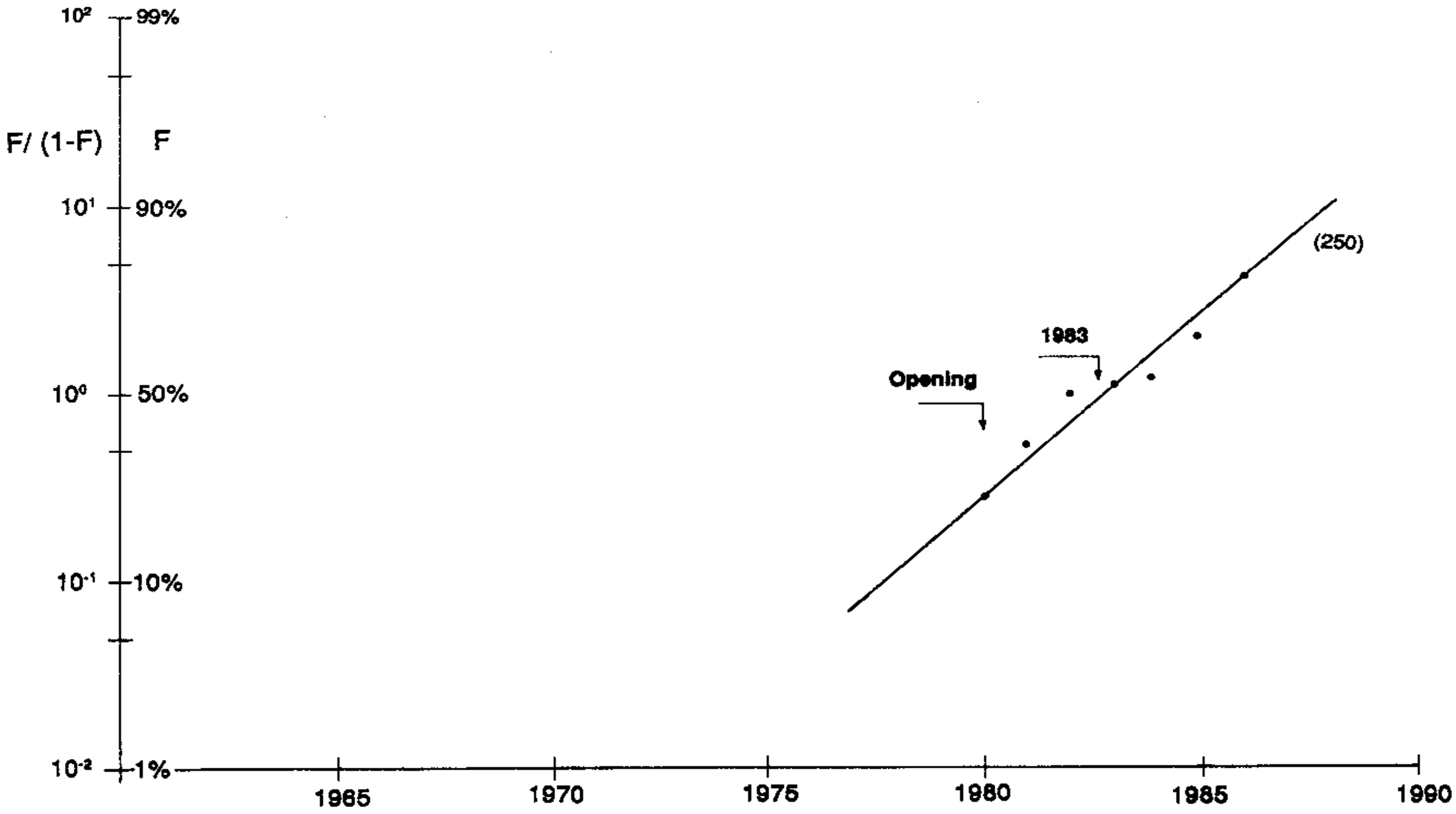
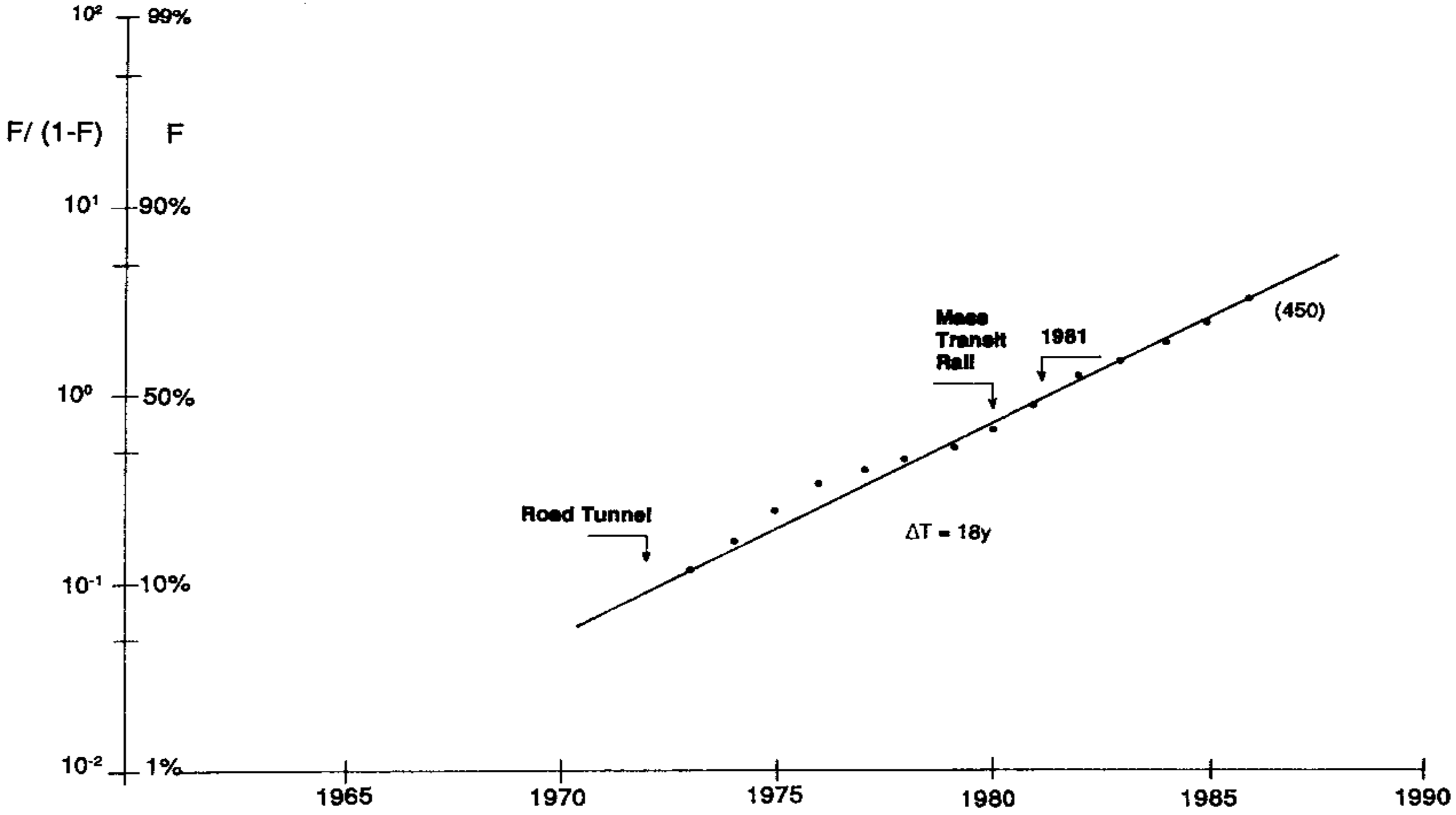
FIGURE 4.29. *Trend in total passengers (10^6) crossing Hong Kong Harbor by Mass Transit Railway*



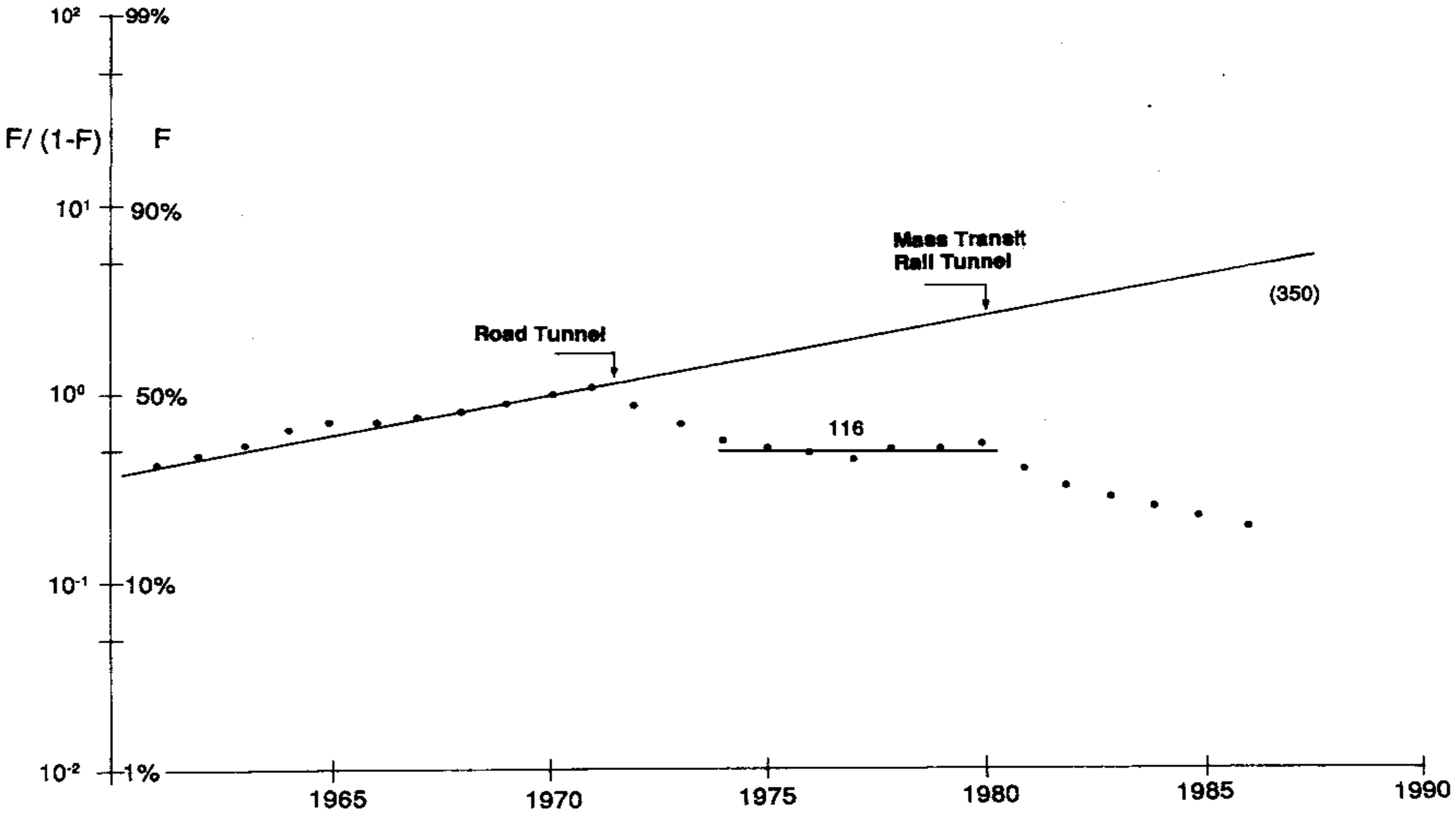
Based on data provided by the Hong Kong Government Transport Department, 1987.

FIGURE 4.30. *Trend in total passengers (10^6) crossing Hong Kong Harbor by public ground services (franchised buses and Mass Transit Railway)*



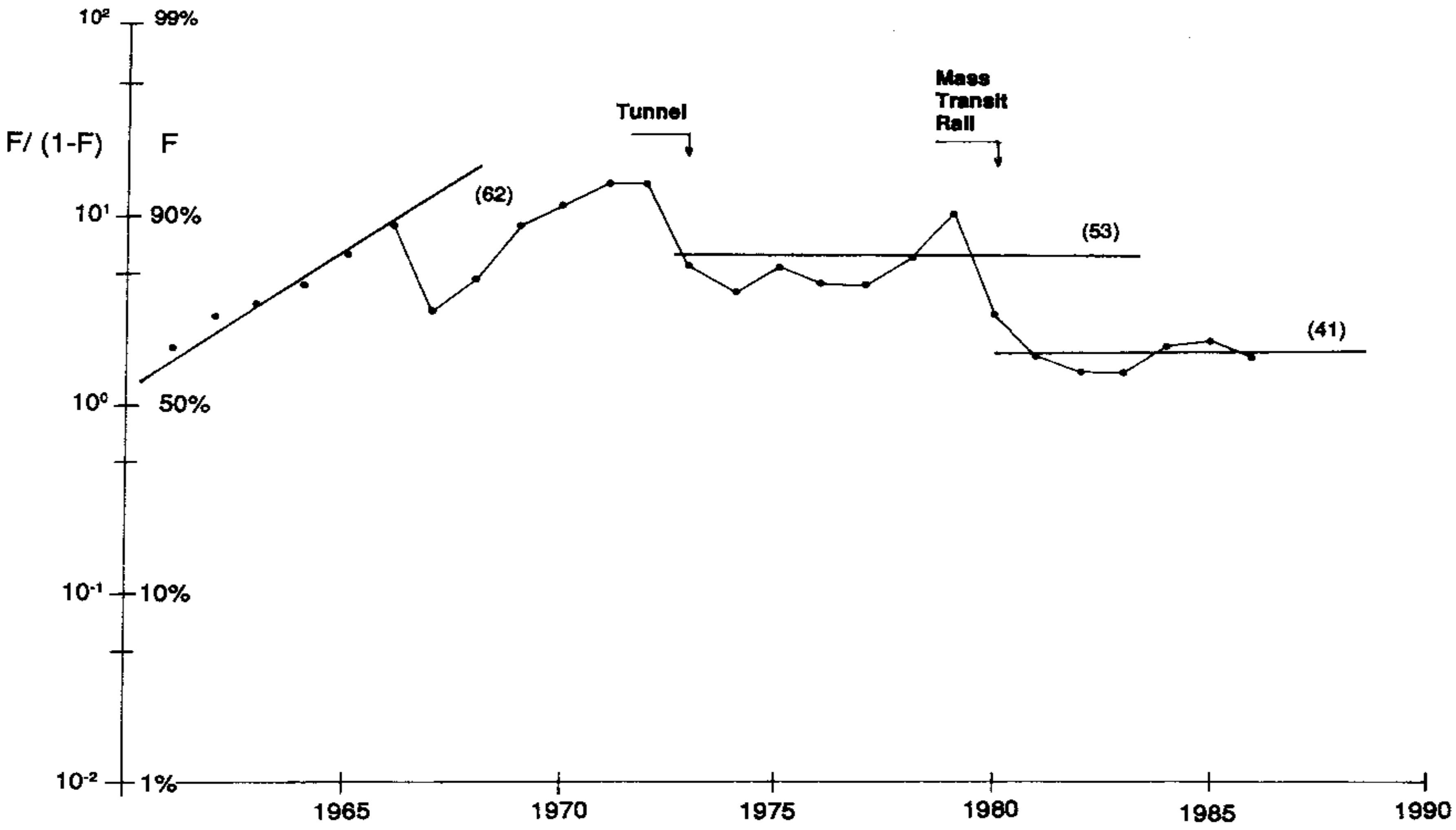
Based on data provided by the Hong Kong Government Transport Department, 1987.

FIGURE 4.31. *Trend in total passengers (10^6) crossing Hong Kong Harbor by Hong Kong Yaumati Ferries*



Based on data provided by the Hong Kong Government Transport Department, 1987.

FIGURE 4.32. *Trend in total passengers) 10^6) crossing Hong Kong Harbor by Star Ferries*



Based on data provided by the Hong Kong Government Transport Department, 1987.

of saturation, as some times happens. The tunnel had no drastic effect, merely leveling off of the passengers carried. The Mass Transit Railway, on the contrary, drained away 12 million passengers in one year, and apparently in a stable form.

It is noteworthy that the sum of the passengers carried by both lines and compared with the total traffic (figure 4.27) declines in a perfectly smooth fashion.

The Hong Kong case, with its impeccable documentation, allows an insight into the mechanisms of traffic evolution and substitution of unparallel quality that is invaluable when applied to the Messina case.

