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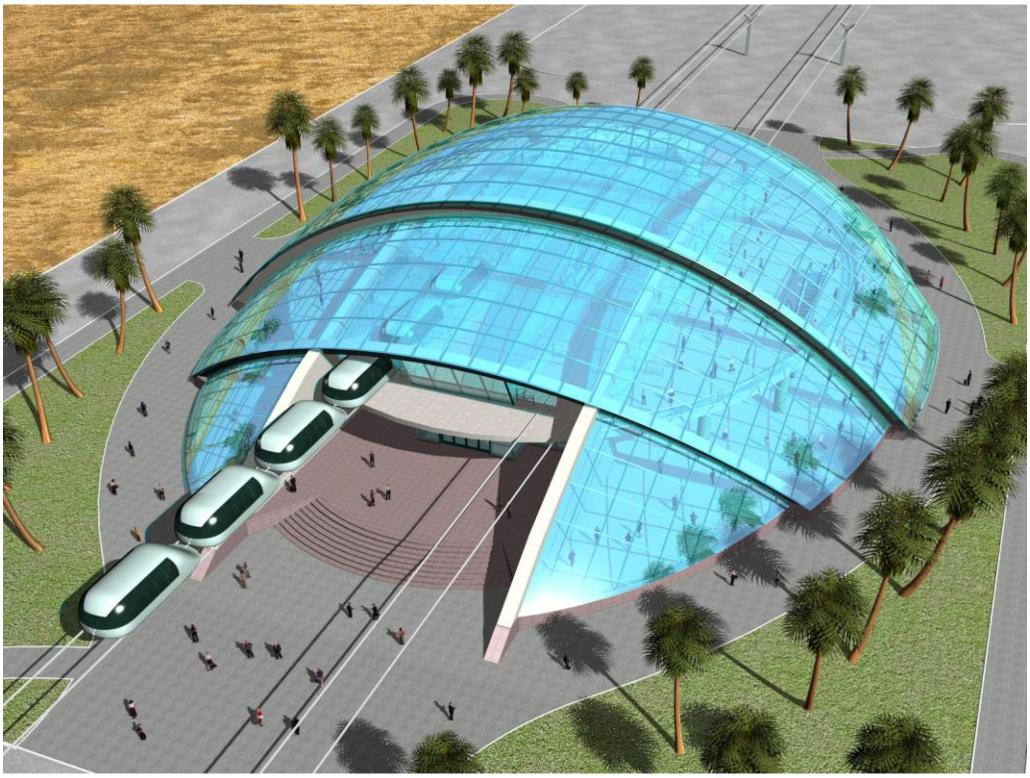
String Transport Unitsky

in questions and answers



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Technical aspects

1. What is it the String Transport Unitsky (STU)?

String Transport Unitsky (STU) is a special automobile on steel wheels that is put on two string-rails installed on the supports (fig. 1—12). High smoothness and rigidity of a string track structure makes it possible for STU to easily reach the travel speeds of 250—350 km/h that in future could be increased to 450—500 km/h.

It is possible to design STU routes as multiple-track structures with tracks located either on common or free standing supports.

2. What is it a string-rail?

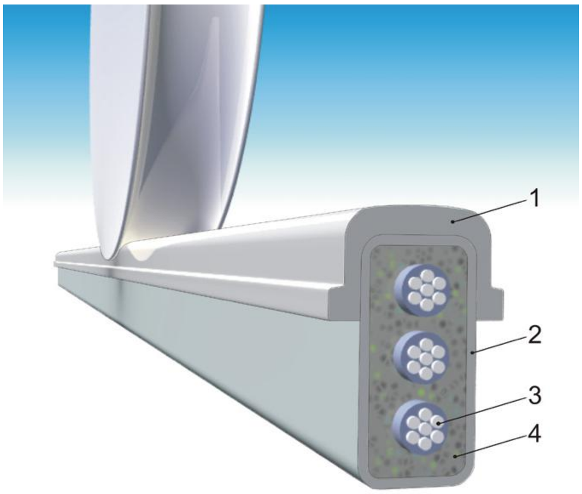

Fig. 13. Two-rim steel wheel on a string-rail:
1 — rail head; 2 — body; 3 — string; 4 — concrete

String-rail is a conventional unsplit (along the whole length) steel, reinforced concrete or steel-reinforced concrete beam equipped with a rail head and additionally reinforced with pre-stressed (stretched) strings (fig. 13). Maximal string tension per one rail (depending on a span length and mass of the rolling stock) is 100—500 tons (at +20 °C temperature). It combines the qualities of a flexible thread (at a large span between the supports) and a rigid beam (at a small span under the wheel of a transportation module and above the support) therefore under the impact of a concentrated load of the wheel the deflection (curvature) radius of a string-rail will be equal to 300—500 m and more. Therefore, it enables a wheel to roll smoothly, without shocks both in the middle of a span and above the support. A string-rail is characterized by the high degree of strength, rigidity, smoothness, technological production and mounting, low material consumption (steel: 20—50 km/m, concrete: 0.005—0.015 cub. m/m), a wide range of working temperatures (from –70 to +70 °C). It provides an ideally smooth road for the rolling wheels as it has no technological or temperature joints along its whole length (rail head is welded as a single weaving). The cost of the assembled string-rail is estimated from USD 50,000 per 1 km which, for example, is less than that of the assembled rail of a railway.

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 the rigid components (reinforced concrete structure) and flexible bunches of steel wires and cables stressed to about 100 kgs/mm^2 tension and put in special channels inside the beam. The beam and the wire bunches are fixed with solidification mixture, for example, cement solution or epoxy resin filled in the channels to make a single structure.

Fig. 1. Double-track STU in a city,
Speed up to 150 km/h

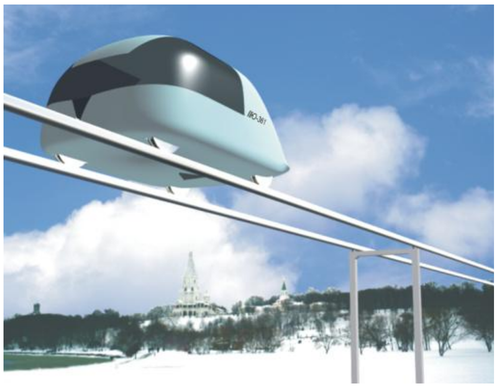

Fig. 2. Medium-speed single-track STU route,
Speed up to 250 km/h

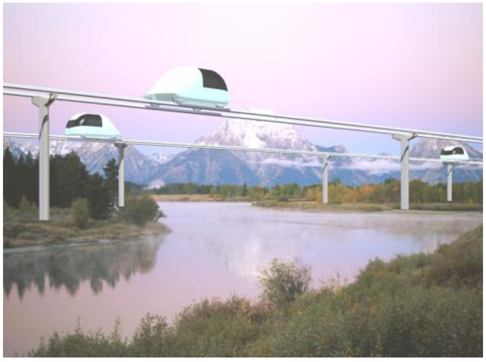

Fig. 3. High-speed route at foothills,
Speed up to 400 km/h

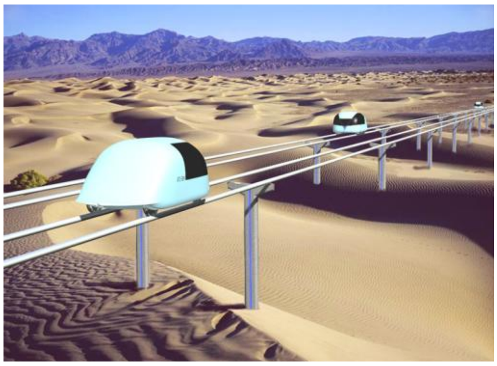

Fig. 4. Super high-speed route in a desert,
Speed up to 450 km/h

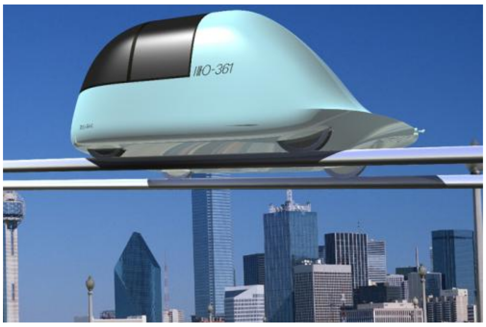

Fig. 5. STU at great height in a city

Fig. 6. Mini-bus on string-rails

Fig. 7. Bus on a string track structure

Fig. 8. City bus on a string-rail built in asphalt

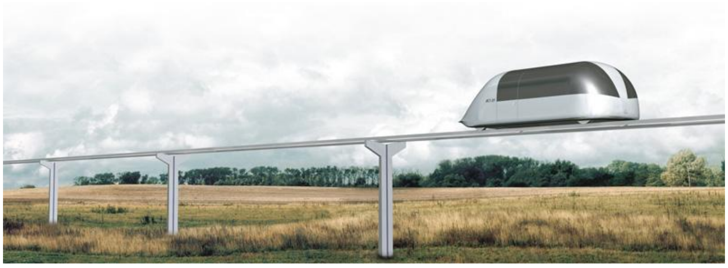

Fig. 9. Single-track STU route in a plain

Fig. 10. Freight STU train (megaSTU) for carrying friable freights in mountainous conditions

Fig. 11. Freight STU train (megaSTU) for carrying liquid freights

Fig. 12. Freight STU train (megaSTU) for carrying timber

Another analogue is a hanging bridge that has a rigidity beam supported by a cable fixed with a sag. The beam and cable are fixed with a suspension to make a single structure.

A principal distinction that distinguishes hanging bridges from the string-rail is attributed to 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 filled with solidification mixture that acts as a suspension and in combination with a body as a rigidity beam.

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

Design of a string-rail envisages the sags of a string (cable) at spans of 20—50 m to be equal to 10—50 mm. A string with such deflection could be easily installed inside any structure with small cross-sectional dimensions (fig. 14).

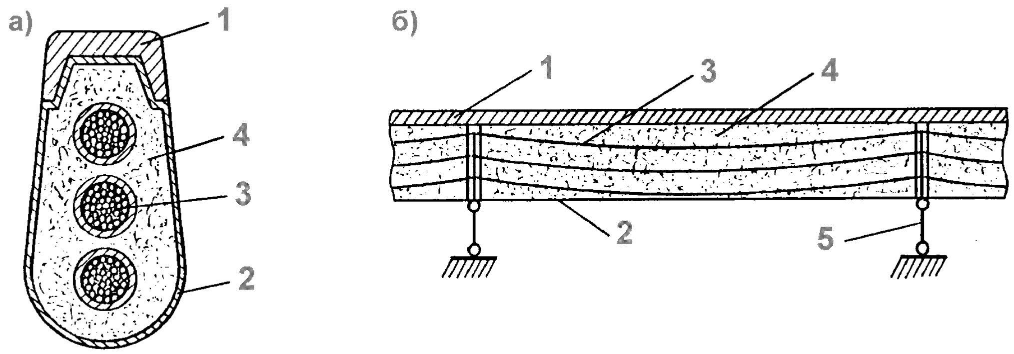

Fig. 14. One of the alternative designs of a string-rail:
a) cross section; b) longitudinal section;
1 — head; 2 — body; 3 — string; 4 — filler; 5 — supporting mast

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

A string-rail is characterized by the following maximal longitudinal dimensions: width — 120 mm, height — 250 mm. Mass of a running meter is 40—75 kg out of which steel makes 50—80%.

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

Yes, it is. In terms of material consumption a single-track STU track structure (including two string-rails) could be comparable to one modern heavy railway rail (including blocking, bolt fixtures, etc.) of the same length (steel consumption per 1 running meter of a track structure ranges from 40 to 100 kg).

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

No, it does not. All materials necessary for its manufacturing are produced today by industries of any developed country including Russia. For example, a rail head along which a STU vehicle is actually moving could be made of steel used for railway rails. Therefore the same rolling mills only equipped with more simple instrumentation could be used for this purpose because a head profile is simpler than that of a railway rail (it is closer to a channel and its linear mass is much less than that of a rail amounting to 15—25 kg/m).

A STU string is made as a twisted or non-twisted cable consisting of the high-strength steel wires of 1—5 mm diameter. This wire with a tensile strength of 90—350 kgs/mm² is industrially produced to be used for cables and ropes in hanging and guy rope bridges, reinforced structures, steel cord of automobile tires, etc. Dozens of steel marks produced by the large-serial manufacturers are suitable for string manufacturing therefore there is no need to list them. A ribbon, band, rod made of steel or other high-strength material could be also used as a string.

The same is true for other string-rail components, track structure, supports and STU transportation module — all these components are either produced by industry or initiation of their production would not be a problem.

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

8. Linear track scheme?

Linear track scheme is given in fig. 15.

Depending on a span length the following two specific types of STU track structures are recognized:

1 — conventional design (span up to 100 m);

2 — with additional supporting cable structure (span more than 100 m) with a cable installed:

a) at the bottom;

b) at the top with a parabolic sag;

c) at the top as a guy rope.

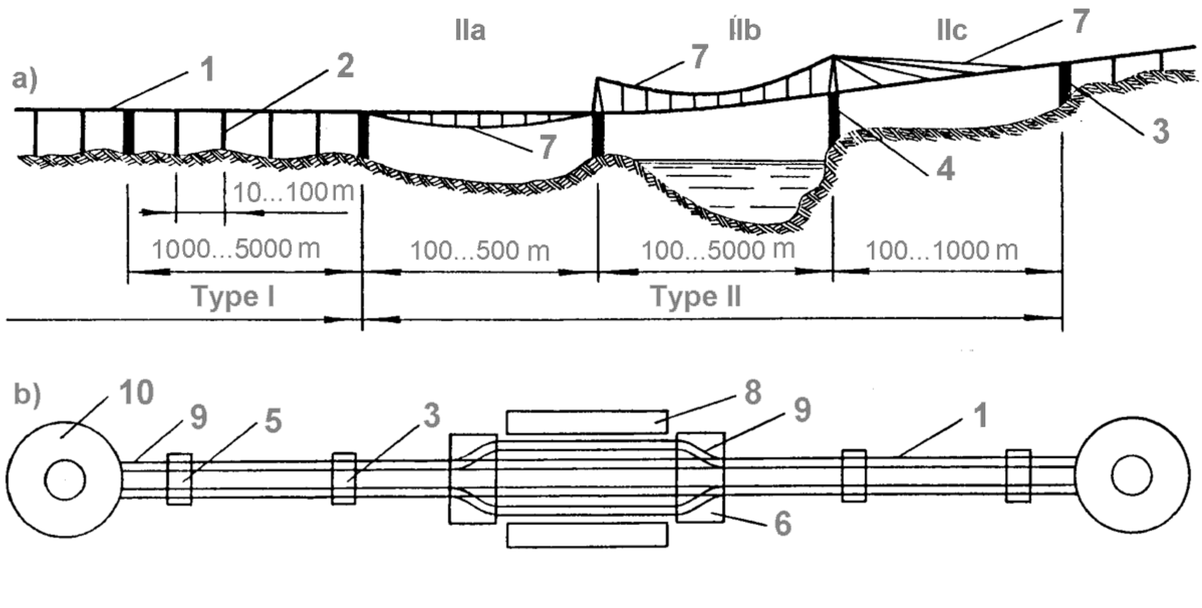

Fig. 15. Linear track scheme:
a) side view; b) top view;
1 — double-track structure; 2 — supporting mast; 3, 4, 5, 6 — anchor supports including: intermediate, pylon, terminal, switch ones, respectively; 7 — supporting cable; 8 — intermediate station; 9 — track section made of conventional rails (of railway type); 10 — ring terminal.

STU supports are sub-divided into the following three typical categories: anchor (installed with 1,000—5,000 m intervals and more), brake (200—500 m and more) and supporting masts (10—500 m).

9. How much is the strain tension of strings?

An optimal strain tension of one string-rail is equal to 250 tons (at the estimated tensile strength of the wire amounting to 100 kgs/mm^2 the summary cross sectional area will be 25 cm^2 per one rail and the mass — about 20 kg/m; if a string is made of three cables a diameter of each cable should be of about 35 mm).

For comparison: cross section of a modern hanging bridge reaches 1,500 mm and its tensile strength is 100,000 tons and more. By the way, a STU and a hanging bridge will have approximately the same carrying capacity (including passenger and freight traffic flows). The tension strain of one rail-string in the amount of 250 tf, 500 tf and 1,000 tf will ensure the span lengths of 50 m, 100 m and 1,000 m, respectively.

10. What is the maximal possible span?

STU spans exceeding 100 m in length should be supported by a special cable (fixed on the top or bottom) designed as a hanging or guy rope bridge. Taking into account the light weight of a track structure and STU modules cables with 100 mm or 200 mm diameter made of the high-strength steel wire will be sufficient to support the spans of 1,000 m and 2,000 m, respectively.

Modern composition materials will ensure a maximal span length of 5,000—6,000 m.

11. How rigid is a track structure?

An important quality of a track is its relative rigidity: a ratio between the sag of the structure under the weight of the rolling stock located in the middle (or 1/4) of a span and the span length. Modern bridges, including hanging bridges, are designed in Russia and abroad for the estimated relative deformation of 1/400—1/800. STU is designed as a more rigid structure in which, for example, a sag of the string structure with a 30 m span under the weight of a transportation module (5,000 kgs) will amount to about 20 mm or 1/1500.

