Closing the infrastructure gap through innovative and sustainable solutions

Authors: O. A. Chevtchenko[1,2], R. Bakker[1,3], D. Oster[1], C. Hicks[1,4] and Z. Huhn[1,5]
[1]ET3 Global Alliance, Inc. Longmont, Colorado, USA; [2]HTS-powercables.nl B. V., Apeldoorn, NL;
[3]Quantum Trains International B. V., Apeldoorn, NL; [4]PBD Industries, Inc. Big Sky, Montana, USA;
[5]Venture Smarter, Inc. D.C., USA

Corresponding author: o.a.chevtchenko@gmail.com

Executive summary: This strategy paper explains transition of existing infrastructure into truly sustainable form with ET3tm (Evacuated Tube Transport Technologies) while: closing the investment gap, boosting economies, GDP growth, trade, transport of passengers, goods, energy, communications, water, waste, addressing “the need for speed” and providing quantum leap in quality of life. Relevant stakeholders are invited to take part; the market opportunity exceeds US$75 trillion.

1 Introduction

1.1 Infrastructure investment In the “business as usual” scenario, to keep up with the projected global GDP growth (3%/year) and to control climate change, global infrastructure investment demands US$93T (trillion) in the years 2015 to 2030 [1]. This is shared as 43%, 29%, 21% and 7% respectively by energy, transport, water & waste and telecommunications [1]. On average US$6.2T per year is currently needed, but only US $2.5T is invested leaving an investment gap of US$3.7T per year. To compare, the year 2015 global GDP was US $75T, so the annual demand is 8% of that. With the same trends continued, in the year 2050 annual GDP will be US$147T; the cumulative investment for infrastructure: US$217T (needed), US$87T (invested) and US $130T (the gap). Meanwhile, the gap widens with time [1], making it clear that traditional “proven and reliable” solutions cannot cope and there is a clear need for innovation. In our view, the traditional approach could only bridge the gap by asking for more funds. In contrast, truly innovative technologies applied to infrastructure will allow boosting of: trade, transport, communications and quality of life, while closing the gap, see figure 1 and explained below.

1.2 The issue and the timing The transition to sustainability already causes a huge wave of innovative attempts, however not all of them make life more comfortable, convenient and affordable. In fact major innovations that truly add value, often meet more resistance and disregard than support and acceptance. Meanwhile, we are exhausting natural resources at an alarming rate: the 23 COP meetings confirm the inefficiency of the traditional approach (with the USA - the 2nd largest polluter - staying out of the Paris agreement and in contrast with reports of how other nations are meeting climate targets). So the Earth’s surface temperature rise continues with the five warmest years on record being after 2010 and year 2017 being one of the warmest since 1880 [2]. Additionally, urbanisation together with noisy, polluted air and other spoiled resources; congested, ageing infrastructure; lack of trust in global finance, a stagnant economy (with 10 years slow growth following the global financial crisis), scarcity of long-term investments, inequality; poor mobility and connectivity; mounting waste problem; and lack of clean water and food for many (see [2] for more). This calls for a paradigm shift. We find that the root of these inefficiencies lies in the illusion that we all will be fine with minor innovations of current technologies (smart urbanisation, renewables, electric vehicles, self-driving cars, etc.) as well as in the fear of losing the return on existing infrastructure investments that would be displaced by major innovation. Altogether this results in negligence of and resistance to true innovation, lack of vision and responsibility that lead to such wan present and future. For example [1] focuses on how to mobilise finance to make existing marginal infrastructure environmentally sustainable, while the way to make it adequate, sustainable, with lower investment is long known [3].

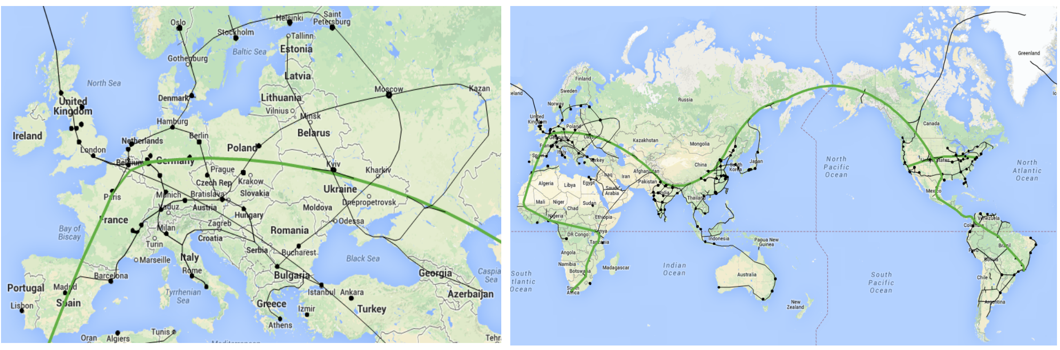

Figure 1 The world can certainly close its infrastructure gap in year 2050 by using ET3: examples of the proposed priority routes for Europe (left) and World [6]; the black and the green lines are $ET3_{nl}$ and $ET3_{gl}$ respectively

We are confident that tangible results can be achieved even before the year 2030 with the right approach. And in the year 2050 we expect much of the existing infrastructure be transformed into unified, standardised, automated, clear and easy-to-manage system transporting goods, passengers and services with outstanding comfort, safety, speed and capacity [3]. This innovation will be highly profitable and it will accelerate global GDP growth. The purpose of this paper is in explaining our strategy offering ET3 as the solution and inviting interested stakeholders to take part in the upcoming change.

