The Nature of the City

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Workshop: Future Cities - Do Cities Have Limits?

Public lecture

  

Preface

I last visited Glasgow 60 years ago, as a four-year-old child, when my family was spending a year in the UK. My father, a professor of British history, came to research John Bright, Richard Cobden, and other Victorian reformers. We sailed from and to New York on the magnificent Clyde-built ships, the RMS *Queen Mary* and RMS *Queen Elizabeth*. We visited the Forth Bridge, most of whose steel came from the Hallside Steelworks of the Steel Company of Scotland, about 15 kilometers from the University of Glasgow campus. My father preferred cities like Glasgow and Rochdale, the mill and market town where John Bright was born, to stately homes. So do I. To understand the nature of Glasgow, Rochdale, and all other cities, let's go back to basics.

Acknowledgments

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Cover page: Ordnance Survey map of Glasgow, 1885–1900. Reproduced with the permission of the National Library of Scotland. http://maps.nls.uk/view/101466212

Page 2: Jesse and his family aboard the RMS *Queen Mary*, 1955, and at the Forth Rail Bridge, 1956.

Page 24: Population density map of Scotland's Central Belt. Source: http://www.gonnaemapit.com/2014/08/population-density-in-scotland.html

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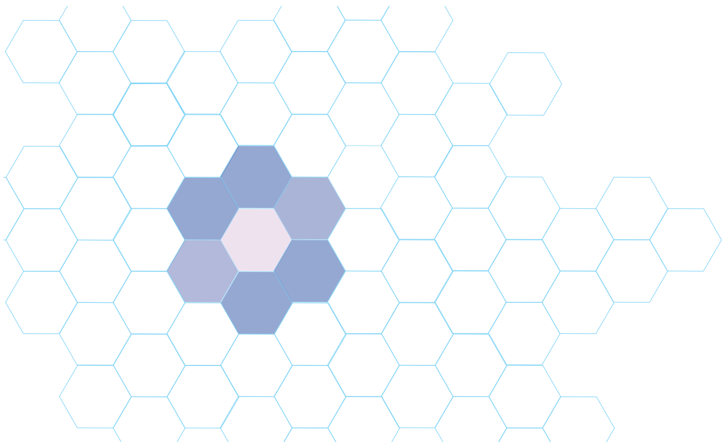


The nature of the city begins with the nature of the village. Villages fill geographical areas with their territories. Village territories, historically documented and often preserved today, are about 20 km^2. As they fill an area, the villages have shapes rather like hexagonal tiles, hexies, about 5 km in diameter. German geographer Walter Christaller established the rational interpretation of geographical distribution of human settlements in 1933 in his seminal work on central places in southern Germany. The building stone of Christaller's central place theory was the village.

Christaller observed that every village possessed the basic services for daily use, for example, a baker, tailor, cobbler, and smith, and a small church or shrine. Less frequently used services, for example, a cooper, miller, or wheelwright, concentrate in a village that also serves the six neighboring ones. In the bunch of seven villages, this one attains a higher second-level of hierarchy. The hierarchical process continues, and at the center of six bunches of seven villages is a seventh bunch with a small city, providing third-level services, such as a court or hospital.

Hierarchical centers have populations of increasing size according to their hierarchical level. However, up to about 1800 their physical area never exceeded that of the village territory, 20 km^2. If the village succeeded as a trading center or a political and administrative unit, fields became houses and the 20 km^2 filled to the limit. The walls of ancient cities neatly prove the rule. Hadrian's Rome and York in 1775 never exceeded 20 km^2 of enclosed area (see **Figures 1** and **2**). Persepolis, Marrakech, and Vienna also followed the rules.

The reason reduces to the fact that people travel about one hour a day, and 5 km uses up the one hour on foot. Until 1800, basically all cities were pedestrian cities. In the pedestrian order, the basic unit of one village had a 5 km diameter, the second level of seven villages a diameter of 15 km,

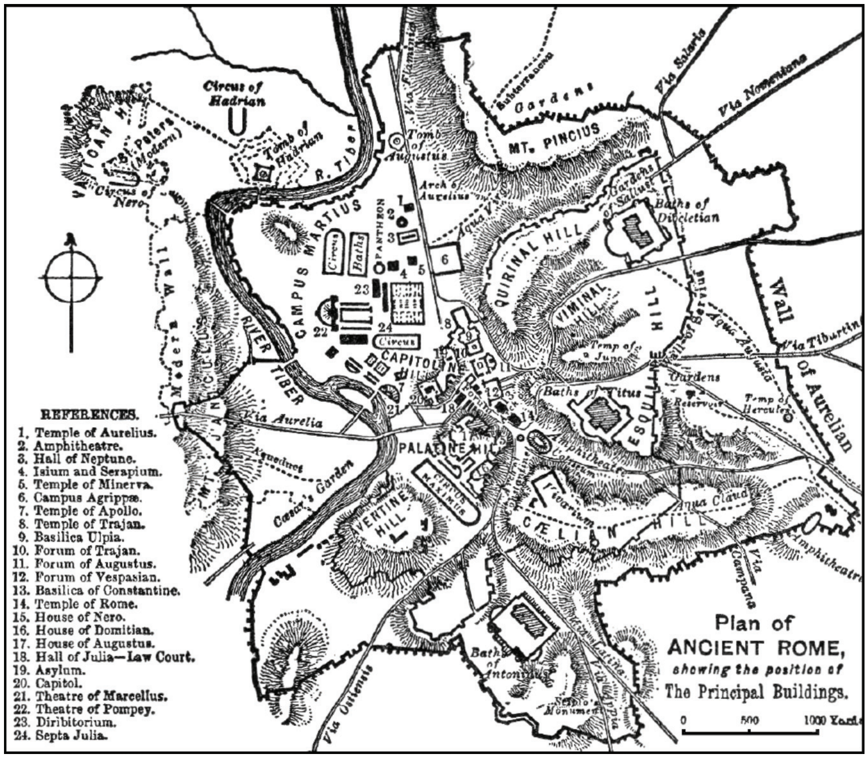


Figure 1.
Imperial Rome, diameter 5 km.

Source: http://www.best-of-rome-italy.com/support-files/ancient_rome_map1.pdf

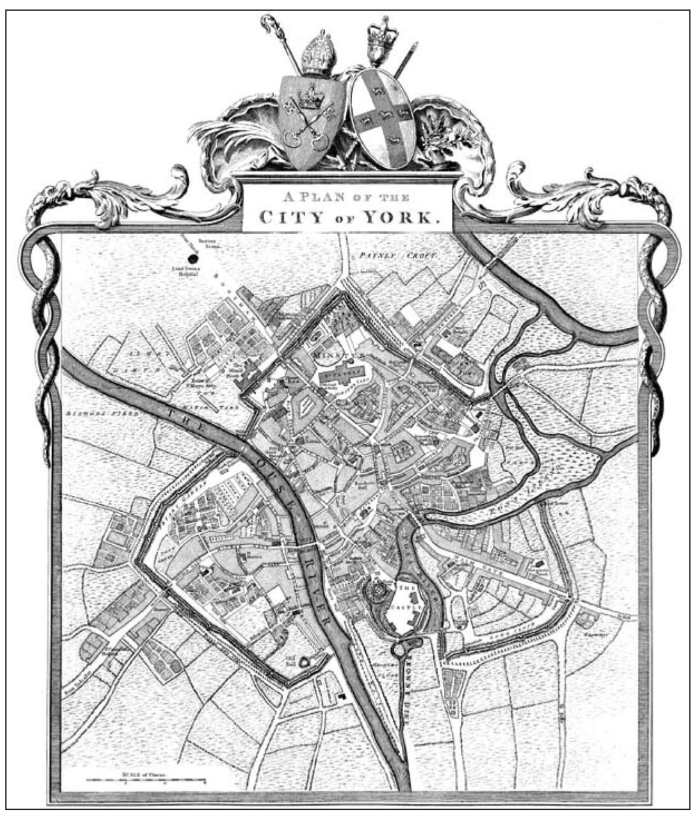


Figure 2.
York, town plan from 1775, diameter 5 km.

