Discussion of Nakićenović paper

by Cesare Marchetti

The excellent phenomenological description of the evolution of the transport system by Nakićenović can be better illuminated by expanding on the driving forces, anthropological in nature, that lead man to a relentless search for faster and faster means of transportation.

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 is obvious. However, exploiting a large territory is also expensive, both because it requires the physical exertion of moving over large distances, and because moving means to be in the open, under the possible attack of enemies and predators.

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

The third point is that man has a cave instinct. The protection of the high tree with dense foliage of the tropical rain forest has found a good substitute in the hiding shade of the cavern, where he 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 work of Zahavi of the World Bank at the time he did it, and that Nakićenović quotes in his practical results, is in my opinion most remarkable because it shows the quintessential unity of the 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, giving a robust basis for forecast in space and time.

The basic verification by Zahavi is that the *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. It is curious to observe how pervasive the effects of the instinct are. Even people in prison for a life sentence, and having nowhere to go, walk around one hour a day. (I wonder what happens in closed monasteries.) Walking about 5 km/h, and coming back to the cave for the night, gives a radius of the territory of about 2.5 km and an area of about 25

km^2. This is the definition of the territory of a village, and as Fig.1 shows, this is precisely the mean area of the greek villages today, sedimented through a history of pedestrian populations.

The same principle operates when a city through its importance, political or economic, expands her population and as a consequence her physical size. No city walls of large ancient cities (up to 1800) have a diameter greater than 5 km or 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/h, the physical size of the city can grow in proportion as the historical analysis applied to the city of Berlin clearly shows (Fig.2). The commuting fields, based on cars, of a dozen of American cities are reported in Fig.3. On the same chart and the same scale, if schematized, are also reported the greek villages of Fig.1. *Cars make all the difference.* Having a speed 6 or 7 times greater than a pedestrian, expand daily connected space 6 or 7 times in linear terms, or 50 times in area. Ancient cities had typically a maximum size of about 1 million people. We are moving today toward a 50 million people conurbation like Mexico City (Fig.4). If the Japanese will complete a Shinkansen Maglev connecting Tokyo to Osaka in less than one hour, and with large transportation ca-

pacity, then we will witness a 100 million people city.

It we expand the reasoning, we can muse about a 1 billion people city which would require an efficient transportation system with a mean speed of about 150 km/h. This could happen in China, as *the aggregation stops at cultural and political barriers.* The accent is set on transportation as the unifying principle of the world, and not communication as the current wisdom indicates. One one side the explosion in communication during the last 20 years did not dent transportation expansion; on the other hand, they tend to move together (Fig.5) as Grübler has shown, pointing to a synergetic more than a competitive situation.

Communication and transportation moving together, one can be used as a proxy for the other for measuring the intensity of interactions. We can look, e.g., at interactions between communities of different language (e.g., culture), or between communities of the same language but different political aggregations. The results of the analysis are obtained by looking at telephone calls between cities in Quebec (French speaking) and Ontario (English speaking), and nearby United States. As we can see in Fig.6, *cultural barriers or political barriers* bring a *reduction of communication (and personal movement) by an order of magnitude.*

The reduction can be seen by applying a gravitational model

to communication and transportation, which works well in both cases, except for the very different factor as explained in the legend of Fig.6. This means that the Maglev which Nakićenović proposes for the European core will link Europe but not really unify it in the sense of the Shinkansen. Mixing people may favor cultural compatibility, as history shows. Furthermore, cultural traits are slow to modify and fast transportation may finally raise the central problem of *how to realize a viable multicultural society.* This is not only an inevitable political and religious problem, but also an ecological one so to speak, as it will be a certain bonus to *preserve the cultural diversity* of human population on top of 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 going to basic principles and I tried in that direction. Man, as I said before, is a cave animal and *spends much time in his cave, more that two thirds.* There are his family, his furniture, and his cultural roots. In order to preserve all that it seems almost necessary to permit a person to come back to the cave wherever the work and the business brings him during the day.

My *Gedankenexperiment* which I presented at Marrakech at a congress related to the problem of linking Africa (or better the Magreb) to Europe with a bridge or a tunnel across the Gibraltar Strait, was based on the explicitation of the maximum potential of a *Maglev*. At the Polytechnic of Lausanne a Maglev transportation system between the major Swiss cities has been proposed, having the characteristic of running in an evacuated pipe (air pressure equivalent to 15.000 meters). The reason for that is to have a small tunnel, almost fitting the size of the train. Due to the conformation of Switzerland such connections have to go into tunnels for the most part, and the cost of tunneling is dominant over every other component of the system.

Operating in a vacuum, however, removes the most important constraint to vehicle speed, Maglevs moving more or less frictionless on a magnetic cushion. We still have a limitation on the acceleration that common people can take. I assumed 0.5 G or 5m/sec^2 as acceptable as 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) 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 can go to work in

Paris, and cook dinner for her children in the evening. Vice versa for shopping special items in special cultural atmosphere. With appropriate interfaces such trains could carry hundreds of thousands of people per day. ***The idea behind is to save the cultural roots without impeding work and business in the most suitable places.*** Incidentally, businessman who can afford the extraordinary cost of air travel do exactly that. They take the plane because it permits coming back at night to sleep in their beloved cave, with family, cultural and status symbols in place.

