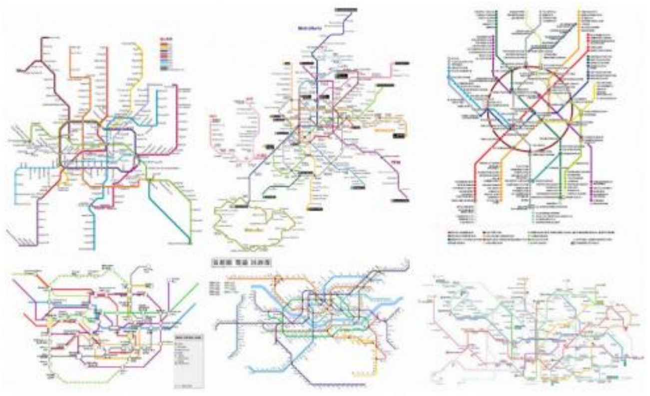
# Study shows subway systems develop in remarkably similar ways

22 May 2012, by Bob Yirka



A sample of large subway networks in large urban areas, all displaying a core and branches structure. From left to right and top to bottom: Shanghai, Madrid, Moscow, Tokyo, Seoul, Barcelona (Figures from Wikimedia Commons)

(Phys.org) -- Visitors to major cities in the world might disagree, but a small group of French and British researchers has found that regardless of city density, structure and other factors, subway systems running in the biggest cites in the world are more alike than not in truly fundamental ways. In their paper published in the *Journal of the Royal Society Interface*, the team says that all of the large city subway systems in the world grow in a way that share common features - such as the fact that they all have central cores with a branch topology.

The team focused on the fourteen largest cities and their subway systems and found that mathematical equations could describe some of their attributes regardless of how long the subway systems have been in existence. They found for example, that about half of all the stations in any large subway system can be found on the outer branches rather than clustered around the core. They also found that the distance from the center of the city to its farthest station is just about double the diameter of the system's core; again, regardless of system. And that's not all. They also found that the number of branches in a subway system is roughly equal to the square root of the number of stations and that twenty percent of stations situated in the core link two or more lines together allowing people to transfer from one to the other.

The researchers point out that none of this is planned, at least not in systematic way. City planners, they say, start out with a design that seems optimal for existing conditions then expand when needed. Thus, the systems grow organically in ways that reflect rider needs, which the researchers suggest means that there is likely some underlying fundamental rules that govern ridership and decision-making that is common to all subway systems, regardless of country, geography, climate or density, which results, they say, in a common optimal design.

If the underlying rules can be described, the thinking goes, then future planners would be able to skip the intermediate steps that lead to the optimal design, likely saving hundreds of millions of dollars in the process, or perhaps better yet, small adjustments might be made to further optimize the general model which could benefit all such systems throughout the world.

**More information:** A long-time limit for world subway networks, *J. R. Soc. Interface*, Published online before print May 16, 2012, doi: 10.1098/?rsif.2012.0259 (arXiv pre-print arxiv.org/abs/1105.5294 )


**Abstract**

We study the temporal evolution of the structure of the world's largest subway networks in an exploratory manner. We show that, remarkably, all these networks converge to a shape that shares similar generic features despite their geographical and economic differences. This limiting shape is

made of a core with branches radiating from it. For most of these networks, the average degree of a node (station) within the core has a value of order 2.5 and the proportion of $k = 2$ nodes in the core is larger than 60 per cent. The number of branches scales roughly as the square root of the number of stations, the current proportion of branches represents about half of the total number of stations, and the average diameter of branches is about twice the average radial extension of the core. Spatial measures such as the number of stations at a given distance to the barycentre display a first regime which grows as r2 followed by another regime with different exponents, and eventually saturates. These results-difficult to interpret in the framework of fractal geometry-confirm and yield a natural explanation in the geometric picture of this core and their branches: the first regime corresponds to a uniform core, while the second regime is controlled by the interstation spacing on branches. The apparent convergence towards a unique network shape in the temporal limit suggests the existence of dominant, universal mechanisms governing the evolution of these structures.

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APA citation: Study shows subway systems develop in remarkably similar ways (2012, May 22) retrieved 27 November 2021 from https://phys.org/news/2012-05-subway-remarkably-similar-ways.html

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