Working Paper

Introducing TGV Trains in Europe Elements of Systems Analysis

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Executive Summary

The problem of introducing faster modes of transportation has been analyzed in its generality using two methodological approaches.

The first one reduces traveling behavior to basic instincts, that of territorial animal and the cave dweller. They permit not only a generic illustration of the behavior of the traveler, but a quantitative and precise modeling. This line descends from the seminal work done by Zahavi at the World Bank.

The approach reduces technological evolution of travel machinery and infrastructures to a process of successive substitution which can be described using a simplified version of Volterra-Lotka equations of ecological competition. We dubbed it epidemic diffusion of action paradigms.

The results are crisp, quantitative, and predictive. Concerning the specific object around which all the analysis rotates – the introduction in Europe of higher speed trains – it comes out that trains moving at 200 to 300 kilometers per hour mean speed are welcome ameliorations to the rail transport system, but, in their long-range configuration they do not match the evolutionary constraints of the transportation system.

A constructive proposition is formulated, where 300 km/h mean speed could really become trump card. The counter-intuitive result is that these trains should be used to link large cities, point to point with smaller cities inside a radius of about 100 km. The rationale is that people usually do about three round trips per day, one long and two short ones. The long trip, however, is about 40 (20+20) minutes. Connecting two cities with a transit time of less than 20 minutes will practically fuse them transforming the intercity trip into intracity trips, which are almost two orders of magnitude more frequent.

Some examples of these possible connections are given with a total track length comparable to that of the projected European fast train network.

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Introduction

Schumpeter and Montroll, in very different contexts of modeling, noted that progress can be reduced to a spatio-temporal sequence of substitutions. In the case of transport, after the historical horse and buggy, starting from the XVIII century, we have witnessed a brisk (in secular terms) evolution of the means of transportation. The next one substituting the previous ones in 100 years or so.

The basic technologies for overland transportation can be reduced to their infrastructures: canals, railways, paved roads and motor ways and airports. What will be the next technology is everybody's guess, but Magnetically Levitated Trains (Maglevs) are a good candidate as they fit into the various constraints imposed by the quality of future *system demand.*

The substitution process has found its basic description into a *Logistic Substitution Model* (see Appendix) which was used first at IIASA to map primary energy substitution, but later found a very wide application in the description of all sorts of economic and social processes. For the case of transportation modes, we can measure their dynamic of substitution through that of their infrastructures, e.g., in the USA (*Figure 1*). On a shorter term we can also see the different modes operationally (passenger kilometer) through their substitution (see *Figure 2*). The process is of very general character and independent from the social or political context. The numerical parameters of the equations are, however, specific of the country (*Figures 3* and *4*).

Figures 1 to *4* show the substitution in relative terms but the exercise can be repeated also in absolute terms. The straight lines in our charts are logistic S curves and we see our infrastructures grow for one or two pulses (usually each of them embedded in a Kondratiev 55-year cycle), then they stay constant (one Kondratiev cycle), and finally start wearing down. From a functional point of view (e.g., passenger kilometers) they keep growing during the expansion pulses in absolute and relative terms. During the stationary phase they tend to lose in relative terms but to be stable in absolute terms. Passenger kilometers transported by European railways are more or less the same as they were in the thirties, at the end of the previous Kondratiev cycle. When the infrastructure starts losing pieces at the rim (*Figure 6a,b*), also in absolute terms, the functional indicators will start going down.

At this point, typically, the old technology tries to fight back by introducing new tricks and some reorganization of the system. The situation is very clearly described by what happened when steamships by their superior reliability (but inferior economics) started substituting sailships. The latter could not compete with the strict time tables for transporting precious mail and human flesh, but they could for bulk and in fact carried coal to the bunker points around the world to refuel the coal-guzzling steamers. The new technology, however, had much potential in store and kept explicitating it. The *Windjammer* replied with an all-out effort. The big merchant-man of 1850 was about 700 tons and had a crew of 25; by 1900 it was 6000 tons and had a crew of 16. In 1848 tea clippers sailed home from China *against* the monsoons in 129 to 146 days. In 1871 the spread was between 104 and 127 days. The times for the trips *with* the monsoons did not change. But finally they came to the end of the rope and the steamers kept improving. The situation is clearly depicted in *Figures 7* and *8*, showing the diffusion of the new steam technology for the UK and the functional substitution at the world level.