4.3.3. Lisbon

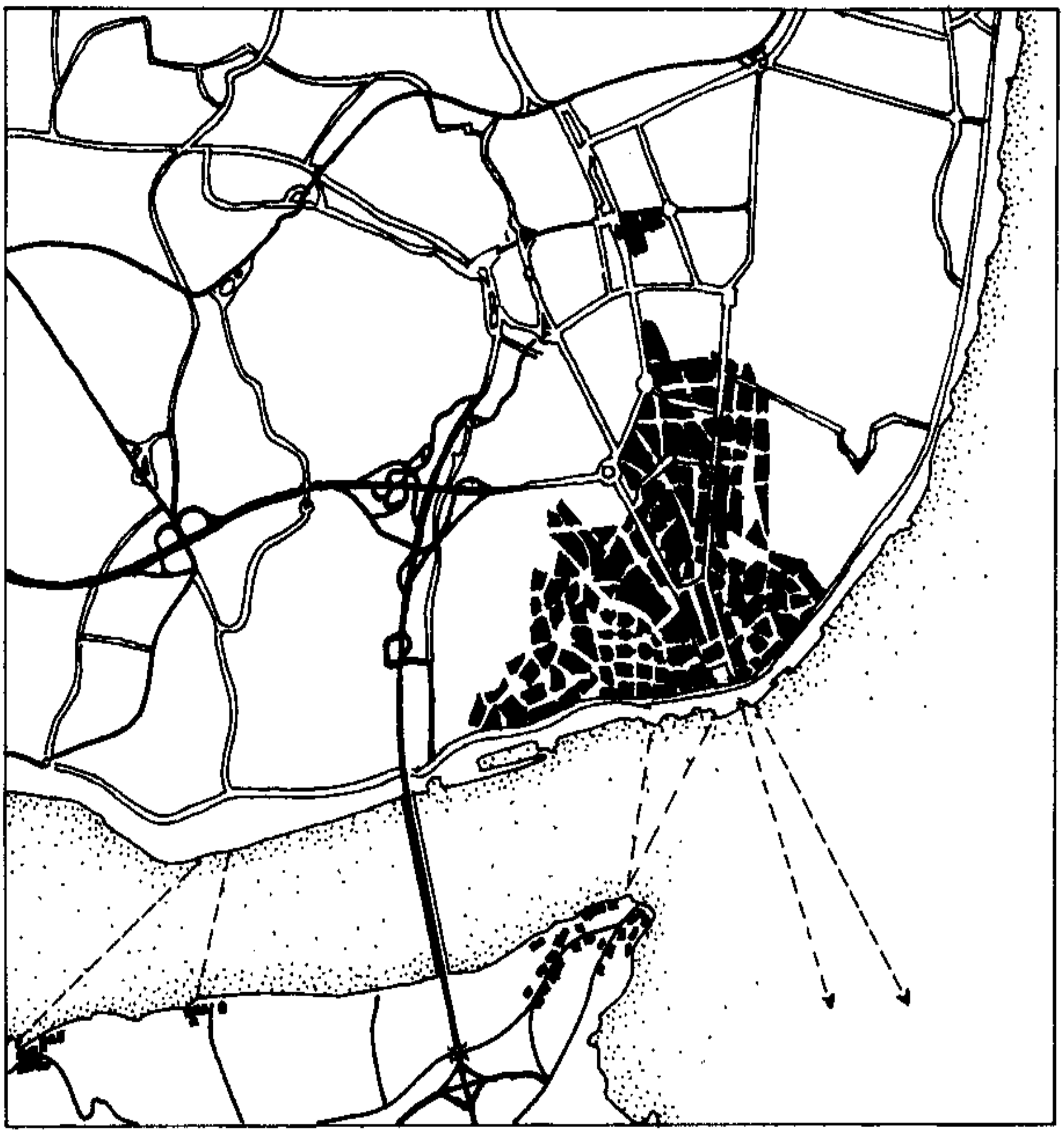
The center of the city of Lisbon is located on the northern side of the Tago River estuary (figure 4.33). As happens when any natural barrier is not too impervious, an independent city developed on the southern side. The estuary is relatively wide, a couple of kilometers at the neck, more or less like the harbor channel between Hong Kong Island and Kowloon. Because the ferries have transit times, inclusive of access and waiting times, above the critical half an hour, the two cities behaved independently, i.e., f*erry traffic could be considered as intercity traffic.*

As in the case of Istanbul, the decision to build a bridge had no connection with the idea of easing local traffic. The bridge was to be part of a motorway system, intended to shorten the route linking the north and the south of the country. The very visible location near the capital was probably chosen for political reasons: the bridge symbolized the creative capacity of the regime.

While their purpose differed, in part, the Lisbon and Istanbul bridges affected their urban areas in the same way. The cities on the southern bank (primarily, Almade and Seixal) were linked to central Lisbon by ferries carrying people and vehicles. As in Istanbul, waiting, loading, unloading, and transit takes about 40 minutes, which our TTB model defines as an intercity trip. As in the case of Istanbul, the construction of a bridge bringing transit times below the twenty-minute threshold for daily commuting created an explosion of new traffic, as the two urban areas merged functionally into one, with traffic levels characteristic of intracity traffic.

The evolution of the ferry traffic across the Tago is shown in Figu-

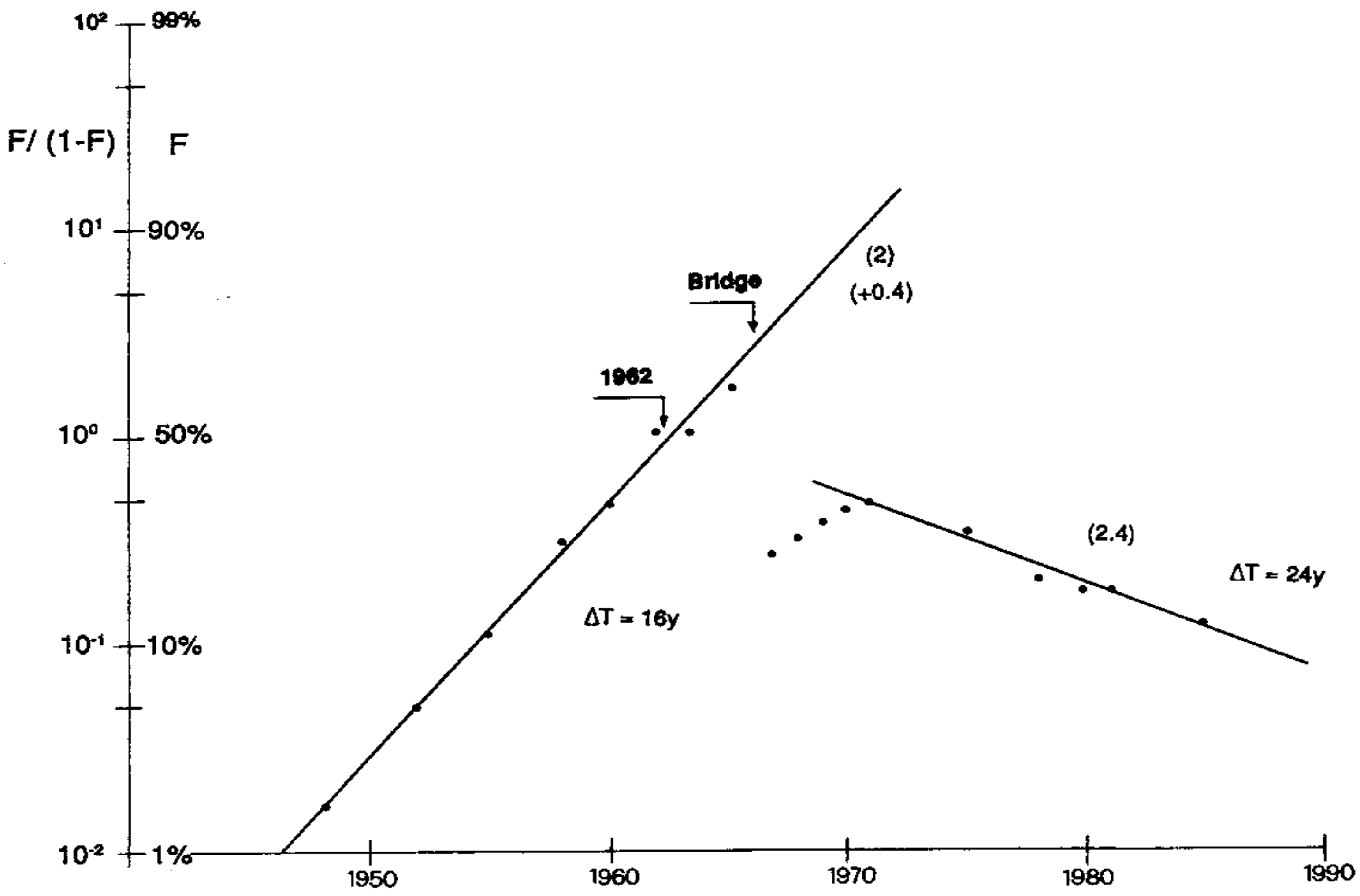
FIGURE 4.33. *Centre of the city of Lisbon*



re 4.34 for vehicular traffic. Here we have some pre-1940 data, which allows us to pinpoint a previous saturation level of 0.4 million vehicles a year around 1940. During the present Kondratiev cycle, traffic has developed along normal lines, although with a fairly short time constant, 16 years, pointing to some sort of technical saturation of the ferry system. The saturation point can be estimated at 2.0 million vehicles per year plus the carryover of 0.4 million from the previous Kondratiev cycle.

The opening of the bridge in August 1966 instantly reduced this ferry vehicular traffic by 1.0 million vehicles in comparison with expected growth in 1967. The loss still totaled 1.0 million in 1971 owing to

FIGURE 4.34. *Trend in total vehicles (10^6) using Lisbon ferry service*



Based on data provided by Ferreira, 1987.

a certain recovery of ferry traffic. After that, the traffic appears to smooth out with a time constant of 24 years. It should be 0.24 million in 1988, or 10% of the saturation point (2.0 million + 0.4 million from the previous K-cycle).

If we look at the bridge *per se* (figure 4.35), vehicular traffic began at about 2.6 million a year and increased logistically with a saturation point of *26 million vehicles* due to be reached in the first half of the 1990s. The time constant of 20 years is the correct one to match saturation with the end of the K-cycle. This saturation is neatly *ten times larger* than in the case of the ferry taken in isolation. As vehicular traffic on the ferry is steadily disappearing, we can conclude that *the bridge has created 23.6 million annual vehicle transits.*

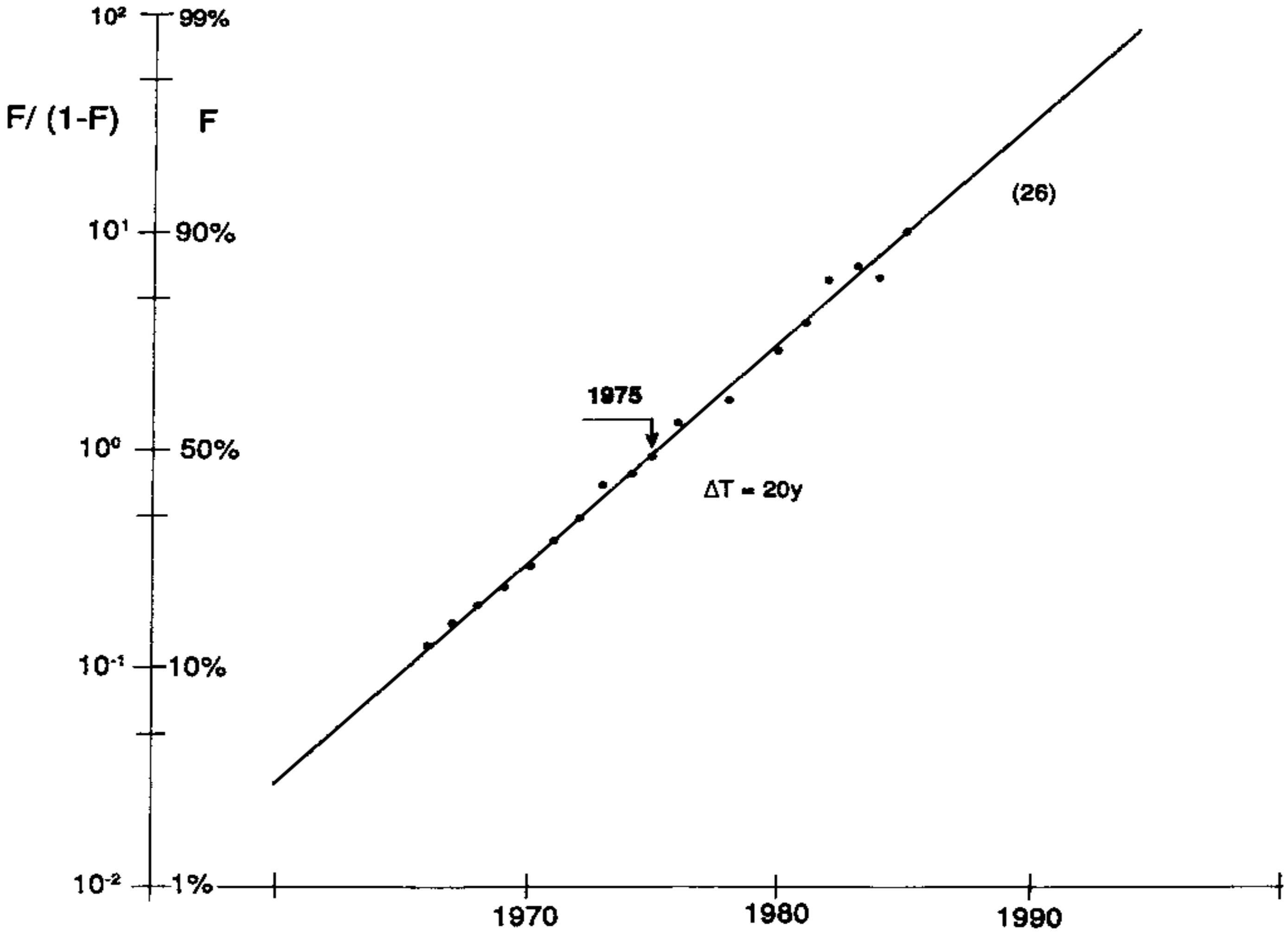
We can also look at the vehicular traffic, ferry plus bridge, using the same 26 million vehicles per year as the only saturation point (figure 4.36). This procedure is not strictly correct, but it can be justified because ferry vehicular traffic is already fading out and the chart is intended only to give a *vue d'ensemble.*

For passenger traffic, it is not possible to make a general map, because the data for the bridge are not available. They can only be roughly estimated as the traffic is a mixture of cars, buses, and trucks. For that reason, the ferry traffic of passengers must be analyzed *per se.* As shown in figure 4.37, passenger traffic on ferries saturated at around 10.0 million per year at the end of the K-wave in 1940, and should grow by another 40 million for this current wave. Although some instabilities appeared between 1974 and 1980, they seem unrelated to the opening of the bridge in 1966, because for six years traffic kept growing as usual. The time constant of 26 years is correct for a process starting at the beginning of a K-cycle and ending with it.

Overall, there was an obvious breakthrough in the volume of traffic due to the opening of the bridge – an order-of-magnitude increase, in comparison with the preceding context, if we look at the bare saturation levels. Following the principles of traffic generation, this should be local traffic, stimulated by the shortening of transit times *below the critical level.*

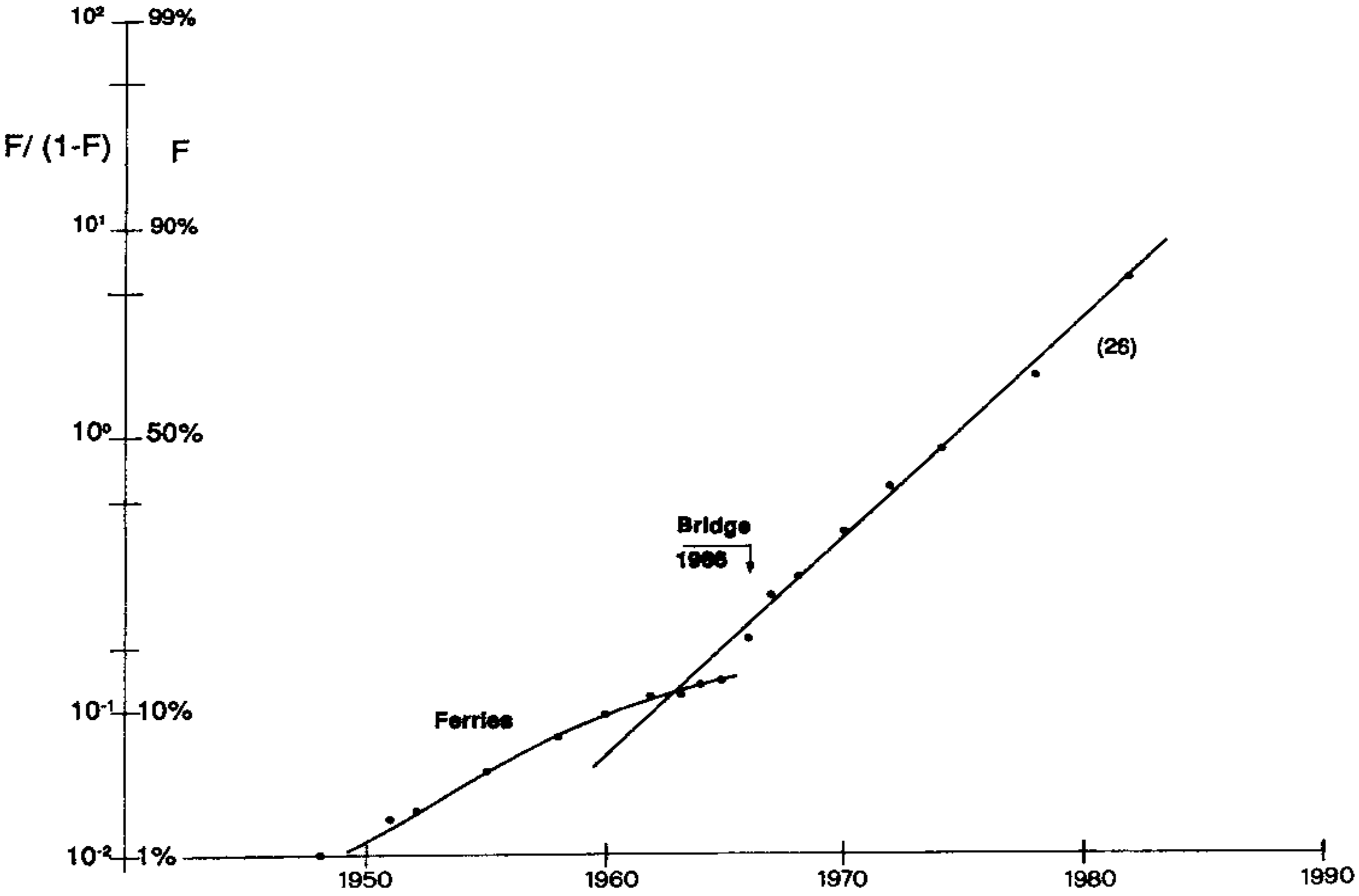
This hypothesis was confirmed by a 1979 inquiry on origin-destination of vehicles crossing the river. Most of the traffic is of urban-suburban character, linked to the urban development of the southern bank. Because urban developments and city growth have time constants much longer than the 20 years predicted for the development of traffic on the