Source: http://www.oldtowns.co.uk/Mapshop_Yorkshire/Jeff-1775/sheet-4-4.htm and the third level of 49 villages a 45 km diameter. Introducing mechanical transport such as a tram, bus, or subway changes the scale of the base. Lower hierarchical levels disappear, melting into single units with sizes corresponding to the speed of the dominant mode of transport. Cars have a mean speed of about 40 km/h, so that in a car society the first two levels of organization may disappear, gradually as technologies are adopted. The present landscape of settlements is of course a hybrid.

Along with travel time, to which I will return, there is an additional logic proposed by engineer John Virirakis in 1972, minimization of energy. Virirakis proposed the organization of a city as the outcome of interaction between economic operators who provide services and the residents who use them. The objective of the economic operator is obviously economic survival, and that of the resident is to minimize the effort to reach the services with appropriate frequency. The final result of a trial-and-error process where services (such as shops) open up more or less stochastically and close, if they are not sufficiently patronized, leads to internal organization of the city with quarters or boroughs of different population density, but organized in clusters of seven, like villages. The central borough serves the surrounding ones for the less frequently used services. The clusters organize hierarchically. The distribution of services minimizes the total length of trips, or rather travel time, for the population, relative to any other distribution. Total traveling for using the facilities is constant and independent of size. We can say structure is preserved, over a range of scales.

Ten times more inhabitants do not use ten times more area. In fact, size is inversely proportional to local population, meaning that density decreases exponentially in cities. The consequence is that the central quarters are very small, so that all facilities are at a short distance. Thus, Manhattan is very practical for people like me who live there.

Anthropological basis

Recognizing that people travel about an hour per day, we must now build an anthropological foundation. At the most basic level, hominids are animals who operate from a protected refuge, originally a cave. We try to minimize the time we search and maximize the efficiency of foraging, and we also seek at night to return to the cave, the secure base. Exposure is dangerous, and it turns out that in all societies humans average a bit more than an hour daily traveling. Current studies show that, averaged over the population, travel time is about 70 minutes per day, but for convenience let's say one hour. The spread, which depends on age, occupation, and other variables, is less than what most people expect. Following transportation scientist Yacov Zahavi, we call this the travel time budget, and it is well established by many surveys.

Humans also have a travel money budget. About 10% of GDP, or about 15% of an individual's disposable income finances movement. The 15% could correspond to about one of the eight hours per day dedicated to consumption, a speculation. A tough recession like 2008 makes a dent but not for long, as we see in the US (**Figure 3**).

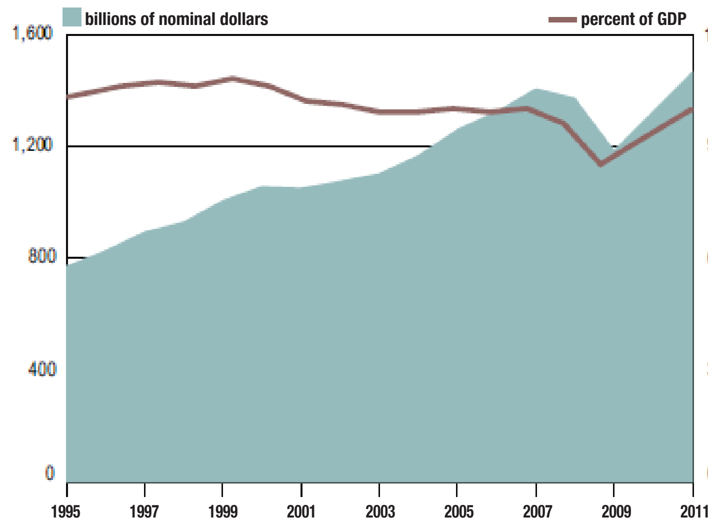


Figure 3. US transportation spending, 1995–2011. Travel money budget: 10% of GDP (or somewhat higher fraction of disposable income).

Source: US Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, *National Transportation Statistics,* table 3-9, available at bts.gov as of October 2013.

Within these time and money budgets, people allocate time and money between different modes of transport in such a way as to maximize distance, the size of their territory. A larger territory offers more resources. Because travel time is fixed, people use money to buy speed.

The number of trips per day ranges only between three for people in cities and four or five for people in villages and the countryside. The main trip is from home to school or work, whether field or factory or office. This round-trip may use on average, say, 50 of the 70 minutes daily. The second and third trips are typically for shopping and social contact, to buy a fresh loaf of bread and to go to the pub, say.

In addition to the main daily round-trip to work or school, from time to time a longer trip is needed, usually for business. Because a working day can last 12 to 14 hours, and one must dedicate at least 4 to 5 hours to the business proper, inclusive travel time in each direction cannot be more than

3 to 4 hours door to door if one is to return home for the night. Practically speaking the high-speed part cannot be more than about 1.5 hours, which in turn establishes another spatial hierarchy. To give an example, Paris has access to more than 100 million people by short flights that allow return the same day. In a society whose businessmen fly, the key is how many 1.5-hour flights a city has with other cities, which together form an operational nucleus.

Amazingly, travel patterns are invariant to income or level of development, culture or nationality, and religion, and are basically anthropological. With increasing income, however, the distance traveled daily increases quite regularly as long as technology increases the modes or options for travel. In round numbers, walking achieves about 5 km/hr, cars 50 km/hr, and planes 500 km/hr. In a 1998 study spanning from 1880 into the 1990s, Cesare Marchetti, Perrin Meyer, and I found that income and technology had compounded the mobility of Americans almost 3% per year for over a hundred years from about 5 km daily to about 50 km (**Figure 4**). Speed is expensive both because faster machines have always been more expensive than slower ones per kilometer, but especially because people travel in time and in the same time they cover more kilometers. Even if cars and planes cost more or less the same per kilometer, a plane costs ten times as much per hour.

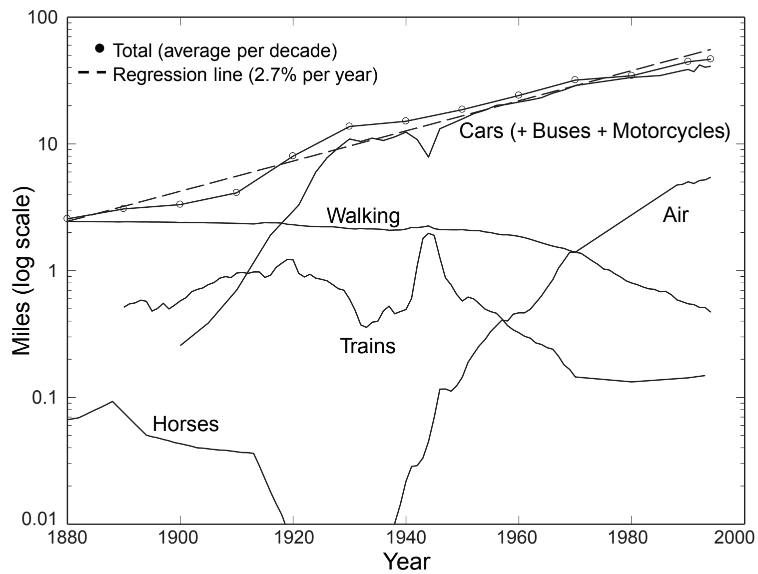


Figure 4. US passenger travel per capita per day (range).
Source: Ausubel, Marchetti, and Meyer, 1998.

