuel cutoff, air bumps, thunder storm clouds, lightning, heavy snowfall, glaze ice or a foreign object on a take-off runway, chassis failure, puncture of a pneumatic tire, fog, etc.

Thus, SkyWay has all prerequisites to become the safest mode of transport, which can be appreciated by a passenger when choosing a means of transport.

#### **48. What will happen in case of power supply cutoff?**

At electrified tracks, each rail automobile has an accumulator battery, which will be constantly recharged from the network on the move. In case of de-energizing, power supply will be automatically switched over to accumulators. Their energy reserve is enough for a module to get to the nearest station or to the next not de-energized track section.

At non-electrified tracks, each unibus is provided with emergency-starting electric accumulator-powered drive. Therefore, if a standard internal combustion engine is out of operation, a unibus can reach the nearest station independently using its emergency-starting electric drive.

#### **49. What will happen if a track is out of operation at all and there is nobody to help (war, earthquake, etc.)?**

Every unibus has the main and emergency exit, and each passenger seat will be equipped with a rescue rope of an “Evacuator” type to help a passenger descend on the ground. Furthermore, every unibus will be equipped with an extension ladder and an emergency hose to enable quick evacuation of passengers from the “second level”, if necessary. In these cases, an emergency electric drive and control system will ensure a unibus stop not in an arbitrary place, but in a safe place, where there is a possibility for safe passengers’ descent to the ground surface.

#### **50. What is the maximum angle of ascent?**

On a plain track, SkyWay movement is analogic to movement of other kinds of rail

transport – a unibus wheel rests on its supporting part similar to a wheel of a conventional train. Friction forces in the “steel wheel – steel rail head” pair will ensure a steady ascent with the gradient of up to 150‰ (15%), if all unibus wheels are driving. At high angles of ascent of 200–300‰ (20–30%) and more, every unibus must be equipped with an additional group of drive rollers clenching string rails with the pre-designed side force. This provides additional friction forces and traction. With special unibus design, it can move up even vertically likewise an ordinary lift in multi-storeyed buildings.

Naturally, design of a rail on mountainous track sections will be different from that on a plain section. The same is true about the unibus itself, its chassis and wheels. In this case, a more powerful engine is also required. However, all this will allow to overcome mountains and mountain passes in a straight line, eliminating hairpin turns or tunnels.

At mountainous track sections, there can be additionally installed a traction rope, and a rail automobile will be equipped with special grippers to enable fixing to the rope. A traction rope, which has its own external drive, will ensure, if necessary, ascent of rail automobiles at a gradient of up to 500–600‰ (50–60%) and more.

### 51. How are terminals and stations designed?

One of the design alternatives envisages that terminal stations have a ring-shaped design with a moving (rotating) platform or floor (Fig. 29). Diameter of a terminal station is about 60 m, which could be extended to 100 m and more (Fig. 30) to cope with the high passenger flows (more than 100,000 passengers per 24 hours).

Intermediate stations (Fig. 31) and terminals (Fig. 32) with intensive passenger flows will be equipped with turnout switches and sheds to enable the circulation of unbuses independently of the traffic schedule. Stations with small passenger flows may be designed as open platforms located on the route. Embarkation (disembarkation) of passengers on them is facilitated in the course of braking of single not fully-loaded unbuses.

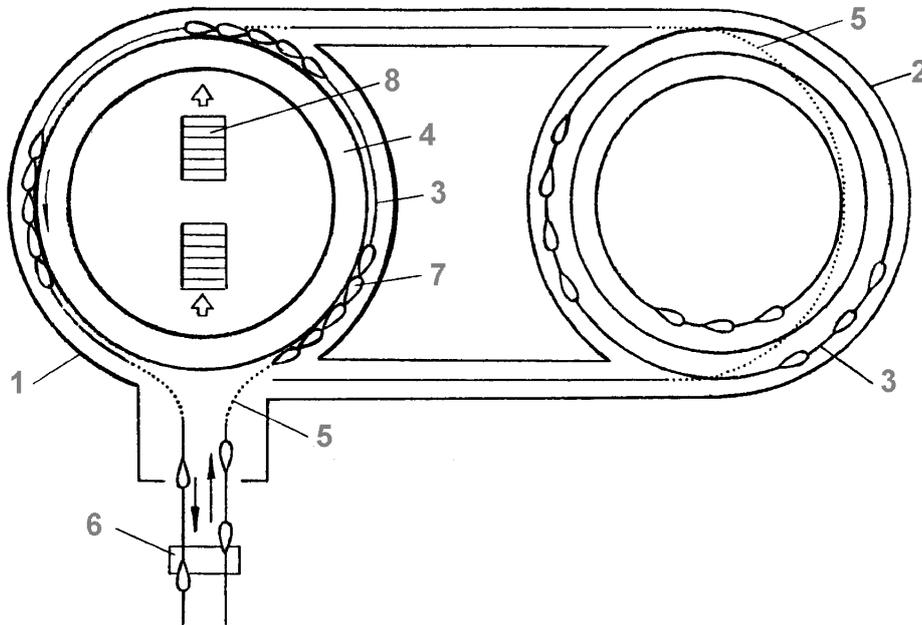


Fig. 29. Scheme of a ring terminal (variant):

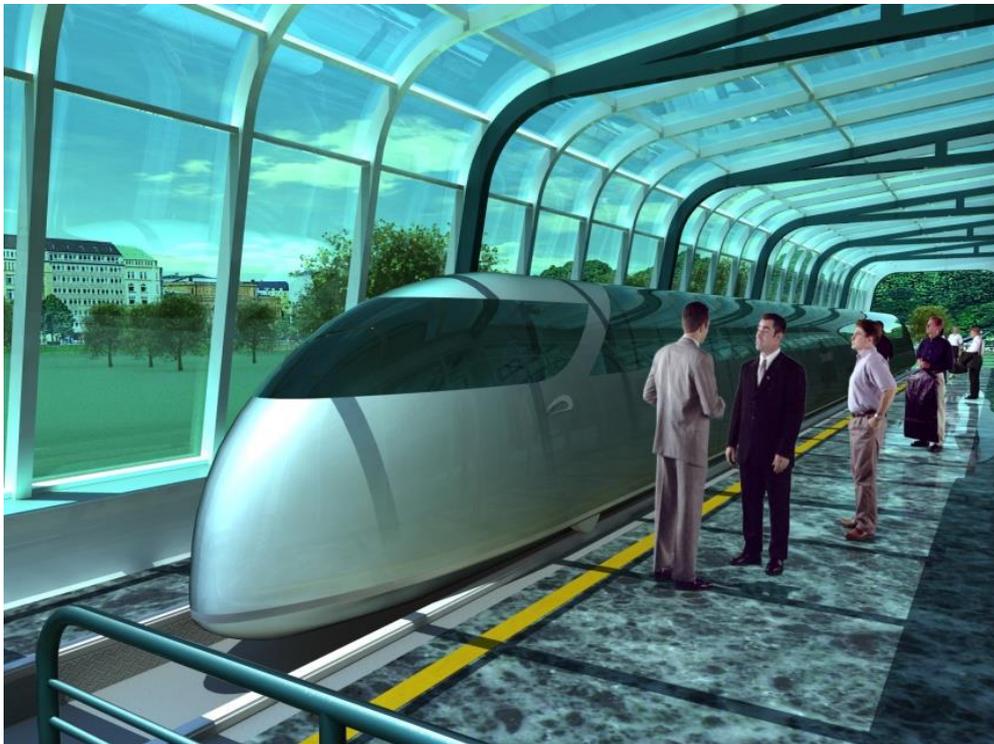
- 1 – terminal building; 2 – depot building; 3 – ring track; 4 – ring-shaped moving platform;
- 5 – turnout switch; 6 – terminal anchor support; 7 – unibus; 8 – entrance (exit) to the terminal.

## 52. How embarkation and disembarkation of passengers is arranged at the ring terminal?

A passenger entering the terminal hall pays attention to luminescent display panels, which accompany each unibus (the display panels are fixed on a unibus or on the wall of the hall in the form of a running line) to indicate the terminal station name, for example, "Terminal". If a passenger fails to find the necessary destination station, he can get into a vacant unibus and press "Terminal" button on the control panel (at each chair inside a unibus). At the speed of the moving platform 0.5 m/sec. (with a unibus joined to it) and 50 m diameter of the ring track, passengers will have up to 2.5 minutes to board a unibus.

When the cabin is closed (automatically or manually), a unibus is detached from the moving platform and directed to the line by a turnout switch. If for this or that reason the cabin was not closed or no passengers boarded a unibus, it returns to the second round. Passengers are disembarked at the destination in a similar way but in a reverse order.

In its general form, this scheme reminds a luggage delivery scheme at circular transporters of modern airports. If necessary, some unibuses are sent to a depot located either in a separate building or on the other floor of the terminal.



**Fig. 30. Passenger terminal station**



**Fig. 31. Interchange station from intercity to urban SkyWay route**



**Fig. 32. Two-level station at the intersection of double-track SkyWay route**

### **53. How are freight terminals arranged?**

Freight terminals intended for automatically controlled loading and unloading of freight unicars have a ring-shaped design, like passenger terminals. They are characterized 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, bulk and piece freights. For example, a terminal with about 100 m diameter will have a carrying capacity of about 100,000 tons of oil per 24 hours (36.5 million tons per year), and it is considerably smaller in size than, for example, a sea port of similar carrying capacity.

#### **54. What is a maximum throughput capacity of a high-speed route?**

For the rolling stock consisting of five 20-seat minibuses (with 100 m distance between them on the route), travel speed of 360 km/h (100 m/sec.) and circulation frequency of 60 seconds, the maximum carrying capacity of one track (one line) during the rush hours will be 12,000 passenger/hour (288,000 passengers/24 hours or 105 million passenger/year). In this case the route will have a reserve to increase its carrying capacity by 3–5 times without the construction of additional lines, due to the increase of the number of minibuses in one rolling stock (up to 10 pcs.) and reduced traffic interval between them (to 20–30 seconds).

Urban SkyWay routes, both mounted and suspended types, can be designed for passenger traffic of 20–30 thousand passengers/hour or more, i.e. at the level of a traditional underground metro. The capacity of urban minibuses for such lines of the "second level" can be up to 100 people.

Minimal on-line distance between single freight unicars on a speedy line will be 50 m (provided one module stays on one span), therefore, the maximum carrying capacity of one line with the freight carrying capacity of one module amounting to 5 tons will be 36,000 t/hour or 864,000 t/per 24 hours (315 million t/year). For a double-track route, the maximum carrying capacity will be respectively 72,000 t/hour, 1.73 million t/per 24 hours and 631 million t/per year.

Any SkyWay route – urban, inter-city, freight, specialized, both mounted and suspended types – can be designed, if necessary, to ensure transportation volume of 1 million people per day or 1 million tons of cargo per day. This is on one haul distance. The network of the "second level" routes will have a significantly larger volume of transportation. For example, if they build in Moscow a network of SkyWay "air metro" with the total length of about 1,000 km (about three times longer than the lines of the Moscow subway), its carrying capacity can be at the level of 30–50 million people a day (with an average trip distance of 12 km, as it is today in the Moscow subway).

The actual volume of high-speed freight and passenger traffic will be by one order lower, therefore, SkyWay routes will be operating at 10–20% capacity, which, in the end, will contribute to higher durability, reliability and safety of the transportation system performance.

#### **55. Can the freight SkyWay carrying capacity be higher than that of an oil pipeline?**

Its maximum carrying capacity (in one direction) is up to 200–300 million tons per year, and the net cost of oil and condensed gas transportation will be even somewhat lower than that of oil and gas pipelines. In this case, it is possible to use airtight return containers of, for example, 10,000 kg capacity, equipped with an electronic card with the information indicating oil composition, extraction site, etc. This will prevent mixing of oil extracted in various oil fields as it occurs nowadays, but to refine light, high-sulphur, high-paraffin and other oils separately. Whereas a conventional pipeline (gas pipeline) is capable to transport only oil (gas) and only in one direction, SkyWay is capable to transfer alongside with them ore, coal, sawn timber and other raw materials, and backwards – food products, building materials, equipment, refined petrol products (such as gasoline, diesel fuel, etc.), as well as shift workers, etc., etc.

Moreover, the cost of a SkyWay route will be even lower than that of an oil pipeline of the same carrying capacity. Loading and unloading of oil and gas containers will be arranged on an automated duty in small-size freight terminals of about 100 m diameter.

#### **56. What kind of freights will it be possible to transport by SkyWay?**

Actually, SkyWay is capable to transport almost any indivisible cargo of up to 10 tons at high speeds; up to 20 – 30 tons – at reduced traffic speeds (up to 100 km/h), up to 40 – 50 tons – on a special multi-wheeled platform. Therefore, SkyWay is appropriate for 99.9% of the bulk freights such as: oil, petrol products and other fluid cargo, coal, ore and other bulk cargo, food

products, furniture, rolled metal products, building materials and structures, chemical products, special freights (condensed gases and cryogenic liquids, radioactive and explosive substances, weapons), etc., etc.

We have designed a range of special containers, docking with maritime, railway and automobile containers for liquid, bulky, piece and special cargo. Containers for perishable goods, for example, food products will be equipped with a temperature control system (in winter) and air conditioning (in summer); containers for environmentally hazardous freights will have a multi-layer high-strength body frame, etc.

## **57. Is there a risk of leaf falling caused by a unibus rushing above a forest?**

This question was asked in 1997 at the State Science Committee of Belarus by its Chairman, after the SkyWay author was supported by the President of the Republic of Belarus (since the Chairman of the Committee remained unconvinced, the inventor received from him not support and assistance, but opposition).

No, leaves will not fall. We shall not even feel any air vibration standing at 10–15 m distance from a unibus rushing at 450 km/h speed. It is attributed to its high aerodynamic qualities (aerodynamic drag coefficient is  $C_x=0.075$ ) and low module energetics (average engine power — about 200 kW). In terms of physics, any land transportation system has a zero efficiency coefficient – and SkyWay is not an exception here – because it has zero useful transportation work: with zero cargo speed at both departure and destination stations and stays approximately at the same height above sea level. In the end, all energy supplied to the land vehicle engine is ejected into the environment in the form of track and adjacent ground vibrations, abrasion of the gravel cushion, noise, rattle of wheels, air gusts, etc., and it all is ultimately converted into heat.

Therefore, environmental impact is determined rather by the intensity of energy ejection per 1 unit of a track and the type of this energy, than by the travel speed. SkyWay is characterized by the lowest energy ejection intensity compared with all other types of transport, for example, at 360 km/h speed per 1 unit of a track amounting to 1,600 joulemeter or 380 calories/m (against 4,000 joulemeter for "Mercedes-600", the closest to SkyWay in terms of its dimensions and speed, though this Mercedes will not be able to reach 360 km/h speed; for a high-speed train – 80,000 joulemeter, i.e. 20 times more). SkyWay energy ejection is also characterized by the most favorable type; a velvet, joint-free track, high damping, light weight of wheels, etc. will exclude rattle of wheels; the ideal shape of a vehicle body form will eliminate aerodynamic noise (high-frequency vibrations caused by turbulent air flows, air flow imbalances, etc.).