FIGURE 4.35. *Trend in total vehicles (10^6) using the Tago Bridge*



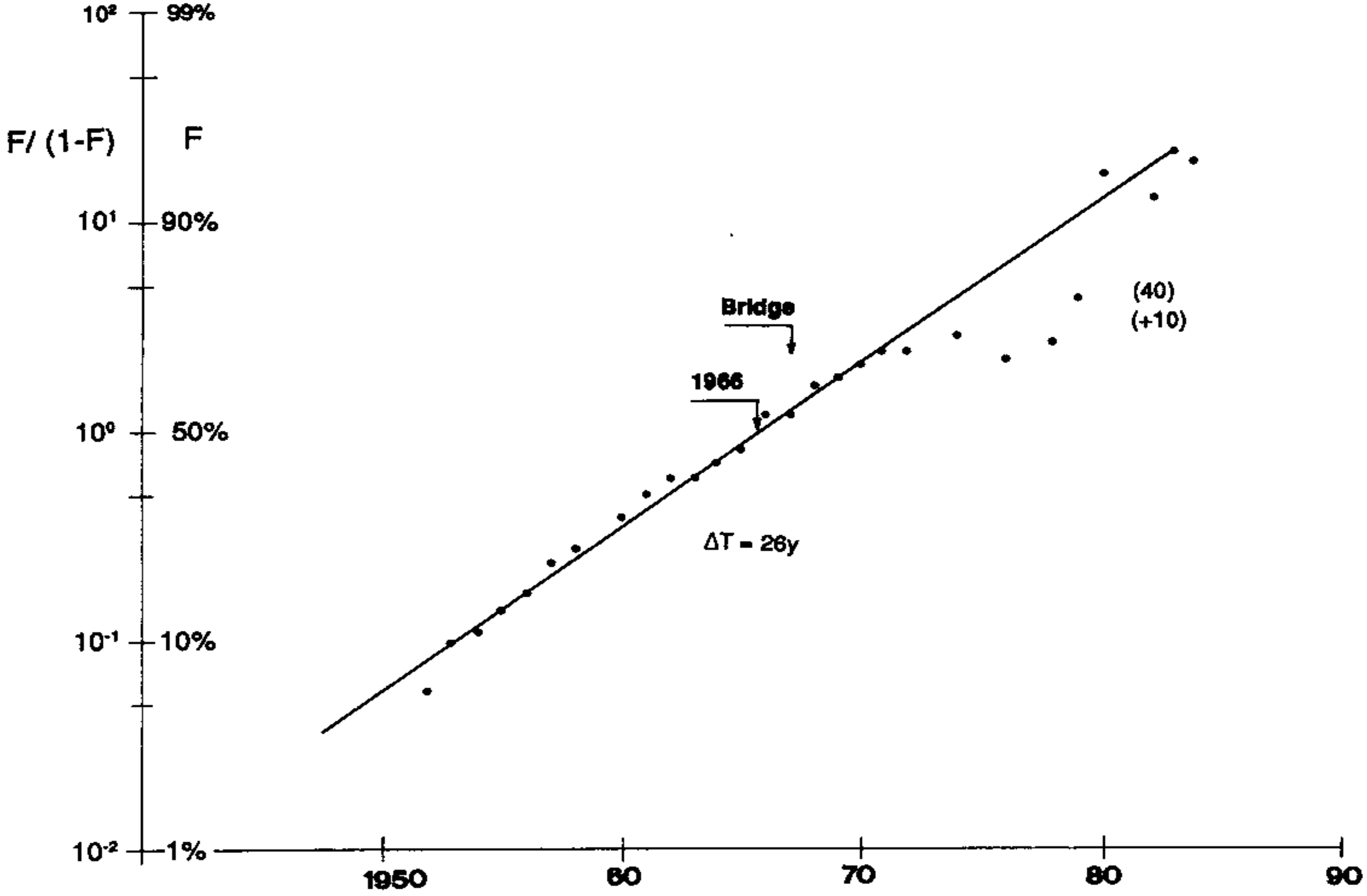
Based on data provided by Ferreira, 1987.

FIGURE 4.36. *Trend in total vehicles (10^6) using Lisbon ferries and the Tago Bridge*



Based on data provided by Ferreira, 1987.

FIGURE 4.37. *Trend in total passengers (10^6) using the Lisbon ferries*



Based on data provided by Ferreira, 1987.

bridge, one should expect another pulse of expansion after 1995, i.e., for the next Kondratiev cycle.

Saturation of the technical capacity of the bridge (2 x 2 lanes) occurred in 1977, and saturation of the reinforced capacity (2 x 3 lanes) is expected to occur in 1989 (Ferreira, 1987). This is not far from the logistic saturation of 26 x 10^6, and corresponds on the logistic to 25.3 x 10^6 vehicles per year.

Obviously, the bridge cannot accommodate the next growth pulse, and this is a very important point to be considered for the Messina bridge. As these structures are meant to last for 100 years and more, they should be conceived from the beginning in such a way that expansion of the capacity is possible without rethinking their whole structure (as in Hong Kong) or without building more bridges (as in Istanbul). A second bridge is, in fact, also being considered in Lisbon.

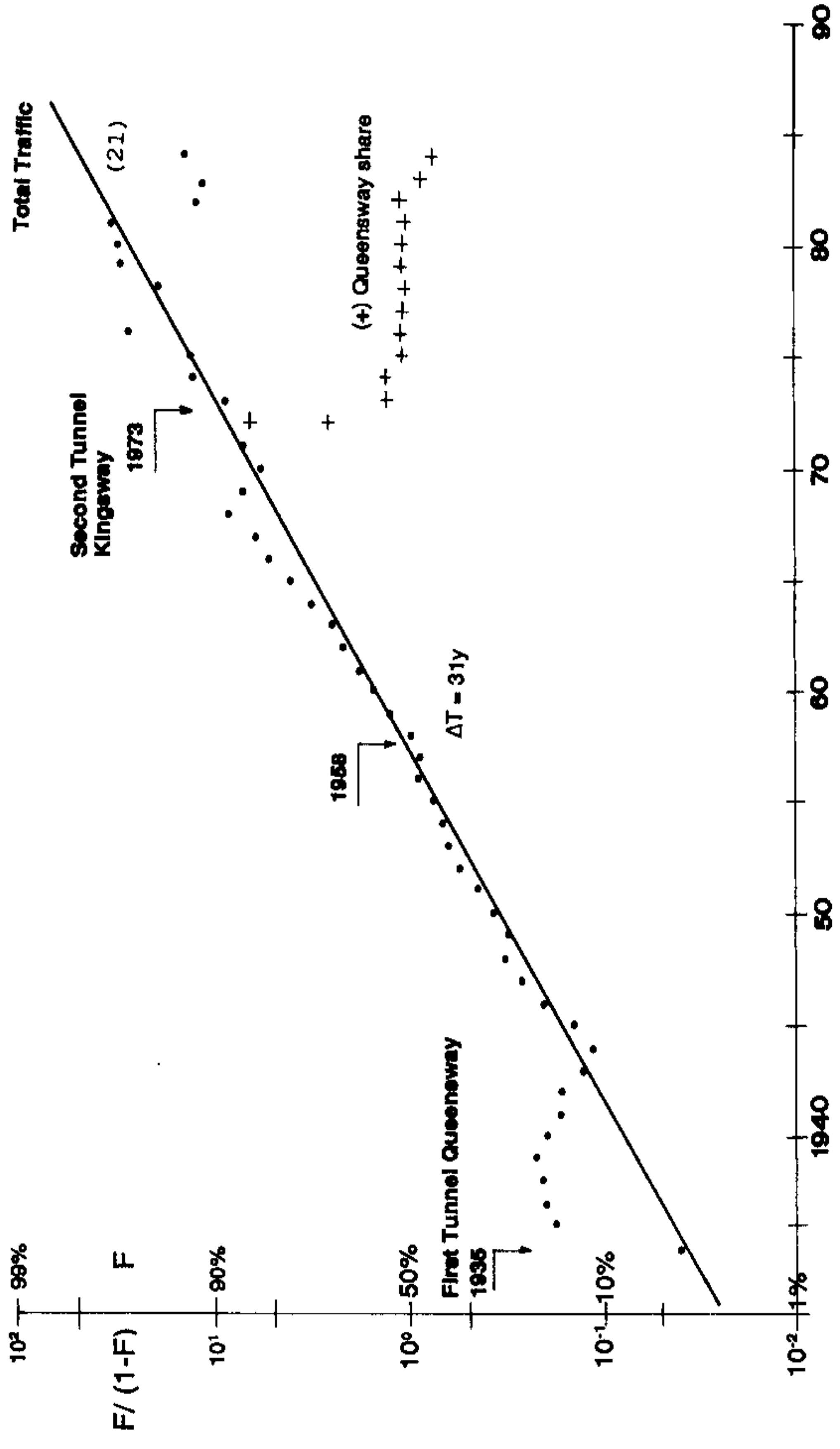
4.8. The Mersey Tunnels

This British case is methodologically interesting because it shows very clearly what happens when capacity is added without substantially modifying transit times. Traffic data have been gathered only for the tunnels, and apparently no study documents the traffic between the regions before the tunnels were constructed, so we have to limit our analysis to the point quoted above.

The first tunnel, *Queensway*, opened in 1935, appears to have attracted a rush of experimenting travelers during its early years (figure 4.38). The flow stabilized after World War II on a logistic path with a central point in 1958 and a D*T* of 31 years, meaning that traffic grew at an annual rate of 7.3% over that 31-year period. The center point date and the D*T* are appropriate for a saturation at the end of a K-cycle, if slightly early.

The traffic saturation point is 21 million vehicles per year, but technically the Queensway began to be clogged by traffic in the mid-1960s, and a second tunnel, *Kingsway*, was opened in 1973. Traffic split between the two, but not 50/50 between the two equivalent tunnels, as one might expect. It took commuters about four years to adjust to the new access route. At present, the Queensway share is not half of the current traffic, but *exactly half of the saturation traffic for* the logistic of growth. As I found no physical reason for this peculiar split, the reason might be metaphysical. The conclusion here is that a logistic of traffic growth

FIGURE 4.38. *Trend in total vehicles (10^4) using the Mersey tunnels*



DATA SOURCE: Mogridge, 1986.

is not perturbed when extra capacity is introduced. A factor of ten increase in traffic during a K-cycle of 55 years is equivalent to a mean growth of 4.2% per year, which can be considered in line with GNP growth in real terms, and general traffic growth (ton-km or pass-km) which typically increases a little faster.

4.3.5. The English Channel

Although the famous Channel Tunnel has not yet been built and one can only speculate about its effects, it may be interesting to examine the evolution of the traffic there in connection with our models.

Traffic between Great Britain and the Continent has intensified over the centuries, stimulated by the increased number, activity levels, and mobility of the populations on the two sides of the Channel. The number of *air* passengers between London and Paris and London and Amsterdam ranks at the top for traffic between cities in Europe.

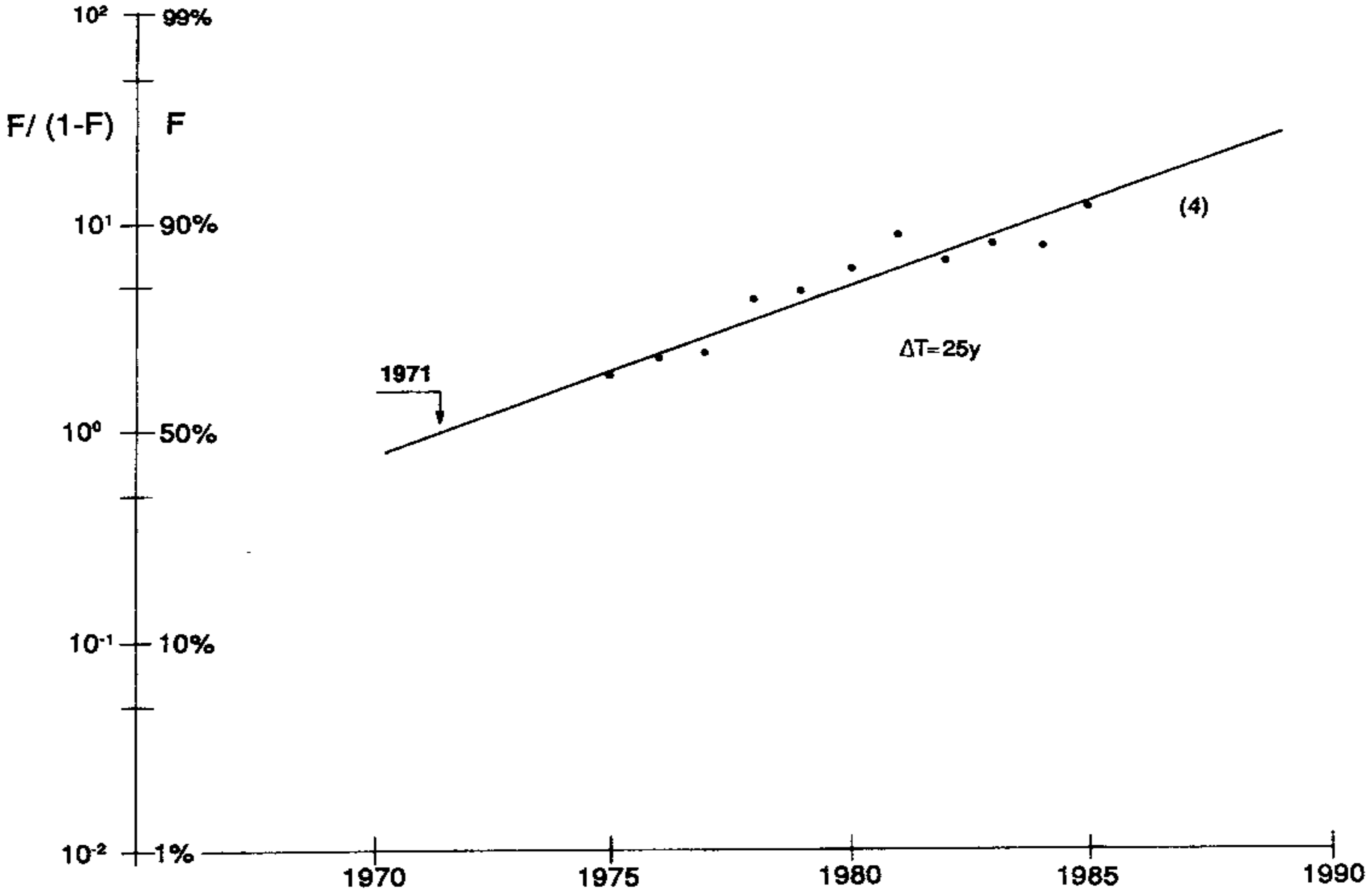
Looking at population densities, one sees a single megalopolis developing in the Brussels-Amsterdam-Ruhrgebiet area with tails toward Paris and Frankfurt. On the British side, a London-Manchester «corridor» is in the making. These two conurbations, holding perhaps 50 million people, will inevitably develop their own fast transportation networks, with the Channel becoming the barrier to be made porous.

Airplanes will not be adequate to handle the massive traffic that will want to cross that barrier in the next 50 years; the only viable solution appears to be a Maglev train, running at 1000 km/h or so, presumably in a tunnel of appropriate topography (Marchetti, 1987).

However, Channel entrepreneurs (it will be privately financed!), like old generals, try to win the next war using the weapons and the strategies of the last one. The problem is that current and advanced train technology with rails and wheels will not be capable of providing sufficient speed and/or perhaps even capacity to satisfy the demand of the year 2050. This is an obvious time horizon for an infrastructure of the size and complexity of the tunnel under the British Channel.

