

FOUNDATION "YUNITRAN"
RESEARCH CENTRE "YUNITRAN"

TECHNICAL OFFER

CIRCULAR HIGH-SPEED STRING TRANSPORT LINE

**"TAIPEI - TAICHUNG - KAOHSING - OLUANPI - TAITUNG -
HWALIEN - TAIPEI"**



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High-Speed String Transport Line

"Taipei - Taichung - Kaohsiung - Oluanpi - Taitung - Hualien - Taipei" (1125 km)

1. String Transport System

1.1. Principal Route Diagram

The String Transport System (STS) is a string rail route to carry electrical wheel vehicles. A specific feature of the route are the strings within the rails stretched to the total force 250 tf per rail. The strings are rigidly secured to anchored supports spaced every 500...2000 m, the route structure being carried by intermediate supports spaced every 10...100 m. The strings are arranged within the rails having a deflection of several centimeters increasing to the span center and reducing to zero over the supports. Hence, the rail head supporting the vehicle wheel statically has no deflection or joints throughout its stretch. While remaining highly straight and rigid the STS rigid structure promises to allow speeds of 350...400 km/h and more in future. The design, technological and other STS features are demonstrated in more detail in [1].

An international invention application "Linear Transport System" has been filed under # PCT/IB94/00065 dated 08.04.94 under which an international patent search has been accomplished, it has undergone expertise and initial patents have been obtained in the Russian Federation and the South African Republic (the patenting is underway in 20 countries).

1.2. Line Route Diagram

Fig. 1 shows the route line diagram.

The optimum spacing between intermediate supports is 25 m. This spacing can be reduced to 10 m along the stretches with more intricate profiles or increased to 100 m. When the spacing is larger (the modern materials allow to have the spacing 2,000 m and more) the route structure will be supported with ropes or cables (like suspended bridges).

Considering that the STS is easily adaptable to the terrain profile the intercity line can run along the shortest cuts or straight. When necessary, the route structure can be curved in both vertical and horizontal planes. For comfort (so that passengers are not affected by overloading along curved stretches) the curvature radii should be at least 10 thous.m.

The stretch of the route will amount to 1125 km, out of them 980 km will run over the flat country and 145 km over the mountains.

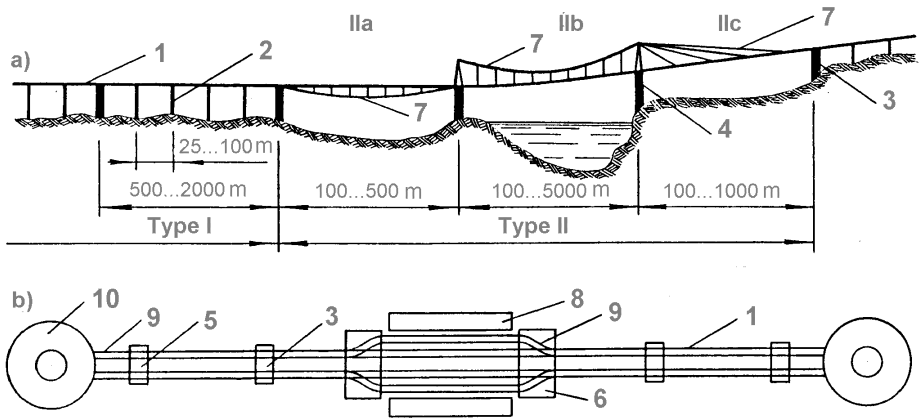


Fig. 1. Route Line Scheme:

a) side view; b) top view; 1 - double-track structure; 2 - support; 3,4,5,6 - anchored supports, correspondingly: intermediate; pylon; end; with switch point; 7 - supporting rope; 8 - intermediate station; 9 - part of the route constructed with normal rails (railway type); 10 - end of route station.

1.3. Route Structure

Depending upon the span the STS structure is divided into two typical types (Fig. 1): I - common design (the span is up to 100 m); II - additional supporting cable structure (the span is over 100 m) with the cable arranged: (a) underneath; (b) above with parabolic deflection (c) above as guy ropes.

1.3.1. Rail-String

Fig. 2 shows the rail-string design.

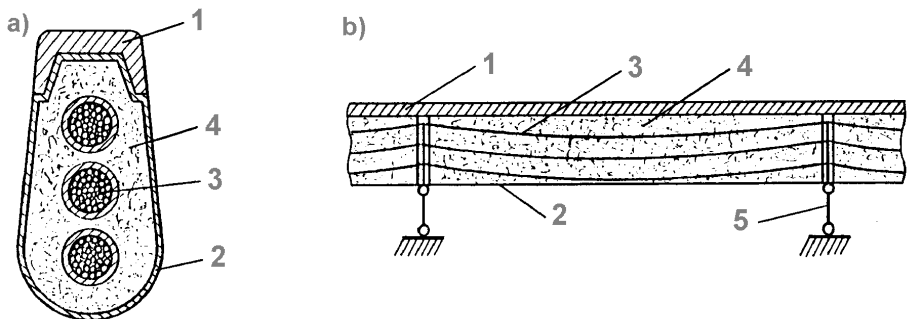


Fig. 2. Rail-string Design:

a) cross section; b) lengthwise section; 1 - head; 2 - body; 3 - string; 4 - filling; 5 - support

Each rail head is a current carrier electrically insulated from the carrying structure and other supports and rails. Each rail has three strings of wires 1...3 mm in diameter stretched with the total force 500 tf for the route structure and 1000 tf for the double-track route. The wires in the string are encapsulated in a protective sheath between the supports, they are not linked together being arranged in a special corrosion resistant composition. The strings are rigidly secured in the anchored supports. The strings will be anchored to the walls of the tunnels along the sea portions. A modular design of the rail has been developed for reducing consumption of materials and facilitating their fabrication and erection. The rail design is described in more detail in [1].

1.3.2. Carrying Cable

Like the strings in the rail, the carrying cable is made from heat resistant steel wires enclosed into a protective watertight sheath. The free space in the cable is filled up with a corrosion resistant filler. The longer the span the greater is the cable diameter. For example, due to a low material consumption for the route structure and its light weight, the cable 100 mm in diameter carries the STS span 500...1000 m long, i.e. it allows to cross wide rivers in a single span.

1.3.3. Route Structural Rigidity

The STS route structure requires little material, about 100 kg/m, still allowing to achieve a highly strong tensioning of the strings. It has a typical small deflection of the structural elements both under its own weight (see Table 1) and under the weight of moving vehicles.

Table 1

Deflection of the STS Structure under its own weight

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

The deflection figures in Table 1 determine the height of the STS spans, their slimness and aesthetic appearance. In any case, the STS structure is much slimmer than

bridges, road arteries, viaducts and other similar structures of highways and railways or girders of monorails.

The strings will have a deflection after erection concealed within the rail. When the span is 25...50 m the string will have the relative deflection $1/1600$... $1/800$ and absolute deflection 1.6...6.3 cm in respect to the span. This deflection is easily accommodated within a specially designed rail 20...25 cm high.

In any case, the above deflections appear after erection without affecting the smoothness of rail heads which are very rectilinear when unloaded. The route curvilinearity in the vertical plane appears under a moving load, it is induced by winds and moving vehicles in the horizontal plane. The maximum static deflection produced by a vehicle (2,500 kgf) braked in the span center will be within $1/800$ for the rail and $1/2400$ for the span supported by the cable. Dynamic deflections at speeds over 200 km/h will be significantly less than those indicated above (within $1/10,000$... $1/2,000$, or within 5...10 mm in absolute figures for a 25-m span). These figures prove that the STS is more rigid (in respect to the rolling stock) than railways, bridges and highway loops which have a greater estimated deflection under nominal loads.

The structural features of the route and the modes of movement of the vehicles have been investigated and designed so as to eliminate resonance phenomena in the rail-string. Moreover, appearing vibrations will remain behind a moving vehicle, they will attenuate within 0.1...0.5 s, consecutive vehicles will run along undeflected, perfectly smooth rails.

Variations of temperature-induced deformations of rail-strings are compensated by temperature strains, hence, variations of the span relative deflection will insignificantly affect the route's rail-string smoothness when the span between the anchored supports remains unchanged. The string will not have any deformation seams along its stretch, it will respond to temperature variations like a telephone wire or a power transmission line which are also suspended with deflection between supports without joints for several kilometers, like the strings in the rail. The maximum temperature variations for 100°C , for example, -50°C (winter) to $+50^{\circ}\text{C}$ (summer) will cause relative deflection variations within $1/10,000$ basically without any effect upon the route smoothness. Elongation strains in the string will add approximately 500 kgf/cm^2 in the summer and deduct the same 500 kgf/cm^2 in the winter. A smaller temperature difference, for example, along the sea portion arranged in the tunnel, will produce a milder strain deformation of the rail-string.