Energy will be mostly ejected in the form of added air mass movement. Since this air mass is relatively large, air movement will be in the form of a slight wind blow with its velocity decreasing proportionally to the square of the distance from the running unibus. Moreover, a SkyWay route will be rather free than full of unbuses – an immovable observer will see a vehicle passing by at high speed in portions of second with the next one coming only in 1–2 minutes (at the traffic intensity of 20,000—50,000 passengers per 24 hours). Therefore, the average energy ejection intensity from SkyWay into the environment will be very low amounting to 15–30 W/m×sec.

## **58. What are travel limitations by weather or any other factors?**

There are none. SkyWay is not afraid of fog, rain, thunder storm, snowfall, hail (travel speed can be reduced under heavy hail to avoid damages in a nose part of a module; though armored modules can be used in hail hazardous areas), icy conditions, sand and dust storms, hurricane wind. SkyWay is likely to withstand a tornado twister, which could be attributed to its high-strength track structure, very low windage area and high streamlining qualities not only in construction components but also in a transportation module. For example, modern building

structures, such as reinforced concrete bridges, are not stable to tornados, whereas SkyWay structures are characterized by tenfold higher specific strength, i.e. estimated per 1 unit of surface.

SkyWay is more than any other transportation system resistant to natural disasters, such as earthquakes, landslides, heavy rains, floods, river overflows, tsunami, and the advance of desert sands. SkyWay 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, etc.

SkyWay design alternatives for various geographic conditions are given in Fig. 35–40.

### **59. What is the traffic intensity on a high-speed route?**

To enable the transportation of passenger flows of 20,000 passengers per 24 hours in two directions, the average distance between two consecutive 10-seat unibuses (or 20-seat unibuses at 50% loading) moving at the speed of 300 km/h should be as follows: 7.2 km (or 86 sec.) for the flow of 20,000 pass./24 hours, 2.9 km (35 sec.) – for the flow of 50,000 pass./24 hours; 1.4 km (17 sec.) – for the flow of 100,000 pass./24 hours. To ensure the two-way freight traffic, the average distance between high-speed freight unicars of 4,000 kg carrying capacity will be as follows: 1,150 m (13.8 sec.), 580 m (6.9 sec.) and 290 m (3.4 sec.), respectively.

### **60. Are the routes provided with turnout switches?**

A SkyWay route will be equipped with turnout switches for super high-speed (for the travel speeds of 350–500 km/h), high-speed (200–350 km/h), speedy (120–200 km/h) and low-speed (under 120 km/h). For example, high-speed switches will be installed at terminal approaches and departures. It will enable non-stop circulation of transit unibuses without deceleration and stops, bypassing the terminal (without entering it). Such switches will be designed as elaborate engineering structures having the length of more than 100 m.

Other sections of a route (including stations and stops) are provided with medium-speed turnout switches to make unibuses slow down at their approaches. In this case traffic control system prepares special time and place for this maneuver, which implies certain compression of a transportation flow ahead and behind a unibus to give it 1–2 minutes for maneuvering alone at several kilometer distance from the nearest unibuses.

Low-speed switches, as the lowest costly and safest, could be installed more frequently, actually at each anchor support. It makes it possible for any unibus to stop practically at any route spot allocated for this purpose (information about the stop is to be provided at least 5–10 minutes before it, so that a control system could smoothly re-arrange the transportation flow).

In structural terms, SkyWay turnout switches are close to the railway turnout switches, though they have their peculiar features defined by the two-rim wheels or an anti-derailment system with lateral thrust support rollers.

In addition, alongside with horizontal switches, vertical devices are also possible as due to the small weight of a rail vehicle it is easy to transfer it to the other level of a transportation junction (up or down).

### **61. How can a passenger get off the track if its height is, for example, 10 m?**

It is much easier and safer than to leave a plane flying at 10,000 m height, because a plane is unable to unload its passengers between the airports. A SkyWay passenger can get out not only in the terminal or a station, but also in the interval, at any anchor support, i.e. on the average in every 2–3 km. While boarding a unibus, a passenger gives a command to the onboard computer (by voice or digital code) about his destination. If the passenger's choice for leaving is a 10 m support 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).

After getting off the unibus, the passenger lets it go, primarily informing the traffic control system (using onboard computer) about his departure time from that place and destination. There cannot be the slightest doubt that the ordered unibus will be waiting for him at a strictly fixed time – the computer will not neglect his order.

Embarkation and disembarkation of passengers at terminals and stations is much easier: you get in (or out) a unibus coming to the terminal building (like at modern bus stations). In this case, the track height has no significance as it could bypass the terminal, perhaps, even several kilometers away from it. High-speed accesses (exits) to the route require acceleration (deceleration) sections of more than 1,000 m length, therefore, turnout switches will be located several kilometers away from the terminal. A passenger will arrive to it not by the main route, but by the branch line, which, if necessary, could enter the terminal building not at the height, but at the ground level.

Emergency modes for passenger evacuation from a breakdown unibus are described above.

## **62. Isn't it boring for a passenger to see flashing structures, trees, etc. in the window?**

In a plain, the highest point of a mounted SkyWay is its rail-string with a moving unibus, therefore, there are no structural components before the passenger's eyes (unlike railways or highways). One of the main reasons to lay down certain sections of a route at the height of 20–30 m and more is associated with the need to keep trees safe and sound under the track, i.e. below the level of the passengers' eyes giving them a possibility to enjoy a bird's eye view of natural landscapes with a convenient observation sector of 100 m ahead and on both sides of the route.

## **63. Are there any problems in electrified SkyWay routes associated with "rail — wheel" current collection at high travel speeds?**

No, there are not, similar to the high-speed railways that are provided with two (not one) current collectors installed on the top (overhead contact wire) and the bottom (rail) and all the problems are at the top, where current is collected from the immovable and flexible copper wire. At high sliding speeds of current collector, its trolley wire is sparking, burning, and transversal and longitudinal vibrations appear in it, as it has to transmit electric power estimated at hundreds and thousands of kilowatts through a point contact moving at speeds of hundreds of kilometers.

At the same time a train wheel is rolling (not sliding) along a rail, therefore, electric power is transmitted through a stationary contact (a wheel surface has zero speed within its contact zone with a rail) which has no clearances thanks to the high contact force pressing a rigid wheel to a rigid rail. This "wheel – rail" current collection scheme is most reasonable in SkyWay (left "wheel – rail" – right "wheel – rail"), other variants of current collection are also possible, including that with the help of a contact wire. In this case, current collection conditions are more favorable for SkyWay – current collector requires about 200 kW input power, which is by one or two orders less than for an electric train.

SkyWay may have a traditional contact wire laid at the side along one of the string rails or arranged in the interval between the left and right string rails.

## **64. It is known that a strong, especially gusty wind is capable to destroy power transmission lines. And what about SkyWay?**

The SkyWay track structure and supports are characterized by higher strength than high-voltage power transmission lines by several orders at approximately equal windage area. Taking into account low windage capacity of the SkyWay structure and unbuses, the relative track sagging at a span of the mounted SkyWay track structure under the effect of a side wind of 200 km/h speed will have the value of about 1/5,000 which will not have a serious impact on the

transport line operation.

The SkyWay track structure and supports are designed in such a way that they exclude resonance effects in them under gusty wind, which otherwise could result in their destruction caused by a stalling flutter. The basic distinction of the mounted SkyWay track structure (of course, in addition to its rigidity) from power transmission lines is related to the fact that a sag of the wires in spans of power transmission lines reaches several meters and they could be easily set swinging like a seesaw. In the mounted SkyWay (see Fig. 13) this sag is estimated at several centimeters and it is "enclosed" inside the rigid and ideally smooth beams (rails) that in their turn are cross-fixed to form a spatial structure (the left and right string rails are connected with each other by cross-bars and create sufficiently rigid frame). It is difficult to swing this structure even by a hurricane, therefore, it is possible to design a SkyWay route resistant to any wind, even to tornado waterspout.

## **65. Where else is it possible to use SkyWay?**

SkyWay could be used as a low-speed (under 100 km/h) special purpose transportation: internal transportation to serve logging operations, transportation of ore, slags and production waste to dump pits, at the development of sand and gravel quarries, coal, ore, oil, gas and other deposits, for garbage removal from cities to waste deposits, etc.

Lack of strict requirements to speedy transport, as well as reduction of requirements to traffic safety due to the absence of passengers will decrease the cost of special purpose SkyWay as compared with other high-speed SkyWay routes by 2–3 times and more.

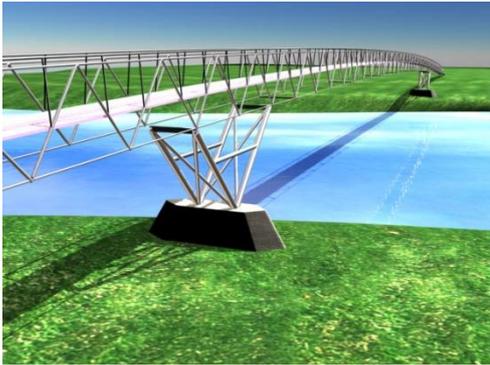
SkyWay technology could be used as a basis to design low-cost and fast-built string pedestrian crossings (Fig. 33), automobile and railway bridges, overpasses, flyovers, ferries (Fig. 34), elevated roads for monorail tracks and trains on a magnet suspension as cheaper alternatives of a string load-bearing structure as compared with conventional beam, truss and guy-roped span structures. In this case, the cost of string span structures will be 2–3 times lower than that of similar beam span structures.

## **66. Is it possible to pass SkyWay routes across the sea? If so, how?**

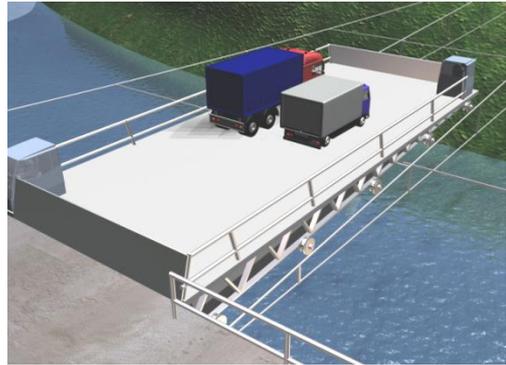
SkyWay can become a universal mode of transportation capable to pass across the land and sea. At sea depths up to 20–30 m, for example, on its shelf, the SkyWay routes arranged on the supports installed in the sea bottom will pass at 10–20 m height and more above the water surface (depending on building requirements to underclearances, Fig. 35 and 36).

At greater depths a SkyWay track can be put in tunnels (pipes) of 2.5–3 m diameter laid either in the sea bottom (under 200–300 m depth) or in the water at about 50 m depth (Fig. 37).

In the latter case tunnels produced by SkyWay technologies (pre-stressed) have zero buoyancy (or to be more precise – slight excessive buoyancy). They require anchoring to the sea bottom in every 1–2 km. Small unibus weight (up to 10–15 tons) and their rare distribution on the route (on the average in every 1,000 m and more) prevent tunnel submergence under the weight of a passing rail vehicle. High bending stiffness and special tunnel design contribute to the high evenness and rigidity of the SkyWay track structure at various travel speeds irrespective of the sea (ocean) depth. The construction costs of small-diameter tunnels placed in the water column, for example, will be by 7–10 times less than for the creation of traditional underground tunnels of metro, which are placed not only in the soil column, but also in the same ground water that is under pressure, because groundwater is present on the land at the depth of 10–50 m practically everywhere.



**Fig. 33. Foot bridge over a river**



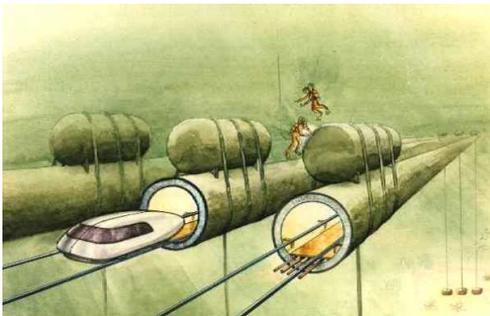
**Fig. 34. Ferry service**



**Fig. 35. Single-track SkyWay route on sea shelf**



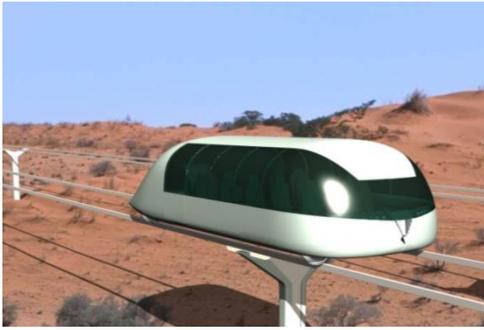
**Fig. 36. SkyWay route along sea coast**



**Fig. 37. Variant of embodiment of sea section at SkyWay route**



**Fig. 38. Single-track SkyWay route along river**



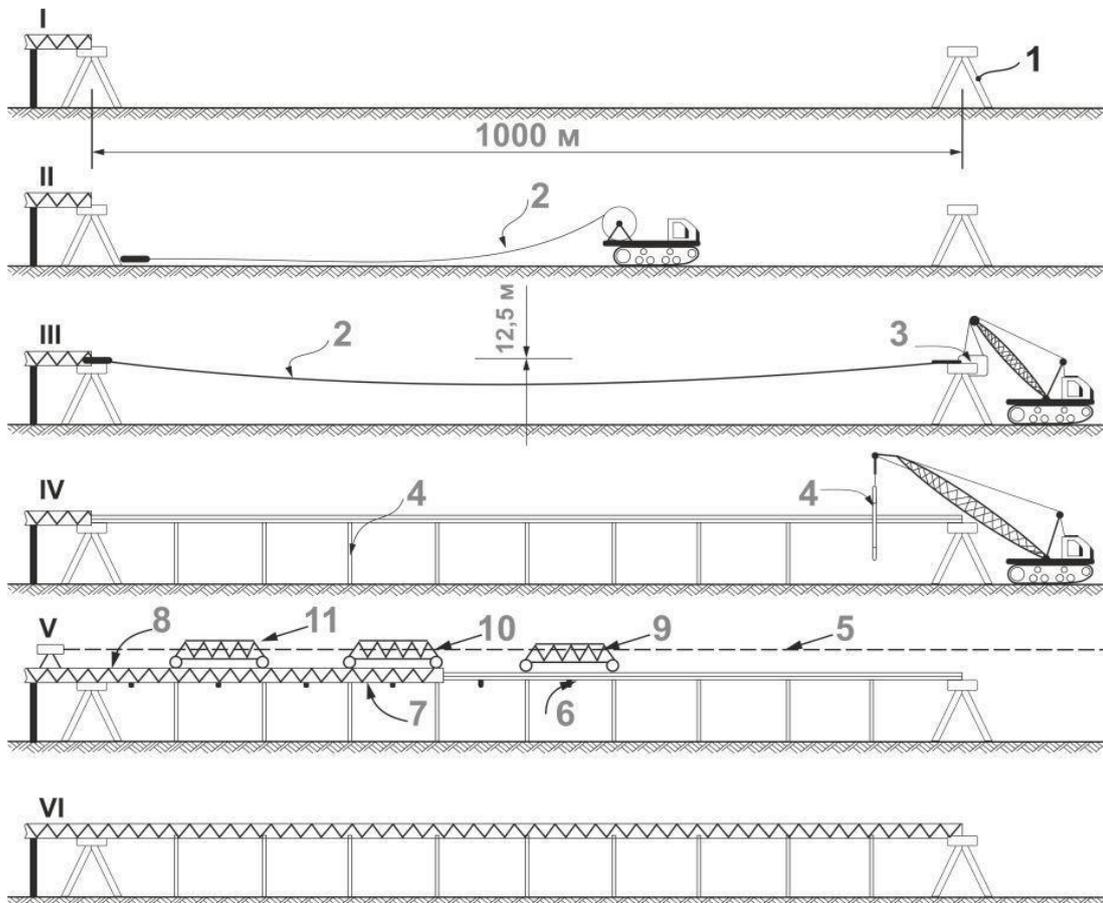
**Fig. 39. Single-track SkyWay route in desert**



**Fig. 38. Single-track SkyWay route in mountains**

## 67. Will SkyWay construction technology be complicated?

In technological terms, it was possible to start SkyWay construction in the 19<sup>th</sup> century, when all necessary structural and building materials, mechanisms and equipment were already available. The technology of constructing a SkyWay route is much simpler than building a bridge with the same span (Fig. 41).