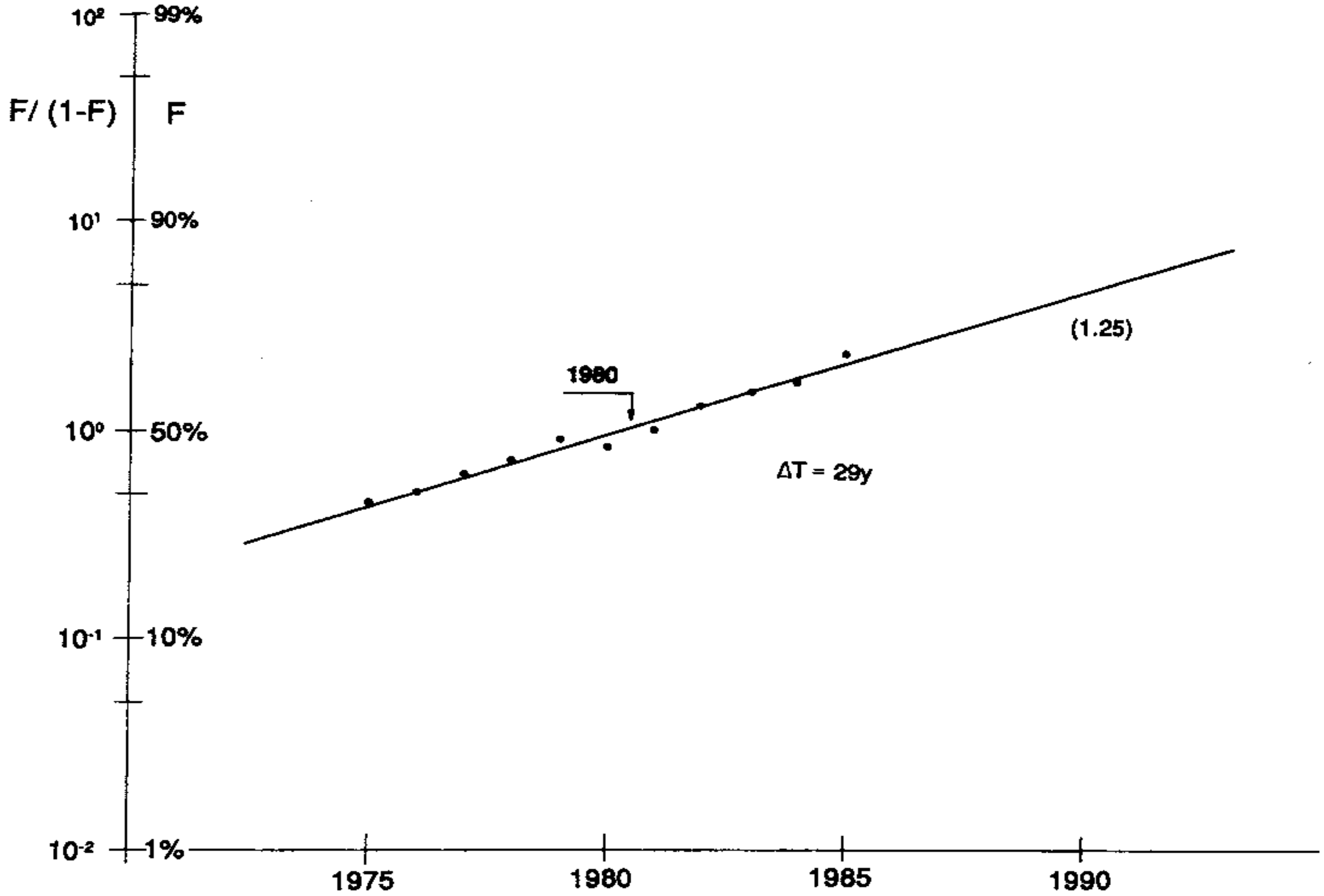
The evolution of passenger, car, and truck traffic across the Channel in the last 50 years is mapped in figures 4.39 and 4.40. Car traffic will reach its saturation point in the 1990s, with 4.0 million cars/year carried on the ferries – a very modest figure if we compare it with, say, the 26 million crossovers of the Lisbon bridge or the 29 million of the Bos-

Figure 4.39. *Trend in passenger cars (10^6) crossing the English Channel by ferry, 1970-1990*



Based on data provided by the U.K. Department of Transport, 1982.

FIGURE 4.40. *Trend in trucks (10^6) crossing the English Channel by ferry*



DATA SOURCE: Mogridge, 1986.

phorus bridge (which represent more the limits on their technical capacity than a measure of future demand).

Thus, Channel traffic is intercity, interregional traffic and not very sensitive to relatively small changes in transit times. Nor is it *sensitive to large changes in capacity*, as the Mersey tunnels case has shown.

The number of trucks is also relatively modest: 1.25 million per year with a saturation point that will come, as usual, around 1995. The time constant is correct, and the mean growth over the central half of the Kondratiev cycle is comparable to the mean growth of European economy during that period. The only hint of a breakthrough is that the *opening of the economic frontiers in 1992 will make the political boundaries more permeable.*

However, nobody seems to have explored to date the *time constant* for a system *to react to the suppression of a political barrier.* Our analysis of intracity processes indicates time constants in the range of 10-20 years, at the national level. The time constants for international adjustments may well take one or two Kondratiev cycles.

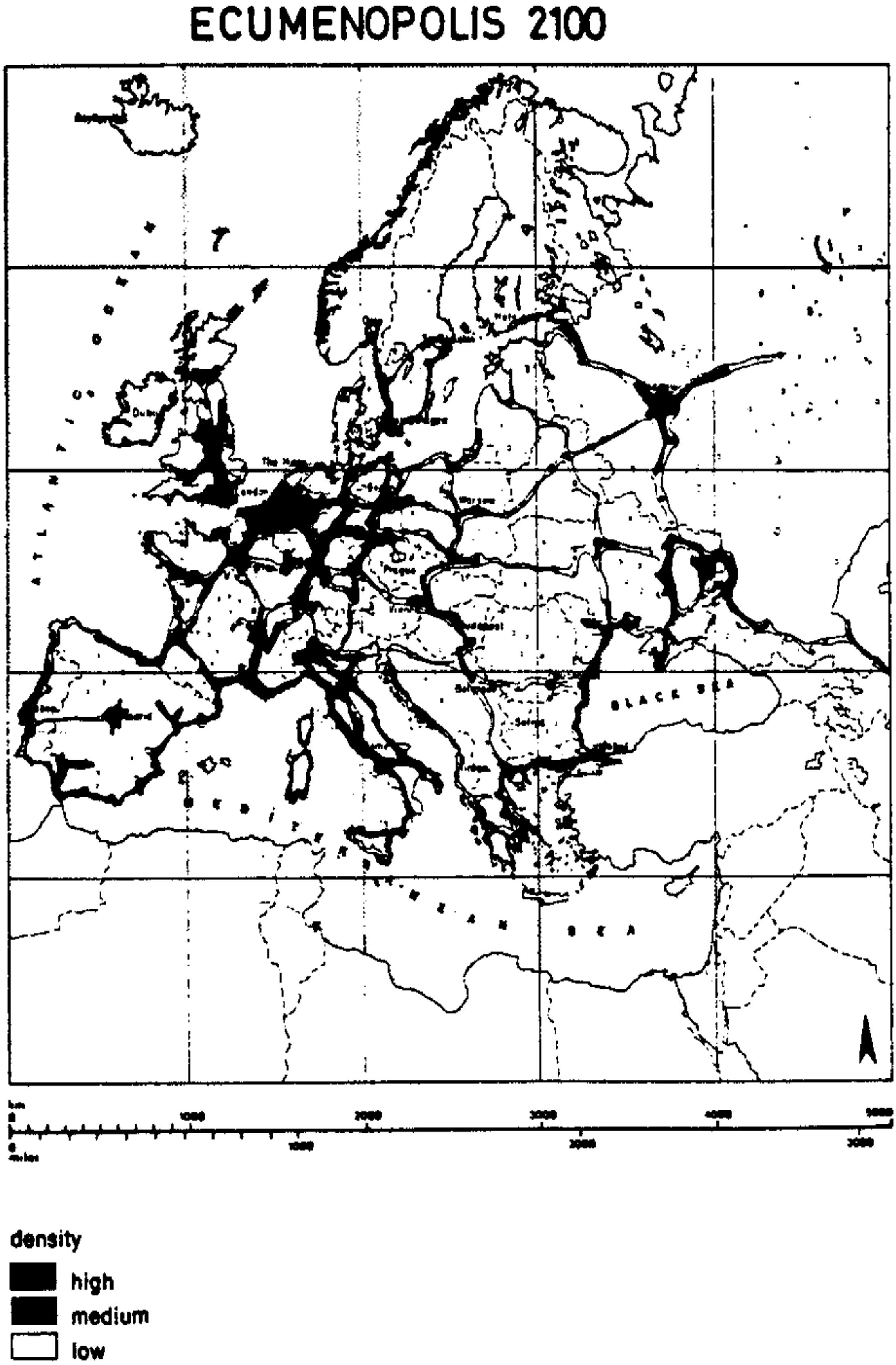
The conclusion that can be safely drawn is that the tunnel, which will only marginally reduce long-range trip-time, *will not «create»* new traffic. New traffic will be generated *only when* the tunnel hosts a *very fast transportation system*, joining the megaclusters of populations on the two sides of the Channel, with transit times comparable to those in the single city context. Then the traffic will switch from an intercity to an intracity mode, increasing between one and two orders of magnitude, following the pattern of the Istanbul and Lisbon cases.

Part III: THE MESSINA CASE

The Strait of Messina not only separates the continent from a large island (Sicily) with about five million inhabitants, but also constitutes the gap in a conurbation basin estimated to contain a couple of million people, counting cities and communes from Catania to Patti on the Sicilian side and from Reggio to Vibo Valentia on the Calabrian side. According to Doxiadis and Papaioannou (1974), the coastal strips will host part of a megalopolis that can be expected to develop progressively during the next 100 years (figure 4.41).

During its technical lifetime of at least 100 years, the Messina bridge must therefore serve two different classes of demand – the one coming

FIGURE 4.41. *Contiguous urban development in Europe, in 2100*



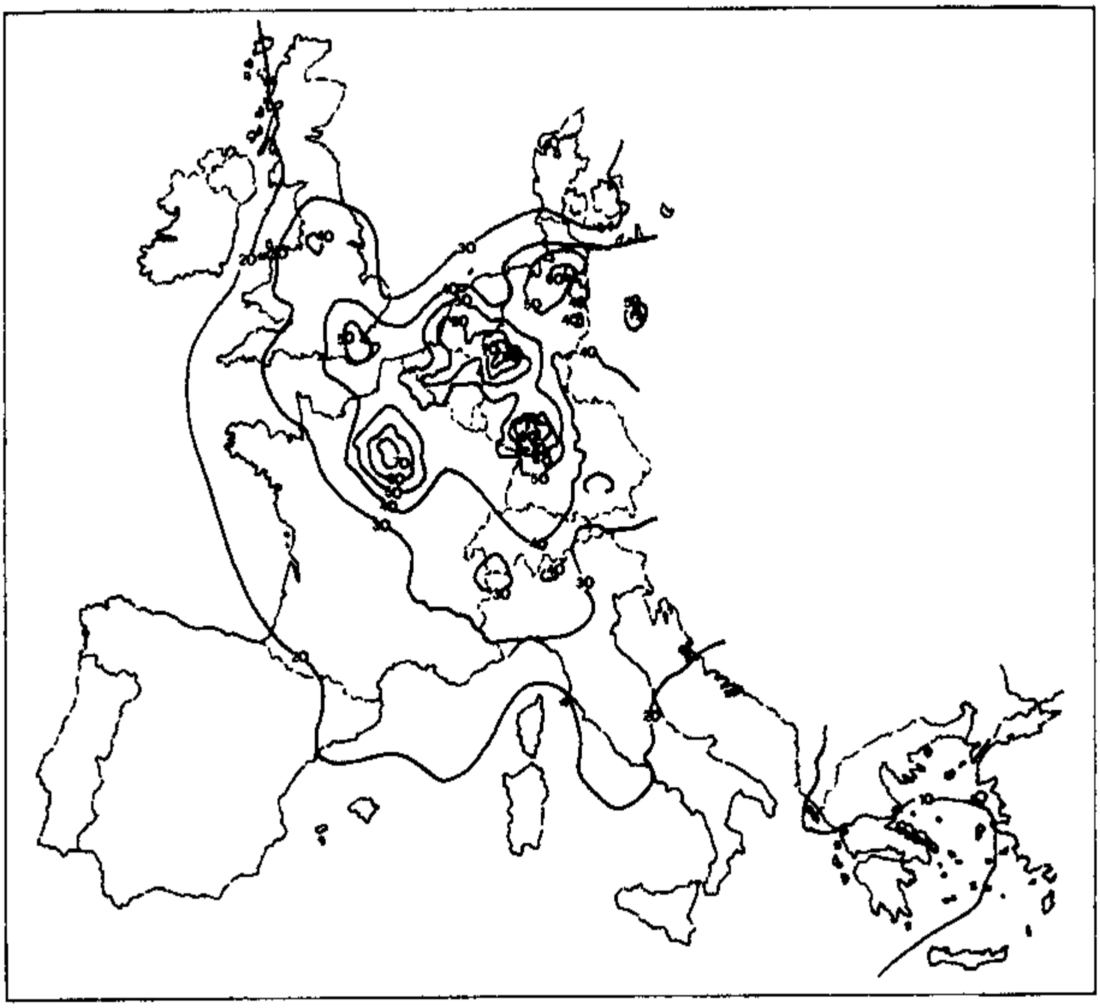
SOURCE: Doxiadis and Papaioannou, 1974.

from the interaction of Sicily with the continent, and the second coming from internal movements in the megalopolis. Because the two classes of demand have different characteristics and dynamics, they will be analyzed separately.

4.4. *The Sicily-Calabria Connection*

Sicily and Calabria are marginal regions in comparison with the activity cores in central-northern Italy and in central-northern Europe. This is well shown in a study sponsored by the Commission of the European Communities (Keeble et al., 1982), in which a gravitational model was applied to productive activity and transport in Europe to construct a connection intensity or *accessibility map* (figure 4.42). Interpreting from the map, the marginality index of Sicily and Calabria is about five times

FIGURE 4.42. *Regional accessibility and economic potential in the European Community*



SOURCE: Keeble, 1982.

that of Bavaria. In this situation air traffic can indicate the demand from the subsystem for a higher connectivity with the larger system. Incidentally, as our studies on global traffic in Europe show, air transport of goods is growing rapidly as goods of ever-low specific value are accepted.

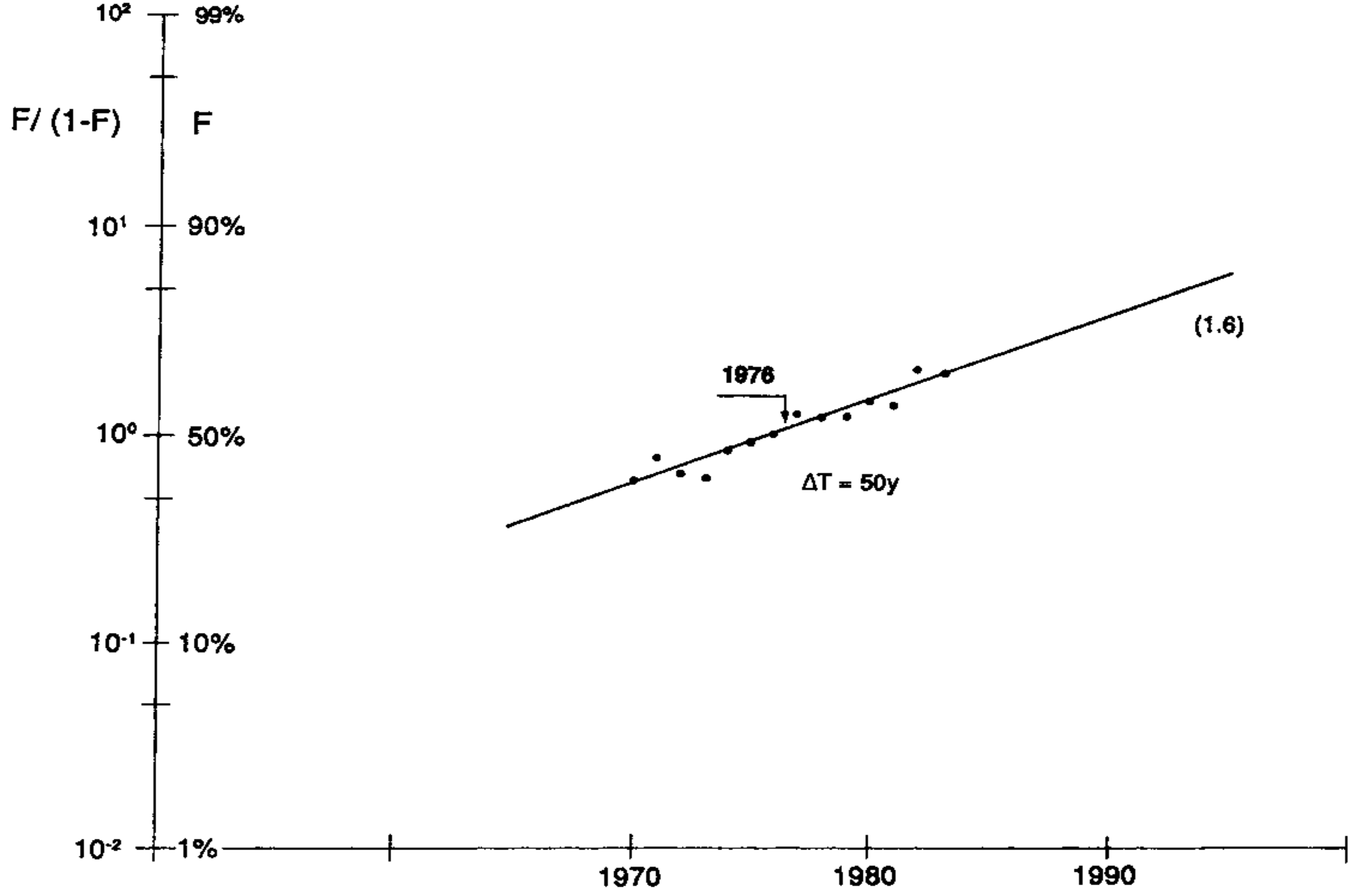
Passenger traffic trends for the airports of Catania, Palermo, and Reggio are analyzed using the logistic growth model and set out in figures 4.43 and 4.44. Palermo airport has a saturation point of 1.1 million passengers (in and out), to be reached around 1995 with a time constant of 38 years. This implies a mean growth rate for the 38 years (around the central point in 1970) of about 5% per year. Catania has a saturation point of 1.6 million passengers, a time constant of 50 years, and a mean growth rate for the 50 years around the central point of 4.5% per year. The central point (50% of saturation) for Palermo is in 1967, and for Catania in 1976, showing a later development for Catania which was predestined to become, due to the higher saturation point, the busiest airport in Sicily. Catania airport passenger traffic overtook Palermo's actually in 1985. Reggio airport plays a much less important role in the area, with traffic about 20% that of Catania.

Looking at the situation in mainland Italy, as a point of comparison (figure 4.45), we find a central point for Italy in 1970, more or less in tune with Palermo, but with a time constant of only 20 years, i.e., a growth rate for the 20 years around 1970 of 12% pear year. Looking at the saturation points, however – 34 million passengers for Italy and 2.6 million for Sicily – we find a ratio of 8%, which corresponds to the ratio of the population.

In other words, the isolation of Sicily stimulated some early air traffic, which grew at a slower pace than in Italy as a whole, but which will reach the all-Italy level around the end of the century in terms of passengers per population. Lower income levels in Sicily seem exactly to compensate the greater advantage of taking a flight to central or northern Italy.