2 Closing the gap, impact of innovative transport on the infrastructure

2.1 Transport of freight and passengers The global demand and the investment available are US$1.8T/ year and US$0.7T/year. The year 2050 EU transport targets are: 1) total emissions (↓60%); 2) a shift (↑50%) of medium length journeys from road to rail 3) carbon emissions (↓40% for air and water) [4]. To rephrase, following EU plans in 2050 we will still mainly use conventional (rail, road, air and water) transport known to all as slow, expensive, or both. With this plan, transport will become more expensive as the intended shift from road to rail proves (e.g., in Germany currently rail transports 10% of passengers and 24% of freight at a cost per kilometre five times that of road [5]). Moreover, what we miss in this picture is addressing the "*the need for speed*": present trends indicate that customers of the 3rd millennium expect their (e-commerce) deliveries within minutes or hours, not days or months.

We think, the reasons for such transportation plan are lack of: vision, responsibility and innovation. Indeed today it is common to plan huge investments in road, rail, air and water transport. It is already long known [3] that every euro invested in ET3 will reduce transport emissions >10 times, ET3 could save 60% of the planned EU transport investment while providing more traffic volume at 5 times faster speeds, ET3 eliminates >10 times more CO_2 and reduces the energy costs >50 times (see also Table 1), thereby addressing all transport targets far more effectively. If only 20% of the planned investment were to be redirected into an ET3 network, ambitious climate targets could be achieved twice as fast. In other words, this step allows meeting all climate goals with far less investment and at the same time building up to 30 thousand km/year of the ET3 network; yet to spend €0.35T/year on keeping the obsolete technologies operational, adjusting to the change, providing smooth transition (thus respecting the right for return of those who already invested in conventional transport) and to finally close the transport infrastructure gap ($1.1T/year) entirely. Moreover, all the global environmental targets can be met 10 years earlier. Clearly, this approach can be applied anywhere (primarily along the foreseen ET3 routes, figure 1 and [6]). Dialogues and systematic studies with interested stakeholders are welcome.

Below we illustrate the potential impact of ET3 on the existing connection Berlin to Hamburg (B-H) in Germany. Because of the relatively short distance (289 km) travel by road and rail currently dominates, <u>option T0</u>, Table 1, see section 8.1 for further details. The situation will qualitatively remain the same in year 2030 (freight and passengers growth of 38 and 12% respectively [5]), so in the "business as usual" scenario with modest upgrade the infrastructure gap will be widening. Moreover, "*the need for speed*" remains unanswered, as none of the shippers offer fast delivery at attractive price (e.g., typical delivery times for any sizeable cargo by road or rail are at least 12 hours for the B-H connection, meaning that the average speed of such a delivery is <25 km/h).

This situation can be drastically improved with an ET3 connection built parallel to the existing one, see <u>option T1</u>, Table 1. According to the ET3 routes [6], the national level $ET3_{nl}$ would be sufficient, figure 1, left: the maximum speed is 1.3-2 thousand km/h. The network includes freight and passenger handling hubs, capsules, interchanges, etc. all matching the capacities of <u>option T0</u> for freight and passengers, Table 1. The resulting costs are listed in Table 1 see e.g., [3, 7] for more details. At the modest investment and the total load (utilisation) factor of 0.4 <u>option T1</u> (€4B) will fully match the freight and the passenger capacities of <u>option T0</u> (€10B) with excellent economics: the 6 €cent/ton/km and 27 € per one-way ticket, 1st class allow the RoI of 10 years (at RoI of 40 years the cost-prices are 4 times less). The delivery time decreases to 18 minutes (e.g., a freight of 500 ton, on pallets, figure 2, left), while passenger travel time will be 12 minutes (figure 2, right at the average speeds of 578 and 693 km/h respectively). On demand, the passenger capacity can increase many times, as the load factor is only 0.012. On a medium (longer) term, the capsule speed can go to 2 (10) thousand km/h for elevated

Table 1. Options to strengthen the connection Berlin-Hamburg: transport of freight and passengers

Option	Connection Berlin-Hamburg	Freight				Passengers					
		Investment cost, B€	Capacity Mt/yr	Return cost €ct/tkm	Load factor	Investment cost, B€	Capacity Mp/yr	Travel time minutes	1-way ticket cost, €	Load factor	Max. speed km/hour
T0	Existing (road + rail)	5	121	5 to 2.3	0.3	5	74	180 to 90	10 to 80	0.5	150 to 230
T1	**ET3 as proposed in years 1997-2017**	**2**	**121**	**5.7**	**0.4**	**2**	**74**	**12 to 10**	**27**	**0.012**	**1300 to 2000**
T2	Hyperloop, as proposed in 2017-2018	12	3	313	0.8	12	3.2	20	951	0.8	1080