**Fig. 41. Technology of constructing SkyWay route (variant):**  
 1 – anchor support; 2 – twisted or non-twisted cable (string component); 3 – cable stretching mechanism; 4 – intermediate support; 5 – sight line; 6 – cross-bar; 7 – rail body; 8 – railhead; 9, 10, 11 – technological platforms to install cross-bars, rail body and railhead, respectively. I – installation of anchor support; II – laying of string cables along the track; III – string stretching and anchoring; IV – installation of intermediate supports; V – assembly of rail components and track structure; VI – ready track section.

One of the variants of SkyWay construction technology is the following.

A prefabricated string element (for example, twisted reinforcing cable K-7) is stretched to the assigned length with the help of technological devices (with tensile strength or string elongation used as a control parameter) and fixed rigidly at its ends, for example, mechanically (by means of a squeezing anchor unit) or by welding to anchor supports. In this case, not the wire itself is welded, to avoid its weakening, but its special cap at the end of the cable, or the anchor fastening that may be fixed to the support mechanically.

Intermediate supports are preliminary installed on the route: either in the process of string stretching or after it. After the installation of intermediate supports and stretching of strings, they are tested by a technological platform capable to move independently and to record its location respectively to the supports.

Moving from span to span, the platform is used to install sequentially, span after span, the hollow rail body, to fix it in the designated position, to put the filler, to fix the railhead, crossbars and do other works necessary for the track structure installation. All the above works can be easily mechanized, automatized and carried out irrespective of weather conditions during 24 hours. All this contributes to the higher flow-line construction rates (about 500 m per 24 hours), lower labor intensity and net cost.

To eliminate micro-unevenness and micro-waviness of working surfaces of the assembled railhead and its cross gap-free joints they should be grinded away along the whole length. A special multi-purpose machine, moving along the track on its walking support-legs, will leave after itself assembled intermediate supports with the ready string-rail track structure, which will firmly fasten to anchor supports on reaching them.

## **68. What is the cost of SkyWay construction and operation in comparison with other transport systems?**

SkyWay will have the lowest cost among other transport systems if, of course, different transportation systems of the "second level" of similar carrying capacity, comfort level, travel speed, etc. are compared correctly. The cost of competitive transportation routes built on a plain is as follows (including cost of infrastructure, rolling stock and land acquisition): on embankment – USD 30–50 million/km and more, in overpass design – USD 50–70 million/km and more (speed up to 350 km/hour), "Transrapid" system (train on magnetic levitation, Germany) – USD 70–90 million/km and more (speed up to 350 km/hour), modern highway and conventional railroad: on embankment – USD 3–5 million/km and more, in overpass design – USD 40–60 million/km and more (speed up to 150 km/hour), monorail road – USD 50–60 million/km and more (speed up to 60 km/hour).

The SkyWay communication system of the same carrying capacity will be considerably less costly (by 5–10 times) than other known transportation systems of the "second level" which is attributed to its extremely low consumption of traditional (not unique) materials and structures for its track and supports. For its laying, SkyWay does not need earthen embankments, excavations, granular or sand sub-bases, flyovers, bridges, viaducts, overhead crossings, culverts, pedestrian crossings, multi-level junctions and other high-cost structures.

## **69. What is the travel net cost per passenger?**

The net cost of travel per passenger (operating expenses divided by passenger traffic) on a high-speed passenger SkyWay route 1,000 km long at the speed of 450 km/h will not exceed 9 USD excluding depreciation and 18.5 USD including depreciation (calculation is taken from the business plan of «Evraz Transnet" Ltd. for the part of Transnet route 1,000 km long with passenger traffic of 20 thousand passengers/day). Low-speed passenger transportation (up to 100 km/h) will be by 1.5–2 times cheaper.

Thus, the operator of a high-speed SkyWay route will have the opportunity to set the lowest travel fares for services in the transportation industry, not to use government subsidies and, at the same time, get a substantial profit.

## **70. What is the net cost of freight transportation?**

The net cost of high-speed freight transportation by SkyWay will be lower in comparison with other types of high-speed transport, at a sufficiently high average speed of up to 450 km/h.

The average net cost of high-speed transportation of 1 ton of cargo on a plain route at 1,000 km distance will be less than 10 USD (excluding depreciation of transport overpasses and infrastructure) and not more than 20 USD including depreciation.

Low-speed freight transportation (up to 100 km/h) will be by 1.5–3 times cheaper.

## **71. What is the construction cost of 1 km SkyWay route?**

The cost of 1 km SkyWay route will be different. It depends on the following aspects: single-line track or double-line track; high-speed or low-speed; urban or intercity; passenger, freight, cargo-passenger or purpose-designed; mounted or suspended types; ultra-light, light, medium, heavy or super-heavy classes; with frequent stations, terminals, depots, freight terminals and other infrastructure elements or, conversely, their rare location along the route; the type of applied control system: manual, semi-automatic or automatic; the type of traffic organization applied; the type of terrain the route passes across: a plain, mountains or sea shelf, tundra, permafrost or desert; low or high supports; small or large spans, etc., etc.

It should also be noted that the cost of traditional motor-roads, unlike the SkyWay, does not include the cost of rolling stock (cars, buses, minibuses, trolley-buses) and infrastructure (stations, terminals, pedestrian subways, garages, gas stations, bridges, crossovers, multilevel transport interchanges, etc.). For example, on a single kilometer of a modern highway there can be cars worth of more than USD 10 million, which may significantly exceed the cost of the highway itself, not to mention the cost of right-of-way and infrastructure – petrol stations, repair and servicing workshops, car washes etc. In addition, the cost of the destructed fertile soil (the most valuable biological resource of the planet) is not amenable to calculations at all.

Averaging all of these indicators, one kilometer of an equipped high-speed SkyWay double-track route (450 km/h speed) will cost in the range of USD 3–5 million – on a plain area; USD 7–10 million – in the mountains; USD 5–7 million – on sea areas when locating the route over water (on sea shelf) and USD 10–15 million – locating in a pipe (laid afloat in the water column, seabed or under the seabed).

## **72. What is the structure of construction expenses for a SkyWay route of the "second level"?**

A SkyWay complex includes: stationary facilities (terminals, stations, depots, freight terminals, repair garages, sub-stations, control system, signaling, communication, turnout switches) which require 20–30% of the total expenses. The share of a track structure and supports amounts to 50–70% (with 40–55% for a track structure and 10–20% – for supports). Costs for project design – 7–10%, rolling stock – 10–15%.

## **73. Is the cost of fuel and electric energy determining in the structure of the transportation net cost?**

Yes, of course. About 70–80% of the transportation costs, not including depreciation. SkyWay is a speedy transport, therefore a lot of energy goes to the acceleration of speed (by the

way, a much smaller part: the average is by 5–7 times less than in other types of high-speed transport).

#### **74. What costs of building materials and structures are included in budgeting the value of string-rail routes?**

When determining the cost of structures at construction in the Russian Federation, the following enlarged prices were used:

- assembled steel structures, depending on their complexity and steel grade used – 5,000–7,000 USD/ton and more;
- structures of high-strength aluminum alloys – 10,000–15,000 USD/ton.
- assembled reinforced concrete structures – 400–500 USD/m<sup>3</sup> and more;
- assembled concrete structures – 200–300 USD/m<sup>3</sup> and more.

The cost of the terminal stations and process rooms has been calculated based on 2,500–3,500 USD/ m<sup>3</sup> (general construction works plus engineering and technological equipment), 1,500–2,000 USD/ m<sup>3</sup> of the depot and freight terminals area.

#### **75. What will be the cost of a "family" and public high-speed multi-seat unibus?**

The cost of a "family" high-speed rail vehicle (capacity of 3–5 people) on electrified SkyWay tracks can be estimated in comparison with cars, which are most similar both by size and by design.

The electric motors commercially produced for SkyWay with 25–50 kW capacity will be 1.5–2 times less costly than an internal combustion engine of the same capacity, and also – safer, more durable and easier to operate and maintain. A unibus body will be less costly than the car body of the same size due to its simpler design (no radiator, hood, lights, dimensional, braking and other lights, windshield wiper, glass lifting mechanisms, etc.).

Chassis and suspension of a SkyWay unibus will also be easier and cheaper than in a car (no unreliable and expensive pneumatic tyres, wheels turning mechanisms, simplification of torque supply to non-turning wheels, no demand to performance on bad roads, etc.).

The system of control for the motor's rotation and torque on the wheel is approximately equal by cost and complexity in both vehicles (in SkyWay it is the control unit for the motor's rotation, in a car – gearbox, engine clutch, control system for fuel supply to the motor, etc.). The traffic control system of a unibus will be much easier and cheaper than in a car, because the controlled parameters will be not much: speed of movement, distance to the nearest unbuses and the location (coordinate position) of a unibus on the track.

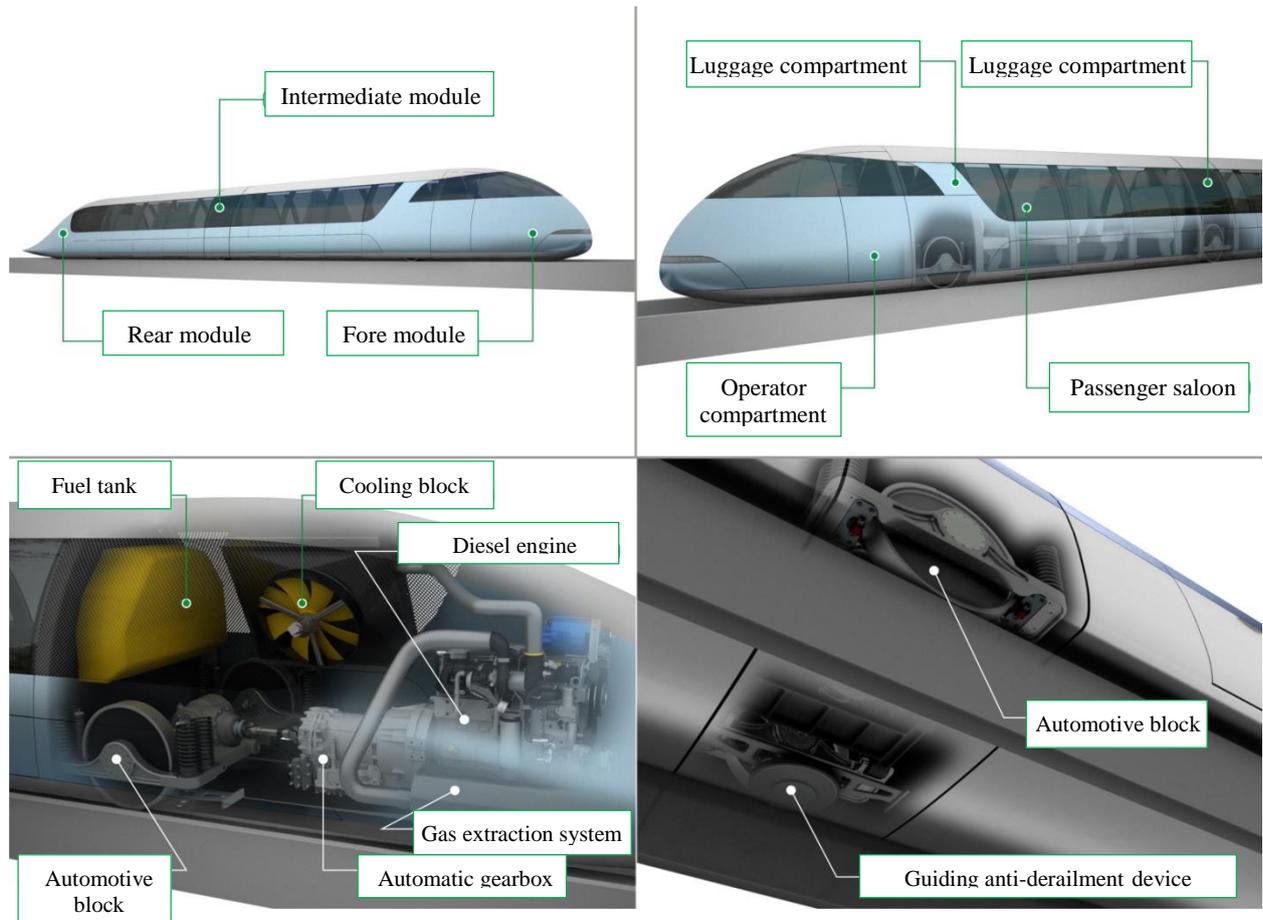
Driving a car is a complicated task, which in spite of the progress of computerization today is only solvable by driver's brain (driver's factor is very important not only for car driving but also for its cost: nowadays people all over the world – millions of people – spend many hours driving a car, though being very short of time). In the SkyWay unibus this problem is solved by a low-cost controller block provided with appropriate software to be controlled and managed by linear computers integrated in a network. The control system of a car, in addition to a driver and executive mechanisms (steering wheel and column, wheel turning mechanism, accelerator, clutch and brakes pedals, gear shift mechanism, etc.), includes a whole system of information visualization necessary for driving control. It is absent in SkyWay, in particular: windshield wipers on a wind screen to provide for its cleanliness and visibility, headlights and sidelights, marker lights, instrument panel, mirrors, horn signal, etc.