Therefore, a string track will be much smoother for the rolling than, for example, a track of the high-speed railway road laid on a modern reinforced concrete or steel bridge.

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

Table 1

Deflections of STU structure under the impact of its own weight

Span length, m	Static (mounting) deflection of structural elements			
	strings in a rail		guy cable	
	Absolute deflection, cm*	Relative deflection	Absolute deflection, m**	Relative deflection
25	1.6	1/1600	—	—
50	6.3	1/800	—	—

* deflection is hidden ("sewn up") inside the string-rail body

** deflection is located under or above the track structure

Span length, m	Static (mounting) deflection of structural elements			
	strings in a rail		guy cable	
	Absolute deflection, cm*	Relative deflection	Absolute deflection, m**	Relative deflection
75	14.1	1/530	—	—
100	25	1/400	0.25	1/400
250	—	—	1.56	1/160
500	—	—	6.25	1/80
750	—	—	14.1	1/53
1000	—	—	25	1/40

12. What about thermal strain?

Neither a rail body and head or a string is exposed to any longitudinal deformation (stretch) and their length remains invariable in summer and in winter. Like the wires in telephone or electric transmission lines that similar to strings in a rail are fixed to the supporting masts with a sag to stretch for many kilometers without any joints the rail and string system will not have any expansion deformation joints along the whole length. However, temperature drop could change the stressed strained state of a structure.

Design of a STU track provides for the structure stability so that at any estimated temperature variations the rail and string are exposed only to the stretching force but not to compression stress. For example, at maximal temperature drop of 100 °C (from +60 °C in summer to –40 °C in winter) variations of the maximal tensile force will be within the range of 2,000 kgs/cm^2: from 8000 kgs/cm^2 (in summer) to 10,000 kgs/cm^2 (in winter) and from 0 to 2000 kgs/cm^2 for a string and rail, respectively. Under the reduced temperature drop a deformed stress will be proportionally reducing.

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

In fact, track deflection will be observed in a string sag (i.e. in a vertical plane) which will be proportional to its initial sag and relative variation of tension. At 100 °C temperature drop (or a more neutral value of 50 °C) a maximum vertical deflection of a track with a 50 m span will amount to about 5 mm or 1/10000. In this case 5 mm upward and downward deflection of a track will be observed in winter and in summer, respectively.

Such micro-unevenness which is easily compensated by a wheel suspension would not affect the smooth motion of a vehicle moving at speeds up to 500 km/h. Furthermore, as far as thermal deflections were preliminary assigned and pre-determined for the given air temperature the track profile could be automatically corrected, if necessary, by a wheel suspension controlled by a computer.

14. Will the rolling stock produce a great impact on the string tension?

The impact will be within the range of 1% which could be attributed to the kinematic qualities of a string track structure. Fig. 16 shows a string block system in which the string tension does not depend on the external load *P* but it rather depends only on tensile force *T*.

Such structure could be transformed into a linear scheme of a greater length (fig. 17).

Analysis showed that at $P < 0{,}01\ T$ (which is provided in STU) the difference between the deformed stress values of structures shown in fig. 16 and 17 does not exceed 1% (more precisely 0.1—0.5%). In the engineering estimates this difference could be neglected and structures could be considered identical. It considerably distinguishes a STU from other building structures, for example, bridges or overpasses. The latter are exposed to millions of loading cycles in the course of their operation and in each case the stress in various structural components, for example, reinforced beams, increases by 2 and more times. All this results in the development of fatigue phenomena and, therefore, reduced service life of structures and growing maintenance and repair costs.

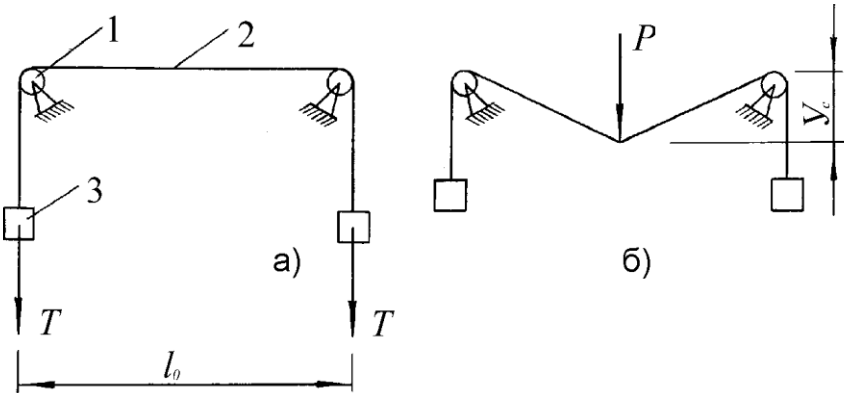

Fig. 16. String block system:
a) without external load; b) with a load; 1 — block; 2 — string; 3 — load.

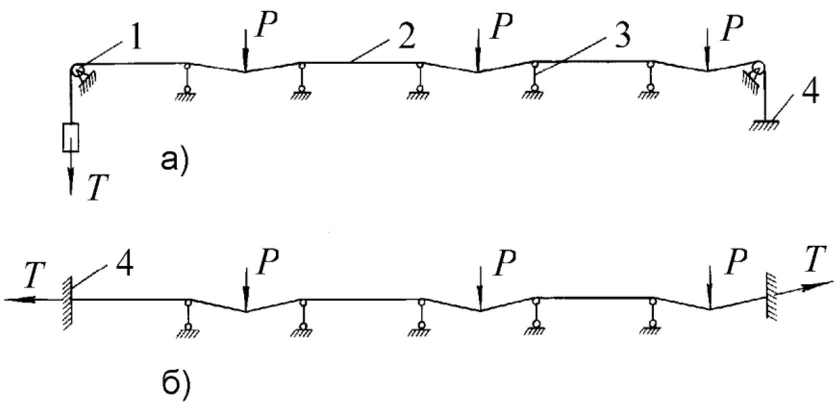

Fig. 17. String linear scheme: a) with a block at the end of a string; b) with a string sealed off;
1 — block; 2 — string; 3 — swing support; 4 — fixing (anchor).

As far as the deformed stress of a STU remains practically invariable during the whole period of its operation irrespective of the number of loads the total durability of such string transportation system will be increased.

15. How accurate the track parameters are observed?

The left and right string-rails will be linked with each other every 10—50 m with special cross cleats that fix a gauge like sleepers of a railway. The side thrust in the interval. between them, for example, under the impact of a hurricane side wind, in the amount of 100—150 kgs per 1 wheel will change the gauge width by 1—2 mm as a result of rail deflection which will not pose any danger to the rolling wheel of a vehicle moving at speeds up to 500 km/h.

16. Could a vehicle fall down if the rails are sliding apart?

This risk exists at railway roads including the high-speed railways when numerous derailments could be attributed to this reason, mainly to the fact that the train wheels have one flange. In a STU module each wheel has two flanges (on the left and right side of the rail head, see Fig.18) and an independent suspension.

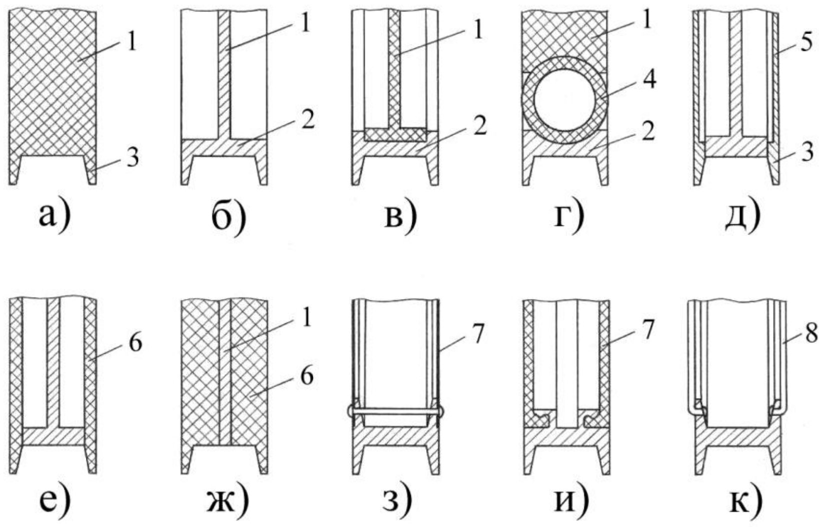

Fig. 18. Design of the supporting part of a wheel:
a), b) — solid (monolithic) wheel; c), d), h), i), j) — combined with a moving rim; e), f), g) — combined with moving flanges; 1 — wheel body; 2 — rim; 3 — flange; 4 — elastic toroidal component; 5 — flexible plate; 6 — flexible disk; 7 — membrane; 8 — spoke.

Therefore, a transportation module would not be critical to the gauge width. For example, a wheel suspension could be designed in such a way that the variation in a gauge width by 20 mm would not result in derailment but rather would provide the regular travel conditions. In this respect coming off the track is more typical for cars that are kept on the road surface only by a frictional force and often fall down to the side ditch, especially under icy conditions, whereas the rims available on the wheel pair of trains keep them stable on a track.

17. As a rule, twisted cables are used for similar structures. Why straight wires are more reasonable for a STU string?

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

Overstrain also gives rise to intertwisting of wires caused by a very high contact stress and abrasive wear within their contact zone. Ultimately it could result in cable breaking therefore it is very important to check the wholeness of each wire. Furthermore, wires of a twisted cable located at an angle to the longitudinal axis (and, therefore, to the longitudinal load) are characterized by a lower carrying capacity and lower elasticity module of a cable: $(1.5—1.8)\times10^6$ kgs/cm^2 against $E=(2—2.1)\times10^6$ kgs/cm^2 for steel.

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

1. In case some wires are broken their length is reduced (a string is put in a protective envelope filled with special anticorrosive mixture like lubricant grease) and their stress is not transmitted to other wires; the structure becomes non-critical to the number of wire breaks;
2. Contact stress is absent, therefore, there is no local wear, wire defects, overstrain zones, etc.;
3. Elasticity module of a strain will be equal to that of steel — $(2—2.1)\times 10^6$ kgs/cm^2;
4. The absence of elasticity requirements makes it possible to use wire of larger diameters (3—8 mm), thus, the summary surface of a string will be smaller and, therefore, it will be characterized by the higher corrosion and mechanical resistance and durability.

All the above qualities will contribute to the higher structure durability and reduced consumption of the high-strength steel for a string which will be 1.2—1.5 times less than for a twisted cable.

18. What is a probability of a string break?

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

Each high-strength wire is subject to marginal checking before it is installed. Furthermore, a linear STU 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% (fig. 17). Therefore, during the whole service life of the route the deformed stress of its most important component — a string — will be practically invariable (static) which will also contribute to the increased lifetime of a system due to the lack of fatigue accumulation.

All this makes it is possible to forecast a longer service life of a STU as compared with its closest analogue — a hanging bridge, which is estimated at more than 100 years. In this case, with each wire of a string working independent (all of them are twisted and placed parallel to each other in a string) any wire break (up to 50% of wires) would not result in falling down of a structure that will be supported by the wires that remain intact as well as the tensile stress remaining at the level of 1%.

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

19. What if a track is fully broken?

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

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

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

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

20. What contributes to the high evenness of a string track?

First of all, is there anything more even than a string strained to the high stress? It is possible to straighten out even initially uneven or curved string. All cross sectional track components (a string, rail head and body) are kept in a stretched out condition all time, in winter and in summer.

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

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

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

21. And what about rail deterioration?

Thanks to the lower contact tension in the “wheel — rail” pair (50— 60 kgs/mm^2 against 100—120 kgs/mm^2 for railways which is attributed to different, more favourable bearing geometry) deterioration of a rail head will be less intensive than in railway transportation (1 mm deterioration of the rail height after it was exposed to the train load of 100 million tons). Furthermore, deterioration of a rail will be reduced as a result of lower loads on the wheel as well as more favourable dynamics within a "wheel — rail" contact zone, the absence of breaking stress (under the wheel) and higher buffer action of all rail-string components to eliminate peak dynamic loads, etc. The head size is estimated for the whole service life of a STU (50—100 years), for example, to the head thickness of 20—25 mm is enough to ensure the summary volume of transportation in the amount of 500 million tons.

Moreover, a rail, or, more precisely, its head, will be made up of technologically convenient sections without any clearances, for example to reach the length of 20 m. Deteriorated or defected section of a rail could be replaced, if required.

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

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

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

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

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

23. How long are the intervals between the supports?

Two characteristic types of supports are used:

a) anchor supports with strain anchoring (fig. 19);
b) supporting (intermediate) masts to support a track structure in the intervals between anchor supports (fig. 20).

The following span dimensions are used depending on the ground features and track requirements: 1,000—3,000 m (up to 10 km, if necessary) for anchor supports; 20—100 m (up to 500 m, if necessary) — for intermediate supports.

24. Are there any curves along the route?

As far as a STU is non-critical to the ground features of the site it is possible to design it as a straight line to make the shortest path. However, if necessary, the track could have curves both in vertical and horizontal plane (fig. 21).

To provide travel comfort for passengers (passengers should not feel the impact of over-loads at curved sections) the curvature radii should be not less than 10,000 m, 15,000 m and 20,000 m for the travel speeds of 300 km/h, 400 km/h and 500 km/h, respectively. Turns are envisaged if the curvature radii in a horizontal plane are lower. It is possible to use a lower curvature radius, less than 1,000 m, but in this case the travel speed on such sections of a track should be reduced to 100-150 km/h.

A minimal curvature radius is 20 m and in this case a rail on the curved sections of a track with a 100 m radius will be made without strings (like railway rails) and will be supported by a beam or girder span structure of a conventional or string type.

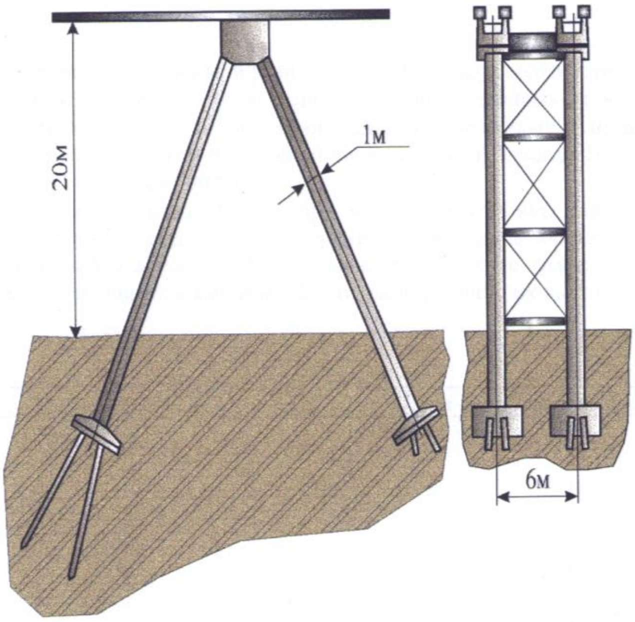

Fig. 19. Anchor support of a double-track STU route

Fig. 20. Small-height intermediate support of a single track STU route

Fig. 21. Anchor support combined with a station and track curve

25. How heavy are the loads on the supports?

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

Intermediate support of a single-track STU route is exposed to a minimal vertical load of 20 ts (including movable load with a 50 m span) and maximal emergency load of 250 ts (with a 500 m span).

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

Therefore, the estimated horizontal stress of 250 ts per 1 rail and 500 ts per an 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) or technological (in the process of assembly when the given anchor support is terminal because the track is not further extended). Under the standard performance regime anchor supports (except two terminal supports being the most powerful ones) are not exposed to horizontal stress.

26. What is the height of the supports?

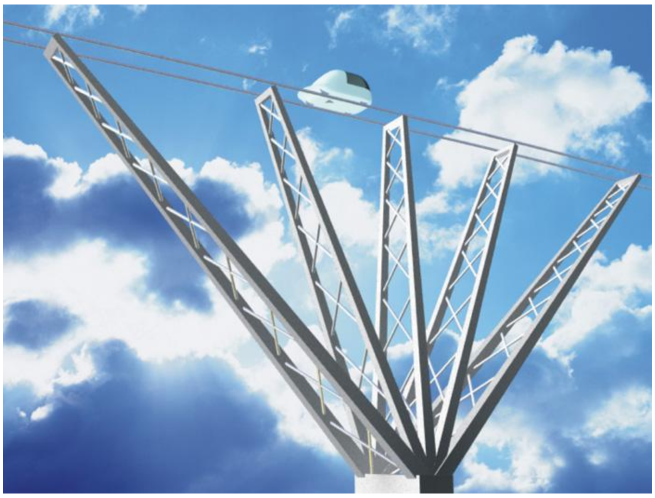

Fig. 22. Supporting mast of great height combined with a vertical curve

Minimal height of the supports is 2—3 m which is necessitated by the need to enable safe passage of agricultural machinery, wild and domestic animals under the STU track structure. In some cases the height of the supports could be equal to zero and in this case the rail head will be located on the ground level (fig. 8) and the track structure will be installed on a special sleeper framework built in the ground. Maximal height of the supports which is limited only by the economic feasibility could reach the values of 100 m and more (fig. 22).

