

**ANTHROPOLOGICAL INVARIANTS  
IN TRAVEL BEHAVIOR**

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# Foreword

The study of travel behavior is mostly in the hands of economists, or of urbanists and geographers who tend to use the tools of the economist.

What Marchetti shows in this paper, incorporating a wide variety of information from anthropology, geography, and his own research in transport statistics, is that travel patterns can be almost completely reduced to basic instincts. As these are very stable, we have here important invariants explicitated, that can be very useful in transport forecasting and infrastructure planning. Marchetti's view that humans are "naked apes" in many dimensions of their behavior involving territory and personal contacts, should enrich our understanding of travel patterns.

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Director



# Anthropological Invariants in Travel Behavior

C. MARCHETTI

## ABSTRACT

Personal travel appears to be much more under the control of basic instincts than of economic drives. This may be the reason for the systematic mismatch between the results of cost benefit analysis and the actual behavior of travelers.

In this paper we put together a list of the basic instincts that drive and contain travelers' behavior, showing how they mesh with technological progress and economic constraints.

## Introduction

That man is a territorial animal is a statement that does not need demonstration. History is a collection of squabbles between human groups competing for territories; but also brothers sharing the same room squabble for its division in areas of influence. Now the *basic instinct* of a territorial animal is to *expand its territory*. A larger territory means larger resources and opportunities and the rationale for accretion is obvious. Exploiting a large territory is also expensive, however, both because it requires the physical exertion of moving over large distances, and because moving means to be in the open, under the possible threat from enemies and predators.

For an animal, and for a pretechnological man, a balance can be struck by *adjusting* one single parameter: *mean traveling time per day*. Strictly speaking this fixes only the "*exposure time*," but, in fact, multiplied by the mean speed of movement of a certain animal, it fixes a distance, or a *range*, that is a territory.

The second point is that *man has a cave instinct*. The protection of the high tree with dense foliage in the tropical rain forest has found a good substitute in the hiding shade of the cavern, where man spent most of the time not devoted to gathering and hunting. This relic is important as the big business of air transport pivots on this instinct, as we shall see in a moment.

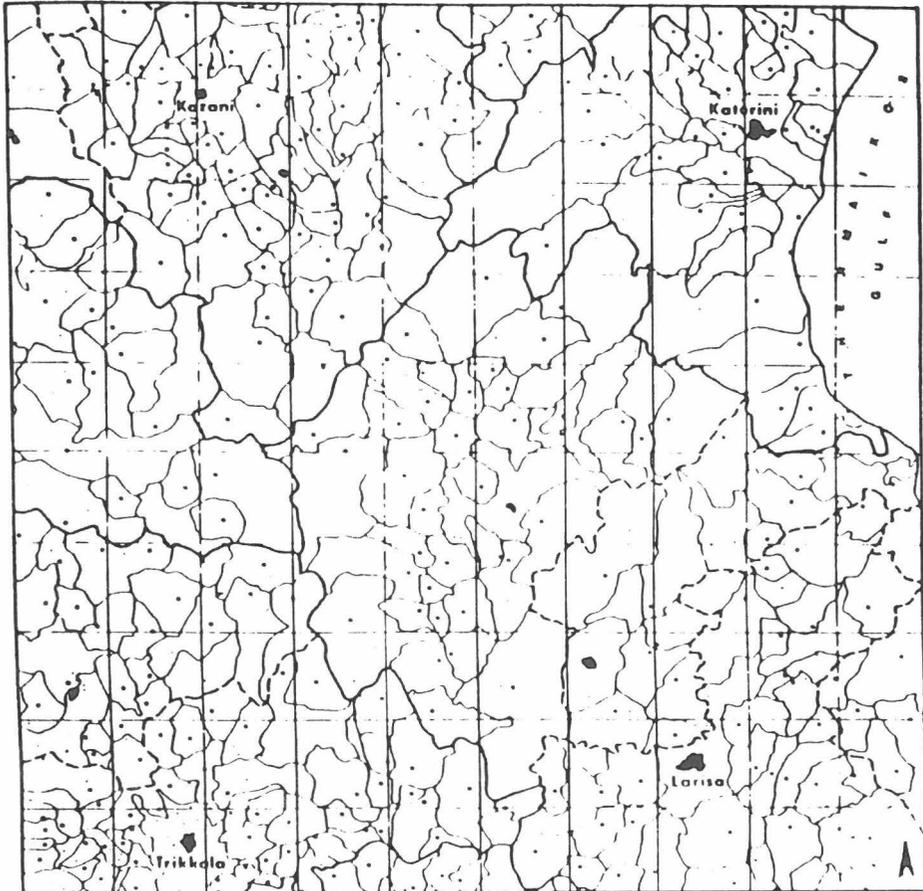
The field work of Zahavi [6, 7], who was at the World Bank when he did it, is in my opinion most remarkable because it shows the *quintessential unity of traveling instincts around the world*, above culture, race, and religion, so to speak, which gives unity to the considerations relative to the history and future of traveling, and provides a robust basis for forecasts in time and geography.