Nakićenović speaks of a European core, and puts it in a relatively short-term time horizon. I must add that functional integration at high hierarchical level (e.g., having a common foreign policy) may not require a full integration at lower level, that integration hitting e.g. against linguistic barriers. A suggestion in that sense comes from an analysis I did on the rank–size of world cities. This rank–size is an image of the ***distribution of tasks*** between the largest cities of the world (or of a nation) in running the system. As shown by Zipf in his seminal work in the Forties, a well-developed system shows a fractal structure in the size of the cities' population. In 1920 London was the world's largest city and her rank No.1 was obvious in terms of politics and finance. The ranking of world cities sat on a nice straight line as it should according to Zipf (Fig.7). If

we repeat the exercise now, we find that the world cities line has a big knee (Fig.8). In a sense, either the world is short of large cities or it is not in some sort at equilibrium.

However, air transportation has made it possible to commute between cities, if not every day, but for the necessary number of times, to the elite of society in functional terms, managers, politicians, professional of 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 Tokyo–Nagoya–Osaka. Assimilating corridors to cities and repeating the exercise we find the fit of Zipf paradigm. This is certainly not a proof but a strong suggestion that the movement of the elites is sufficient for a functional integration at the highest level. Most corridors are between cities culturally and politically homogeneous, a generalization is then not advisable. But some strong interconnections between cities like London and Amsterdam may be testbeds for studying the effect of barriers at the level of the elites also in this case.

If these effects are not so strong as for the bulk, in the sense they can be digested in a relatively short time, then *hypersonic planes* operating shuttles at world level with elites coming back to their cave at night wherever they have to go, can become the *backbone*

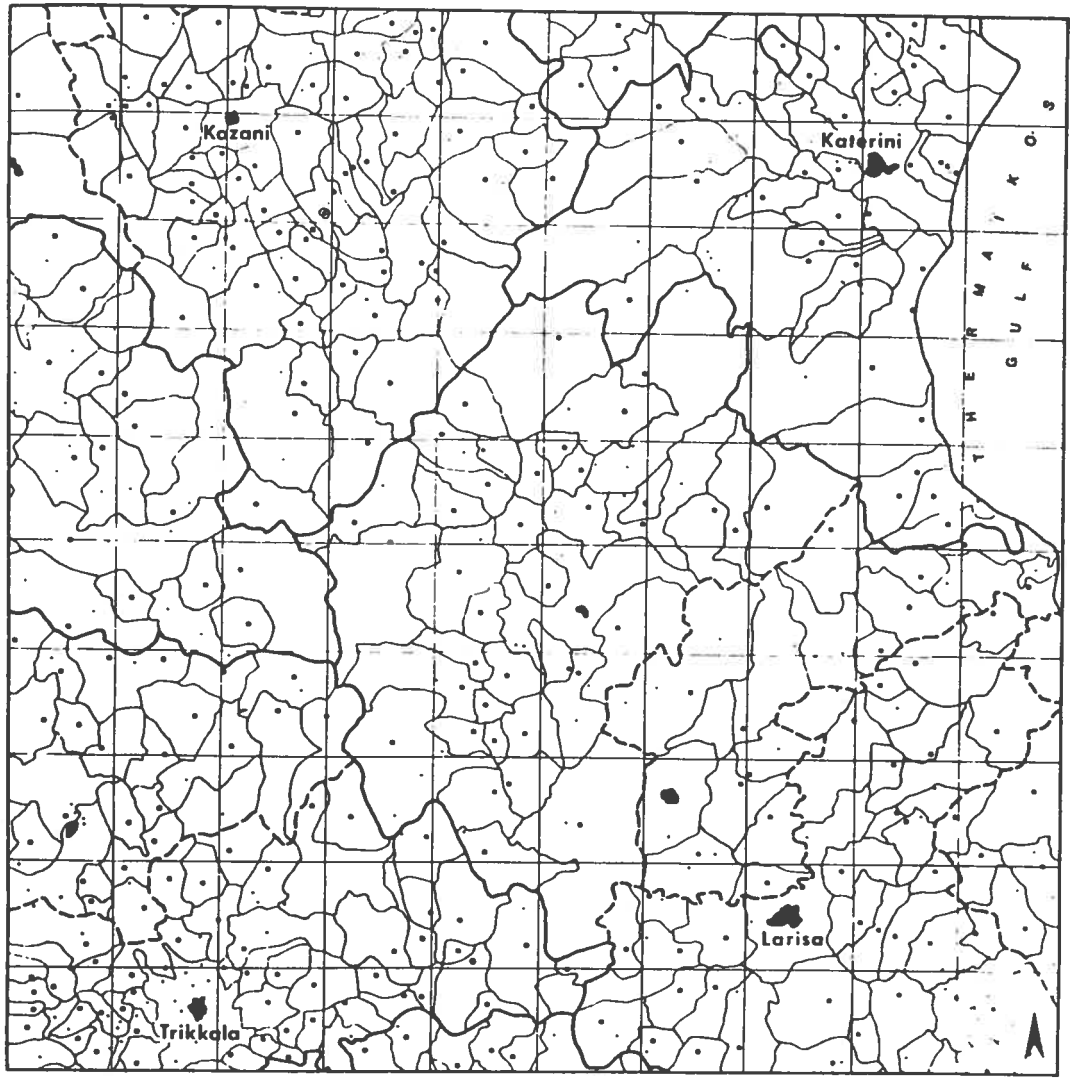
of a single world. Speed is a unifying principle as the case of the evolution of "on foot empires" and "horseback empires" in China shows (Fig.9). They finally reached the same final dimension *measured in time.*

Fig.1

The agricultural area referring to a village has been settled along the centuries. Here is reported a piece of Greece, with villages marked as points on the map. the mean area around the villages is a little above 20 km^2, pointing to a radius of about 2.5 km. This is also the ***largest*** radius of the walls of ancient citities, like Rome, Persepolis, or Marrakech, or Vienna. Also the connected part of Venice has such dimensions.

