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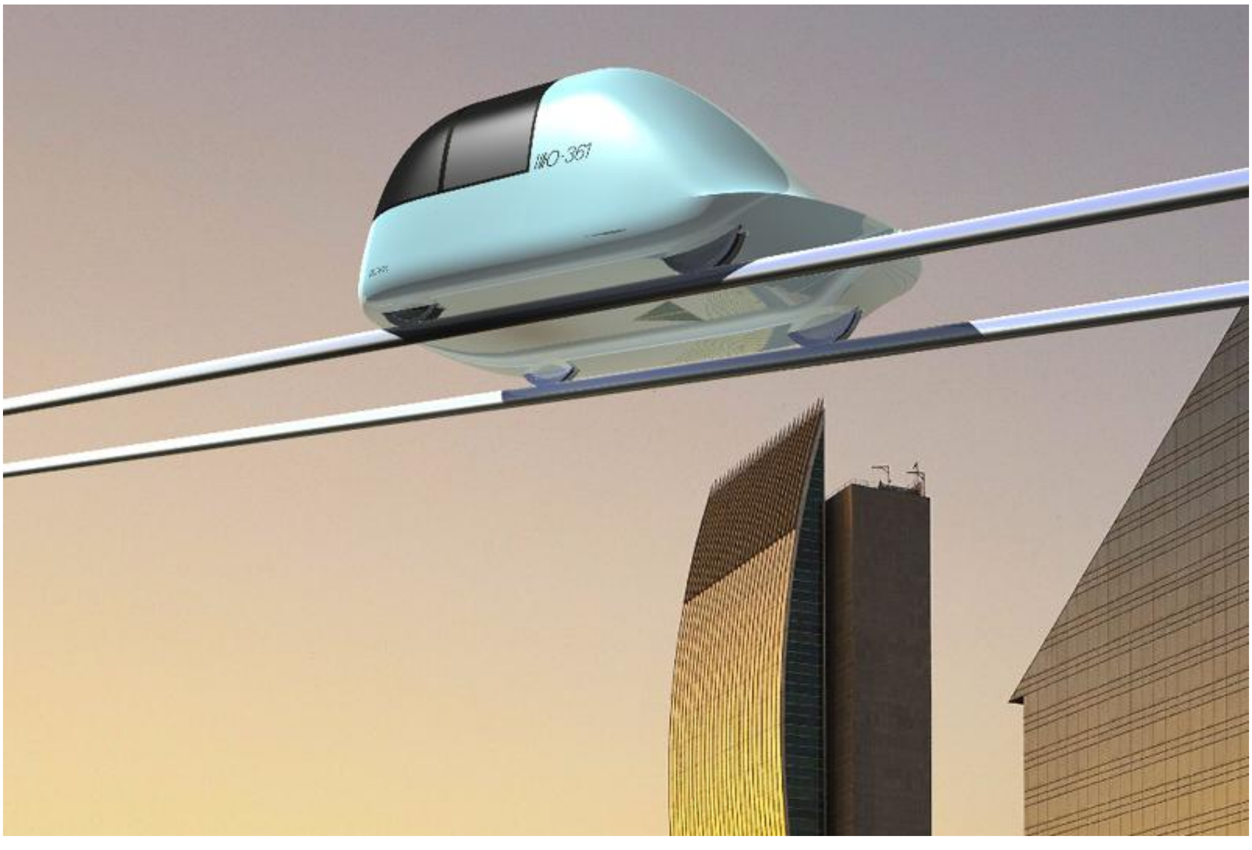
Pre-project Proposal

High-speed String Transportation Route “ABU DHABI — DUBAI — SHARJAH”



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1. Description of Unitsky String Transport

Unitsky String Transport (UST) is designed as a string rail road elevated on the supports above the ground along which wheeled transportation modules (unibuses) with 50-passenger and up to 5 tons of freight capacity are circulating with the travel speed up to 350 km/hour.

UST is the cheapest, most durable, economically efficient and safe system among all other known modes of transportation of the second level, i.e. systems with the elevated track structure installed on the supports such as train on a magnet suspension, mono-rail and cable roads. The UST advantages against other modes of transportation could be attributed to the following complex of its structural peculiarities.

1.1. String

String is made of twisted seven-wire K-7 cable with 15.2 mm diameter. Depending on assembly and operation conditions traditional cables (breaking stress — 24—26 tons, permissible normative strength in the track structure — 14 tons), cables with a protective cover or polyethylene envelope including protective lubrication (breaking stress — 26—28 tons, permissible strength — 20 tons) are used. The cost of cable is USD 1,000-3,000 per 1 ton.