Optimal height of the supports on a flatland or slightly rugged terrain is 5—6 m which makes it possible to cross without great cutting any forest, as well as highways and railways, small and medium rivers with minimal environmental impact. At heavily rugged terrain the average height of supports could be 10—20 m.

27. Is manufacturing of supports associated with high material consumption?

No, it is not. Reinforced concrete or steel supports are used. Reinforced concrete consumption for supports with the average height of 6 m per 1 km of a dual-way STU track is about 150 m^3 (for comparison: reinforced concrete consumption for a two-sided enclosure of a high-speed railway reaches 750 m^3/km). Therefore, STU supports are associated with lower costs and material consumption than, for example, enclosure of a high-speed railway (without which it is not possible to ensure its 100% safety, because even a moose getting into a track could be a cause of derailment).

Comparison of reinforced concrete consumption for STU supports and railway sleepers shows that material requirements for the supports of a STU route would be equal to those for 1/3 of the total number of sleepers for a railway of a similar length. In case of steel supports steel consumption will not be high amounting to about 100 t/km for a single-way track which is a bit more than mass of a modern heavy railway rail of a similar length (1,000 m).

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

A STU track is based on the superstructure of supports exposed to displacement in three main directions: axial, side and downward. For example, displacement of the top a 10 m support in the direction of a vehicle movement (along the track) even at 100 mm will result in the lowering of the road bed by as little as 0.5 mm, thus the evenness of the track will be practically intact (or at 10 mm displacement the lowering will amount to 0.005 mm).

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

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

To eliminate the consequences of unforeseeable displacements (for example, as a result of earthquake or land slides, etc.) each support is provided with a system of track adjustment to ensure an accuracy of 1 mm.

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

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

30. What if an anchor support is blown up?

Taking into account the support strength not less than 10 kg of trotyl and thorough preparations are necessary to blow it up (STU will be provided with a ramified security system including electronic control of all track components and vehicles and visual control such as track observation from a specially equipped helicopter). Security service is capable to trace terrorists' preparations and to stop the movement on a dangerous section.

Even if an anchor support is destroyed a STU will remain operative because anchoring of strings is arranged in such a way that power transmission to the next section will be facilitated by-passing the body of a support. It means that even if an anchor support is broken continuity of a string route will not be interrupted.

31. Future vehicles will be driverless. Is it dangerous?

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

Transportation vehicles of the first STU routes will be operated by drivers because automatically controlled systems are extremely expensive and economically not feasible at the small-serial production. Later as the networks of STU routes are further developed they will be transferred to driverless operation.

32. How high is a probability of vehicle collision?

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

STU envisages the following 3 braking regimes: operating (acceleration — 1 m/sec^2 braking length — more than 3,500 m at 300 km/h travel speed), urgent (acceleration — 2.5 m/sec^2 braking length — 1,400 m), and emergency (10 m/sec^2 — 350 m).

Emergency braking envisages the use of all braking systems including special electromagnetic braking systems. It also implies simultaneous switching of emergency braking system with the life-saving air cushions in a passenger saloon to eliminate injury of passengers (maximal overloads for passengers will be approximately the same as in a passenger car hit against immovable barrier at the speed of 10 km/h).

Similar collisions observed, for example, in the motor ways could be attributed to the following factors:

1. Each car is driven individually without coordination and consideration of actions of other actors (by-passes, turns, cars excessively close to each other, driving to the counter-flow lane, etc.).
2. The distance between cars in a flow is insufficient (10—50 m) which is often less than a braking length necessary for a vehicle to stop.

3. Delayed and often inadequate driver's response to emergency situation on the road, etc.

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

33. What is the dynamic track rigidity?

Dynamic, rather than static, rigidity is more important for a STU like for any other high-speed transportation system. Specific structural features of a track structure and the relevant vehicle movement regimes were investigated and specified to show that resonance phenomena were absent in a string-rail (for speeds 400—500 km/h). Moreover, track vibrations observed behind moving vehicles will be damped over 0.1—0.5 sec. to enable the next vehicle to move along the undisturbed, ideally even track.

The principles used there were similar to those applied for the design of hanging bridges: any component is to damp the structure vibrations within its own frequency range. Therefore, it is possible to damp all kinds of possible structural vibrations from the low- to high-frequency ones, including the impact of single modules and their flows, wind (including gusty wind), etc. In this case inertness and high strength of a track will contribute to lower dynamic amplitude of structural vibrations amounting to less than 1/2000, i.e. less than static. (For comparison: carriageway of a highway is considered even if a clearance between a 3-meter rod and the road surface will be not more than 10 mm, i.e. its relative unevenness is about 1/300).

34. A module moving along the string: would not it be a wave-like motion?

Firstly, a module will be going not along the string but along the rail which is characterized by the higher rigidity than, for example that of the R-75 railway rail. Therefore, under a module wheel the string-rail will behave rather as a rigid beam than as a flexible thread and under the impact of a concentrated load of a wheel the curvature radius of a string-rail will be 300—500 m and more. It will make the wheels of a rail automobile to move smoothly and without shocks both in the middle of a span and above the supports.

Secondly, modern cars or railway trains including the high-speed railways could move in a wave-like manner when their track structure is designed as an elevated road installed on the supports. As a result of a compromise between the requirements to reduce material consumption for the span structures and to achieve maximally high values of the track rigidity under the impact of the designed load the worldwide normative relative rigidity for the spans of bridges and overpasses was generally accepted at the level of 1/400—1/1,000, for example, for the high-speed railways it is equal to 1/600—1/1,000. Therefore a wheel of the high-speed train moving along the bridge with a span, for example, of 30 m will have a sine curve and amplitude of 30—50 mm and the wave length of 30 m. In this case the wheel pair of a train is very heavy (its mass is about 1 ton) and a suspension is sufficiently rigid. Nevertheless, for passengers travel by a high-speed railway will be very comfortable, without vibration or noise which, for example, more comfortable than traveling by bus.

String track structure is designed on the basis of the norms that are currently used to design bridges, overpasses, elevated roads, viaducts and other transportation facilities installed on the supports. Therefore the rigidity of a string road will be similar to that of bridges or overpasses of the high-speed railway roads. In this case the rolling motion of a wheel of a STU module will be smoother and calmer due to its smaller mass amounting to 40—60 kg. Each wheel is provided with an independent and relatively soft “automobile” suspension and two flanges and the wheel rim and boss are separated by an intermediate rubber serving as a damper.

Furthermore, the head of a string-rail will have a camber in each span, i.e. upward bending in relation to the supports which in the middle of a span will amount to 30—50 mm to be equal to the track deformation under the impact of the designed load. Therefore, each string span deformed under the weight of a transportation module is flattened to form a straight line to provide an ideally even way for the rolling wheel.

Unevenness of a track results from the fact that a module mass is not strictly specified (for example, mass of a 20-seat module could vary within the range of 2,000 kg depending on its loading — with full load or without load) as well as from the differences observed in the string tension of a rail in winter and in summer which could reach 100 tons. As a result during certain periods of time (strong heat or severe frosts) unevenness in the amount of 6—10 mm could be observed in spans for some modules (over-loaded or empty) in the middle of a span, or its relative value is 1/3000—1/5000. During some other periods of time the track unevenness for modules with a normative load will amount to 1/5000—1/10000 which means that this track is by one order more even than that of a high-speed railway road.

35. Is a STU vehicle more economically efficient than a passenger car?

In comparison with a 5-seat high-speed passenger car an electrified STU transportation module is characterized by the higher efficiency (on conversion to 1 passenger), approximately by 20 times, which could be attributed to the following factors: improved aerodynamic qualities (2—3 times); increased electric motor efficiency (more than by 90% against 30% of a real internal-combustion engine efficiency), increased (2—3 times) carrying capacity, reduced (1.5—2 times) mechanical losses (especially in a "wheel — road surface" pair: "steel — steel" in a STU against "rubber — asphalt" in a motor car).

Specific electric energy consumption of a STU is as follows: 0.016 kW×hour/t×km and 0.014 kW×hour/pass.×km for freight and passenger traffic, respectively, at the travel speed of 300 km/h; and 0.031 kW×hour/t×km and 0.025 kW×hour/pass.×km for the travel speed of 400 km/h, respectively. The given data refer to the transportation modules of 4,000 kg carrying capacity and 20-seat passenger vehicles with their engine power being 40 and 80 kW (for the speed of 300 km/h) and 100 and 200 kW (for the speed of 400 km/h), respectively. (It is easy to recalculate electric energy consumption on conversion to combustible fuel consumption to get: 1 liter of gasoline = 8.78 kW×hour of electric energy).

High-speed STU rail automobile that was given the name of "unibus" represents the most economically efficient mode of transportation among all known transportation modes. Its super high economic efficiency is especially visible at low speeds such as 100 km/h traditional for motor transportation. At stable motion with the above given speed along the horizontal section of the road a 50-seat unibus with the weight of 10 tons will need an engine of 9 kW power (out of which 6.6 kW — for aerodynamic resistance, 1.5 kW — for rolling resistance and 0.9 kW — transmission losses). In this case fuel consumption by a diesel used as its engine per 100 km of travel will amount to 2 liters (or 0.04 l/100 pass.×km or 0.4 l/1,000 pass.×km). Fuel consumption by the best passenger cars is 20—30 times higher amounting to 1—1.5 l/pass.×km.

36. What is the rotation speed of a module wheel?

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

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

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

Fig. 23 shows various drive unit alternatives.

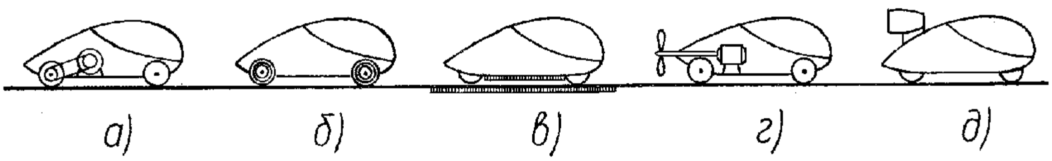

Fig. 23. Transportation module with various drive unit types:
a), d) — rotation wheel and propeller drive, respectively; b) — motor-wheel; c) — linear electric engine;
e) — gas turbine.

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

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

38. How much noise is produced by rattling wheels taking into account that they are made of steel?

No rattle noise at all, even at high travel speeds as it is the case with high-speed railways with their rails laid down without interruption for 1 km length. A rail-string head is dismountable, i.e. easy to replace, if necessary; it has no clearances along the whole route length while any micro- or macro-unevenness could be easily grinded off with a special polishing machine.

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

39. Is a wheel subject to a shock while over-passing a support?

No, it is not.

Firstly, because a rail-string has no joints on the support and there is no difference between this and other sections of the track.

Secondly, coming closer to a support a rail deflection (with a relative value of about 1/2000) is smoothly reducing to a zero (at the moment when it over-passes a support). Moreover, as far as a string-rail under the module wheel is exposed to bending strain like a rigid beam the curvature radius of a string-rail under the impact of a concentrated load of a wheel will be equal to 300-500 m and more. Therefore, the motion of a module wheel will be smooth, without any shock both in the middle of a span and above the support.

Thirdly, dynamic deflection of a track under the impact of wheels will be always observed behind the wheels at travel speeds above 200 km/h, therefore, no bending is observed when a wheel is passing over a support.

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

No, it is not.

It was proved by the numerous wind-tunnel tests of a transportation module (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 hurricane side wind (with 200 km/hour velocity) the tilting effort will be within the limit of 100 kgs which for a module mass, for example, of 5,000 kg will not pose any risk of breaking a wheel-rail contact. Derailment implies not only the breakage of a wheel-rail contact but also the scale of the breakage to exceed the height of a suspension and a wheel flange.

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

This risk exists for a ground transportation vehicle (moving in the immediate vicinity of the ground surface) which results from screening effect. For example, tilting effort observed in a high-speed car is attributed to uneven flow-around in the clearance between the car bottom and the road and above the car. Therefore, anti-wing is installed. At 10—20 m height above the ground a screening effect disappears which is attributed to small vehicle dimensions.

Furthermore, the body of a rail STU automobile is designed in such a way as to provide for symmetrical flow-around eliminating any cross or tilting efforts at any standard travel speeds.

42. What if as a result of a vehicle failure it is unable to move further?

In this case it will be taken in tow by a transportation module going ahead or behind which is equipped with a special automatic docking joint. Moreover, each module will be equipped with the emergency electric drive supplied from the on-board accumulator therefore it will be able to reach the nearest stop or station independently moving at lower speed.

As a last resort, a special evacuation module will come to the emergency vehicle (along the same of counter track) to evacuate passengers and a failure module or if it is not possible to bring the emergency module to the ground. Specially equipped helicopters could be also used for emergency and rescue works along the route.

Furthermore, evacuation of passengers could be facilitated with the use of special devices such as emergency hoses, extension (flexible) ladders, etc.

43. Why are the transportation modules so small?

Indeed, the optimal carrying capacity of a high-speed passenger (up to 20 seats, fig. 24) and high-speed freight (up to 5,000 kg) module contradicts to the advanced transportation development trends including motor, railway and air transportation focused on the constant increase in their carrying capacity and overall dimension of transportation vehicles. All this in dictated by the existing problems associated with the need to reduce travel costs and to improve traffic safety. However, consequences of the recent traffic accidents and especially 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 trend of constant growth including all modes of transportation.

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

Small STU modules are capable to ensure higher carrying capacity of the transportation system as a whole than, for example, large-scale, costly railway trains or airbuses with high carrying capacity that because of their large dimensions are unable to circulate with high frequency. For example, if at the travel speed of 360 km/h (100 m/s) the rail automobiles for 20 passengers circulate along the route at 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.

Freight carrying capacity of the low-speed freight trains (speed up to 100 km/h) could amount to 1,000 tons and more (fig. 10—12) and the optimal wheel load is 5 tons as it is in freight motor transportation. The length of such trains could reach 100 m and more.

44. As it is known, passenger car is not notable for its comfort. What about a STU vehicle?

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

STU gives people an opportunity to combine efficient solution of the basic functional task — comfortable and quick carrying of passengers 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 surrounding natural landscapes. Each vehicle is equipped with air conditioning devices supplied with initially clean air taken at the height of 5—10 m and lacking the smell of fuel and lubrication, sun-heated asphalt, exhausts of car flows, etc. typical for highways.

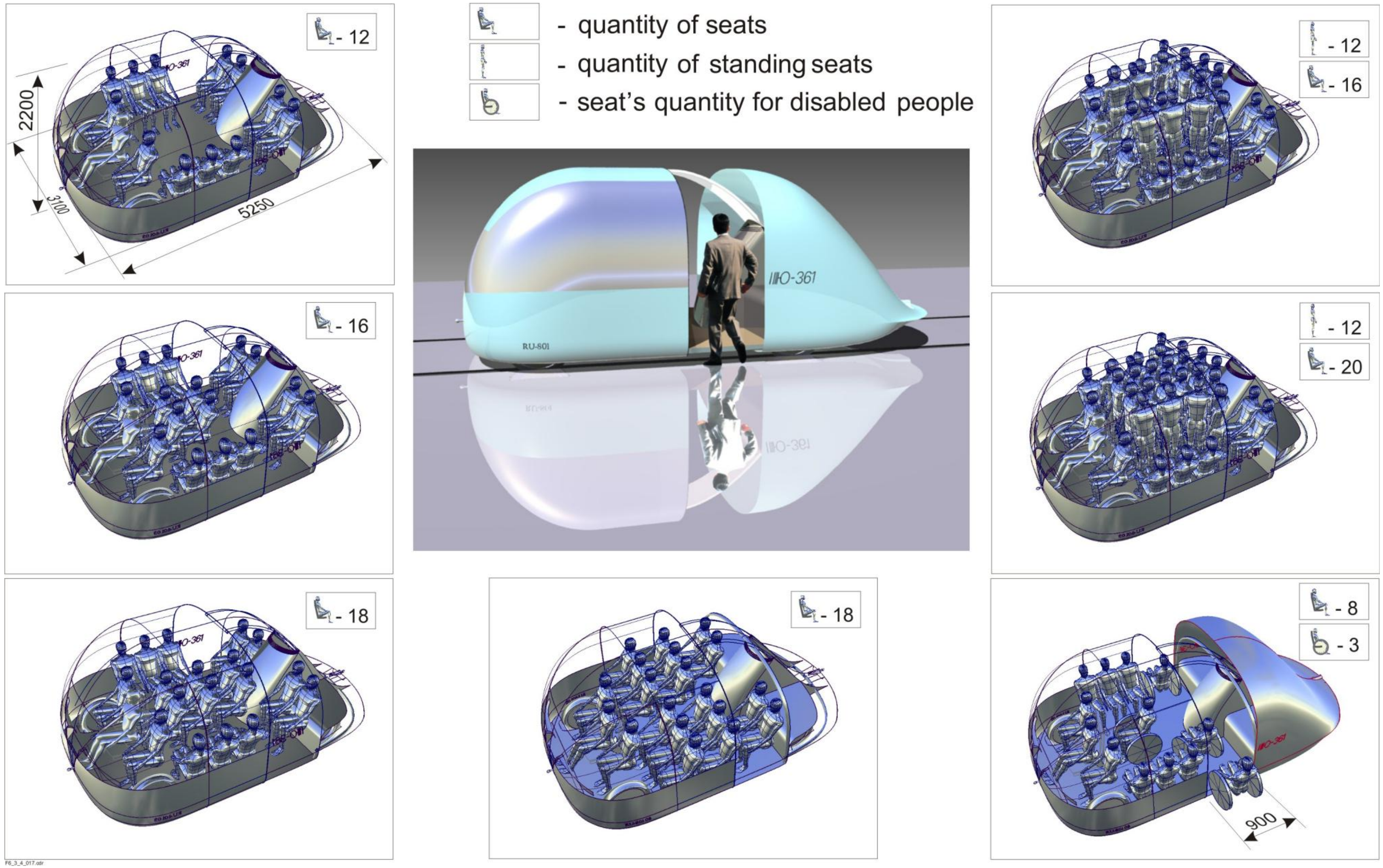

Fig. 24. Variants of passenger dissemination in Unibus U-361

Passengers are offered a wide range of additional services such as multi-canal musical and TV programmes, inter-city telephone communication, special services for businessmen, passengers with children and invalids. STU vehicles that in terms of their dimensions are larger than mini-vans are hermetic, equipped with a system of vacuum or chemical toilets which exclude waste disposal on the track (fig. 25).