The penetration of railway infrastructure in Europe is given in *Figure 6a,b* in terms of kilometers of tracks. After two waves up and one steady it is clear that railways have to fight for their survival. And they do it following quite precisely the lines of the sailships. Collaborating with the competing mode, e.g., carrying road vehicles piggy-back over long stretches. Or competing by trying to conquer *speed* which is what all the competition is about. The sums earmarked for this last fight-back are very considerable, in the order if hundreds of billion ECU. *Our system analysis tries to identify the most profitable way to use them.*

Mobility Principles: The Travel Time Budget (TTB) and the Travel Money Budget (TMB)

Man is a territorial animal as our books of history clearly display. He is territorial in macro and micro with very strong parallels with the behavior of territorial animals. One of the tenets is that a large territory offers more resources than a small one. But it is harder to exploit and defend. So a compromise has to be found by optimizing between various constraints. Extensive field studies made originally by Zahavi under the spur of the World Bank and focusing on actual behavior more than on economic interpretations, have shown this behavior being contained into few very simple boundary conditions. *First* people move around *one hour a day* (mean over a population). *Second* people spend about *15% of their disposable income* to finance this movement. Inside these two boundary conditions they allocate this money and this time between different modes of transportation in such a way as to *maximize distances*, i.e., the size of their territory. With increasing income the distance covered with mechanical transportation increases quite regularly by about 4% per year as illustrated in *Figure 4* showing France since 1800.

Because Travel Time is Fixed They use their Money to Buy Speed

The boundary conditions given above are for a population, and there is obviously a large spread depending on age, sex, and profession, but if we want to analyze global response from the social system to changes in the structure of the means of transportation made available, then this level of aggregation may be sufficient. A *third* empirical observation of great importance is that the number of *round trips per day* oscillates between three for people living in cities to four or five for people living in villages or countryside.

Man is a shy animal spending about 75% of his time protected in his hole, the home. Another 15% is taken by work, nowadays mostly done indoors. This is true for Germany (*Table 1*) or for Greece showing

Table 1. Characteristic sizes of daily budget, (a) mean for all persons, (b) for the group of housewives without cars.

Characteristic size of time budget	(1)	(2)	(3)	(4)	(5)	(6)	(6a)	(6b)	(6c)	(7)
	Daily budget elements of activities (Minutes per person and day)									
(a) Mean value for	German average person older than 10 years									
251 Work days	1046	182	14	49	31	65	19	30	16	53
50 Saturdays	1161	46	4	20	36	61	20	31	10	112
65 Sundays & holidays	1211	21	1	2	4	59	24	30	5	142
all 366 days 1976	1090	135	10	37	27	64	21	30	13	77
Maximum value	1314	232	29	89	66	90	45	50	31	211
Minimum value	975	0.5	0	0	0	36	9	16	0	24
Standard deviation	75	73	7	25	13	9	5	6	6	42
(b) Mean value for	German housewives without car									
251 Work days	1276	19	0	1	56	47	25	14	8	41
50 Saturdays	1255	10	0	1	48	50	23	21	6	76
65 Sundays & holidays	1260	4	0	0	5	57	27	26	4	114
all 366 days 1976	1270	15	0	1	46	49	25	17	7	59
Maximum value	1360	80	14	22	108	109	85	60	29	241
Minimum value	1097	0	0	0	0	22	10	2	0	5
Standard deviation	40	17	2	2	26	14	10	9	6	38

(1) At home.
(2) Work.
(3) Business.
(4) Education/training.
(5) Shopping.
(6) Traveling; (6a) on foot, by bicycle or motor cycle, (6b) in motorized individual traffic, (6c) with public transportation.
(7) Other.

that the quality of the climate and of the weather is of not primary importance. The time spent, unprotected, moving around has to be used at best, and in fact it is. Virirakis, analyzing the spacial structuring of the services in a "natural" city like Athens, found that by using or not using them, the customers imposed a spacial distribution that minimizes total travel. As they mostly move at constant speed on foot, this corresponds to minimizing travel time.

The three trips are of very different length. Usually the large one (~50 minutes per day) is used for moving to work and back. This is understandable as it permits the largest choice in order to optimize the two most important options in the life of a person, his workplace and his house. If we define a city as the conurbation inside which people move daily, we find that these constraints strictly define the maximum physical size a city can have. For a city on foot the maximum diameter is about 5 km (one hour on foot) and for a city on cars it is about 40 km. Checking historic walled cities shows that imperial Rome, Vienna (in 1700), Marrakech, or Beijing all had diameters of about 5 km. An analysis of the urban size of Berlin from 1800 to present (*Figure 9*) shows a neat matching between the speed of the fastest transport in operation and the size of the city.