1.2. String-rail

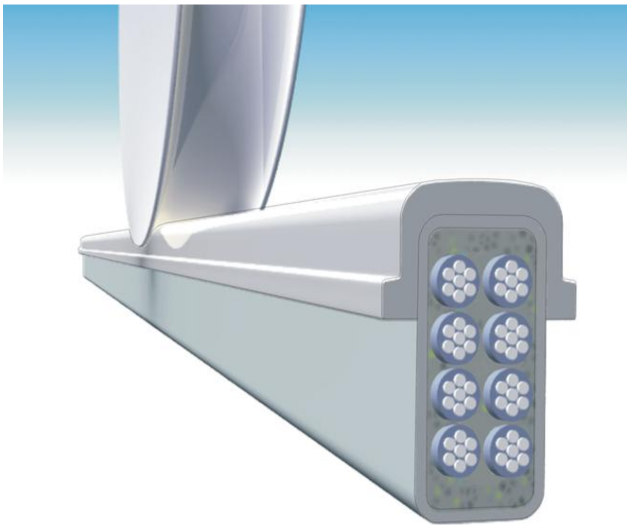

Fig. 1. Design alternative of a string-rail and wheel

String-rail is an ordinary continuous (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. 1).

Maximal string stress per one rail (depending on a span length and mass of the rolling stock) is 200—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) and when exposed to the concentrated load of a 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 a high degree of strength, rigidity, smoothness, technological production and mounting, low material consumption (steel: 20—60 km/m, concrete: 0.005—0.02 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 USD 100,000 per 1 km which, for example, is less than the cost of assembled railway rail of a trunk line.

1.3. Track structure

Track structure is designed as two string-rails to make a gauge of 2,000 mm width. It is equipped with switch-over devices similar to those used for trams. It is possible to install it on the supports, on the ground (with a special sleeper frame, spacing between sleepers — 5—10 m), or on a sand, gravel or concrete longitudinal (0.2—0.4 m wide) cushion. It could be designed as dismountable structure. A UST gauge is almost 1.4 times wider than that of a railway and centre of mass of the rolling stock is located 1.5-2 times lower to ensure steadiness of movement along such track to be 2—3 times higher.

1.4. Supports

Supports are subdivided into anchor supports, exposed to horizontal load of strings (installed every 2—3 km) and supporting masts exposed to vertical load (installed every 10—50 m and more). For UST routes it is possible to use either earlier designed standard supports with their height ranging from 0.5 to 20 m, made of reinforced concrete (assembled or monolithic) or steel welded structures and additionally designed supports meeting special customer requirements. Depending on soil peculiarities either pile (driving, screw, filling, injected) or slab (monolithic or assembled) foundations are possible. Supports could be installed practically in any kind of soils. Supports and unsplit string-rail form a rigid frame structure therefore bearing capacity of supports is increased, for example, compared with a mono-rail by 8 times (the cost of supports was accordingly reduced). The cost of intermediate and anchor support is USD 500 and USD 50,000, respectively. If UST supports were replaced by an embankment of the same height its cost would be higher.

1.5. Wheel

Wheel is made of high-strength steel (Fig. 1). It has an independent “automobile” suspension and two rims each 40 mm high (against a wheel pair and one rim 30 mm high in each railway wheel). Between its rim and nave the wheel is provided with damping and sound-absorbing polymeric gasket. Rolling resistance coefficient is 0.0005 (1.5—2 times lower than that of a railway wheel having a conic rest surface); mileage is up to 1 million km. A steel wheel of UST is cheaper than a rubber wheel and 5—10 times more durable.

1.6. Transportation module

Transportation module (unibus) is a kind of an automobile put on steel wheels (Fig. 2). Like an automobile it could use a diesel, gasoline or turbine engine or a combined engine (for example, "diesel — generator — energy accumulator — electric engine"). If necessary, it could use ecologically clean energy sources such as natural gas, hydrogen, spirit, compressed air, flywheel energy accumulator, solar, wind, etc. Furthermore, UST could be electrified using external power sources (like a trolley-bus, tram or metro) or autonomous energy sources — on-board accumulators, condensation energy or fuel batteries, etc.

High-speed unibus has a unique shape characterized by the lowest aerodynamic resistance coefficient among all known transportation vehicles (C_x = 0.07—0.1) which is 3—4 times better than that of a modern sports automobile; these results were obtained in the course of numerous wind-tunnel tests). Unibus is the most economically efficient transportation vehicle among all known vehicles. Its super efficiency is especially visible at low speeds, for example, 100 km/hour traditional for motor transportation. At stable motion along the horizontal track section a 25-passenger unibus with the weight of 5 tons requires the engine of 8.3 kWt power (out of which 6.6 kWt — for aerodynamic resistance coefficient, 0.8 kWt — for rolling resistance of a steel two-rimmed wheel on a steel rail, 0.9 kWt — transmission losses). In this case fuel consumption per 100 km will be 2 liters (or 0.08 l/100 pass.×km or 0.8 l/1,000 pass.×km), while fuel consumption by the best passenger cars is 10—15 times more (1—1.5 l/100 pass.×km). At serial production the cost of a unibus will be about USD 50,000 (for small, 5—7-passenger modules with travel speed up to 250 km/hour).