Upon passengers' desire a vehicle can be stopped at any of the intermediate stations, i.e. every 5—10 minutes or at any of the anchor supports, i.e. every 2—3 km (every 15—30 seconds).

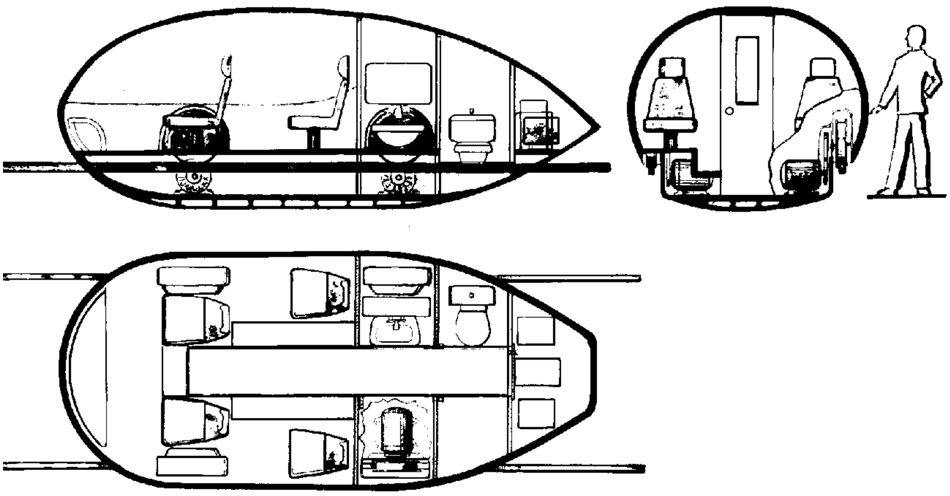

Fig. 25. 4-seat long-distance vehicle

45. What about icy conditions of road, is it dangerous?

No, it is not, as it is not for a railway road: contact mechanical stress under a steel wheel exceeding 1,000 kgs/cm^2 provides for ice crumbling and blowing off the rail, thus, making it self-cleaning.

By the way, a greater hazard for a railway is associated rather with deep snow than icy conditions to the effect that the train wheels fail to reach a rail and a train is put on its "belly". Both snow and ice pose a hazard for a car which rubber wheels are characterized by very small contact stress of 5 kgs/cm^2; as a result ice is not crushed and snow is compressed. A motorway which road surface does not have a self-cleaning capacity requires special machines to remove ice and snow.

On the contrary, snow drifts are not dangerous for STU, because even in regions with heavy snowfalls the snow depth would not exceed 3 m which is lower than STU supports.

Tests carried out at the STU testing unit in the town of Ozyory, Moscow Region, proved that icy conditions of the road do not pose a danger for STU. A modified ZIL-131 truck put on special steel wheels with 700 mm diameter was easily climbing up (slope 1:10) in winter time with 50 mm of ice on the rail head. Ice was specially frozen because after the first run of a wheel it was thrown down off the rail.

46. Maximum travel speeds: limitations and required engine power?

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

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

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

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

Low aerodynamic drag makes it possible for a 20-passenger vehicle with the engine capacity of 80 kW, 200 kW and 400 kW to reach the travel speeds of 200—250 km/h, 350-400 km/h and 450—500 km/h, respectively. (It should be noted that at high travel speeds in aerial environment required engine power is growing proportionally to cubic speed with 90—95% and more of its power used to overcome aerodynamic drag).

It is known that as the travel speed increases the wheel-rail cohesion is going down. To reach the travel speeds of 300—350 km/h and 400—450 km/h a friction coefficient of a "wheel — rail" pair of a STU with four driving wheels is to be not less than 0.04 (to provide 100 kgs thrust) and 0.07 (to provide 180 kgs thrust), respectively, which is easily reachable.

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

47. Is everybody ready to take a risk of traveling along the strings at the height of 5—10 m?

This risk of a purely psychological nature could be easily eliminated in future. It was time when people were afraid to travel by trains, cars, and later to fly by aircraft. Strange as it is, but passengers feel themselves most safe sitting in a car, whereas 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 (or died from after-accident injures) all over the world amounts to 1.2 million including about 50 million who become invalids or cripples (according to the data of the World

Health Organisation; their statistics also show that the annual number of people killed in wars is considerably less — 500,000).

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

None of the above mentioned causes is observed either in STU or 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 2003 the total number of people killed in air crashes all over the world was less than 1,000). However, factors resulting in aircraft crashes are absent in STU, in particular, a bird does not pose a hazard for a module whereas even a dove coming in a turbine of a plane could be a cause of a catastrophe; a STU module is not subject to a risk of icing, engine stop, shortage or cutting off fuel; bump, thunder storm clouds, lightning; it has no inflammable materials whereas fuel of aircraft tanks tend to explode or inflame when a plane is falling down, etc.

Thus, a STU has all prerequisites to become the safest mode of transportation which could be appreciated by a passenger making a choice of a travel mode.

48. What if power supply is cut off?

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

At non-electrified routes each module is provided with emergency-starting electric drive supplied from accumulators. Therefore, is a standard internal combustion engine is out of operation a module could reach the nearest station independently using its emergency-starting electric drive.

49. What if a track is out of operation and there is nobody to help (war, earthquake, etc.)?

Each module has an emergency exit and each passenger seat is equipped with a rescue rope and seat belt to help a passenger to descend on the ground. Furthermore, each module is provided with an extension ladder and emergency hose to enable quick evacuation of passengers, if necessary.

50. What is a maximum angle of elevation?

On a plain STU is moving at high speeds with its wheels resting upon their supporting part like wheels of a conventional train. However, a distinctive feature of a STU wheel is associated with the availability of two (not one) rims which enables a different wheel-rail supporting pattern within the mountainous sections of a track, i.e. through its rims like a V-belt drive. It makes it possible to increase the frictional force in a "wheel — rail" friction contact by many times and to get a maximum angle of elevation of 45—60°.

Naturally, design of a rail on mountainous and flatland sections of the route will be different as well as its transportation module, its running gear and wheels. In this case a more powerful engine is also required. However, all this makes it possible to cross the mountains and mountainous passes straightforward, eliminating hairpin turns or tunnels.

51. How are terminals and stations designed?

One of the design alternatives envisages that terminals have a ring-shaped design with a moving (rotating) platform or floor (fig. 26).

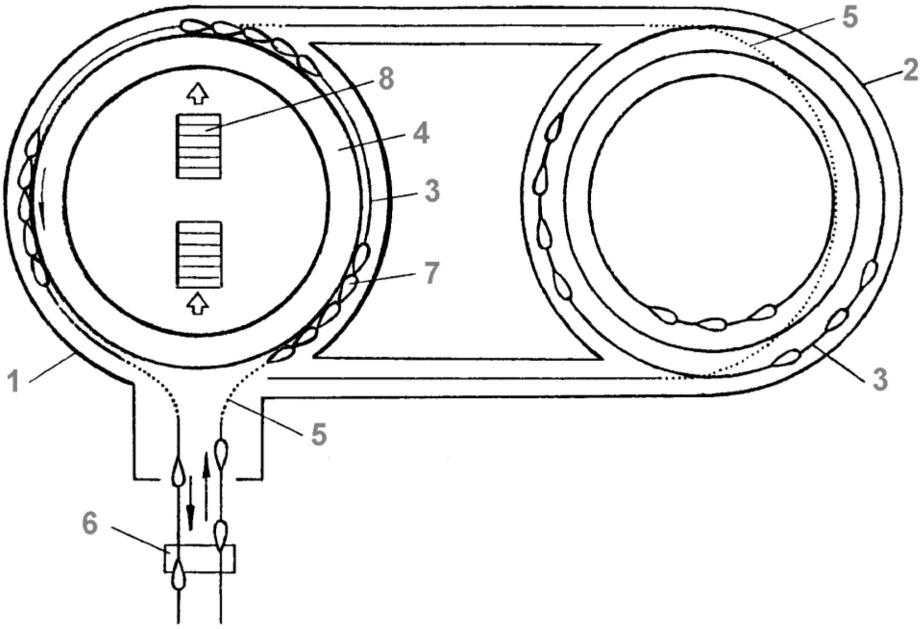

Fig. 26. Scheme of a ring terminal:
1 — terminal building; 2 — depot building; 3 — ring track; 4 — ring-shaped moving platform; 5 — switch; 6 — terminal anchor support; 7 — vehicle; 8 — entrance (exit) to the terminal.

Diameter of a terminal is about 60 m which could be extended to 100 m and more (fig. 27) to cope with the high passenger flows (more than 100,000 passengers per 24 hours).

Intermediate stations (fig. 28) and terminals (fig. 29) with intensive passenger flows will be equipped with switching devices and sheds to enable the circulation of vehicles independent of the general traffic schedule. Stations with small passenger flows are designed as open platforms located on the route. Loading (unloading) of passengers is facilitated in the course of braking of single not fully-loaded vehicles.

52. How loading and unloading of passengers is arranged at the ring terminal?

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

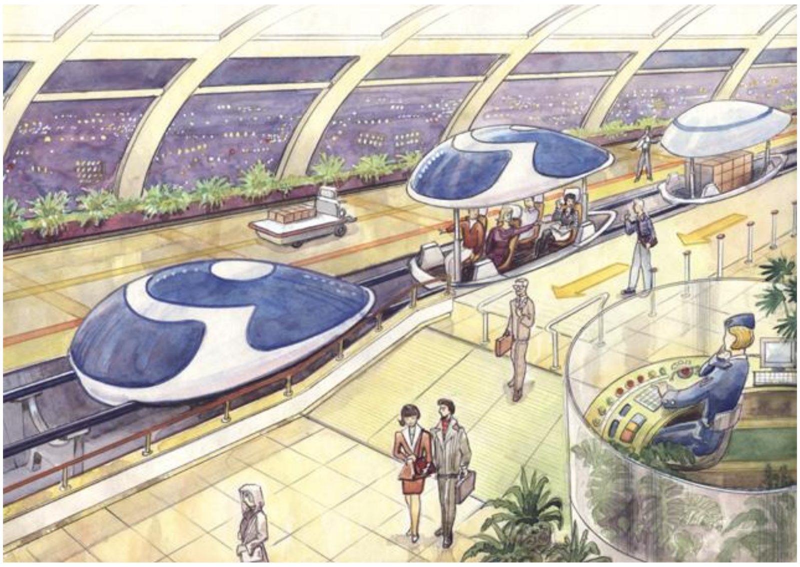

Fig. 27. Freight-passenger terminal

Fig. 28. Two-level station at the intersection of single-track STU routes

Fig. 29. Two-level terminal at the intersection of double-track STU routes

When the saloon is closed (automatically or manually) a vehicle is detached from the moving platform and switched to the line. If for this or that reason a vehicle saloon was not closed or there were no passengers a vehicle returns to the second ring. In a similar way but in a reverse order passengers are unloaded at the destinations.

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

53. How are freight terminals arranged?

Freight terminals intended for automatically-controlled loading and unloading of freight modules 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, friable 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) which is considerably smaller in size than, for example, a sea port of similar carrying capacity.

54. What is a maximal carrying capacity of a high-speed route?

For the rolling stock consisting of five 20-seat vehicles (with 100 m distance between them), travel speed of 360 km/h and circulation frequency of 60 seconds the maximal carrying capacity of one line during the rush hours and of the route as a whole (two lines in two directions) will be 6,000 pass./hour and 12,000 pass./hour (288,000 pass./24 hours or 105 million pass./year), respectively. In this case the route will have a reserve to increase its carrying capacity without construction of additional lines.

Minimal on-line distance between freight modules will be 50 m (one module on one span), therefore, maximal 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 maximal carrying capacity will be 72,000 t/hour, 1.73 million t per 24 hours and 631 million t per year.

The actual volume of freight and passenger traffic will be by one order lower, therefore, STU routes will be operating with 5—10% capacity which, in the end, will contribute to the higher reliability and safety of the transportation system.

55. Is the STU carrying capacity higher than that of an oil pipeline?

Its maximal carrying capacity (in one direction) is up to 315 million tons per year, net cost of oil transportation is somewhat lower than that by oil pipeline. In this case it is possible to use airtight return containers of 5,000 kg capacity, equipped with an electronic information map to indicate oil composition, extraction site, etc. which prevents mixing of oil extracted in various oil fields as it occurs nowadays and facilitates isolated refining of light, high-sulphurous and paraffined oil. Whereas a pipeline is capable to transport only oil and only in one direction, a STU is capable to carry a variety of other goods, alongside with petrol products (such as gasoline, diesel fuel, etc), in both directions, including: ore, coal, sawn timber and other raw materials; food products, building materials, equipment; as well as shift workers, etc.

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

56. What kind of freights will be carried by a STU?

STU is capable to carry various freights including: of 4,000—5,000 kg — at high travel speeds; of 10—20 tons at reduced travel speeds (up to 100 km/h), of 30—40 tons — at special many-wheel platform. Therefore, STU is appropriate for 99.9% of the mass-scale freights such as: oil and petrol products, coal, ore, food products, furniture, metal-rolling, building materials and structures, chemical products, special freights (liquified gases and cryogen liquids, radioactive and explosive substances, weapon), etc. (fig. 10—12).

Special containers are designed for liquid, friable, piece and special cargo to be fixed with seaport, railway and automobile containers. Containers for perishable goods, for example, food products are provided with temperature control devices (in winter) and air conditioning (in summer); containers for environmentally hazardous freights will have a multi-layer high-strength envelope, etc.

57. Is there a risk of leaf falling caused by a vehicle rushing above the forest?

No, there is not. You even do not feel any air vibration standing at 10—15 m distance from a vehicle rushing at 350 km/h speed which could be attributed to its high aerodynamic qualities (aerodynamic drag coefficient — C_x=0.075) and low module energetics (engine power — 160 kWt). In terms of physics any transportation system has a zero efficiency coefficient and STU is not an exception because it has zero useful transportation work: with zero cargo speed at origin and destination and approximately invariable height. In the end, all energy supplied to the vehicle engine is ejected in the form of track and ground vibrations, noise, rattle of wheels, air gusts, etc. in the environment, ultimately converted into heat.

Therefore, environmental impact is evaluated rather by the intensity of energy ejection per 1 unit of a track and the type of this energy than by the travel speed. STU is characterized by the lowest energy ejection intensity per 1 unit of a track amounting to 1600 J/m or 380 cal/m (against 4,000 and 80,000 J/m for "Mercedes-600" closest to a STU in terms of its dimensions, and a high-speed train, respectively). Energy ejection is characterized by the most favourable conditions provided by a velvet, joint-free STU track, high damping, light-weight wheels which make it possible to eliminate rattle of wheels; and ideal shape of a vehicle body contributing to the elimination of aerodynamic noise (high-frequency fluctuations caused by turbulent air flows, etc.).

Ejected energy is in the form of added air mass movement and whereas the air mass is relatively large, air movement will be in the form of a slight wind with its velocity decreasing proportionally to the square of the distance from the vehicle. Furthermore, a STU route will be rather free than full of vehicles — immovable observer will see a vehicle passing by at high speed in portions of second with the next one coming only in 1—2 minutes (at the traffic intensity of 20,000—50,000 passengers per 24 hours). Therefore, the average energy ejection is very low amounting to 15—30 W/m×sec.

58. Are there any weather or other travel limitations?

There are none. STU is not afraid of fog, rain, thunder storm, snow, hail (travel speed can be reduced under heavy hail to avoid damages in a nose part of a module; also armoured modules can be used in areas of hail hazard), icy conditions, sand and dust storms, hurricane wind. A STU is likely to withstand a tornado waterspout which could be attributed to its high-strength construction, very low sailing effect and high flow-around qualities of building components and a transportation module (for example, modern building structures such as reinforced concrete bridges are stable to tornado whereas STU structures are characterized by even higher specific strength, i.e. estimated per 1 unit of surface).

STU is more than any other transportation system resistant to natural disasters such as earthquakes, land slides, heavy rains, floods, high water, attack of desert sands. STU 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.

STU design alternatives for various geographic conditions are given in fig. 32—37.