All this means a city is a spatial structure invariant to travel time. For a given city the travel time structure is basically independent of its spatial evolution. Modern urbanization is a spatial reorganization driven by faster transportation technologies. Thus, a city is a time structure more than a geometrical one. And we can define a city simply as the conurbation inside which people move daily.

City size is determined by the longest trip done with the fastest means of transport in about half an hour. In other words, the diameter of a city will be about one hour transit time by the fast mode. The center is the area of maximum accessibility for the maximum number of persons. The definitions of center and periphery are also not geographic but temporal.

To summarize, human settlements are organized to provide hierarchical contacts in a time frame of about one hour. The parameter that transfers this organization into space is transport speed. This speed is actually the independent variable regulating the entire system.

Modes of travel

So, travel centers on the home and extends into a range depending on the speed of transport available to the individual and on cost relative to the disposable income of the individual or family. The fact that a traveler spends about one hour per day for daily movements creates a strict link between space and speed. The speed that can be extracted from the transport system thus defines the structure of human settlements. "Speed" means inclusive speed, like Darwin's inclusive fitness. It spans the time from when the traveler leaves home to when she or he walks in the office, for example, including minutes spent waiting for a bus or searching for parking.

With growing wealth, technology introduces faster means. The new modes are faster, but usually not cheaper, especially at the outset, so travelers do not rush to use them. Rather the new means gradually capture the market, as people can afford more and become familiar with how a new system operates, and as the system itself improves in many dimensions, including safety, comfort, and pollution. Picture slow penetration of new technologies of transport adding speed while substituting for the old ones in time allocation among various modes of travel.

Up to 1800, most people lived at one speed, the 5 km/hr a person can walk. We used to walk 5 km per day, and now Americans walk perhaps 1 km per day. In the US, mechanical mobility surpassed walking only during the decade 1900–1910 and in France during the 1920s. Although tiring, running is three to four times faster than walking and quite reliable for the able-bodied. High speed lasts only an hour or two. The Incas sustained their civilization for centuries on foot in a large empire, where the farthest outposts were two weeks from the center for the relay runners.

Horses can run faster and longer than people. They can sustain 20 km/hr for several hours per day and reach a speed of 50 km/hr for a few minutes. Horses topped transport for a few thousand years. They allowed the sovereign to send and receive messages and thus helped determine the kingdom in which you lived. Horses made big empires for the Romans, Chinese, and Huns.

In a few places horses also greatly expanded personal territory. The horse, of course, is the image of the American West. Horses were cheap transport in the United States because they did not compete with people for land for food. In effect, they established the low price of a gallon of gasoline in the United States. The vast American West was quickly divided into territories controlled by ranchers, farmers, and "Indians," all with horses.

However, the great expense of horses in most societies severely limited their use, and so in most places they made no impact on the basic structure of the human settlements, although they did create famous challenges of pollution and many jobs.

Trains (commercialized about 1830) and motor cars (first produced in the 1890s) displaced horses. Canals (on whose towpaths horses and mules pulled barges), rails, roads, and airways have successively occupied shares of the overall length of the transport infrastructure of countries including Britain, France, and America.

Although we may think of trains as fast, in practice their inclusive speed has always been slow, because of travel to and from the stations, changes, stops, and serpentine routes. To reach the University of Glasgow campus, I traveled by train from Leuchars to Glasgow, a distance of 105 km. The segment on the train lasted 162 minutes, or about 40 km/hr. The inclusive travel time was slower because I needed to taxi from St. Andrews to Leuchars train station and then again to my hotel in Glasgow.

Today European intercity trains still average only about 60 km/hr, measured as air distance between stops. German trains, perceived as efficient, average 65 km/hr with a peak of only about 100 km/hr. A TGV may reach 400 km/hr on its rails, but inclusive speed is perhaps half this value. The greatest effect of trains was thus in regions where distances of, say, 100 km or less mattered greatly.

Compared with railroads, cars have the great advantages of no waiting time and no mode change, offset in some places by parking shortages. One could say cars have infinite frequency. In practice, cars are about eight to ten times as fast as pedestrians. Their mean speed is about 40–50 km/hr, combining travel within and between cities. Public vehicles such as buses go about 20 km/hr, or 10 km/hr in midtown Manhattan.

Expanding in linear space eight times, one acquires about 60 times the area. Cars thus expand territory from about 20 km^2 for the pedestrian to about 1,200 km^2 for a license holder and those who can hire one. Sixty villages become one town. The car effectively wipes out two levels in the former hierarchy of settlements in which, in Christaller's classic formulation, clusters of seven (pedestrian) villages support a town, which in turn joins with six other towns to support a city. The car thus reshuffles 60% of the population into larger urban areas.

In the United States, the average distance a car travels has remained about 9,000 to 10,000 miles per year since 1935. The time a car works each day has also remained about an hour, so the average speed of a car has stayed constant at about 40 km/hr. More horsepower made no difference to speed.

By the way, sailing was just walking on water. A typical 19th century sailing ship from Glasgow to Boston took about 50 days for the 5,000 kilometers or about 4 km/hr. In 1912 the steamship RMS *Titanic* averaged about 30 km/hr and peaked at just under 40. The steamship *Queen Mary* achieved average speed equal to a car, 40–50 km/hr. Maritime transport did smartly reduce friction and smooth coastlines and other terrestrial impediments. Most goods today still spend time on the water, and seawater made Glasgow great.

Alas for Glasgow as well as Liverpool, Belfast, and many other ports, flying finesses the problem by smoothing Earth itself, elevating travelers to levels where the mountains and valleys do not interfere. For animals, flying is energetically cheaper than running, but requires extremely sophisticated design. Flying has a high fixed energy cost, because support is dynamic. One must push air down to stay up. Energy cost thus depends on time in flight and penalizes slow machines. So, the successful machines tend to be fast. The mean speed of a plane is 600 km/hr with takeoff and landing, an order of magnitude faster than the intercity trains. Reflecting on the troubles of Glasgow during the second half of the 20th century, we understand that it was aviation that nearly killed the city, not London or unions.

During the past 70 years, passenger-kilometers for planes have increased by a factor of 100. The United Arab Emirates, with a population about the same as Scotland, has invested massively in aviation infrastructure, and in 2014 Dubai International Airport became the world's busiest with about 70 million total passengers. Nearby Doha and Abu Dhabi rank, respectively, 20th and 30th globally. Nations and cities need to play in the air game to compete at the top level.

We could go into the side stories of bicycles, trams, and other vehicles, but suffice it to say that low-cost speed is what brings success. Successful infrastructures diminish substantially the time of travel.

Zipf and rank-size

As mentioned, Christaller theorized why cities organize into a hierarchy of size. The idiosyncratic American statistician and linguist G.K. Zipf collected data showing that populations of cities follow simple rules, basically a Pareto Distribution or discrete power law probability distribution (**Figure 5**). One of his most powerful examples shows the growth of the rank-size distribution of American cities from 1790 to 1930. The top city grew from about 50,000 inhabitants to 8 million and the ranks from a dozen to about 5,000. From a bumpy beginning a smooth hierarchy emerged. The system wins.

