ComplexTrans

DEFINITION

COMPLEXTRANS IS A GLOBAL MIXED LAND TRANSPORT SYSTEM

- **for passengers and goods**
- **for both urban and intercity travel**
- **combining individual and mass transport**

BASED ON DEEP COMPATIBILITY BETWEEN ROAD AND RAILWAY VEHICLES AND THEIR EXTENSIVE COMBINED USE (Fig. 1).

HOWEVER, EVEN WITHOUT COOPERATION OF BOTH (RAIL AND ROAD)
BRING THE COMPLEXTRANS-VEHICLES MANY ADVANTAGES
IN COMPARISON WITH ANOTHER ADVANCED CARS.

DESCRIPTION

Introduction

ComplexTrans delivers major improvements in the following aspects (Fig. 2)

1) **long-distance passenger and freight transport**
2) **urban passenger transport**
3) **urban freight transport**
4) **improved quality of life in cities**
5) **cooperation with air transport**
6) **reduced transport energy demands**
7) **land transport electrification, substituting oil with electrical energy, reduced C02 emissions**
8) **integration with the electrical grid and support for renewable sources of electrical energy (wind and solar)**

The ComplexTrans system relies predominantly of four types of vehicles: (Fig. 3)
road – coupemobiles (Fig. 16) and mobile freight transport modules (Fig.26)
railway – double-deck passenger-freight cars (Fig. 4, Fig. 5) and rapid freight wagons (Fig. 3 – right down)

Important roles in the ComplexTrans system are also played by:
road – ordinary passenger cars capable of being loaded in transverse direction onto ComplexTrans trains using their own power, passenger transport modules (Fig.28), lead/power vehicles in transport module platoons (Fig.27), low-height electric buses and other (mostly small-size) motorised and non motorised vehicles for individual passenger transport (Fig.8)
railway – electric power coaches/trains for passenger transport capable of coupling/uncoupling during travel (under preparation) and shuttle power coaches/trains for passenger transport.

1) Long-distance passenger and freight transport

The backbone of the ComplexTrans system is high-capacity railway service provided by trains of double-deck cars that carry passengers on the upper floor and “**cargo**” **on the lower floor** (Fig.4, Fig.6) **-** another variant involves double-deck cars with both floors carrying cargo (Fig.5).

The “**cargo**” **is understood to consist of**

- compatible passenger cars (so-called coupemobiles) and their passengers,
- mobile wheeled transport modules (containers) intended primarily for freight transport, and
- passenger transport modules or ordinary-sized passenger cars on transport pallets (Fig.7).

Other small vehicles for individual transport can be carried by service cars (Fig.8)

At terminals (Fig.9)**, individual freight wagons** adapted for higher speeds or their small groups **are coupled to ends of trains** to carry larger or heavier cargo (Fig.10).

The mixed transport of passengers, cars and freight guarantees high and profitable utilization of the ComplexTrans trains which **can therefore operate at short intervals, offering an attractive high-capacity service.**

The throughput of a double track with trains of twenty coaches running at 5-minute intervals thus matches the throughput of a road with at least one car travelling in each direction every two seconds.

ComplexTrans trains travel across continents and subcontinents along their transport corridors at speeds of approximately 200 km/h ± 20% (Fig.12)**.** Two-floor terminals outside city borders (Fig.11) located approximately 50 to 200 kilometres apart are used for short dwell times, no longer than 5 minutes. This time serves for simultaneous boarding and alighting of passengers and loading and unloading of the above-mentioned “cargo”.

Terminals for ComplexTrans trains are linked to cities mainly

by road

- with low-height electric buses that stop right at terminal platforms, or
- with privately-owned coupemobiles (Fig.16) transported by the trains, and with cars, or
- with platoons of freight or passenger modules carried by the trains, which are guided on the road by a lead/power vehicle (Fig.27)

by railway

- with shuttle trains between ComplexTrans terminals and railway stops located in cities that run on existing urban and suburban routes, with transfer points at terminals, or
- with ComplexTrans power coaches/trains capable of coupling/uncoupling during travel which stop in city centres and allow passengers to transfer to moving ComplexTrans trains (Flügelwagen), or
- with sidings for freight railway wagons (Fig.9) .

The average speed of ComplexTrans trains on long-distance routes reaches about 125 km/h ± 20%, including stops and waiting times, depending on the gradient profile of the track, the distances between stops and the length of the route (Fig. 14 Fig. 15). **In a single day (16 hours), one can thus visit destinations approximately 800 km away, attend a meeting, and return.** The travel time spent in the comfort of passenger’s own coupemobile can be used for work, entertainment or relaxation (Fig.8), and is therefore not wasted.

Staying in their private space allows passengers to extend one-day trips by one or two nights (Fig.14) and therefore **use the extended time to visit destinations up to 1500 km away, attend a meeting, and come back,** a service which outperforms even air transport or high-speed trains in terms of comfort, "speed" and low price.

Freight transport in the ComplexTrans system involves speeds almost equal to those of passenger transport. Freight transport times are only slightly longer – due to collecting and delivering the goods outside the peak hours.

Thanks to the high utilization of ComplexTrans trains, the short intervals between them, the reduced energy consumption, and with no need to drive the road vehicle that is carried by train, the cost of the transport in the ComplexTrans system can be lower or at least no higher than the present-day cost of the road transport – and similar to just the fuel price in private individual transport. The railway segment of the ComplexTrans system is financially self-sufficient (Fig.15).