1.7. Infrastructure

It includes stations, terminals, loading and unloading terminals, depots, garages, filling stations. Elevation of a track structure to the second level opens up new possibilities for the construction of stations and terminals (fig. 3). Thanks to more favourable operation regimes of a rail automobile the need in garages and filling stations is reduced as compared with traditional motor transportation. Compact unibus design makes it possible to reduce the size, and consequently, the cost of terminals, stations and platform length by 5—10 times compared with railway transport.

a)

b)

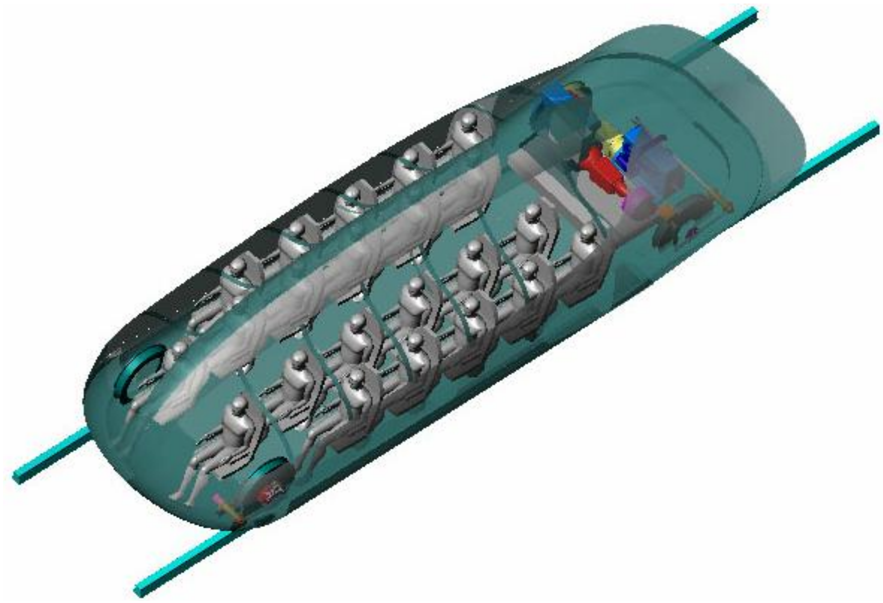

Fig. 2. High-speed passenger module: a) external view; b) salon.

- Capacity — 25 passengers; Estimated travel speed — 250 km/hour;
- Design (maximum) speed — 300 km/hour;
- Drive — internal combustion engine (diesel) with 120 kWt capacity;
- Fuel consumption (diesel fuel) at cruising speed (250 km/hour) — 12 l/100 km.

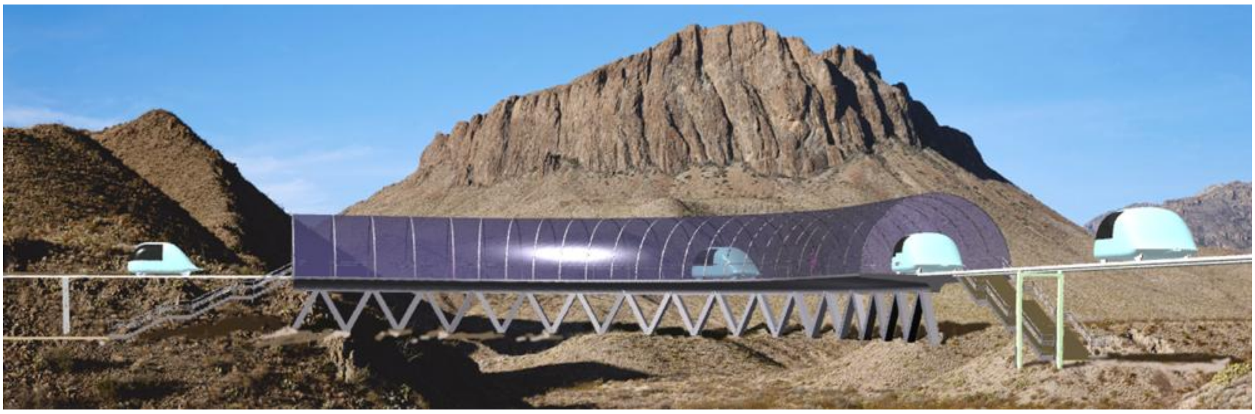

Fig. 3. Station combined with anchor support and UST turning angle

1.8. Project solutions

UST track structure and supports are designed as a transportation elevated road in accordance with Russian construction norms and rules (SNiP 2.05.03-84 “Bridges and pipes”) as well as with the basic provisions for bridge standards of the USA and EC countries, therefore, no certification is required. Each designed UST route like any other transportation facility is subject to the expertise of relevant state authorities.