Legend: B€= € billion; Mt/yr = million ton/year; €ct/tkm=€ cent/ton/km; Mp/yr = million passengers/year. For <u>T0</u> , T<u>1</u> , T2 the time to investment return (RoI) is 40, 10, 40 years of operation respectively. For <u>T1,</u> <u>T2</u> we assume 10% of the revenue is used for RoI. The load (utilisation) factor is the ratio of the time connection is in use at full capacity to the total available time.

tube sections (underground tubes) and the travel time to 10 (3) minutes. These latter performance milestones can be met and funded by ET3 itself. Moreover, option T1 in parallel to option T0 can take as little as ¼ of the flow (Table 1), still have competitive RoI at the same (or slightly higher) prices, with "*the need for speed*" fully addressed (while less use of road and rail will also result in their longer lifetime, necessary for transporting freight not compatible with ET3, which is <10% of the total [3]). Therefore, it will provide a smooth transition (e.g., of 30 years) into the brighter future and redundant and resilient hybrid operation of the connection, without any congestion or capacity reduction in cases such as peak hours, bad weather, need for repair, etc. Such an ET3 connection can be build in 2 years with just one thousand skilled workers [7]. After some years of operation option T1 will allow to proceed step by step with expanding into ET3 network while generating sufficient means for maintaining and transforming the aging conventional infrastructure (road, rail, air, water, pipeline, cable, etc.) first nationally and then globally [3, 6] and section 3. Put simply, ET3 connecting Germany's two largest cities with a travel time of just 10 minutes will effectively merge the cities (and the connection areas) into one with Germany's largest port becoming one with Berlin port and with Hamburg becoming an integral part of the capital. The importance of ET3 for longer-distance transportation (e.g., "the new silk road" [3], figure 1, right) is clear from that ET3 compatible freight between Hamburg and Beijing can be delivered in 2 hours (compared to 30 days by ship, 10-15 days by train) at the same price and capacity as by train or by ship. Yet another example of ET3 capability is shown in figure 3.

In addition, option T2 [18] is evaluated by extrapolating the recent data. Namely, for the system described in [19] costs €2.4B, having only two stations spaced by 57 km, aiming to transport only passengers at capacity of 3.2 Mp/year and similar more recent data for the 140 km-long Abu Dhabi-Dubai connection: €4.8B for 140 km long connection, 19 passengers or up to 20 tons freight per pod. To arrive at the listed in Table 1 data for option T2, we assumed that the 289 km-long system has 6 stations (spaced by 58 km), the same passenger capacity, and works at the headway time of 99 s. Lower headway times of 10 to 20 sec are mentioned [19],, but are excluded here, as they need more airlocks in parallel and drive up the costs rapidly. The comparative differences in value and safety of options T1 and T2 are listed in [17]. At the highest investment, option T2 (€24B) is capable to match only 2.5 and 4% of respectively the connection's freight and passenger capacities, Table 1 (thus being competitive only in passenger capacity of only rail and not of road) and fails completely to match the freight capacity of either rail or road). In our view, option T2 is not competitive, economically unsustainable and clearly it has no added value as compared to option T1, see also [17]. It is unjustifiably expensive, though relatively fast.

To summarise, the **ET3** connection (the **fastest, inexpensive and with sufficient capacity**) easily competes in all key parameters with road, rail and Hyperloop (HL). Moreover, the **HL** connection (**fast, the most expensive and lacking the capacity)** fails to compete with road (except for shorter delivery and travel times), or rail (in the investments costs for both freight and passengers, in the freight capacity and the cost per ton·km, in the one-way ticket price). Both road and rail are slow as compared to ET3. Even though we do not compare it here to air transport, it is clear from Table 1 that HL while being potentially as fast as an airplane, fails to compete in the two-way ticket price of €210 for B-H connection. When used, it will widen the infrastructure gap instead of tightening it. We therefore exclude option T2 from further consideration.

2.2 Energy transport The global demand (the investment available) is $2.6(1.1)T/year [1]. The year 2030 EU targets are [4]: 1) emissions of green house gases (↓40%); 2) renewables & grid (↑27%); 3) energy efficiency (↑27%). In our opinion, the reasons are lack of vision, responsibility and of innovation. Indeed, it is common approach to address the renewables target by investing in wind, solar, bio-, etc. However, every euro invested in ET3 (instead of wind) eliminates >12 times more CO_2, returns >7 times more clean energy (by reducing the need for it) as the example from the Netherlands shows [8] and it provides much more energy efficiency (instead of building a wind park, that has energy efficiency comparable to that of a power plant, for the same money ET3 network is built replacing 50 times less energy efficient transport and thus resulting in the proportional savings) [8] thereby addressing all targets far more effectively. Therefore, when >10% of the above investment is redirected into ET3 network, more ambitious climate targets are achieved already, This step allows to meet all climate goals with far less investment and at the same time to build over 40 thousand km/year of the ET3 network,