The empirical conclusion reached by Zahavi is that all over the world the *mean exposure time* for man is around *one hour per day*. This is a mean over the year and over a population, but the tails of the distribution are not spread much around the central value. The effects of the instinct are pervasive. Even people in prison for a life sentence,

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# Village Patterns in Greece



Mean area  $22 \text{ km}^2$

**Fig. 1.** Territory around villages in Greece. The agricultural area referring to a village has been settled by trial and error during the centuries. This figure shows a part of Greece, with villages marked as points on the map. The mean area belonging to each village is a little above  $20 \text{ km}^2$ , pointing to a radius of about  $2.5 \text{ km}$ . This is also the *largest* radius of the walls of ancient cities, like Rome, Persepolis, Marrakech, or Vienna. The connected core of Venice has the same dimensions today [2].

having nothing to do and nowhere to go, walk around for one hour a day, in the open. Walking about  $5 \text{ km/hr}$ , and coming back to the cave for the night, gives a territory radius of about  $2.5 \text{ km}$  and an area of about  $20 \text{ km}^2$ . This is the definition of the territory of a village, and, as Figure 1 shows, this is *precisely* the mean area associated with Greek villages today, sedimented through centuries of history. The same principle operates when a city, through its importance, political or economic, expands its population and, as a

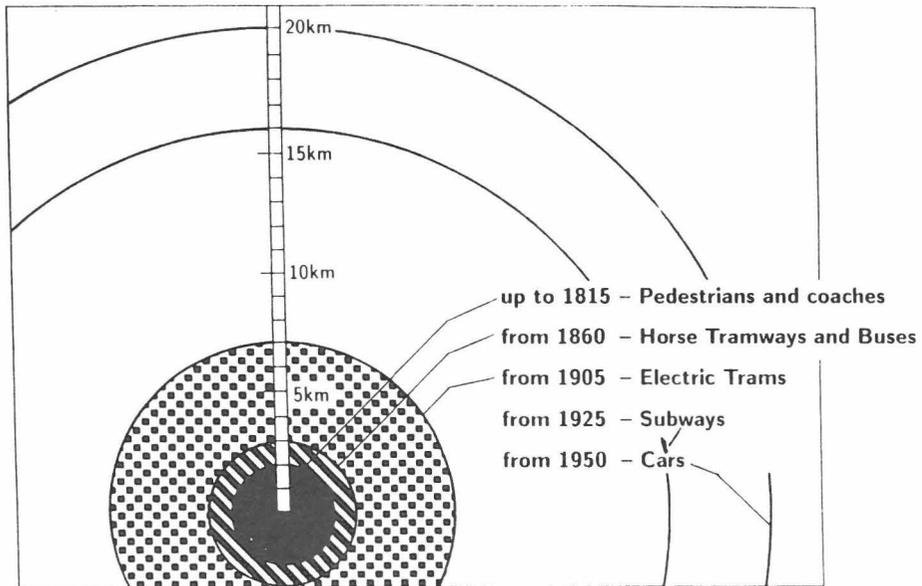
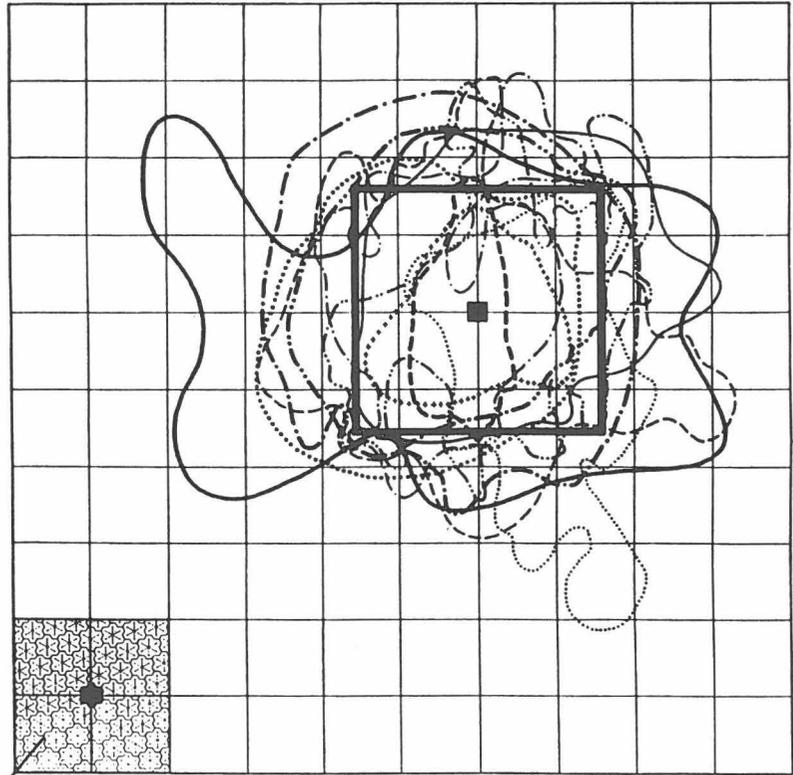


Fig. 2. City dimension and speed of transport: The case of Berlin. The fact that the "daily radius" depends on the speed of transportation is clearly manifested by the evolution of the size of the city of Berlin. The Berlin of 1800 was very compact with a radius of 2.5 km, pointing to a speed of 5 km/hr, the speed of a man walking. With the introduction of faster and faster means of transportation the radius of the city grew *in proportion* to their speed, and is now about 20 km, pointing to a mean speed for cars of about 40 km/hr. The center of the city can be defined, then, as the point that the largest number of people can reach in less than 30 minutes. Reducing the access to the geometric center, for example, through zoning, can displace the functional center elsewhere, for example, outside the city. Shopping centers are a typical consequence of poor transportation toward the center of the city.

consequence, its physical size. There are no city walls of large, ancient cities (up to 1800), be it Rome or Persepolis, which have a diameter greater than 5 km or a 2.5 km radius. Even Venice *today*, still a pedestrian city, has exactly 5 km as the maximum dimension of the *connected core*.