The interior design is approximately the same for a unibus and a car and could be varied depending on the customer's desire. In addition, a number of components is absent in the electric SkyWay unibus and in the transport 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 in serial production the cost of an electric "family" SkyWay unibus will be by 2–3 times less than that of a passenger car or a mini-bus of the same carrying capacity and comfort. Therefore, it will be more accessible for individual use (in the future, thanks to SkyWay advantages, it will be possible to develop an extensive network of SkyWay transportation similar to the existing highway network).

A multi-seat (public) unibus will be close in size to modern long-distance buses and in serial production will be not more expensive, if their costs are compared at their same capacity (see Fig. 42, which shows a high-speed unibus driven by a diesel engine).



**Fig. 42. Design version of high-speed mounted passenger unibus**

A multi-seat electric urban unibus will be also close in size and cost to the urban tram of the same capacity (see Fig. 43, which shows the urban suspended unibus driven by the electric energy storage). With the same capacity, the unibus will be 2—3 times lighter than a tram and, accordingly, cheaper.

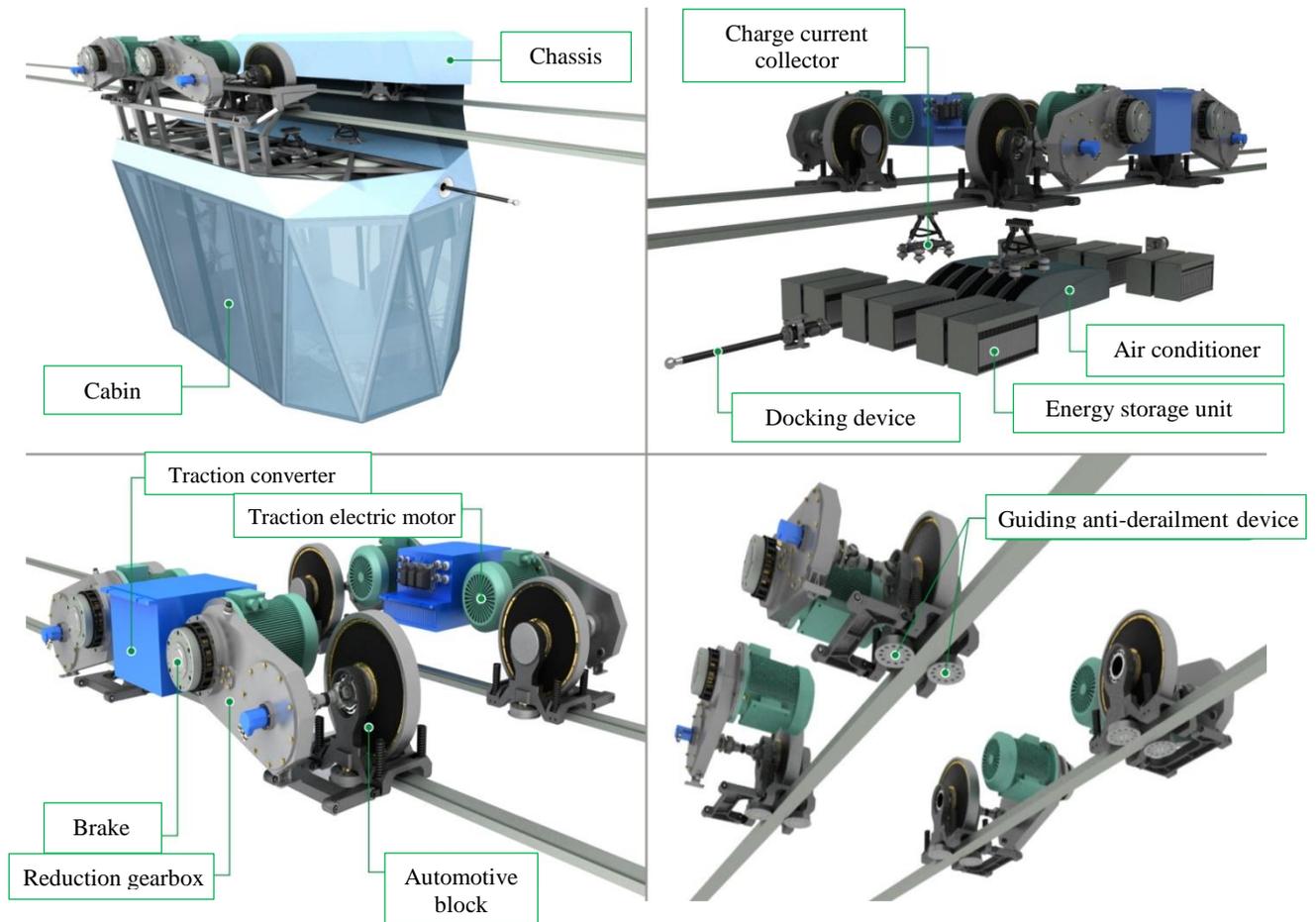


Fig. 43. Design version of urban suspended passenger unibus

## 76. What cost of rolling stock is applied in the calculations?

Depending on the interior, the cost of a passenger unibus for high-speed transportation will be approximately equal in commercial production to an average passenger car – USD 10,000–15,000 per 1 passenger, while unibuses can be made more comfortable than a traditional passenger car. The non-stop travel range of such unibuses is up to 900 km to make the journey time about 2 hours. Unibuses for long trips, equipped with toilets, washbasins and, if necessary, a shower, a bath and other services, will cost more – 20,000–25,000 USD/passenger.

In commercial production the cost of the rolling stock for low-speed freight transportation of industrial cargo (ore, coal, oil, etc.) will be approximately equal to the cost of the conventional rail rolling stock – 1,000 USD for 1 ton of carrying capacity.

Passenger unibuses can be produced against a custom order and equipped like a single or double hotel room or office (furniture, computer equipment, modern satellite, including facsimile, communication, etc.). Thus, in the future a unibus will become not only a means of travel but also a work place (especially for business travelers) and a recreational place in the tourist and other trips.

It should be understood that the cost of a high-speed and safe unibus includes an automatic control system. Therefore, it is incorrect to compare directly such unibus with a more slow-speed, dangerous, less efficient and polluting passenger car, which is controlled by a driver (it costs a lot of money to raise and train a driver, and then to take his time driving a car. Therefore, for a valid comparison, these costs must be taken into account; it costs a lot of money, lives and health of people, taken away by a car. Each year about 1.5 million people are killed and more than 20 million people become disabled and crippled on the motor-roads of the world; by conservative estimates,

these losses amount to more than USD 2 trillion annually and must be somehow correlated with the price of cars).

It is also incorrect to compare a high-speed freight SkyWay unitruck, equipped with a wheel drive and an automatic control system, with a railway wagon that is not self-propelled, but is driven by a locomotive (which also has its cost) and is managed by a team of drivers and dispatchers.

## **77. How fast will a SkyWay route pay off?**

The cost payback of the SkyWay transport system depends mainly on the following factors:

- the workload of the route (volume of passenger and freight transportation);
- normative operation profitability (and related ticket price);
- operating costs;
- cost of fuel (electric energy).

As per calculated to date financial models of "Evraz Transnet" Ltd., the cost payback of high-speed intercity SkyWay routes can be from 3 years and above after commissioning the tracks in operation, even at such low flows, as 20 thousand passengers per day.

At the passenger flow of 100 thousand passengers per 24 hours, the SkyWay route will pay off in 1–1.5 years. Larger passenger flows can be even in such a sparsely populated country like Australia, for example, at the route "Melbourne–Sydney–Brisbane", for which the expert assessment of Australian specialists is 150–200 thousand passengers per 24 hours, if the speed will not be below 350 km/h and the fare will not exceed 200 USD (for the distance of 1,600 km).

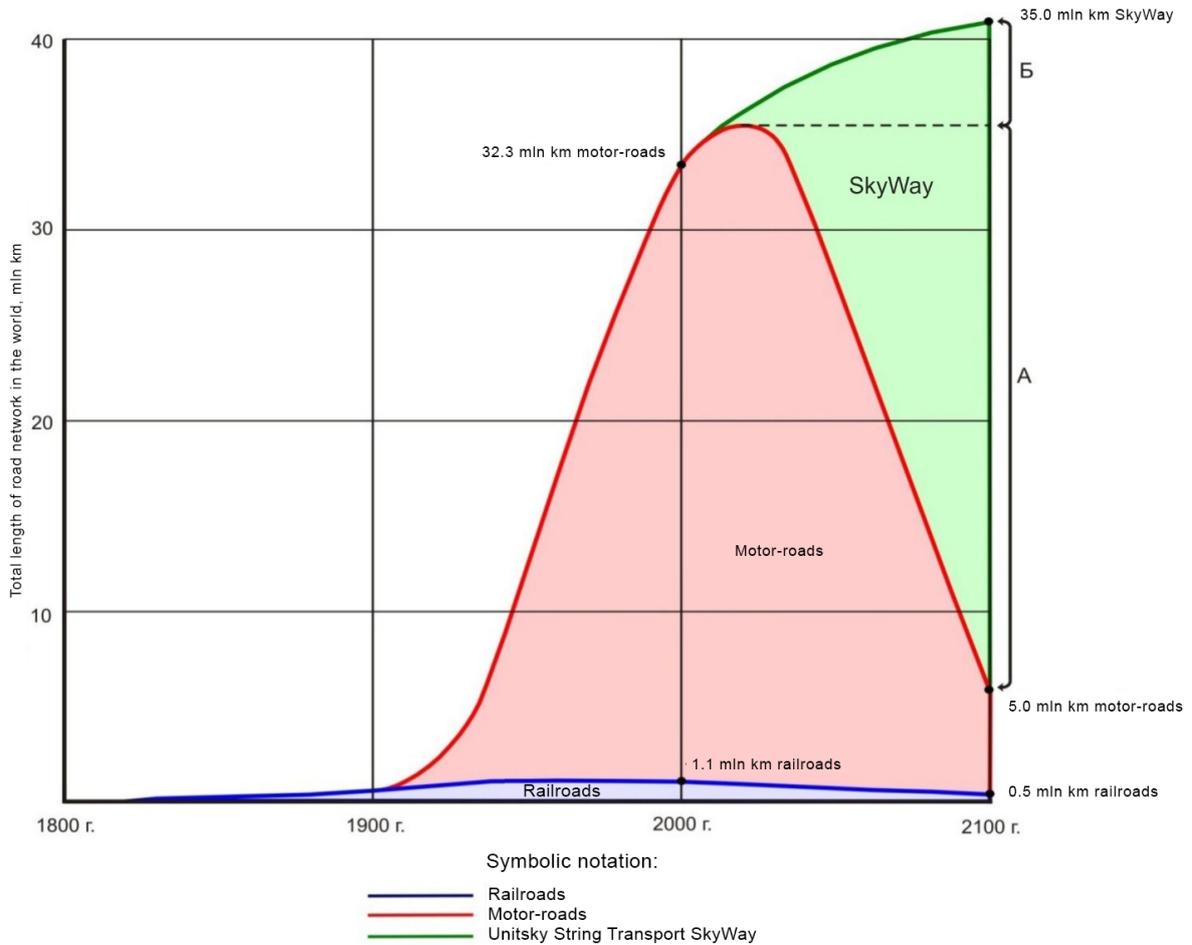
## **78. What niche does SkyWay open in the economy of a particular country and in the world at large?**

Almost a hundred years ago, Henry Ford managed to make a tremendous breakthrough not just in the U.S. economy, but also in the whole world by his program of motorization. The SkyWay economic potential is not lower. In its essence and scale, the SkyWay can also be correlated with the development of modern Internet – it may become the base for the creation of the global transportation "web" Transnet.

The potential niche of string transportation in the world economy in the XXI century exceeds USD 100 trillion, which, for example, is above the capacity of the niche, which was created and occupied within 20 years by Bill Gates with his Microsoft Corp., unknown at that time, and one of the richest people of the planet today. In each of such countries as Russia, China, India, USA the potential volume of orders for SkyWay in the twenty-first century exceeds USD 10 trillion. The forecast for development of the world transport networks, including SkyWay, is shown in Fig. 44.

If the first pilot sections of certified passenger and freight SkyWay are demonstrated in the sales Center of string technologies in 2016, by 2030 the construction of new roads in the world may stop, and their length will begin to decrease approximately at the same rate as their development in the twentieth century, approximately by 300 thousand kilometers annually. With the same intensity, they will be replaced by more effective tracks of the "second level", therefore SkyWay will have to build about the same quantity in the future – 300–350 thousand kilometers a year.

In addition to the replacement of departing roads of the "first level" (during the twenty first century – 25–28 million kilometers, or an average of 350–370 thousand km/year), it will also be necessary to build new routes of the "second level" in previously undeveloped regions and new directions. All new roads in the XXI century will amount to 8–12 million kilometers (of these, 2–3 million kilometers or more – on the territory of Russia), or on the average, 90–130 thousand kilometers a year (see Fig. 44).



A – replacement of outdated and cost-intensive railway and motor roads built in the XX-th century by the new generation transport system of the "second level" – SkyWay (27 mln km)  
 B – SkyWay construction in previously undeveloped regions and directions (8 mln km)

Fig. 44. Forecast for development of global transportation industry in dynamics until 2100

A growing network of SkyWay routes will bring about a considerable additional income from training future employees. The above scope of works, provided conventional B and motor roads, high-speed railways, routes of trains on magnetic levitation and monorails were built, would, undoubtedly, be beyond the power of any largest company, as it would have to employ for this purpose the entire adult population of Russia. For example, the major company "Russian Railways" currently employs over 1.5 million people for the total length of the railway network of only 87 thousand kilometers, or about 20 persons/km.

SkyWay will also create new non-traditional markets with the income part of over USD 100 billion per year. One of such markets – the sale of two natural renewable resources of Russia: high-quality drinking water (lake Baikal, the mineral resource) and Siberian cold climate and natural resource), namely large-scale supply to China, India and other tropical countries of high-quality food-grade ice as a source of drinking water, its properties having no analogues in the world, and – cold in such large volumes, for which power plants in many countries of the world would have to burn additionally and annually several hundred million tons of coal, oil and gas and transmit the generated electrical energy for many thousands of kilometers to multiple air conditioners and refrigerating chambers.

## 79. What is the economic efficiency of the SkyWay large-scale use?

SkyWay is a branch-generating program that has high economic efficiency due to the following advantages:

- significant reduction in the cost of the "second level" tracks and infrastructure;
- significant reduction in the resource intensity of the transport system and cost of the land withdrawn for its construction;
- significant saving of fuel (energy) at the operation of the rolling stock;
- significant reduction of accidents rate;
- significant improvement in the environmental friendliness of the transport services.