Figure 2. Examples of freight arrangement (left) and passenger experience (right) inside ET3 capsule [6]

Figure 3: Examples of the two-way transport connection (with the same capacity, 1 million passengers/day) comprised of: conventional 18-lane freeway for 100 km/h that is 72 m-wide (left, [https://commons.wikimedia.org/wiki/File:Highway_401.png]) and operated at load factor of 0.5; a pair of ET3 vacuum tubes for 600 km/h operated at load factor of 0.16 (right, the elevated by 6 m tubes have diameter of 1.5 m each and the overall footprint of 1x1 m^2 every 25 m). Such ET3 connection costs less than 1/4 of the freeway connection and fits in one lane. Notably, the same ET3 connection operated at full load is close in capacity to a 100-lane freeway, such as the 400-m wide Beijing-Hong Kong-Macau Expressway (not shown).

to spend €0.5T/year on renewables and keeping the obsolete technologies operational, adjusting to the change and to eliminate the energy infrastructure gap ($1.5T/year) entirely. Moreover, transporting of energy-rich substances (such as LNG) with ET3 [9] and of electricity with high temperature superconductor cables [10] adds most of the value. For instance, undergrounding of the 5 x 2 GW SuedLinks in Germany with such cables saves up to €27B, enough for bringing ET3 to commercial deployment in the country and it provides plenty of land for building ET3 networks.

2.3 Water and waste The global demand (and the investment available) is $1.3(0.5)T/year [1]. Impact of ET3 on water transport was explained in [3], here we only demonstrate the potential impact of ET3 on waste management. A removal of waste by truck costs today 1 €/m^3km (30 €/m^3 or 11 €/month per household, which gives the same 30 €/m^3 assuming 4 m^3 of waste per household per year). For instance, instead of using a truck an automated waste removal vehicle connecting waste sources to the nearest ET3 hub (1.5 km) and ET3 network for the waste transport over the same distance of 30 km will result in the total cost of 3 €/m^3, the investment into waste removal can be reduced proportionally. Alternatively, for the price of 30 €/m^3 the distance of 500 km for waste removal can be achieved with ET3. By using RoI of 40 years (Table 1), utilising the excessive capacity and making use of the periods of low demand for traffic (e.g., at night) ET3 can transport waste and water at even lower prices. The added value of ET3 to solving this problem is clear. We hereby invite interested communities, municipalities and authorities to explore this possibility together. Assuming that 20% of the investment available for waste will be redirected to ET3, 8750 km/year of ET3 network can be built. This would dramatically increase quality of waste removal while keeping the obsolete technologies operational, adjusting to the change and close the infrastructure gap ($0.4T/year).

2.4 Telecom and digital services The global demand (and the investment available) is $0.42(0.18)T/year [1]. Following Amazon's way to move huge amounts of data (e.g., 100 Petabyte per AWS Snowmobile, a truck with a 45 –foot shipping container), our company enjoys being the first in offering evacuated tube transport for the same purpose [6]. The advantages are clear from Table 1: reduced shipping times (e.g., from 12 hours to 12 minutes) at the same capacity mean the internet speed reaching 1 Petabyte/s in combination with lower price, higher reliability, independence of weather, flexibility, etc. Use of ET3 powered telecom will strengthen and largely relieve existing congested digital networks: e.g., Germany today remains a "land of woefully slow internet". Assuming that 40% of the available investment will be directed to ET3, 5800 km/year of ET3 network can be built, to dramatically increase quality, speed and volume of telecom, internet and digital services while keeping the obsolete technologies operational, adjusting to the change and finally to eliminate the telecom infrastructure gap ($0.25T/year) entirely. We hereby invite interested telecom leaders, communities, municipalities and authorities to explore this possibility together.

3. Future global infrastructure strengthened by ET3, the proposed scenario

3.1 ET3 networks at national level (1.3 to 2 thousand km/h, $ET3_{nl}$) We propose in overlap with the initial preparation and demonstration phase (starting now), the phase of creating $ET3_{nl}$ network at national levels starting everywhere in year 2020-2023 (preferably along the ET3 routes [6]) and proceeding so that on average 172 thousand km is added each year, see figure 4, left. Therefore at the visible in this frame end of this phase 6 million km of ET3 network is added in year 2050. The total investment of US$75T is in line with the elaborated in sections 1-2 and it will be returned in year 2065.