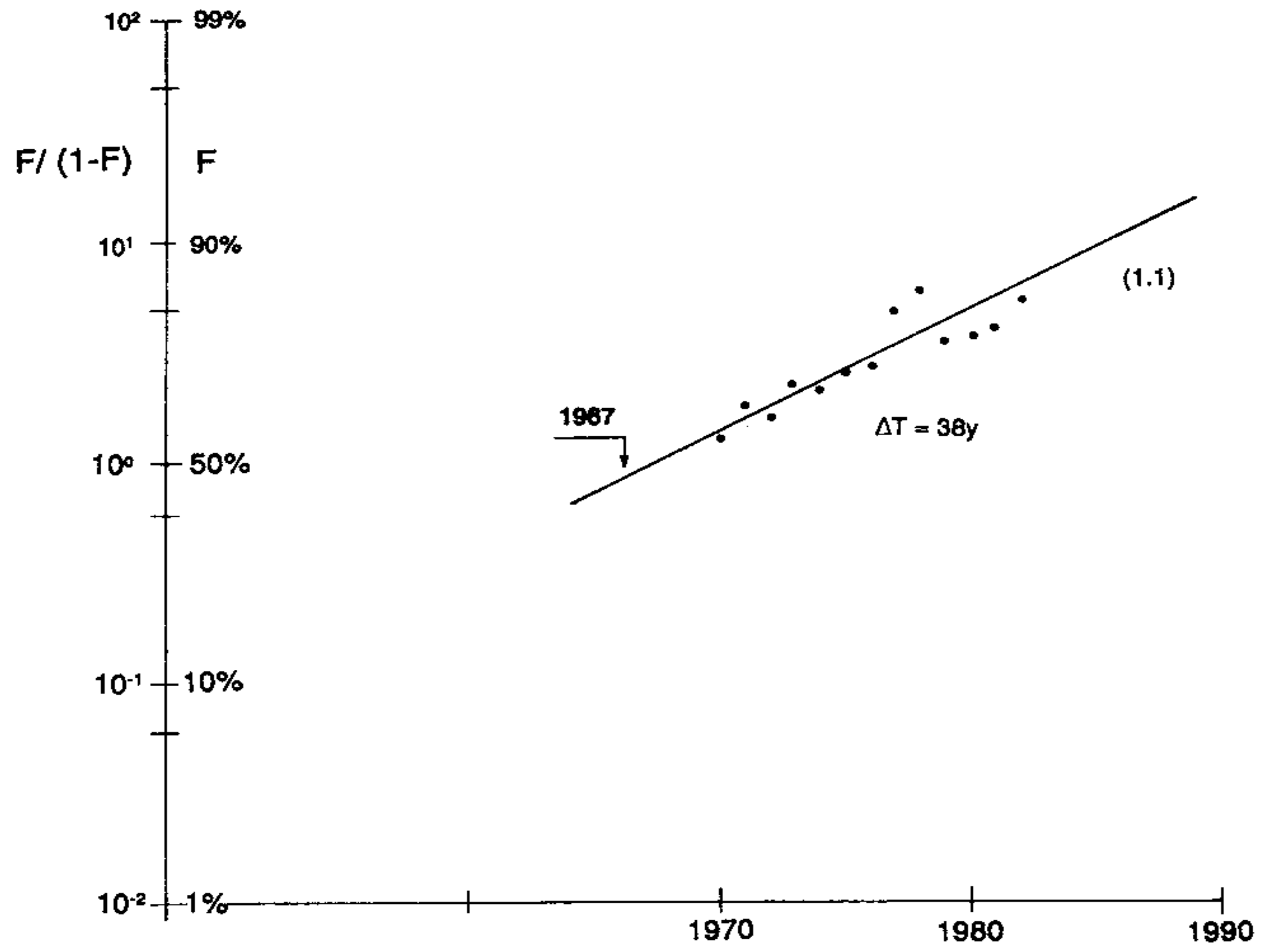
As a European transport study shows (Marchetti, 1987), air traffic should increase by a factor of 20, at least during the next Kondratiev cycle, i.e., up to 2050 worldwide. It is not reasonable to expect in this period that any surface connection to the continent, up to Rome and Milan, could compete with the one- to two-hour transit time of the airplane. Consequently, one should not expect new long-range passenger traffic to be channeled through a bridge.

FIGURE 4.43. *Trend in passengers* (10^6) *in and out of Catania airport*



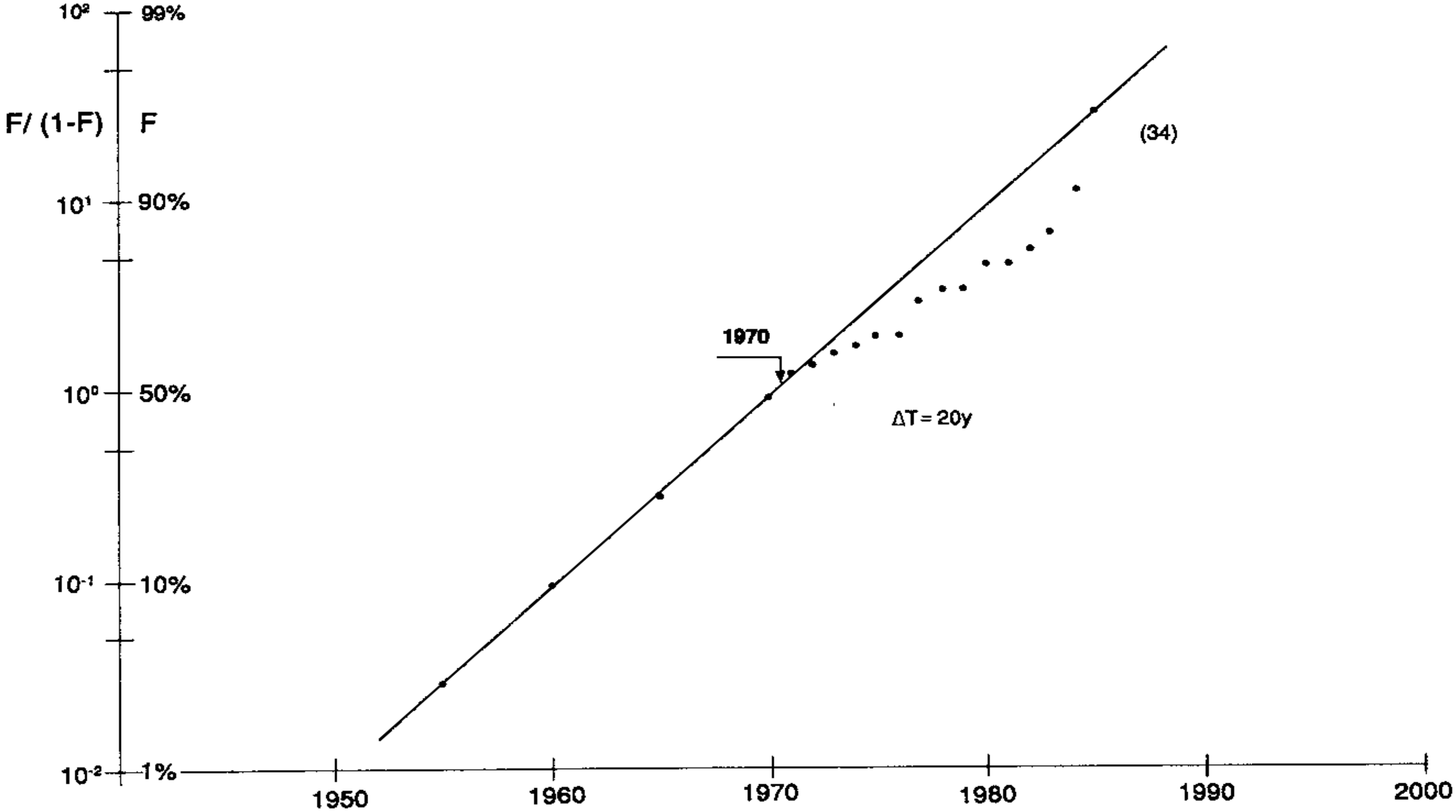
Based on data provided by SOMEA, 1985.

FIGURE 4.44. *Trend in passengers (10^6) in and out of Palermo airport*



Based on data provided by SOMEA, 1985.

FIGURE 4.45. *Trend in passengers (10^6) in and out of mainland Italian airports*



Based on data provided by Annuario Statistico Italiano, various years.

The next step is to look at freight movement through the Strait of Messina. Much freight goes by truck nowadays, and the dynamic of the situation is illustrated in figure 4.46, in which one can see a neat pulse of growth, saturating at 1.0 million annual transits (both ways) in the 1990s. The central point in 1975 and the time constant of 10 years shows this to be a recent and very rapid phenomenon (mean growth rate between 1970 and 1980 of 25% per year).

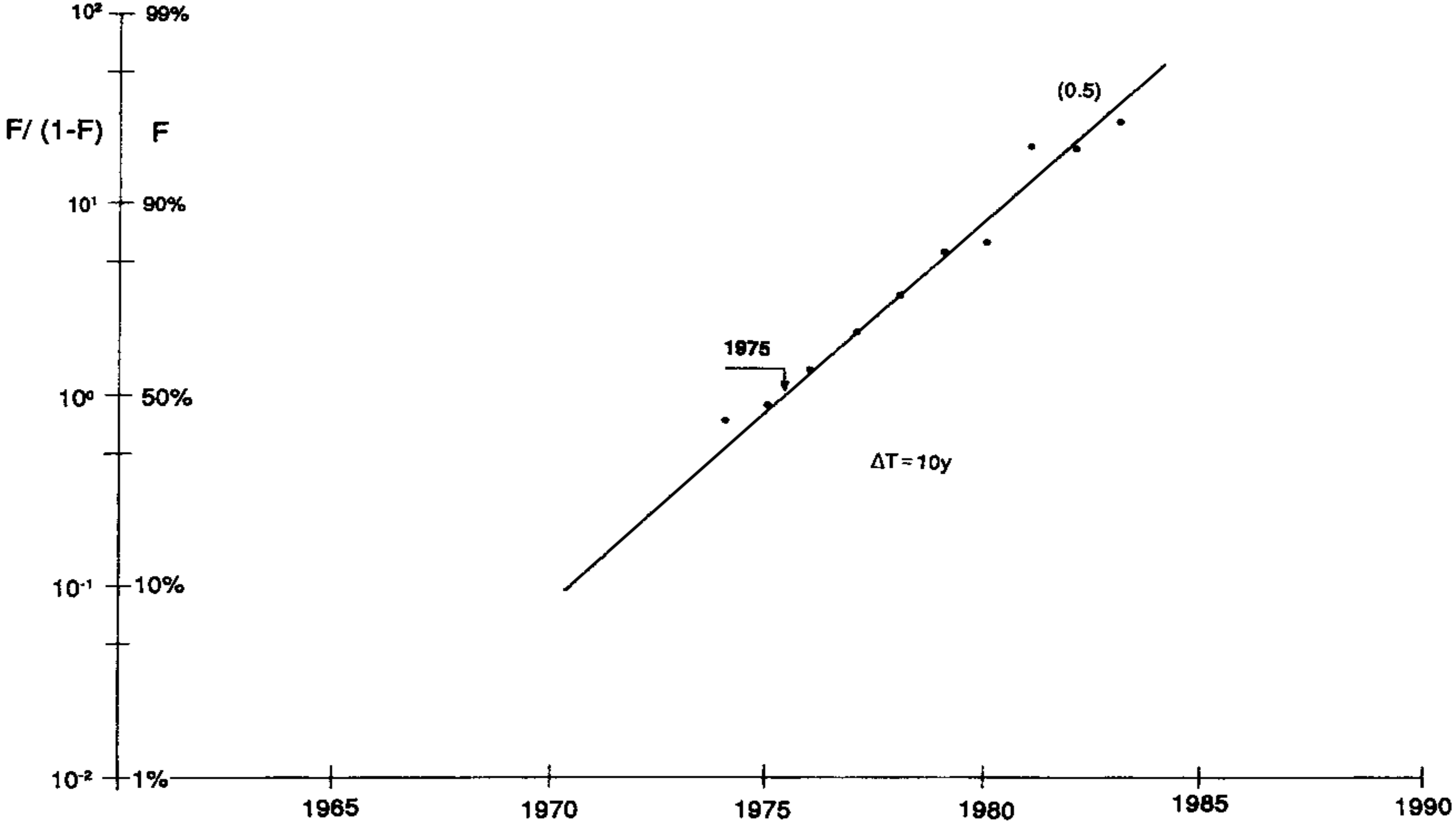
The switch from transporting goods by railway to road, a process that started all over Europe in the 1960s, will reduce railways to carrying only the cheapest goods – and not large amounts of it. This is a typical process when a new transport technology supersedes an old one. The phenomenon can be studied from the beginning to completion, e.g., in the case of steamships versus sailing ships, and runs identically down to details.

At the national level ton-kms carried by railways have been basically level during the last 50 years, with strong oscillations around the mean. Traffic grew (in two 50-year Kondratiev pulses) during the last century and a half, up to the 1930s. In the ecology of large systems, two cycles up, one steady and the next down, is the normal pattern; thus, we may expect railways to lose ground in *absolute terms* from the beginning of the next cycle in the 1990s.

How the railway lost traffic to the road is shown for Italy in terms of market *shares* in figure 4.47. In 1985, 90% of the total ton-kms were transported on trucks. Although the data often miss the logistic at the end of a cycle, one can forecast a market share of 1% for the Italian railways as a whole in 2010. The situation differs somewhat from country to country, but the figures for Europe and the USA are in the same range. Even a railway revival could not be expected to affect the Italian situation.

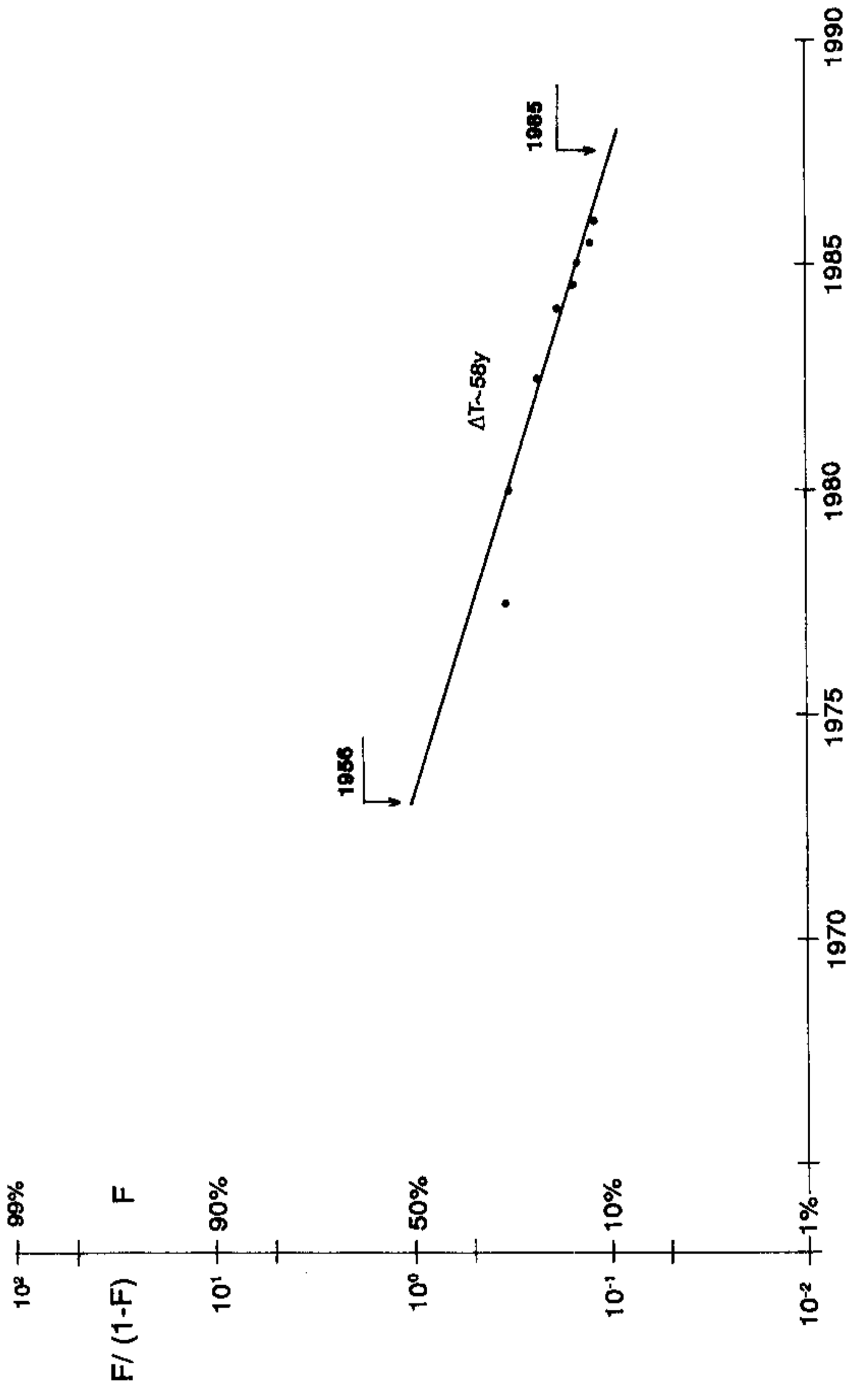
As for freight car movement across the Strait of Messina (loaded and empty, one-way), as figure 4.48 shows, the trend is downward, and with a relatively short time constant of 36 years. A cross-check with loaded cars (figure 4.49) yields similar results. The 33-year time constant means that traffic, totaling about 150,000 cars in 1978, will drop to 30,000 in 1995 and 3000 in 2010, when the bridge will presumably be in full operation. It is not improbable that railways will have ceased to operate by these dates. In any case, *such a diminished level of traffic might be well accommodated by the existing ferries.* A loss of transit time that can be estimated in tens of minutes certainly makes no signi-