ComplexTrans transport is therefore not only rapid, safe and comfortable but also economically advantageous.

2) Urban passenger transport and parking

The automobile (car´s) paradox

The shape and configuration of today's passenger cars is mainly dictated by the demand for the best possible aerodynamic properties, minimized energy consumption during long-distance travel at average speeds about 100 km/h or more, and by sufficient space for 4-5 seated passengers and their luggage. In reality, however, a passenger car most often carries a single person with a small item of luggage across the city at low speeds where its aerodynamic shape is irrelevant. This is the paradox of today's passenger cars – and it is removed by the ComplexTrans system.

Coupemobile (Figs. 16, 17 and 18)

For the transverse loading of cars onto ComplexTrans trains, which is one of the key aspects of the system, the main dimensions and configuration of ComplexTrans cars – coupemobiles – must be specially adapted.

First, their length should be no more than 2.2 metres, to enable them to enter the ComplexTrans trains in the transverse direction, while leaving an aisle for passengers along the rail coach length (Fig.5). For riding, the front and rear wheels slide out forwards and rearwards, respectively increasing the car length to approximately 3.2 m. In no case the comfort for passengers will be reduced by it – the dimensions of passengers space remain the same or will be increased.

The shortened length demands changes to the configuration and other dimensions of the vehicle as well. The width of the vehicle increases to approximately 2 m, as does its height. The **electric drive train of the vehicle and the battery** will be installed below the comfortable rear triple seat. The luggage compartment will be provided above rear seats. There will be three doors in the vehicle. For right-hand traffic, the main entry door will be the one in the right-hand side, and the auxiliary entry door will be the one on the front side in front of the front passenger seat. The third door will be at the back of the vehicle, for access to the drive train and for loading sizable luggage. Between the two front seats, an aisle will be provided with a height sufficient for an almost upright standing passenger, offering comfortable access to all seats. The front and rear axles will be able to slide out forwards and rearwards, respectively. Their extended position will be used for riding on roads in order to improve ride comfort and to better protect the passengers in the event of a low-speed collision. Safety at higher speeds will be provided predominantly by the transport by trains.

In the interior of the vehicle, there will be a collapsible table attached to the left side wall, and rotatable front seats. Consequently, the interior of the vehicle can be used by up to five persons for work or entertainment during train rides and while the vehicle is parked. In addition, one or two people will be able to sleep in the cab, and sizable cargo can be carried in the place of the rear seats (1 or even two euro-pallets).

On the rear side of the vehicle, there will be the possibility to exchange the "empty" battery for a "full" battery or for range-extender for long-distance road travel, what can be done not only on the "tank-station", but everywhere (also on the street during parking) by suitable exchange-vehicle.

- **It means, that no street-recharge infrastructure is needed.**
- **It means also, that only a small battery (for about 200 km range) is needed**
- **It means also, that the range anxiety can be "over"**
- **It means also, that the battery doesn´t need to be in the car´s owner ownership and that such electrical vehicle can be cheaper than the comparable standard car of today**
- **It means also, that the way to fast road transport electrification is open**

The drive train under the rear seats will comprise electric motors driving the rear wheels. The power will be sufficient for a single car to cruise at more than 100 km/h, and for platooned vehicles to travel at a speed of at least 130 km/h.

The battery capacity will be approximately 30 kWh, which will be sufficient for normal one-day urban travel covering a distance of about 150 km. The connection to an external power source will be simple and standardized.

Effective thermal insulation of the vehicle body will reduce the energy demand for heating and air conditioning. Additional advanced opportunities for energy-saving heating and cooling operation will be sought. One of them involves solar panels installed on the vehicle roof to support the air conditioning system and the battery conditioning function.

Coupemobiles are also designed for non-traditional riding and parking modes.

- Lifting points on the body, most probably on the roof, (Fig.17), will enable the vehicle to be lifted by manipulators and elevators in parking facilities, such as underground or above-ground parking houses, parking platforms above pavements or parking spots on the balconies of houses (Fig.25).
- Coupling the coupemobiles together to form short platoons (Fig.19) enables space-saving and energy-saving travel, and allows temporary use of privately-owned vehicles as means of public transport (Fig.21).

All main dimensions and other important parameters of coupemobiles will be standardized.

Coupemobile travel in cities

There will be three modes of coupemobile travel in the urban environment

a) individual travel identical to the use of ordinary passenger cars
b) platooning for individual travel (Fig.19)
c) and platooning for temporary public transport of passengers (Fig.21)

Re b) Coupemobiles will be coupled together, either mechanically in marshalling lanes provided in suitable locations or electronically while in motion, and ride in a platoon for most of the trip. In a suitable location, they will uncouple and continue to their destinations on their own (Fig.19). Platooning means using less space and saving energy. A platoon of five coupemobiles occupies only approx. 40 % of the space needed by five vehicles driving independently. In most cases, the platoons will use special grade-separated intersection structures for coupemobiles (Fig.20) and dedicated lanes, which will motivate drivers to couple their vehicles, and thus reduce traffic density.