The average required investment of US$2.5T/year can be fully or partly taken from the demanded or available ones (for "business as usual", see sections 1, 2), since implementing ET3 provides a huge saving of the conventional infrastructure investment (US$21M/km as clear from Table 1, or US$126T for 6 million km, that is US$4.1T/year). Moreover, additional funds will be available through re-investing (part of) the return (US$54T by year 2050, figure 4, left). As the total length of paved roads (railways) in the world today is around 30 (1.05) million km, we assume that the $ET3_{nl}$ networks will be utilised as much as in Table 1 and based on that the return is calculated, figure 4, left (the horizontal dotted line indicates that by year 2050 the return is equal to the invested US$54T in built 4.4 million km by year 2044, while the return of the US$75T in year 2065 is obtained by extrapolating the trend). In this basic scenario (NL1), in the period of 30 years over 50 million jobs will be created, but in year 2050 only about 20% of the existing paved road connections will be bypassed with ET3. In the five times more ambitious scenario (NL2, eliminating 90% of road emissions) it will be possible to bypass nearly all paved roads, create over 250 million jobs. This scenario demands and saves up to US$375T and US$630T, section 8.2.1.

3.2 ET3 networks at international level (6.5 to 10 thousand km/h, $ET3_{gl}$) We propose after the preparation, the phase of creating $ET3_{gl}$ network starting everywhere in year 2030 (along the ET3 route [6]) and proceeding so that on average 4.3 thousand km is added each year, see figure 4, right. Therefore at the end of this phase (in year 2045) 60 thousand km of the $ET3_{gl}$ network is added. The total investment of US$1.45T in line with [3, 16] is a small fraction (on average US$0.1T/year) of that available (sections 1-2) and it will be returned in year 2050 (as the total length of motorways in the world is currently <0.3 million km, we assume that $ET3_{gl}$ networks will be utilised as much and based on that the return is calculated at the speed of 6.5 thousand km/h, see figure 4, right).

These proposed steps are challenging and require commitment of nations and countries (authorities, businesses) to work together towards this goal. But the rewards by far exceed the risks at the same time offering the escape route for obsolete technologies through the transition period of 30 years. In the Annex, section 8 we briefly review relevant key concepts and technologies. With this much reward in mind, a one-time spending of total €1.1B (<0.44 ppm of the foreseen annual investment) on the full-scale ET3 pilot system (section 8.2.1), is a risk worth taking (the reward/risk ratio $>10^6$). Transport at speeds 1.3 to 2 thousand km/h requires relatively long test tracks and large radii [3], which justifies this investment magnitude. Taking the four-step approach (elaborated in section 8.2.3) further mitigates the risk. Moreover, proper annual budget (€25B) for CTTV, see section 8.2.3, (or 10 ppm of the foreseen investment) seems fully justified.

4 Concluding remarks: closing the infrastructure gap with ET3

With the current trends continued, in year 2050 annual GDP will be US$147T accompanied with the following infrastructure investment landscape (cumulative over the 35 year period): US$87T (invested), US$217T (needed), and US$130T (the gap). When in parallel the proposed scenario is realised (section 3), the infrastructure investment savings of US$126T caused by the ET3 implementation together with (the part of) the returned investment (US$54T, figure 4, left) provide enough resources to close the infrastructure gap (<US $130T, demanded by the remaining conventional infrastructure) entirely and with full confidence. Thereby, our approach opens up the market opportunity for ET3 exceeding US$75T.

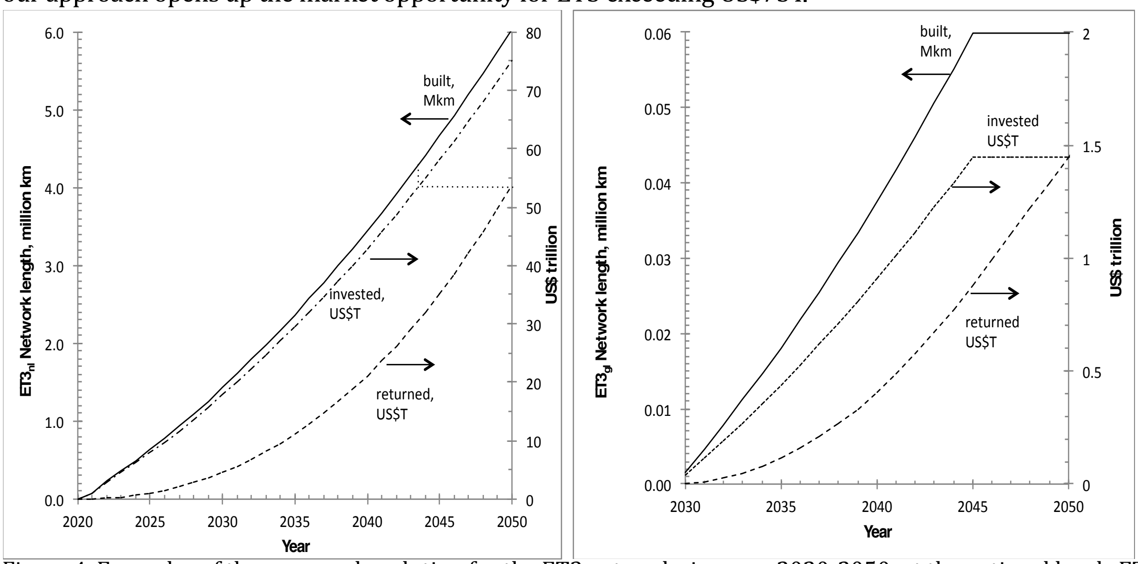

Figure 4. Examples of the proposed evolution for the ET3 networks in years 2020-2050: at the national levels $ET3_{nl}$ (left) and at the international level $ET3_{gl}$ (right)