1.9. UST operation

Lower contact voltage in the “wheel — rail” pair (50—60 kgs/sq. mm against 100—120 kgs/sq. mm in railways), the rail-head wear will be less intensive than in railway transportation (1 mm wear of the rail height after 100 million tons of train load). The rail-head thickness is estimated for the whole service life period of UST (50—100 years), for example the head thickness of 20—25 mm will be enough to handle the total volume of traffic amounting to 500 million tons.

Operation costs are only associated with periodical protection of metal components against corrosion (once per 10—20 years). With a string-rail body made of stainless steel and supports – made of reinforced concrete the operation costs of a route will be reduced to seasonal inspection of structural components (to reveal construction defects and external damages).

1.10. Approbation

Building technology used for the track structure and supports as well as the basic UST nodes and elements were exposed to successful approbation in 2001—2005 using a single-track testing unit built in Russia (town of Ozyory, Moscow Region, Fig. 4). The key unit characteristics are as follows: length — 150 m, summary string stress — 450 ts (at +20°C), height of supports — up to 15 m, maximal span — 48 m, maximal mass of the moving load — 12 t, relative rigidity of the largest span above the load — 1/1,500, metal-consumption of a track structure — 120 kg/m, route slope — 100‰.

The following components were investigated at the testing unit:

- various strings (twisted cables with 27 mm and 15.2 mm diameter made of wire with 3 mm and 5 mm diameter, respectively);
- string anchorage (wedge clips that ensure safe cable fastening — in laboratory tests cables were broken at stress of 24—28 tons everywhere but not in clips);
- relaxation of pre-stressed strings (relaxation of K-7 cable with 15.2 mm diameter, with its estimated stress — 10,400 kgs/sq. cm not fixed during 4 years);

- pile, drilling-injected and slab foundations of intermediate supports (height 2, 5 and 8 meters) and anchor supports (height — 1 and 15 m);
- special high-strength concrete for string-rails (modified by plasticizer and corrosion inhibitor);
- two-rimmed steel wheel, damped with a rubber gasket between the wheel rim and nave (showed safety and stability of movement — during 4 years of operation no contact between the rim and rail head was observed which is attributed to the fact that toroidal bearing surface of a wheel is responsible for standard moving regime);
- wheel-rail cohesion (minimal friction coefficient in the “wheel — rail” pair for raining or icing conditions is 0.15—0.2 enabling design of high-speed UST routes with prolonged slopes up to 150—200‰;
- blocking system of front wheels and link rod against turning;
- correctness of estimates of the stability and rigidity of supports, track structure and strings under the impact of dynamic loads of the rolling stock, seasonal changes of temperature, wind, icing, etc.

2. Layout scheme of UST route

Layout scheme of UST route: “Abu Dhabi — Dubai — Sharjah” is given in fig. 5.

It is proposed to install the track structures of a double-track route on isolated supports with the height of 3—6 m and more which makes it possible to trace each track independently at the distance of 5—10 m from each other and more. It will contribute to the growing comfort of travel (no oncoming vehicles will be seen from unibus windows) and safety of the transportation system (for example, its resistance to terrorist acts will be increased because it is more difficult to simultaneously put out of action two transportation lines installed on separate supports at certain distance from each other).

Optimal length of spans at dry land sections is 20—40 m, at marine sections — 40—60 m (at sea depth up to 10 m) and 80—100 m (at sea depth up to 20 m).

Layout alternatives for UST routes coming along dry land and sea coastal areas are given in fig. 6—8.

Fig. 4. UST testing unit in the town of Ozyory, Moscow Region, Russia

Fig. 5. Layout alternative of UST route "Abu Dhabi — Dubai — Sharjah"