Re c) – The coupemobile owner can enter into a contract with a public transport company for integration into the public transit system. The public transport company will install to the coupemobile the required devices - navigation system, information system terminal, passenger handling system, and others (Fig.21). While driving through the city (e.g. on the way home or from home), the driver voluntarily provides information on his or her destination and the vehicle thus becomes part of the public transit system (Fig.22). The public transport company will provide an online response with information about the stop at which the vehicle should couple to other coupemobiles heading in similar direction and guide the entire platoon of coupemobiles to their destination. The platoon stops for boarding and alighting passengers who booked the ride online using their smartphones. The public transport company provides these passengers with all necessary and available transport information online (Fig.23). The public transport company also ensures that the route does not diverge too much from the direct route, that the number of stops is minimized, and the number of passengers maximized. The platoons enjoy all aspects of the priority given to public transports, and use special grade-separated intersection structures for coupemobiles. Coupemobile owners are rewarded for providing transport services.

This highly comfortable mode of public transit will find use predominantly during peak hours. The temporary incorporation of approximately 20 % individual vehicles into the public transit system will equal about one third of the public transport company fleet. The company will thus be able to use its vehicles more uniformly and efficiently (Fig.24).

One can expect that the operating benefits will bring more private vehicles to this system, which will reduce the urban traffic density by more than 50 % (Fig.24).

Full-scale application of both principles (platooning and implementation to the public transport) can therefore reduce the urban traffic density up to approx. 25 % of today’s level, while maintaining its total capacity.

Parking coupemobiles in cities and their use for non-transport purposes

Parking and the lack of parking space is one of the most burning issues of car traffic in cities.

Coupemobiles do away with the lack of parking space:

a) The footprint of a coupemobile of 2.2-metre length (with wheels retracted) and approx. 2-metre width is about 60 % of that in comparison to ordinary passenger cars. Its short length allows perpendicular parking which is easier and takes up less space. **Coupemobiles therefore occupy approximately 40 % less parking area than the same number of passenger cars.** As a result, there will be more space again in the streets (fig.25).
b) Coupemobiles are provided with lugs for vertical transport by manipulators. **Therefore, above-ground and underground parking spaces** can house large numbers of coupemobiles in a relatively small space. In suitable locations, **parking platforms above pavements** can be provided to which coupemobiles will be lifted using parking manipulators. In all these facilities, coupemobiles will be connected to the electrical grid. The estimated increase in the parking space is no less than 20 % (Fig.25).
c) Newly-erected residential and office buildings will have lifts on their outer walls which will carry not only persons but also coupemobiles to their **parking spots on recessed or ordinary balconies**. An owner will not have to worry about finding a spot any more or about the car being damaged or stolen while parked. Loading and unloading luggage will become easy, as will the preparation of the car for a trip. Finally, the equipment of the vehicle (seats, table, lighting, air conditioning, audiovisual devices and others) will be available for use, i.e. work, entertainment or relaxation, even when the vehicle is not being used for travel. The car will thus become a mobile part of the owner's flat (fig.25).
   Office buildings and accommodation facilities based on cooperation with coupemobiles will be developed as well.
   Coupemobiles parked in this way will need no parking spots in the streets.

3) Transport of goods in cities

Every city needs its supply of goods.

In the ComplexTrans system, intercity freight transport is provided by mobile transport modules transported in the lower floor of the double-deck rail cars of ComplexTrans trains (Fig.26).

The transport modules have a length of about 4.5 metres, width of 2.55 metres and a height of no more than about 2 metres. The transport modules can carry, for instance, 8 Euro pallets or ULD containers of various sizes. The total weight of a transport module will not exceed 3.5 tonnes.

The transport modules have auxiliary low-power electric drives for independent running at low speeds (approx. 25 km/h), providing a short range (approx. 15–20 km). At least two diagonally-positioned wheels are driven. The wheels can turn through 90°, allowing the vehicles to enter the lower floor of ComplexTrans trains in the transverse direction.

The transport modules can be operated via a remote control held by a person on the ground or by a person on a collapsible auxiliary "driver´s balcony".

For road transport, they are coupled together in platoons of 1–3 modules and guided by a lead/power vehicle with a driver (Fig.27).

During the ride, the lead/power vehicle also supplies electric power to and controls the electric drives of the other modules.

The maximum speed of these platoons is approx. 100 km/h.

After unloading from or before loading onto trains, the transport modules with cargo are parked in parking areas near the terminal, and therefore do not take up space in cities (Fig.9).

They are transported to and from customers in platoons guided by lead/power vehicles outside the peak hours, also without interfering with the personal urban traffic (Fig.27).

Their local handling is usually done by the customers themselves, using the module's auxiliary drive. This drive enables also the modules to be loaded in the transverse direction onto ComplexTrans trains, and to travel at limited speed through terminals premises.

4) Improved quality of life in cities

The following summary presents the benefits of the ComplexTrans system for the life in cities:

- **Reduced urban traffic density** thanks to
  - shorter passenger cars (coupemobiles)
  - platooning coupemobiles
  - higher occupancy rates of private coupemobiles thanks to their incorporation into the public transit system
  - coupemobiles using lightweight bridges over intersections
  - freight transport performed outside peak hours

  The estimated traffic density reduction is no less than 50 %.

- **Elimination of parking difficulties** thanks to
  - perpendicular parking and reduced footprint of cars
  - above-ground or underground parking areas or platforms above pavements
  - parking spots on balconies of houses

  The estimated increase in the parking capacity is more than twofold.