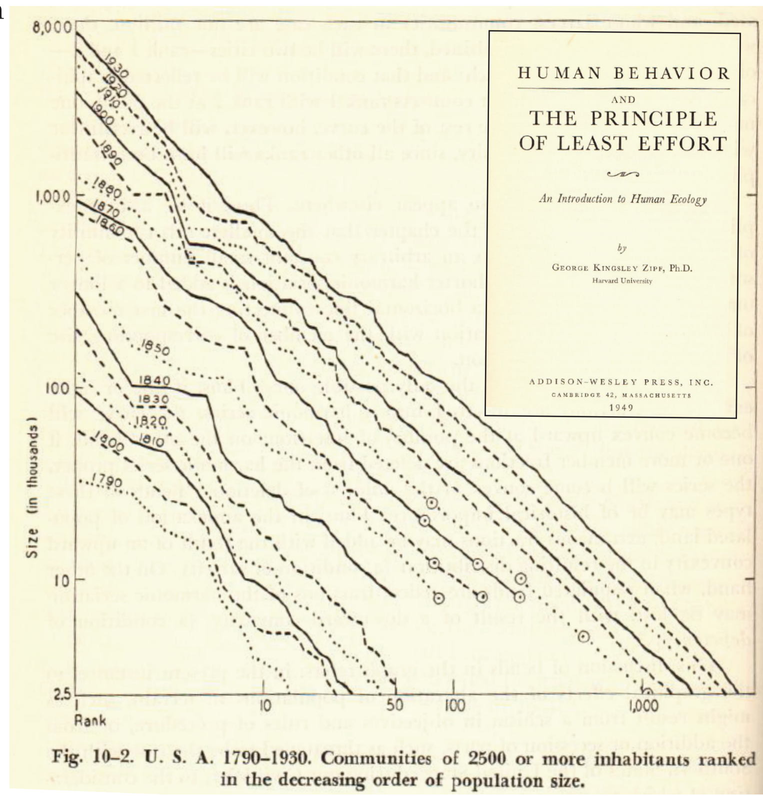


Fig. 10–2. U. S. A. 1790–1930. Communities of 2500 or more inhabitants ranked in the decreasing order of population size.

Figure 5. Rank-size distribution of US cities following Zipf's Law. Source: Zipf, 1949.

As a linguist, Zipf noted that in dozens of languages where he made rank-frequency charts, a few words occur often and most rarely. More specifically, the second-ranked word occurs approximately half as often as the first, and the third item one-third as often as the first, and so on. In his 1946 compendium on human behavior, Zipf made rank-size distributions for cities and found a similar result. He proffered a "principle of least effort" as a possible explanation for languages: neither speakers nor listeners using a language want to work harder than needed for understanding, and the process resulting in about equal distribution of effort leads to a Zipf distribution. The idea resembles what Virirakis found for the hierarchical distribution of services in cities.

Usually a large population corresponds to a higher hierarchical level. Functionally the area commanded by the influence of a city depends on the speed of means of transport. Thus, the population of a city is not just a statistic. A large city can afford a large hierarchy of specializations, providing dominance in the competition with other cities. In the long run the largest become the dominant ones (or vice versa).

Ponder some estimates of Europe's largest cities since the year 1000 (**Table 1**). Take the estimates cautiously because boundaries and survey methods change. We can argue about using metro areas rather than city limits. Still, the dynamic world system lifts and lowers cities. Glasgow attained ninth position in the 1900 list. If a city has the drive to grow, the most modern means of transport provide the tools. In 1900 Glasgow had the ships and rails. To compete in the European region, clearly Glasgow and environs need to operate as a larger city, which means you need speed.

Table 1. The largest cities in Europe, 1000–2015 (population in millions)

1000		1400		1700		1900		2013–2015	
City	Population	City	Population	City	Population	City	Population	City	Population
Constantinople	.450	Paris	.275	Constantinople	.700	London	6.480	Istanbul	14.4
Cordoba	.450	Milan	.125	London	.550	Paris	3.330	Moscow	12.2
Seville	.090	Bruges	.125	Paris	.530	Berlin	2.424	London	8.4
Palermo	.075	Venice	.110	Naples	.207	Vienna	1.662	St. Petersburg	5.2
Kiev	.045	Granada	.100	Lisbon	.188	St. Petersburg	1.439	Berlin	3.5
Venice	.045	Genoa	.100	Amsterdam	.172	Manchester	1.255	Madrid	3.2
Regensburg	.040	Prague	.095	Rome	.149	Birmingham	1.248	Rome	2.9
Thessalonika	.040	Caffa[1]	.085	Venice	.144	Moscow	1.120	Kyiv	2.8
Amalfi	.035	Seville	.070	Moscow	.130	Glasgow	1.072	Paris	2.2
Rome	.035	Ghent	.070	Milan	.124	Liverpool	.940	Minsk	1.9
								Bucharest	1.9
								Vienna	1.8
								Belgrade	1.8
								Hamburg	1.8
								Budapest	1.8
								Warsaw	1.7
								Barcelona	1.6
								Kharkiv	1.4
								Munich	1.4
								Milan	1.3

Note 1: Caffa is Feodosia, decimated by Black Death in 1346.

Sources:

1000–1900 - Chandler and Fox (1974:11–20, 330).

2013 –2015 - https://en.wikipedia.org/wiki/List_of_European_cities_by_population_within_city+limits

Air and maglev

Now consider future cities and their limits. What is to come? As we have seen, new forms of transport can enter the game.

The flying game is still young. In 2015 Americans on average flew about 70 seconds per day (**Figure 6**). Japanese flew about 20 seconds, and Europeans probably about the same. The world average was about 12 seconds. Indians and Chinese fly a second or two per day. Three minutes per day equal about one round-trip per month per passenger for a Glaswegian to London or Amsterdam. That certainly seems feasible for the average Scot a generation hence. During 2015 I flew about 165 hours, or more than 25 minutes per day, and I am not even a top level frequent flier. The jet set in business and society shows what is possible. The cost in real terms of air transport is decreasing, so a larger stratum could allocate some share of its money budget to this mode. For the European air system, the projected level requires an order-of-magnitude increase in the next 25 years, or about 12% per year, a hard pace to sustain without a basic rethinking of planes and airport logistics.

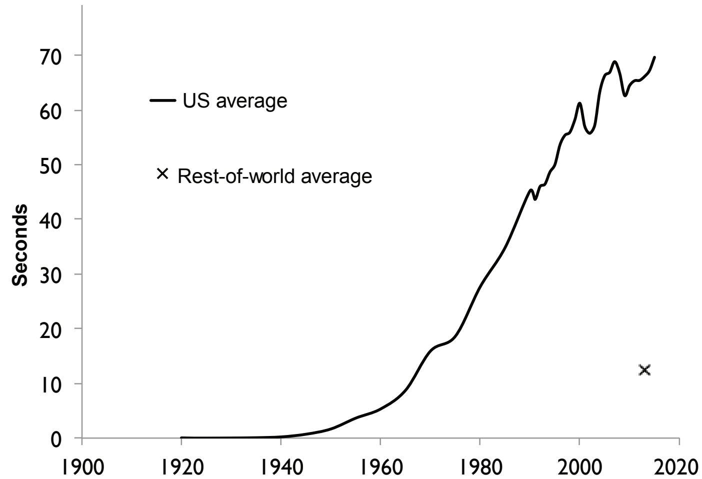


Figure 6. Time spent traveling by air, per day.

Sources: US Bureau of Census (Historical Statistics of the US -1976), Statistical Abstract of the United States (various years 1980s 1990s); Bureau of Transportation Statistics (T-100 Market and Segment); International Air Transport Association (IATA).

Top planes can meet the productivity need in part with greater speed and size for intercontinental travel, but at the continental range, noise and other problems arise, especially in the 500–1,000 km distances that separate many large continental cities. A single route that carries 10 million passengers per year per direction, or 30,000 per day, would require 60 takeoffs and landings of A-380s, a lot to add on present airports. Moreover, in our outlook, airplanes will consume much of the fuel of the transport system, a fact of interest to both fuel providers and environmentalists. Today's jet fuel will not pass the environmental test at future air traffic volumes. Still, we clearly need a high-density mode having the performance characteristic of top airplanes without the problems.

According to our studies, the best bet is on magnetically levitated systems, or maglevs, "trains" with magnetic suspension and propulsion. Maglevs would form the fifth great travel infrastructure following canals, rails, paved roads, and airports (**Figure 7**).