FIGURE 4.46. *Trend in trucks (10^6) crossing the Messina Strait from Calabria to Sicily*



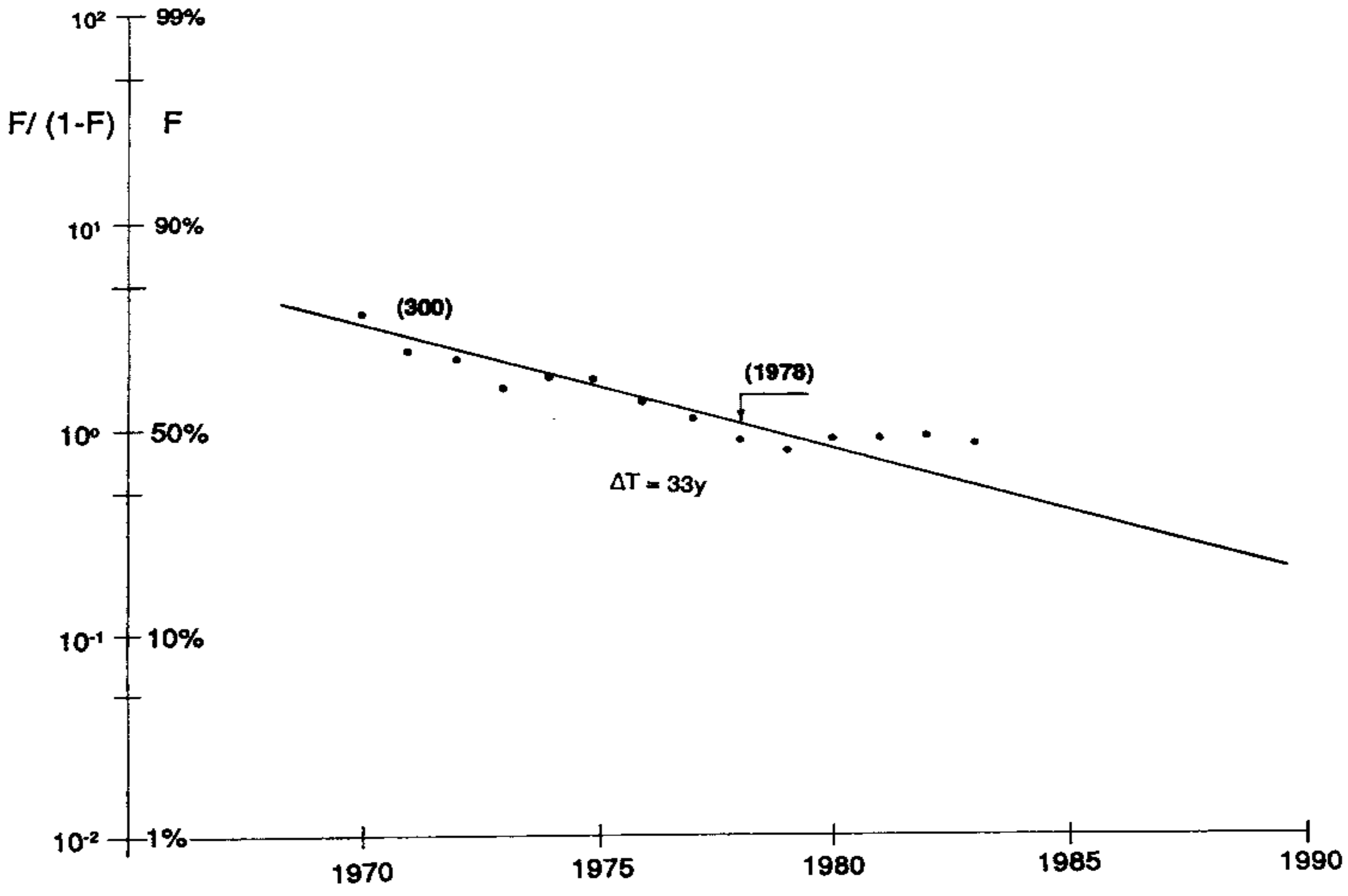
Based on data provided by SOMEA, 1985.

FIGURE 4.47. *Trend in freight (ton-kms) carried across the Messina Strait by rail versus road transport*



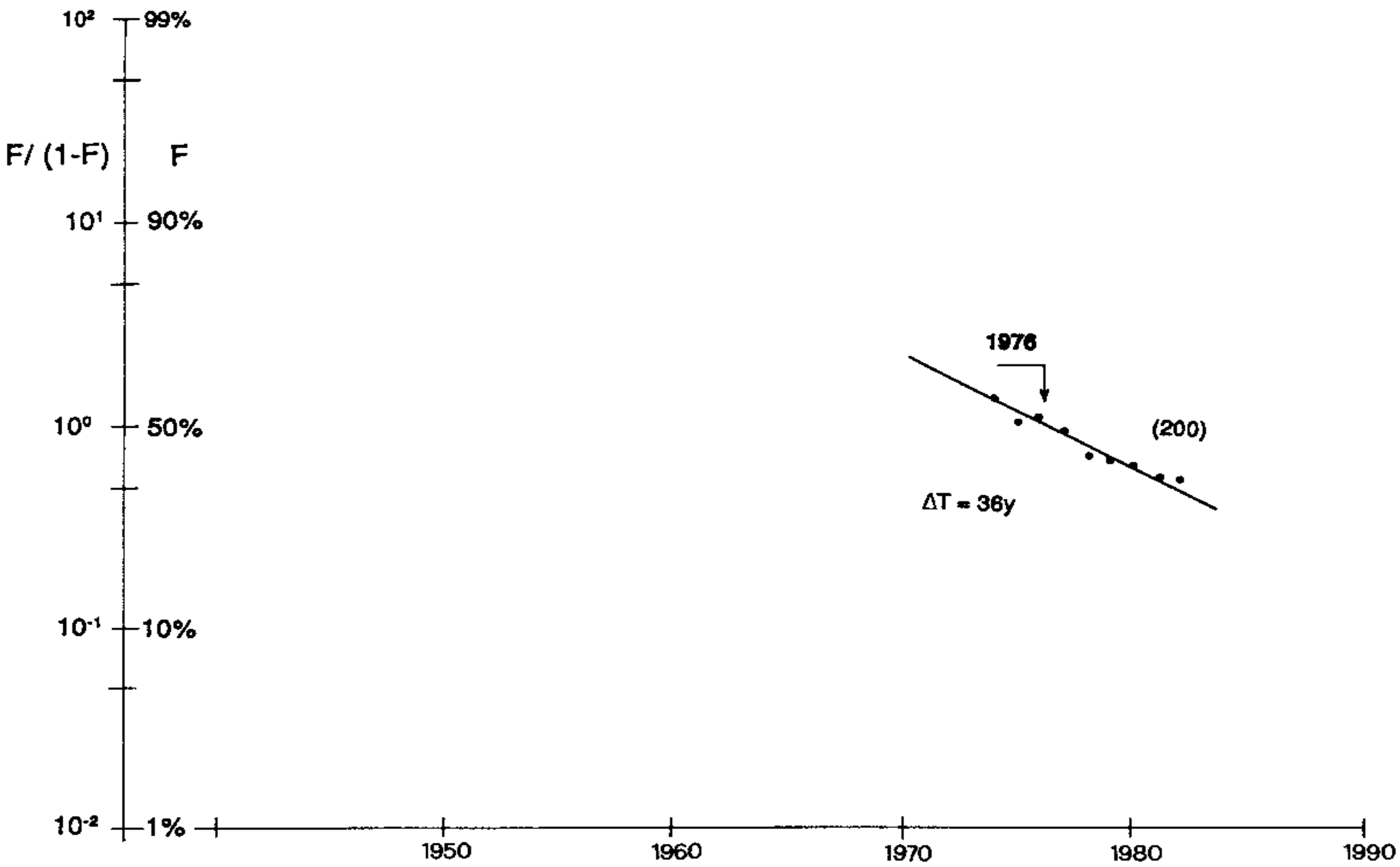
Based on data provided by SOMEA, 1985.

FIGURE 4.48. *Trend in freight cars (10^3) crossing the Messina Strait*



Based on data provided by SOMEA, 1985.

FIGURE 4.49. *Trend in loaded railway cars (10^3) crossing the Messina Strait from Sicily to Calabria*



Based on data provided by SOMEA, 1985.

ficant difference for freight cars that take days and weeks to complete their journey.

It is apparent then that *freight trains will not be a customer of the bridge*. This statement alone merits deeper research, because the absence of freight trains may well *simplify the design of the bridge*. On the other hand, constructing a stronger bridge that might some day accommodate trains, just in case, could be a way to provide the recommended expansion capacity, which will inevitably be needed if the system is intended to facilitate the formation of a *proximal megalopolis*.

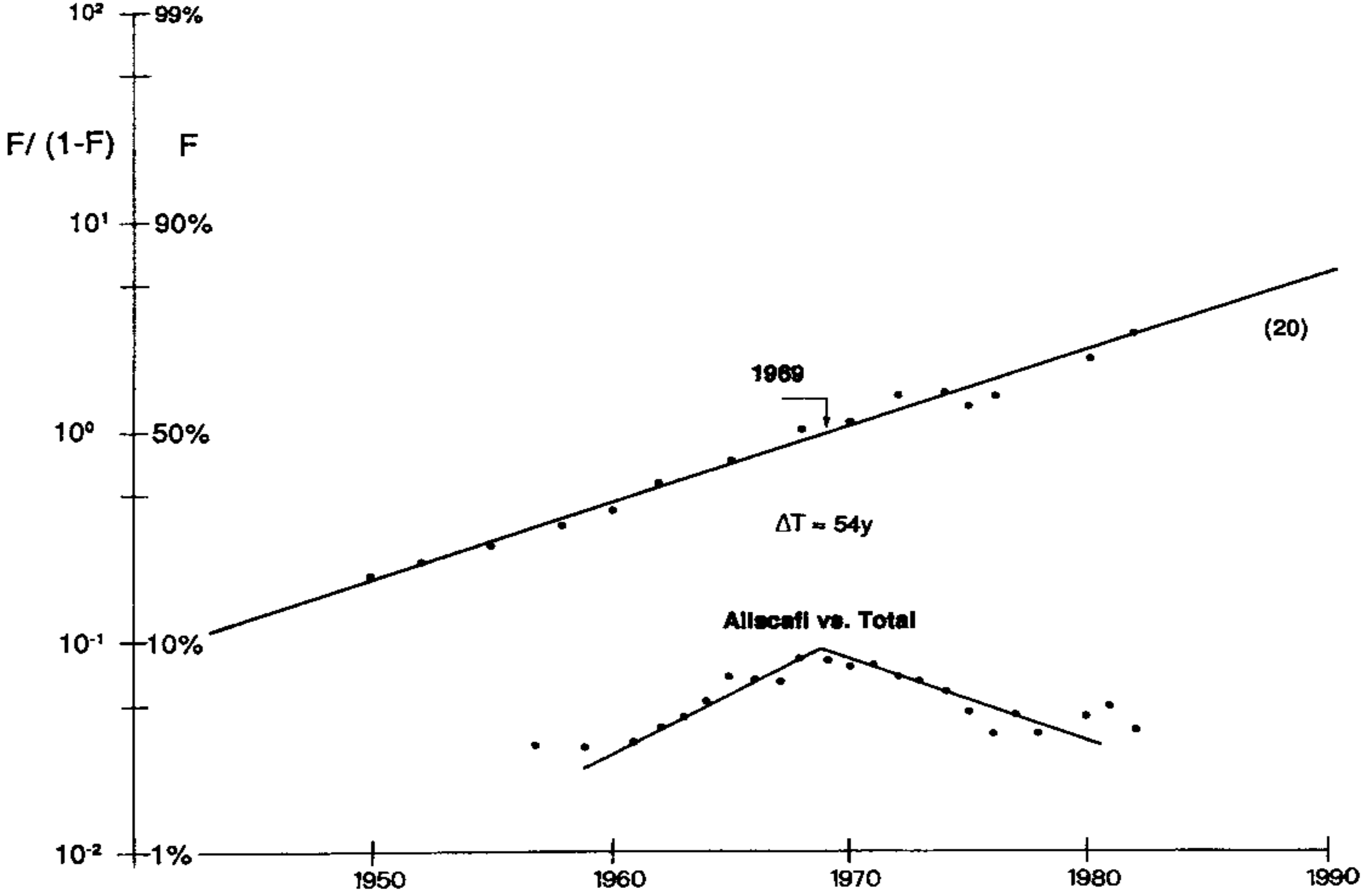
According to the rules of Volterra substitution, road transport, being the most recent to develop, will dominate the freight transport market during the next Kondratiev, completely absorbing railway traffic and possibly even diverting traffic from ships. Clearly, the *bridge must take care of truck traffic*, and an effort should be made to prognosticate its volume and what it will look like during the next century.

The last-plus-one technology of freight transport is airplanes, which will become more important in terms of value of goods transported. The highest-value-freight entering by that mode may well be fruits and vegetables. Off-season fruits from South Africa are already on North European markets, at prices comparable to Italian fruits in season. This may not influence substantially the tons of traffic through the bridge, but it will substantially reduce the *rush traffic* of short shelflife products, such as fruits and especially of vegetables.

The situation is more variegated if we look at passenger traffic across the Strait. Total traffic can be perfectly matched by a logistic from 1950 to 1983, and a central point in 1969, with a time constant of 54 years – just one Kondratiev cycle. The mean growth rate for the central 54 years is about 4.2% per year, moving at a pace similar to that of the global economy (Figure 4.50). A saturation point of 20 *million* passenger transits per year, estimated to be reached at the end of the cycle (1995), may constitute a good basis for considering a bridge. The number looks puny, of course, in comparison with the *800 million* passenger crossings of the harbor channel in Hong Kong. But transit times across the Hong Kong harbor make the two sides a single city!

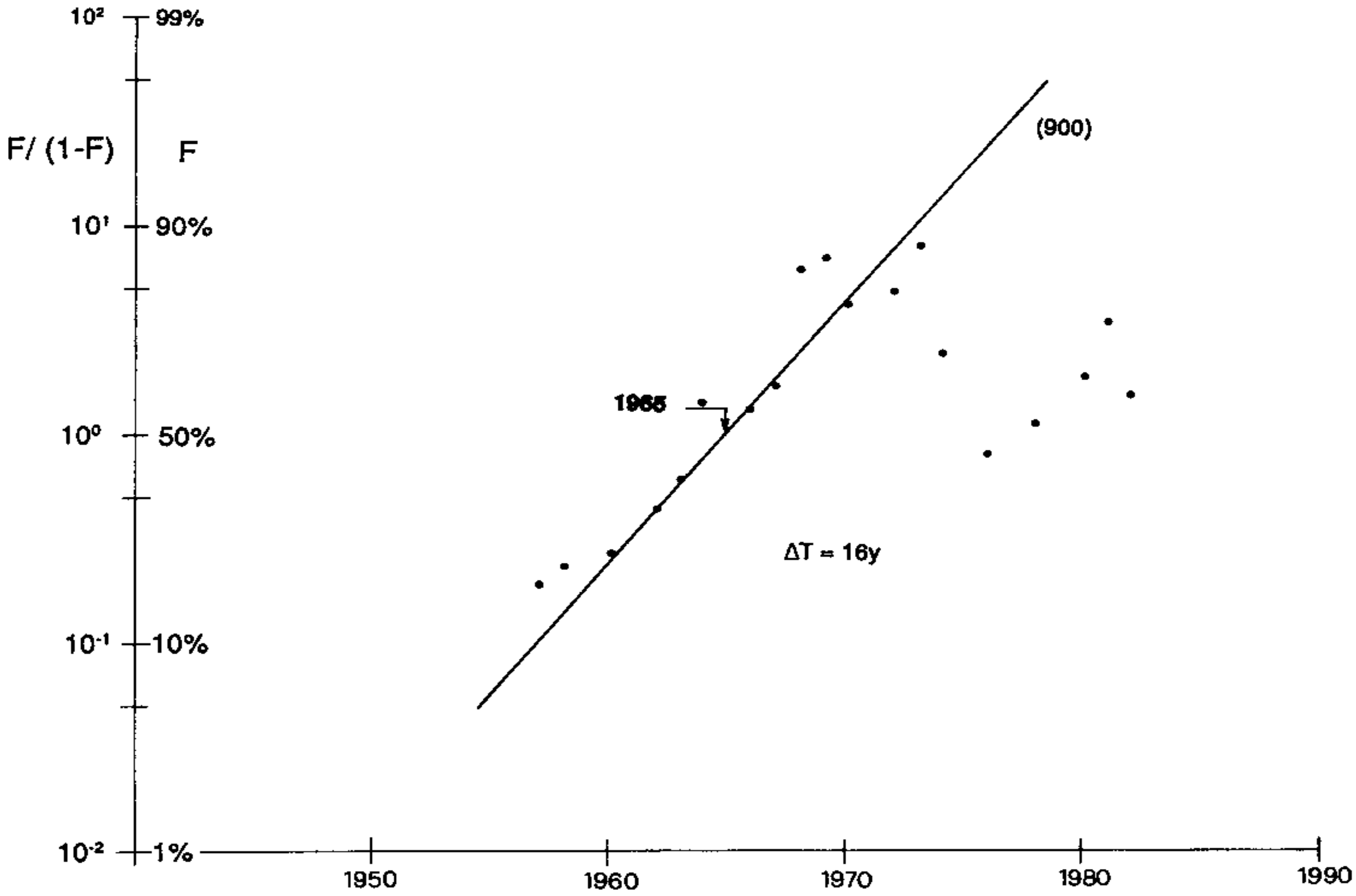
Let us look at this traffic in some detail. Fgure 4.50 shows that Aliscafi's share of total traffic went up and down, reaching its maximum around 1969. This may be simply due to the fact that the system served a special submarket that became saturated at that time. Looking at Aliscafi traffic in isolation (figure 4.51), we see in fact a regular develop-

FIGURE 4.50. *Trend in total passenger vehicles (10^6) crossing the Messina Strait*



Based on data provided by Valleri, 1986.