Fig.1

Village Patterns in Greece



Mean area 22 km^2

Fig.2

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 1800 Berlin was very compact with a radius of 2.5 km pointing to a speed of 5 km/h, 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 of cars of about 40 km/h.

Fig.2

Wachstum einer Großstadt (Berlin)

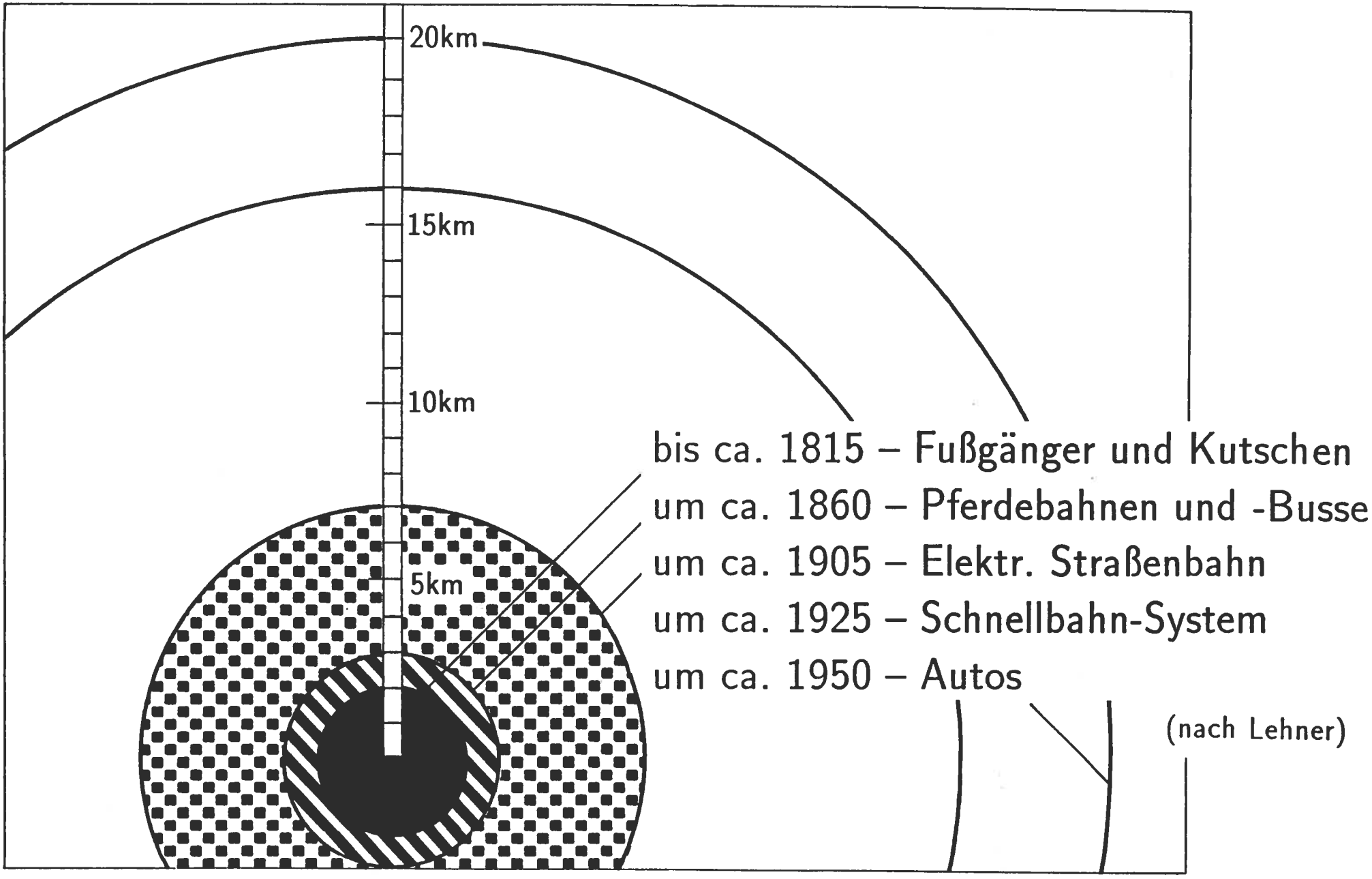
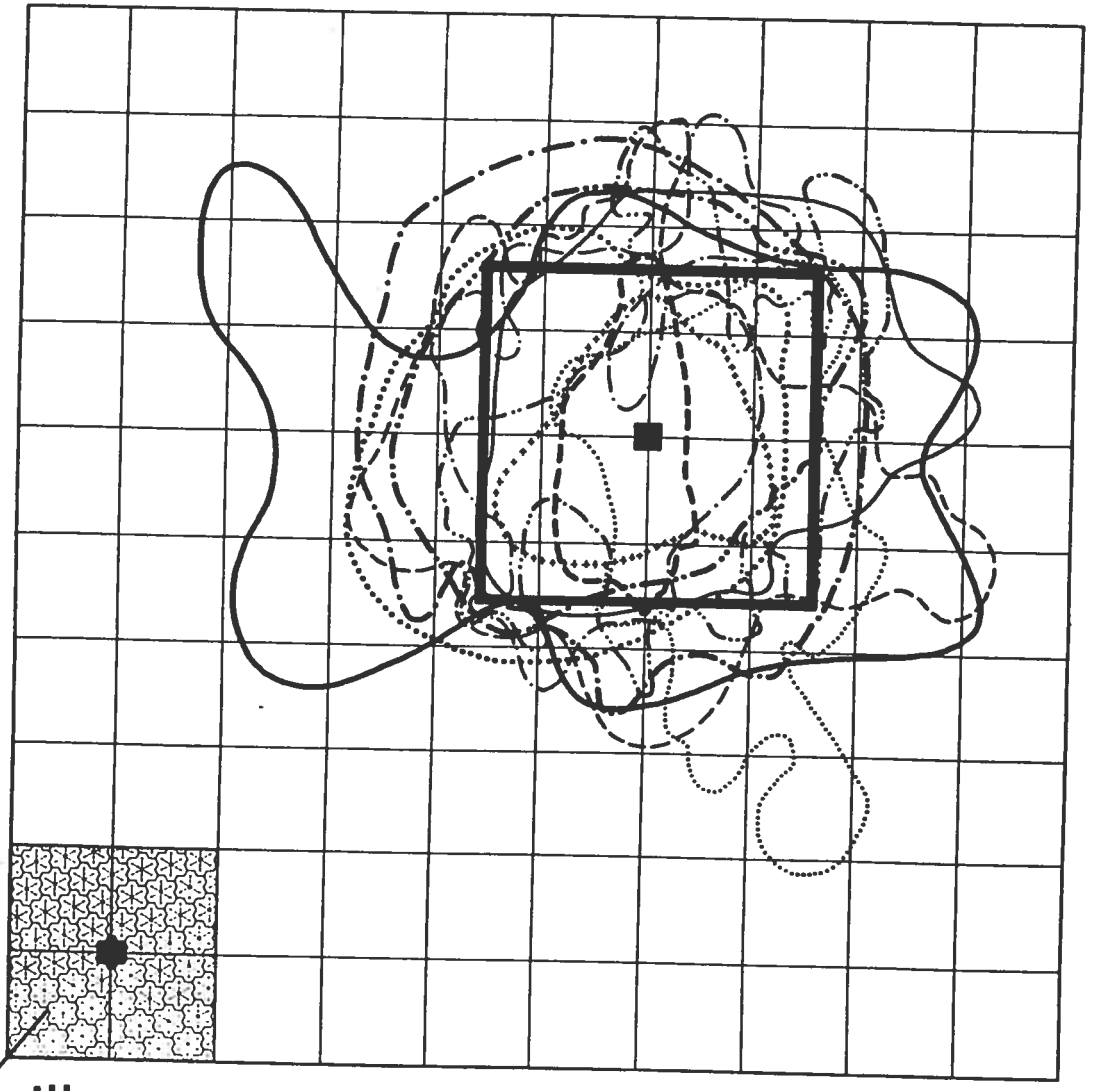