Taking into account a highly streamlined design of the STS and the vehicles, the relative deflection of the STS route overland structure under the influence of lateral winds blowing with the speed 100 km/h will amount to $1/10,000$... $1/5,000$ without any significant effect upon the transport line's performance.

The route's smoothness will not be affected by the ice appearing on the STS structural elements at negative air temperatures. Yet, considering the rail-string small cross section, the streamlined design, high- and low-amplitude vibrations and other factors inhibiting icing, the latter can be fully eliminated. For example, special modules equipped with gas turbine engines can be sent regularly to melt ice film with hot air stream on mountainous lengths of the route during the most risky winter periods.

1.4. Supports

The carrying structure of the supports comprises two basic types: (a) the anchored supports to undertake horizontal forces produced by string and cable elements (Fig. 3); (b) carrying supports to undertake just the vertical load of the STS route structure and vehicles (Fig. 4).

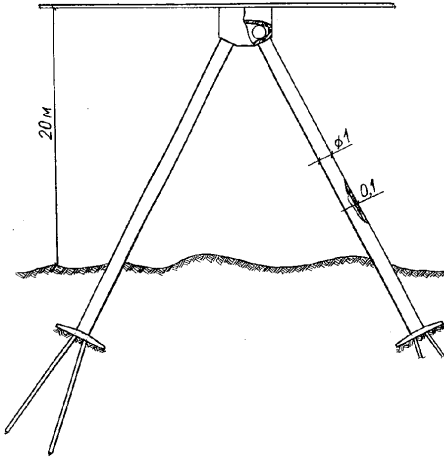


Fig. 3. Anchored support of double-track STS route

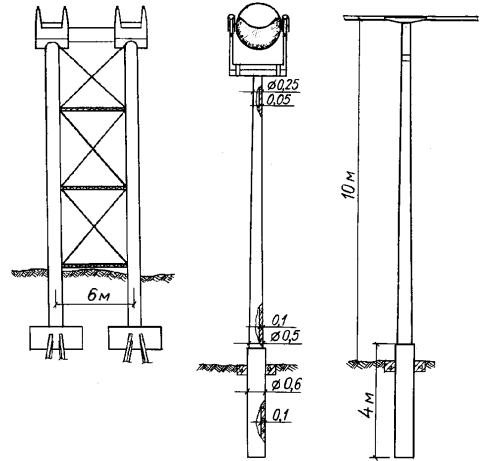


Fig. 4. Small height intermediate support

The anchored supports can be spaced at 0.5...2 km (the optimum flat land span is one km), depending upon the terrain relief. The maximum horizontal loads experienced just by the terminal anchored supports (they are affected by one-way loading) are: 1,000 tf for the double-track and 500 tf for the single-track routes.

The intermediate anchored supports (they comprise over 90% of the total number) will not experience any significant horizontal load in operation, because the forces acting upon the support from each side will become mutually balanced. In accordance with the terrain relief the carrying supports will be spaced at 10...100 m (the optimal span is 25 m). The minimal vertical load upon the support (together with the moving vehicle weight) is 10 tf (the span is 10 m), the maximum load is 35 tf (the span is 100 m).

The mountainous STS route will have the third type of supports - brake supports to undertake (alongside with anchored supports) longitudinal forces of the STS route structure and vehicles weight that caused by the route slope to the horizon. In accordance with the mountain relief and line of the route installation the slope to the horizon will amount over 30°. The vehicle lifting and lowering with the great slope is allowed due to the specific design of running gears and wheels. The specific design of passenger vehicles has been developed so as passenger comfort in the car will not depend on the route slope to the horizon.

In accordance with the route slope to the horizon brake supports will be spaced at 0,1... 1 km.

The terrain relief and the longitudinal route profile and the layout will determine how tall the supports should be. Table 2 is a guide for practically any terrain relief on flat span showing that they should be 15 m tall, on the average. In mountains the average tallness of supports will be 25 m.

Table 2

Determination of average tallness of supports over flat land

Tallness of supports, m	Proportion of the supports in their total number, %
10	70
20	20
30	5
40	3
50	1.5
100	0.5
Total: average tallness of supports -15 m	100

The supports are described in more detail in [1].

The alternatives of one-track STS routes and their supports to suit various geographic conditions are shown in Fig. 5, 6.

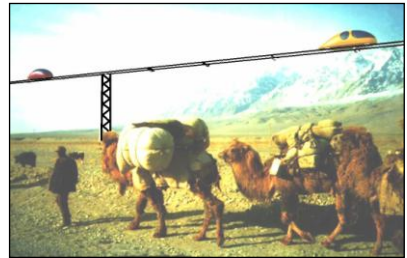


Fig. 5 - 6. Variants of single-track STS routes for various geographical conditions

The carrying supports experience slight vertical, transverse and longitudinal loads (for example, the transverse loads appear during braking, they are transmitted by the rail-strings to the anchored supports. Therefore, the supports have typically small cross-sections, light foundations, they occupy little area and require little earthwork. It is specifically significant not to encroach upon the proprietary rights of land owners which may create serious problems. The STS can be run in a single span (over 2,000 m long) 50...100 m high over expensive land plots with economical land use. Transport communication between the Island of Taiwan and neighbouring small islands may require

just a single span. Since the STS is a "transparent" structure (almost without shadow) it will be ecologically clean, with a low noise level, it can run over residential areas, game preservations, parks, etc.

Designs of unified modular STS supports have been developed: short (5...15 m), average (15...25 m), tall (25...50 m) and supertall (50...100 m) which are unique in their little consumption of materials and they are highly easy to fabricate and erect.

1.5. Vehicle

The passenger vehicle accommodates 10 persons (during peak hours), a cargo vehicle can carry 4,000 kg load, the motors are 80 and 40 kW, respectively, with the energy delivered through wheel which contact the current conducting rail heads (the right and the left) allowing to reach the speed 300 km/h over flat land. The drive can be designed as two motor wheels 40 kW each. A perfect shape of the vehicle body has been selected with the aerodynamic resistance factor $C_x = 0.075$ (the model was tested in the aerodynamic tube and has no analogues in other kinds of transport) allowing to minimize the aerodynamic losses and noise at high speeds. There are technical designs allowing to reduce the aerodynamic resistance factor to $C_x = 0.05...0.06$. To reach 400 km/h the power of the motor of the passenger vehicle should be increased to 200 kW and to 400 kW to reach 500 km/h. For the cargo vehicles to reach the same speeds it is enough to have a motor which is twice less powerful than that of the passenger vehicle (the front surface area of the cargo vehicle is two times less)

The vehicle can operate as a routed taxi from the boarding station to the destination without any driver being steered by the on-board computer. The latter is controlled and guided by line computers and central computers. The vehicle is described in [1] in more detail.

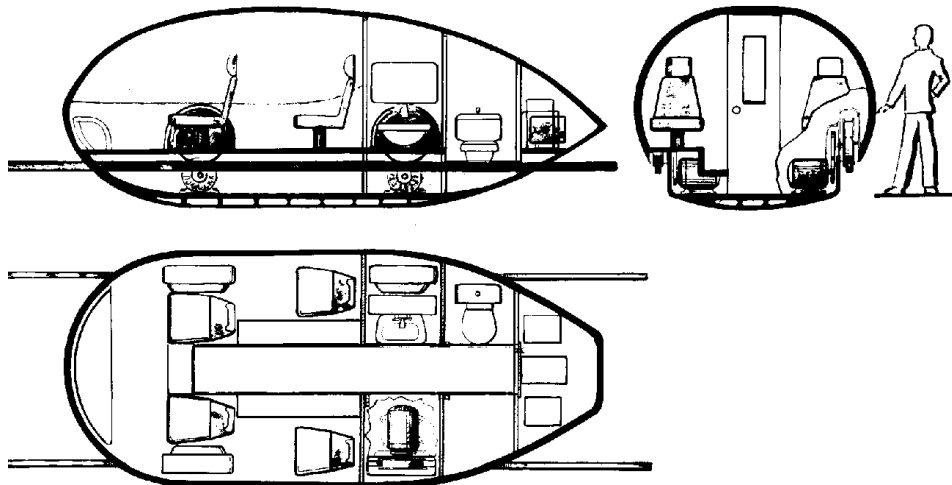


Fig. 7. Long distance travel vehicle for four passengers

1.6. Passenger, Cargo Terminals and Stations

Terminals will be circular with moving (rotating) platforms (Fig. 8) or floors. The terminal diameter is about 60 m which can be increased up to 100 m or more where passenger traffic is heavier (over 100 thous. passengers during 24 h).