If we assume that in the XXI century SkyWay will replace road transport by at least 50%, for this, it would be necessary to build about 20 million kilometers of string-rail tracks (more than 30 million kilometers of motor-roads have been built in the world by today). Since SkyWay is the transport of the "second level", i.e. the track structure is raised on supports above the ground, the savings compared to other known transport systems of the "second level" at similar length will be:

- compared to the monorail roads (they cost 30–50 million USD/km and more): USD 400–600 trillion or more;
- compared with trains on magnetic levitation (their cost is 50–70 million USD/km and more): 600–1200 trillion USD or more;
- compared with motor-roads and rail flyovers (their cost is 30–40 million USD/km and more): 600–800 trillion USD or more.

Today, the cost of developed lands (where roads pass) is from 100 thousand USD/ha to USD 10 million/ha or more (in the cities). On average, about 200 thousand USD/ha. With the inflation rate in land cost rising by 3–5% per year, in the middle of the XXI century this land will cost about 1 million USD/ha. Then the land occupied and withdrawn for the present motor-roads (about 100 million hectares, which exceeds the total territory of such countries as Germany and the UK), would cost around 100 trillion USD (about 3 million USD/ha). If SkyWay replaces the motor-transport by at least 50%, then it would be possible to return about 50 million hectares of land worth of about 50 trillion USD to the land users in the twenty-first century.

High-speed SkyWay rolling stock has the best aerodynamics among all known vehicles, which is confirmed by more than 10 patents for inventions. For example, one of the best sports car from Porsche Co. has the coefficient of aerodynamic resistance  $C_x=0,34$ , while the SkyWay unibus –  $C_x=0,07$  (coefficient  $C_x$  of the unibus was obtained experimentally as a result of repeated blowdowns in a wind tunnel). At the speed of 100 m/sec. (360 km/h), a 20-seat unibus will have the 250 kW power of aerodynamic resistance, but if it had a body contour like the "Porsche" car, this power would have amounted to 1,060 kW. Therefore, aerodynamic resistance power will be reduced by 812 kW, which gives the fuel saving in the amount of 810 tons per year per 1 high-speed rail vehicle (at its consumption of 0.2 kg per 1 kW/hour and 5,000 hours of engine operation per year). At the moderate number of the rolling stock – 1 unibus per 1 km of the route – their required number for the above-mentioned road network will be 20 million pieces. During 20 years of service, the high-speed park of unbuses could save about 320 billion tons of fuel with the total cost of USD 320 trillion (at the average world cost of 1 USD/kg or 1,000 USD/t). For 100 years, the conventional fuel savings will exceed USD 1,500 trillion.

SkyWay will be also one of the safest modes of transportation. Its safety is achieved primarily by the installation of its string-rail track high above the ground, which excludes the possibility of collisions with vehicles of other modes of transportation, pedestrians, animals, etc. It is also achieved by the availability of two flanges and an anti-derailment system on each steel wheel, which makes them stable as opposed to the pneumatic wheels of a car kept on the road by friction force. This is predetermined by the fact that SkyWay is resistant to the impact of hurricane wind, heavy rains, snow, hail, icing, fog, sand and dusty storms, floods, earthquakes, tornados,

landslides and other natural phenomena that could be the cause of human deaths in the course of using the existing modes of transportation. Accident rates at SkyWay will be lower than at aircraft transportation (for comparison, in 2008–2013 the number of deaths as a result of aircraft catastrophes all over the world was less than 1,000 people annually against about 1.2 million people killed and about 50 million injured that became invalids or cripples as a result of road accidents).

If in the XXI century at least 50% of automobile transport is replaced by a safer SkyWay transport, it will be possible to save 60–70 million human lives and to prevent about 1 billion of injured and invalids. If premature human deaths and disability is evaluated by the average world insurance norms at USD 1,000,000 and 100,000 respectively, the total economic effect resulting from the reduced injury rates at transportation within the scale of the global civilization will exceed USD 100 trillion during the century.

Therefore, the economic efficiency of the wide-scale application of SkyWay in the XXI century will be more than USD 2,000 trillion.

### **80. How much does the track cost depend on the relief and terrain features?**

The cost of transport lines is not strongly dependent on the relief and terrain features, therefore, SkyWay routes can be built to develop hard-to-reach areas such as deserts, marshlands, permafrost, taiga, tundra, jungles, ocean shelf, mountains, etc.

For example, if the terrain of rough or mountainous areas require increased average height of supports from 5 m (on a plain) to 15 m, the track cost will be increased only by 15–20%, because the share of supports in the total system cost is small (10–20%). The cost increase will be approximately the same for a SkyWay route passing across a marshland area, desert, permafrost, etc. resulting from the need for additional strengthening of supports and piles, in particular: in a dense bottom of marshland; deep stationary layers of desert sands; below the defrosting depth of piles in summer (specially designed).

### **81. What will be the planetary environmental impact of a large-scale SkyWay application?**

Firstly, consumption of non-renewable energy carriers (such as oil and petroleum products, coal, gas), nonmetals, ferrous and non-ferrous metals will be reduced, which results from the low material- and resource-consumption of the SkyWay track structure and supports. They do not require construction of embankments, excavations, gravel and sand cushions, flyovers, viaducts, bridges, culverts, pedestrian crossings, multi-level junctions and other mineral 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 (10–15 times less than for a car); cautious attitude to vulnerable eco-systems (tundra, permafrost, jungles, marshlands, etc.); possibility to use alternative environmentally sound energy types (wind, sun, etc.) for SkyWay routes services.

Thirdly, alienation of fertile and other lands from agricultural, recreational and residential use for SkyWay routes will be reduced because SkyWay routes do not require large land allocations (less than 0.1 ha/km, i.e. the same as for pedestrian or walking path), and, at the same time, there will be no need for construction of embankments, excavations, tunnels, cutting of woods, reclamation of swamps, demolition of buildings, etc.

## 82. What are the noxious atmospheric emissions as compared with other modes of transport?

The average noxious atmospheric emissions from motor transport and high-speed railways amount to 10 g per 1 passenger/km and about 0.6 g per 1 passenger/km, respectively.

Aviation is responsible for the greatest atmospheric pollution. The total noxious atmospheric emissions from modern aircraft reach 300–400 g per 1 passenger×km. The bulk of aircraft emissions are concentrated within the airport zones, i.e. near 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. Noxious substances stay in the stratosphere much longer – about 1 year. Even conversion to hydrogen aircraft engines will not solve the problem. Exhaust products of these engines, harmless near the earth in the form of water vapor, are converted into ice crystals at upper heights having a screening effect on earth surface.

Noxious exhausts of electrified SkyWay routes will be less than 0.1 g per 1 passenger/km, i.e. lower than emissions from high-speed railways, which results from the lack of dust-generating embankments and gravel cushions, as well as lower deterioration of SkyWay rails, wheels and brake disks.

Moreover, SkyWay vehicles will be airtight, provided with vacuum or chemical toilets to exclude environmental pollution with vital activity products of passengers, 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 strip of land along the highways and railways is exposed to heaviest contamination with passengers' wastes.

The design of freight SkyWay containers excludes the leakage of liquid goods (they have no pumps, breech mechanisms, seals, etc. which could be a source of leakage) and spilling of friable freights. A crash could result in derailment of only one rail vehicle small by size and capacity (the extreme braking distance of the next vehicle will be less than the distance between the two vehicles) with small freight.

At the same time railway accidents sometimes result in the heaviest environmental pollution with hundreds and thousands tons of transported chemical products. Accidents at oil and petroleum product pipelines are often accompanied by atmospheric emissions of dozens of thousands tons of oil and petroleum products, which is especially hazardous for resource extracting northern regions of Russia with their very sensitive eco-system.

Noxious emissions and other key environmental indices of various transport systems are given in Table 2.

Table 2

### Key environmental characteristics of various transportation systems (passenger flow – more than 1,000 passenger/hour, freight flow – 1,000 tons/hour)

Mode of transport	Specific energy resource consumption (liters of gasoline per 100 passenger/km or ton/km)		Noxious substance emissions, kg/100 passenger×km (or 100 t×km)	Land acquisition for transport system, ha/100 km
	Passenger traffic	Freight traffic		
1. Railways (80 km/h):				
• long distance	1.1–1.4	0.7–1.0	over 0.1	300–400
• suburban	1.2–1.5	0.9–1.4	over 0.1	300–400
• urban:				
— underground	1.3–1.7	—	over 0.1	—
— tram	1.9–2.1	—	over 0.1	50–100

Mode of transport	Specific energy resource consumption (liters of gasoline per 100 passenger/km or ton/km)		Noxious substance emissions, kg/100 passenger×km (or 100 t×km)	Land acquisition for transport system, ha/100 km
	Passenger traffic	Freight traffic		
2. Automobile:				
• individual car				
– within a city (average load – 1.6 passengers, average speed – 15–20 km/h)	4.7–6.3	6.6–11.1	above 1	200–300
– beyond city limits (average load – 3.5, passengers, average speed – 80–100 km/h)	1.5–1.7	5.1–9.2	above 1	300–500
• bus				
– within a city (average speed 15–20 km/h)	2.1–2.3	—	above 1	200–300
– beyond city limits (average speed – 40–60 km/h)	1.4–1.7	—	above 1	300–500
• trolley bus (average speed – 15–20 km/h)	1.9–2.5	—	above 0.1	200–300
3. Air transportation:				
• long-distance (900 km/h)	6–10	50–75	above 10	20–50
• local (400 km/h)	14–19	150–200	above 50	10–20
4. Sea transportation (30 km/h)	17–19	0.38–0.95	above 10	5–10
5. River transportation (30 km/h)	14–17	0.57–1.4	above 10	2–3
6. Oil pipelines (10 km/h)	—	0.51–0.57	above 1	50–100
7. Gas pipelines (10 km/h)	—	5.7–6.1	above 1	50–100
8. Conveyer transportation (10 km/h)	—	4.7–9.2	above 1	50–100
9. Hydro-transportation (10 km/h)	—	2.3–4.7	above 1	50–100
10. Cable-rope roads (20 km/h)	0.3–0.5	0.95–1.9	above 1	20–30
11. Train on magnetic suspension (400 km/h)	3.5–4.5	—	above 1	100–200
12. High-speed railway (300 km/h)	2.5–3.5	—	above 1	300–500
13. Monorail (50 km/h)	1.5–2.5	—	above 1	50–100
14. Electrified SkyWay transport (20-seat passenger module, Freight module — 10 tons of load) at speed:				
• 100 km/h (capacity 30 kW)	0.3	0.6	below 0.001	10–20

Mode of transport	Specific energy resource consumption (liters of gasoline per 100 passenger/km or ton/km)		Noxious substance emissions, kg/100 passenger×km (or 100 t×km)	Land acquisition for transport system, ha/100 km
	Passenger traffic	Freight traffic		
• 200 km/h (capacity 70 kW)	0.35	0.7	below 0.001	10–20
• 300 km/h (capacity 150 kW)	0.5	1.0	below 0.001	10–20
• 400 km/h (capacity 300 kW)	0.75	1.5	below 0.001	10–20
• 500 km/h (capacity 450 kW)	0.9	1.8	below 0.001	10–20

**83. Electric energy is not hazardous when consumed by SkyWay, however, is there any environmental pollution when a power plant generates it?**

Hazard is associated not so much with environmental pollution as with the concentration of noxious substances. Air, water and food products contain all chemical elements included in Mendeleev's periodic table that are harmless under certain concentrations. Special survey showed a direct relationship between morbidity rate, especially among children, and the degree of pollution. For example, in experts' opinion this cause (atmospheric 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.

Transport, especially in urban areas is the major source of air pollution caused by atmospheric exhausts thrown out immediately in the human living environment. To have a clearer picture, let us make a theoretical experiment: let us take a low-power transportation vehicle with an internal-combustion engine — a moped — and an electric appliance of similar power, for example, an iron. We switch on both of them in our apartment (their power is equal). In a minute, we will have the following three alternatives:

1. To use a gas mask not to die of suffocation.
2. To switch off a moped and to use a bicycle.
3. To invent a transportation vehicle capable to consume power as safe as an iron, however, excluding the need in pushing pedals as on a bicycle.

We come across similar situations every day and not in theory but in real life, in the home we all live in, which is something more than our apartment, with thousands or even millions of moving vehicles and not mopeds but rather much more powerful and environmentally hazardous cars.

In fact, thermal 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 occurs far from the population concentrations. There are also other, less hazardous or environmentally safe power plants such as hydropower, nuclear, tidal, geothermal, wind and solar electric power stations.

Moreover, SkyWay 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 does not affect the regime of water streams.

There are principal schemes of wind and solar power plants with the vertical axis of rotation, which could be combined with SkyWay 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 SkyWay needs, it is enough

to have an energy source of 100–200 kW/km power or, for example, two wind turbines of 50–100 kW each installed at 1 km distance along the track with their maximum quantity corresponding to the number of supports, i.e. 20–30 units/km to generate the total peak power of 1,000 kW/km and more (for track sections exposed to moderate and strong winds).

Therefore, the total power of SkyWay wind power stations will amount to 1 million kW per each 1,000 km of routes (at the average wind velocity of 10 m/sec.), the net cost of energy generation will be within 0.05 USD/kW-h and the payback period of 5 years. Therefore, in addition to its autonomous energy supply source, SkyWay 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 the required energy supply will be provided directly to consumers through SkyWay.

#### **84. In some cases, diesel is used in the unibus. How much is it environmentally hazardous?**

At the early stages of operating high-speed SkyWay routes, it would be more reasonable to use unibuses driven by an internal combustion engine.

Non-electrified tracks of the "second level" will be less-costly than the electrified tracks by 0.5–0.7 million USD/km, therefore the economic effect from the use of cheaper electrical energy will not compensate the increased capital costs of the construction of the contact network and electrical infrastructure even in the long term. This is because the SkyWay has an extremely high fuel (energy) efficiency, for example, in comparison with road transport – about 10 times higher. Therefore, the cost of fuel (energy) in absolute terms, affects the cost of high-speed transportation on SkyWay tracks to a considerably lesser extent.

The established opinion about the fact that electric energy is the most environmentally safe, is not true.

Firstly, the environment is usually examined at the place of electric energy consumption, but not at the place of production. For example, in Yugra electricity is generated at large thermal power plants by burning hydrocarbon fuel. In this regard, such a power plant is no different from an internal combustion engine, because they have the same efficiency factor – 30–35%.