That the *barrier is time and not space* is easily shown taking the case of cities having a very large river or sea strait inside them and looking at what happens when we move from a slow link (ferries) to a fast one (bridges or tunnels). The cases we will look briefly at are Lisbon and Istanbul. The analysis will show results very pertinent to our question of introducing fast trains, because it gives not only an idea of the effect of the increased speed, but also of the time necessary to assimilate it into reorganization of the community and of its behavior.

We take first the example of Lisbon, a city built on the northern side of the broad outlet of the Tago River. The river is so large at this point that only ferries could be used to cross it until 1966 when a bridge was opened. This bridge was not really intended for the city, well connected with the southern conurbations of Almaide and Seixal by the ferries, at least in the mind of city planners. The bridge, a feat of engineering and of good aesthetics was built where it is in order to be seen from the city as a monument to the constructivity of Salazar's regime. But the propinquity had a snag, not foreseen by the planners, that it reduced transit time between Lisbon and the southern conurbations to a level where the trip could be incorporated into the daily long one. In other words, it transformed *intercity* trips by ferry into *intracity* trips by cars and buses. The difference in frequency is almost two orders of magnitude and we can analyze in detail the process and its dynamics.

Vehicle transported by ferries between 1950 and 1987 are reported in *Figure 10*. The line starts around 1940 because activities usually grow in pulses starting with the beginning of a Kondratiev-wave (the present one started around 1940). We see a saturation point of 2 million vehicles for this wave, plus 0.4 million from the previous one ending in 1940. The opening of the bridge is marked on the figure and brings a drastic fall in traffic (with some pick-up in the following years). The second face of the medal is reported in *Figure 11* showing vehicular traffic over the bridge. It starts with almost three million during the first years, growing logistically to a saturation point of 26 million cars per year. This is also the maximum technical capability of the bridge with 2 $\times$ 3 lanes. The original width of 2 $\times$ 2 lanes was already saturated in 1977 when the 2 $\times$ 3 was put into place.

The cleanness of the example is paradigmatic. Lisbon and the southern conurbations existed before the bridge, and the connection with the ferries was most probably largely sufficient in terms of capacity. Although we do not have data about the capacity offered by Lisbon's ferries, these machines tend to run with low utilization factors. In Hongkong, where we have precise statistics, this factor is about 30%. What happens with ferries, however, is that even when the transit proper takes 20÷25 minutes, as in this case, loading and unloading plus some waiting brings the trip length into the area of one hour. The bridge proper can be crossed in five minutes, although accesses take certainly time, especially because the bridge is apart from the city since it was built for other purposes. What has been observed, in fact, is a *reorganization of residence, jobs, and shopping procedures* to take advantage of the new spaces which were made available to the city inside the *city's time walls.*

We are not going to report on similar examples coming from Istanbul where a highway bridge was constructed on the Bosphorus in a place where the strait is narrow and the banks appropriate for a bridge. As in the case of Lisbon, the bridge *happened to be* in sight of the town of Istanbul and was consequently used as a fast link to the eastern side of the strait where large conurbations were present. It must be clear that the strait was and is equipped with a frequent service of ferries for vehicles and people, so that formally the two sides were well connected (*Figure 12*). The bridge was invaded by local traffic as is shown in *Figure 13*. The saturation point of 29 million vehicles per year is the technical capacity. In fact a second bridge has been constructed in the meantime and opened in 1988. The Tago bridge had a saturation of 26 million vehicles. The difference is in the time constants: 20 years for the Tago bridge and 5 years for the Bosphorus bridge. Although we did not search in depth, a possible explanation is that a large conurbation of perhaps 1 million people already existed on the eastern banks of Istanbul providing a ready source for city organization reshuffling.

We did a similar study for Hongkong, where three tunnels were opened under a 2 km wide strait with the express decision of facilitating traffic (again for trucks in the road tunnels). Things went well and traffic is moving to a saturation point of *800 million* transits per year or about 2.2 million per day. A curious fact is that trucks still prefer ferries in Istanbul and in Hongkong, their timetables being not as sensitive as those of human passengers, but the tolls cheaper.