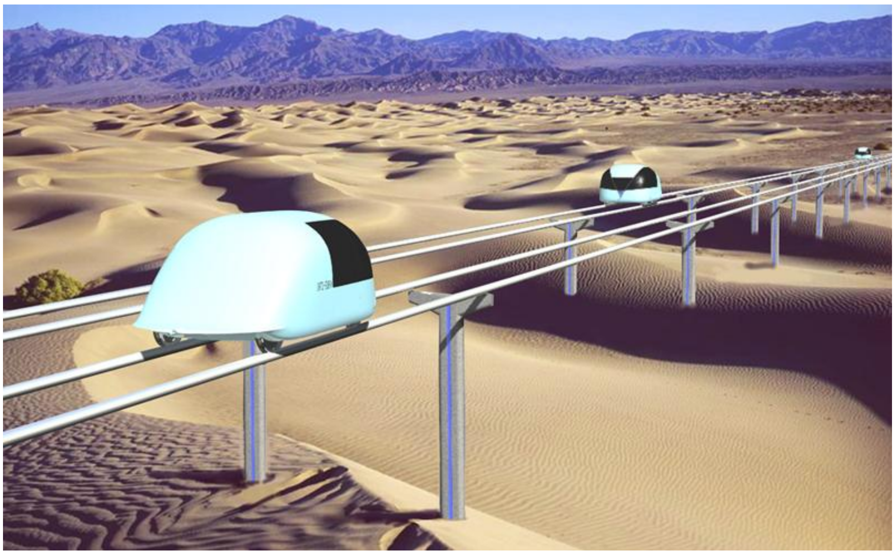

Fig. 6. High-speed UST route in a desert

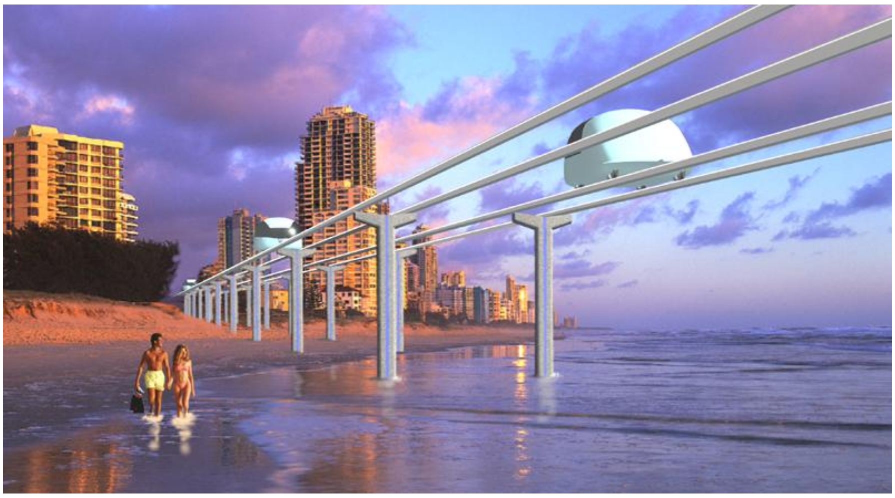

Fig. 7. High-speed UST route on a sea coast

Fig. 8. High-speed UST route passing though a settlement

3. Technical and economic characteristics of a double-track high-speed UST route "Abu Dhabi — Sharjah"

Purpose — freight/passenger route
Length — 138 km
Cost — USD 280 million (see table 1)
Estimated travel speed of transportation modules — 250 km/hour
Travel time — 37 minutes (see table 2)
Average height of supports — 5 m
Average length of spans — 30 m (50 m for marine sections)

Maximum (design) carrying capacity of a double-track route:

- passengers — 100 million passengers/year
- freights — 50 million ton/year

Expected passenger turnover (138 km section) — 12 million pass./year
Expected freight turnover (138 km section) — 3 million ton/year

Table 1

Approximate cost of UST route "Abu Dhabi — Sharjah"

Name of route components	Number (volume of works)	Cost per 1 unit of work, thous. USD	Total cost, thous. USD
1. Transportation line, total, including:	138 km	—	130,000
1.1. Track structure	138 km	450	62,100
1.2. Foundation and supports	138 km	400	55,200
1.3. Technical control system to check the state of supports and track structure	138 km	20	2,760
1.4. Radio-relay system of traffic control	138 km	40	5,520
1.5. Miscellaneous	—	—	4,420
2. Cost of infrastructure, total, including:	—	—	45,000
2.1. Stations	3 units	6,000	18,000
2.2. Freight terminals	3 units	4,000	12,000
2.3. Depot and repair shops	1 unit	8,000	8,000
2.4. Miscellaneous	—	—	7,000
3. Rolling stock, total, including:	—	—	32,000
3.1. Passenger modules	90 units	110	9,900
3.2. Freight modules	220 units	80	17,600
3.3. Emergency reserve modules	10 units	110	1,100

Name of route components	Number (volume of works)	Cost per 1 unit of work, thous. USD	Total cost, thous. USD
3.4. Technical control modules to check the state of the route and to provide its emergency service	5 units	150	750
3.5. Miscellaneous	—	—	2,650
4. Rise in price of the route at difficult sections (passing through the city area, sea, crossing with communications)	30 km	800	24,000
5. Engineering/survey and design works for the route	150 km	40	6,000
6. Project/design works for the track structure, supports, rolling stock, infrastructure and control systems	—	—	20,000
7. Miscellaneous and unforeseen costs	—	—	23,000
Total:	—	—	**280,000**

3.1. Expected passenger flow

1 trip per year (to and from) for each citizen of the country and each tourist to give the total of 12 million passengers per year (2 trips × (3 million persons + 3 million persons)).

3.2. Expected freight flow

Approximately 1 ton of freight per year per 1 resident of UAE to give the total 3 million tons of freight per year.