Fig.3

The geography of the walking man is here reported together with that of the driving man, commuting in a number of American cities. As cars have a mean speed about 8 times that of a pedestrian, so are the radiuses of commuting. The scale is the same. The areas accessible, the territory, however, grow as the square, so the driving man has a territory about 60 times larger.

Fig.3

Commuting Fields of Eleven American Cities



Greek village pattern in scale

Fig.4

At the density of the Hadrian Rome (1 million people over 20 km^2), we could pack 60 million in a city where the speed of transportation gives access to a 60 times larger area. 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.

Fig.4

MEXICO CITY: CITY SIZE

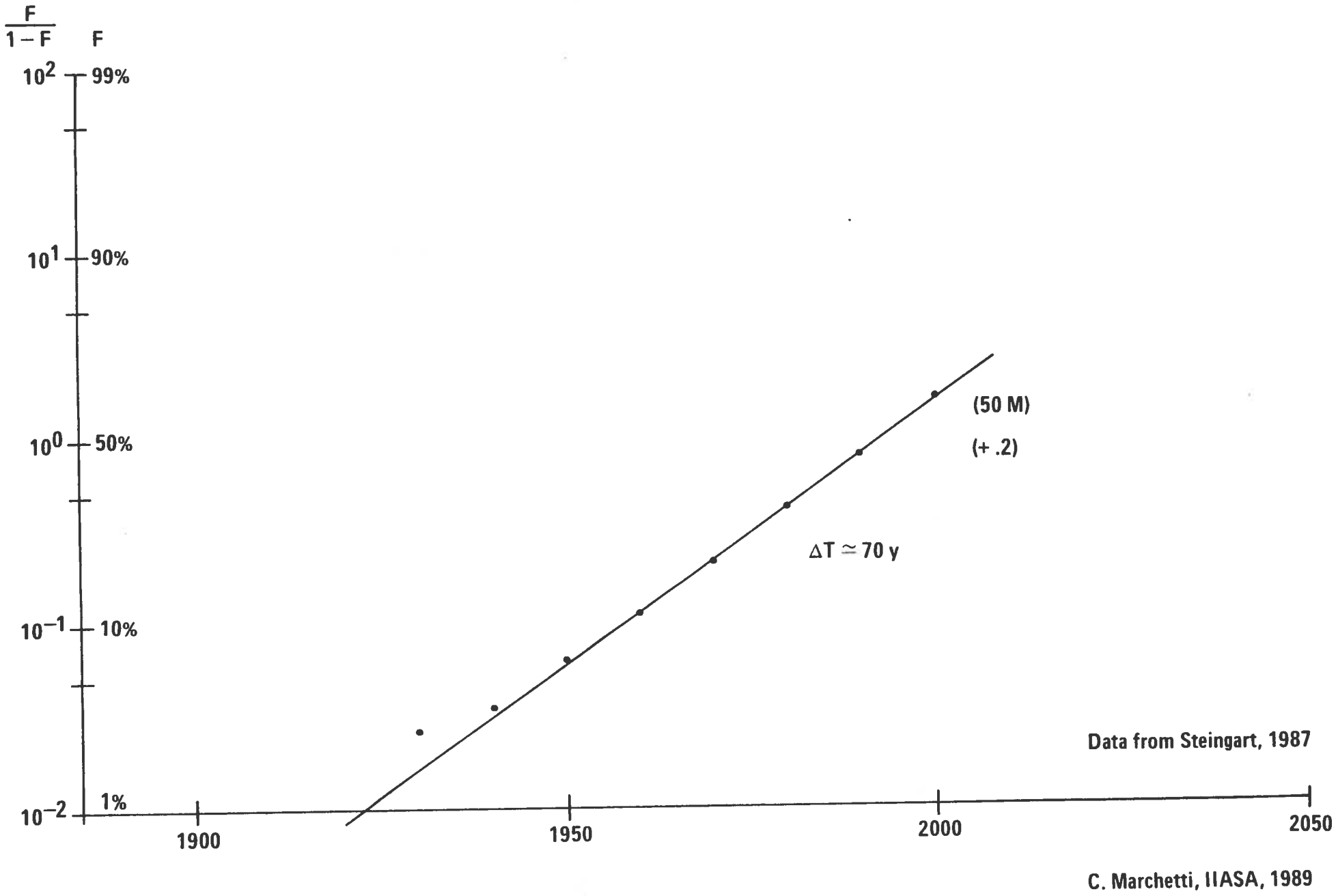


Fig.5

There is much talk about the communication explosion and the possibility it substitutes physical transport or persons. Up to now communication in terms of messages exchanged and transportation in terms of pass-km, seem to move together. The increase in the personal territories increases the number of information exchange points accessible only by telecommunication. In a village all exchange is done face to face without any need of mechanical devices to communicate.

Fig.5

France – Transport & Communication Index

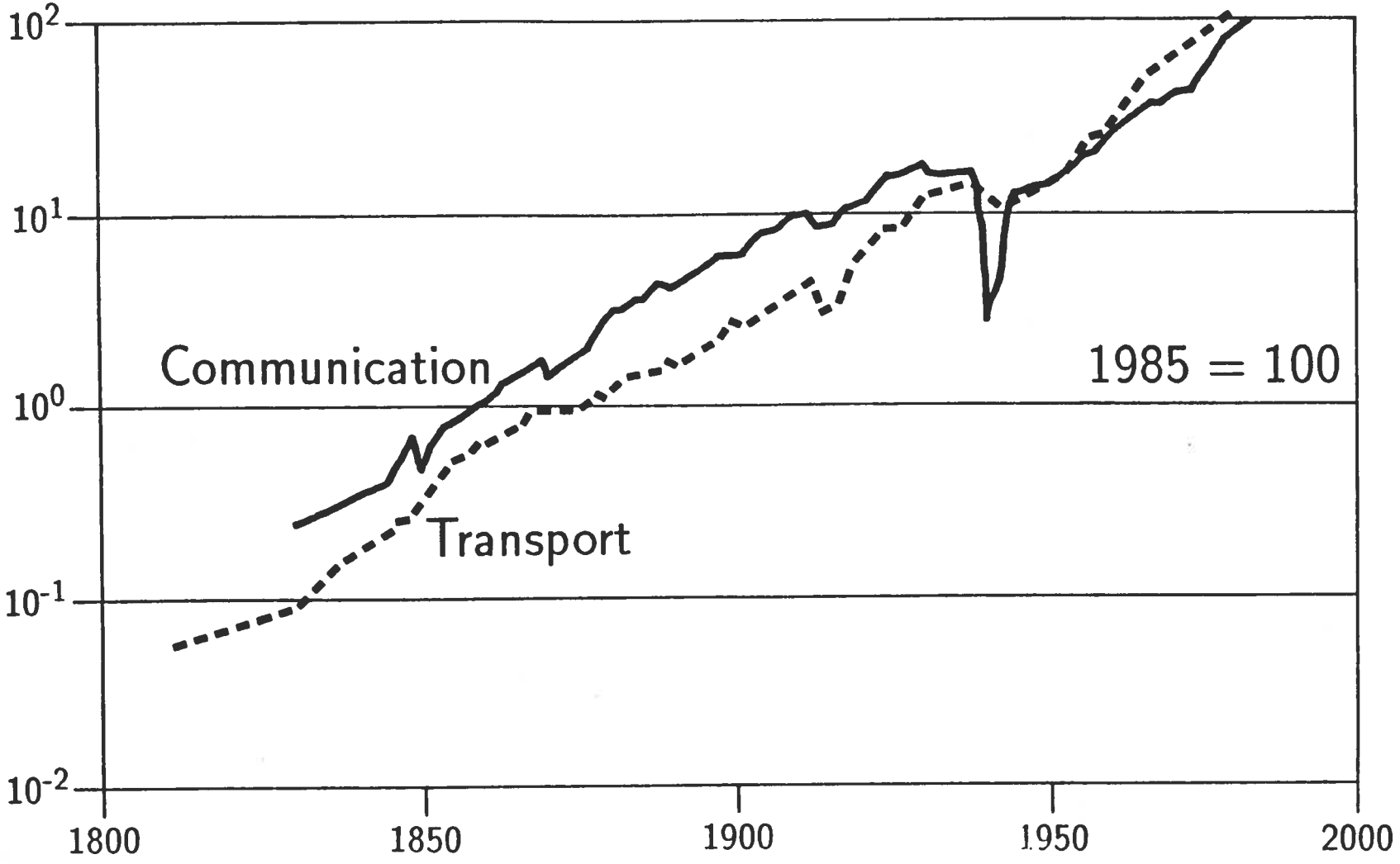
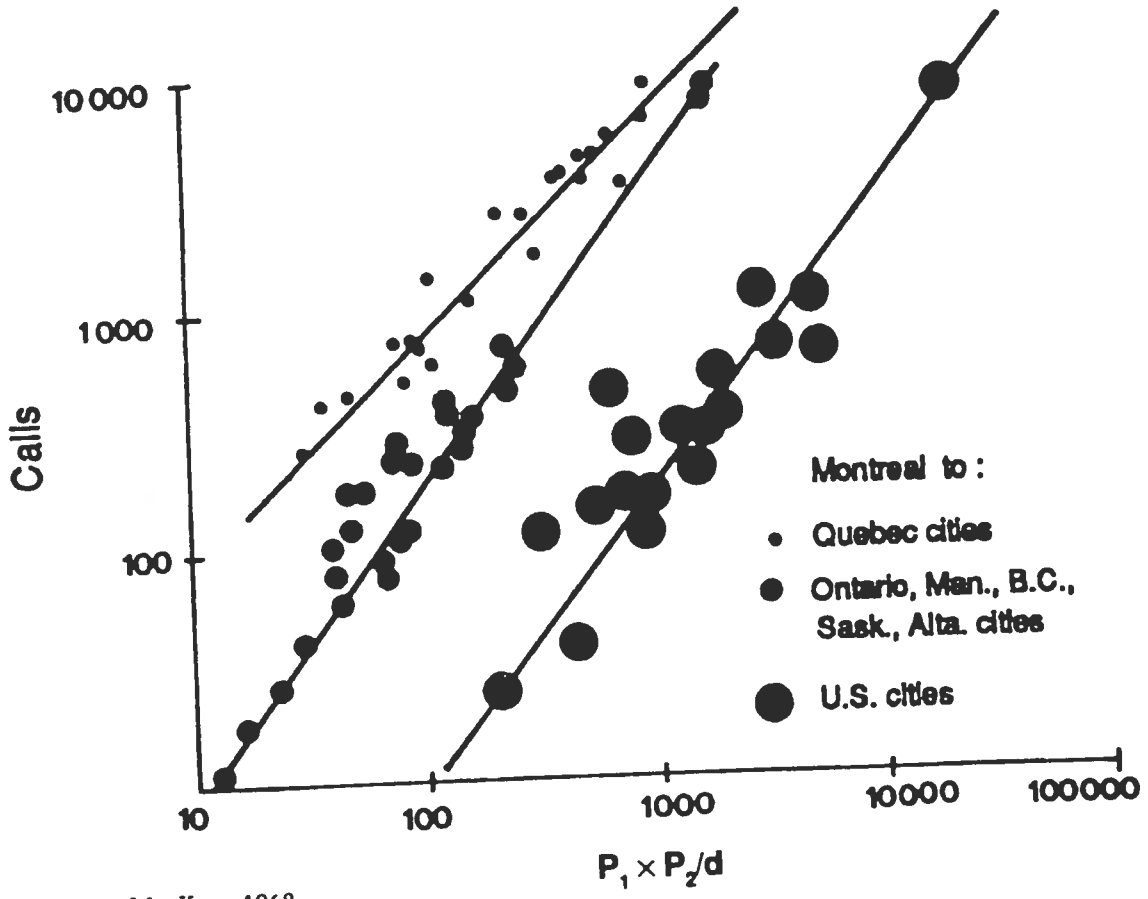