Secondly, mechanical energy in the unibus is transmitted directly from the internal combustion engine to the wheel. The loss is only about 10% – in the gearbox and reducing gear. At the power plant mechanical energy is transmitted from the steam turbine to the electric generator (about 90% efficiency factor), then the resulting electrical energy is transferred along the chain: "the step-up transformer – high-voltage transmission line – step-down transformer – low-voltage power line – feeder cables – transformer substation on the route – contact network – current collector – electric motor – reducing gear". The energy loss in this chain is at least 50% and sometimes much more.

Thirdly, from the point of view of minimization of harmful emissions from burning fuel, a more efficient way is its burning just on board of a high-speed vehicle, but not in the firebox of a power plant, because in the latter case, it will require at least two times more fuel. In addition, the refinement of products from fuel burning in the internal combustion engine of a vehicle, for example, by Euro-5 standards, is not worse than their refinement in waste treatment plants of power stations, and the concentration (the amount of emissions in one point of space) – will be by thousands of times less.

Fourthly, the emission of toxic components at thermal power plants should be added by negative environmental consequences from environmental impacts of powerful electromagnetic radiation from very long high-voltage power transmission lines, as well as environmental losses from significant additional land acquisition for them. Moreover, environmental losses from the involvement of considerable additional natural resources – from copper and aluminium to steel – mining and processing of which produce an additional negative effect on nature. Besides,

significantly greater resources are required for stationary power plants and for the conversion of thermal energy into mechanical work. For example, the expenses for the rated capacity of thermal power plants are at least 2–3 thousand USD/kW (for nuclear power plants – not less than 5 thousand USD/kW), while the cost of a modern internal combustion engine, mounted in a car, is only 150–250 USD/kW.

Fifthly, Chernobyl dispelled the myth of safety and low cost of electric energy. The net cost of producing electric energy from the positions of a global (rather than local) ecology and safety should include environmental impacts not only from the accident on the Chernobyl NPP, but also from acid rains due to coal burning in the fireboxes of power plants and the destruction of millions of hectares of soil and forests under the "man-made seas" of hydroelectric power plants, etc.

In the future, when electric energy becomes truly environmentally friendly, safe and cheap, high-speed intercity SkyWay routes might be additionally electrified, and the electric drive will be mounted in minibuses.

It is planned to use only the electric drive in urban SkyWay routes, as more appropriate. From the standpoint of urban residents, such transport will be environmentally safer.

Table 3 shows the daily emissions of toxic components by a fleet of high-speed SkyWay minibuses on the route "Khanty-Mansiysk – Surgut" (the route distance is 250 km), and, for comparison, Table 4 shows the same emissions by a fleet of minibuses "Gazelle" (modification GAZ-322132, 13 passengers capacity). Tables 5 and 6 show similar data, but based on 1 km length of the route. The calculations are performed for the traffic volume of 5,300 passengers/day. Estimated speed: minibuses – 285 km/h, minibuses – 90 km/hour. Toxicity standard: for minibus engines – Euro-5 (introduced in the European Union in the period 2008–2009, in Russia – in 2013–2014), for minibuses "Gazelle" – Euro-2. The minibus engine is Cummins (USA) with 114 kW capacity (for a 16-seat minibus) and 90 kWh – for a 10-seat minibus.

Table 3

**Daily emissions of toxic components  
by a fleet of high-speed SkyWay minibuses on the route "Khanty-Mansiysk — Surgut"**

Unibus passenger capacity, persons	Emissions of toxic components, depending on the type of fuel, kg/day											
	diesel				petrol				propane-butane			
	CO	HC	NO <sub>x</sub>	Solid particles	CO	HC	NO <sub>x</sub>	Solid particles	CO	HC	NO <sub>x</sub>	Solid particles
10	50.2	19.2	83.6	0.84	128.0	38.4	25.9	0.076	77.8	27.5	21.0	0.1
<b>Total</b>	<b>153.8</b>				<b>192.4</b>				<b>126.4</b>			
16	39.7	15.2	66.2	0.66	101.2	30.4	20.5	0.06	61.5	21.7	16.6	0.08
<b>Total</b>	<b>121.8</b>				<b>152.2</b>				<b>99.9</b>			

Table 4

**Daily emissions of toxic components  
by a fleet of minibuses "Gazelle" on the route "Khanty-Mansiysk — Surgut"**

Type of fuel: petrol, kg/day				
CO	HC	NO <sub>x</sub>	Solid particles	<b>Total</b>
1059.0	208.4	236.5	30.5	<b>1534.4</b>

Table 5

**Relative emissions of toxic components  
by a fleet of high-speed SkyWay unibuses on the route "Khanty-Mansiysk — Surgut"**

Unibus passenger capacity, persons	Emissions of toxic components, depending on the type of fuel, g/day×km											
	diesel				petrol				propane-butane			
	CO	HC	NO <sub>x</sub>	Solid particles	CO	HC	NO <sub>x</sub>	Solid particles	CO	HC	NO <sub>x</sub>	Solid particles
10	200.8	76.8	334.4	3.36	512.0	153.6	103.6	0.3	311.2	110	84.0	0.4
<b>Total</b>	<b>615.4</b>				<b>768.3</b>				<b>505.6</b>			
16	158.8	60.8	264.8	2.64	404.8	121.6	82.0	0.24	246	86.8	66.4	0.32
<b>Total</b>	<b>487.0</b>				<b>608,6</b>				<b>399.5</b>			

Table 6

**Relative emissions of toxic components  
by a fleet of minibuses "Gazelle" on the route "Khanty-Mansiysk — Surgut"**

Type of fuel: petrol, g/day×km				
CO	HC	NO <sub>x</sub>	Solid particles	<b>Total</b>
4236.0	833.6	946.0	122.0	<b>6137.6</b>

The most environmentally safe fuel for unibuses is propane-butane – oil-dissolved gas (see Table 3).

For comparison, Table 7 presents toxic substances contained in tobacco smoke from smoking one pack of statistically average cigarettes (Table 7 shows only the strongest carcinogens and toxins out of 12 thousand different substances and their chemical compounds contained in cigarette smoke). The toxicity of these compounds can be judged, for example, on the assumption that the average lethal dose for humans is: for nicotine – 60–80 mg, for hydrocyanic acid – 80–100 mg.

Table 7

**Carcinogens and toxins contained in tobacco smoke  
from smoking one pack of cigarettes**

Substance	Quantity, mg/pack
CO	200–460
NO <sub>x</sub>	2–12
Formaldehyde	0.4–2
Acetaldehyde	8–28
Methanol	1.6–3.6
Hydrocyanic acid	26
Nicotine	16–60

In the exhaust gases, as in cigarette smoke, solid particles are the most dangerous. When using propane-butane as fuel and at Euro-5 standard of toxicity, 16-seat high-speed unibuses will dispose 0.32 g of toxic solid particles per day on 1 km of the route (see Table 5). About the same quantity of much more toxic substances, such as nicotine and cyanide, is contained in four packs of cigarettes. Therefore, the high-speed SkyWay route "Khanty-Mansiysk – Surgut" by its environmental hazards will be no more dangerous than a thousand smokers, (or, figuratively speaking, not more dangerous than average smokers, who smoke one pack of cigarettes a day, standing by one in every 250 m of the route).

It is necessary to focus attention on the environmental hazards from the existing automobile transport, and not from the SkyWay. For example, the emission of solid particles in the exhaust gases from the fleet of microbuses "Gazelle" in the amount of 122 g/day×km (see Table 6) should be added by 219 g/day×km not less dangerous tiny products of rubber tires wear. Therefore, by the total emission (341 g/day×km) the existing road transport is environmentally more hazardous than SkyWay (at the same volume of traffic, but lower by 3.2 times by the speed of transportation) approximately by 1,000 times. It is equivalent to one million smokers (or average smokers standing by one in every 25 cm on the route "Khanty-Mansiysk – Surgut").

### **85. How much land will SkyWay take away from a land user in comparison with other transport systems, and what damage will the nature suffer in the construction process?**

A high-speed motorway (including separating lanes, numerous traffic exchanges in various levels such as "clover leaf", acceleration and deceleration lanes, recreation parking facilities, filling stations, car washes, etc.) requires land allocation in the amount of 5–8 hectares per 1 km of the road. High-speed railway requires special fencing (on both sides) and noise protective screens (which also poses an insurmountable obstacle for wild and domestic animals, agricultural machines, etc.). In total all these roads require land allocations in the amount of 4–6 ha/km (according to the data on Germany).

Land allocation for modern airports is comparable with right-of-ways for high-speed railway roads, however, lands allocated for this purpose are situated in the immediate vicinity of cities, and therefore they are more costly.

As to SkyWay routes, they do not require embankments, long excavations, flyovers and other similar facilities associated with large land requirements. Land requirements for one intermediate support and one anchor support amount to about 1 m<sup>2</sup> and 20 m<sup>2</sup>, respectively. Therefore, the total right-of-way along the whole length of a SkyWay route will be less than 100 m<sup>2</sup>, i.e. 0.01 ha of land and its conditional width of acquisition strip will be within 10 cm. This is considerably less than land requirements for a pedestrian or walking path.

The SkyWay transport system has a high environmental safety not only during operation but also during the construction phase. SkyWay can be constructed with the help of special technological equipment (technological platforms and combined construction machines) without the use of access roads, as the required constructional materials and elements of structures will be delivered to the place of construction along the finished sections of a track.

In addition, during the construction excavation works may be excluded at all, as they disturb the soil layer, the humus, which has been accumulated over millions of years, because the supports will have a pile foundation. SkyWay may pass without embankments and excavations in any area, while the volume of earth moved, for example, at the construction of one kilometer of a modern highway and railway is 20–50 thousand square meters, and in rugged and mountainous areas exceeds 100 thousand square meters. The SkyWay system is not limited by a span length, therefore, not only a forest, but also separately-standing trees that occur under supports, may be not cut away, because any support can be shifted along the track in either direction during the construction process.

The SkyWay system is characterized by an extremely low consumption of materials for its erection, therefore it will be the most environmentally friendly from a technological point of view. For example, a double-track SkyWay route of an average type, of the same length as a railroad, can be built with the use of materials of two railroad rails and each third railway sleeper. The railroad will have the remaining 2 rails, 2/3 of sleepers, the contact network with copper wires and support pillars, a substantial sand and gravel cushion, earth embankment, bridges, underpasses, viaducts, culverts, etc.

Therefore, the SkyWay construction will not need such number of blast furnaces, ore and ore mines (without which it is impossible to obtain steel and copper), cement plants and factories for concrete products, soil, sand and gravel pits, such a number of motor-road and railroad transportation of construction materials, access roads, etc., that it would create a significant additional, sometimes irreversible environmental pressure on nature.

### **86. How heavy will be the impact of a rail vehicle passing on SkyWay in terms of soil vibration and noise?**

A SkyWay unibus has no projecting parts except its narrow wheels extended by 10 cm from the body; it does not even need windshield wipers and headlights (as it is driverless), which at high speeds could be also a source of noise. The unibus vehicle body has a perfect aerodynamic shape (aerodynamic drag coefficient  $C_x=0.06-0.07$ ), its air flow-around will be symmetrical, without resulting in side or tilting forces, without breakaways and air flow turbulence (that are especially noisy). Wheels could be made of light metal alloys (with 1,000–2,000 kilogram-force per 1 wheel), therefore their total mass will be 30–50 kg.

Thus, the total mass of a railway vehicle will be, for example, by hundreds of times less than that of a train and its length – by tens of times shorter; the mass of a springless part – by tens of times less, the track evenness – much higher (is there anything more straight than a tight strained string?). Therefore, compared with a high-speed train, a unibus will be a much weaker source of noise and soil vibration. The noise will be also reduced due to the fact that the SkyWay track structure has no joints along its whole length, though it has a system of internal dampers and rests on the supports also through a system of dampers capable to reduce and intercept low- and high-frequency track vibrations.

### **87. What are other (non-conventional) hazardous SkyWay impacts, for example, electromagnetic radiation as compared with other modes of transportation?**

Electrified SkyWay routes will be low-voltage lines (about 1,000 V), thus, they will not generate serious electromagnetic pollution and pass at the large height (10 m and more) above agricultural lands, natural reserves and parks. The lack of sliding electric contacts in the "unibus – contact network" pair, low (by tens of times as compared with a railway) electric capacity of the rolling stock exclude environmental pollution by radio interference. The SkyWay system is free of some specific impacts characteristic for aviation, such as powerful electromagnetic pollution from radar stations and radiation (during a many-hour flight each passenger is exposed to additional radiation of several thousand microrentgens caused by natural cosmic gamma-radiation reaching 300–400 microrentgen/hour inside an aircraft against 20mr/h being a standard).

### **88. What are socio-political advantages of the large-scale SkyWay application?**

The major socio-political advantages are as follows:

1. Increased communication possibilities for people (business and personal contacts, tourist trips, excursions and recreation trips including long-term recreation and weekends, etc.).
2. Additional possibilities:
  - application of remote working places without changing habitual place of residence;
  - creation of sustainable residential zones (housing estates) within the walking distance to SkyWay routes;
  - construction of linear cities open to nature along SkyWay routes;

- emergency medical aid;
  - non-interference in traditional people's habits in the sphere of transportation services (for example, a possibility to travel at longer distances with a personal car at a reasonable fare).
3. Individualization of travel with the use of a SkyWay rail vehicle as a personal mode of transport at a more affordable price than a car; in addition, speedier, safer and more environmentally friendly than a conventional car.
  4. Reduced number of accidents at other transportation modes as a result of attraction of a certain part of passenger and freight traffic to a safer SkyWay (annually about 1.5 million people are killed on motor-roads and over 10 million become handicapped or crippled).
  5. Better protection of transportation-energy and communication systems from natural disasters (floods, landslides, earthquakes, tsunami, etc.) and terrorist actions.
  6. Improved transportation qualities:
    - all-weather operation (irrespective of fog, snow, glaze of ice, wind, sand storm and other unfavorable weather conditions);
    - universal use, as this transport will function on both land and maritime sections of transport lines for passenger and freight transportation.
    - this transport will be more affordable, safer, more comfortable, cost-efficient and ecological both for urban, intercity and inter-regional transportation.
  7. SkyWay will contribute greatly to the formation of an integrated, interrelated, more comfortable and safer world.

### **89. What geopolitical advantages will Russia receive, for example, from SkyWay construction in the resource extracting regions of the country?**

About 80% of the industrial potential of Russia is concentrated to the west from the Urals and 80% of its fuel resources – to the east from them. It necessitates to transport hundreds million tons 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 the Pechora coal basin – the largest one in the European part. Its total resources are almost twice as large as those of Donbass. In addition, the Pechora basin is characterized by larger thickness of coal beds, better mining conditions, higher miners' labor efficiency and lower net cost of extraction.

SkyWay will make it possible to increase greatly the export of Pechora coal, especially cleaned one, which is not competitive in the world market at present due to its high cost of transportation to consumers. For example, the cost of American baking coal in shipment ports is 1.6 times higher than the power plant coal delivered from SAR to the Netherlands. The coal transported by SkyWay from the Pechora basin to the port of Kaliningrad would cost by 20–30% less. To whom could the Pechora coal be sold? Naturally, to Scandinavian countries, which today buy it even in the distant Columbia.