3.3. Organization of traffic

For small volumes of traffic such as at the route “Abu Dhabi — Sharjah” (12 million pass./year or 32,900 pass./per day or on the average 2,050 pass./hour at two-shift operation) it would be economically feasible to use passenger and freight modules of medium capacity and medium mass – about 5 tons in loaded condition. It will make it possible to reduce the normative tension of strings in the track structure and, consequently, to reduce the cost of UST route. In this case the total carrying capacity will not be reduced, moreover, it will have a growth potential to100 million pass./year.

Transportation (passenger and freight) module has as its drive a diesel (low-noise impact, economically efficient, meets Euro-4 requirements in terms of emissions) and an automatic gear box. Module is controlled by a driver. At the present stage the use of fully-automatic system to control each module or transportation flow as a whole would not be reasonable. Automatization of control could result in the sharp rise in the cost of the rolling stock and transportation lines whereas the number of servicing staff will not be reduced and no pay-roll savings could be achieved. It could be attributed to the fact that like an airliner a unibus should have on its board at least one professionally trained staff member responsible for the operation of the rolling stock (in the former case — a driver additionally performing functions of a steward, guide, etc. and in the latter case — a steward performing, if necessary, functions of a driver, for example if the automatic system of control is put out of action).

3.4. Transportation module requirements

1. Passenger modules (with 25 passenger capacity).

At two-shift operation one module will make 24 runs per 24 hours. At loading coefficient of 0.8 and utilization coefficient of 0.8 one module could carry 384 passengers per 24 hours or 140,000 passengers per year. For transportation of 12 million passengers per year it will be necessary to have 86 modules.

2. Freight modules (carrying capacity — 3 tons)

One module will make 20 runs per 24 hours. At loading coefficient of 0.8 and utilization coefficient of 0.8 one module will carry 38 tons of freight per 24 hours or 14,000 tons per year. For transportation of 3 million tons of freight per year it will be necessary to have 214 freight modules.

3.5. Travel time and circulation along the route

Travel time for a passenger trip from the centre of Abu Dhabi to the centre of Sharjah will be 37 minutes (see table 2).

Table 2

No.	Name of transportation process	Time, min.
1	Waiting time for loading	1
2	Loading of passengers	1.5
3	Waiting for a trip	0.5
4	Acceleration to the speed of 250 km/hour	1.5
5	Movement along the route	28
6	Braking of a transportation module	1.5
7	Entry to the station	0.5
8	Unloading of passengers	1.5
9	Unforeseen time costs	1
	Total:	37

At the aforementioned utilization and loading coefficients of the rolling stock the total number of passenger modules simultaneously circulating along the route will amount to 86 vehicles. With the track length of 2 × 138 km = 276 km the average distance between the neighbouring passenger modules moving along the route at the estimated travel speed will be 3,200 m and time interval of module circulation — 46 sec.

Circulation of unibuses could be arranged as single vehicles or as a group, for example, of 5 modules with interval of 5 sec. (or at distance of 350 m from each other). In the latter case they will enter and depart from the station every 5 seconds, therefore the platform length should enable simultaneous presence at the station of 5 modules. Intervals of circulation of such trains in which separate modules are linked with each other not mechanically but by “electronic coupling” will be 3.8 minutes.

Based on the optimal dynamic load conditions of a track structure unibuses moving at high speed should be not closer than one span from each other. At the span length of 50 m this distance will amount to 100 m, then maximum (design) carrying capacity of the route “Abu Dhabi — Sharjah” with 25-seat unibuses will be as follows:

$$N_{max} = 12{,}000{,}000 \text{ pass./year} \times (3{,}200 \text{ m}/100 \text{ m}) = 384{,}000{,}000 \text{ pass./year}$$

For combined passenger and freight traffic the maximum carrying capacity of a double-track route should be about 100 million pass./year and 50 million ton/year.

3.6. Annual income and operation profitability of the route

With the cost of passenger ticket “Abu Dhabi — Dubai — Sharjah” being USD 6 (approximate net cost of travel is 1.5 USD/pass. or 0.011 USD/pass.×km) and transportation tariff of USD 10 per 1 ton of freight (approximate net cost of transportation is 3.5 USD/t or 0.025 USD/t.×km) the annual profit from the track operation will be as follows:

$$D = 12{,}000{,}000 \text{ pass.} \times (6 - 1.5) \text{ USD/pass.} + 3{,}000{,}000 \text{ t} \times (10 - 3.5) \text{ USD/t} = \text{USD } 73{,}500{,}000$$

At such annual profit it will be possible to pay back the costs during approximately 5 years. With the cost of a passenger ticket amounting to USD 10 recoupment time will be about 3 years.

Specific capital investments per 1 km of a high-speed route (including infrastructure, passenger and freight rolling stock) will amount to 2.03 million USD/km.

The total profitability of the route operation depending on the tax rates will amount to about 300% including:

a) profitability of freight traffic — approximately 250%;
b) profitability of passenger traffic — approximately 350%.