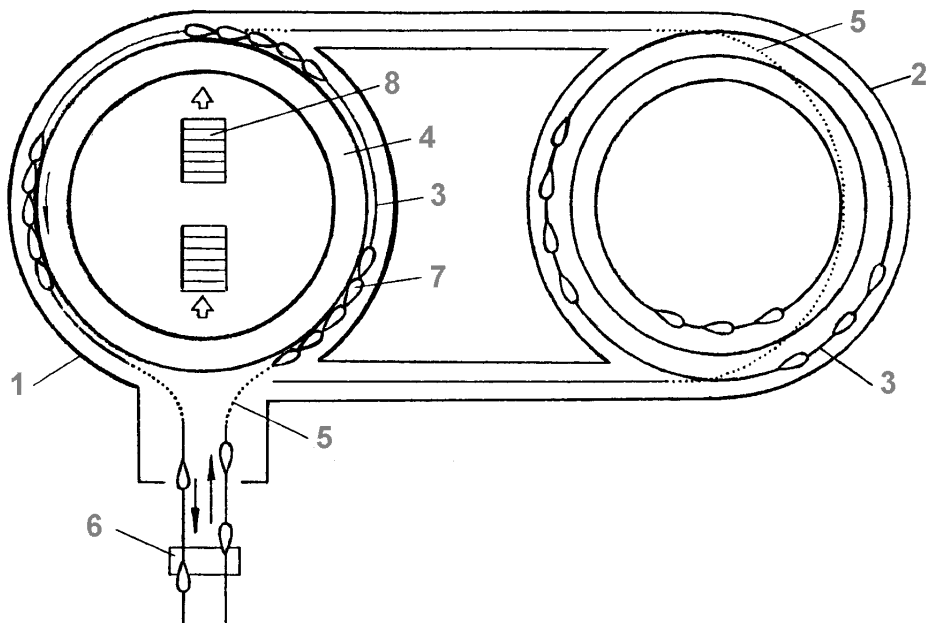


Fig. 8. Station.

1 - Station building; 2 - Garage-workshop; 3 - ring-way; 4 - ring-way mobile platform; 5 - switch point; 6 - end anchored support; 7 - vehicle; 8 - entrance (exit) to the station.

Intermediate stations with significant passenger traffic will have switches and sheds to pass the vehicles irrespective of the main schedule (Fig. 1). The stations with lighter passenger traffic are made as open platforms along the route.

The boarding (landing) of passengers is effected after braking individual vehicles with vacant seats. The route is designed to have 14 terminals and 16 stations.

Circularly shaped cargo terminals will be equipped to load and unload automatically cargo modules. They will be compact with extensive handling facilities employing a unique process of handling operations and specially designed containers for fluid, bulk and piecemeal cargo. For example, a terminal 100 m in diameter will be capable to handle about 100 thous. tons of fluid or bulk cargo, for example, oil (or oil products) a day (36.5 mln tons a year) or much smaller in size than a sea harbor of the same handling capacity.

Individual consignments, such as passenger cars, can be transported on open platforms, though it may require to increase the power of the motor of a cargo module 2...3 times. Thus, passengers can cross the mountains without leaving their cars.

1.7. Management of Passenger and Cargo Traffic

1.7.1. Boarding and Landing

Upon entering into the terminal the passenger sees a lighted sign on each vehicle (the sign can either be on the vehicle wall or on the terminal wall as a running string of information) indicating the destination name, for example, "the terminus". If the required destination is not indicated the passenger can board a vacant vehicle and press the "terminus" button (inside the vehicle). Passengers will have 0.5...2.5 min to board if the moving platform with the vehicle on it has the speed 0.5 m/s and the circular route is 50 m in diameter. After the door is shut (automatically or manually) the vehicle is released from the moving platform, the switch transfers it to the track line. In case the door has not been shut or the boarding has not been completed or there are no passengers the vehicle is returned to the second round on the platform. Similarly the passengers land at their destination in reverse order. In its general implementation it resembles the handling of baggage along circular conveyers at modern airports. If necessary, some vehicles may be directed to workshops in a separate building or at another floor of the terminal.

1.7.2. Cargo Handling

Cargo is handled automatically at cargo terminals. Consignments are delivered to the terminal and thence to a consignee by other means, such as an oil pipeline. Large consignees and consignors, such as oil refineries, will have their own terminals.

Full containers are loaded into the cargo modules which are then marshaled into trains and directed to the transport line. At destinations containers are removed from modules and directed for unloading, their places are occupied by empty containers or containers with other cargoes. The capacity of a container is 1000...4000 kg. Each container is accompanied with an electronic card to be read by the on-board computer to enter the nature of a consignment, its weight, conditions of transportation, destination, consignee, etc.

Passengers can continue to travel in their cars on a special open platform or they can commandeer to dispatch their cars ahead of them or to follow them in an open cargo module and travel in the passenger vehicle.

1.7.3. Traffic

Vehicles are grouped together electronically, for example, into trains of five vehicles with the space between them 100...500 m. The control system along the entire route maintains the same speed of the vehicles in the train and the spacing between them. To maintain the traffic of 1,000 passengers per hour one train of five vehicles should leave the terminal every three minutes. The average spacing between the trains will be 14 km at a speed of 300 km/h. This spacing is sufficient for maneuvering when

passengers board or land at intermediate stations. The running trains will be grouped at boarding stations and by adding vehicles at intermediate stations (at the head or at the tail). Therefore, the control system will both send vehicles and control their location coordinating their "synchronization" in time. Some stations may have special marshaling facilities to accumulate vehicles. The speed will be set from 200 km/h (along the ascents) to 300...350 km/h along horizontal stretches and descents. The line and central computers will control traffic by accumulating information about the location, speed, destination and condition of all major units (the running gear and the drive, in the first place) of each vehicle. Modern control software allows to arrange the transport traffic of STS vehicles with 100-percent safety without man's involvement.

A system similar to the one developed in Japan for the self-controlled Mitsubishi car can be employed to control the STS vehicles. Each vehicle will have three on-board TV, infrared and ultrasound systems running simultaneously. The on-board computer will receive signals from the vehicles ahead to analyze and adjust the proper speed and the spacing. Also, there will be mutual information exchanges and with the line and central computer systems to check the location, speed, condition of the route structure, supports, switches, irregularities, track defects, etc. The on-board computer system will employ microprocessors to process the data from built-in sensors, TV and IR cameras, mechanical means. Relevant commands will be issued for various executive mechanisms. The manoeuvring operations are automatically coordinated with the route on-line computer system in order not to affect the transport traffic.

1.7.4. Traveling Time

Table 3

Time spent by a passenger to travel en route Taipei - Oluanpi (North - South, 405 km)

No.	Transportation process	Time, min at travelling speed	
		300 km/h	400 km/h
1	Waiting for a vehicle to arrive	1	1
2	Boarding	2	2
3	Waiting until start	1	1
4	Joining the main traffic	1	1
5	Design - based acceleration	2	3
6	Traffic along the route	79	58
7	Deceleration	2	3
8	Driving into the terminal	1	1
9	Landing	1	1
10	Unforeseen time losses	5	4
	Total:	95 (1 hr 35 min)	75 (1 hr 15 min)

Thus, maximum time en route while travelling to the most outlying community in Taiwan will be 1 hr 15 min (at speed 400 km/h). A 200 km average distance trip will take 40 min.

Time spent for travelling to other communities is shown in Table 4.

Table 4

Time spent by passengers for travelling from Taipei at a speed 300 km/h

Station	Distance between stations with growing amount, km	Time en route with incrementation
Taipei	20	10 min
Taoyuan	57	18 min
Hsinchu	127	33 min
Taichung	149	38 min
Changhua	186	45 min
Chiayi	267	1 hour 02 min
Tainan	306	1 hour 11 min
Kaohsing	405	1 hour 35 min
Oluanpi		

1.7.5. Route Traffic Capabilities

When trains comprise 10 ten-seat vehicles moving with the speed 300 km/h with the interval 30 seconds, the traffic along a single line during peak hours will amount to 12,000 passengers/h and 24,000 passengers along the route (with two oppositely directed lines) or 576,000 passengers every 24 hours pr 210 million passengers a year. There is still a margin to increase the traffic without adding more lines.

