# The Boundary Problem

A basic canon of the systems approach applicable to any field is the notion that a system is separable and distinct from its wider environment. In short, to formally study such a system, it must have a well-defined boundary beyond which it has no substantial impact on its wider context, while its wider context is usually composed of similar systems which have minimal impact on the system in question. The implication is that the environment defined by its boundary 'excludes' any significant actions or interactions essential for the functioning of the system itself. This is, in some respects, equivalent to the notion that we are defining a closed system which we can study in isolation from any extraneous or exogenous factors that might affect its operation. It is the definition used by Karl Popper (1959) to justify the use of the classical scientific method as fashioned in experimental science where the laboratory must be closed from the outside environment for robust theories to be tested and validated. In the case of cities, historically or at least from the middle of the last century, such boundaries are typically defined to minimise the overall interactions between the system and its environment. The implication is that insofar as there are many distinct systems, to minimise the interactions between one another, they are often arranged as a hierarchy. To minimise the exchange of energies between the system and all the systems within its environment, a good working definition of a system is that it contains the most significant interactions within the system itself (Simon, 1969). This question of course turns on what is regarded as 'significant'.

In large cities with populations greater than a million or so persons, significant interactions are those based on flows such as the journey to work. There are many methods for segmenting cities into clusters based on interactions, similarities in urban activities, hierarchical functions, and demographic differences, but one of the clearest reasons for such segmentation is to identify the extent of a city in terms of its area and density within which its functions are relatively self-contained. Of course, cities are defined with respect to their administrations based on a synthesis of socio-economic and political factors that, to an extent, can coincide, at least somewhat coarsely, with more analytical methods of defining urban extent. But frequently such administrative boundaries only crudely reflect their functioning. In particular the data available to define such units is often inconsistent across different administrations, and this results in somewhat strange boundaries, which can be somewhat dysfunctional when cities are defined.

The best examples of this dilemma involve national boundaries. A particularly visually disruptive one is the boundary between England and Wales. Although most data pertaining to socio-economic functioning is consistent between the two nations with much of it collected by nation-wide UK agencies, many spatial analyses separate the two countries from one another. Because of the cultural dominance of England, Wales is often excluded from analysis (because of the population difference – Wales with a population of 3.2 million, England with 56.5 million). This is despite the fact that there are very strong interactions between South Wales centred on Cardiff linking east with Bristol while the boundary between North Wales and the Liverpool region has significant cross-border flows which are equally problematic. In the figure below, we show typical analyses for England separated from Wales but rarely does one see analyses for only Wales. The picture shown here is visually jarring as well as functionally so, and it raises an alarm when used to make generalisations that pertain to anything wider than

England itself. Every time I see Wales separated from England I ask the question 'why?' and I am drawn to suggest that it is based on a cultural difference reinforced by the media. The same is true for Scotland. When it comes to Northern Ireland where there are stronger interactions between the north and the Irish Republic than with England (other than politically that is), the same strange juxtaposition occurs. The UK itself is also an equally bizarre shape to that of England and Wales when separated from southern Ireland. The fact that the shape of the UK appears more usual to us than that where Wales is separated from England is due to the fact that we are accustomed to seeing the former more so than the latter.