As it is known, Sweden has decided to stop construction of nuclear power plants and to replace them by thermal power plants using gas and coal for their operation. It would be reasonable to invite Sweden, which is a long-established and widely recognized supplier of mining equipment, to cooperate with the Russian Federation in the exploration of new areas in the Pechora basin. Similar proposals could be made to Finland, Norway, Germany and other West European countries, as well as the Baltic countries. It will allow the Pechora basin to become the largest base of baking and power plant coal in Europe.

Practically, all mining industry of the Russian Federation is concentrated in hard-to-reach and underdeveloped northern areas. Their development is hardly possible for Russia without foreign investments. For example, the Russian Government prepared a list of 250 relevant deposits with the total raw resources estimated at USD 12 trillion (oil, gas, coal, copper, silver, etc.). Among

gas and oil deposits, the Timan-Pechora basin (region between Arkhangelsk and North Urals with 2.4 billion tons of proven oil resources) is the largest one, from which it is planned to export 75 million tons of oil per year to Europe in the future.

To the East of this region, right over the North Urals, there is one more promising oil basin: the Priobsk oil field (with 2.4 billion tons of assured oil deposits, too) and the neighboring oil fields of Tyumen, where the basic part of all Russian oil is extracted. The development of the Timan-Pechora oil basin entails the development of Priobsk deposit. The SkyWay communication infrastructure, created especially for this purpose, will make it possible to pass over to the development of the sea shelf of the Arctic Ocean with even more extensive oil and gas resources.

Overall, 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 the planetary scale as a result of reduced or fully eliminated dependency of Europe and the West as a whole on the Persian Gulf region. In experts' opinion, those who control these fuel sources will control, for example, Germany as well.

The Yamal peninsula is the youngest region among other vast sub-Arctic areas characterized by extremely vulnerable natural environment. In fact, it consists of a number of huge ice blocks of 50 meters thickness, sort of run aground and overlapped with a 2 meters layer of sea clay. Yamal is situated about 20 meters above the sea level. It is hardly possible to find any other place on the globe, which space is so vulnerable to the impact of modern technologies and which it would be more appropriate to indicate on the maps in white as an icy area rather than in green, which corresponds to lowlands.

According to experts' estimates, more than 6 million hectares 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 up to USD 100 billion. The SkyWay communication infrastructure will make it possible to minimize environmental implications of deposit development in the northern regions of Russia and, first of all, in the Yamal peninsula.

In this respect it should be emphasized that in future environmental impact will be the major factor to determine costs of developing northern regions. It 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 protests from the public and environmental associations. After the relevant nature preservation measures were taken, which is very expensive under permafrost conditions, the pipeline was built, but finally its cost increased to USD 5 billion, i.e. it was by 8 times more costly.

The key question of all northern projects, without exception, is how oil will be delivered from Russia to other countries of Europe. This factor will determine, which region of Europe will develop at fastest rates. The proposed alternative to deliver oil with the help of SkyWay will make it possible to attract the major share of foreign investments to densely populated regions of Russia, which are going to accommodate the SkyWay route, including the Kaliningrad region with its port. In future, the SkyWay route could be extended in north-east and south-west directions to deliver a substantial part of raw resources from the northern deposits of Russia to the West and to bring western industrial goods and food products to Russia.

The SkyWay program is also in compliance with the future plans of oil delivery to Europe from Kazakhstan (50 million tons per year) and Azerbaijan (25 million tons per year), as all the above mentioned transportation communications can be easily integrated through SkyWay within the area of the city of Smolensk. This development concept for northern areas will be of interest not only to oil and gas companies of Russia (in particular, Gasprom), but to the Government of Russia and local governmental authorities (that are currently facing serious environmental problems generated by oil and gas developers and associated with tundra reclamation, which requires hundreds of years). It will also be of interest for the Government of Belarus and western

investors capable to evaluate their investment efficiency (the expected total volume of investments is USD 100 billion).

## 90. How SkyWay could contribute to the solution of demographic problems?

Along the SkyWay routes characterized 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 will not be necessary to cut down forests, to build motor-roads, etc. resulting in the deterioration of biogeocenosis within the construction zone. It will be easy to develop agriculture and environmentally friendly industries here. These will be the spots of rationally organized society. Creation of linear cities will need less capital investments compared with conventional urban development. It will be simply beneficial, because living in normal natural and social conditions will be more important for man than any material possessions. Thus, the first steps will be made towards a new future society built rather on harmony with nature than on contradictions.

It is necessary to remember that land is the most valuable resource used by the existing transport systems (primarily by high-speed ones). In Europe and especially in Western Europe the cost of 1 hectare of land amounts to millions of dollars as it is either withdrawn from agricultural use or allocated at the expense of reduced recreation zones. It is also excluded from possible building development, which results in higher built-up densities and deteriorated living conditions



Fig. 45. Linear city on the sea shelf

SkyWay supports require as little as 0.05 ha/km of land and if they are designed in the form of buildings, which will make a linear city in their aggregate, there will be no need in additional land allocations for the route at all. Moreover, such linear city could be built on a territory still undeveloped but suitable for living, for example, on a sea shelf, along the shore, located at 1–2 kilometers and more distance away from it (Fig. 45).

Each SkyWay anchor support here could be easily integrated with unusual and architecturally expressive facilities such as a high-rise residential building, office center, sea hotel, restaurant, sports and recreation complex. All of them will be linked with each other by a high-speed, all-weather, storm-resistant "aerial" route. Due to the development of the sea shelf, this solution could increase, for example, the territory of Israel by 300–500 km<sup>2</sup> (30,000–50,000 ha) or Japan – by 10,000–20,000 km<sup>2</sup> (1–2 million ha).

## 91. How will SkyWay cross the borders between countries?

SkyWay unibuses run without stops above the ground, therefore, like an aircraft, to cross the borders of states they need only an air corridor. Passengers or freight are to pass through customs at terminal points – departures and arrivals.

For example, provisions of the Russian Constitution related to the free movement of goods

and people are infringed currently in the Kaliningrad region. There are two borders and two customs on the way of this movement to any other Russian region, SkyWay will remove this problem, as Lithuania or Poland (depending on type of routing) can provide only an air corridor for the transit of goods and passenger traffic.

## **92. What is the degree of SkyWay engineering design maturity?**

All the component elements of the SkyWay transport system already exist at present and are working effectively in various branches of technology. For example, a distinctive feature of the project is the creation of a perfectly smooth and very rigid track for the movement of steel wheels of a rail vehicle. This is achieved through steel strings stretched up to high forces, and the bending stiffness of the rail. But such solutions are very close to the design of suspended and cable-stayed bridges, where over the centuries a significant practical, experimental and theoretical potential has been accumulated. It was used in full during the work on the SkyWay project.

In its essence, the SkyWay transportation module is a kind of a car, arranged on steel wheels. The experience of creating cars by the leading world corporations was also used in the work on the SkyWay. However, the poor aerodynamics of a modern car would not allow reaching high speeds in SkyWay. Therefore, our Company has developed and experimentally tested a unique body shape of the rail car, which has no analogues, for example, also in aviation – its aerodynamic drag coefficient is only  $C_x=0.07$  (the solution is patented in several countries).

The degree of SkyWay engineering design maturity at present is such that its performance and feasibility does not arouse doubts neither from the author and product engineers, nor from technical experts. In addition, all the basic units and elements, as well as the technology of constructing string tracks have been tested at the experimental site, built in the town of Ozyory, Moscow region in 2001 (see Fig. 46–47). Successful tests that took place in 2001–2008 at the experimental site, showed full compliance of calculated and real SkyWay features as regards: strength and stiffness of a string-rail track structure; stable and noiseless rolling of the double-flange steel wheel on the string rail; reliability of fastening a steel rope to the anchor collet clamp; stable motion on the 50 mm thick ice specially frozen on the railhead, etc.

## **93. What was the need in the SkyWay test site built in Ozyory?**

The SkyWay test site (see Fig. 46 and 47) built in the town of Ozyory, Moscow region in 2001, was a scientific experiment, like the Wright brothers' airplane in their time, which showed about 110 years ago that aviation is nonetheless possible, and machines heavier than air can fly. However, it did not become a market product – who will buy an experiment in the market? Therefore, the Wright brothers died in poverty, and the business was made by the others – the Boeing company, which in 14 years after their first flight offered a marketable product – an aircraft of the new generation, but not another experiment (the company's founder William Boeing was engaged in the woodworking business until 1916). Then this company kept in its segment about 50% of the world market for years and decades, however, in 2011 this share dropped to 36%.



**Fig. 46. Modified ZIL-131  
on rail-string span 24 m long  
(October 2001)**



**Fig. 47. Modified ZIL-131  
on rail-string span 48 m long  
(November 2003)**

#### **94. How long has the author been working on the SkyWay project?**

About 30 years, but if we take into account its pre-history (work on a general planetary vehicle – a system for the future wide-scale exploration of near-Earth outer space based on non-rocket string principles, which gave rise to the SkyWay idea), the works started 39 years ago.

It could seem quite a long period, however if we recall the history of engineering, both automobile and railway transport had a much longer pre-history. The train on magnetic suspension, the first patent for which was obtained in Germany in 1936, took longer time to develop, although it was financed much better than the SkyWay. Only the Siemens company and the German government spent for it 6.5 billion euros and 66 years of time (until the first order on the line in China on the route "Shanghai – Airport"). The former Soviet Union was also engaged in magnetic suspension, having spent on it about USD 5 billion for decades, but have not built a single kilometer of magnetic routes. The development of the Airbus A-380 has required 20 years and 12 billion euros, according to some estimates – 20 billion euros. More simple inventions, such as photography, required more than 100 years from the idea to implementation. Therefore, an inventor should start to work on such major developments as the SkyWay at a fairly young age – only in such case he has a chance to see his invention implemented with his own eyes.

It took the author many years (about 10 years) only to formulate and develop his idea, to crystallize its essence, to make design models and technical and economic analysis. It took years for calculations, feasibility study, relevant technical solutions, testing of major units and components, specification of own, inherent only to SkyWay standards, etc., etc. Several more years were spent to patent the principal diagram of the string system in the leading world countries and, in this case, the major problem was rather not patenting itself but the lack of financing (this required about USD 100,000). However, according to independent experts' opinion, the cost of non-material assets created by the author during this period and the exclusive right to know-how exceeded USD 1 billion.

Serial (industrial) lack of SkyWay implementation to the present time is attributed to insufficient financial support rather than to the shortcomings of the SkyWay and its unsolved research and technical problems. All works during these 37 years have been carried out at the expense of the author himself and his immediate circle, whose financial possibilities were very limited. The systematic work on attracting investments began only in 2014, when an investing system on the principles of crowd investing (crowdfunding) was created.

#### **95. What are the guarantees for success of the SkyWay program implementation?**

The guarantee is the SkyWay program itself with its powerful initial potential. The success

will not depend even on particular people (and its author as well), on their particular luck or errors in the course of the program implementation. Let us recall first steps in aviation. They were accompanied with numerous errors, unwise solutions, failures to fly up, air catastrophes. Airplanes are still crashing. In spite of it, aviation has created the most powerful niche in the world economy and is not going to give it to anybody else. It started when nothing was actually known even to aircraft designers about aerodynamics, which makes the basis of aviation.

Let us also recall our recent past when the foundations of rocket construction and modern cosmonautics were laid down. How difficult the problems their designers had to solve were! 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 were not afraid of 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, rushing at enormous speed, is capable to land in the assigned spot of another planet traveling at a distance measured by hundreds of millions kilometers. And how about the 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 the solution of this problem as well.

Or let us take another example – a train on magnetic suspension "Transrapid" (Germany), – or more precisely, the problems of its suspension above the route. An ordinary magnet put to a paper-clip, for example, will result in either:

1. A paper-clip remains still lying on the table; or
2. A paper-clip is jumps and sticks to a magnet.

However, there is a third, fantastic alternative with a paper-clip hanging in the air touching neither a table nor a magnet. This particular alternative was realized in the "Transrapid" project. However, this "paper-clip" weighs a hundred tons and moves at 450 km/h speed.

SkyWay is free of similar difficult problems. A string system is based on simple mechanics, in figurative sense it is the "hardware", in which everything is known and tested long ago including a steel wheel with its drive, a rail, a track, a track structure, supports, pre-stressed structure, control systems, etc. Estimates of the track and supports is the subject of structural mechanics used to design bridges, buildings and facilities; movement of a SkyWay vehicle on the rail-string track refers to the dynamics of a pre-stressed building structure added with the dynamics and aerodynamics of a car on steel wheels.

The same is true for other SkyWay problems, which are either solved in modern engineering or are not difficult to solve using the knowledge of the theory and practice of building structures, railway building, highway building, aircraft construction, electric engineering and electronics, etc.

## 96. What are the complex advantages of SkyWay over other transport systems?

The advantages of SkyWay over other transport systems are presented in Table 8.