- **Improved quality of urban public transit** thanks to
  - voluntary incorporation of privately-owned coupemobiles into the high-comfort system of urban public transit
  - road and railway links between cities and ComplexTrans terminals

  Travel service will be tailored.
  In the ComplexTrans public transit system, every passenger will have their own seat, travel time information, and will benefit from a minimized number of transfers.
  The quality and capacity of urban public transit will markedly increase, as will ridership.

- **Reduced noise level** thanks to
  - reduced traffic intensity
  - exclusive use of the electric propulsion

The reduction in noise level will be substantial and can be expected to be between 5 and 10 dB.

- **Elimination of traffic emissions** thanks to
  - exclusive use of the electric propulsion

  The emissions released in cities will drop to zero.
  The emissions released outside cities (by power plants) will decrease substantially in accordance with the reduced traffic density and with the increased share of emission-free power generation (namely sun and wind energy) supported by the integration of coupemobiles into the electrical grid.

- **Improved energy safety of cities** thanks to
  - coupemobile batteries connection to the electrical grid

  The capacity of a coupemobile battery (approx. 30 kWh) is larger than the average household daily energy consumption (approx. 10 kWh). The close integration of coupemobiles with the electrical grid provided by the ComplexTrans parking facilities will enable electrical energy to be stored at times of excess electricity generation (solar, wind), and to supply it at times of deficit or in the event of failure.

5) Cooperation with air transport (Fig.29)

The ComplexTrans system is ready for the following modes of cooperation with air transport:
- The freight transport modules allow ULD containers to be effectively transported all the way to and from the aircraft. As a result, the delivery of these containers to the end customer can be simplified and expedited.
- With the passenger transport modules, passenger handling can be accomplished during travel, on board of ComplexTrans trains. As a result, the time the passengers spend in airport halls can be cut to a minimum or even eliminated altogether. Travel time can thus be made shorter by several hours.
- Finally, travel by ComplexTrans trains can replace short continental flights.

6) Reduced transport energy demand

The reduced transport energy demand arises from
a) the shift of a major portion of long-distance transport from road to railway
b) reduced density and better free flow of urban road traffic
c) platooning on roads

Re a) – **reduced energy demand of long-distance transport due to the shift from road to railway** (Fig.30)

A car cruising alone at 130 km/h consumes approximately 6 litres (i.e. about 5 kg) of fuel per 100 km. The energy content of one kilogram of fuel is 42300 kJ (11.75 kWh).

To cover a distance of 100 km, a car with passengers weighing about 1600 kg consumes approximately 58.8 kWh of energy.

By contrast, an electric train travelling at 160–200 km/h consumes energy in the amount of approx. 30 Wh/t.km.

To travel a distance of 100 km, one coupemobile weighing 1.6 t carried by a ComplexTrans train (together with a share of the train weight of 7 t, i.e. 1/6 of the rail car weight plus the appropriate share of the locomotive weight) will require
(1,6 + 6) . 30 . 100 = 22,8 kWh.

It should be noted, however, that this value does not account for the efficiency of the conversion of the primary energy to electrical energy which depends on the method of energy generation from the primary energy resources and, in the case of renewable sources, such as sun and wind, which are sufficient and free of charge, becomes somewhat irrelevant and only affects the required dimensioning of the power source and investments costs.

The comparison of the consumption values suggests **that the consumption of a coupemobile carried by a ComplexTrans train equals only about 39 % of that of a car running independently on a road.**

Shifting the passenger road transport that is powered by oil products to electrified railway can thus save more than half of the required traction energy.

To make road transport as energy-efficient as electric-powered railway transport, the consumption would have to be decreased to less than 3 litres of fuel per 100 km (at the speed of 130 km/h).
As the Dieselgate scandal shows, this goal is still far ahead.

Another conclusion is that an ordinary passenger car carried by train would consume about (1.6 + 12) . 30 . 100 = 40.8 kWh per 100 km which is only 30 % less than the amount consumed when driving on a road. The reason for this higher energy consumption is the fact that the rail coach can only accept three ordinary passenger cars.
This reveals why today's transport of cars by train is uneconomical and why it is important to adapt cars for the intermodal road-rail transport system to enable them to be loaded in the transverse direction and fit twice as many as ordinary cars into the rail coach.

Re b) – **reduced energy demand of urban road transport thanks to reduced density and improved free flow of urban road traffic** (Fig.24)

The average passenger car occupancy in the city is about 1.3–1.4 persons.
By replacing passenger cars with coupemobiles (with five comfortable seats) which can be incorporated into the public transit system, the occupancy can be increased two or threefold.
If one half of the coupemobiles on roads is incorporated into the public transit system, **the total number of travelling coupemobiles will drop by 25–30 %**.

The coupemobile-based public transport relies on coupemobile platooning. Platooning reduces the average aerodynamic drag of coupemobiles.
The priority given to public transport improves the free flow of platoons and reduces the energy consumption even further.
Reduced traffic density in cities will also improve the free flow of individual urban transport and reduce its energy consumption.
The total reduction in the urban road transport energy demand can be estimated at approx. 40 %.