When introducing mechanical transportation with speeds higher than 5 km/hr, the physical size of the city can grow in proportion, as the historical analysis applied to the city of Berlin clearly shows (Figure 2). The commuting fields, based on cars, of a dozen American cities are reported in Figure 3. On the same chart and to the same scale, the Greek villages of Figure 1 are shown in schematic form. *Cars make all the difference*. As they have a speed of 6 or 7 times greater than a pedestrian, they expand daily connected space 6 or 7 times in linear terms, or about 50 times in area. Ancient cities typically had a maximum population of about 1 million people. Today the population may tend to reach 50 million people in conurbations like Mexico City (Figure 4), with a population density equal to that of Hadrian's Rome. If the Japanese complete a *Shinkansen Maglev* (a magnetically levitated train) connecting Tokyo to Osaka in less than one hour with a large transportation capacity, then we may witness a city of 100 million people. If we expand the reasoning, we can muse about a city of 1 billion people, which would require an efficient transportation system with a *mean speed* of only 150 km/hr. This could



Greek village pattern in scale

Fig. 3. Commuting fields in 11 American cities. The geography of the “walking man” is shown here on the same scale as that of the “driving man” commuting in a number of American cities. As cars have a mean speed of about eight times that of a pedestrian, the commuting distances are about eight times as great. The areas accessible – the *territory* – however, grow as the square of the distance, so the driving man has a territory which is about 60 times larger than the walking one [2].

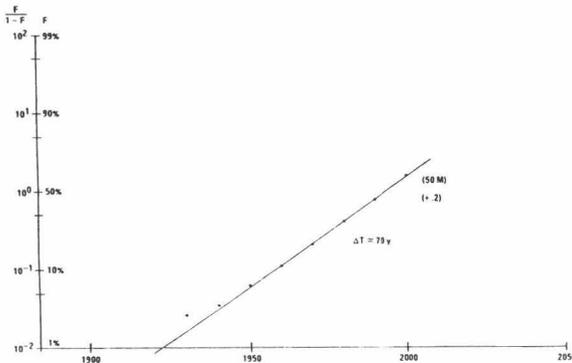
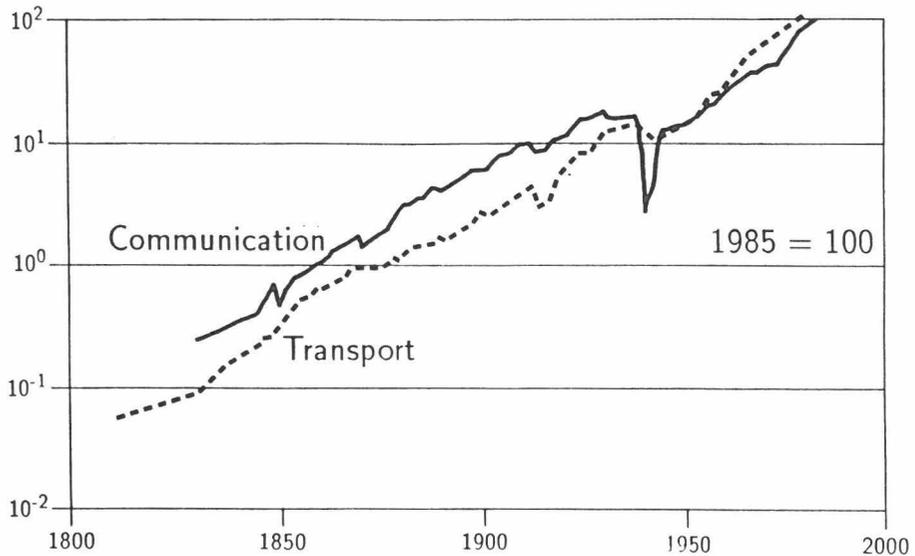


Fig. 4. City size and transport speed: The case of Mexico City. At the density of Hadrian’s Rome (1 million people over 20 km<sup>2</sup>), we would pack 60 million people in a city where the speed of transportation gives access to an area 60 times larger, meaning an eight-fold increase in speed of transportation. The logistic analysis of the growth of Mexico City points to a saturation level of about 50 million, well in tune with these top-down estimates. We took a transportation speed of 5 km/hr for Rome and 40 km/hr for Mexico City.



**Fig. 5. Transport and communication: A historical survey for France. There is much talk about the communication explosion and the possibility of it substituting the physical transport of persons (the “wired city”). Up to now, communication in terms of messages exchanged and transportation in terms of pass-km, seem to move together as the indexes show for France. The increase in personal territories increases the number of information exchange points accessible only by telecommunication. In a village all exchanges are carried out face to face without any need for mechanical devices to communicate [4].**

happen in China, as *these aggregations tend to stop at cultural and political barriers as we shall see.*

The accent can be set, then, on *transportation as the unifying principle of the world, and not communication* as the current wisdom indicates. On one side the so-called explosion in communication during the last 20 years did not dent transportation expansion; on the other hand, they tend to move together (Figure 5) as Grübler has shown, pointing to a synergistic more than a competitive situation [4]. As communication and transportation move together, one can be used as a proxy for the other for measuring the effect of the political-cultural barriers we cited before. We can look, for example, at interactions between communities of different languages (e.g., culture), or between communities with the same language but different political denomination. The results of the analysis are obtained by looking, for example, at telephone calls between cities in Quebec (French speaking) and Ontario (English speaking) and the nearby United States. As we can see in Figure 6, *cultural barriers or political barriers bring a reduction by an order of magnitude in communication, and supposedly in personal movement.*

The reduction can be seen by applying a gravitational model to communication and transportation, which works well in both cases and differ in the numerical coefficient as explained in the legend of Figure 6. This means that a superfast Maglev connection system for the European core may link it without really unifying it in the sense of the Shinkansen area, at least in the short term – 50 years, for example. Mixing people may favor cultural compatibility – as history shows. Cultural traits are slow to modify and fast transportation may finally raise the central problem of *how to realize a viable multicultural society,*