The minimal distance between cargo modules along the line is 50 m (50...100 m is the minimal urgency deceleration by throwing out a braking parachute), hence the ultimate traffic capacity of a single line at a speed 300 km/h is 24 thous. t/h or 576 thous. t/day (210 million t/year). The maximum traffic capacity of a double-track line is 48 thous. t/h. 1,150 thous. t/day, 420 million t/year.

The actual scope of cargo and passenger traffic will be one order of magnitude less because the route will operate at its 10-percent capacity, it will promote the reliability and safety of the transport system in operation, in the long run.

1.8. Safety and Reliability

1.8.1. Safety at Terminals

The safety of passengers is achieved by the synchronization of speeds and the circular terminal platform, for example, by joining them with mechanical means. The platform should move with the speed 0.4 m/s for the passenger traffic of 2,000 passengers per hour with a full turn during 6.5 min (when the outer diameter is 50 m).

Electrical safety is achieved by using safe electrical voltage (12 or 24 V) or batteries in vehicles, or electrical current of the same voltage supplied through the rail track to exclude shock hazards.

1.8.2. Transport Line Electrical Safety and Reliability

Safety is ensured by a relatively small voltage in the line (about 1,000 V), insulation of current carrying rail heads and supports and by non-conductive vehicle bodies made from composite materials. Hence, in case a vehicle misses the rail track it will not produce any short-circuiting between rail heads.

When the traffic reaches 1,000 passengers per hour (24 thous. passengers a day and cargo traffic 2 thous. t/h or 17.5 million t/year) along a leg 100 km long, 35 passenger vehicles and 170 cargo vehicles will run simultaneously with the total power of motors 9,600 kW. No additional transmission lines to supply the STS and its infrastructure are needed, because the rail-string will allow to transmit the electrical power over 10,000 kW (up to 100,000 kW, if it has a special design). Therefore, the STS should be connected to the existing grid every 100...300 km and more.

1.8.3. Traffic Safety

Traffic safety is achieved by failure-free operation of all the systems effective to maintain the routine mode of traffic: the computerized control means, reliable electronic systems, communication lines and measuring instruments, executive mechanisms of switches and drive controls and the braking system, reliable mechanical members of the route structure, STS supports, etc. A hundred-percent safety of the traffic processes is evidenced by the experience of operation of high-speed railways in the world. For example, high-speed railways in Japan have transported over 5 billion passengers during 20 years of operation without any accidents or casualties.

The STS employs four vehicle braking modes: routine (acceleration is 1 m/s^2 , the braking path is 3,500 m), urgent (2.5 m/s^2 , the braking path is 1,400 m), emergency (10 m/s^2 , 350 m) and extreme (50 m/s^2 , 70 m). The emergency and extreme braking are achieved by actuating all the braking systems, including parachutes provided in each vehicle. Once the explosive charge ejects the parachute, safety air cushions are inflated in the passenger salon to exclude lethal traumas under the above loads (the peak overloads will be approximately equal to those experienced by car passengers in collisions with immovable obstacles at a speed 25 km/h).

In case of power failure each vehicle is equipped with a battery and an emergency starting motor which will deliver the vehicle at a slower speed to one of the

stations or emergency stop platforms on each anchored support, i.e. after every 1...2 km.

If necessary, particular dead portions can be run through solely on batteries which can be recharged en route on the rest live STS portions.

1.8.4. STS Structural Reliability and Functioning

STS cable and string elements of rails and carrying structures are exposed to the utmost strain. Since they are in the corrosion resistant medium in the special sheath and in a mechanically strong body protecting them against external effects, their service life can amount to hundreds of years. Also, the traveling load alters the stress-strain state of these elements only by one per cent (see [1], p. 8) and this state remains basically unchanged during the entire period of operation extending the service life and saving operation costs. Since the string elements are located in different remote places (mutually isolated wires in the strings of the left and right rails, the one-way and return lines, the upper and lower strings, etc.), the probability that they snap simultaneously is close to zero, even in case of disasters, such as earthquakes, floods, landslides, hostilities, etc.). Even in case 90% of carrying wires snap, the structure will not collapse, unlike other structures, such as bridges, highway loops, viaducts, modern skeleton buildings, etc.

The STS route structure remains highly durable even when destroyed by terrorists. A support is secured to the route structure with a special unfastening mechanism which releases it making just the rail-string span longer and increasing its corresponding deflection. It will not destroy the integrity of the route even in the case when several supports in line are destroyed.

The results of a model of the STS vehicle tests in the aerodynamic tube at a speed 250 km/h at the Central Research Institute named after the Academician A.N. Krylov (Saint-Petersburg) have manifested that lateral winds blowing with the speed within 100 km/h produce lateral capsizing forces within 100 kgf. They will not affect the functioning of the transport system, the more so they will not derail vehicles.

1.8.5. Ecological Safety

The STS transport system is highly safe ecologically both during erection and in operation.

The STS can be erected without any special equipment (such as platforms or construction power shovels) without using road approaches because the necessary materials and structural members will be delivered along the erected route stretches. Also, erection may obviate the need of earthwork destroying the soil level or the humus accumulated during millions of years, because the supports will be erected on posts driven into land as foundations. these features are extremely essential when the route runs over fertile or most valuable plots of land.

The STS will consume electricity for its operation as an ecologically clean source of energy. Passenger vehicles and cargo transport modules will be airtight and they can stop only at special stations, it will eliminate contamination of the environment by passengers or any other sorts of industrial waste. the containers are designed to

exclude leaks (they will have no pumps, valves, seals and other joints which may leak) or losses of bulk cargoes. Any crush along the route may cause derailing of just a single module (the extreme braking path of the next module will be less than the distance between the two), also a parachute will be activated to decelerate the container so that it does not disintegrate when it drops on the land surface.

The STS needs no embankments, cuttings, tunnels, bridges or conduits. One carrying support occupies just one square meter, the anchor support occupies 10 square meters. Hence, one kilometer will require the area less than 100 square meters, i.e. 0.01 hectare, therefore the conventional land alienation will be within 10 cm. It is much less than the area occupied by a walking path.

The length of a span is not critical because both forests or individual trees along the route may remain because any support can be shifted this or that way straight during construction.

The STS route will not interfere with the migration of soil and surface water, animals, reptiles, crop growing or any other land use.

The STS will be a low-voltage line, so it will not create any electromagnetic interference and it can pass quite high (up to 100 m) over residential buildings, crop land, over game preservations and parks. Absence of sliding electrical contacts in the vehicle-contact grid couples (unlike railways) and the power of the motors exclude radio noise.

The STS requires extremely few materials for its erection, therefore it will be ecologically clean in this respect. For example, a single-track route as long as a railway can be erected from the materials of just a single rail and each third sleeper (the railway has still the second rail and 2/3 of sleepers, the contact grid, rail conduits, viaducts, etc.). Hence, the STS for its erection will not require as many blast furnaces, ore, mines (to produce steel, copper), cement and reinforced concrete plants, earth, sand and gravel quarries, the scope of deliveries by trucks and by railway cars of the materials, special approaches, etc., which would incur an additional, sometimes irreversible ecological damage.

The STS vehicle has no projecting parts, excepting narrow wheels protruding for 10 cm from the body. It needs no windshield wipers or lights (because there is no driver) which produce noise at high speeds. The wheels can be fabricated from light alloys (the load per wheel is 500...1500 kgf), therefore they can weigh within 10...20 kg. Hence, a STS train weighs hundreds of times less than a railway train, it is tens of times shorter and runs much smoother because of the track smoothness (what can be more straight than a strongly tensioned string?). Therefore, the STS train will produce hundreds of times less noise and vibration than high-speed trains.

1.9. Communication Infrastructure

The STS will be not only a high speed and ecologically clean transportation system providing comfortable, cheap and quick delivery of goods and passengers. It will also become an important demography forming factor and a powerful communication system providing transportation of information and energy, because electric power lines,

electric power stations using renewable, ecologically clean sources of energy as well as wire and fiberoptic communication can be easily combined with the STS.

1.9.1. Autonomous Power Supply.

It's a well-known fact that now the strongest negative impact on the nature is caused by electric powerful stations. That's why an autonomous power supply based on renewable sources of energy (wind and solar) should be used in the STS. Wind power is one of the cleanest sources of energy taking into account its influence on the environment. The atmosphere and water resources are not polluted by wind power generation. It doesn't exhaust limited reserves of mineral resources and doesn't change regime of water resources. Special wind-driven and solar generation units combined with the STS are also designed. Thanks to this capital constructiob cost is reduced. For example, capital cost for proposed wind-driven unit is estimated as 1000 US\$ per 1 kilowatt while capital cost for a nuclear pwer plant has increased from 300 US\$ per 1 kilowatt in 1960 to 4000-5000 US\$/kWt at present time. This is mainly caused by increased enviromental and safety requirements primordially, in the future they will be used more often than traditional sources of electrical energy.