Re c) – **reduced road transport energy demand thanks to platooning** (Fig.31)

The aerodynamic drag of a car travelling at more than 50 km/h is the main component of the running resistance and increases with the speed squared.
An independently running coupemobile with a relatively large front area and a lack of space for providing an aerodynamic shape has sub-optimal aerodynamic properties. It is not very well suited for independent running at higher speeds, unless equipped with a spoiler or a streamlined mask.
However, if coupemobiles are coupled into platoons, then the front vehicle acts as an aerodynamic drag reducing device for the trailing vehicles which are therefore drafting and consume less power and less energy to overcome the aerodynamic drag.
Platooning is therefore economical – the longer is the platoon, the greater are the energy efficiencies.
The average energy saving from platooning in intercity travel can be estimated at approx. 20 %. If the platoon reaches higher speeds, the transmission of traction forces between individual vehicles in the platoon must be dealt with (e.g. by mechanical coupling). Otherwise, the power of the first vehicle could not maintain the required speed of the entire platoon. Also pullout spoilers between the cars in the platoon will be used for aerodynamic drag reduction.
Urban trips at lower speeds, understandably, result in lower energy savings due to the lower speed. However, the improved free flow of platoons in urban environment justifies the estimate that **the total energy savings in urban transport will still reach approx. 20 %.**

Expected energy savings arising from the implementation of the ComplexTrans system

The annual energy consumption in the Czech Republic is approximately 1800 PJ (petajoule) of primary energy and the energy consumption of the whole world is about 600 EJ (600 000 PJ).

(For illustration – the Czech nuclear power station in Temelin annually generates up to approx. 50 PJ which equals about 10 % of all energy produced by Czech power plants.)

The transport share of the energy consumption of the Czech Republic is approx. 25 %.
In turn, road transport (individual, but, freight) has more than 90 % share of transport.

Therefore, the annual consumption of the road transport in the Czech Republic is about
1800 . 0.25 . 0.9 = approx. 400 PJ = 400 000 TJ = 400 000 000 GJ of primary energy.

At the same time, the aforementioned amount of energy for transport is obtained almost exclusively from oil products.

Shifting 50 % of long-distance road transport to ComplexTrans railway can save about 60 % of the energy required for this half of long-distance transport.

The remaining road transport (which was not shifted to railway) can also achieve energy savings from platooning: approx. 20 %.

Consistent implementation of the ComplexTrans concept in urban transport (platooning of coupemobiles and their use in public transit) can reduce the number of vehicles in cities (and thus the energy consumption by the public transit in cities) by approx. 50 %. Platooning saves additional 20 % of energy.

After implementing the ComplexTrans concept, the road transport energy consumption can decrease by estimated 40 %, whereas the comfort, speed, and safety of travel will improve.

The ComplexTrans global land transport system implemented in the Czech Republic will reduce the energy consumption by about 160 PJ (more than triple the annual production of 2000 MW Temelín nuclear power plant (NPP)).

Czech Republic accounts for a mere 2 % of Europe and 0,3% of the whole world.

Implementation of the ComplexTrans across the entire world would deliver energy savings matching the production of 1000 power plants of the size of the Temelin NPP at least.

7) Land transport electrification, substitution of oil with electrical energy, reduced CO_2 emissions

Electrification of land transport arises from

a) the shift of a major portion of long-distance transport from road to electrified railway
b) the support for and facilitation of electric propulsion being implemented in coupemobiles

Re a) – **electrification by the shift of a major portion of long-distance transport from road to railway**

ComplexTrans trains will mainly rely on electric propulsion. The coupemobiles carried by them will therefore also use for transportation electric energy. By this means, the energy for long-distance land transport, now provided by oil, can be generated as electric energy using renewable resources.

Re b) – **electrification by the support for and facilitation of electric propulsion being implemented in coupemobiles (and freight transport modules)**

Today’s passenger cars have a range of 500 to 1000 km on a tank of fuel. If electric cars were to measure up, they would require a sizable battery weighing half as much as the car alone – or even larger. As a result, their consumption and price would soar, whereas their utility value would decline. Reasonable promotion of road only electromobility thus requires significantly improved batteries which will be available one day but this will take much effort and time.

By contrast, the ComplexTrans concept enables electromobility to expand without changing the current parameters of traction batteries because it enables cars to be carried across long distances by train where the car battery is not used and is even recharged. ComplexTrans cars can therefore do with batteries of approx. 30 kWh or less capacity, which provide a sufficient two-days range in the urban environment (about 200 km). Reasonable batteries of this capacity are already available today. By this means, almost entire land transport can be electrified (Fig.32).

If there is still a need for an electric car to cover a distance by road which exceeds its range dictated by the battery capacity, "petrol" stations will offer rental range-extenders (generator units). These will consist of a generator powered by a combustion engine and a fuel tank of sufficient capacity. The generator unit will be temporarily attached to the rear (partially instead of main battery) of the coupemobile and then returned to the "petrol" station.

Nevertheless, devices other than the generator unit are also available as electric power sources – e.g. fuel cells.

The same approach (it means long-distance transport in the train and need for smaller energy reservoir) will lead to the implementation of electric propulsion in the freight transport modules. In addition, it will be possible to supply these – while platooning – from the generator unit (or another electric energy storage) on the lead/power vehicle.

As the above description shows, the ComplexTrans system leads to much easier and faster electrification of the entire land transport than the development of high-capacity batteries.