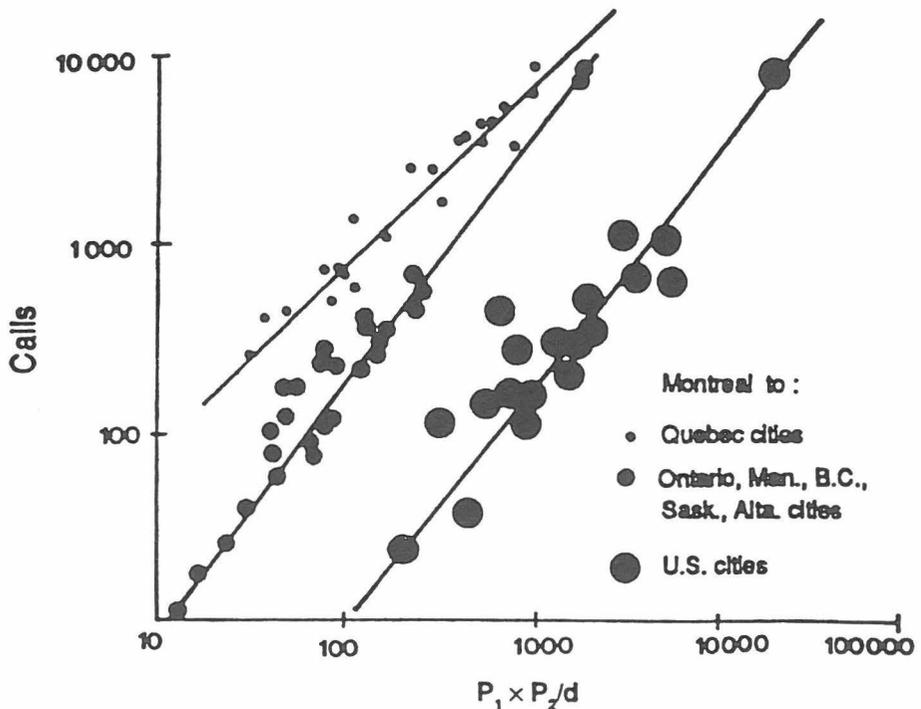


Fig. 6. Messages as measure of interconnection: The case of Canada. Due to parallelism between message exchange by telephone and traveling, we may use the first as a proxy for the second, at least in an approximation where we look for ballpark figures. Here, we are trying to assess the barrier effect of political and cultural differences. The base model is gravitational [8], meaning that in a homogeneous system telephone calls between two cities are proportional to the product of their population divided by some power of their distance  $KP_1P_2/d$ .

The model works also for systems with different languages (here Ontario and Quebec) but equal political systems, and for systems of the same language (Ontario and nearby USA) but different political systems. The *proportionality coefficient K is an order of magnitude smaller, showing that cultural and political differences are very powerful interchange barriers*, however. Similar results are obtained by looking at travel inside Europe, where real unification may take longer than the abolition of frontiers or the construction of a fast connection grid with Maglevs [1].

however. This is not only an inevitable political and religious problem, but also an *ecological* one, so to speak, as it seems like a good idea to *preserve the cultural diversity* of human populations in parallel with the *biodiversity* of living species.

In one of my *Gedankenexperimente* I explored the possibility of using transport technology in such a way as to leave the possibility of saving cultural roots, allowing intense interaction at the same time. Such problems can be solved only by going back to basic principles and I tried to go in that direction. Man, as I said before, is a cave animal and *spends much of his time in his cave, actually more than two thirds* (Figure 7). His family, his furniture, and his cultural roots are there. In order to preserve all that it seems almost necessary to permit a person to come back to the cave, wherever his work and business takes him during the day.

City and Country	Percent
Athens	75*
Belgium (65 urban areas)	75
Bulgaria (Kazanlik)	61
France (6 cities)	71
West Germany	70
Poland (Torun)	76
USSR (Pskov)	61
USA (44 cities)	68

Fig. 7. Time spent at home by adults in various countries [2].

My *Gedankenexperiment*, which I presented at Marrakech in a congress related to the problems of linking Africa (or better the Magreb) to Europe with a bridge or a tunnel across the Gibraltar Strait, was based on the exploitation of the maximum potential of the *Maglev*, the magnetically levitated and driven train. At the Polytechnic of Lausanne a *Maglev* transportation system about 700-km long linking the major Swiss cities with transit times of 10 minutes has been proposed (Figure 8), with the characteristic of running in an evacuated pipe (air pressure equivalent to a height of 15,000 meters) [3]. The rationale is to have a *small tunnel*, almost fitting the size of the train. Due to the mountainous conformation of Switzerland, such connections have to be made in tunnels for the most part, and the cost of tunneling is dominant over every other component of the system.

Operating in a partial vacuum, however, removes the most important constraint to vehicle speed, as *Maglevs* move more or less in a frictionless manner on a magnetic cushion. We still have a limitation on the acceleration that humans can take. I assumed 0.5 G or 5 m/sec<sup>2</sup> as an acceptable one. It is the acceleration (for a few precious seconds) of extremely expensive cars, like Ferraris and Porsches.