The proposed wind-driven electrical units will work at wind speed of 2 m/sec and will have power of 5 kWt at wind speed of 5 m/sec, 50 kWt at 10 m/sec, 150 kWt at 15 m/sec. They will be started up easily; they will not create any noise. They will not be dangerous for birds because their rotation speed will be low. Being deployed at some height, wind-driven units will allow to use soil under them for agriculture and so on. It's enough to have two 50-100 kWt wind-driven electric units at every kilometer of the STS line to satisfy the needs of string transport system. The maximum quantity of wind-driven electric units corresponds to the number of supports, e.w. 20-50 units per one kilometer. Their total power will reach up to 1000-5000 kWt/km. Thus, combined power of the STS wind-driven electric units will be 1-5 mln kWt per 1000 km of the STS lines (in case of wind speed of 10 m/sec). The cost price of one kWt of electric power elaborated by wind-driven electric units will be 0.02 US\$. The expenses will be compensated within 6 years. That's why the STS in addition to its autonomous power supply can be used as a powerful electric power station to satisfy the needs in energyof those users located along the STS lines. In this case electric power will be transmitted to users by the STS lines and there will be no need to construct high voltage power lines which are rather expensive and dangerous to the environment. It's necessary to stress that in to order create the same energy potential with the help of nuclear power plants serious investment in billions of US\$ should be allocated. At the same time the problem of wind-driven electric units construction for the STS can be solved using local investments of those who live along the STS lines.

The fact that wind-driven electric units are distributed along the STS lines will be positive because together with windless zones there will be areas with strong winds which will supply the whole STS line with electric power.

1.9.2. Linear Towns

The STS lines will help to solve some demographic problems as well. Along those lines especially in mountains linear towns built in the harmony with the nature can be constructed due to ecological safety of transport infrastructure. In this case there is no need to cut forests, build highways and destroy biogeocenosis in the construction zone. It will be easy to develop agriculture and ecology friendly industry. These linear towns will become basis for a rationally organised society. Construction of linear towns will require less capital investment compared to traditional building. It will be beneficial to live there because life in favourable natural and social conditions will become for a human being more important than to possess this or that thing. This will help to establish basis for future life of the society, life in unity with the Nature.

1.10. Attractive Appearance and Comfort

The majority of the people spend their active time within a closed, limited space. Due to the ergonomics the common transport means allow to see some land surface, a portion of the road, etc.

The STS both solves the problems of comfort and its functional objective to fast deliveries of passengers to their destinations. Large windows, comfortable seats, soft silky tracks transform a common trip into the delight of enjoying the sights of nature from the birds' flight.

The appearance of slim route structures, support and stations will fit into the natural landscape without impairing the ecology or destroying even fine natural components and the historical architectural styles along the route adding islands of modern architectural shapes.

Each vehicle will be air conditioned, passengers will enjoy a broad variety of other services, multichannel music and TV, world telephone communications, special services for businessmen, passengers with children, disabled people. The STS vehicles are airtight equipped with a system of pressurized or chemical water closets to accumulate waste.

Passengers can command vehicles to stop at any intermediate station, i.e. after every 10...20 minutes.

1.11. Construction Process

The string prepared in advance is stretched to a certain tensioning (the force of tensioning or elongation in tensioning serve as a reference parameter) and its ends are secured rigidly, for example, by welding, to anchor supports. The intermediate and brake supports are erected beforehand or in the process of tensioning or after. A platform is sent along the intermediate and brake supports and the string which can travel independently and fix its position rigidly in respect to the supports. The hollow rail body is mounted with the help of the platform span after span, then it is fixed in the specified position and filled with a filler the rail head, the cross plank are erected and other necessary operations are performed to erect the route structure. All these

operations are easily mechanized and automated, they can be performed during 24 hours every day in any weather to expedite construction reducing labor consumption and cost. To eliminate microroughnesses and microwaviness of working surfaces after the rail head is erected and to remove gaps between its joints the system can be polished throughout its length.

The STS construction process is shown in Fig. 9.

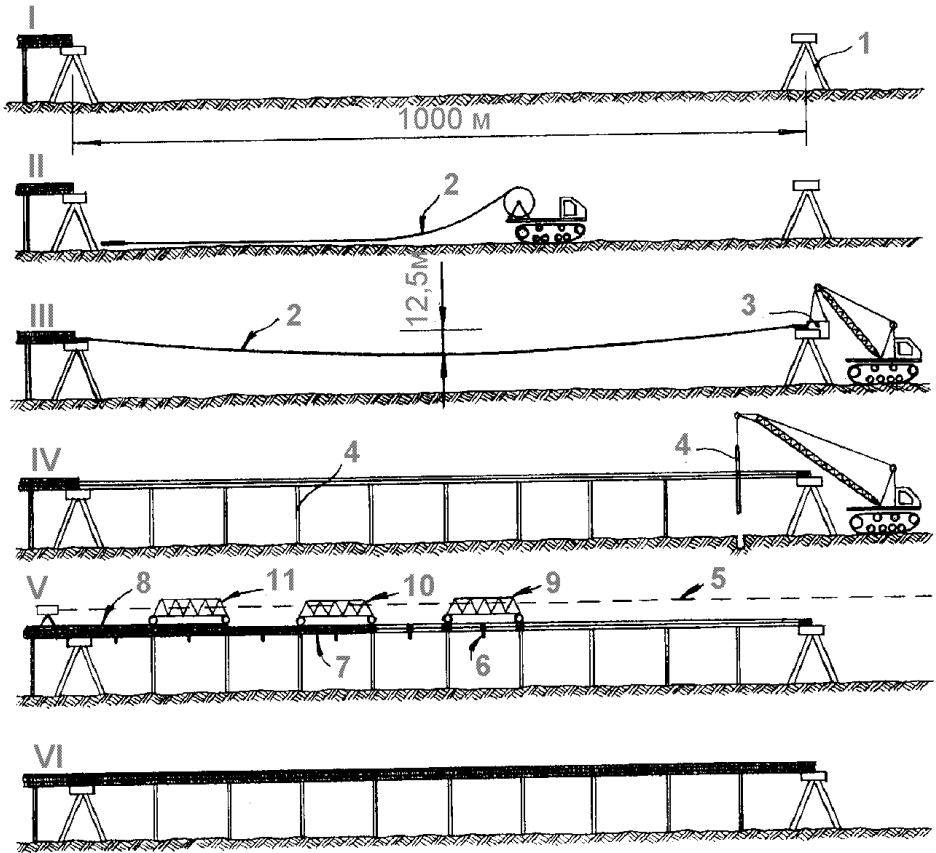


Fig. 9. STS construction process.

1 - anchored support; 2 - rope (string element); 3 - string tension mechanism; 4 - intermediate support; 5 - sight line; 6 - cross board; 7 - rail body; 8 - rail head; 9, 10, 11 - technological platforms for installation of, correspondingly: cross planks, rail body and rail head;

I - anchored support construction; II - placement of string ropes along the route; III - string stretching and anchoring; IV - installation of intermediate supports; V - erection of rail parts and route structure; VI - constructed part of the route.

The STS can be erected with a special erection combine which tensions the string and other tensional rail members over the combine rather than over the anchor

support. the combine moves along the route on its walking legs and places assembled intermediate supports with the ready rail track, once it reaches the anchor support it fastens them together securely.

1.12. Feasibility Parameters

Tables 5 and 6 introduce the feasibility parameters of the flat land and mountainous portions of a double-track route 1 km long, respectively, Tables 7 and 8 show their total costs.

The following aggregate prices were used to evaluate the cost of structures: metallic structures depending upon their complexity and steel grade - 1,500...5,000 US \$/t; aluminium structures - 5,000 US \$/t; reinforced concrete structures - 750...1,000 US \$/m³, US\$ 500 per cubic meter of monolith reinforced concrete. The average price of materials and structures for mountainous portions of the route is increased by 25...50%. Sixteen intermediate stations have been projected each US\$ 5 million. The cost of terminals (14) and service buildings was estimated 3,000 US \$ per m² of the area (general construction works plus engineering and technological equipment), 1,500 US \$/m² of the area of garages (workshops) and 1,000 US \$ per sq. m of the territory of cargo terminals (9).

The cost of a double-route track will be US\$ 1.1 million for the flat land portions and 2.05 million for the mountainous portions per km, the total of the complete 1,125 km route together with its infrastructure is US\$ 2,480 million, including 1,710 million directly for the STS route and 770 million for infrastructure.