59. What is the traffic intensity of a high-speed route?

To enable the transportation of passenger flows in two directions the average distance (frequency) between two neighbouring 10-seat vehicles (50% loading of a 20-seat vehicle) moving at the speed of 300 km/h should be as follows: 7.2 km (or 86 sec.) for the flow of 20,000 pass./24 hours; 2.9 km (35 seconds) — for the flow of 50,000 pass./24 hours; 1.4 km (17 seconds) — for the flow of 100,000 pass./24 hours. To facilitate the two-way freight flows the average distance between freight transportation modules 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 accesses and switching devices?

A STU route is equipped with super high-speed (for the travel speeds of 400—500 km/h), high-speed (200—350 km/h), speed (120—200 km/h) and low-speed (under 100 km/h) switching devices. For, example, high-speed switches will be installed at terminal accesses to enable non-stop circulation of transit vehicles without deceleration, bypassing the terminal. Such switches are designed as elaborate engineering structures having the length of more than 100 m.

Other sections of a track (including stations and stops) are provided with medium-speed switches to make vehicles slow down at their accesses. In this case traffic control system envisages special time and place for this maneuver which implies certain compression of a transportation flow ahead and behind a vehicle to give it 1—2 minutes for maneuver at several km distance from the nearest vehicles.

Low-speed switches as the lowest cost and safer could be installed more frequently, actually at each anchor support. It makes it possible for any vehicle to stop practically at any spot allocated for the purpose (information is to be given at least 5—10 minutes before the stop so that a control system could smoothly re-arrange the transportation flow).

In structural terms STU switches are close to the railway switching devices, though they have their peculiar features defined by the two-rim wheels.

Furthermore, alongside with horizontal switches vertical devices are also possible as due to the small weight of transportation modules it is easy to remove them to the other level of a transportation exchange (up or down).

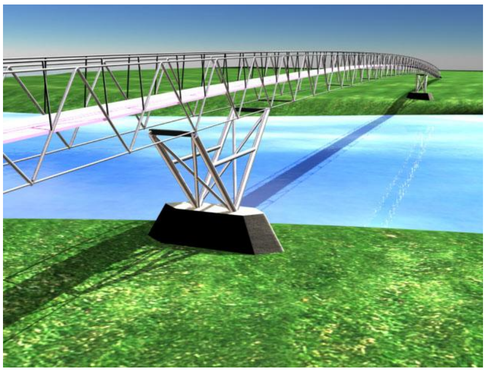

Fig. 30. Pedestrian bridge over the river

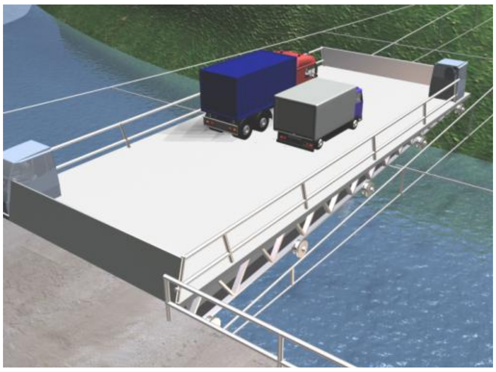

Fig. 31. Ferry crossing

Fig. 32. Single-track STU route along the sea shelf

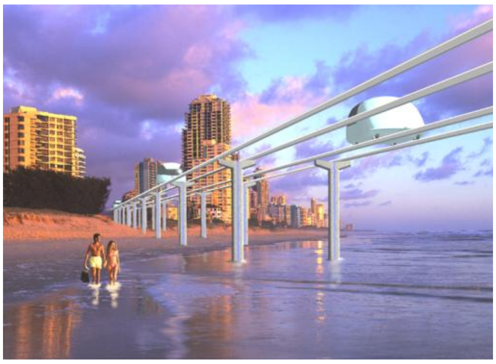

Fig. 33. STU route along the sea coast

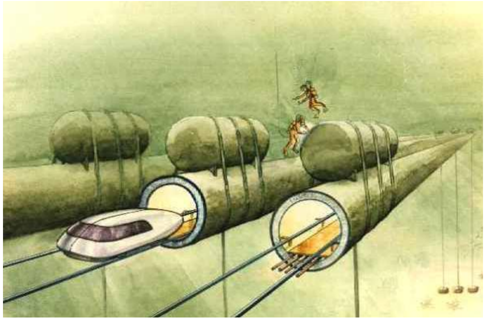

Fig. 34. Design alternative of a marine section of STU route

Fig. 35. Single-track STU route in the mountains

Fig. 36. Single-track STU route at foothills

Fig. 37. Single-track STU route in the mountains

61. How to get off the track if its height is, for example, 10 m?

It is much simpler and safer than to leave a plane flying at 10,000 m height which is unable to unload its passengers between the airports. A STU passenger can get out not only in the terminal or station, but in the interval, at any anchor support, i.e. on the average every 2—3 km. Passenger getting in a vehicle gives a command to the on-board computer (by voice or digital code) about his destination. If passenger's choice is a 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).

Getting off a passenger informs the traffic control system (using on-board computer) about his departure time and destination. There cannot be the slightest doubt that the ordered vehicle will be waiting for you at strictly fixed time — your order will not be neglected by computer.

Loading and unloading of passengers at terminals and stations is much easier: you get in (or out) a vehicle coming to the terminal building (like modern bus stations). In this case the track height has no significance as it could go several km away from the terminal. High-speed accesses require acceleration (deceleration) lanes of more than 1,000 m length, therefore, switching devices are located several km away from the terminal to which passengers are brought by the branch lines which could enter the terminal building at the ground level.

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 STU is its rail-string with a moving vehicle, therefore, there are no structural components before passenger's eyes (unlike railways or highways). One of the reasons to lay down certain sections of STU routes at the height of 20—30 m and more is associated with the need to keep trees save and sound under the track, i.e. below the level of 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 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 top (overhead) and bottom (rail) and all problems are related to current collection from immovable and flexible copper wire on the top. At high sliding speeds of current collector its trolley wire is sparking, burning, exposed to pitching and rolling as through a point contact moving at speeds of hundreds of km it has to transmit electric power estimated at hundreds and thousands of kilowatt.

At the same time a train wheel is moving (not sliding) along a rail, therefore, electric power is transmitted through a stationary contact (a wheel has zero speed within its contact zone with a rail) which has no clearances thanks to the high contact force between rigid wheel and rigid rail. This "wheel — rail" current collection scheme was used in a STU (left "wheel — rail" — right "wheel — rail") and in this case operation conditions are more favourable for a STU current collector which requires about 100 kW input power which is by one order less than for an electric train.

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

STU track structure and supports are characterized by higher strength than high-voltage power transmission lines at approximately equal sailing qualities. Taking into account lower sailing capacity of a STU structure and vehicles, the relative track deflection under side wind of 100 km/h velocity will be 1/10,000—1/5,000 which will not have a serious impact on the transportation system operation.

Design of a STU track and supports eliminates resonance effects under gusty wind which otherwise could result in their destruction caused by stalling flutter. The basic distinction of a STU 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 swing. In a STU this sag is estimated at several cm and it is "enclosed" inside the rigid and ideally smooth beams (rails) that in their turn are cross-fixed to form a solid structure difficult to shake even by a hurricane, thus, it is possible to design a STU resistant to any wind, even tornado waterspout.

65. Where else is it possible to use a STU?

STU could be used as a low-speed (under 100 km/h) special purpose transportation: internal transportation to serve logging operations, slag refuse disposal, sand and gravel quarries, coal, ore, oil, gas and other deposits, garbage removal, etc.

Lower transportation and traffic safety requirements of a special purpose STU in the absence of passengers will contribute to its lower (by 1.5—2 times and more) cost as compared with other high-speed string routes

STU technology could be used as a basis to design low-cost and fast-built string pedestrian crossings (fig. 30), automobile and railway bridges, overpasses, elevated roads, ferries (fig. 31), elevated roads for monorail roads and trains on a magnet suspension as cheaper alternatives of a string load-bearing structure as compared with conventional beam, girder, or guy rope span facilities. 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 trace STU routes along the sea?

STU will become a universal mode of transportation capable to pass across the land and sea. At sea depths under 50 m, for example, a STU route put on the supports installed in the sea bottom will pass at 25—50 m height and more on the shelf above the water surface (depending on building requirements, fig. 32—33).

At greater depths a STU track can be put in a tunnel (pipe) of 2.5—3 m diameter installed either in the sea bottom (under 500 m depth) or in the water at 50 m depth (fig. 34).

In the latter case tunnels have zero buoyancy (or to be more precise — excessive buoyancy) and require anchoring every 1—2 km in the sea bottom. Small module weight (up to 10 tons) and low circulation frequency (on the average every 1,000 m) prevent tunnel submergence. High deflection rigidity and special tunnel design contribute to the high evenness and rigidity of a string track structure under various travel speeds irrespective of the sea (ocean) depth.

67. Does a STU require elaborate building technology?

In technological terms it was possible to start STU construction in the 19th century when all necessary structural and building materials, mechanisms and equipment were already available. A STU route requires much simpler building technology than a bridge with a similar span (fig. 38).

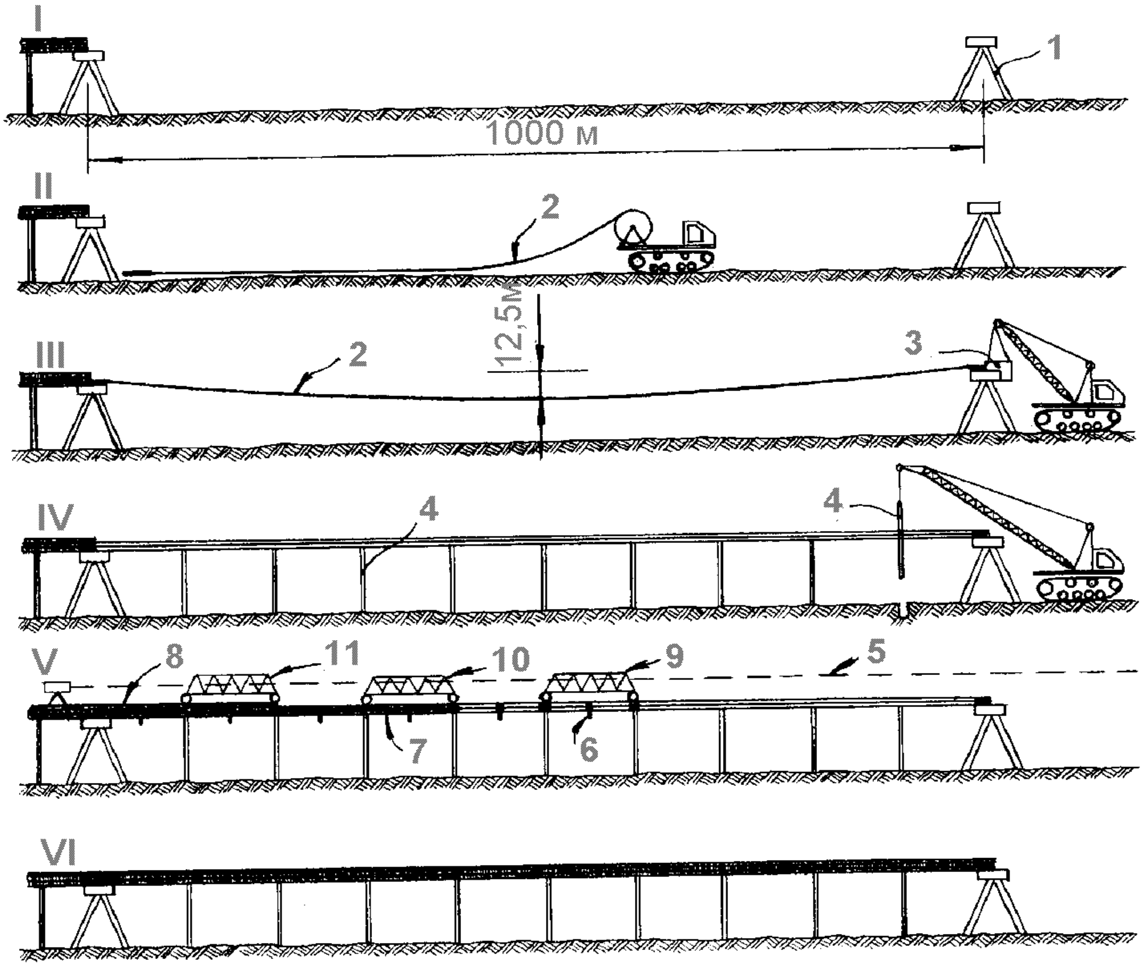

Fig.38. STU building technology.
1 — anchor support; 2 — cable (string component); 3 — cable adjusting mechanism; 4 — intermediate support; 5 — sight line; 6 — cross plate; 7 — rail envelope; 8 — rail head; 9, 10, 11 — technological platforms to install cross plates, rail envelope and rail head, respectively.
I — installation of anchor supports; II — laying of string cables; III — string adjusting and anchoring; IV — installation of intermediate supports; V — assembly of rail components and track structure; VI — ready track section.

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

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

Moving from span to span a platform is used to install the hollow rail body, to fix it in the designated position, to put the filler, to fix the rail head, cross plates and do other works necessary for track installation. All the above works could 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 labour intensity and net cost.

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

Economic aspects

68. Cost of a STU in comparison with other transportation systems?

A STU has the lowest cost among other transportation systems of similar carrying capacity, comfort level and travel speed, etc. The cost of competitive transportation routes built in a plain is as follows: USD 10—15 million/km — for a high-speed railway; USD 20—40 million/km — for "Transrapid" system (train on a magnet suspension, Germany); USD 3—10 million/km — for a motorway; USD 15—25 million/km — for a mono-rail road.

A STU route is many times (3—10 times) cheaper than other known transportation systems which is attributed to its low material consumption (including its track structure and supports); and no need in construction of elevated roads, bridges, viaducts, overpasses and other high-cost structures.

69. What are the travel costs for passengers?

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

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

Table 2

Travel costs within a STU system: "Moscow — London (Paris)" at 2,830 km section ("Moscow — London")

Indicator	Traffic volume (in two directions):					
	passenger traffic, thous. pass./24 hours			freight traffic, thous. tonnes/24 hours		
	20	50	100	50	100	200
1. Given cost (at 2,830 km section):						
- USD/pass.	72.60	32.71	19.43	—	—	—
- USD/ton of freight	—	—	—	19.99	16.66	15.01
Including:						
1.1. Total transportation cost	66.47	22.58	13.30	6.65	3.32	1.67
including:						
- amortization allocations	25.48	10.19	5.10	2.55	1.27	0.64
- maintenance cost	15.51	6.20	3.10	1.55	0.78	0.39
- profit allocations	25.48	10.19	5.10	2.55	1.27	0.64
1.2. Rolling stock costs, total	6.13	6.13	6.13	13.34	13.34	13.34
including:						
- amortization allocations	0.63	0.63	0.63	1.05	1.05	1.05
- maintenance cost	0.63	0.63	0.63	1.05	1.05	1.05
- profit allocations	0.63	0.63	0.63	1.05	1.05	1.05
- cost of electric energy	4.24	4.24	4.24	10.19	10.19	10.19
2. Number of vehicles to serve the whole route (at average travel distance of 1,000 km), number of units	1530	3820	7650	19100	38200	76400

Indicator	Traffic volume (in two directions):					
	passenger traffic, thous. pass./24 hours			freight traffic, thous. tonnes/24 hours		
	20	50	100	50	100	200
3. Cost of the rolling stock, USD million	45.9	114.6	229.5	191.0	382.0	764.0
4. Average distance between the neighbouring vehicles in a transportation flow (single vehicles in one line):						
- time frequency, sec	86.4	34.6	17.3	6.9	3.5	1.7
- distance, km	9.60	3.84	1.92	0.77	0.38	0.19

70. What is the cost of freight transportation?

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

Average net cost per 1 ton of freight to be carried on a plain at 1,000 distance will be as follows: USD 7—9 (for a dual-way freight flow of 50,000 t/24 hours), USD 5—7 (100,000 t/24 hours) and USD 3—5 (200,000 t/24 hours).

71. What is the cost of 1 km of STU route?

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

Table 3 show the key technical and cost data (million USD/km) of various types of STU systems for construction, for example, in Gulf Countries (for long routes in desert with the length of more than 10 km built beyond the city built-up environment*).