It should also be noted that the electric propulsion of coupemobiles means that they consume no oil at all, as the electric energy can be generated using other (renewable) resources.

No oil used for propulsion of coupemobiles also means that their operation generates no fumes or greenhouse gases (CO_2).

The annual oil consumption is just under 4000 million tonnes, of which almost two thirds are used in transportation, where road vehicles account for approximately three quarters of the transportation volume.
Given the petrol/diesel fuel density of about 0.85 kg/l, the combustion engines of road vehicles use about 2000 billion litres of diesel and petrol. The combustion of every litre of diesel fuel of petrol generates 2.9 kg CO2.
As a result, road transport accounts for almost 6000 million tonnes of CO2 released into the atmosphere every year.
Consistent worldwide implementation of the ComplexTrans system would completely eliminate most of this amount of CO2 (Fig. 33).

ComplexTrans therefore significantly contributes to the effort to slow down global warming.

8) Integration with the electrical grid and support for renewable sources of electrical energy (mainly wind and solar)

Wind and sun are among the most important renewable sources of electric energy. Unfortunately, their performance depends on weather and the time of day. When there is no wind and sunlight, the facilities dependent on them deliver no (or minimum) energy. By contrast, under favourable conditions, these resources provide excess energy and some of the generation facilities may even have to be shut down.

Hence, power sources dependent on sunlight and wind power require high-capacity energy storage to store excess energy and deliver it at times of low energy production. Such storage facilities, are still rare due to their high cost and, often, due to technical inadequacy.

The today´s best proven energy storage concept appears to be the water pumped storage power plant. These plants can store energy from renewable sources in the form of the potential energy of water in reservoirs and convert it at appropriate times into electric energy using their hydroelectric facilities. The difficulty with this energy storage concept is that locations suitable for building pumped storage plants are not abundant.

A promising concept is the P2G technology. Excess electric power is used for producing hydrogen or methane which are then added to natural gas distribution networks. Its advantage lies in the fact that gas storage and distribution facilities are already in place. Storing energy in this way therefore does not require extreme major costs.

Other efforts, for instance, involve seeking ways to use electric power compressors to store energy in the form of compressed air in underground caverns or abandoned mines, and retrieve it by letting the compressed air expand in turbines.

Electric cars (coupemobiles) batteries offer a great potential for storing electric energy efficiently without additional investment costs (Fig.34).

Electromobility based on plug-in vehicles offers small energy storage capacities in the form of individual vehicle batteries. However, when added together, these make up huge energy storage. Let us imagine that all passenger cars in the entire Czech Republic are replaced with coupemobiles with 30 kWh batteries. At 5 million coupemobiles, the total battery capacity will be 150 000 000 kWh. With 5-hour charging time, the power input for recharging all batteries will be 30 000 000 kW (i.e. 30 000 MW). Today's capacity of all Czech power plants is approx. 20 000 MW. After full-scale electromobility is achieved, it will increase to approx. 50 000 MW. In the future, empty batteries of all passenger vehicles in the Czech Republic will thus be able to absorb approx. 60 % of the entire installed power plant capacity for 5 hours.

In reality, however, only about one third of electric cars connected to the grid can be used, and therefore the energy storage capacity will equal to approx. 20 % of the installed capacity. Even this will make substantial contribution to the system based on wind and solar energy. The energy storage can be extended accordingly.

Estimates of the actual storage capacity must reflect the amount of the battery energy used every day. The reason is that only at least partially discharged batteries can be used for energy storage.

ComplexTrans offers a great potential not only for energy storage in batteries but also for using the energy stored in them. Conditions for free flow of coupemobiles will be provided by reducing the urban traffic density and by their temporary incorporation into the public transit system. The drivers will be motivated to join by the resulting benefits. In addition, the transport of coupemobiles by ComplexTrans trains and the new parking spots will enable coupemobile batteries to be connected to the grid for a substantial part of day. Consequently, they can be effectively utilized for storing and delivering energy.

It can be assumed that good energy management based on storing excess energy in the coupemobile battery and delivering it when needed can provide the coupemobile owner with a revenue that covers not only the energy used for transport but also the battery replacement costs.

Furthermore, regular participation in urban public transit can provide additional revenue that covers most of the costs associate with vehicle purchase and maintenance.

It is therefore possible that consistent use of the opportunities in the ComplexTrans system will ultimately allow some coupemobile owners to obtain and operate their vehicles "for free" ☺.

The coupemobiles, which have the battery accessible from the back (and during perpendicular parking from the street), don´t need any special infrastructure for battery recharging and don´t need a big battery.

The coupemobile will order the battery exchange by itself and the battery will be exchanged during the night time by battery-exchange-vehicle. The owner of coupemobile will not more spend a time for battery recharging.

For longer trips the coupemobils use the transport in trains (and battery will be recharged during the trip) or will use the range-extender (appropriate tank capacity for long distances).

ComplexTrans system solves the electrification of road transport completely.

The batteries needn´t be a fix part of the cars and can stay in the ownership of an energy distributors. It makes the purchasing price of the electric car much more appropriate and enables the fast implementation of electric cars.

Also the distributor will have a profit of the ownership of batteries, whose can be better implemented in the electric grid with renewable resources of electricity – wind and sun.