Table 9 lists the major feasibility indicators, Table 10 lists the costs of transportation (the cost of transportation of one passenger and a ton of cargo). The following parameters unlisted in the Tables were used for the estimates: cost of electrical energy - 0.05 US \$/kW-h; returns yielded by the transport system: 80% from the passenger traffic and 20% from the cargo traffic.

The cost of transportation of a passenger over a distance of 405 km from Taipei to Oluanpi at an average passenger traffic 50,000 passengers during 24 hours will amount to 5.12 US\$, one ton of cargo (at 100,000 tons during 24 hours) will cost 1.42 US\$. The whole transport system will yield a profit of 140 mln US\$ a year.

The profit can be increased significantly by raising the indicated price of tickets to 10 US\$ (the price of railway tickets). It will yield an additional profit of 250 mln US\$ per year (at 50,000 passengers during 24 hours). The transport system will pay back its cost during 6.4 years. With passenger traffic 100 thous. per day the route will pay back within 3 years. Cheap traffic along the transport system is due to its low cost (below the cost of a railway of the same length) and insignificant specific energy consumption for traction (for example, a STS vehicle, under other equal conditions, is cheaper than a car 12 times when estimated per passenger, including 3 times due to improved aerodynamics, 2 times due to a greater efficiency of the motor and 2 times due to a greater passenger capacity) because a 10-seat vehicle can reach the speed 300 km/h with a motor just 80 kW. The cost of transportation can be reduced still more if individual

power plants are erected along the route which can generate energy cheaper than 0.05 US\$/kW envisaged by the project.

A high passenger and cargo traffic is possible along the route because it will link the regions of Taiwan in which over 10 million people live, short traveling time (with the average distance between the cities along the route 50 km, the average traveling time between them is 20 min), cheap trips allow to make one-day business trips and mutual visits of tourists, businessmen, shoppers, etc.; it will allow many people to go to jobs from one communities to another along the route. It will make car tourism cheap, because personal car can be delivered, for example, from Taipei to Oluanpi (405 km) at a cost just US \$ 4 within less than 2 hours.

Table 5

Consumption of materials and cost of one km flat land portion of a double-track route

Structural element	Material	Consumption of materials per km		Tentative cost, thous. US\$/km
		Mass, tons	volume, m ³	
1. Rail-strings, total				450
Including:				
1.1 Heads	Steel	96	-	190
1.2. Body	Al sheet	5	-	25
1.3. String	Steel wire	79	-	160
1.4. Filler	Composite	-	45	20
1.5. Gluing wax	Composite	1	-	10
1.6. String protective sheath	Polymer	4	-	20
1.7. String water insulation	Polymer	2	-	10
1.8. Others		-	-	15
2. Cross plates		-	-	20
3. Intermediate supports (15 m tall), total		-	-	190
Including:				
3.1. Posts	Reinforced Concrete	-	96	70
3.2. Cross pieces, stay guys	Reinforced concrete	-	46	35
3.3. Support upper structures	Steel	8	-	20
3.4. Pile foundation	Reinforced concrete	-	48	48
3.5. Others		-	-	17
4. Anchored supports (15 m tall), total		-	-	105
Including				
4.1. Support bodies	Reinforced concrete	-	50	38
4.2. Pile foundation	Reinforced Concrete	-	36	36
4.3. Metallic structures	Steel	2	-	5
4.4. Anchor fixtures	Steel	2	-	10
4.5. Others		-	-	16
5. Earthwork		-	-	20
6. Rail power supply system		-	-	40
7. System to monitor the conditions of supports and route structure		-	-	10
8. System to monitor transport traffic		-	-	20
9. Emergency power supply system		-	-	20
10. Transport traffic control system		-	-	30
11. Emergency stop points		-	-	20
12. Surveying and mapping		-	-	50
13. Cost of land and its preparation		-	-	50
14. Other tasks		-	-	25
15. Unforeseen expenses		-	-	50

TOTAL:

1100

Averaged consumption of materials and cost of
one km mountainous portion of a double-track route

Structural element	Material	Consumption of materials per km		Tentative cost, thous. US\$/km
		mass, tons	volume, m ³	
1. Rail-strings. total				680
Including:				
1.1 Heads	Steel	125	-	300
1.2. Body	Al sheet	5	-	30
1.3. String	Steel wire	91	-	220
1.4. Filler	Composite	-	45	45
1.5. Gluing wax	Composite	1	-	10
1.6. String protective sheath	Polymer	4	-	20
1.7. String water insulation	Polymer	2	-	10
1.8. Others		-	-	45
2. Cross plates		-	-	40
3. Intermediate supports (25 m tall), total		-	-	460
Including:				
3.1. Posts	Reinforced Concrete	-	162	162
3.2. Cross pieces, stay guys	Reinforced concrete	-	95	95
3.3. Support upper structures	Steel	12	-	35
3.4. Pile foundation	Reinforced concrete	-	80	120
3.5. Others		-	-	48
4. Anchored and brake supports (25 m tall), total		-	-	220
Including				
4.1. Support bodies	Reinforced concrete	-	96	96
4.2. Pile foundation	Reinforced Concrete	-	55	82
4.3. Metallic structures	Steel	2	-	6
4.4. Anchor fixtures	Steel	2	-	10
4.5. Others		-	-	26
5. Earthwork		-	-	80
6. Rail power supply system		-	-	40
7. System to monitor the conditions of supports and route structure		-	-	20
8. System to monitor transport traffic		-	-	30
9. Emergency power supply system		-	-	30
10. Transport traffic control system		-	-	40
11. Emergency stop points		-	-	30
12. Surveying and mapping		-	-	70
13. Cost of land and its preparation		-	-	80
14. Other tasks		-	-	50
15. Unforeseen expenses		-	-	180

TOTAL:

2050

Cost of a circular double-track STS transport line
‘Taipei - Oluanpi - Taipei, flat land portions (980 km)

No.	Description of route elements	Q-ty, volume	Item cost, thous. US\$	Total cost, mln US\$
1	Way structure	980 km	470	461
2	Supports	980 km	295	289
3	Terminals	14	30000	420
4	Intermediate stations	16	5000	80
5	Garages and workshops	6	15000	90
6	Earthwork	980 km	20	20
7	Rail power supply system	980 km	40	39
8	System for monitoring the condition of the supports and the way structure	980 km	10	10
9	Transport traffic control system	980 km	20	20
10	Emergency power supply system	980 km	20	20
11	Transport traffic control system	980 km	30	29
12	Emergency stop platforms	980 km	20	20
13	Surveying	980 km	50	49
14	Cost of land and its preparation	980 km	50	49
15	Research and development	-	-	25
16	Pilot double-track STS leg	20 km	2000	40
17	Other elements of the route infrastructure	-	-	100
18	Cargo terminals	9	20000	180
19	Other tasks	-	-	50
18	Unforeseen expenses	-	-	129

TOTAL:

2120

Cost of a circular double-track STS transport line
 Taipei - Oluanpi - Taipei, mountainous portions (145 km)

No.	Description of route elements	Q-ty, volume	Item cost, thous. US\$	Total cost, mln US\$
1	Way structure	145 km	720	104
2	Supports	145 km	680	97
3	Earthwork	145 km	80	12
4	Rail power supply system	145 km	40	6
5	System for monitoring the condition of the supports and the way structure	145 km	20	3
6	Transport traffic control system	145 km	30	4
7	Emergency power supply system	145 km	30	4
8	Transport traffic control system	145 km	40	6
9	Emergency stop platforms	145 km	30	4
10	Surveying	145 km	70	10
11	Cost of land and its preparation	145 km	80	12
12	Research and development	-	-	10
13	Pilot double-track STS leg	3 km	5000	15
14	Elements of the route infrastructure	-	-	20
15	Other tasks	-	-	10
16	Unforeseen expenses	-	-	43

TOTAL:

360

Engineering and Economic Indicators of the STS double-track
Taipei - Oluanpi - Taipei line