Fig.6

The parallelism between e.g. message exchange by telephone and traveling permits to use the first as a proxy for the second, at least in an approximation were we to look for ballparks. Here we are looking for the barrier effect of political and cultural differences. the base model is gravitational (Zipf), meaning that in a homogeneous system telephone calls between two cities is proportional to the product of their population divided by some power of their distance.

The model works also for systems of different language (here Ontario and Quebec) but equal political system and for systems of equal language (Ontario and nearby USA) but different political systems. However, the *proportionality coefficients are an order of magnitude smaller*, showing that cultural and political differences are very powerful interchange barriers. Similar results are obtained looking at travel inside Europe whose real unification may take longer than the construction of a fast connection grid of Maglevs.

Fig.6



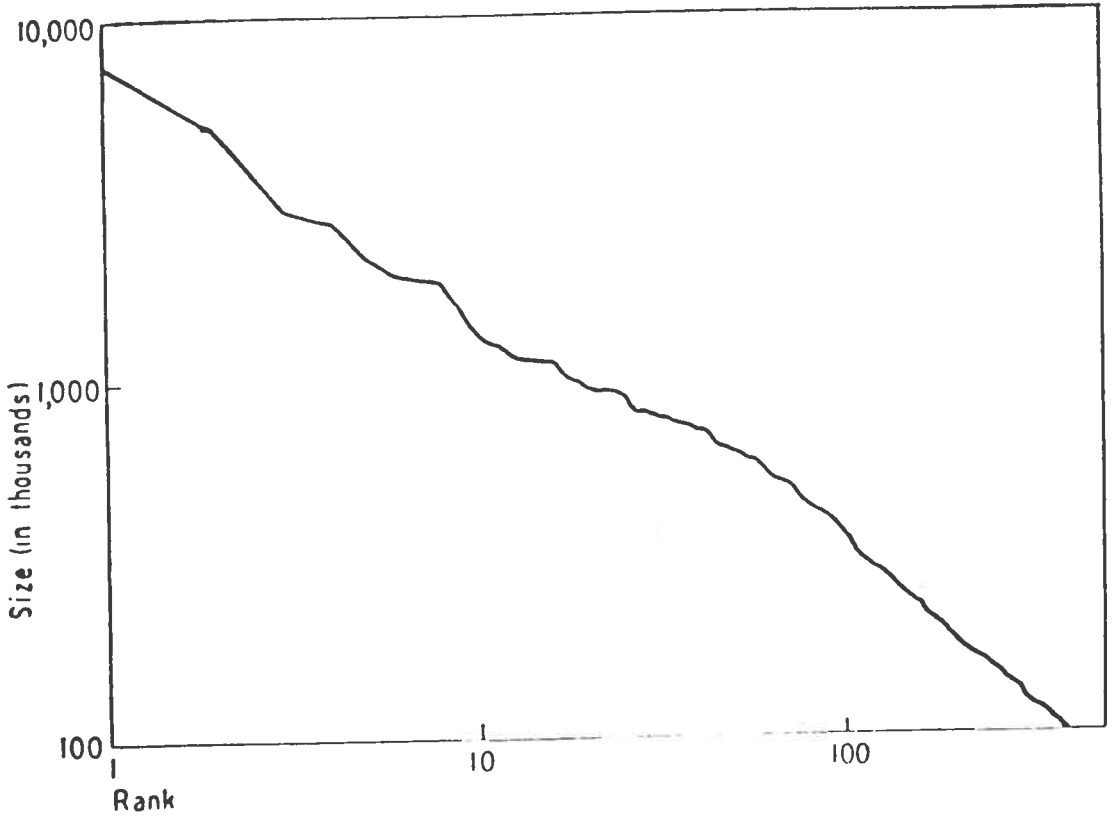
SOURCE: MacKay, 1968.