A very important *rule of thumb* gained from these analyses is that when two conurbations are meshed into one by a fast connection, the traffic changes from intercity to intracity and the *number of transits* (both ways) *closely matches the population of the smaller conurbation.* In other words, if the smaller conurbation has 10^5 inhabitants, the transits per day will be around 10^5. If it is a public service (like train and metro in two of the tunnels in Hongkong), this permits rapid amortization on one side, but requires peak quality in organization to face peak loads of 10^4 passengers per hour, or so.

Where to best located fast trains?

Let us now come to the central point of our discussion: *how to best use the increased performance of trains.* Japan led the way in fast trains with the Shinkansen opening the first line in 1969. The technology had at least 10 years. So we should expect, 30 years later, something more exciting on the market. Put it in a blunt quantitative way, Shinkansen technology can make 300 km/h top speed and the new SNF (or BB) trains *500 km/h.*

Daily trips provide the largest market in terms of number of trips, as we said, but also in terms of passenger kilometers. Just to give a figure, 90% of the *passenger kilometers* on *railways* in Germany is concentrated in the 0–50 km range. In the case of cars and road transport, 60% of the passenger kilometers are again concentrated in the 0–50 km slice. So the short range is the really fat market and the problem is how to use the best technology in road transport for that segment. The answer is very simple and derives from the *20-minute one-way trip length* that fixes the discontinuity between daily trips and the rest.

The analysis leads then to use very fast trains in their best performance for 20-minutes trips or so, to connect centers having at least 10^5 inhabitants providing the basis for a number of trips per day of the same order of magnitude. A 500 km top speed train can make about *100 km in 20 minutes* if one takes into account acceleration–deceleration procedures. Because stops consume more or less ten minutes in stop proper (5 minutes) plus decelerations–acceleration, *stops are by necessity to be avoided.* These trains *run from point to point only, as in the case of airplanes.* As airways have already discovered and experimented, the best practical configuration is that of *hub and spokes*, meaning a large center (hub) connected radially (spokes) to a number of smaller centers. We have tried a few big cities in Europe (hubs) to see where the spokes would end ($<$ 100 km away) and the results are reported in *Table 2*. The search is occasional and should only serve to start looking around. However, even at this extremely rudimentary stage, the result gives some quantitative hints on the market. The nine hubs list 80 spokes. If the mean length of each spoke were only 50 km, that *would give 4000 km of TGV lines*, capable of absorbing all the present level of goodwill and money available in the direction of Very Fast Trains of conventional design planned for Europe.

Table 2. Some possible hub and spoke connections.

Paris (12)	Reims	Beauvais	Rouen	
	Troyes	Compiegne	Amiens	
	Fontainbleau	Orleans	Beauvais	
	Chartres	Evreux	St. Quentin	
Milano (10)	Piacenza	Bergamo	Lecco	Torino
	Parma	Como	Novara	Alessandrio
	Brescia	Varese	Vercelli	Genova
	Cremona			
Frankfurt (13)	Ludwigshafen	Kaiserslautern	Kassel	Pforzheim
	Karlsruhe	Koblenz	Würzburg	Wiesbaden
	Heidelberg	Siegen	Hellabron	Mainz
	Bonn			
Berlin (9)	Leipzig	Magdeburg	Frankfurt/Oder	
	Dessau	Wittenberge	Cottbus	
	Halle	(Stettin)	Stendal	
Hamburg (10)	Kiel	Braunschweig	Bremen	
	Lübeck	Hannover	Bremerhaven	
	Rostock	Wolfsburg	Flensburg	
	Schwerin			
Manchester (9)	Sheffield	Bradford	Blackburn	
	Liverpool	Leeds	Nottingham	
	Stoke	Blackpool	Birmingham	
London (11)	Ipswich	Portsmouth	Reading	
	Southend	Southampton	Oxford	
	Brighton	Bournemouth	Luton	
	Cambridge	Northampton		
Bruxelles (6)	Liège	Gent	(Eindhoven)	
	Maastrich	Brugge	(Breda)	
	Antwerpen	Mons		

The meshing of the activity of medium cities into large ones has very important consequences. In a study I did some years ago on the distribution of cities at world level, by the usual rank–size analysis (Zipf), see *Figure 14*, I found a curious "shortage" of very large cities, as demanded by a functional (fractal) hierarchy of tasks, but obviously difficult to run as urban conglomerates. By putting "corridors" in the list, the problem appears to be neatly solved (*Figure 15*). A corridor is a chain of cities served by fast connections, typically air-shuttles with frequencies in the order of a fraction of an hour and transit times below one hour. It seems that such mobility provided to the elites is sufficient to integrate the cities, and position them into higher hierarchical slots. European cities seem to be in a saturation stage and so is urbanization in Europe (*Figure 14*). Because positions in the rank of nations is related to availability of *centers* large enough to sit in a high rank, *coagulation through hubs and spokes* could create fairly large centers. These could later be connected by shuttles into larger ones.