Operating a *Maglev* between Casablanca and Paris at constant acceleration (CAM), that is, by accelerating halfway and braking the other half at 0.5 g, the train would cover the distance in about 20 minutes. In other words a woman in Casablanca could go to work in Paris, and cook dinner for her children in the evening. Vice versa for shopping for special items in a special cultural atmosphere. With appropriate interfaces, such trains could carry hundreds of thousands of people per day. *The idea behind this is to save cultural roots without impeding work and business in the most suitable places.* Incidentally, businessmen who can afford the extraordinary cost of air travel in Europe do exactly

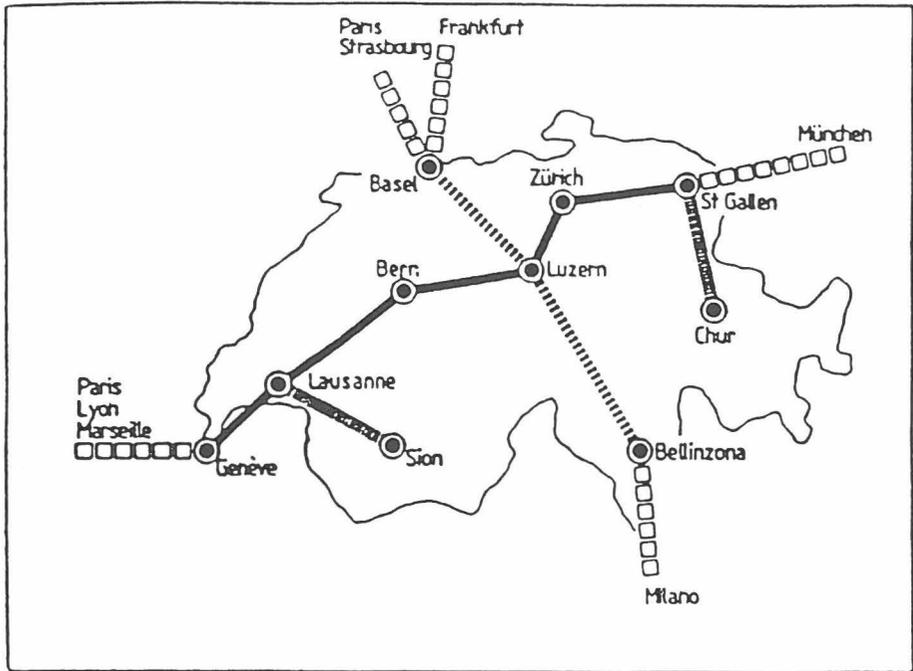


Fig. 8. Proposal for a "SwissMetro" made by the Federal Polytechnic School of Lausanne, Switzerland. A Maglev train would run in a partially evacuated tube to save on tunneling costs. The time taken to connect two adjacent cities is kept constant at about 10 minutes. The consequence of such an arrangement would be the fusion of these cities at all levels of operation. The pivot city, Bern, could become the "city center" of the system.

that. They take the plane because it permits them to come back at night to sleep in their beloved cave, with family, cultural, and status symbols in place.

Speaking of a European core, I must say that functional integration at a high hierarchical level (e.g., having a common foreign policy) may not require full integration at a lower level, which would be an integration hitting against cultural and linguistic barriers. A suggestion in that sense comes from an analysis I did on the rank-size of world cities. This rank-size images the *distribution of tasks* between the largest cities of the world (or of a nation) in running the system and filling a territory fractally. As shown by Zipf in his seminal work in the 1940s, a well-developed system shows a fractal structure in the size of the population of cities (Figure 9). In 1920 London was the world's largest city and her number one ranking was obvious in terms of politics and finance. The ranking of the world's cities sat on a nice straight line *as it should* according to Zipf. If we repeat the exercise now, we find that the world cities line has a big knee (Figure 10). In a sense, either the world is short of large cities or in some way it is not at equilibrium.

Air transportation has made it possible to commute between cities, however, if not every day, at least for the necessary number of times, for the "elites" in functional terms — managers, politicians, professionals of a high rank. The sets of cities where air shuttles work, showing high density of this kind of exchange, have been dubbed by Doxiadis as *corridors*. They often have a linear structure like Boston–New York–Washington, or

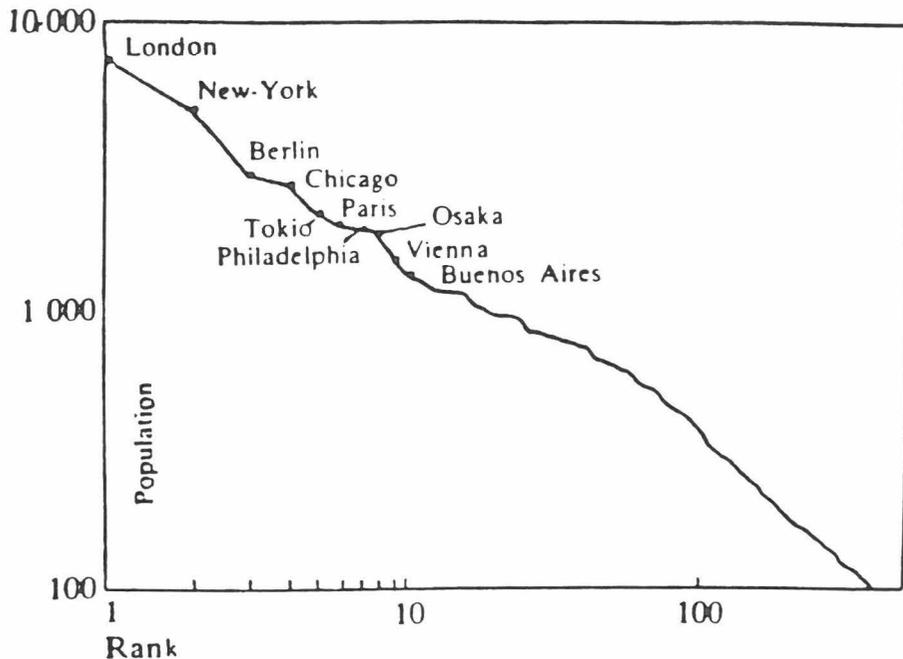


Fig. 9. The rank-size distribution of the world's largest cities in 1920. Zipf showed that in an interconnected system the population size of cities tends to have a constant ratio when ordered in a decreasing size sequence (rank). According to Zipf, who ordered these sequences in a log-log "rank-size," matching a straight line is the manifestation of some sort of equilibrium in the distribution of tasks. Rank number one belongs to the city with the highest rank functions in world politics and finance. At world level, London fitted well into that position in 1920. The distribution can also be interpreted as a fractal set that fills a space [8].