5 Conclusions

1 Closing the infrastructure gap before the year 2050 by strengthening existing infrastructure with ET3 is entirely feasible and it can be achieved in three coordinated phases: 1) bringing to maturity this novel technology, including full scale commercial deployment (2-5 years); 2) expanding ET3 networks around the globe at national levels (30 years); 3) connecting the national ET3 networks into the international network (15 years)

2 Proposed scenario (NL1) allows before the year 2050 to completely reverse the trend for cumulative infrastructure investment (from the current costly: -US$87T) to future profitable: +US39$T (calculated e.g., as: -US$87T+US$126T), and at the same time it offers the escape route for obsolete technologies through a transition period of 30⁺ years. In this calculation we did not include the effect on humans and economies of transport becoming faster, safer, more comfortable, sustainable and affordable, of changes in value of land, etc. With these included, ET3 combines the huge investment savings in conventional infrastructure with the rapid returns and: short delivery and travel times everywhere, greatly improved quality of life, capacity, safety, reliability, economics, ecology for transport of passengers, information, goods, energy, water, waste altogether resulting in the GDP increase of >10%.

3 When compared to ET3 in competitiveness, economic viability, volume and return of investment, speed, capacity, energy efficiency, sustainability, etc., the alternatives: conventional modes (road, rail) lose and HL fails, similar (somewhat better) result is expected for T Flight. Moreover, these three versions of ETT are not compatible with each other. We therefore urge end users of infrastructure, general public to encourage their states, the policy and decision makers, authorities, business, country leaders and governments join the efforts and together create the 3rd millennium infrastructure. Therefore we invite all progressive and rationally thinking leaders, multinational conglomerates, corporations, financial institutions and funds, decision makers, governments, authorities, nations, communities, general public and individuals to accept this innovative strategy and together make our world a better place by strengthening the existing infrastructure with ET3.

6 Acknowledgements

This study is funded internally and for this reason is property of the authors and of PBD Industries, Inc. Relevant stakeholders interested to apply ET3, contact us at: et3@et3.eu; et3@et3.com.

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Annex

The mighty companies are entering stakeholder race [16], currently in ways rather irrational and empirical, by trial and error: for example HL and T Flight networks are not compatible with each other or with ET3. As the case with HL shows, the difference in the key performances of the less-so and optimal solutions can be striking (Table 1) and that namely the end users are to pay for these differences, while the ET3 offer is much more attractive, section 3. These end users are most of us, creators of GDP.

8 Key concepts and technologies

8.1 Conventional transport Conventional transport by road, rail, water remain relatively slow and affordable, while by air may be faster but usually more expensive. Road transport stands out almost in every country keeping up to 95% of the share and offering most attractive combination of capacity, delivery/travel time at reasonable price. All four conventional modes are environmentally unsustainable and polluting (noise, fine particles, heat, chemicals, etc.; except rail all use fossil fuels, etc.) They still will be polluting after switching from fossil to electrical energy. For the B-H connection (section 2.1) the total investment costs for 4-lane road of 6 M€/km and 2-track rail of 29 M€/km are assumed. The resulting freight costs are 5 to 2 €cents/km/ton and the delivery times are 5-13 hours; for a passenger one-way ticket price is 10-80 € with travel time of 1.5-3 hours. In this example we assume the annual rail traffic of 45 Mton of freight (close to that of the Betuwelijn, NL) and of 3.6 million passengers (Deutsche Bahn data), the others are transported by road, for which a traffic mix is assumed of 14% of 30-ton trucks and 86% of 3 passenger cars.

8.2 The 5th transportation mode: Evacuated Tube Transport (ETT) In brief (we quote here the abstract from ref. 10 in [3], year 1997): "An evacuated tube transport (ETT) system comprises: evacuated tubes along a travel route for both directions; capsules to transport occupants or cargo within the tubes; equipment providing continuous transfer to tube while preserving vacuum; capsule suspension that substantially eliminates drag; coordinated acceleration device; energy recovery braking; vibration control structures; tube alignment devices; automatic capsule switch and synchronisation; automated operation, inspection, and maintenance; methods of construction; redundant data, safety and security systems. Low and high technology embodiments are comprehensively disclosed. Possibilities include replacement or augmentation of: vehicles, power lines, energy storage devices, power plants, heaters, air conditioning, water and sewer pipes, and communication cables and satellites. ETT provides continuous, environmentally benign, sustainable, local and international travel. Aerodynamic limitations, weather exposure, and obstacles are essentially eliminated; the system enables a quantum improvement in safety, speed and efficiency"; we also refer specifically to [13] (both are open access references published in year 2011): "the ETT vacuum chamber will be a circular tube with an inside diameter of about 2–5 m", to figures 1-4 and Table 1 [13], to "ETT vehicles will run in a vacuum environment …1013–10.13 Pa {10 to 0.1 mbar}" in section 6 [13], etc. As shown, ETT offers many ways for non-optimal market entry resulting in being fast, but rather expensive (Swissmetro, HL, T-flight) and therefore hardly competitive and economically viable only on demand. We knew from the start that ET3 (section 8.2.1) will be faster (0.6 to 10 thousand km/h limited by the Earth's escape velocity of 11 km/s) [3]) and that the larger diameter versions of ETT ([13, 22]), especially those using low vacuum quality (pressure e.g., 1 mbar) will be rather expensive and less fast. Moreover, Institute of Evacuated Tube Transportation (ET3 licensee) of Xijing University originating from year 2002 [3, 13] and Applied Superconductivity Lab of Southwest Jiaotong University in China, e.g., ref. 3 in [20]) are long known as ETT and ET3 supporters and promoters. Part of ETT optimised for smooth market entry is ET3.