FIGURE 4.51. *Passengers* (× 10^3) *carried by Aliscafi*



Based on data provided by Valleri, 1986.

ment, fitted with a logistic with center point in 1965, time constant of 16 years, and saturation point at 0.9 million passenger transits. Traffic levels became very scattered thereafter, and focusing on that particular subsystem may help us to understand local mechanisms.

When we look at ferry passenger traffic from a different angle – that of private versus public services, such as railway ferries – we find private firms making inroads into the public, but saturating for the moment being at around 60% of the total (figure 4.52).

For examining ferry car transport we have statistics from three different sources that do not match well. Nevertheless, they do give an approximate idea of the situation. The results are set out in figure 4.53 for total traffic, saturating at about 1.3 million transits per year (both ways). The sharp increase of 0.62 million cars (transported by private ferries) between 1981 and 1980 – almost doubling their number in one year – seems improbable. Therefore, we omitted the figures for 1981, 1982, and 1983. In any event, the difference between one or *two* million does not change the conclusion that the volume of traffic is small and comparable with that of Lisbon before the Tago River bridge was built. The builders of the Messina bridge should be encouraged by the facts that the Tago River bridge is already saturated at *26 million* transits per year and the Bosphorus bridge more or less at the same level.

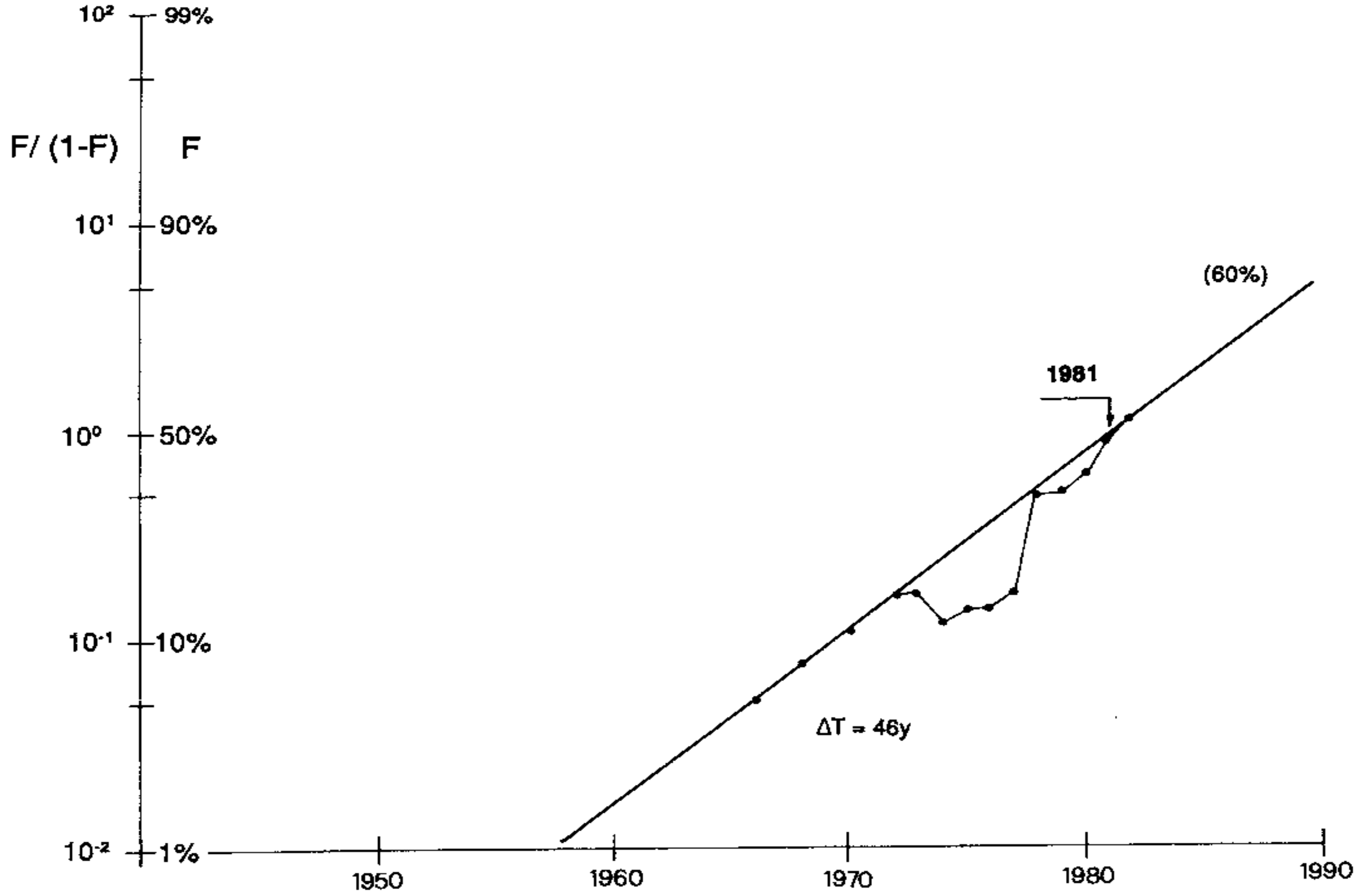
Car transits on F.S. Ferries were reasonably smooth until private ferries began operating in 1965 (figure 4.54). Although F.S. traffic continued to increase until 1973, it then started oscillating and now seems stabilized at the 1965 level, i.e., about 0.4 million transits per year both ways.

4.5. *Conclusions*

A posteriori application of the models to various case studies shows them to be a sharp lens for *inspecting* the details of what happens when a new infrastructure changes the boundary constraints of a given traffic milieu. The models also provide a tool for *forecasting* inside a Kondratiev cycle. (Forecasting over longer periods of time is possible, but reliable statistics over a couple of cycles, i.e., in the range of 100 years, are necessary. The exercise has been done at IIASA for France and the United States.).

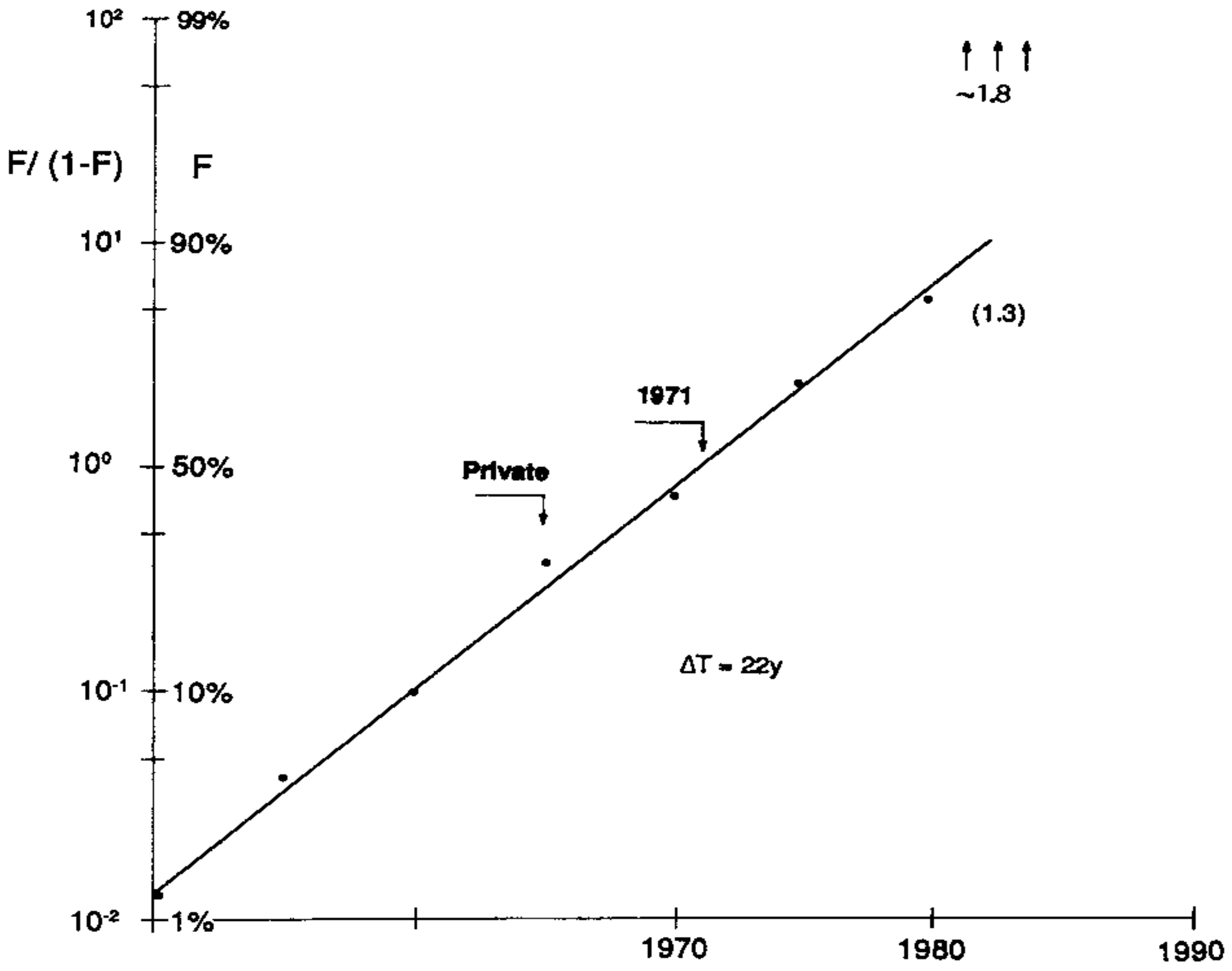
A bridge across the Strait of Messina will probably *not modify long-range freight traffic.* This freight will be carried primarily by *trucks* that will take the bridge for simplicity's sake, even if the gain in time is not significant.

FIGURE 4.52. *Trend in private ferry passenger vehicles as a percentage of total ferry passenger vehicles crossing the Messina Strait*



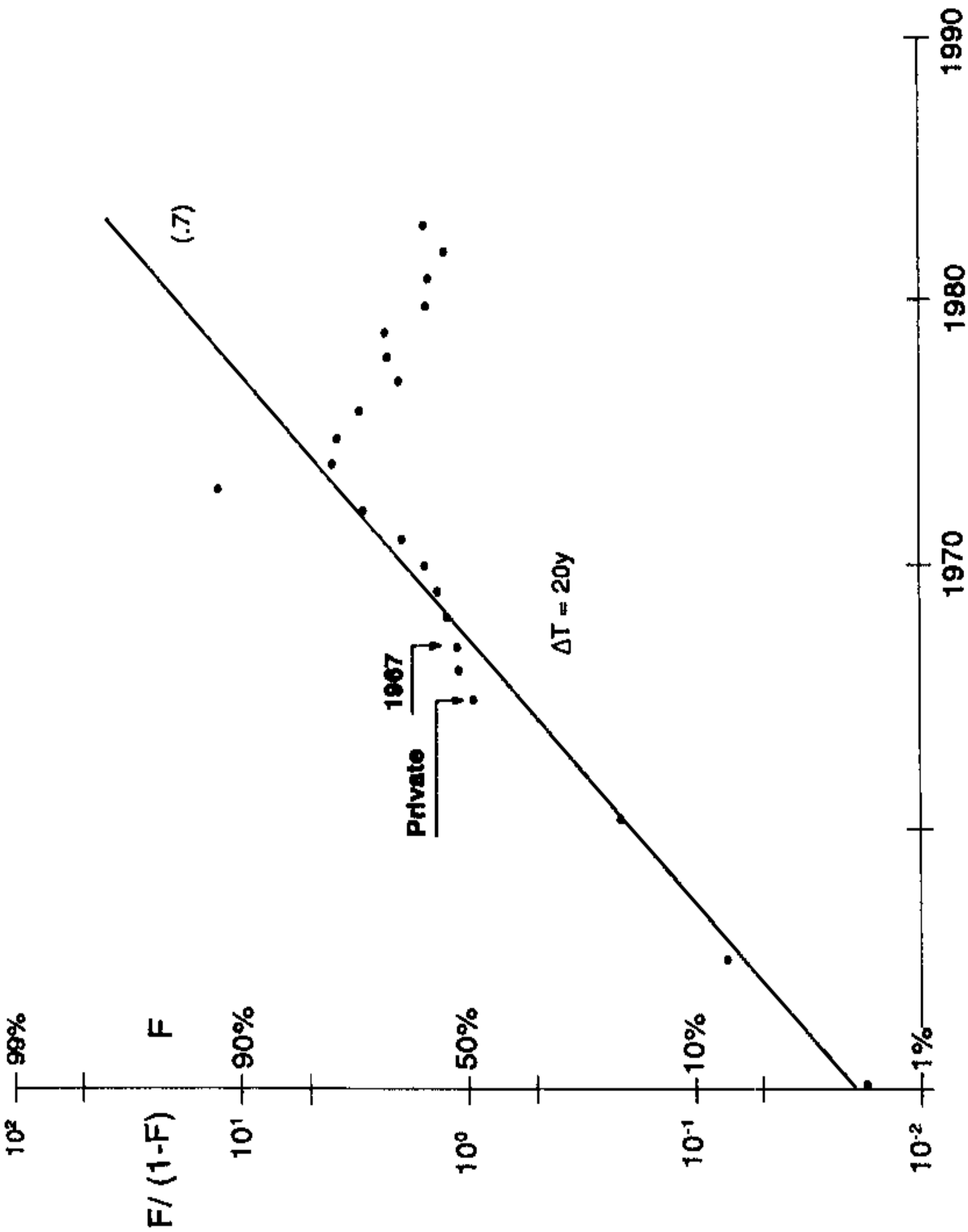
Based on data provided by Valleri, 1986.

FIGURE 4.53. *Trend in total cars (10^6) crossing the Messina Strait*



Based on data provided by Valleri, 1986.

FIGURE 4.54. *Trend in cars (10^6) crossing the Messina Strait by F.S. Ferries*



Based on data provided by Valleri, 1986.

F.S. trains are bound to have a decreasing importance, and consequently it may not pay to have them on the bridge. The capacity of the F.S. ferries, which is now sufficient, will be redundant in the near future. A revival of F.S. function, providing «*gliding auto routes*» east-west in northern Italy, and north-south for the rest of the country, although very interesting conceptually, will not penetrate the institutional barriers, in my opinion.

Passenger traffic is the real plum because the number of transits can easily switch from the present estimated saturation point of *20 million to 200 million*, if the appropriate *time formula* is found. If the link to another conurbation requires a transit time, say, of 40 minutes, like the ferries in Istanbul, plus some waiting time, then the two conurbations are time-separated and operate as independent units with traffic typical of *intercity traffic*. If the link to the other conurbation becomes a fast one, requiring a few minutes for the connection, then the conurbations become *time-connected* and the traffic becomes typical of *intracity traffic*. The definition of the latter notion means each person has a chance more or less daily to «cross the straits» – which psychologically becomes equivalent to crossing the street – and do all business, jobs, shopping on both sides.

An idea of the intensity of intracity traffic is given by Hong Kong, where the 1.5 million people living in Victoria interact freely with the 2.0 million living in Kowloon, generating roughly 800 million trips per year across the harbor. This roughly accounts for one crossing (one way) per person per day.

A useful rule of thumb is to imagine every citizen making three trips per day outside the home – one of them longer. This longer trip will «cross the river» if the transit time is not longer than 20 minutes or so. In the Messina situation, the number of transits per day would be roughly equal to the current population of the smaller city, Reggio Calabria, beyond the strait: 200 million transits per year. The rule works for Hong Kong and Lisbon.

The Messina *bridge* should be made the *link that functionally fuses Reggio Calabria and Messina first, and later a chain* of smaller cities down to Catania. This could be done by a *fast means of transport, organized as a Metro*, with short, very frequent (minutes) trains. The new technologies of *magnetic levitation*, already commercially available, offer superb comfort, speed and complete automatization. To fuse Reggio, Messina and Catania into a single functional unit, these Metro trains should be capable of at least 200 km/h and have very good acceleration, both characteristics easy to obtain with Maglevs.

This infrastructure would also create the preconditions for a linear city along which the inevitable emigration from inland will condense, in urban conditions more desirable than the blobs of central cities. Such necklaces of urban «beads» are appearing around the world, often referred to as «corridors», unified by air shuttles. The most gigantic of them, the Tokyo-Osaka «Shinkansen» corridor will be unified (one-hour transit time!) most probably by a Maglev line. As the evolution of this megalopolis-corridor is nearly complete, a short description may be useful in considering the shape of the Messina system.

Messina-Reggio as the Nucleus of a Megalopolis?

The emerging Japanese megalopolis may provide useful analogies for the planned Messina project. In 1966, the year of consolidation into one continuous unit from Tokyo to Yahato, its population was 69.2 million, its area 76,000 km^2, and its population density was 900 inh./km^2 (Doxiadis and Papaioannu, 1974). It had four main centers (see again figure 4.5).

The backbone of the transportation system along this strip has been the train, in particular the famous «bullet train». The bullet train covers the distance between Tokyo and Osaka, the more densely populated stretch of the megalopolis, in about three and a half hours. This time is at the limit for an eperopolis, where one goes, occasionally, from A to B to do business and comes back to A the same day. The time strain is well manifested by the increasing number of passengers *flying* along the corridor, as is done with the famous «shuttle» flights in the US east and west corridors.

The high density of demand can be satisfied only by misusing large plans, often Jumbo 747s designed for long-range service, in the absence of short-range planes (200-300 km) of appropriate size. This caused a major accident. There is growing need for a high-density mode having the same *speed* characteristics of a plane. Japan, in fact, has been developing its own brand of Maglev for the past 20 years.