3.7. Comparative technical and economic indices of the route depending on the size of freight and passenger flows

Fig. 9—11 show relationship between various technical and economic indices and the size of freight and passenger flows.

Fig. 11 shows that even if passenger and freight flows drop to 5.0 million pass./year and 0.5 million t/year, respectively, the total profitability of the route operation will remain positive thanks to the high profitability of passenger traffic.

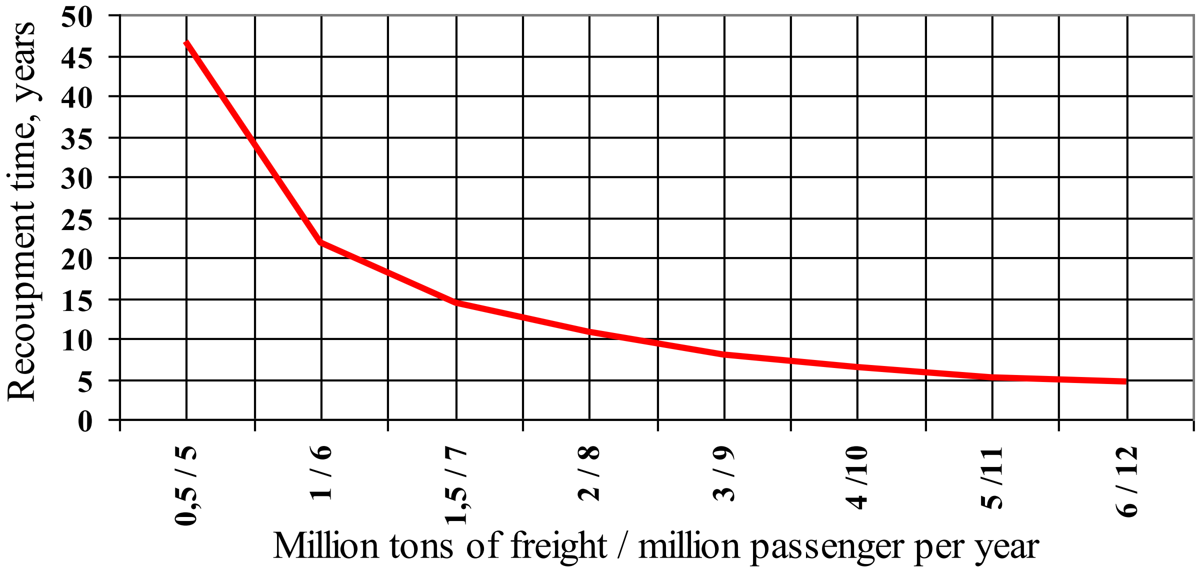

Fig. 9. Dependence of recoupment period of capital investments in route construction “Abu Dhabi — Dubai — Sharjah” (138 km) on the size of freight and passenger flows