Table 3

Key technical and cost data of various types of STU systems for construction in Gulf Countries

Types of STU	Key technical characteristics of a dual mode (passenger/freight) STU (for a double-track route)	Cost of a double-track STU (million USD/km) depending on the speed regimes used for the system operation				
		STU component	up to 100 km/hour	up to 200 km/hour	up to 350 km/hour	up to 500 km/hour
MicroSTU 	Width of a gauge, m 1.5 Capacity of a module: • number of passengers up to 6 • freights, ton up to 1 Volume of transportation: • thous. pass./24 hours up to 50 • thous. ton/24 hours up to 10	Track structure Infrastructure Rolling stock **Total:**	1.4—1.6 0.7—0.9 0.4—0.6 **2.5—3.1**	1.9—2.5 1.5—1.8 1.1—1.5 **4.5—5.8**	2.6—3.1 2.2—2.7 1.9—2.2 **6.7—8.0**	3.2—3.8 2.9—3.5 2.5—3.0 **8.6—10.3**
MiniSTU 	Width of a gauge, m 2.0 Capacity of a module: • number of passengers 7—20 • freights, ton 2—3 Volume of transportation: • thous. pass./24 hours up to 200 • thous. ton/24 hours up to 20	Track structure Infrastructure Rolling stock **Total:**	2.4—2.7 1.2—1.5 0.9—1.2 **4.5—5.4**	3.5—3.9 2.8—3.1 1.6—2.1 **7.9—9.1**	4.3—4.9 3.6—4.2 2.5—3.1 **10.4—12.2**	5.1—5.7 4.4—4.9 3.2—3.7 **12.7—14.3**

* under conditions of cross-country and urban built-up environment the cost of STU systems will be by 30—50% higher

MacroSTU 	Width of a gauge, m 2.5 Capacity of a module: • number of passengers 21—60 • freights, ton 4—6 Volume of transportation: • thous. pass./24 hours up to 500 • thous. ton/24 hours up to 50	Track structure Infrastructure Rolling stock **Total:**	3.5—3.9 1.7—2.1 1.5—1.8 **6.7—7.8**	4.5—5.2 2.7—3.5 2.5—2.9 **9.7—11.6**	6.5—7.5 4.5—5.5 3.4—4.0 **14.4—17.0**	7.7—8.2 5.6—6.1 4.2—4.8 **17.5—19.1**
MegaSTU 	Width of a gauge, m 1.5; 2.0; 2.5 Capacity of a train: • number of passengers up to 500 • freights, ton up to 500 Volume of transportation: • thous. pass./24 hours up to 500 • thous. ton/24 hours up to 200	Track structure Infrastructure Rolling stock **Total:**	2.4—3.0 1.2—1.8 1.5—2.1 **5.1—6.9**	3.5—4.1 2.6—3.4 2.8—3.6 **8.9—11.1**	— — — **—**	— — — **—**
Light monoSTU 	Length of a span, m up to 1,500 Capacity of a module: • number of passengers up to 10 • freights, ton up to 1 Volume of transportation: • thous. pass./24 hours up to 100 • thous. ton/24 hours up to 10	Track structure Infrastructure Rolling stock **Total:**	0.9—1.2 1.2—1.8 0.3—0.6 **2.4—3.6**	1.4—1.7 2.0—2.5 0.8—1.2 **4.2—5.4**	— — — **—**	— — — **—**
Medium-size monoSTU 	Length of a span, m up to 2,000 Capacity of a module: • number of passengers 11—20 • freights, ton up to 2 Volume of transportation: • thous. pass./24 hours up to 150 • thous. ton/24 hours up to 15	Track structure Infrastructure Rolling stock **Total:**	1.5—2.4 1.5—2.1 0.6—1.2 **3.6—5.7**	2.6—3.5 2.2—2.8 1.4—2.1 **6.2—8.4**	— — — **—**	— — — **—**
Heavy monoSTU 	Length of a span, m up to 3,000 Capacity of a module: • number of passengers 21—50 • freights, ton up to 5 Volume of transportation: • thous. pass./24 hours up to 300 • thous. ton/24 hours up to 30	Track structure Infrastructure Rolling stock **Total:**	2.7—3.9 1.8—3.0 1.2—2.4 **5.7—9.3**	4.1—5.3 3.2—4.5 2.6—3.8 **9.9—13.6**	— — — **—**	— — — **—**

72. What is the structure of construction expenditures for a STU route?

A STU complex includes: stationary facilities (terminal, stations, depot, freight terminals, repair garages, sub-stations, control system, signaling, communication, switching devices) which require 20—40% of the total expenditures. The share of a track structure and supports amounts to 35—45% (with 15—25% for a track structure and 10—15% — for supports). Other costs include: design, adaptation of research and pilot design results and a pilot track section — 5—10%, rolling stock — 5—10%, other expenditures — 10—15%.

73. What makes the cost of passenger tickets?

Compared with other high-speed transportation systems STU is characterized by a very low net travel cost, thus, the cost of tickets should be increased and the route operation should give the profitability of 100—200% (which will make it possible to pay back the expenditures during 3—5 years).

The structure of expenditures (for 100% profitability) is as follows: balance profit — 50%, track and rolling stock amortization — 22%, maintenance costs — 16%, fuel (electric energy) — 12% (for average vehicle speed of 300 km/h).

74. What is the cost structure of freight traffic at 100% profitability?

Balance profit — 50%, fuel (electric energy) — 30% (for average vehicle speed of 300 km/h), track and rolling stock amortization — 15%, maintenance costs — 5%.

75. The cost of transportation will in many respects be defined by the cost of fuel?

It should be remembered that STU is a high-speed transportation therefore the major portion of power (by the way, less than in other high-speed transportation modes) is used to gain the necessary speed. At the same time the cost of a string route is very low, the share of amortization and maintenance costs is reduced and energy consumption is approximately invariable. It is especially true for the net cost of freight traffic with the share of energy costs amounting to 60% and 80% for the travel speeds of 300km/h and 400 km/h, respectively. For passenger traffic this share is lower amounting to 30% (travel speed — 300 km/h) and 40% (travel speed — 400 km/h).

76. Is the cost of oil transportation by a STU lower than by a pipeline?

The cost is by 1.1—1.5 or in some cases 1.5—2 times lower which will depend on price-formation policy. The costs for a STU route will be repaid not so much by oil transportation but rather by passenger and freight traffic including transportation of food products, building materials and structures, chemical and petroleum products, etc.

77. What cost of building materials and structures is used as a basis to calculate the cost of string routes?

The following integrated prices were used as a basis to specify the cost of structures:

- USD 1,500—3,000/t — assembled steel structures depending on their complexity and steel mark;
- USD 5,000/t — aluminium structures;
- USD 500—750/m^3 —assembled reinforced concrete structures and USD 300—500/m^3 — monolithic reinforced concrete;
- USD 100—200/m^3 — concrete.

The cost of terminals and technological premises was estimated at USD 3,000/m^3 — terminal building (general construction works plus engineering and technological equipment), USD 1,500/m^3 — depots and garages and USD 1,000/m^3 — area of freight terminals provided with basic services.

78. What is the cost of the electric car for STU?

The cost of the rolling stock for electrified STU routes could be evaluated against the cost of a passenger car which in terms of its dimensions and design is very close to a STU vehicle. The cost of electric engines for a STU of serial production with 25—50 kW power is 1.5—2 times lower than that of an internal-combustion engine of equal power; STU engines are characterized by higher reliability, durability and are easy for maintenance and service. A body of a STU transportation module is cheaper than that of a car of similar size which is attributed to its simpler design (lack of radiator, doors, luggage carrier, hood, headlights, marker, braking and other lights, windshield wiper, window raiser, etc.; fig. 39).

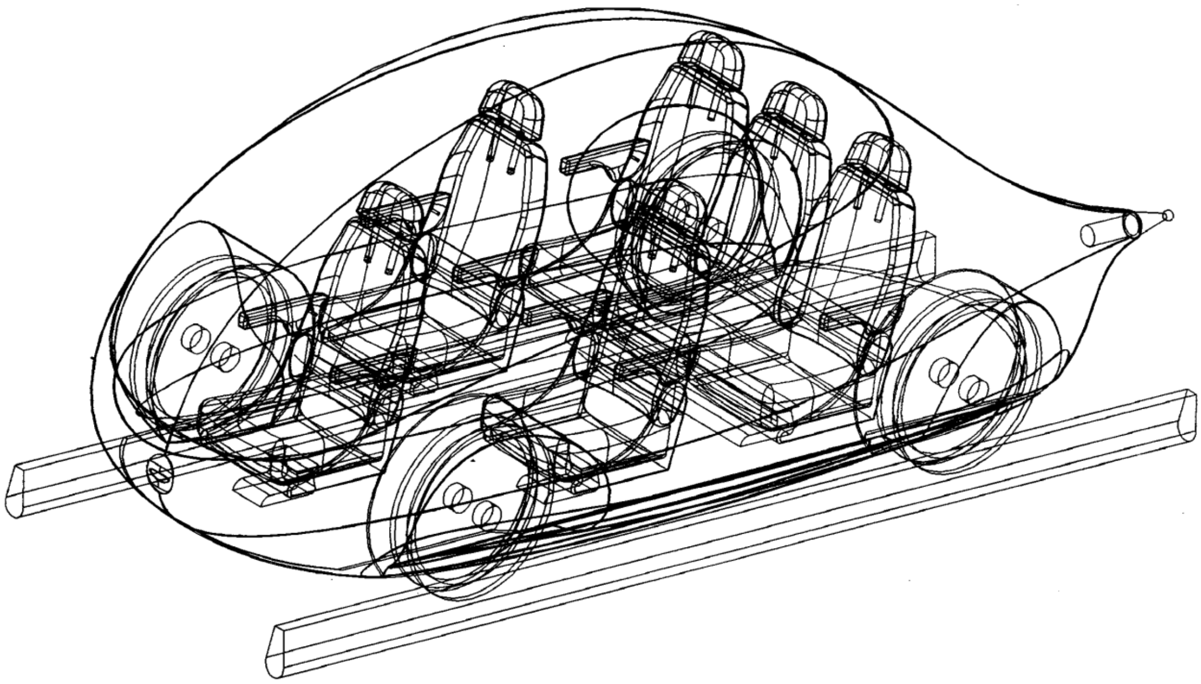

Fig. 39. Design alternative of a high-speed 6-seat passenger vehicle

Undercarriage and suspension of a STU vehicle is also simpler and cheaper than in a car (no unreliable and high-cost rubber tires, wheel turning mechanisms, simpler operating mechanism for turning moment of non-rotary wheels, no cross-country travel requirements, etc.).

The cost of rated engine speed and turning moment systems (control block in a STU and gear box, clutch, fuel supply, etc. in a car) is approximately the same in both transportation modes. Drive regulation system of a STU vehicle is much cheaper and simpler as the number of parameters is less: travel speed, distance to the nearest vehicles and on-line location (coordinates).

Driving a car is a complicated task which in spite of the progress of 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 a STU vehicle this problem is solved by a low-cost controller provided with appropriate software to be controlled and managed by linear computers integrated in a network. Control system of a car in addition to a driver and executive mechanisms (steering wheel and column, wheel turning mechanisms, clutch pedal, brakes, gear shift mechanism, etc.) includes a system of information visualization necessary for driving control which is absent in a STU, in particular, windshield wiper in a wind screen to provide for its cleanliness and visibility, headlights and parking lights, marker lights, instrument panel, mirrors, horn signal, etc.

Interior design is approximately the same for a STU vehicle and a car and could be varied depending on customer's desire. Furthermore, a number of components is absent in a STU vehicle and transportation system as a whole, for example: fuel tank (and, consequently, the whole chain of accompanying elements such as filling stations on a track, oil refinery plants to produce gasoline and diesel fuel, oil pipelines, oil wells); fuel feed system; exhaust outlet, silencing and combustion system (for example, more strict environmental requirements imposed in the recent years in a number of countries resulted in considerable growth in the cost of cars).

In view of the above said it will be appropriate to forecast that under serial production the cost of a STU vehicle will be 1.5—2 times lower than that of a passenger car or a mini-bus of similar carrying capacity and comfort and, therefore, it will be more accessible for individual use (in the future thanks to STU advantages it will be possible to develop an extensive network of string transportation similar to the existing highway network).

79. What is the estimated cost of the rolling stock and how it affects the net cost of travel?

The cost of a 10-seat passenger vehicle and freight transportation module (5,000 kg carrying capacity) was estimated at USD 50,000 and USD 20,000, respectively. Obviously, these figures are overestimated. Nevertheless, the share of the rolling stock in the total travel cost (amortization and maintenance costs) amounts to as little as 5—10% and 15—20% for passenger and freight traffic, respectively. It means that the rolling stock is not critical to its loading, thus, it is possible to increase the share of 1—5-seat vehicles and to make them more comfortable (to provide toilets, washroom, shower, bath).

Moreover, a number of vehicles can be designed as a hotel single-room or office (to include furniture, computers, modern satellite communications, fax machines, etc.), thus, to make STU not only a means of transportation but a place of work (especially during mission trips) or rest. Even if the cost of such vehicle is USD 100,000 and more its fare will be only by 30—50% higher than the cost of a ticket in other transportation modes.

80. Is it possible to take with you a private car and how much will it cost?

Passenger could register his personal car as his luggage like any other cargo under 5,000 kg. Taking into account the fact that a car is oversized cargo it will be transported in specially equipped transportation modules of large size and with higher power engines. If a trip is not very long (0.5—1 hour; 150—300 km distance) passenger may stay either in a car or to take a passenger vehicle. In this case a car will arrive in a destination simultaneously with its owner who can remove to it immediately.

Net cost of car (1,500 kg mass) transportation, for example, from Berlin to Moscow (distance — 1,830 km) will amount to USD 100—150.

81. How soon the STU track expenditures will be paid back and how high are financial risks?

Recoupment period of a STU system depends on the following main factors:

- loading (volume of passenger and freight traffic),
- normative operation profitability (and related ticket price),
- maintenance costs and
- the cost of fuel (electric energy).

For example, the payback period for a concrete track — "Berlin — Moscow" (1,830 km), ticket price — USD 40/pass. (140% profitability) and passenger flow of 50,000 pass./24 hours — will be 8 years. In this case the annual profit will amount to USD 480 million (the cost of a track including infrastructure and the rolling stock is USD 3.9 million). For passenger flow of 100,000 pass./24 hours the track expenses will be paid back during 3.5 years (profit — USD 1.1 billion/year).

Travel time to come from the centre of Berlin to the centre of Moscow by a STU even at relatively low average travel speed of 300 km/h will be approximately the same as by plane (about 6 hours) but more safe and comfortable. Therefore, it is appropriate to compare a STU fare with air fare to show that USD 60/pass. is not a high price for a ticket (at 260% profitability). Then, the annual profit of a track will be USD 800 million and USD 1.6 billion for passenger flows of 50,000 and 100,000 pass./24 hours with the recoupment period of 4.8 and 2.4 years, respectively.

Financial risks will be minimal because it is a financially sustainable project. Even at 20% loading of the target traffic volume the route will not be unprofitable to give but a small profit. In all our examples the cost of electric energy was taken as USD 0.05 kW×hour and the cost of fuel — USD 0.5/l.

82. What niche in the economy of an individual country or the world economy is opened for STU?

Almost 100 years ago Henry Ford with his automobilization programme managed to make a revolution not only in the USA economy but in the world as a whole. Economic potential of a STU is not less. In its essence and scale a STU is comparable with Internet.

Potential niche of string transportation in the world economy exceeds USD 1 trillion which, for example, is larger than a niche created 20 years ago by Bill Gates and his Microsoft Corporation, then unknown and now the richest man of the planet. Potential volume of orders for STU in a number of countries such as Russia, China, India, USA exceeds USD 100 billion.

83. What is the economic efficiency of a wide-scale application of STU?

STU is a branch-generating programme characterized by the high economic efficiency resulting from the following factors:

- reduced cost of STU routes and infrastructure;
- reduced cost of lands allocated for route construction;
- fuel savings (energy resources) in the course of the rolling stock operation;
- lower accident rates.

If to assume that in the 21st century STU will be able to press out 50% of motor transportation then it will be necessary to build about 10 million km of string roads (today more than 20 million km of highways are available in the world). As STU represents the second-level transportation, i.e. its track structure is elevated above the ground on the supports, the economy as compared with other known modes of transportation of the second level will be as follows:

- USD 100—150 trillion as compared with mono-rail roads (their cost is estimated at USD 5—8 million/km);
- USD 190—390 trillion as compared with trains on a magnet suspension (their cost is USD 20—40 million/km);
- USD 90—290 trillion as compared with the elevated highway and railway roads (their cost is USD 10—30 million/km).

Today the cost of developed lands (with roads) ranges from USD 100,000 per 1 ha to USD 10 million per 1 ha (in cities), on the average — about 200,000 USD/km. At the inflation rates of 3—5% per year the cost of these lands in the middle of the 21st century will be about 1 million USD/ha. Then the cost of lands occupied by the existing motor roads (about 60 million ha which is equal to the summary area of Germany and Great Britain) will amount to about USD 60 trillion (about 3 million USD/км). If STU presses out at least 50% of motor transportation it will be possible to return to land users the total of about 30 million ha of lands with the total cost of about USD 30 trillion.

The high-speed rolling stock of STU is characterized by the best aerodynamic qualities among other known transportation modes which was supported by more than 10 patents. For example, one of the best sport cars of "Porsche" has aerodynamic resistance coefficient C_x=0,34 against C_x=0,08 in STU unibus (C_x coefficient of unibus was obtained experimentally as a result of numerous wind tunnel tests). At the travel speed of 100 m/s (360 km/h) aerodynamic resistance power of a 20-seat unibus will amount to 250 kWt, however, if the outlines of its body were similar to those of a "Porsche" car this power were equal to 1062 kWt. Therefore, aerodynamic resistance power was reduced by 812 kWt which gives the fuel economy in the amount of 812 tons per year per 1 module (for consumption of 0.2 kg per 1 kWt/hour and 5,000 hours of engine operation per year). At the small number of the rolling stock — 1 module per 1 km of the route — their required number for the aforementioned road network will be 10 million. During 20 years of service the high-speed park of unibuses could save about 160 billion tons of fuel with the total cost of USD 80 trillion (at the average world cost of 0.5 USD/kg or 500 USD/t).