The precise example is that of Japan which somehow through the Shinkansen, but in particular through air shuttles, is coalescing about 80 million people in the Tokyo–Osaka strip, the largest conurbation in the world. In 1900, when long-range travel was too slow for this kind of synthesis, the rank–size of cities at world level showed London at the top, a counterproof of an evident economic and political situation (*Figure 14*). The connecting technology were trains.

One of the questions that comes to mind is what happens to the smaller cities when connected to a large one. Will they become dormitories losing their present character? The question is not easy to answer as some examples move in one direction and others in the contrary direction. The British examples, when trains were introduced, lead to specialization in the sense of luxury residences outside the large towns; the Italian examples tend to show a swamping by lower social segments attracted by lower rents. Or they can specialize in quality (or price) services, in terms of, e.g., marketing textiles, apparel, food and restaurants, etc. So perhaps knowing some of the future, local authorities may well take channeling measures.

There will be some time available. As the sample of Lisbon shows, if interaction requires development, the transient can well last for 20 years. If there is a pent up demand as in the case of Istanbul, where only some reorganization was necessary, then five years were sufficient to saturate *the first* bridge. I think ten years is a good rule of thumb for local decision makers to provide the proper umbrella for the changes.

Let us now move to the next step, that of trips longer than 20 minutes. As said in the beginning, man is a territorial animal centered into his cave, where he likes to come back at night to find reassuring familiar patterns and protection. Most of these 1-day trips are of business character, and most of them are short range (< 50 km). But we are now interested in analyzing the long-range connections. Doxiadis in his path-opening book *Ecumenopolis*, had clearly identified the habit and classified the area reached by these occasional commuters as *Eperopolis*. An example taken from that book is reported in *Figure 19*.

Because one working day can be up to 12 hours long, and at least 4 or 5 hours have to be dedicated to the business proper, total transportation time cannot be more than 3 hours ($\times$ 2) door to door. This means that the long-distance part cannot be much longer than 1.5 hours. In fact field analysis shows a high sensitivity in switching from plane to train or vice versa when this "seuil" is crossed.

This very simple logic rules out many proposed fast train links whose rationale is to compete with airplanes especially for the rich business travel. A school-book case is that of the Italian "Pendolino" which takes "only" 3.5 hours to go from Milan to Rome and failed to attract business travel except when Milano airport is fogged out. Or of the Shinkansen which did not inhibit an extremely active "air bridge" between Tokyo and Osaka where fleets of long-range 747s are loaded with up to 750 passengers in extremely packed configurations.

On the other hand, in spite of the flourishing little niche of *air transport*, the numbers are small. In Germany, air trips for all purposes, inland and outland, are 0.5 per person per year, or about 35 million. Of these about *half are business* and the other half mostly vacation trips. Business trips (> 50 km) account for 1% of train trips or 0.25 trips per person per year in Germany. For car trips beyond 50 km they account for one trip per person per year. These are one-way trips and this means 60 million business trips per year for the whole of Germany (beyond the 50 km limit).

If we compare this market with that of 20-minutes daily trips, we are clearly off by more than two orders of magnitude. Consequently, we have to look at the few channels where this flow is concentrated. One of them is through "twin" centers, like Milano–Rome, Barcelona–Madrid, Amsterdam–London, etc. These twin centers are easily revealed by air shuttle service, formal or informal (one plane every hour). As an analysis done at IIASA shows, the problem here is that in the medium future the size of planes will not be sufficient to satisfy such level of demand with a reasonable number (e.g., 50) of flights per day. This is already the case for the Tokyo–Osaka and other connections in Japan. Here a train with different characteristics from the plane, e.g., the potential for launching *one train per minute*, may come to rescue. The train should, however, have a speed similar to that of a plane, around 600 km/hr *mean*. Maglevs seem more adaptable to this task as they are completely passive, with external drive (like San Francisco cable cars) and under computer control.