Tokyo–Nagoya–Osaka. *Assimilating corridors to cities* and repeating the exercise we find a fit according to Zipf's paradigm. This is certainly not a proof, but a strong suggestion that the movement of the elite is sufficient for a *functional integration at the highest level*. Most corridors are between cities that are culturally and politically homogeneous; a generalization is then not advisable. Some strong interconnections between cities like London and Amsterdam may be testbeds for studying the effect of cultural and political barriers at the level of the elite.

If these effects are not so strong as for the bulk of the population, in the sense that they can be digested in a relatively short time, then *hypersonic planes* operating shuttles at world level, with the elite coming back to their cave at night wherever they have to go, could become the *backbone of a single world*. *Speed is a unifying principle*, as the case of the evolution of "on foot empires" and "horseback empires" in China shows (Figure 11). They eventually reached the same final dimension *measured in time* of about *one month* for a return trip from the periphery to the capital. If it takes longer, as happened when Rome lost control of the sea, then the periphery splits, building an independent political unit (the Eastern Roman Empire). This one-month maximum time lag in the dominant-to-subject feedback cycle has never been studied to my knowledge but the evidence that comes from the evolution of Roman, Persian, Chinese, and Inca

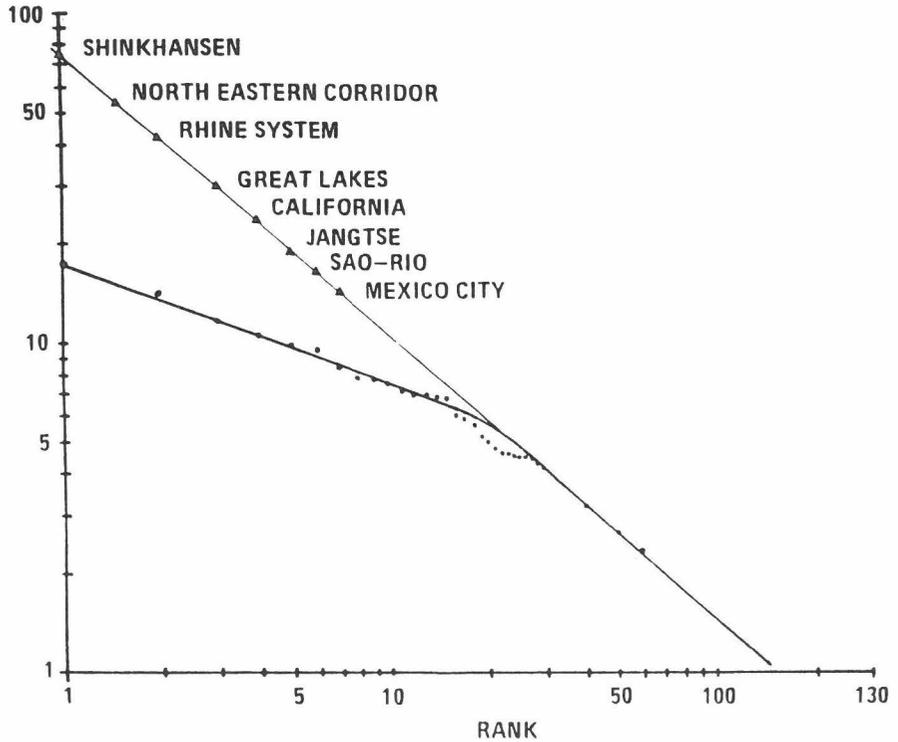


Fig. 10. "Corridors" as functional units. If we repeat the Zipf chart of 1920 today, we find that the rank-size of world cities line bends sharply at around a population of 7 million. Projecting from the smaller cities upward, one could say that, in the Zipf logic, we are short of very large cities. However, counting "corridors", that is, sets of cities connected with air shuttles and very fast trains, as single units, we find Zipf's order again. This may mean that the daily movement of the "elite" is sufficient to ensure the highest rank functions, with corresponding sizes equal to the sum of the connected cities.

empires points to another subjacent, basic instinct. The splendid transport networks empire builders were forced to put in place appear to be a necessary consequence.

Trips of longer periods are the ones made by tourists (historically preceded by pilgrims) about once a year. Coming from a tourist attractor (Florence), I have always been curious about the driving forces behind tourist wanderings, and being familiar with the species I am very skeptical about their rationalizations. My hypothesis is that there is again a basic drive behind this. If I can describe the behavior of a tourist, perhaps a little sarcastically: he chases a target as far away as possible, hopefully unexplored (unpolluted means he is the first to go there). Once the place is reached, he collects material for tales and physical souvenirs. Then he comes back and fills the heads of colleagues, friends, and parents with the tales of the magnificent land he has just discovered. The behavior is very much reminiscent of the *dancing bee* telling where the blossoming tree is located and the mass and kind of flower (she carries the souvenirs, pollen and the perfume, on herself). Souvenirs then become a tangible testimony that the tales are veridical (man is a born liar). When Moses sent scouts to Palestine, they traveled back loaded with specimens, in particular, a bunch of grapes so large that two men with a pole were needed