Parameter	Magnitude
1. Transport line characteristics	
1.1. Total cost, million US\$	2480
1.2. Depreciation deductions, %	5
1.3. Annual operation cost & cost of maintenance and routine repairs, thous. US\$	20
1.4. Term until fully repaid, years	20
1.5. Route stretch, km	1125
2. Vehicle characteristics	
2.1 Cost, thous. US\$:	
- passenger	30
- cargo	10
2.2. Number of seats:	
- business class	10
- first class	5
- deluxe	1
2.3. Carrying capacity, kg:	
- passenger	2000
- cargo	4000
2.4. Transport module weight (net), kg	1500
2.5. On-line utilization factor	0.75
2.6. Reserve park of vehicles, %	20
2.7. Average annual speed, km/hour	300
2.8. Engine power, kW:	
- passenger	80
- cargo	40
2.9. Vehicle annual run along 405 km leg, thousand km:	
- passenger	1400
- cargo	1400
2.10. Annual transportation volume by one transport module (along a 405 km leg):	
- passengers	34600
- cargo, tons	13800
2.11. Specific power losses for traction:	
- passenger, kW·h/ passenger·km	0.027
- cargo, kW·hour/ton·km	0.033
2.12. Depreciation deductions, %	10
2.13. Annual operation cost, %, versus vehicle cost	10
2.14. Term until repaid, years	10

Cost of Transportation along 'Taipei - Oluanpi - Taipei Line,
the Taipei - Oluanpi stretch (405 km)

Parameter	Scope of transportation (both ways)					
	passengers, thousands/day			cargo, thous. tons/day		
	20	50	100	50	100	200
1. Reduced costs 405 km leg):						
- US\$/pass.	11.57	5.12	2.98	-	-	-
- US\$/ton of cargo	-	-	-	1.95	1.42	1.14
1.1. Costs along the transport line, total	10.75	4.30	2.16	1.07	0.54	0.26
Including:						
- depreciation deductions	4.93	1.97	0.99	0.49	0.25	0.12
- operation cost	0.89	0.36	0.18	0.09	0.04	0.02
- deductions for profit	4.93	1.97	0.99	0.49	0.25	0.12
1.2. Cost of vehicles, total	0.82	0.82	0.82	0.88	0.88	0.88
Including:						
- depreciation deductions	0.09	0.09	0.09	0.07	0.07	0.07
- operation cost	0.09	0.09	0.09	0.07	0.07	0.07
- deductions for profit	0.09	0.09	0.09	0.07	0.07	0.07
- energy cost	0.55	0.55	0.55	0.67	0.67	0.67
2. Number of vehicles for the entire route of 1125 km, at average transportation stretch 405 km), pcs	590	1460	2950	3670	7340	14680
3. Rolling stock cost, US\$ million	18	44	88	37	73	147
4. Average traffic interval between vehicles (single vehicles along one line)						
- seconds	86.4	34.6	17.3	13.8	6.9	3.4
- spacing, km	7.2	2.9	1.4	1.15	0.58	0.29

2. Comparison of the STS Performance and Economics with other High-Speed Route alternatives

2.1. General

The STS performance is better to compare with railway, automobile, air transport means and magnetic suspension trains, since the major competitors of the STS will be automobiles and traditional high-speed railways.

In all these cases a great significance should be attached to the specific consumption of electrical energy for transportation. STS transport modules have a comparatively small specific energy consumption in motion. For example, at speeds 300 km/h: 0.027 kW · pass/pass · km for passenger and 0.033 kW · h/t · km cargo traffic. High efficiency of STS motors, small energy losses in motion (good aerodynamics and low mechanical losses when a rigid wheel runs over a rigid track) make the STS transport the most economical among the existing types of high-speed transport means running with the same speeds. compared with high-speed railways in the same measures the consumption of energy is reduced 5 times, compared with magnetic suspension trains 10 times and compared with jet planes 20 times.

The STS route requires less materials, therefore it is cheaper. For example, to erect the carrying portion of the STS flat land route an insignificant amount of reinforced concrete is required - 280 m³/km for a double-track route with supports 15 m tall. About 500 m³/km is required if its consumption for stations and auxiliary systems is added. For comparison: consumption of reinforced concrete just for enclosures high-speed railways and routes of magnetic suspension trains is 750 m³/km.

Since the scope of earthwork is little, so are the expenses. The STS route can run without embankments or excavations along any terrain. Earthwork will have a localized nature (drilling of holes for supports totally 100...200 m³/km, or not earthwork is required at all in case the foundation is erected on piles. For comparison, to construct a kilometer of a modern motorway or railway requires to 10,000...50,000 m³, 100,000 m³ in cross country or mountainous places.

The consumption of other structural for the route and supports is as small, because cheap, available, mass-produced materials will be used.

The STS rolling stock cost can be estimated in comparison with passenger cars which are the closest analogs in dimensions and designs.

Mass produced electric motors 25...50 kW are 1.5...2 times cheaper than internal combustion engines of the same power, they are more reliable, durable, easier to operate and maintain.

The STS transport module body will cheaper than a car body of the same size because of its simpler design (absence of radiators, doors, baggage space, front hood, lights, dimensional, braking and other warning lights, windshield wipers, windows lifting mechanisms, etc.).

The STS vehicle will have a cheaper and simpler running gear and suspension (no unreliable and expensive tires, wheel turning mechanisms, simpler torque transmission to stationary wheels, no problems with tractability, etc.).

The r.p.m. and torque control systems of these two transport means cost are approximately similar and are as intricate (it is a motor r.p.m. control unit in the STS and the gear box, clutches, fuel injection system, etc, in cars).

The vehicle steering system is much simpler and cheaper than in cars, because there will be few parameters: the speed, spacing between vehicles and location (the coordinate) of a vehicle along the line. Irrespective of the computer technology progress it is still complicated to steer a car, so far only human brain can tackle the problem (the driver factor should be considered when evaluating the cost of running a car: at present hundreds of millions have to drive cars for hours daily with their own daily shortage of time). A cheap controller with its own control software will tackle the problem with the STS controlled and guided by on-line computers integrated into a net. To control a car,

in addition to servomechanisms (the steering wheel and its mounting, wheel turning mechanism, gas, brake and clutch pedals, gear mechanism, etc.) a whole system is required to visualize information for steering which is unnecessary with the STS, such as windshield wipers with their actuating mechanisms and detergent delivery system (to keep the windshield clean and to ensure proper visibility), main and auxiliary lights, instrument panel, mirrors, horn, etc.

The STS vehicle will have about the same exterior and interior as a car and can be widely variable in response to individual tastes.

Also, the STS vehicle has no fuel tank (thus, no gas filling stations along the route, refineries providing gasoline and diesel fuel, oil wells are required); it does not require any system of removing and additional combustion of exhaust (for example, more strict ecological norms in many countries have recently made cars much more expensive).

Considering the above argumentation it can be predicted that mass produced STS vehicles will be 1.5...2 times cheaper than passenger cars of the same capacity, thus, it will be easier available (in future the STS advantages may lead to the creation of a wide string transport net comparable with the current network of motorways).

2.2. High-Speed Railways

High-speed railways (HSRW) designed for speeds 250...300 km/h are becoming more and more popular in the world. Their extension has gained priority in the transport, for example, the Council of Ministers of the European Community projects to invest about 300 billion ECU (until the year 2010) into their construction.

The common railway transport is not suitable for high speeds. Moreover, the earth bed subsidence should not exceed 1 mm, hence loose soil should be removed to a depth of several meters to erect such railways. As a rule, loose soils occupy lowlands, flooded lands, marshy land, which are a natural water system accumulating and distributing moisture among rivers. Back-filling (and compacting) in great volumes will impair the natural water flow with a serious risk of dehydration of some territories, swamping of others, losses of forested lands, arable and crop fields, etc. In fact, the high-speed route embankments will become a dike (a dam) for soil and surface water. Also, such lines will require a special enclosure (from both sides) and noise screens to fence off wild and home animals, agricultural activities, etc. In general, a high speed line will require 3.2 hectares/km (the data for Germany), the entire route will require 3600 hectares of rather expensive land to be vacated. Moreover, there is no worldwide experience of erecting the HSRW in the mountains. Hence, its erection of mountainous portions 145 km wide is highly problematic and would be too expensive (10...15 billion US\$).

A high-speed train is a rather strong source of noise and soil vibrations, which is not surprising with its weight of hundreds of tons, its length of hundreds of meters and locomotion consuming thousands of kilowatts. The train has a great variety of projecting pieces, connectors, joints each acting as a noise source. One wheel pair weighs about a ton, it would sure hit against microroughnesses, letting alone macroroughnesses of rail joints, for example.

The major disadvantage of high speed railways is their cost. For example, experts of the European Bank of Reconstruction and Development have evaluated that a

high-speed route between Saint-Petersburg and Moscow (660 km) will cost 6...8 billion US \$, transportation of a single passenger will cost 123 US\$ (approximately as much as along European high-speed routes). The high-speed route Taipei - Oluanpi - Taipei may be estimated to cost 20...25 billion US\$, the cost of transportation of one passenger over 405 km leg will be 75 US\$. These figures exceed 5...10 times those for the STS.