Table 8

### Advantages of SkyWay

Index	Index relative value	SkyWay advantages justification
1. Average cost of transport system (route*,	100%	SkyWay cost is reduced due to: low material requirements for rail-string track structure, supports, rail vehicles and basic infrastructure components; use of traditional, inexpensive and readily available materials and initial raw materials, machine-building blocks and integral units; high-tech route

\* the cost of routes include also the average cost of land withdrawn from land-users for the alignment of the transport system

Index	Index relative value	SkyWay advantages justification
infrastructure** and rolling stock***): <ul style="list-style-type: none"> <li>• SkyWay</li> <li>• railway transport</li> <li>• automobile transport</li> <li>• monorail track</li> <li>• train on magnetic suspension</li> </ul>	150–200% 300–500% 1,000–1,500% 1,500–2,000%	construction, infrastructure construction and manufacturing of rail vehicles; low cost and high-performance operation (without traffic jams, high-speed and accident-free all-weather traffic, etc.) of rail vehicles (this requires a smaller number of vehicles per unit of transportation work); small area of occupied land and the volume of earthworks.
2. Volume of earth moved during the construction of route with infrastructure: <ul style="list-style-type: none"> <li>• SkyWay</li> <li>• monorail track</li> <li>• train on magnetic suspension</li> <li>• automobile transport</li> <li>• railway transport</li> </ul>	100% 200–500% 400–600% 3,000–5,000% 4,000–6,000%	Decrease in the volume of earth moved during the construction of the SkyWay is achieved due to: lack of excavations, embankments*, bridges, overhead crossings, retaining walls, culverts and other engineering structures; decrease of size and depth of support foundations due to reduced loads on supports, for example, in comparison with the monorail; exclusion of solid roadbed (or rail-sleeper grid in railways), requiring resting on gravel and sand cushion and compacted soil; reduction of the support cross section, for example, in comparison with the monorail – by 2–3 times.
3. Consumption of fuel (electric energy) per 1 passenger per unit of transportation work (at 100 km/h speed of the rolling stock): <ul style="list-style-type: none"> <li>• SkyWay</li> <li>• railway transport</li> <li>• river transport</li> <li>• monorail track</li> <li>• train on magnetic suspension</li> <li>• automobile transport</li> </ul>	100% 200–400% 300–600% 500–1,000% 800– 1,200% 1,500–2,500%	The main reasons for the reduction of fuel (or electric energy)consumption in passenger and freight traffic in SkyWay: low rolling resistance to a steel wheel on a steel rail compared with a pneumatic tire (by 20–30 times); cylindrical resting of a wheel (in the railway the bearing surface of the wheel is a cone); low aerodynamic drag coefficient (blowdowns in a wind tunnel allowed to create the optimum shape); two bearing flanges at each wheel and anti-derailment side rollers (on the railway there is one ridge on the wheel) and the lack of wheel pairs (each wheel has independent suspension); improved aerodynamics of the rolling stock, including due to the exclusion of the screen effect (the lack of a continuous solid roadbed); higher efficiency of a steel wheel compared with electromagnetic suspension; reduction of the weight of rolling stock per unit of cargo; increased evenness of the track surface (due to the exclusion of temperature expansion joints and preliminary tension of strings and the railhead).
4. Consumption of materials for the construction of track and infrastructure and		The main reasons for the decrease in consumption of materials for the creation of the SkyWay (reduction of the system's resource intensity): exclusion of continuous material-intensive and expensive driving roadbed, resting on a gravel and sand

\*\* infrastructure includes: stations, railway terminals, freight terminals, depots, maintenance workshops, garages, crossings, bridges, overhead crossings, interchanges, filling stations, power transmission lines, power substations etc., as well as the land occupied by them

\*\*\* there is taken into account the average cost of passenger and freight rolling stock per 1 km of roads length (for highways – motorcycles, cars, vans, buses, trolley-buses, trucks, etc.)

\* the volume of earthworks in the construction of modern motor-roads and railways amounts up to 100 thousand cubic m/km and more, which makes them more expensive and causes considerable damage to the natural environment

Index	Index relative value	SkyWay advantages justification
manufacturing of the rolling stock: <ul style="list-style-type: none"> <li>• SkyWay</li> <li>• railway transport</li> <li>• monorail track</li> <li>• train on magnetic suspension</li> <li>• automobile transport</li> </ul>	100% 1,000–1,500% 1,000–1,500% 1,500–2,000% 2,000–3,000%	cushion and an earthen embankment (it was replaced by compact supports and string rails, having a low consumption of materials and cost); reduction of material consumption for the track structure due to the use of pre-stressed strings (thanks to this the track structure works not as a bridge beam for bending but as a rigid thread) without decreasing the strength and stiffness of the track structure; reduced loads on supports and their foundations (only 1–2% of supports experience increased stress — these are anchor supports); reduced material consumption of a rail vehicle (calculated per unit of cargo) compared with traditional automobile and railway rolling stock.
5. Total environmental pollution during the construction and operation of the transport system: <ul style="list-style-type: none"> <li>• SkyWay</li> <li>• monorail track</li> <li>• train on magnetic suspension</li> <li>• river transport</li> <li>• railway transport</li> <li>• automobile transport</li> </ul>	100% 200–300% 200–300% 250–350% 300–400% 1,000–1,500%	The main reasons for the decrease of the total pollution of the environment (SkyWay in comparison with other transport systems): a significant reduction in fuel (energy) consumption to transfer passengers and cargo throughout the whole speed range (under equivalent external conditions); no wear of rubber tires and asphalt and their smell in hot weather; no dusting, easily destructible earthen embankments and excavations, gravel and other cushions; the exclusion of using de-icing salts and snow-cleaning machines in winter; no high voltages, large currents and strong alternating electromagnetic fields; low resource consumption of the system, which improves environmental safety at the stage of construction (increased technological ecological purity due to reducing the ecological load on nature at the stages of extraction and processing raw materials and performance of construction and installation works at the construction site).
6. Total operating costs (including consumption of fuel and electric energy, cost of repairs and maintenance of track, rolling stock and infrastructure, staff salaries etc.): <ul style="list-style-type: none"> <li>• SkyWay</li> <li>• railway transport</li> <li>• river transport</li> <li>• train on magnetic suspension</li> <li>• automobile transport</li> <li>• monorail track</li> </ul>	100% 150–200% 150–200% 200–300% 200–300% 400–600%	Low operating costs in SkyWay are conditioned by the following: low fuel consumption per unit of transportation work; increased service life of rail-strings, supports, and rail vehicles (due to the lack of temperature expansion joints and high evenness of rail-strings, SkyWay has virtually no dynamic shock impacts from rolling wheels); all-weather operation of rolling stock (in the pouring rain, hail, heavy fog, hurricane winds, glaze ice, heavy snowfall, flood, etc.); there is no need to clean the track structure of snow and ice in the winter time; in extreme weather conditions (hurricane wind, torrential rain, flood, earthquake, tsunami, etc.) there is no need to restore the track due to the lack of its destruction; reduced volume of repair and maintenance work on the track both due to higher durability of the system and reduction of its material consumption.
7. Transport accidents rate (injuries and deaths of people, domestic and wild animals): <ul style="list-style-type: none"> <li>• SkyWay</li> <li>• monorail track</li> <li>• train on magnetic suspension</li> <li>• river transport</li> </ul>	100% 100% 110% 100–150%	High stability of a unibus on the string rails (due to the anti-derailment system and independent suspension on each wheel) and the "second level" of traffic rule out a collision with ground vehicles, people, domestic and wild animals and will make SkyWay the safest transportation system: accident rate with injuries or deaths will be lower than in railways and aviation today, i.e. approximately 10,000 times less than on the motor-roads. Due to the absence of embankments and excavations there will be no obstacles to the natural movement

Index	Index relative value	SkyWay advantages justification
<ul style="list-style-type: none"> <li>• railway transport</li> <li>• automobile transport</li> </ul>	300–500%  above 10,000%	of ground and surface waters, movements of people, animals, agricultural and other machines that will reduce accident rate and improve the security of the system. The lack of embankments, unstable to mechanical impacts, will increase the sustainability of the transport system for floods, landslides, tsunami, earthquakes and others natural disasters as well as terrorist acts (thanks to the high strength margins of supports, track structure and the inaccessibility of the string rail, raised to a considerable height).
8. Comprehensive negative impact on the environment (during the creation and operation of tracks, infrastructure and rolling stock): <ul style="list-style-type: none"> <li>• SkyWay</li> <li>• monorail track</li> <li>• train on magnetic suspension</li> <li>• river transport</li> <li>• railway transport</li> <li>• automobile transport</li> </ul>	100% 200–300%  300–500% 400–600% 500–800%  1,500–2,000%	SkyWay impact on the environment will be minimal at all stages of the life cycle, as: <ul style="list-style-type: none"> <li>– the efficiency factor of suspension systems of the rolling stock relative to the track structure (i.e. steel wheels) is the highest of all known and promising solutions (99,95%) and will not be surpassed in the future (for example, the efficiency factor of the electromagnetic suspension in the train "Transrapid", Germany, is about 40%), therefore a rail vehicle, in combination with high aerodynamic qualities, is the most economical vehicle of all known ones with minimal impact on the environment;</li> <li>– continuous rail track with a smooth surface for rolling (the working surface of the rail will be grinded for eliminating fine irregularities) will make the rolling of wheels quiet throughout the whole speed range; high aerodynamics of rail vehicles (better than in sports cars by 4–5 times, according to experimental data) will exclude the occurrence of aerodynamic noise in all speed range; laying of SkyWay routes, unlike in other ground transportation systems, will not lead to the destruction of natural landscapes and ecosystems, and will significantly reduce deaths of people, domestic and wild animals on the routes;</li> <li>– low volume of earth works and small area of land acquisition for SkyWay will result in the minimal withdrawal of fertile soil, the humus in which has been created by nature over millions of years, from land use and the process of green plants' generating of oxygen necessary for its constant and continuous reproduction in the atmosphere of our planet.</li> </ul>

### 97. How much do the SkyWay technical and economic indices depend on the parameters of the rolling stock?

Technical and economic indices of SkyWay, as the transport system of the "second level", depend largely on the weight and size parameters of rail vehicles. Like in any other overpass, the string-rail track structure and supports in the SkyWay should be designed for the calculated load and for specified (maximum) speed of the rolling stock movement.

Therefore, during the feasibility analysis and the choice of a particular alternative for a SkyWay project implementation, it is important not to overstate, taking into account the perspectives, capacities and, accordingly, weight of designed rail vehicle and its calculated speed. Otherwise, the cost of the SkyWay may be significantly and unduly inflated, the profitability of the system operation will be reduced, and the period of its payback will be increased by several times.

## **98. "String" is a misfit name, something weak, unreliable. Isn't it possible to come up with something better?**

"String" is nothing more than an image, which suggests that the main design feature of the SkyWay is the presence of stretching and pre-stressing in the track structure and its "second level" of arrangement above the ground surface. Therefore, comparison of a fundamentally new transport system of the "second level" with a guitar and a balalaika that some experts and almost all opponents do, is equal to a search of hands on a "skyscraper" – hands, with which it scrapes the sky.

"String" is a very strong image. Only those who know the technique and the structure of our world badly may disagree with this. Out of the four types of resistance of structural materials to external mechanical impacts in our material world – stretching, compression, bending and twisting – the most favorable for materials and structures made of them is stretching. The Creator knew it, therefore, when he was creating our world, he laid quantum strings as its basis (according to the modern knowledge of the string theory, the whole structure of our Universe is composed of quantum strings with a characteristic size of about  $10^{-32}$  cm, i.e. about the Planck length). The living nature knows it, therefore the extremely lightweight and durable spider web consists of a system of superfine strings, and our tubular bones have such a high strength only because they are reinforced with pre-stressed (stretched) fiber strings. Competent engineers know it, therefore even railway sleepers of concrete are made string-type, with pre-stressed high-strength wire. Actually, strings are used in hanging and cable bridges, structures of pre-stressed concrete, Ostankino TV tower and many more. In addition, no one doubts the strength, stiffness and reliability of such structures just because they have strings.

To show the strength, reliability, durability and other advantages of a string structure, it is necessary to compare properly the already mentioned balalaika with the Moscow monorail (both of these structures experience significant static and dynamic loads):

1) Those who traveled on the monorail, know, what kind of track evenness is there – no comparison with the smoothness of a string. And do you know how many curved beams, impossible to straighten, were simply discarded during the construction of this "ultra-modern" route of the XXI century, where speed – as much as 20 km/h – is by 2.5 times less than on the first Stephenson's railway built almost two centuries ago?

2) A string in balalaika breaks not because it is played on, but because it was most likely overstressed while tuning (manufacturing) of the instrument, or was not properly fixed. However, balalaika is not to blame; the notorious human factor is to blame.

3) Let us consider the dynamics of structures, bringing them down to the same scale. A balalaika string has a transverse dimension of about 0.5 mm, and the hand that furiously pounds on it for years – has a length of about 0.5 m (from finger tips to the elbow). The Moscow monorail has a transverse size of bearing beams about 1 m, i.e. it is by 2,000 times thicker than a string. Let us increase the hand by 2,000 times – up to 1,000 m – and try to strike imaginatively the Moscow monorail with the Dubai skyscraper, the highest in the world. It would crumble not from the strike, but from the blow of the wind occurred with it. However, the balalaika string experiences these tortures for years. We can hold also a reverse mental experiment – let us reduce the rolling stock creeping on the monorail by 2,000 times, to the size of a fly that will start to crawl on a balalaika string at the speed of 3 mm/s touching it with its small feet consecutively (for a structure it is worse than a rolling wheel). It is obvious that the fly will "play" the balalaika at least five hundred years, and the SkyWay does not need any longer.

## 99. How hard will it be to certify the SkyWay?

No special problems will arise for the SkyWay regarding the certification. Of course, they will occur, but not as complex as, for example, during the certification of aircraft resting on air in flight, with a takeoff weight of hundreds of tons; or high-speed railway systems, with composite trains hundreds of meters long and weighing hundreds of tons; or trains on magnetic elevation with their exotic electrodynamic suspension relatively to the track structure, which are known to pass the certification successfully anyway. By certification, SkyWay is closer to motor-roads and structures on them, as well as the automobile transport for which, in fact, these roads are designed. This whole road complex is the certification analogue for the SkyWay.

The SkyWay consists of three fundamentally different and independent objects, separated from each other in creation and certification:

1) a rail car – unibus – as a self-propelled vehicle is a kind of a tram (for electrified tracks) or a bus (for non-electrified tracks). Therefore, it must be certified as a streetcar or a bus, but not as a railway train, with which the unibus has only one common feature – the material for wheels (steel);

2) a string rail, arranged on intermediate supports and fixed by its ends in anchor supports, is a kind of a pre-stressed steel-reinforced concrete overpass, assembled with certified materials and blocks directly on a construction site. In general, overpasses and other similar building structures – bridges, overcrossings, viaducts, dams, etc. – are not certified anywhere in the world. Therefore, the transport line of the "second level" will be designed, the documentation on it will pass the expert examination, and then the string overpass will be built and commissioned into operation, for example, in Russia – by the bridge standards (Construction rules and regulations "Bridges and pipes");

3) the infrastructure – stations, terminals, service parking garages, etc. – consists of buildings and certified equipment and machinery manufactured by industries. Non-standard equipment – turnout switches, automatic control system, etc. – will be certified additionally. The SkyWay infrastructure will be designed, built and commissioned in the same way as other traditional construction sites, buildings and structures.

## 100. When will creation of the Transnet world network begin?

According to preliminary estimates, the creation of global Transnet communication network based on string technologies will begin approximately in 3 years, after the demonstration of SkyWay certification track sections for each of its types – a high-speed intercity system, an urban system and a cargo system for transportation of industrial cargo.

As before, in the history of creating and developing transport and other complex technical systems in the nineteenth and twentieth centuries, currently, customers, experts and consumers have certain mistrust in a new innovative product. Only after the start of its commercial production for the world market in accordance with the declared developer's features, they can believe in high consumer qualities of the product, and, particularly, estimate their true value.

The product offered to the mankind will not be really the Transnet transportation network (the so-called "hardware"), but the social component of this "hardware" – "a transport service". By its accessibility, comfort, safety, efficiency and environmental friendliness, this service should be of due quality, exceeding international standards and meeting the requirements of the XXI century. Certification and demonstration of SkyWay tracks will become the landmark followed by multiple orders and large-scale construction of not only innovative, but also a certified SkyWay communication system. At first millions of people will benefit from its services, then – billions of them.

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