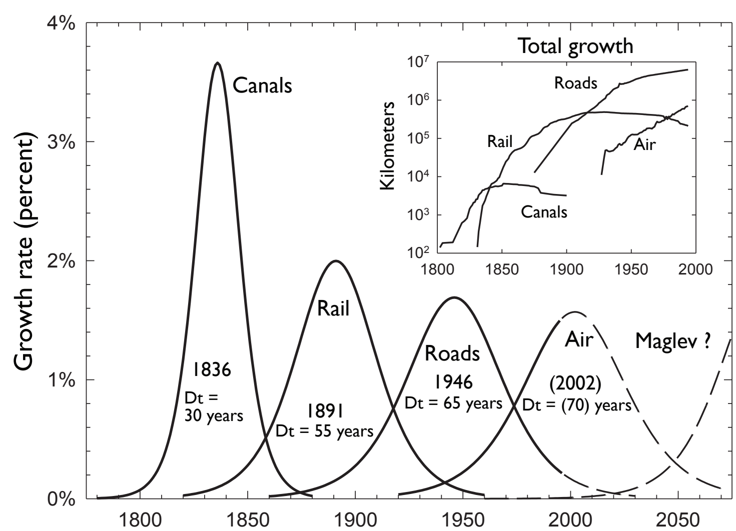


Figure 7. Idealized growth of US transport infrastructure.

Source: http://phe.rockefeller.edu/green_mobility/

The maglev is a vehicle without wings, wheels, and motor, and thus without combustibles aboard. Suspended magnetically between two guard rails that resemble an open stator of an electric motor, it can be propelled by a magnetic field that, let's say, runs in front and drags it. Hard limits to the possible speed of maglevs do not exist, above all if the maglev runs in an evacuated tunnel or surface tube.

Elon Musk has proposed a variant called the hyperloop that would speed between Los Angeles and San Francisco at about 1,000 kilometers per hour, accomplishing the trip in about 35 minutes and thus comfortably allowing daily round-trips, if the local arrangements are also quick.

Vacuum or partial vacuum is the key. Now vehicles move within a fluid, dissipating most of the energy used to propel them. The needed breakthrough is to run the vehicles in evacuated tubes or tunnels. Evacuated space is expensive but offers high speed. Evacuated means simulating the low pressure that an airplane encounters at 10 to 15 thousand meters of altitude. Tunnels solve the problem of permanent landscape disturbance, but tubes mounted above existing rights-of-way of roads or rails might prove easier and cheaper to build and maintain.

Spared a motor and the belly fat called fuel, the maglev could break the "rule of the ton," the weight rule that has burdened mobility. The weight of a horse and its gear is about a ton. Similarly, the weight of a train per passenger, an auto that on average carries little more than one passenger, and a jumbo jet at takeoff all average about one ton of vehicle per passenger. Per passenger, the maglev could slim to 300 kilograms, dropping directly and drastically the energy cost of transport.

Will maglevs make us sprawl? This is a legitimate fear. In Europe, since 1950 the tripling of the average speed of travel has extended personal area tenfold, and so Europe begins to resemble Los Angeles. In contrast to the car, maglevs may offer the alternative of a bimodal or "virtual" city with pedestrian islands and fast connections between them. Maglevs can function as national and continental-scale metros, at jet speed.

Looking far into the 21st century, we can imagine a system as wondrous to today's innovators as our realization of cars and motorways would seem to Charles Rolls and Henry Royce when they first met in Manchester in 1904. Because the maglev system is a set of magnetic bubbles moving under the control of a central computer, what we put inside is immaterial. It could be a personal or small collective vehicle, starting as an elevator in a skyscraper, becoming a car or taxi in the horizontal maglev network, and again becoming an elevator in another skyscraper. The entire bazaar could be run as a videogame where shuffling and rerouting would lead the vehicle to its destination swiftly, following the model of the Internet. Taking the steering wheel away from the driver multiplies chances for system optimization. In the end, a maglev system is a common carrier or highway, meaning private as well as mass vehicles can shoot through it.

In any case, a logical step is to speed traffic between Glasgow and Edinburgh airports and later to London. The airport now forms the fulcrum of intercity transport, as the train station did a hundred years ago. Thus, the intracity transport net, in particular the subway, must absorb the airport and tie to it in a superfast manner (10 minutes) to keep a role for the city center. The airport becomes the interface of all the intercity transport. For the next 30 years or so, air will continue penetrating the hour of travel and augment mobility. All the rest must be conceived around it.

The distance between Glasgow and Edinburgh airports is 80 km (**Figure 8**). If the journey from Glasgow to Edinburgh takes 20 minutes, then the system becomes a single city. The speed required could be achieved by a TGV operating at 240 km/hr. The combined cities would total about

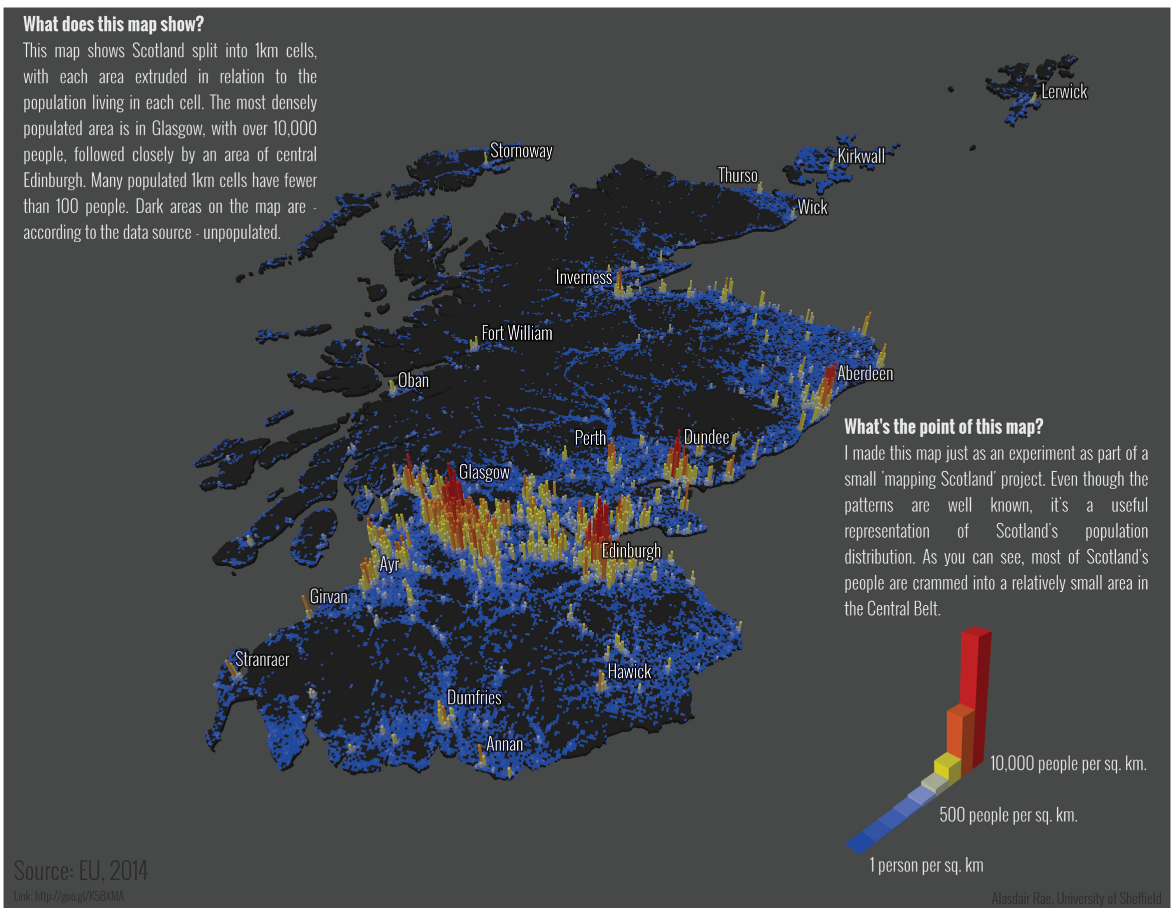


Figure 8. Population density of Scotland.