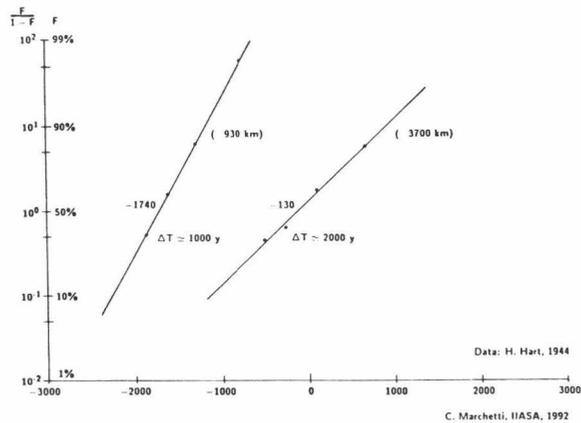


Fig. 11. Travel speed and the maximum size of an empire. As the Chinese say, past history contains all useful precedents to interpret the present. It may be interesting to muse about how transportation speed shapes the empires. Here, the size of the largest empires in Chinese Asia are reported. They can be ordered in two logistics having saturation points of  $0.7 \times 10^6 \text{ km}^2$  and  $\sim 10 \times 10^6 \text{ km}^2$ , or mean diameters of  $\sim 930 \text{ km}$  and  $\sim 3700 \text{ km}$ . In both cases, this corresponds to about a 15-day return trip from the center on foot, and on horseback, respectively. Apparently, empires where the periphery is more than 15 days away from the capital split, showing that *fidelity to the central power has a holding time of one moon*. Rome's empire had to split when Rome lost control of the seas. An overland trip to the Black Sea took one month. The good news is that with current airplanes a world government is possible. With mach-7 airplanes and matching Maglevs, a world city is also possible. The assimilation of the technologies in political terms, however, will take some time.

to carry it. Seen from this systemic point of view, we can perhaps study the tourist phenomenon through a fresh and objective approach.

There is another fundamental observation made by Zahavi that links instincts and money. Because of its generality it could be dubbed as a money instinct. People spend about 13% of their disposable income on traveling. The percentage is the same in Germany or Canada, now or in 1930. Within this budget, time and money are allocated between the various modes of transport available to the traveller in such a way as to *maximize mean speed*. The very poor man walks and makes 5 km/day, the very rich man flies and makes 500 km/day. The rest sit in between. People owning a car use it for about one hour a day (Figure 12) and travel about 50 km/day (Figure 13). People who do not have a car spend less than 13% of their disposable income, however, presumably because public services are underrated and consequently there is no possibility of spending that share of income traveling one hour per day (Figure 14). Contrary to the risk of all this "exposure," the number of people killed by road traffic seems to be invariant to the number of vehicles (Figure 15).

Technology introduces faster and faster means of transportation, which also are more expensive in terms of time of use. These new technologies are introduced roughly every 55 years in tune with the Kondratiev cycle. Their complete adoption takes about 100 years (Figure 16). We are now in the second Kondratiev for cars and most mobility comes from them. It was about 10 km/day earlier, and is now about 40 km/day. Airplanes are making inroads into this situation and they promise to bring the next leap forward in mobility, presumably with the help of Maglev trains. Hypersonic airplanes promise to glue the world into a single territory: the famous global village.

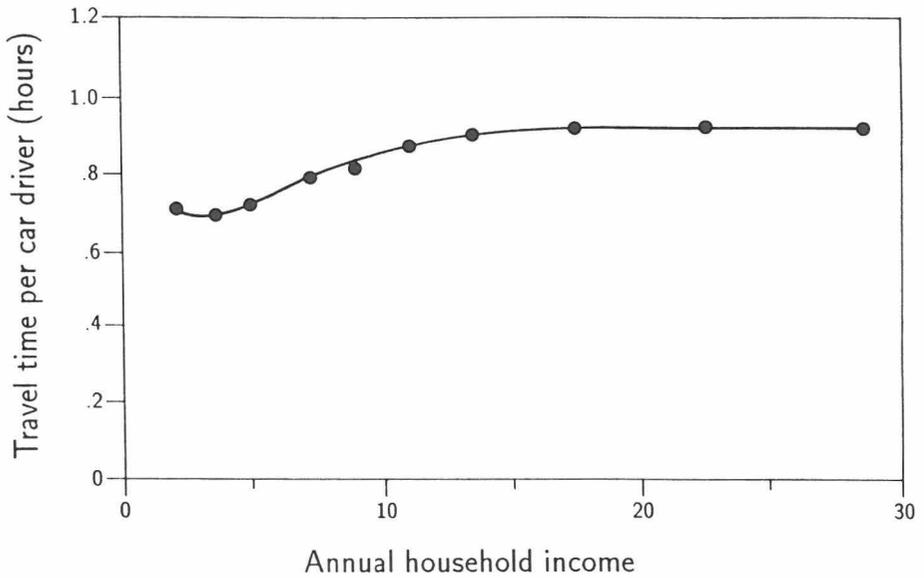


Fig. 12. How long do car owners use their mobility prosthesis. The owner of a car clings to it for most of his "exposure time" of one hour a day. Cars provide high mobility today at costs accessible to most. Low income has a small effect on car use.