NON-FINANCIAL BENEFITS

The ComplexTrans system (Fig.36) offers significant opportunities for

- improving the comfort, speed and safety of land transport of passengers and goods in both urban and intercity traffic (Fig.40)
- substantially enhancing the quality of transport and life in cities
- reduced transport energy consumption
- electrification of land transport, reducing the dependence on oil, and eliminating greenhouse gas emissions from transport
- supporting renewable energy generation (solar and wind)
- making the life on the Earth better.

The foundation for these major improvements to the quality of life on Earth is the integration between two fundamental land transport modes, road and railway (Fig.35),
and certain shift in thinking (Fig.41).

If we find the courage to accept it, we can reap in about 10-15 years its first benefits (Figs.37, 38, 39). Are we able to do so and when? (Fig.41)

PATENTS

Patents for the fundamental system-oriented ComplexTrans solutions have been filed with the European Patent Office in 1998. Given the scale of the project and the general international situation, no partner was found at that time who would take on and develop it. Therefore, the patent was not maintained and the basic solution is free accessible. However, new patents applications for partial solutions have been prepared.

COMPLETION DATES

ComplexTrans project began to be developed in 1992, inspired by American touring project for families travelling with their passenger cars from the area of the Great Lakes to their holiday destination in Mexico using broad-gauge and wide-profile railway.

At the first stage of the ComplexTrans project, **double-deck rail cars for European railways** would be designed, where the lower deck would carry three longitudinally-positioned passenger cars, and the upper deck would be used by their passengers or other passengers as well (Fig. 4 – the vehicle on the right)

Once a **cost-benefit analysis** (Figs. 15 and 30) has been developed, it was found that passenger cars must be adapted for entering and leaving the trains in the transverse direction, in order to expedite their loading and unloading, to double the number of cars carried, and to make their transport more efficient and competitive with respect to road travel (Fig. 4, left, Fig. 6).

This gave rise to the **idea of a Coupemobile**, a car that is compatible with rail transport (Figs. 16 and 17).

The considerations of efficiency of the transport of coupemobiles led to the adaptation of coupemobiles for use by passengers even during rail travel, and to the concept of double-deck rail cars where coupemobiles are carried on both decks (Fig. 5, right).

Another step involved an improvement to the efficiency of transport by introducing **freight transport modules** (Figs. 26 and 27) which wait for vacant positions on ComplexTrans trains (Fig. 6, left) and can thus guarantee an almost 100 % utilization of the lower deck, leading to **financial self-sufficiency of the rail transport in the ComplexTrans** system (Fig. 15). Another very important factor in the connection between the road and rail transport concerns **the short intervals between ComplexTrans trains** (Fig. 4), which further improve the efficiency and attractiveness of the system. This stage led to a spin-off concept of passenger transport modules that primarily fulfil some accessory roles of the ComplexTrans system (Figs. 28 and 29).

The consideration of merging the ComplexTrans system with freight rail transport led to the development of the concept of fast freight wagons (Fig. 3 – bottom right) that would be connected to the back of ComplexTrans trains individually or in short groups during their waiting times at terminals (Figs. 9 and 10). Thanks to this solution, ordinary freight trains could be almost completely eliminated, as well as goods stations and marshalling yards. In addition, **all trains could travel at a uniform speed** (Figs. 13 and 14).

Along with this concept, ideas of the **organization of transport under the ComplexTrans system** were developed, including the **locations and layouts of terminals** (Figs. 9 and 11) and **platforms** (Figs. 6 and 7), identification of the **optimal travel speed** (Fig. 13) for **reaching the destination within a single day** (Fig. 14) and the possibility of **abandoning traditional timetables**.

Another step under the ComplexTrans project concerned parking of coupemobiles in urban areas and their non-transport use (Fig. 25). The short length, retractable axles, and door configuration (Figs. 16 and 17) of coupemobiles enables **space-saving parking, leading to much larger number of parking spots per unit of area** (Fig. 25, left). Adding lugs for vertical transport (Fig. 17) of coupemobiles led to designing completely new parking platforms above pavements (Fig. 25, centre), in parking towers and even on balconies of residential buildings (Fig. 25, right), office buildings, and dedicated motels. The interior of a coupemobile can thus be used 24 hours a day.

Later on, a concept of **creating platoons of coupemobiles** for road travel was adopted (Fig. 19), the purpose of which is to improve the flow of individual transport in the urban environment by reducing the clearance between the vehicles in the platoon, faster passage through intersections (Fig. 19, centre), and using slender grade-separated intersection structures (Fig. 20) designed for such platoons.

From this concept, it was only a short step to realizing that **coupemobile platoons** are essentially electrically-powered temporary “buses” (Fig. 21) which can be, with coupemobile owners' voluntary consent, **incorporated temporarily into an energy-efficient and comfortable urban public transit** run by a public transit operator (Figs. 21, 22, and 23).

In this context, first estimates were developed of the **improvement of the quality of life in cities** resulting from the expanding use of coupemobiles (whose original purpose was to enhance the quality of long-distance individual transport) through reduced traffic density, introduction of comfortable public transport (Fig. 24), reduced demand for parking space (Fig. 25), and electric propulsion of coupemobiles (Fig. 32).

Subsequently, the potential of the **connection between the land transport segment of the ComplexTrans system and air transport** of passengers and goods was explored (Fig. 29). First, the freight transport modules were optimized in order to accommodate ULD containers of various sizes, and consideration was given to handling passengers during travel by ComplexTrans trains, using passenger transport modules.