Source: Map and text by Alasdair Rae, http://www.gonnaemapit.com/2014/08/population-density-in-scotland.html

1.1 inhabitants in their Council area, and move to a higher rank in Britain and Europe. But why not go with even faster maglev, link the airports in 10 minutes and allow the combined metro areas of the two cities, totaling about 3.1 million to function as a single city? This would restore the region to about tenth place in Europe, and second in the British Isles.

Speaking of Britain, 6 million people yearly fly between the five London airports and Glasgow (550 km, 2.5 million passengers) and Edinburgh (530 km, 3.5 million passengers). Six million per year equals more than 16,000 per day, carried by 341 flights per week from Edinburgh to London and 322 from Glasgow, a total of 660 flights, about one-sixth of all takeoffs and landings. These would be fine routes for a maglev initially at 600 km/hr, and later faster, allowing easier same-day return trips. Present traffic could fill a maglev from each city every hour from 6 am to 10 pm with 500 passengers.

Relieving the airports of 6 million of the 20 million passengers who now use them and one-sixth of all takeoffs and landings would in turn allow aviation to grow more readily, in particular to Amsterdam, Frankfurt, and Paris and other continental hubs that are less than two hours away and again allow same-day return visits.

Globally the tendency is to concentrate into larger and larger cities with the exception of Europe, where population centers larger than 1 million have been rather stable since the 1960s. This may contribute to the weakening position of Europe, unless the smaller European centers, including Glasgow, sufficiently interconnect in 20 minutes to integrate them, or in the medium time mode (one to two hours) to integrate them at the highest functional level.

In short, maglevs and aviation can allow Scotland's Central Belt to operate at a high level in both Britain and Europe. The limit is indecision to invest.

Telecom

Naturally, we ask in the era of smart phones whether the explosion of telecommunication substitutes partly or totally for travel. The answer is telecom does not interfere at all with the quantity of travel but modifies the objectives. Travel is born in our instinct to use the means that technology allows to reach our objective of maximizing territory or access to resources.

The wired city can eliminate the component number one in travel, travel to work, 50 minutes or 35 km per day for car owners. However, if we work from home, we immediately absorb the freed-up travel time with more trips for social or leisure purposes. Ditto when we shop from home. Moreover, travel extends contacts spatially, and thus extends also the necessity of telecom. They enjoy parallel growth.

In fact it is not at all clear to me that people will abandon the office. In the case of finance, the system operates in an abstract electronic way the world over, and the operators can be completely delocalized. But bankers continue to choose to aggregate in New York, London, Frankfurt, Tokyo, and a few other cities. The desire for direct personal contact continues to create the opportunity for cities to succeed.

By the way, telecommuting does not spare petrol. The Internet surely lifts the efficiency of foraging, but the necessity remains for personal contact, that is, travel, to arrange and operate the necessary contracts of life. The travel time budget gets spent.

Cars, drones, hoverboards

At this point it makes sense to offer a hopeful note about cars, or about cars enriched with information. Cars are not well suited for densely populated cities. The basic and growing incompatibility expresses itself in the expanding areas where cities limit car entry. The share economy may provide a way forward. As we have seen, a car is used on average only about 50 minutes per day. Immense capital sits wastefully parked for 23 hours daily. In the US the beginning of a plateau in the population of cars and light trucks suggests we are approaching peak car.

The reason may be that drone taxis are poised to win market share. While the average personal vehicle motors about an hour per day, a car shared like a Zip Car gets used eight or nine hours per day, and a taxi even more. BMW and Daimler have recently entered the car-sharing service business with ReachNow and Car2Go. Users rent when and where they need mobility based on the motto "pick up anywhere, drop off anywhere." Billing is per-minute, and fuel costs and parking charges in public car parks are included. Users locate cars using an app, and a chip in the driving license acts as an electronic key.

As venture capitalists know, driverless cars can work tirelessly and safely and accomplish the present mileage with fewer vehicles. Indeed, if streets could be substantially cleared of parked cars, then speed could rise and thus mobility.

The efficient routing of the driverless car will spare petrol and pollution. If the cars operate on fuel cells or batteries, urban air quality issues will be a subject of nostalgia, like fogs from burning wood and coal.

Drones can come by air as well as by land, as we are well aware. In fact, aerial delivery could also reduce surface traffic and further lift ground speed and help the central city. Drones and their piloted precursors enable mobile stores, the modern version of yesteryear's tinkers. The store comes to you.

Planes started by carrying only the mail and a few pricey people. They have progressively captured lower value goods. The largest air freighter now carries 200 tons. With an increase in traffic, old and new airframe companies are designing a variety of airships for freight, blimps redux. One thousand tons seem technically portable. Air freighters could revolutionize cargo transport and reduce the role of the road in long-distance distribution of goods. And help build high, dense cities from the sky.

More generally, we are likely to see a progressive subtraction of freight from trucks and a stabilization of the ton-kilometer and confinement of it to local retailing. This fits both with the trend toward air freight and with the larger trend of dematerialization, especially in cities. The idea of dematerialization of our society simply means that value-added per unit of weight keeps increasing. More properly one should say dematerialization of value added.

It is also worth mentioning that we could see a renaissance of walking or, more likely, personal travel prostheses such as the increasingly popular hoverboard self-balancing scooter. Magnet technology propelling maglevs could find creative outlets at the individual level. More promising for revenue is the personal scooter. Scooters and electric wheelchairs are a domain of explosive experimentation, and one I would enter if I were a young engineer. I do not expect we will lift our walking speed, but many people who have stopped walking owing to age or obesity or other issues can gain or regain mobility. In aging, urbanized societies, this could wonderfully ease isolation of people, just as Skype and email do.

Social climate – What attracts entrepreneurs

The entrepreneur irreplaceably contributes to renewal of social systems, but is not necessarily loved or even appreciated. Russian and other Slavic cultures refer often to the "spekulant," a word charged far more negatively even than the English "speculator." An entrepreneur is a speculator in the sense that he or she risks much hoping to gain much more.

Darwin rightly described the struggle for life as brutally selective. The gene pool incorporates perhaps 1% of biological mutations. In the ocean somewhere between 100 and 1,000 kinds of tiny microbes exist for each kind of larger organism that might merit the title of species and a Latin binomial. These ratios must be tied to mechanisms of stochastic exploration of vital systems and are the price to pay to maintain the evolution of the system.

Economic reality resembles the biological. Perhaps 3% of new products survive on the shelf of a supermarket after six months. Entities in every new sector from search engines to rap music have high rates of mortality. In the capitalist system the entrepreneur is a kamikaze with an impetus for self-exaltation who sacrifices himself to open new ways for the squadron that follows.

High-risk entrepreneurs will sensibly slip away from areas where the social and political climate is invidious, jealous, bureaucratic, and conservative. Repression of speculators was a fundamental cause of the weakness of the planned economies, which by definition could not risk and speculate.

In fact, at the most basic level entrepreneurs are communicators who put together information, people, and things taken from the four corners of the world. They need an agile and efficient system of transport for information, people, and things to stimulate their enterprise. Today, an airport is quintessential.

A second point evident from analysis of urban function is the dimension of the city. By dimension, I mean the number of inhabitants, who define the possible level of specialization and thus the hierarchy of possible services. The village has a small shop in which we find a little of everything with little choice, while we find specialized businesses in x, y, and z in Glasgow, or better, London. The availability of choice and sophisticated advice of expert sellers lift the chance of winning choices for the entrepreneur, who inevitably knows little of everything.