8.2.1 Fastest ETT with competitive price and sufficient capacity for freight and passengers

Evacuated Tube Transport Technologies, ET3^{tm} (option T1, Table 1) Daryl Oster founded the ET3.COM, Inc. in year 1997 [11, 12]. The current ET3 concept is optimised for maximum value competitiveness and for smooth market entrance (tube diameter of 1.5 m, high vacuum quality inside: pressure around 1μbar, the same as in a thermos bottle; the concept: a car instead of train, truck or bus [3]), as Table 1 clearly illustrates. Capsules move without friction through pairs of bidirectional ET3 tubes (mainly elevated on pylons for $ET3_{nl}$ and mainly placed in underground tunnels for ET3gl) that are connected into networks. ET3 uses coordinated linear ac/decelerators to speed up and slow down capsules e.g., near access portals (terminals). The passive switching, the interchanges are conceptually similar to those of highways, more details e.g., in [6, 7]. As a result, ET3 network connection is the fastest (1.3 to 10 thousand km/h), the cheapest (assuming 40 years for RoI) offers the highest capacity, see Table 1 and other advantages e.g., in [3, 6-9, 16]. "ET3 can use any type of maglev" [3, 6-15]. Hundreds of ET3 documents (many published well before year 2013) provide compelling evidence of authenticity and originality of ET3 and leave little room for successful imitations. Moreover, ET3 has never publicly abandoned any of the above, always understanding that the larger diameter ETT networks are available on demand, but not optimal for the market entry ([3], Table 1). ET3 has no intention to give its intellectual property away for free, instead it offers affordable for most participation and licensing conditions. ET3 GA enjoys being the first and has nothing to hide: the concept and the expected cost details are long time in public domain e.g., [3, 6-9, 11-13], the open consortium has transparent and traceable history; everyone interested in the technology can get an access and contribute to implementation by becoming a licensee ([14] or consult the ET3 interactive page, the last one of the "Links" in [15]). ET3 per kilometre investment costs (€13.8M/km, Table 1) are higher that of road transport (€6M/km, section 8.1), nevertheless in order to keep our approach simple and uniform, by means of the following calculation we justify that implementing ET3 instead of road offers the same savings (€21M/km, used in section 3.1) as in Table 1. Indeed, assuming that average car (truck) consumes 15 (67) litres of fuel for 289 km (B-H connection) worth €20 (90), it is easy to see from Table 1 that over the lifetime of 40 years with 23.5 million cars and 3.8 million trucks passing each year total spending on fuel only will exceed €28B (that is €96M/km of fuel costs). Therefore, in cases when there is no railway in parallel to road (as in Table 1), ET3 can directly compete with road (with the same savings as in Table 1: (€21M/km) by offering e.g., 25% lower prices per tkm and per passenger (than that for road). The corresponding ET3 price reduction can be achieved by using 20% of revenue instead of the assumed 10% (Table 1), by increasing RoI (e.g., from 10 years to 20), by further increasing the speed, etc. Moreover, our study shows that nearest ET3 portal can be within 1-2 km range (e.g., next to ET3 routes, figure 1), since per kilometre costs of ET3 are generally comparable to that of road.

8.2.2 ET3 Global Alliance (ET3 GA) founded in 2012 by Daryl Oster [11] through all forms of intellectual property (IP, such as multiple patents, publications, talks, videos) enjoys being first in the world in developing a revolutionary concept and pilots of ET3, e.g., [3, 6-15]. The only way that removes the unnecessary costs and other multiple barriers (e.g., compatibility issues), brings order in the implementation process (section 3) and the one we promote here is by cooperating with ET3 GA. This is especially relevant in cases when public funds are getting involved. Rather than building ET3 networks itself, in return for royalties ET3 GA provides a framework and platform with superior knowledge, know-how, advice, guidance, coordination and leadership (on the best added value and first come-first served bases) to consortia focused on owning, building and operating ET3 networks. In this respect ET3 GA offers its support through licensing and compensatory shares to anyone eligible entering into a contract (and when such participation results in any valuable ET3 implementation). In simple words, almost any natural or legal person or entity interested and capable in owning, creating and operating (parts of) ET3 networks anywhere, can count on the support of ET3 GA [14]. ET3 GA has all evidence needed to convince any interested stakeholder to invest in the pilot project.