STU will be also the safest mode of transportation. Its safety is achieved first of all by the installation of its string track high above the ground which eliminates collisions with other modes of transportation, pedestrians, animals, etc. as well as by the availability of two flanges on each steel wheel which makes them stable as opposed to the rubber wheels of a car kept on the road by friction force. This fact also contributes to STU resistance to the impact of hurricane wind, heavy rains, snow, icing, fog, sand and dusty storms, floods, earthquakes, tornado, landslides and other natural phenomena that could be the cause of human deaths in the course of using existing modes of transportation. Accident rates at STU will be lower than at motor transportation (for comparison, in 2003 the number of deaths as a result of aircraft catastrophes all over the world was less than 1,000 against about 1.2 million people killed and about 50 million injured and became invalids or cripples as a result of road accidents). If in the 21st century at least 50% of automobile transportation is replaced by a safer string transportation it will be possible to save 50—60 million human lives and to prevent 1.5—2 billion of injures and invalids. If premature human deaths and disability is evaluated by the average world insurance norms at USD 500,000 and 50,000, respectively the summary economic effect resulting from the reduced injury rates at transportation within the scale of the global civilization will amount to about USD 100 trillion.

Therefore the economic efficiency of the wide-scale application of STU in the 21st century will be more than USD 300 trillion.

84. How much the track cost depends on the relief and ground features of the site?

The cost of transportation lines is not strongly dependent on the ground features of the site and its ground features, therefore, STU routes can be built in difficult of access areas such as deserts, marshlands, permafrost, taiga, tundra, jungles, ocean shelf, mountains, etc.

For example, if ground features require increased height of supports (from 5m on a plain to 10 m), the track cost will be increased only by 20—30% because the share of supports in the total system cost is small (15—25%). The cost increase will be approximately the same for a string route passing across marshland area, desert, permafrost, etc. resulting from the need in additional strengthening of supports and piles, in particular: in a dense bottom of marshland; deep stationary layers of desert sands; below the defrosting depth of a pile in summer (specially designed).

Environmental aspects

85. What will be the planetary environmental impact of a large-scale STU application?

Firstly, consumption of non-renewable energy carriers (such as oil and petroleum products, coal, gas), ferrous and non-ferrous metals will be reduced which results from the low material- and resource-consumption of a STU including its track and supports which do not require construction of embankments, depressions, overpasses, viaducts, bridges and other resource-consuming facilities.

Secondly, it contributes to lower environmental pollution as a result of: use of electric energy being the most clean energy type; low specific energy consumption (5—10 times less than a car); cautious attitude to vulnerable eco-systems (tundra, permafrost, jungles, marshlands, etc.); use of alternative environmentally sound energy types (wind, sun, etc.).

Thirdly, alienation of fertile agricultural lands for string routes will be reduced because STU routes do not require large land allocations (less than 0.1 ha/km, i.e. the same as for pedestrian or walking path), construction of tunnels, cutting of woods, demolition of buildings.

86. Noxious atmospheric emissions as compared with other transportation modes?

Average noxious atmospheric emissions from motor transportation and high-speed railways amount to 10 g per 1 pass./km and about 0.6 g per 1 pass/km, respectively.

Aviation is responsible for the greatest atmospheric pollution. Summary noxious atmospheric emissions from modern aircraft reach 300—400 g per 1 pass.×km. The bulk of aircraft emissions are concentrated within the airport zones, i.e. in the vicinity of large cities, generated by aircraft flying at low heights and engine reheating. At low and medium heights (up to 5,000—6,000 m) nitrogen and carbon oxides remain in the atmosphere for several days after which they are washed away as acid rains. At upper heights aviation constitutes the only source of pollution with noxious substances capable to stay in the stratosphere much longer — about 1 year. Even conversion to hydrogen aircraft engines will not solve the problem. Exhaust products of engines harmless near the earth in the form of water vapor are converted into ice crystals at upper heights having a screening effect.

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

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

Design of freight STU 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. Crash could result in derailment of only one vehicle (extreme braking distance of the next vehicle will be less than the distance between two vehicles) with small freight.

At the same time railway accidents sometimes result in the heaviest environmental pollution with tons of transported chemical products. Accidents at oil and petroleum product pipelines are often accompanied by atmospheric emissions 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 are given in Table 4.

Table 4

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

Mode of transportation	Specific energy-resource consumption (litres of gasoline per 100 passenger/km or tonnes/km		Noxious emissions, kg/100 passen-ger/km (or 100 tons/km)	Land require-ments, ha/100 km
	Passenger traffic	Freight traffic		
1. Railways (80 km/h): a) arterial b) suburban c) urban: - underground - tram	 1.1—1.4 1.2—1.5 1.3—1.7 1.9—2.1	 0.7—1.0 0.9—1.4 — —	 over 0.1 over 0.1 over 01. over 0.1	 300—400 300—400 — 50—100
2. Motor transportation (100 km/h): a) individual car: - within the city limits (average load - 1.6 passengers) - beyond the city limits (average load - 3.5 passengers) b) bus - within the city limits - beyond the city limits c) trolley-bus (60 km/h)	 4.7—6.3 1.5—1.7 2.1—2.3 1.4—1.7 1.9—2.5	 6.6—11.1 5.1—9.2 — — —	 over 1 over 1 over 1 over 1 over 0.1	 200—300 300—500 200—300 300—500 200—300
3. Air transportation: a) long-distance (900 km/h) b) local (400 km/h)	 6—10 14—19	 50—75 150—200	 over 10 over 50	 20—50 10—20
4. Sea transportation (30 km/h)	17—19	0.38—0.95	over 10	5—10
5. River transportation (30 km/h)	14—17	0.57—1.4	over 10	2—3
6. Oil pipelines (10 km/h)	—	0.51—0.57	over 1	50—100
7. Gas pipelines (10 km/h)	—	5.7—6.1	over 1	50—100
8. Conveyer transportation (10 km/h)	—	4.7—9.2	over 1	50—100
9. Hydro-transportation (10 km/h)	—	2.3—4.7	over 1	50—100
10. Cable-rope roads (10 km/h)	0.3—0.5	0.95—1.9	over 1	20—30
11. Train on a magnet suspension (400 km/h)	3.5—4.5	—	over 1	100—200
12. High-speed railway (300 km/h)	2.5—3.5	—	over 1	300—500
13. Monorail (50 km/h)	1.5—2.5	—	over 1	50—100
14. Electrified string transport (10-seat passenger module; freight — 5 tons) with the speed of: - 100 km/h (30 kWt engine power) - 200 km/h (70 kWt engine power) - 300 km/h (90 kW engine power) - 400 km/h (200 kW engine power) - 500 km/h (400 kW engine power)	 0.3 0.35 0.5 0.75 0.9	 0.6 0.7 1,0 1.5 1.8	 below 0.001 0.001 0.001 0.001 0.001	 10—20 10—20 10—20 10—20 10—20

87. Electric energy when consumed by STU is not hazardous, however, when generated by a power results in environmental pollution, is it true?

Hazard is associated no so much with environmental pollution as with concentration of noxious substances. Air, water and food products contain all chemical elements included in Mendeleyev's periodic table that are harmless under appropriate concentrations. Special survey showed a direct relationship between morbidity rate, especially among children, and degree of environmental pollution. For example, in experts' opinion this cause (environmental pollution) is attributive of the reduced life expectancy in Russia approximately by 3—5 years.

According to the estimates substandard water quality "is responsible" for the reduction of life expectancy by 2—3 years. Contribution of acute and chronic food intoxication in reduced life expectancy is estimated at not less than 1—2 years.

Transportation, especially in urban areas is the major source of air pollution caused by atmospheric exhausts immediately in the human living environment. To have a more clear picture let us make a theoretical experiment: let us take the lowest power transportation vehicle with internal-combustion engine — a moped — and electric appliance of similar power, for example, an iron. Both of them we switch on in our flat (their power is equal). In a minute we'll have the following three alternatives:

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

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

In fact, heat power plants give rise to environmental pollution but in terms of one unit of power this pollution is lower than that generated by cars and it is observed far from the population concentrations. There are also other, less hazardous or environmentally safe power plants such as hydro-power, nuclear, tidal, geothermal, wind and solar electric power stations.

Furthermore, STU will contribute to the promotion of autonomous energy supply systems based on renewable energy sources such as wind and sun. In terms of direct environmental impact wind energy is one of the most clean energy sources. It does not generate noxious atmospheric emissions and water contamination, does not result in the depletion of limited non-renewable mineral resources and transformation of water regime.

There are principal schemes of wind and solar power plants with vertical axis of rotation which could be combined with STU 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 STU needs it is enough to have an energy source of 100—200 kW power or two wind power stations each of 50—100 kW installed at 1 km distance along the track with their maximum number corresponding to the number of supports, i.e. 10—20 units/km to generate the summary peak power of 500—2,000 kWt/km (for a track exposed to moderate and strong winds).

Therefore, the total power of wind power stations of a STU will amount to 0.5—2 million kWt per each 1,000 km (at the average wind velocity of 10 m/sec.), the net cost of energy generation will be within USD 0.02/kW and the recoupment period of 6 years. Therefore, in addition to its autonomous energy supply source a STU could become a powerful electric power plant capable to meet the needs of surrounding areas. In this case it is not necessary to have high-cost and environmentally hazardous high-voltage power transmission lines as users' energy supply will be facilitated directly by a STU.

88. What are land requirements for a STU compared with other transportation land users?

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

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

As to STU routes, they do not require embankments, tunnels bridges, overpasses and other similar facilities associated with large land requirements. Land requirements for one supporting mast and one anchor support amount to about 1 m^2 and 20 m^2, respectively. Therefore, the total right-of-way along the whole length of a STU route will occupy less than 100 m^2, i.e. 0.01 ha of land and its conditional width will be within 10 cm which is considerably smaller than land requirements for a pedestrian or walking path.

89. What damage to nature could be caused by STU construction? What about other transportation systems?

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

Furthermore, its construction implying the use of piled foundation could fully eliminate excavation and earth moving works which could damage the layer of soil with its humus accumulated during millions of years. STU could pass through any terrain without any embankments or land excavation whereas, for example, a modern highway or railway construction is associated with earth removal in the amount of 10,000—50,000 m^3 and 100,000 m^3 for mountainous country. STU is not critical to a span length, therefore, there is no need in cutting of forests or even free standing trees as it is possible to displace any support, if required.

STU is characterised by very low material consumption for its construction which makes it most environmentally clean in technological terms. For example, material consumption for a single-track STU route will be the same as for two railway rails using each third sleeper (and in this case railway will require 2/3 of sleepers, contact network with copper wire and supports, powerful gravel cushion, earth embankment, bridges, overpasses, viaducts, etc.).

Thus, STU does not require a great number of blast furnaces, ore, mines (necessary for steel and copper production), cement plants and manufacturing of reinforced concrete products, sand, gravel quarries, intensive motor and railway traffic to deliver building materials, access roads, etc. which could produce additional, sometimes irreversible environmental pressure.

90. How heavy is a STU module impact in terms of soil vibration and noise?

A STU module has no projecting parts except its narrow wheels extended for 10 cm from the body; it does not require windshield wipers and headlights (as it is driverless) which at high speeds could be a source of noise. A vehicle body has a perfect aerodynamic shape (aerodynamic drag coefficient C_x=0.075—0.1), flow-around is symmetrical not resulting in side or tilting forces, no air flow turbulence (that are especially noisy). Wheels could be made of light metal alloys (with 1,000—1,500 kgs load per 1 wheel) with the total mass of about 30—50 kg.

Therefore, the total mass of a STU vehicle will be, for example, by hundreds of times less than that of a train and its length — by tens of times shorter; mass of a spring-free part is tens of times less, track evenness much higher (is there anything more straight than a tight strained string?). Thus, compared with a high-speed train a STU vehicle is a much weaker source of noise and soil vibration. A system of internal and support dampers capable to reduce low- and high-frequency track vibrations will also contribute to lower noise impact of a STU track structure.

91. What are other (non-conventional) hazardous STU impacts, for example, electromagnetic radiation as compared with other transportation modes?

Electrified STU routes will be low-voltage lines (about 1,000 V voltage), thus, they do not generate electromagnetic pollution and could pass at the large height (up to 50 m) above housing estates, agricultural lands, natural reserves and parks. The lack of sliding electric contacts in a "vehicle — contact network" pair, low (by tens of times as compared with a railway) electric capacity of the rolling stock exclude environmental pollution with radio noise. A STU system is free of specific impacts such as powerful electromagnetic pollution of radar and radiation in aviation (during a many-hour flight each passenger is exposed to additional radiation caused by natural cosmic gamma-radiation reaching 300—400 microroentgen/hour against 20mr/h being a standard).

Social and political aspects

92. What are socio-political advantages of the large-scale STU application?

The major socio-political advantages are as follows:

1. Increased communication capacity (business and personal contacts, tourist trips, excursions and recreation trips including long-term recreation and weekends, etc.).
2. Wider possibilities:
   - to work further from home without changing habitual place of residence;
   - to develop sustainable residential zones (housing estates) within the walking distance of STU;
   - to build linear cities open to nature along STU routes;
   - to provide urgent medical aid;
   - not to interfere in human traditional habits in the sphere of transportation services (for example, a possibility to travel at longer distances with a personal car at reasonable prices).
3. Individualisation of travel with the use of a STU transportation module as a personal mode of transportation at more affordable price than a car.
4. Reduced number of accidents at other transportation modes as a result of attraction of a certain part of passenger and freight traffic by a STU (annually about 1.2 million of people are killed in road accidents and 50 million become handicapped or cripples as a result of injures).
5. Better protection of transportation-energy and communication systems from natural disasters (such as flood, land slides, earthquakes, tsunami) and terrorist actions thanks to the interaction of STU control components.
6. Improved transportation qualities:
   - all-weather operation (irrespective of fog, snow, glaze of ice, sand storm, etc. and other unfavourable weather conditions);
   - universal use (including land and sea sections).
7. Contribution to the formation of integrated, interrelated and safer global environment.

93. What are socio-economic advantages of the large-scale STU application?

The major socio-economic advantages are as follows:

1. Reduced share of financial resources necessary for the long-lasting construction projects:
   - low capital intensity of STU (considerably lower than for any other high-speed transportation system, for example, tens of times lower than for a train on a magnet suspension;
   - shorter recoupment period (3—5 years).
2. Reduced cost of transportation service, higher accessibility and attractiveness for all population groups at higher service quality (speed, comfort, safety).
3. Accelerated and improved integration and cooperation economic links both at the national and international level.
4. The cost of STU lines in not strongly dependent on the relief and ground features of the site which makes it possible to develop hard to access areas such as deserts, marshlands, permafrost, taiga, tundra, jungles, ocean shelf, mountains, etc.
5. No need in construction of special power transmission and communication lines including fibro-optic ones that are easily integrated with STU.

6. Possibility to form a global high-speed STU infrastructure within short time limits (during 10—15 years) which will have a multiple effect in other industrial sectors.

94. How STU could contribute to demographic problem solution?

Along STU routes characterised by environmentally sound infrastructure and noiseless vehicles it is possible to build linear cities located within the walking distance and harmoniously integrated in the natural environment. In this case it is not necessary to cut forests, to build highways, etc. resulting in the deterioration of biogeocenosis within the development zone. It will be easy to develop agriculture and environmentally friendly industries; to form the spots of rationally organized society. Construction of linear cities will be associated with lower capital investments than conventional development. Simply, it will give more benefits for a man because living in normal natural and social conditions will be more important than any material possessions. Thus, the first steps will be made towards a new future society built rather on harmony with nature than in conflict.

It is necessary to remember that land is the major resource used by the existing transportation (first of all high-speed) systems and what is more important — the most valuable resource. In Europe and especially in Western Europe the cost of 1 hectare of land is estimated at millions of dollars as it is either land withdrawn from agricultural use or allocated at the expense of reduced recreation zones or withdrawal from possible development which results in higher built-up densities and deteriorated living conditions of millions of population. For example, some Western experts forecast that if China orients its policy to the large-scale construction of high-speed roads which require allocation of more than 3 ha of land per 1 km, in the 1st quarter of the 21st century it will be in the face of famine that by its scale is comparable with that of the period of cultural revolution which took the lives of more than 30 million people.

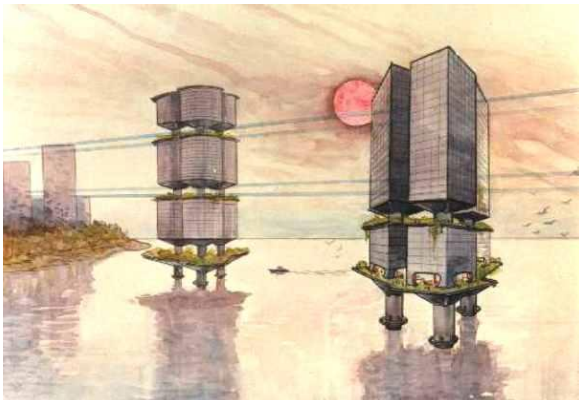

Fig. 40 Linear city on a STU route along the sea shelf

STU supports require as little as 0.01 ha/km of land and if they are designed in the form of buildings which in their aggregate will make a linear city, there is no need in additional land allocations. Moreover, a linear city could be built on a still undeveloped but suitable for living site, for example, a sea shelf located at 1—2 km distance away from the shore (fig. 40).