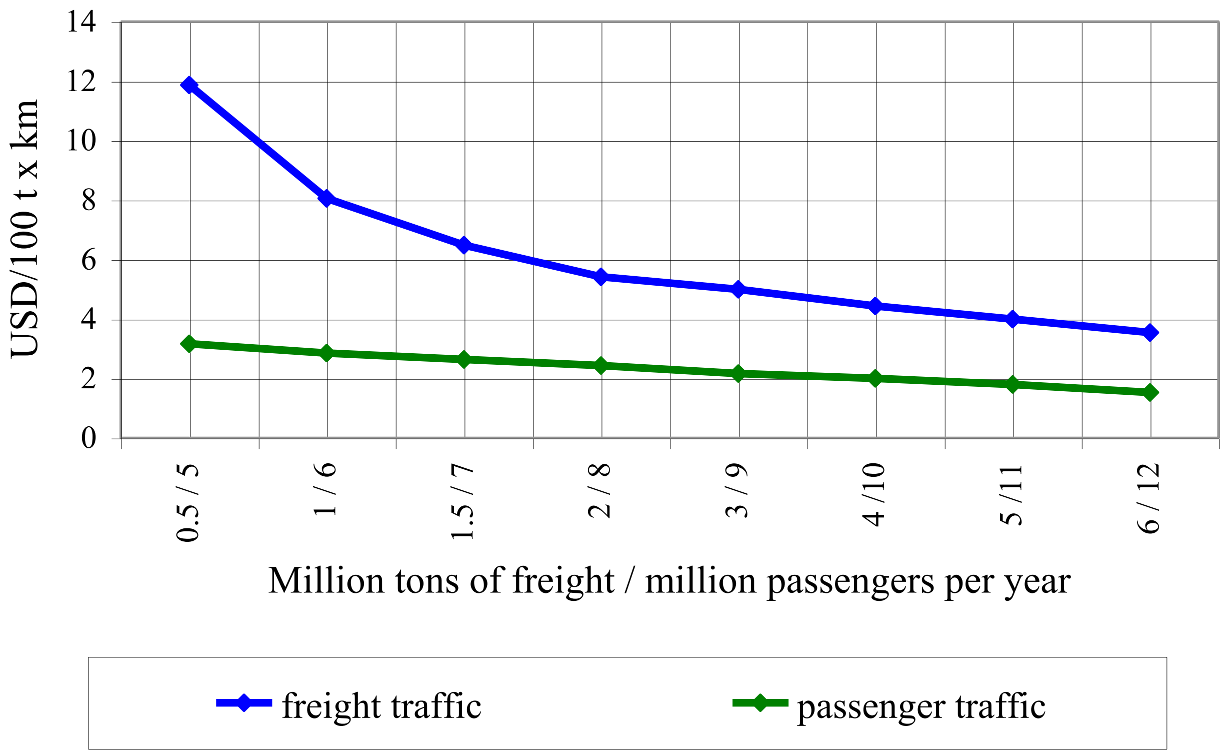

Fig. 10. Dependence of the net cost of traffic along the route "Abu Dhabi — Dubai — Sharjah" (138 km) on the size of freight and passenger flows

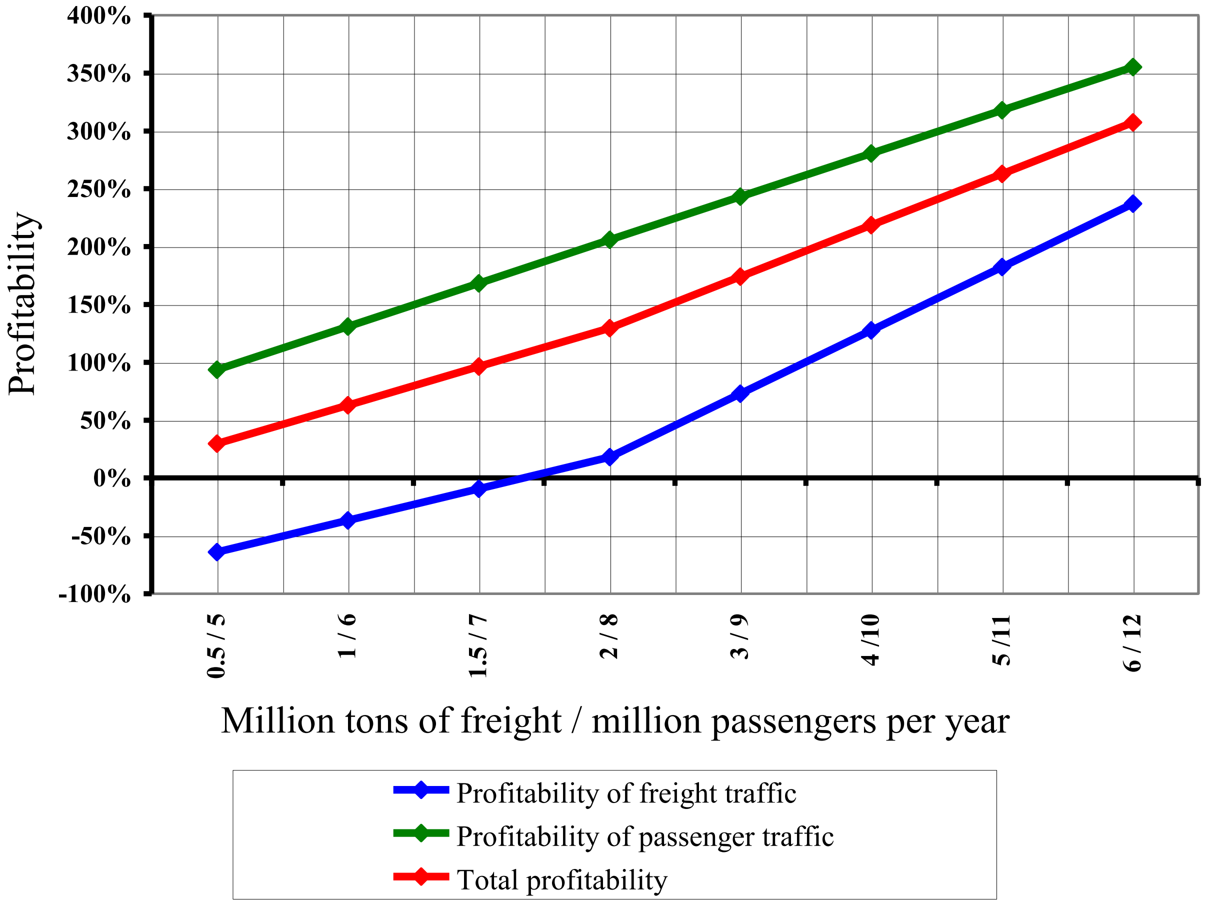

Fig. 11. Changes of the route profitability
“Abu Dhabi — Dubai — Sharjah” (138 km)
depending on the size of freight and passenger flows