The other possibility is to look for the "connection core" inside an economic area. I will take some results from a study done by Erlandson at the Geographic Institute of Lund (1991). He looks at the number of air connections (5-day work week) between all cities in Europe, selecting the group where each city has > 25 connections per week with all the other cities in the group. The connections with more than 25 flights per week (5 days) are reported in *Figure 7*. The core connections are reported in *Figures 18* and *19* with a zoom on the time dynamics. The first core (full lines) is made by the cities that interconnect with all others in that group (with > 25 flights per week). The cities at the end of the dashed lines connect with the central core minus one. They can spring in and out with the opening of a new flight. Milano, with the air schedules of 1991, springs into the central core.

This central core is the natural candidate for TGVs, provided transit times do not exceed the *Eperopolis Paradigm*. Again they should be considered as point to point connections, just like airplanes. The very high speed explicitated will almost inevitably require new tracks. *Being* *point to point connections, each track may have different characteristics in terms of power source and gauge. The Shinkansen which shares some of the thinking presented above, is different from the other Japanese trains both in terms of power source and track gauge.*

The discussion about creating a high-speed rail network in Europe is very heated and many interests of financial character and of political prestige are stretching the problem outside its rational and economic basis. Our first round of reflections shows that the network planned, basically an international and relatively long-range one *does not* look like a *first choice for a rational investment.* First, long-range travel is thin, even if the magic one hour time connection is kept in mind. Second, there are political and cultural barriers that separate *different countries* and communities speaking different languages inside a given country. This entails a *reduction in traffic by about an order of magnitude, coeteris paribus.*

Long-range fast connection is now safely provided by airplanes. The number of air passengers and *their evolution in time* is the best indicator for the intensity of the link (*Table 3*). Because city underground transportation systems (i.e., fast intracity transportation) are or will be linked to airports, the best location for fast intercity end stations will be at the airport themselves so that incoming traffic can be added to local traffic. This configuration has already been adopted, e.g., by Lufthansa in Germany on short stretches where present railway speed permits connections more or less respecting travel time constraints. These trains are formally treated as planes and tend to move only point to point with no intermediate stops. Higher speeds will permit a larger area coverage, up

Table 3. Number of air links per working week for selected European couples of cities.

Link	Non-stop flights per week
Paris–London	243
London–Paris	242
London–Amsterdam	211
Amsterdam–London	211
London–Dublin	158
Dublin–London	157
Barcelona–Madrid	153
Madrid–Barcelona	151
Bruxelles–London	135
London–Bruxelles	130
Milano–Rome	132
Rome–Milano	131
London–Glasgow	130
Glasgow–London	130
Väst–Berlin–Frankfurt	120
Frankfurt	
Väst–Berlin	120
Edinburgh–London	115
London–Edinburgh	110
Munich–Frankfurt	105
Frankfurt–Munich	105
Zürich–Genève	103
Genève–Zürich	102
Stockholm–Göteborg	100
Göteborg–Stockholm	100

to including some of the links proposed for the TGV network.

The general problem of providing speed and mileage to people appears much simpler and clearer if looked at in historical perspective. *Figure 5* reports the case of France since 1800 giving the distance traveled per person and per year, using mechanical means of transport (including bicycles!). This distance was a very low 20 meters per day in 1800 showing an extremely static society where only the top elites were mobile. The value for 1985 is still relatively low, about 25 km per day per person. As I belong to the elites who do 250 km per day (thanks to airplanes) and do not feel tired, this means there is still much space to go before reaching saturation. With the historical rate of growth of 4% per year (dashed line fitting *all transport modes*), to cross two orders of magnitude will take about 120 years. This increase in total traffic of 4% will be picked up by the faster means of transport: the car until everybody permitted to drive will have one. In Europe we are not far from that level of ownership. So finally the airplane, in the present and hypersonic version, will take all the increase.

This means large figures. Airplanes take now 10% of intercity passenger kilometers in Europe. At 4% per year the passenger kilometers will double in less than 20 years. If all the new traffic were absorbed by airplanes this would mean an increase in air traffic by a factor of ten in 20 years. Our hubs and spokes may well take a share of this traffic, but it is clear that some connection will be too overloaded to be served by airplanes. This is the area where chances are open for very fast trains (400 km/hr mean speed point to point) and superfast trains (700 km/hr mean speed point to point). As investments decided during the next 10 years will become operational during the following 10 years, this look into the future may be of great interest for fixing a rational policy.

A More Detailed Analysis on How People Move in the Medium Distances

As we have seen, people tend to stay mostly home and move mostly short range, *inside* the city and the village or the nearest territory. The size of the area covered by all this leaving the nest and coming back to the nest is quintessentially determined by the speed of the means of