Glasgow, with its half million inhabitants, is small in the concert of great European cities. Its size inhibits access to advanced and expansive parts of innovation. There is a way out. One has to think of corridors in which cities unite by efficient transport, like all of California, where one can go and do one's business and return in a day. A corridor or Central Belt can behave with unity from the point of view of highest hierarchical functions, even while conserving the identity of the lower level centers. In other words, the various cities are a little like the quarters in a virtual super-city.

These rosy images from the imagination need to correspond to a reality. It is not entirely true that people make history. Usually history drizzles and pelts them until they get enraged and engaged, expressing entrepreneurs, saints, and leaders in the process. A storm is coming to Scotland in the form of the crises of the European Union and Britain's relation to it.

Glasgow produced the gloried shipbuilder John Brown and Company. In lieu of ships and locomotives, opportunities will open for magnetically levitated vehicles and mobile scooters. Opportunities will also abound for construction in three dimensions, which nature already does with flowers and fruit but humans are just learning to achieve. Infinite demand continues for information handling, not to mention brewing. Traditions in banking, publishing, education, and other industries in the Central Belt can be put to use.

Density and beauty

High density can be beautiful. Density does not in itself have negative effects, notwithstanding experiments on crowding of rats. What matters is first to make the small space available to a person extremely pleasant, as the crowded Japanese have done. Second, one must provide the hierarchy of personal and group privacy that old cities realized with internal courts and small piazzas. Most important is the home, where people spend two-thirds of all their time averaged over a week.

Le Corbusier, the Swiss-French architect, and one of the great criminals of the 20th century, wrote that "Une maison est une machine-à-habiter," a house is a machine for living. And indeed the drawback of modern cities is that they are rarely built to the measure of humanity. Rather they resemble a patchwork of "machines to live in."

Glasgow had its Le Corbusier, Sir Basil Spence, who bulldozed the Gorbals and built the brutalist Queen Elizabeth Square flats in Hutchesontown (**Figure 9**). Medieval cities, now preciously restored, held the secrets: intricate personal links and beauty. They matched density with human demands.

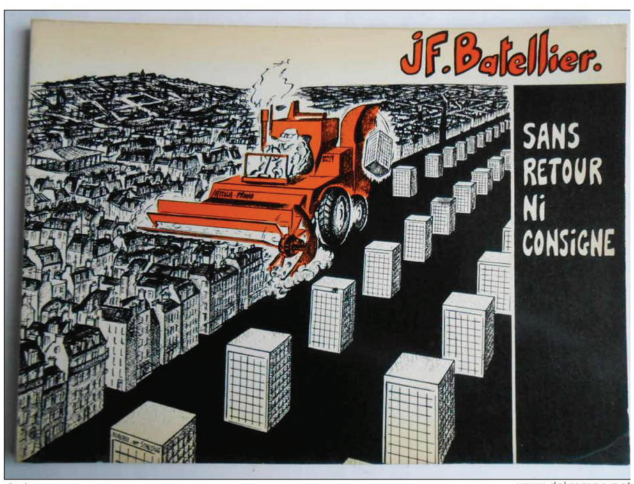


Figure 9. Sir Basil Spence in the Gorbals. No Deposit, No Return, Jean-François Batellier, 1978

And now we can do what medieval or Victorian builders could not with services like water supply and wastewater and of course electricity, heating, and chilling. We can aim for truly three-dimensional or cathedral cities made of abundant materials, such as stones, polished or upgraded for example into foamed glass. In the cities we can reconstruct nature sublimated in art.

An accessible center is key. An inaccessible center ceases to function as a center. Life drains from it. A center without life becomes a sinister periphery for the poor. When penetrability into part of the city is reduced, decay begins. People and business leave. Like tissue deprived of blood circulation, it becomes cold and finally gangrenous. Misguided pedestrianization causes gangrene. If one reduces traffic through a reduction in speed, one must compensate with rapid transit systems, which increase traffic. No blood means no life, so one should accept pedestrianization only with compensatory measures.

Polycentricity means the city has been unable to solve its transport or accessibility problems to the satisfaction of users, especially toward the center. The periphery develops the functions of the center. A Randstadt or Edge City is de-optimized.

Importantly, the mode and whether it is public or private matter not, only low-cost speed. People are ready to accept the inconveniences of public travel if there is a marginal speed gain over private transport. People avoid going into spaces where speed approaches zero, as in badly organized or operated city centers.

Conversely, people are attracted to beauty, which can also calm agitation. It may seem Edwardian, but I believe key personnel involved with traffic and transport should wear glorious uniforms, appropriate for those who bestow speed. Gender parity may help in this regard. World War I opened occupations in security and transport to women, and one result was good appearance, but I am confident that the Glasgow School of Art could do even better. Because electrification will make future mobility quieter, travelers and urban residents in general can also enjoy music in more settings, a pleasant prospect in the city of never-loud Belle and Sebastian.

Roles of heating and cooling – Liberation of environment

Where does all this leave green Nature? Even sunny Californians spend only 5% of their time, about 70 minutes each day, outdoors. As Scots know, weather after all does not much determine human behavior. Time budgets are similar in Glasgow and Tenerife.

We need to take care not to exaggerate the importance of weather or climate for cities. As we have said, humans are cave animals and everywhere spend only an hour or so per day exposing themselves to bears and ultraviolet. And in large part, we have built cities to isolate ourselves and our prosperity from the environment. High incomes, great longevity, and large population concentrations have been achieved in every class of environment on Earth. Americans manufacture computers in hot, dry Phoenix and cool, wet Portland. We perform heart surgery in humid Houston and snowy Cleveland. Europeans grow flowers in the Netherlands and vegetables in Belgium year-round. The metro in Budapest runs regardless of the mud that slowed Hungarians for a thousand years. In Berlin and Bangkok we work in climate-controlled office buildings. We have insulated travel, communications, energy generation, food availability, and almost all major social functions from all but the most extreme environmental conditions of temperature and wind, light and dark, moisture, tides, and seasons.

About 60 km south of Berlin a former Soviet airship hangar known as the Aerium became a tropical paradise in 2004 (**Figure 10**). With over 66,000 m^2 of floor space and 5 million m^3 of enclosed space, the Aerium is a self-contained tropical holiday destination in the gray heart of Europe. Open 24 hours a day, 7 days a week, the dome can accommodate 6,000 people at one time. The temperature is always 26 degrees C. The global average temperature is about 15 degrees C, so clearly humanity likes some warming.

For all the poetry about Nature, we have basically retreated into walled cities, autarchic except for the input of energy, or negentropy. Most of this no longer arrives by chlorophyll.

In practice, the natural trend toward the megalopolis is creating zones of great density, leaving the possibility of creating very low density patches or "sanctuaries" where people might go when they wish or simply observe through millions of mini-cameras placed here and there, including on other animals.

Scotland in fact exemplifies this trend, as a national map of population density shows (see **Figure 8**). The average population density across Scotland in 2011 was about 70 people per square kilometer compared with about 400 in England and Holland and 1,000 in Bangladesh. The average figure misleads because two-thirds of Scots gravitate to the Central Belt. Most Scots experience life in a densely populated country. Glasgow's density of over 3,000 people per square kilometer is almost half that of Hong Kong's 6,500.