Gravitational plot of telephone calls between cities in French speaking Canada, English speaking Canada and the US [calls+pop(1)x pop(2)/distance]

Fig.7

Zipf showed that in an interconnected system the size of the largest cities tends to be in constant ratio when ordered in decreasing sequence. According to Zipf, who ordered the sequence in a log-log rank-size, matching a straight line is the manifestation of some sort of equilibrium in the distribution of tasks. Rank No.1 belongs to the city with the highest rank functions, world politics and finance. London fitted well into that position in 1920. The chart comes from Zipf.

Fig.7



Cities of the world (about 1920)

Fig.8

If we repeat the Zipf chart of 1920 today, we find that city size bends sharply. Projecting from the smaller cities upward one could say that, in the Zipf logic, we are short of very large cities. However, counting "corridors", i.e., set of cities connected with air shuttles and fast trains, as single units, we find Zipf's order again. This may mean that the daily movement of the elites is sufficient to ensure the highest rank functions, corresponding to sizes equal to the sum of the connected cities. A good omen and pathway for the unification of Europe in the concert of world power.

Fig.8

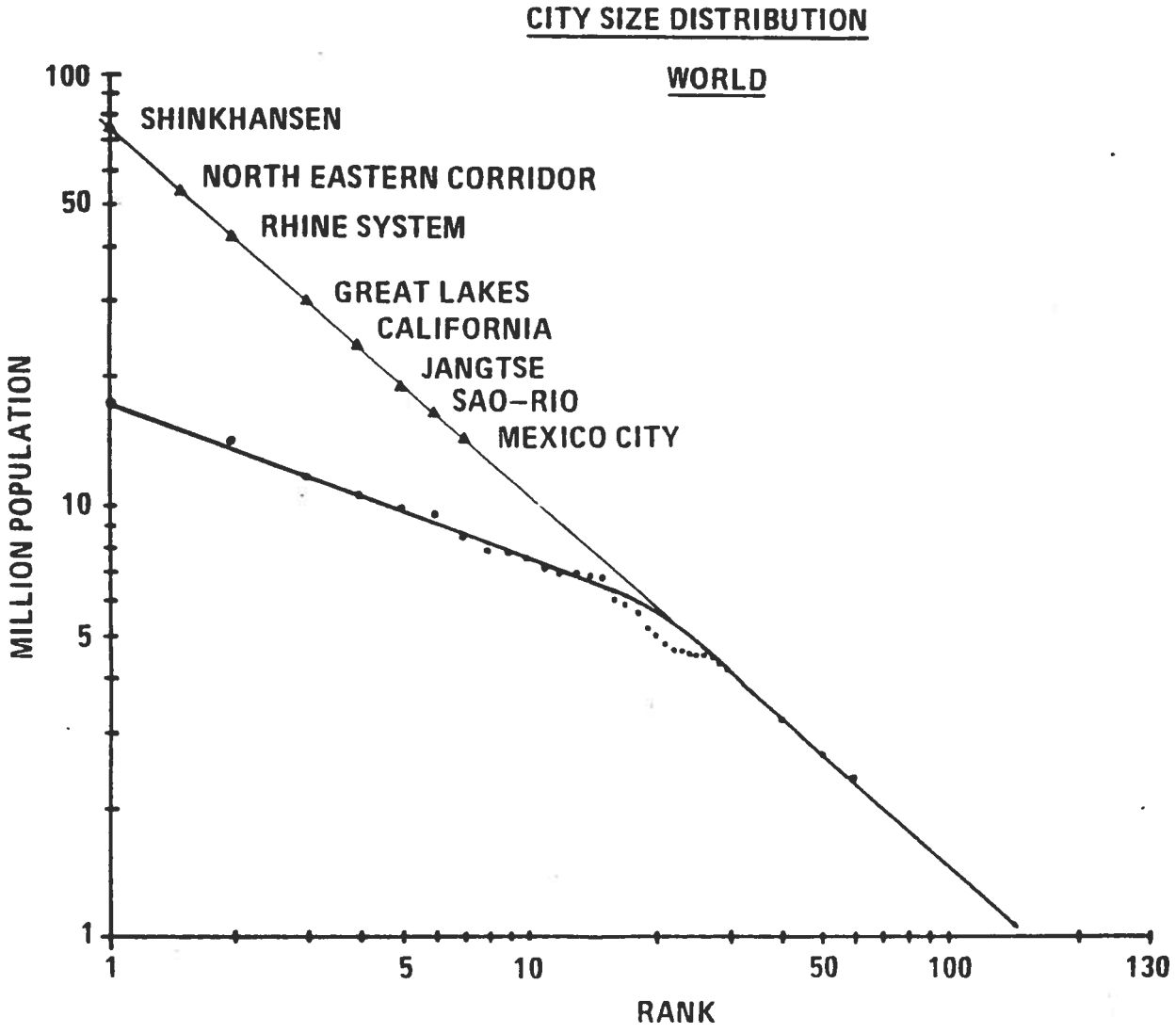
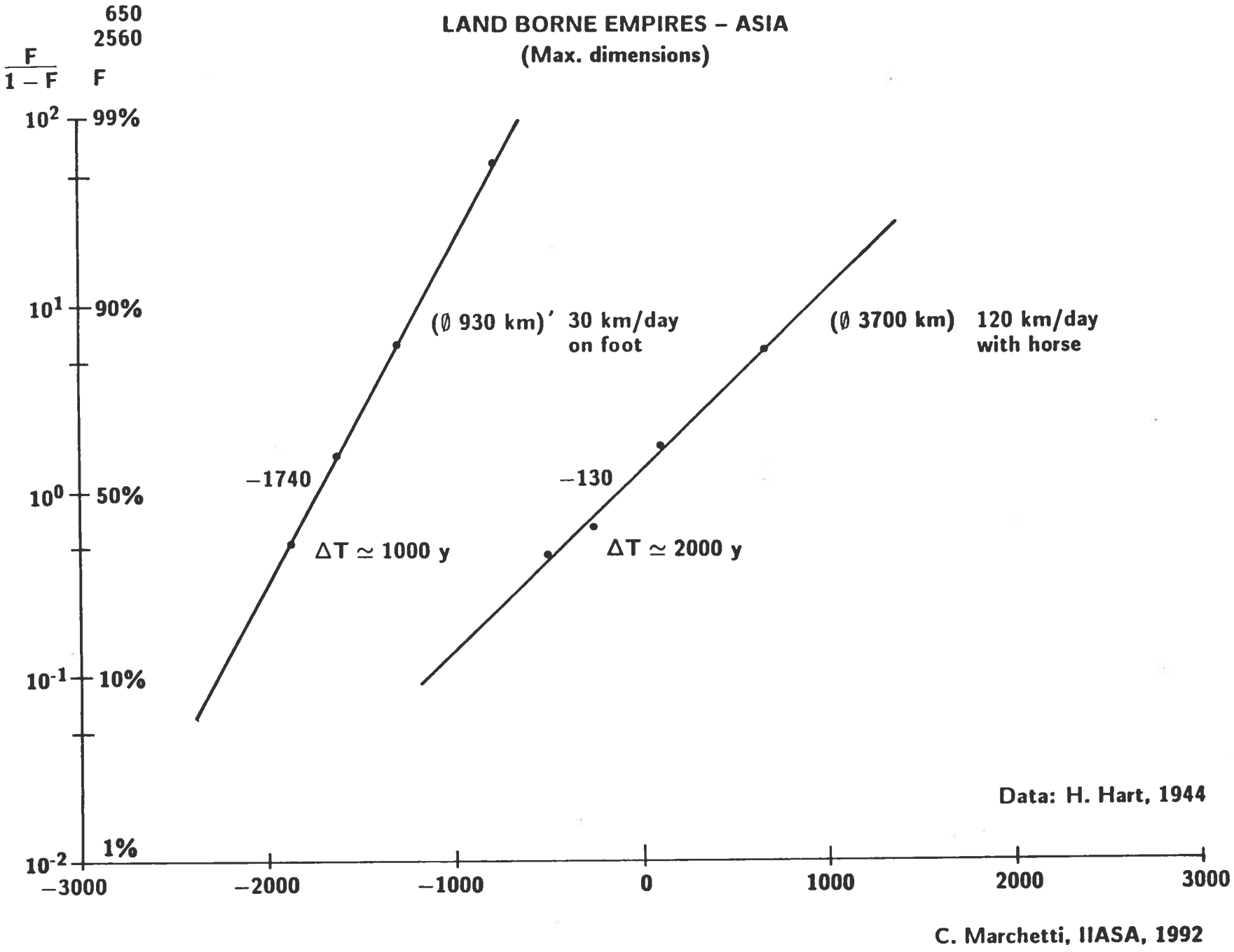

CITY SIZE DISTRIBUTION
WORLD
100
50
10
5
1
MILLION POPULATION
SHINKHANSEN
NORTH EASTERN CORRIDOR
RHINE SYSTEM
GREAT LAKES
CALIFORNIA
JANGTSE
SAO-RIO
MEXICO CITY
1
5
10
50
100
130
RANK

Fig.9

As the Chinese say, history contains all useful precedents. It may be interesting to muse 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 10^6 km^2 and $\sim$ 10 10^6 km^2, or *mean radii* of $\sim$ 450 km and 1800 km. In both cases this corresponds to a 15-day trip 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 and China had finally to split with not very constructive consequences. The good news is that with current airplanes a world government is possible. With mach-7 airplanes and matching Maglevs also a world city is possible. The assimilation of the technologies in political terms, however, may take some time. We are trying to construct a logic to evaluate it.

Fig.9


LAND BORNE EMPIRES – ASIA
(Max. dimensions)
650
2560
F / 1 − F
F
10^2
99%
10^1
90%
10^0
50%
10^-1
10%
10^-2
1%
(Ø 930 km)' 30 km/day
on foot
(Ø 3700 km) 120 km/day
with horse
−1740
ΔT ≃ 1000 y
−130
ΔT ≃ 2000 y
Data: H. Hart, 1944
−3000
−2000
−1000
0
1000
2000
3000
C. Marchetti, IIASA, 1992