The means required for erection of just flat land high-speed railway routes "Taipei - Oluanpi - Taipei" would be sufficient to construct complete STS routes about 10 thousand kilometers long.

2.3. Analysis of Motor Transport Capabilities

The automobile transport is known to be unable to compete with railways and air transport at distances above 200...400 km and more serving as a complement of the integral transport system.

Lack of competitiveness of the automobile transport as a major means of the future passenger and cargo traffic along the Beijing - Hong Kong (Taibej) route is apparent due to the following reasons:

- even erection of a new multilane motorway will not truly increase the speed and the comfort of the automobile transport which will be much less than that of the STS with an average speed of a passenger car being below 100...110 km/h, the buses will be still slower. It means that the time needed to reach from downtown Taipei to downtown Oluanpi will be at least 3...4 hours, while an STS vehicle covers the distance within 1 hours and 35 minutes (within 1 hours 15 minutes at 400 km/h);
- erection of such motorway (with the account of dividing strips, multiple loops at various elevations of the "clover leaf" types, acceleration and deceleration strips, parking lots for rest, etc.) will require a strip 2.5...3 times wider than a high-speed railway for the same passenger traffic or 750...900 (!) than for a STS;
- exhaust into the atmosphere by the STS will be less than the HSRW with its 0.6 grams per passenger-kilometer, or automobiles with their more than 10 grams per passenger kilometer;
- the STS vehicles will be airtight with all the waste collected and dumped at depots. Experience manifests that the strip along motorways is most exposed to waste disposed by car passengers;
- erection of a multilane motorway across the mountains will be extremely costly, 10...15 billion US\$, while the same STS mountainous route will cost just 0.36 billion US\$.

2.4. STS versus Aviation

The STS is advantageous when compared with the air transport due to the following considerations.

Research of transport means has allowed to discriminate clearly between the competitiveness of the air and railway transport. The so-called "transport niches" are implied defining the range of distances and speeds at which a transport means provides passengers with the utmost comfort and speed all with the least energy losses.

The analysis includes whether the absolute speed of transport means is essential for passengers or the time to reach an airport or a railway station, waiting until

departure, baggage handling or the actual time of traveling. The distance is estimated between destinations as the so-called "zones of equal accessibility" located downtown. Hence, for example, an air passenger needs 5...7 hours to travel from downtown Beijing to downtown Hong Kong (2000 km), i.e. almost the same time as with the STS traveling at 400 km/h (7 hours 30 minutes).

However, the ecological safety is the governing factor in all these comparisons. Modern airplanes release totally 300...400 g/passenger-kilometer or 500...600 times more harmful substances into the atmosphere than the high-speed railways or the STS, respectively. Actually, this parameter is expected to reduce 3...5 times when aviation switches over to the double-contour turbojet engines.

The major share of the exhaust accumulates exactly in the vicinity of airports, i.e. around large cities when planes fly low and the engines are boosted.

At low and medium altitudes (up to 5,000...6,000 m) the atmospheric pollution with nitrogen and carbon oxides persists for several days, after that they are trapped by moisture and produce acidic precipitation.

Aviation is the sole pollutant at higher altitudes with the harmful substances persisting in the atmosphere much longer, about one year. Even conversion to hydrogen engines fails to solve the problem. Harmless releases of the engines as water vapors close to the land surface convert into ice crystals shielding land.

Moreover, the noise effect is specifically strong around airports and electromagnetic noise around radar stations.

During a long flight each passenger is exposed to extra radiation of several thousands McR due to natural cosmic gamma-rays. (Irradiation doze within the aircraft amounts to 300...400 McR/h vs 20 McR/h normal).

It is an important factor to consider that airports require land areas comparable with those for high-speed railways, yet these areas are located straight near cities implying that they are more valuable.

A significant disadvantage of the air transport is that passengers and cargo are delivered exceptionally to one terminal, while STS train can deliver them to any intermediate station.

The major factor is the travel cost which will exceed many times that of the STS when the cost of traveling to the airport and back is added.

Thus, the circular Taipei - Oluanpi - Taipei future passenger and cargo traffic lines manifest obvious advantages of the string transport routes.

2.5. Applicability of Transport Means with Magnetic Suspension

Magnetic suspension transport (MST) requires solution of sizable scientific and engineering problems. Actually, the MST is still being experimented upon, though a number of countries have erected separate short stretches. Alternatives of implementation of the "Transrapid" System (FRG) and electrodynamic suspension and linear synchronous motors have been evaluated, they require to employ the effect of superconductivity. The MST requires 4...5 times more investment than high-speed railways and 30...50 times more than the STS. For example, the projected Transrapid route Berlin - Hamburg (Germany) 300 km long is estimated to cost 19 billion DM. Hence, a MST just flat land route Taipei - Oluanpi - Taipei may be estimated to cost 40...50 billion US\$, or 60...80 billion US \$ with the account of the mountainous portion.

This amount is enough to erect complete STS routes about 50 thous. km long.

3. Stages of Implementation of the STS Project

The primary objective is to complete research and development (25 million US\$) to select, optimize and adapt to the terrain relief and operation conditions of design, technological, engineering and other solutions, the know-how accumulated by the author during 18 preceding years and the specialists which he attracted to cooperate and then at the “NTL Transportlinien GmbH (Germany), since 1997 at the Research Center “Yunitran” (Belarus) and since 1998 at the Foundation “Yunitran” (Moscow), because it received the non-material assets accumulated during this period: patents, know-how, engineering knowledge, designing, technological and other achievements and their cost exceeds 14 billion US \$, according to the estimate of the Institute of Independent Assessment of Investment and Credited Projects (Minsk). The program had been elaborated to develop the design of the transport line and the vehicle (with all their components) with the account of wages of designers and other staff, the cost of materials and standard pieces, equipment, expenses to attract contractors, etc. The program is for the conditions in the Republic of Belarus, but it can be easily adapted to the conditions of any other country with the help of correction factors.

A special designing bureau should be created together with several laboratories (to investigate motion dynamics; control, communications and safety systems; electric motors and power supply and reliability of structures) and major services (the general designer, the chief economist, the chief process engineer, the chief engineer, the chief construction engineer, the chief power engineer, the chief communications expert). This stage can be accomplished within 2...3 years providing the corresponding finances become available and 100...120 designers are recruited. Research and development can be combined with the erection of a pilot STS leg 10...20 km long.

In combination with research and development the pilot route leg (40 million US\$) should be erected and pilot vehicles should be fabricated (2 million US\$). With sufficient finances it can be accomplished within 2...3 years. The pilot leg can be erected in any country where investors believe their investments can enjoy protection and the designer can be sure of the proper protection of the intellectual property and the copyright. A special research and designing center should also be established in this country.

The route survey can be started parallel to the erection of the pilot leg as well as the survey of other transport lines if there are clients for such projects. It will allow to become leaders of the world super high speed transport market in the 21-st century.

Development, designing and erection of the STS circular route “Taipei - Oluanpi - Taipei” can be started simultaneously with development, designing and erection of the route “Beijing - Hong Kong (Taipei)”. This work can be started as implementation of the national transport programs in mainland China and the island of Taiwan. In the process of implementation of the national programs a unified line can be coordinated for constructing the route, to elaborate design, technological and operational standards. Then each country can independently erect its own portion of the transcontinental route with its ramification (if necessary), for example, China - the route “Beijing - Hong Kong” and Taiwan - the route “Taipei - Oluanpi - Taipei” - mainland

(through the Taiwan Strait). After that, in future, the route can on one side be extended to Western Europe and on the other side to Indonesia.

The STS circular route in Taiwan can be erected at stages. The first stage can be the erection of the STS branch in the north-west of the island as the most passenger and cargo intensive one (Taipei - Taichung, 130 km), then in the south-west (275 km) and in the east (390 km). After that three transverse STS branches "east-west" (vias mountains) can be erected: Hsinchu - Ilan (100 km), Taichung - Hwalien (125 km) and Kaohsing - Pintung - Taitung (105 km).

Another order of priority of the STS circular route erection is also possible.

The start is the erection of the western leg of the northern circular route Taipei - Taichung, then - the eastern leg Taipei - Hwalien which is locked with a small circle by the route Taichung - Hwalien. Then goes the intermediate circular route consisting of the lines: Taichung - Kaohsing, Hwalien - Taitung and Kaohsing - Taitung. The end can be the erection of the line Hsinchu - Ilan and the southern semicircle Kaohsing - Oluanpi - Taitung.

The STS, due to its strong competitiveness, will be able to conquer the world markets of high-speed communications. It will create a new economic niche by forcing out high-speed railways, trains with magnetic suspension and aviation.

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