8.2.3 Bringing ET3 to maturity As mentioned in sections 1-2, there is only one way to address doubts and questions on this innovative technology: by demonstrating its capabilities in pilot projects. Transport at speeds 1.3 to 10 thousand km/h requires relatively long test tracks and large radii [3], which fully justifies the investment magnitude. To illustrate, ET3 can be seen as a new kind of accelerator transporting through a network of tubes from origin to destination "macro-particles" (capsules of 0.5 ton, 5 m long, 1.3 m in diameter, at max. speed 3 km/s, kinetic energy 3.9 GJ) and fully avoiding collisions by automated control and coherent motion (whereas e.g., LHC at CERN that namely collides much smaller particles at higher speed and energy of 14 TeV, 15 orders of magnitude below 3.9 GJ. While CERN makes nations smarter, ET3 will make nations and economies much faster, more competitive and sustainable). Considering the added value of ET3, it therefore makes sense to create for this purpose similar to (and perhaps next to) CERN international organisation (CETTV) studying ET3 and developing ET3 pilots, promoting both, educating, taking care that all parts of the national and global ET3 networks are compatible and to the same standard, coordinating relevant activities, etc. and to provide it with the proportionate budget. The risk of the one-time investment in such demonstrator (€1.1B) bringing ET3 to the full-scale commercial deployment (TRL 9) is mitigated by taking e.g., the four step approach: 1) €1M for the feasibility and capsule demo, 2) €10M for a demo of ET3 main components: freight and passenger capsule, vacuum tube, airlocks, propulsion, etc., 3) €0.1B for a demo of ET3 main systems: of fully operational capsules in fully operational vacuum tubes, levitation, propulsion, guidance, emergency stops, control, interchanges, switching, speed, capacity, safety reliability, etc., 4) €1B for the fully operational and economically sustainable commercial prototype. The steps are linked by the condition: every next step is financed when all targets of the previous one are met.

8.2.4 Fast, more costly ETT with sufficient capacity for freight and passengers

Quantum Train (QT): Quantum Train Intl. founded in 2013 [15] supports ET3 implementation primarily in the Netherlands and Europe. On demand, the company also promotes ETT with the larger tube diameter (3 m, the concept: a train instead of a car), magnetic levitation, use of linear motors/generators at stations and along the tracks to ac/decelerate trains, similar to **T-flight**.

T flight announced in August 2017 by CASIC [22], is a larger than ET3 tube diameter ETT (3 m, the concept: a train, a bus, a truck instead of a car; the pod length and diameter are 36 and 2.2 m respectively, 20 tons, 16 passengers per pod, speeds up to 4000 km/h only possible in the high quality vacuum, headway time of 189 s are mentioned). The QT, T flight (and ET3) are sharing the same philosophy resulting in much higher capacity than that of HL, see Table 1 and [17].

8.2.5 Less fast, the most expensive ETT with insufficient capacity for freight and passengers

In this paper we call **Hyperloop** (**HL**) a group of companies involved in this activity: Space$X$-Hyperloop announced in August 2013, Virgin Hyperloop One founded in June 2014, Hyperloop Transportation Technologies founded in November 2013, etc. [18-21]. In our view, HL adds little value to ETT and ET3 concepts by repeating and copying them. The HL alfa [21] concept is largely a copy of ETT version described e.g., in [13], the differences (e.g., pneumatic instead of magnetic suspension) are largely abandoned by HL as impractical, therefore current concept of HL is even more a copy of [13].

As a result of this imitation process, marketing and engineering successes of HL in fact prove the correctness of our approach. The key problem of HL is that it is not optimised for broad market entry and therefore is not competitive or economically viable (Table 1, [17, 20]), and we think it never will be: this place is already taken by ET3 [3], the history of ETT is written [12] and the only way now is in productive cooperation e.g., through licensing [14]. Our position is that since HL is a form of ETT, their engineering progress supports correctness of ETT and ET3 concepts, while its own concept [21] is a poor copy of that for non-optimal for market entry version of ETT [13], such as T flight. Why to invest in the fast connection (with option T2, Table 1) 6 times more, for a passenger to pay >35 times more, for freight transport >55 times more than it is really needed (with option T1)? Why should any rationally thinking taxpayer, investor, passenger or shipper pay so much more for HL, when there is ET3 [3, 6, 7, 11, 19]? Notably, all relevant parameters of ET3 used in Table 1 are published long ago [3, 6, 15, 16], moreover the lack of economic viability, of capacity, etc. for HL when compared to ET3 was addressed in May 2016 [17]. It would be beneficial for all to accept the reality, continue the dialogue [16] and stop imitating and wasting resources. As clear from Table 1, HL currently fails in its main goal: it ends up being *relatively fast and most expensive* instead of cooperating with ET3 GA and becoming *the fastest and affordable*. Thereby, it puts at risk reputation of the investors, business and country leaders, other groups, entities and individuals supporting it.