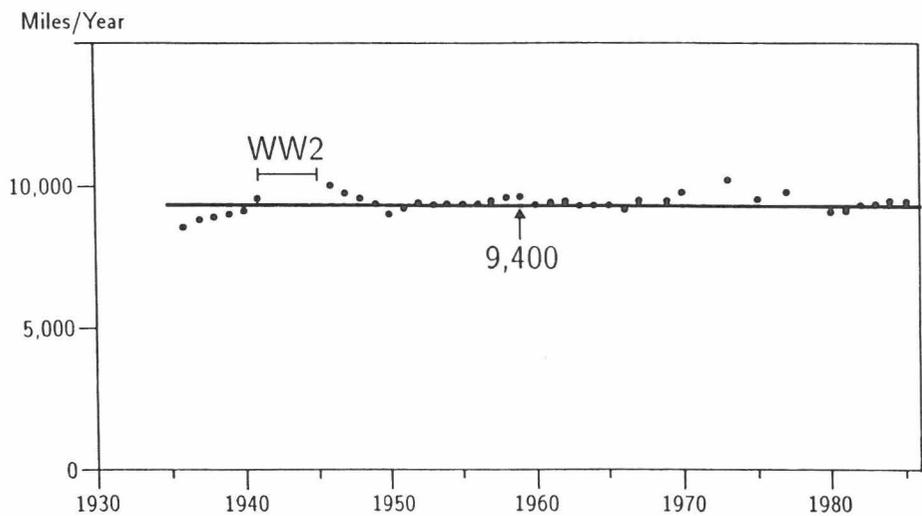


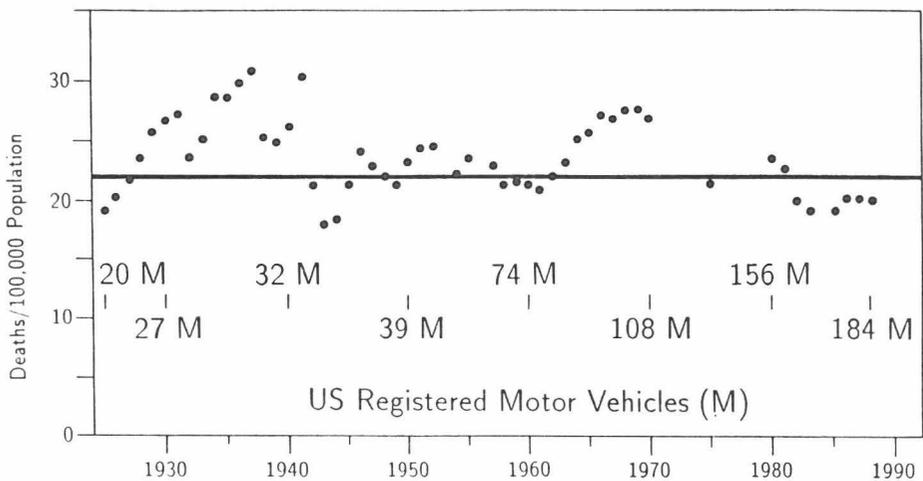
Fig. 13. A historical overview of car mileage in the USA (miles/year). The regularity in the use of cars (about one hour per day) is mirrored in the stability of mileage per year, reported here for the USA. This implies a curious stability in the mean speed, about 30 miles/hr—since Henry Ford's times. Data from [5].

NATIONWIDE vs. Total Household Expenditures, %			
US	1963–1975	13.18 ± 0.38	
Canada	1963–1974	13.14 ± 0.43	
UK	1972	11.7	
West Germany	1971–1974	11.28 ± 0.54	

URBAN vs. Household Income, %			
		<i>With Cars</i>	<i>Carless</i>
Washington, DC	1968	11.0	4.2
Twin Cities	1970	10.1	3.4
Nuremberg Region	1975	11.8	3.5

**Fig. 14.** Rates of travel expenditure in various countries. Expenditure on travel appears to add up to quite a stable mean value of about 13% of *personal disposable income*. This budget is allocated between transport modes in a way that realizes maximum mean speed (i.e., territory). People who do not have a car use public services, which are usually underpriced, and in the available hour for travel appear unable to spend the whole budget.



**Fig. 15.** Death rates due to road traffic and circulating vehicles. Death rates due to motor vehicle traffic appear to be largely independent of the number of vehicles in circulation and stable around 22 per 100,000 per year since Henry Ford's times. We seem to be facing here another basic instinct in risk management. Data from [5].

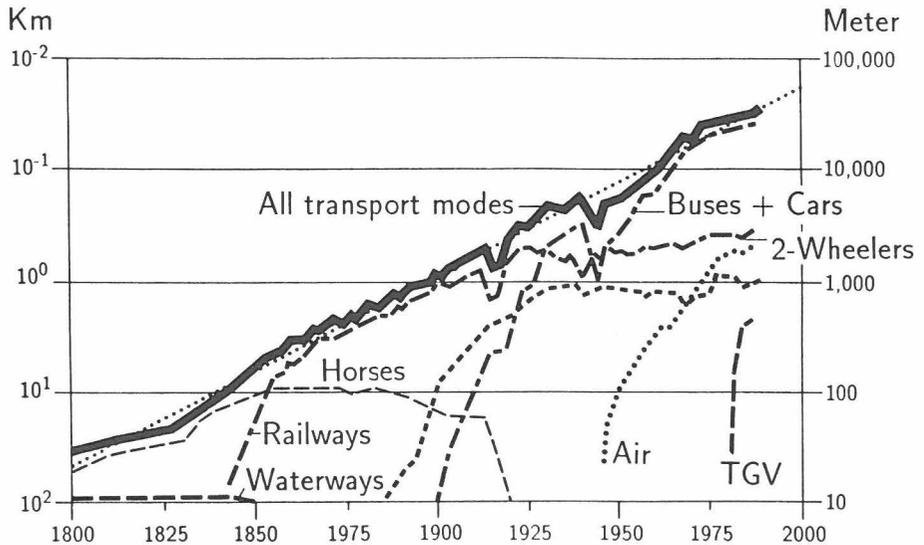


Fig. 16. Technical innovation in transport and the increase in mobility for France. During the last 200 years transport technology has been in search of speed at accessible costs. About every Kondratiev cycle a new basic model of transportation is introduced. The last one was the airplane; the next one will most probably be the Maglev. The share of the fastest mode of transport in the time budget of the traveler keep increasing, with the costs decreasing and his disposable income increasing. The increase in mean speed for the last 200 years for France appears to be a fairly stable 3% per year taking into account all mixes of transport modes. The basic drive of man's territorial instinct is behind this technological evolution. The chart reports distance traveled per day on vehicles [4].

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