This train is planned to cover the distance Tokyo-Osaka (about 600 km) in one hour. (Incidentally, the mean speed of an airplane, taking into account takeoff, landing and ceiling times, is about 600 km/h.) Because Japan is a hilly and mountainous country and the track of this fast train must run almost straight, about 50% of the track will be in tunnels.

Complete enclosure of the track in a «pipeline» would eliminate aerodynamic noise and the bangs when the train enters or leaves a tunnel.

A buried pipeline would also solve the problem of expensive rights of way in Japan. With complete enclosure, moreover, air pressure inside the tube can be reduced, permitting much higher speeds at reduced drag, as for airplanes flying at high altitude.

Although these developments may take another 20 years to be incorporated into an operating project, they promise bulkhead to bulkhead transit times in the range of 20 minutes, welding the megalopolis into a single unit, where people may travel in an «*intracity spirit*», with a couple of trips per day per person to any destination inside the city range. Of course, this will be possible only if the travel cost is aligned with the disposable income of the local population. These trains could then carry the order of *100 million passengers per day* – the potential demand in the Japanese corridor if the TTB and TMB are appropriately met. The technologies to manage such fluxes of passengers at the stations have yet to be invented however.

Coming to the much more modest, but conceptually identical, case of the *Catania-Messina-Reggio* megalopolis, we observe that the «attraction of the sea» and the «repulsion from the mainland» led to a rapid increase in the population of a necklace of cities located along the eastern coast of Sicily.

The three provinces in the strip have almost equal surface area and about a couple of million of inhabitants. It is not too difficult to calculate the order of magnitude of potential traffic across an arbitrary line, e.g., the bridge. One has to know, however, speed and cost of the main transport system, plus disposable income of the population. The first two parameters can, up to a point, be controlled by the planners: the third can be estimated from secular trends.

Trip rate is one of the measurements more thoroughly analyzed as a generator of urban traffic, and shows good regularities. To greatly simplify, the average active adult makes about three trips per day. Extended field measurements show that when the system provides more speed, e.g., through highways, the distance traveled increases accordingly, but the number of trips remains basically constant. This means a large territory is treated like a small one, size providing only a better choice of facilities, i.e., travel objectives. Available speed being different in different directions, these movement fields (territories) tend to be elliptic, with the long axis pointing toward the center of the nearest city, as transportation infrastructures usually radiate from it.

Assuming that any city developing out of the link between Catania and Reggio with a superfast public transport will be linear, and further postulating a Maglev subway *taking 20 minutes for the whole stretch*, we can estimate the *conceptually maximum flow* of passengers across the bridge.

The 60 minutes of TTB can be allocated to one long trip taking 10 + 10 minutes Maglev and 10 + 10 minutes walking, and two short trips each taking 5 + 5 minutes by car. In this scenario every traveler living in the area of Reggio will cross the bridge every day. Roughly half the population travels; this means the crossings (one way) originated from Reggio will roughly correspond to its population.

Assuming the targets of the trips would be distributed in proportion to the population in a certain area, then the *incoming* traffic will be roughly the same. In other words, the population *on the smaller side of the linear city linked by the bridge is the direct indicator for the number of crossings.*

If this simple, but intuitive and visual, way of reasoning seems unrealistic, we can check it against a real case, e.g., Hong Kong, where Victoria, the city on the island, has about *two million inhabitants*. Kowloon and the mainland are linked by a number of ferry lines and two fast tunnels – one for road traffic and the other for a subway. Most passengers (80%) are carried through the tunnels. As shown in the logistic analysis of the development of this cross-harbor traffic, the saturation point will be about 8×10^8 single crossings per year, estimated to be reached toward the end of the century. This corresponds to about *one million double crossings per day*. In 1986 the traffic had already reached 70% of the saturation point, i.e., 0.7 million.

In the case of the Tago estuary crossing in Lisbon, ferries will saturate with 50×10^6 passengers per year and the bridge with 26×10^6 vehicles per year. As these vehicles include buses, one can roughly add 50×10^6 passengers per year. These 10^8 pass/yr point to a city of about 140,000 people on the south bank of the estuary, which is approximately its actual size.

4.5.1. Considerations on the Transport of Goods

Because the Messina bridge should be useful and appropriate for its technical life, the technologies for transport of goods, as well as passengers, should be seen in a similar time perspective – say, 100 years. As always, it is instructive to look at their evolution in a historical context, in order to assess general trends.

First, the most expensive goods tend to move by the fastest and more reliable means of transport. When they first appeared, steamers were much more expensive than sailing ships, in terms of capital investment and their profligate use of fuel. Their coal, in fact, was carried to their bunker points around the world by the much cheaper sailboats! But steamships had two important advantages: they were not merely *faster*, they could *keep schedules*. So the most important items carried then were mail and human flesh. Achievements in machinery performance and general design made steamships progressively more competitive, in ton/km cost terms, and in a mere 100 years sail-powered ships no longer carried freight (figure 4.55).

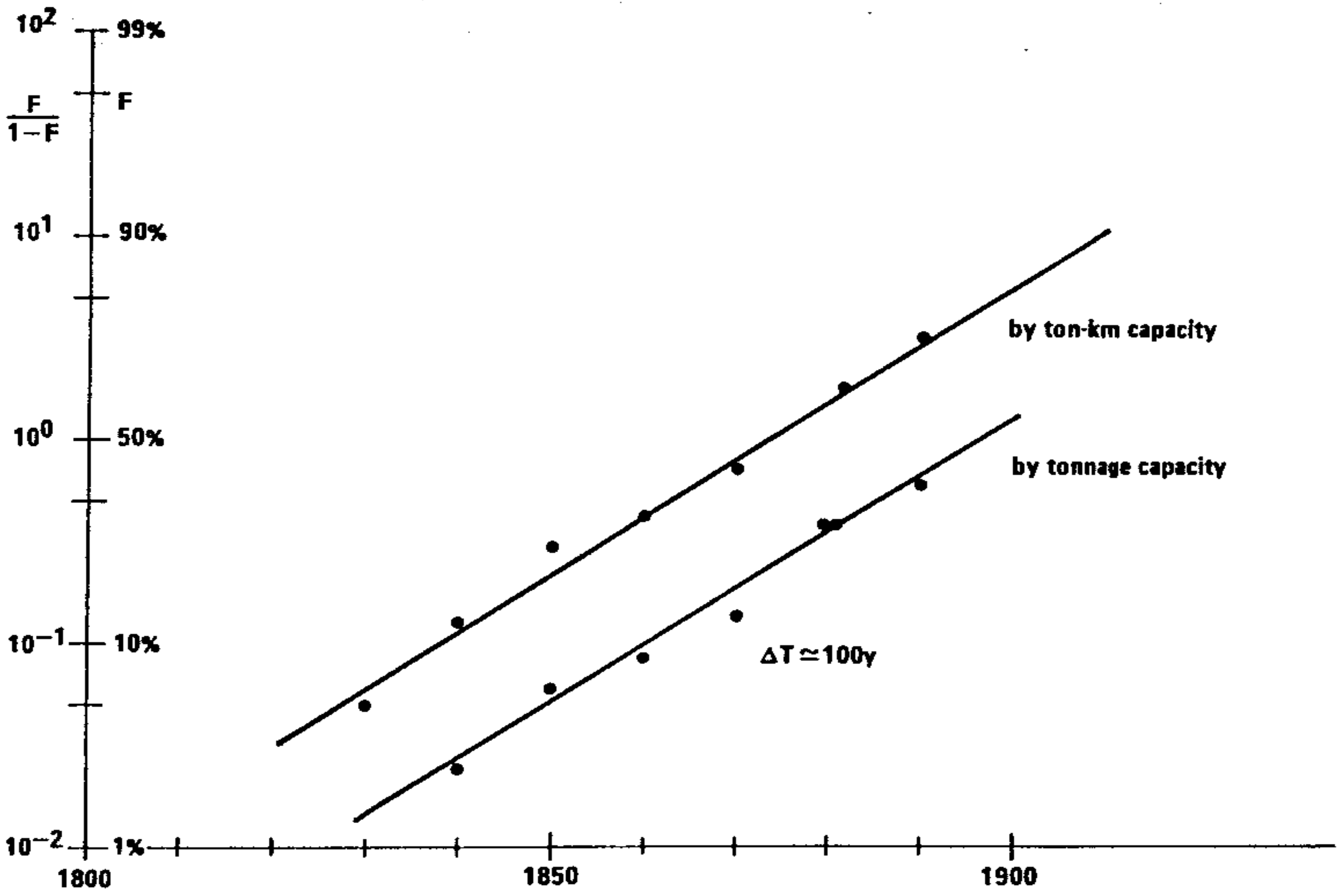
A similar story can be told for railways, which at the beginning also transported essentially mail and people, and successively lower-value goods. At their zenith in many parts of the world, trains carried almost everything. Now they haul almost only low-value goods. Taking away coal and grain, very little business would be left on American railway systems, in its heyday the most powerful network of the world. Similarly, when the Italian railways want to deliver goods on the mainland, e.g., from Milan to Rome, with appropriate speed and reliability, they use lorries. This indicates the point they have now reached in their trajectories, and leaves little hope for the next 100 years, unless they are drastically reconfigured.

The most advanced technology now is the airplane. Airplanes started their commercial career carrying mail, especially in the USA, during the heroic 1920s. In the 1930s they began carrying a significant number of passengers. During the last 20 years, progress in machine performance, size and general design has made them increasingly competitive for the transport of goods.

Jumbo 747s now carry ripe pineapple from Honolulu to New York and the East Coast, or auto bodies from Turin to Detroit. The cutoff line for the value of the goods that can profit from the characteristics of the air system – speed and efficient handling – becomes progressively lower. Fresh summer fruits from South Africa sell in winter in Vienna at prices not significantly different from the same fruits in summer, coming from Italy or Spain.

This means that *vegetables and fruits* from Sicily which are now in search of speed in order to reach the markets of northern Italy and Northern Europe in perfect condition, may take to the air, shunning progressively all other means of transport. Contrary to many analysts,

FIGURE 4.55 *Steamship versus Sailship performance in tonnage and productivity, world-wide*



then, the construction of the Messina bridge will probably have *no consequences* in this field.

Freight now accounts for only 15% of air transport traffic (ton-km), worldwide. Most goods are actually transported using the extra capacity of passenger flights and, in a few cases, using airplanes originally designed for passenger traffic and adapted for freight. The largest, the 747, carries about 100 tons. With the growth in traffic, a variety of planes specifically designed for freight will emerge, and technically 1000 ton freighters may be possible. As in the case of all-freight steamers, such air freight carriers may revolutionize the transport of goods, reducing the role of the road to retailing operations. The time horizon for such a process is about 50 years, within the next Kondratiev cycle.

From a functional point of view a solution for the possible revival of the Italian railways would be to provide «gliding auto routes» for the competing road vehicles – thus, sharing their success if only in a subordinate way. This would be consistent with the general trends of traffic in Europe described in Marchetti (1987).

One of several proposals would reduce operative track to one line east-west in northern Italy, and two lines north-south along the coasts. Railways would operate train platforms at a *mean* speed attractive for road traffic (150 km/h) with embarking-disembarking points every 200 km or so. These points should be chosen to facilitate the final retailing by major auto route, and have no strict connections with the cities and their centers, where railway stations are usually located and which do not usually constitute divergence points for freight traffic. All railway crossings would overfly road traffic, so that trains and road do not interact. The frequency of these platform trains should be in the 10-minute range, if a sizable fraction of the long-range road traffic is to be absorbed by such a mode of transport.

A similar situation occurred when steamships began to replace unpredictable, and consequently unscheduled, sailships, for carrying passengers, mail, and valuable cargo. These steamers, which required large amounts of coal, had to refuel at convenient places along their routes. All the coal to service these bunker points was transported by sailships, providing them with a brisk business *for a good 50 years.*

This is the only configuration I can imagine to resurrect the railway system *and produce substantial long-range train traffic for the bridge during the next 50 years.* But institutional resistance makes its implementation very improbable.

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MATHEMATICAL APPENDIX

The equations for dealing with different cases are reducible to the general Volterra-Lotka equations

$$\frac{\mathrm{d}N_i}{\mathrm{d}t} = K_i N_i + \beta_i^1 \sum_{n}^{j=1} a_{ij} N_i N_j, \tag{1}$$

where N_i is the number of individuals in species *i*, and *a*, *ß*, and *K* are constants. The equation says a species grows (or decays) exponentially, but for the interactions with other species. A general treatment of these equations can be found in Montroll and Goel (1971) and Peschel and Mende (1986). Since closed solutions exist only for the case of one or two competitors, these treatments mainly deal with the general properties of the solutions.

In order to keep the analysis at a physically intuitive level, I use the original treatment of Verhulst (1845) for the population in a *niche* (Malthusian) and that of Haldane (1924) for the competition between two genes of different fit. For the multiple competition, we have developed a computer package which works perfectly for actual cases (Marchetti and Nakicenovic, 1979), but whose identity with the Volterra equations is not fully proven (Nakicenovic, 1979).

Most of the results are presented using the coordinates for the linear transform of a logistic equation originally introduced by Fisher and Pry (1970).

The Malthusian Case

This modeling of the dynamics of population systems started with Verhulst in 1845, who quantified the Malthusian case. A physically very intuitive example is given by a population of bacteria growing in a bottle of broth. Bacteria can be seen as machinery to transform a set of chemicals in the broth into bacteria. The rate of this transformation, *coeteris paribus* (e.g., temperature), can be seen as proportional to the number of bacteria (the transforming machinery) and the concentration of the transformable chemicals.

Since all transformable chemicals will be transformed finally into bacterial bodies, to use homogeneous units one can measure broth chemicals in terms of bacterial bodies. So N (t) is the number of bacteria at time t, an $\bar{N}$ is the amount of transformable chemicals at time 0, before multiplication starts. The Verhulst equation can then be written

$$\frac{dN}{dt} = aN(\bar{N} - N)\,, \tag{2}$$

whose solution is

$$\mathrm{N}\ (\mathrm{t}) = \frac{\bar{N}}{1 - e^{-(at + b)}} \tag{3}$$

with b an integration constant; a is a rate constant which we assume to be independent of the size of the population. This means that there is no «proximity feedback». If we normalize to the final size of the system, $\bar{N}$, and explicate the linear expression, we can write equation (2) in the form suggested by Fisher and Pry (1970).

$$\log \frac{F}{1 - F} = at + b\,, \quad \text{where} \quad F = \frac{N}{\bar{N}} \tag{4}$$

Most of the charts are presented in this form. $\bar{N}$ is often called the *niche*, and the growth of a population is given as the fraction of the niche it fills. It is obvious that this analysis has been made with the assumption that *there are no competitors*. A single species grows to match the resources ($\bar{N}$) in a Malthusian fashion.

The fitting of empirical data requires calculation of the three parameters $\bar{N}$ a, and b, for which there are various recipes (Oliver, 1964; Blackman, 1972; Bossert, 1977). The problem is to choose the physically more significant representation and procedure.

I personally prefer to work with the Fisher and Pry transform, because it operates on *ratios* (e.g., of the size of two populations), and ratios seem to me more important than absolute values, both in biology and in social systems.

The calculation of $\bar{N}$ is usually of great interest, especially in economics. However, the value of $\bar{N}$ is very sensitive to the value of the data, i.e., to their errors, especially at the beginning of the growth. The problem of assessing the error on $\bar{N}$ has been studied by Debecker and Modis (1986), using numerical simulation.

The Malthusian logistic must be used with great precaution because it contains implicitly some important hypothesis:

- That there are no competitors in sight.
- That the size of a niche remains constant.
- That the species and its boundary conditions (e.g., temperature for the bacteria) stay the same.

The fact that in multiple competition the starts are always logistic may lead to the presumption that the system is Malthusian. When the transition period starts there is no way of patching up the logistic fit.

The fact that the niches keep changing, due to the introduction of new technologies, makes this treatment, generally speaking, unfit for dealing with the growth of human populations, a subject where Pearl (1924) first applied logistics. Since the treatment sometimes works and sometimes not, one can find much faith and disillusionment among demographers.

One-to-One Competition

The case was studied by Haldane for the penetration of a mutant or of a variety having some advantage in respect to the preexisting ones. These cases can be described quantitatively by saying that variety (1) has a reproductive advantage of k, over variety (2). Thus, for every generation the ratio of the number of individuals in the two varieties will be changed by $\dfrac{1}{(1-k)}$.

If n is the number of generations, starting from $n = 0$, then we can write

$$\frac{N_1}{N_2} = \frac{R_0}{(1-k)^n}, \quad \text{where} \quad R_0 = \frac{N_1}{N_2} \text{ at } t = 0 \qquad (5)$$

If *k* is small, as it usually is in biology (typically 10^{-3}), we can write

$$\frac{N_1}{N_2} = \frac{R_0}{e^{kn}} \tag{6}$$

We are then formally back to square one, i.e., to the Malthusian case, except for the very favorable fact that we have an initial condition (R_0) instead of a final condition ($\bar{N}$). This means that in *relative terms* the evolution of the system is not sensitive to the size of the niche, a property that is extremely useful for forecasting in multiple competition cases. Since the generations can be assumed equally spaced, *n* is actually equivalent to time.

As for the biological case, it is difficult to prove that the «reproductive advantage» remains constant in time, especially when competition lasts for tens of years and the technology of the competitors keeps changing, not to speak of the social and organizational context. But the analysis of hundreds of cases shows that systems behave exactly *as if*.

Multiple Competition

Multiple competition is dealt using a computer package originally developed by Nakicenovic (1979). A simplified description says that all the competitors start in a logistic mode and phase out in a logistic mode. They undergo a transition from a logistic-in to a logistic-out during which they are calculated as «residuals», i.e., as the difference between the size of the niche and the sum of all the *ins* and *outs*. The details of the rules are found in Nakicenovic (1979). This package has been used to treat about one hundred empirical cases, all of which always showed an excellent match with reality.

An attempt to link this kind of treatment to current views in economics has been made by Peterka (1977).