Each STU anchor support could be easily integrated with unusual and architecturally impressive facilities such as a high-rise residential building, sea hotel, restaurant, sports and recreation complex with a filled-in beach around it in the form of an island, etc. with all of them linked with each other by a high-speed, all-weather, storm-resistant track. This solution could increase, for example, the area of Israel (by 300—500 km^2 — 30,000—50,000 ha) or Japan (by 10,000—20,000 km^2 — 1—2 million ha).

95. Is it possible to use STU for military purposes?

Undoubtedly, like any other transportation system. For example, a motorized division with small arms (about 10,000 people) could be re-located at 1,000 km distance during 3.5—4 hours. Furthermore, continuous circulation of specially equipped modules containing mobile rocket units difficult to detect by external observation aids could be arranged along the STU roads.

96. How will STU cross the borders between countries?

STU vehicles moving without stops above the ground like aircraft do not need to cross the borders of states but rather need an air corridor. Passengers or freights are to pass through customs at origins and destinations.

For example, provisions of the Russian Constitution related to free circulation of goods and people are currently infringed in Kaliningrad Region which results from the need to cross three borders and to go through three customs in order to move from this region to any other region of Russia. STU helps eliminate this problem because Belarus, Lithuania and Poland (depending on a STU alternative) could provide an air corridor only to handle transit freight and passenger trips.

97. What geopolitical advantages for Russia could give, for example, STU construction in resource extracting regions of the country?

About 80% of industrial potential of Russia is concentrated in the west from the Urals and 80% of its fuel resources is concentrated in the east which necessitates transportation of hundreds of millions of 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 Pechora coal basin — the largest one in the European part with its total resources almost twice as large as in Donbass. In addition, Pechora basin is characterized by higher thickness of coal seams, better mining conditions, higher labour efficiency and lower net cost of mining.

STU makes it possible to sharply increase the export of Pechora coal, especially cleaned coal, which high transportation costs to the users make it not competitive at the present day world market. For example, the cost of American caking coal in shipment ports is USD 47/t and the cost of energy coal delivered from SAR to the Netherlands is USD 30/t. The cost of coal transported by a STU from Pechora basin to Kaliningrad port could be by 20—30% lower. Where to sell Pechora coal? Naturally, to Scandinavian countries which today have to buy coal even in the far Columbia.

As it is known Sweden decided to stop construction of nuclear power plants and to replace them by heat power plants using gas and coal for their operation. It could be reasonable to invite Sweden which is a long-established and widely recognized supplier of mining equipment for collaboration with the Russian Federation to develop new areas of Pechora basin. Similar proposals could be made to Finland, Norway and other West European countries which will contribute to the development of Pechora basin to become the largest base of caking and fuel coal in Europe.

Practically, all mining industry of the Russian Federation is concentrated in hard to reach and underdeveloped northern areas the development of which is hardly possible without foreign investments. For example, the Russian Government prepared a list of 250 relevant deposits with the total raw resources (oil, gas, coal, copper, silver, etc.) estimated at USD 12 trillion. Among gas and oil deposits Timan-Pechora deposit (situated between Archangelsk and North Urals with 2.4 billion tons of explored oil resources) is the largest one which in the future plans 75 million tons of oil per year for delivery to Europe.

Further in the east, immediately behind the North Urals there is one more promising oil basin: Priobsk oil field (with 2.4 billion tonnes of explored oil deposits) and neighbouring oil fields of Tyumen which is responsible for more than one half of the total Russian oil output. Development of Timan-Pechora oil fields entails development of Priobsky deposit and a STU communication infrastructure especially provided for the purpose will make it possible to promote development of a sea shelf of Arctic Ocean with even more extensive oil and gas resources.

On the whole, it is a possibility for the region rich in fuel resources to be integrated in the world economy so as to give rise to geopolitical transformations of planetary scale as a result of reduced or fully eliminated dependency of Europe and the West as a whole on Persian Gulf region. In experts' opinion those who control these fuel sources will control, for example, Germany as well.

Yamal peninsula is the youngest region among other vast sub-Arctic areas characterized by extremely vulnerable natural environment. In fact, it consists of a number of huge ice blocks of 50 m thickness, sort of run aground and overlapped with a layer of sea clay of 1—2 m width. Yamal is situated 20 m above the sea level. It is hardly possible to find any other place on the globe which space is so vulnerable to the impact of modern technologies and which it would be more appropriate to indicate in the maps in white as icy area rather as green which corresponds to lowlands.

According to experts' estimates more than 6 million ha of pasture lands in Yamal were damaged as a result of unwise mineral extraction solutions. Their reclamation will require allocation of gigantic financial resources estimated at USD 50—100 billion. Communication infrastructure based on the use of STU will make it possible to minimize environmental implications of deposit exploitation in the northern regions of Russia and first of all in Yamal peninsula.

In this respect it should be emphasized that in future environmental impact will be the major factor to identify development costs of northern regions which is proved by international experience. For example, initial project cost of a gas pipeline in Alaska (USA) was estimated at USD 600 million, however, its construction was blocked as a result of protest made by the public and environmental associations. After the relevant nature conservation measures were taken which turned to be very expensive under permafrost conditions a pipeline was built but then its cost increased to USD 5 billion.

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

STU programme is also in compliance with the future targets 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 are easily integrated through a STU within the area of city of Smolensk. This development concept of northern areas is interested not only for oil and gas companies of Russia (in particular, Gasprom), but for the Government of Russia (ministry of economy, environment, finances, etc.), local government bodies (that are currently facing serious environmental problems generated by oil and gas developers associated with tundra recovery which requires hundreds of years), as well as the Government of Belarus and western investors capable to evaluate their investment efficiency (expected total volume of investments — USD 200 billion). If a STU infrastructure has one owner (for example, Gasprom of Russia) it is possible to propose a price policy which will make delivery of the Russian raw resources to the West free, as all costs will be included in passenger fare. And in this case a STU fare will be lower than that for railway passengers. As a result Russian goods will be more competitive in the West and will bring additional profit.

Other questions

98. What is the most serious STU disadvantage?

The only serious STU disadvantage, unfortunately still not eliminated, is associated with the lack of already built at least 1 km of STU track. But, as it is known, this drawback was in its time inherent in highways and railways, aircraft and trains on a magnet suspension, electric cars and other inventions ever made by man.

Nowadays this STU shortcoming could be easily eliminated as all basic STU components have been already available and efficiently operating in various technical fields. For example, one of the distinctive features of the project is associated with the need to provide an ideally even and very rigid track capable to carry a transportation module wheel which is achieved through the use of steel strings strained to high stress. However, this solution is very close to the design of hanging or guy rope bridges and the relevant practical, experimental and theoretical potential gained during hundreds of years was in full value used in the STU project.

STU transportation module in its essence is a variety of a high-speed electric car put on the steel wheels. The relevant experience of the leading world automobile corporations was also used in the STU design. In this case poor aerodynamic qualities of a modern car do not allow to gain high travel speeds. Therefore, a unique shape of a STU module was proposed having no analogues in the world including aviation with its aerodynamic drag coefficient amounting to C_x=0.075 (patented in a number of countries).

The current development level of STU is at the stage which does not arise any doubt in terms of its operative qualities and validity among its authors and developers as well as among experts. In this case all STU basic nodes and components as well as building technology of string routes were tested at the pilot section built in the town of Ozyory of Moscow Region in 2001 (fig. 41—42). Successful tests carried out in 2001—2006 at the pilot section proved full compliance of the designed and actual STU characteristics including, in particular: strength and rigidity of a string track structure, stable and noiseless movement of two-flange wheels along the string-rail; reliability of steel cables fixed by anchor tongs fasteners; stability of movement along the specially frozen ice of 50 mm thickness on the rail head, etc.

Fig. 41. Modified ZIL-131 on a 24 m string span (October, 2001)

Fig. 42. Modified ZIL-131 on a 48 m string span (November, 2003)

99. Why a pilot STU testing ground is necessary?

The key stage of practical implementation of a STU implies construction of a pilot testing ground to carry out full-scale pilot industrial testing of a string transportation system. A testing ground includes scientific research complex with a laboratory building, design bureau, assembly unit, autonomous power supply block, storage and other facilities and a pilot STU track.

Construction of a pilot STU track implies the following stages:

1. First, one span (2,000 m) between anchor supports will be built with 60—80 intermediate supports (with their height ranging from 1 to 10 m) installed with the spans ranging from 25 to 50 m. This section will be used to test building technology of intermediate and anchor supports, strain adjustment and anchoring, formation of a rail-string and track structure and checking of technical equipment. A track structure and supports will be also exposed to static tests to investigate movement dynamics and behaviour of a transportation module for the travel speed up to 150 km/h.
2. After successful tests the necessary corrections will be made in the design of transportation line, module and a track and the track will be extended by 6 km to reach the total length of 8 km. It will make it possible to gain the speed of 350 km/h and to start testing of the high-speed (more than 200 km/h) acceleration/deceleration regimes, control systems and non-standard operation conditions.
3. The final stage envisages extension of the track length to 15—20 km with its terminal sections designed as rings of about 1,000 m diameter with variable curvature radii and including switching devices which will make it possible to band the route and to reach the maximal travel speeds of 450—500 km/h. It is also proposed to test high-speed travel regimes, turns and basic infrastructure components (switching devices and stations).

Approximate cost of the first two stages is estimated at USD 15 million, implementation period — 2.5—3 years. The third stage will be associated with approximately the same cost and time requirements.

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

After the STU pilot industrial testing on a testing ground, standardization and certification it is possible to recommend the high-speed transportation system of a new generation for its application both in developed and developing countries. If the full-scale tests prove theoretical research and tests of a STU model track and its rolling stock carried out within the framework of the Habitat project a STU could be proposed for the world community as the most environmentally friendly, less capital- and resource-intensive and most economically efficient transportation system capable to cope with the requirements of the 21st century.

The tasks to be solved at the testing ground are as follows:

1. String track structure is not referred to beam or cable structures, therefore, the world experience in construction and operation of bridges and overpasses, mono-rail and cable roads and other transportation is not appropriate for a STU. Thus, a rail-string being the basis of a STU track structure is to be optimized experimentally (rail rigidity, tensile strength of a string, optimal span length, choice of filler and its physical and mechanical qualities, etc.) and tested at low (under 200 km/h), high (200—350 km/h) and super high (400—500 km/h) travel speeds of a transportation module.

2. A STU electric module has four steel wheels with "an automobile" (independent) suspension, each of them with two rims (flanges) which makes a STU rolling stock principally different from that of railway, highway and mono-rail roads. Furthermore, a module is moving along the two pre-stressed rigid threads (rail-strings) of great length, rested upon rigid (anchor) and flexible (intermediate) supports. It is a principally new scheme of a high-speed track structure for the world experience which moving dynamics is in need of further study. So vibration frequency and amplitude of a rail-string, wheel suspension, module body, supports as well as the generation of resonance frequencies in the track components, module and supports are to be further investigated.

3. High-speed movement of small-size modules at 5—10 m height above the ground requires a special approach to their aerodynamic qualities, optimization of the shape of their body and evaluation of the impact of climatic factors such as wind, rain, snow, icing, high and low temperatures, etc.

4. STU supports and their components (anchor, intermediate, braking) differ from the supports of bridges, elevated and cable roads, power transmission lines both in terms of their design and static and dynamic loads and specific requirements. All this requires experimental testing.

5. New track and rolling stock solutions require non-traditional approaches to the infrastructure design which is also to be exposed to experimental testing (including switching devices, terminal components, stations, freight terminals, etc.).

6. New transportation concept is associated with new approaches to its design standards (shape and geometrical dimensions of a rail head and supporting part of a two-rimmed wheel, track width, distance between two contra-flow lines, dimensions of a transportation module, etc.); electro-technical standards (voltage and type of current — direct or alternating, etc.), technological, operational and other standards), therefore, all of hem are in need of experimental optimization.

100. How long has the author been involved in the STU project?

About 20 years, or even 28 years if we take its pre-history (project of a planetary transportation vehicle — a system for the future wide-scale development of near the ground cosmic space based on non-rocket principles which gave rise to a STU idea).

It could seem quite a long period, thought if we remember the history of engineering and automobile and railway transportation their pre-history was much longer. Trains on a magnet suspension required much more time for their development, though only FRG spent for them billions of DM which was not the case with a STU. The former USSR was also involved in magnet suspension projects and spent several billions of dollars during few decades, though not a km was built. Even more simple inventions such as photography required more than 100 years from the moment of its idea to implementation. Thus, inventor has a chance to see his invention with his own eyes, put into life only if he starts his project, especially a large-scale one like a STU, in a relatively young age.

It took the author many years (about 10 years) only to formulate and develop his idea, to crystallize its essence, to make the estimates and technical and economic analysis. It took years to promote the calculations, feasibility study, relevant technical solutions, testing of major units and components, specification of STU inherent standards, etc. Several more years were spent to acquire a patent for a principal scheme of a string system in the leading world countries and in this case the major problem was associated rather not with a patent itself but with the lack of finances (which required about USD 100,000). However, in independent experts' opinion the cost of non-material assets created by the author during this period is evaluated at USD 1 billion.

The fact that a STU is still unrealized is attributed to the lack of financial support rather than to the shortcomings of a STU and its unsolved research and technical problems. All works during these 28 years have been carried out at the expense of the author himself, whose financial possibilities are very limited. Without patents (first of them were obtained as late as in 1997) attraction of investments to support the programme was out of the question. It will be only possible to start the fund raising only in the year 2000.

Unfortunately, the author was not lucky to meet in his life a person like Rakhmaninov. As it is known, famous composer, pianist and conductor who lived in the USA in emigration in the 1920's met another emigrant Sikorsky, then already known aircraft designer living in poverty. This man, being so far from the engineering sphere, believed in the poor designer who was fully neglected and had no orders, gave him USD 5,000 (today it is equivalent to USD 500) and said: "I believe in you. Pay back if you can, if not, all right let it be so". Who knows if helicopter industry of the USA could come into existence without this support?

101. What is the difference between the investments in a STU programme and a specific STU route?

The same, for example, as in "Automobile" and "Automobile VAZ 2110" programmes. In the former case it is an automobile in general which could have hundreds of modifications (concrete marks), good or bad. Thanks to efficient technical and economic solutions "Automobile" programme has been flourishing for more than 100 years and will be a success further on until a new more efficient programme, for example a STU project, is proposed. As to "Automobile VAZ 2110" programme it could be not very successful and lose in competition with other programmes.

It is approximately the same with a STU. It is possible to build, maybe not very successfully, a concrete STU route, for example, "Moscow — Nizhny Novgorod" which for this or that reason could be non-profitable and investor will suffer losses. On the contrary, that who invested money in a STU programme is not going to meet losses. Negative experience is also experience. Then the next transportation line, for example, "Minsk — Moscow" will be built based on the obtained results to become profitable and eliminate possible risks and losses. According to the world statistics profit coefficient of investments in scientific research and experimental design and construction works at the final stage of a research programme will be 1:100 or even 1:1000.

102. What guarantees success of STU programme?

It is the programme itself with its powerful initial potential. It is not even concrete people (and its author as well) and concrete tasks and errors in the course of the programme implementation that identify its success. Let us remember first steps in aviation. They were accompanied with numerous errors, unwise solutions, failure to fly up, air catastrophes. Air planes are still crashing and what of it? Aviation created the most powerful niche in the world economy and in not going to give it to somebody else. It started when nothing was actually known even for aircraft designers about aerodynamics which makes the basis of aviation.

Let us remember our recent past when the foundations of rocket construction and modern astronautics were laid down. How difficult were the problems their designers had to solve! Let us consider only two of them: rocket stability and fuel combustion in a jet engine. In stable state a rocket looks like a pencil put on its edge. Can you imagine something more unstable? Is it appropriate to speak about launch accuracy? Designers neglected these difficulties and today it is hardly possible to find any other system being more accurate than a rocket. A spaceship launched from the Earth at enormous speed is capable to land in the assigned spot of another planet moving at a distance measured by hundreds of millions kilometers. And how about a problem of fuel combustion when the heat power per 1 sq. m of a combustion chamber of a jet engine reaches 1 million kW? It seemed that there were no adequate materials to resist this power but designers managed to find a solution of this problem as well.

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

1. A paper-clip remained still lying on the table; or
2. A paper-clip is jumping to stick to a magnet.

However, there is a third, fantastic alternative with a paper-clip hanging in the air not touching either a table or a magnet which was realised in a "Transrapid" project.

STU is free of similar difficult problems. A string system is based on simple mechanics, in figurative sense it is like "iron", known and tested long-long ago including its wheel, drive, rail, track, track structure and supports, control systems, etc. Estimations of a track and supports is the subject of structural mechanics used to design bridges, buildings and facilities; movement of a STU vehicle refers to structural dynamics including dynamics and aerodynamics of a four-wheel car.

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