In another step of the development of the ComplexTrans land transport system, its **integration with the electrical grid** (Fig. 34) was considered, where the system’s inherent characteristics enable not only **“rapid and simple” electrification of land transport** but also **support for the expansion of the difficult-to-regulate renewable energy sources** (solar and wind), while **improving the security of electricity supply**.

Concurrently with the project, along with the refinement of its details, and in relation to changes in energy prices, more accurate **tentative profitability calculations** (Fig. 15) were completed for the ComplexTrans system, as well as calculations of **energy efficiencies** (Fig. 30). In addition, the potential was explored for **replacing petrol and diesel with electricity** as the means of propulsion, and the associated **reduced emissions of greenhouse gases** that contribute to global warming (Fig. 33).

In the next development stage, a technical and organizational assessment of the potential use of independent powered cars of the ComplexTrans system (Flügeltriebwagen) will be conducted. These cars are capable of being **coupled and uncoupled during travel**, which promises attractive options arising from shorter travel times, i.e. greater distances that can be covered in a single day.

Furthermore, the concept of the **transport connection between the terminals, cities, and city centres** will be developed, focusing on low-height electric buses and shuttle trains.

It will be **reviewed and optimized** the possibility of **cooperation with existing 20', 40' and 45' transport maritime containers**.

Other partial-scale technical solutions which promise to improve the efficiency and comfort of the railway segment of the ComplexTrans system are ready for further development.

It will be important to focus on social aspects of the project: improving the mobility to provide better social security, connecting various nations and delivering effects on their cooperation, promoting more leisurely life, improving transport safety, and supporting good health.

A very important part of the ComplexTrans involves **seeking partners for its further development**. This activity takes place at three levels: **publication activity, direct contacts, and involvement in support programmes**.

The **publication activity** began in 2007 by a talk given at an international conference on rail vehicles in **Graz**, Austria (Moderne Schienenfahrzeuge). In the same year, a talk was given at the Prorail conference in **Žilina**, Slovakia. In 2011, a talk was given at the Interrailexpo conference in **Changchun**, China based on an invitation and arrangement for reimbursement of travel costs. In 2014, a presentation was given at the science-oriented Comprail conference in **Rome**, Italy.

With increasingly adverse conditions in transport and accelerating global warming, the interest in information on the ComplexTrans system is rising. As a result, several talks were given in 2015 in Germany for the Association of German Engineers (VDI) in **Braunschweig**, at the professional conference Rad-Schiene in **Dresden**, at the GoSmart-GoRail conference of the International Association of Public Transport (**UITP**) in **Munich**, as part of a series of lectures on technologies of the future for Volkswagen (**VW**) in **Wolfsburg**, and also during the TransportDay at the headquarters of the International Union of Railways (UIC) held on the occasion of the **climate conference in Paris**, France.

Owing to the expanding publication activity, cooperation was established with the University of West Bohemia * early in 2016. As part of this cooperation, talks were given at the European conference entitled **Transport Research Arena in Warsaw**, Poland, which focused on the future of transport, at science conference **Sustainable City 2016** in Alicante, Spain, at conferences in **Dresden, Germany**, with the theme "Eisenbahn als Antrieb Energiewende", and **IRFC 2017 in Prague**, Czech Republic .

Papers are being prepared for professional and scientific journals.
More information to the publications can be found at https://cz.linkedin.com/in/hofmanjiri

*the University of West Bohemia took part in completing sub-tasks of the ComplexTrans across a period of several years, together with the Faculty of Transportation Sciences of the Czech Technical University in Prague and Jan Perner Transport Faculty of the University of Pardubice.

As part of **direct contacts**, global corporations have been approached since a number of years which could in their future-oriented activities contribute to developing any segment of the ComplexTrans system. Recently, these contacts involved Deutsche Bahn (DB), VW, Airbus, and Bosch. Nevertheless, these global corporations primarily focus in generating profit in a near term which is inconsistent with the ComplexTrans project.

As a result, attention focused recently on multinational organisations and **contacts have been established with EC, DG MOVE, UIC, UITP and others**. These organisations operate more globally and are better positioned for supporting the development of the ComplexTrans project. Yet, these organisations too are oriented on achieving progress in a relatively short terms.

As for the **participation in support programmes**, the first step was taken in 2000 when a project focused on ComplexTrans was submitted by a consortium of mostly Czech entities to the FP5 programme GROWTH. However, it was not awarded support. The EC, however, recommended to revise and complete the project documents and apply for funding again. Nevertheless, this has not taken place.

Several other attempts have been undertaken in Czech republic but none of them was completed, mostly on account of the co-funding which is required from the investigator under support programmes. Given the long-term nature of the ComplexTrans, this is practically impossible for entities from the private sector, especially with regard to high development costs.

The purpose of the above activities is to **identify a suitable form of participation of public entities, the private sector, and involvement of public demand**, evaluate the options of the project in such context, and elaborate the ComplexTrans concept further at an international level (Figs. 37, 38, 39).

CONCLUSION

Global transport system ComplexTrans offers a chance to **significantly improve transport, energy and life on Earth** while maintaining all principles of **sustainability**.

It is time to start the pilot project. (Fig. 38)