Globally and in Scotland, the built environment could grow from 5%–6% of the land surface today to, say, 10%. Meanwhile, if humanity continues the shift toward landless and vertical agriculture, then much more land will be

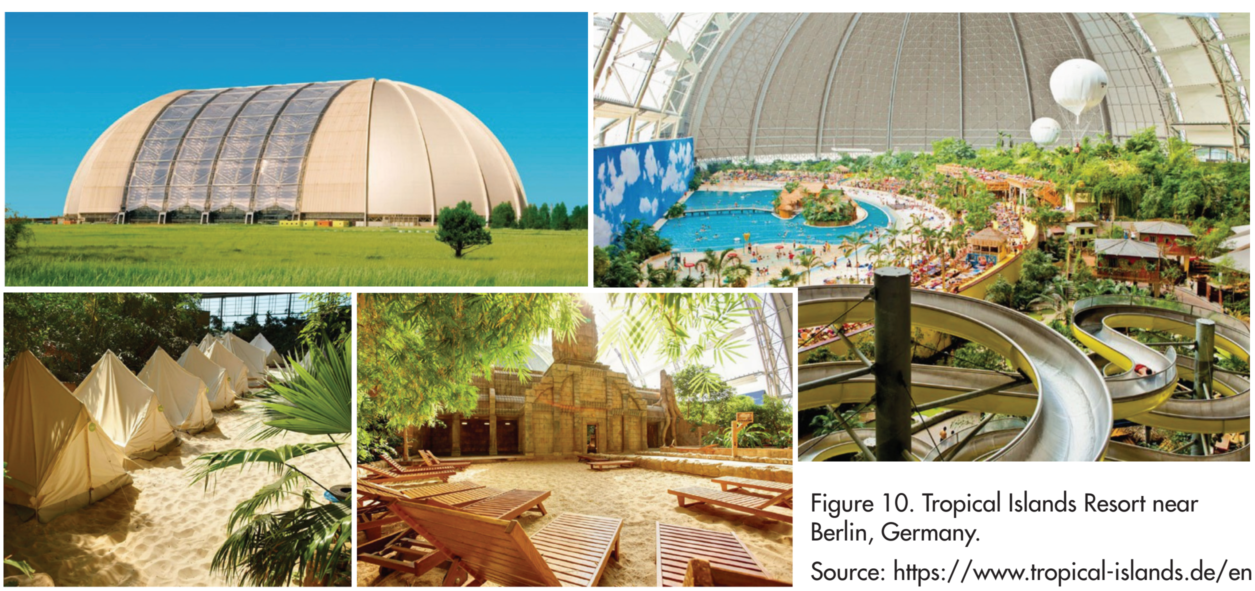


Figure 10. Tropical Islands Resort near Berlin, Germany.

Source: https://www.tropical-islands.de/en spared for Nature. Cities will function essentially as closed systems where most materials, including water, will be recycled. The only physical input need be free energy and the only output heat, or negentropy.

A highly efficient hydrogen economy, landless agriculture, industrial ecosystems in which waste virtually disappears during this silicon century — these can enable large, prosperous human populations to coexist with the salmon, wildcats, and golden eagles and all that underlie them. The bluebells and the Celtic rain forest can tranquilly regrow for the amusement of naturalists. Ponder the walled city as the prototype of the spaceships we may eventually send to other parts of the universe

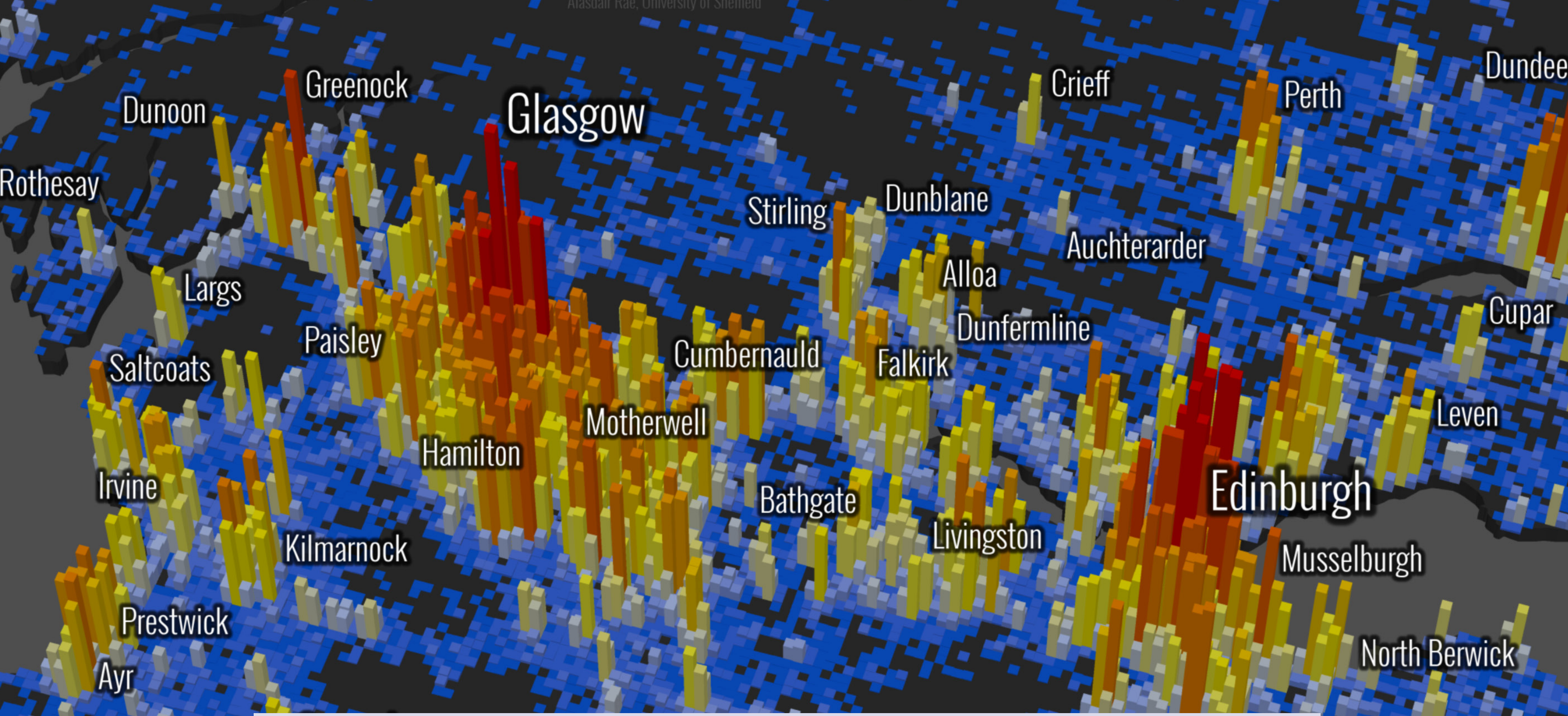
Indeed, Nature can return in cities themselves. Whales now breach New York Harbor again, and bald eagles also nest within the city's limits. Wildlife experts estimate that about 10,000 foxes roam the city of London, more than the double-decker buses. Foxes ride the London Underground for free.

Conclusion

While the city is not a machine for living, it is a machine for communication, through exchange of information, services, and objects, but above all by direct contacts among persons. We are still jabbering monkeys grooming one another. In a village, the swarm of exchanges comes in one container without specialization. When villages grow into cities, the services and contacts become hierarchical. These tend to assemble in bunches of seven, with the central one collecting the functions at the next hierarchical level, which we might call the weekly, and then the monthly or bimonthly, and so on. This structure permits needed contacts while minimizing distance traveled. Cities grow in space in proportion to the velocity of the means of transport. Organization is not in space but in time. People travel in time, not in space. More speed means a larger territory and all the choices it brings, for business, education, and leisure. A person on foot can choose among the 1,000 people of the village. The jet set has a billion among whom to choose.

How to prosper? It is helpful to be early, but not too early, with the growing technologies and industries. In transport, these may include maglevs and blimps, drones and scooters. All the associated technologies matter too, for example, for tunneling and system control. Also important, a strong aesthetic.

Happily, development of cities permits faster and easier restoration of Nature in the rest of the land. Scotland and Glasgow can once again exemplify the best nature of cities, inside and out. As the builders of the Forth Rail Bridge understood perfectly, the limit to successful cities is low-cost speed.



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