a) An Arbitrary Partition of a System and its Environment
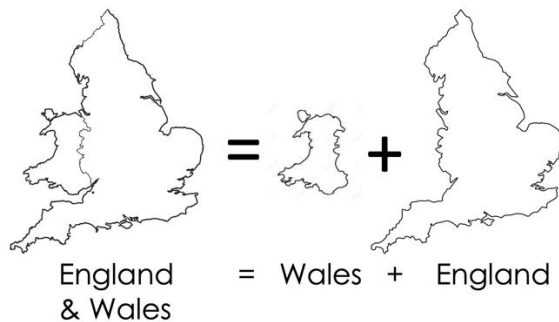
b) The Morphology in the GBA
red to blue is high to low population density
Scale 200kms from east to west
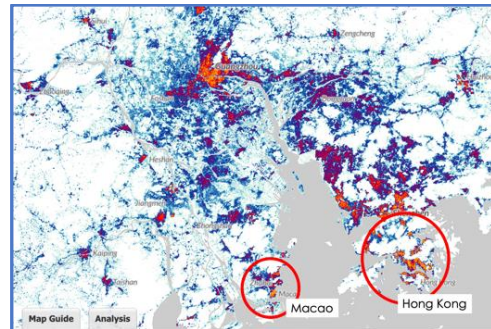
To elaborate this problem of national and cultural differences across political boundaries, consider the cities that comprise the Greater Bay Area (GBA) which is centred on the Pearl River delta and includes the cities of Guangzhou, Shenzhen, Zhuhai, Foshan, Dongguan, Zhongshan, Jiangmen, Huizhou, and Zhaoqing as well as two special administrative regions, Hong Kong, and Macao (Macau) (Wiki, 2023). This region also includes significantly different political entities where Hong Kong and Macao have different political regimes from other cities in Guandong province while other cities astride the border such as Shenzhen have different degrees of access to other cities in mainland China (Shandong, H., et al., 2021). I have seen countless spatial analyses of this region where Hong Kong and Macao (shown in the red circles above) are simply not considered in the analysis but as the figure above shows, it is impossible to separate these poles which define the extremes of the region in terms of its overall morphology. In fact the complexity of this region is such that although it clearly consists of many clusters of different sizes and although we have not yet applied many community detection algorithms to identify these, the system is sufficiently convoluted in terms of its morphology to make drawing boundaries around many of its urban components is quite hard. This is problematic in terms of the way the SARs such as Hong Kong and Macao have been restricted and constrained with respect to their role in the region's economy since the colonial era ended in the late 1990s.

In many fields, where boundaries play a critical part and define a particular extent of the system, arguably all the interesting features happen on the boundaries. It was Mandelbrot (1982) who first described the mathematical formula that visually generated what came to be called the figure named after him – the Mandelbrot set. When zooming in to finer and finer levels of resolution, this generates an object whose boundaries look the same with the same degree of regularity and morphology at every level of disaggregation, every level of zoom. In terms of the boundaries in the GBA, then political and historical issues coalesce at the

boundaries of Macao and Hong Kong on the Chinese border where you can often see dramatic symbolism relating to the way the GBA is segmented. For these boundaries which we show schematically in the circular regions in the above figure, they are very different from boundaries that are defined by the morphology of the whole area where clusters with similar shaped extent at all scales exist. In short what the GBA illustrates is that there are many different kinds of boundaries in terms of shape. Thus the original concept of a system and a distinct environment is rather a too rigid concept to be illustrative of the complexity of city systems composed of cities as systems as is now characteristic of our global urban world (Berry, 1964).

We have already hinted that there are many different kinds of boundary defining the spatial extent of a city and the constellation of agglomerations that compose the megalopolitan regions where cities begin to fuse into one another, as they have done in the GBA. We note that in such city systems which are formed from systems of cities where individual cities at all scales fuse into one another, the clusters can be arranged hierarchically. This mirrors the way central place systems evolve and it is likely that boundaries between the cities that make up such agglomerations are arranged hierarchically too. There has not been much research on this generalisation of the concept of a boundary for we must assume that cities exist across a continuum and this implies that they are connected in such a way that they cannot be separated into a core system and an environment. Great Britain is a good example of this kind of spectrum and the percolation methods that Arcaute et al. (2016) have devised to explore this continuum from the smallest to the largest clusters by successive aggregation, clearly reveal the fact that it is increasingly difficult to separate urban areas from one another physically. The implication in this case is that the entire system of cities must be treated as an integrated city system which exists on all scales.

The significant point in this argument is that cities are increasingly connected to one another can and their wider environment cannot be easily broken off from the city system itself. This is a hard lesson to learn because it means that our traditional way of defining the urban world in particular and social systems in general flies in the face of the actual nature of the systems we deal with. Boundaries are thus everywhere but the notion of one boundary separating the system from everything else is no longer as relevant as it was. Physically this is still the case in the large urban agglomerations as portrayed in morphological terms by Smith (2023) but when we come to consider the multitude of flows that provide the glue sticking the hierarchy of cities together, many of these are invisible to us, especially those that relay on electronic communications which are growing dramatically in number and content. There is a message here that we need to shift our focus rapidly to deal with systems of cities rather than city systems echoing Berry's call some 60 years ago. The idea of a system that can be separated from the rest of the world by a well-defined boundary is increasingly obsolete and we must begin to fashion our theories and models to deal with a global world. This of course is happening but we need to take it on board with respect to the city systems that we use to explore the urban future, with respect to the analytical theories and tools we are focused on in this journal. Not just for city systems and systems of cities in the developed north but in the global south too, in fact everywhere (Brenner, 2013).

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