Urban Evolution Prediction Model: Transport and GIS

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Abstract

Cities can be regarded as the quintessential example of complexity. To a certain extent, the history of human civilization is the history of urbanization. Therefore, understanding the process and form of urban development provides insights which help policy makers allocate limited resources more effectively. This paper establishes a theoretically conceptual model, called dynamic urban potential energy theory, to simulate and assess urban evolution and points out the interrelationships between four basic urban factors, which are transport, culture, economy and population. There is a complicated interaction between urban factors and they change over time. The inter-dependencies of the different variables of the city give rise to its 'self-organization', where structure and organization can be 'created' as well as destroyed as the city evolves. All the urban factors are connected and organized by transport lines and they have energy to cast their influences by transport networks. However, their energy will be consumed via transport. Thus, the consumption of transport determines which region the urban factor can affect. All urban factors are interacting with each other and producing the urban form as consequence. Therefore, transport can be used to estimate and assess the urban evolution. The main part of this paper indicates the mechanism of urban evolution and provides a model of urban planning for policy makers.

Cities are complex systems, they grow as civilizations develop economically or culturally and the form of cities are the most direct manifestation of this developmental process. Most conventional urban morphology models are large scale (exploring form change) in order to describe the mechanisms of urban evolution. Because of this, in the current project, for this purpose, cities have been divided into urban factors, which include transport, environment, structure, population, economic and the like, to describe the city form. The urban internal factors drive city development. Many factors are involved in urban evolution and the underlying relationship dependencies between them need to be discovered, which is vital to know the whole patterns of the urban issues. Some researchers use urban self-organization theory try to describe and understand those complicated interactions between urban objects. They have proposed solutions in term of urban energy consumption, policy, economy, urban space and like this. The aim of this paper is as follows. Building upon the urban self-organization theory research, this paper proposes a new theory, called dynamic urban factor potential energy, to indicate the mechanism of urban evolution and provide a model of urban planning for policy makers. This theory will form the basis of an urban evolution prediction model, which the theoretical significance is mainly presented as prediction of urban evolution when single or multiple urban factors have been changed intentionally or unintentionally, to related policy makers to make urban planning more predictable and controllable. It is of great theoretical and practical significance to develop and strengthen the dynamic urban potential energy balance study extend to the urban evolution field to support planning, geographic decision-making, and urban research fields. This model can predict and evaluate the consequence of urban planning by simulating urban revolution.

To setup a mathematical model to observe and summarize the interaction patterns and regulation between these urban factors, this research will concentrate on transport, population, urban spatial evolution and culture, in order to explore the interaction mechanisms and evolution laws between them. The novelty of the grid approach is that the urban evolution prediction model represents the whole city as a grid (P1). Vertices represent stores of potential related to urban factors (e.g. population, cultural or

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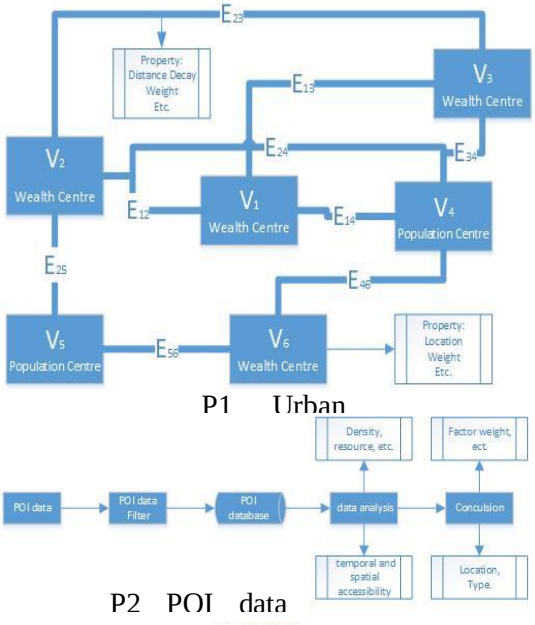
economic wealth) and edges in the grid represent flows (e.g. people goods, energy, information). Inputs to the model are the spatial location and attributes of urban wealth centers, population centers and traffic networks. The algorithms driving the automatic data filter take POI data, and apply the method of nuclear density analysis, weighted superposition analysis and hot spot analysis to extract the location of urban wealth centres and population centres, and then classify them (P2). The vertex, which has potential energy to promote and extend itself, represents wealth centres or population centres and edges represent traffic networks. Every vertex has its own weight, which describes how much potential energy it has to extend or promote itself and every edge has a specific weight to describe the cost of transport per unit length. In addition, spatial network accessibility and time consumption, a location attraction gravity model, resource evaluation and standard deviation elliptical analysis are used to analyse the extracted urban wealth centres and population centres in order to quantify their potential energy. All the vertices are connected by edges as transport lines connect urban factors and the vertex casts its influence alongside the edge. The capacity of a traffic line decides the upper limit of the buffer area, which beside the traffic line, and costs of transport per unit distance decides the pace of the potential energy of wealth center declines. Vertexes will automatically optimum select the most economical and effective path in order to exert maximal extension with minimal transport cost, until their energy is exhausted. When a wealth center used up all its potential energy, it can no longer effects on other areas. However, not all the urban factors are constant. The proposed model also takes dynamic change of network scale and spatial distance into consideration. The weight of vertices and edges can be influenced by internal and external factors like investment, science & technology revolutions and so on. Thus, the weight is dynamically changing, including increase, decrease, creation and extinction.



On the other hand, the traffic networks are not entirely appropriate to the urban grid. In many cases, traffic congestion or great loss of transportation capacity are very common and that will affect the urban vertices positively or negatively. Comparing with the ideally traffic networks, the percentage of total amount of the waste of traffic costs is an index to describe the potential power which will reform the city. I named this index as urban evolution index. Due to consistently and continual culture, science and tech development create forces to enhance energy of urban factors, the traffic network no longer suitable to the city. So the index will continually increase and when it reach a threshold the potential power will drive the urban evolution. Just as the villages of agricultural age were replaced by the towns of the industrial age, as well as animal drawn vehicles replaced by chemical energy vehicle.

References

Glenn Lyons, Cody Davidson (2016).Guidance for transport planning and policymaking in the face of an uncertain future. *Transport Research Part A,* 88 (2016), 104-116.

Nicolis G, Prigogine I, 1977 *Self-organization in Non-equilibrium Systems* (John Wiley, New York)

P M Allen, M Sanglier, *Urban evolution, self-organization, and decisionmaking,* Environment and Planning A, 1981, volume 13, pages 167-183

Beitske Boonstra* and Luuk Boelens, *Self-organization in urban development: towards a new perspective on spatial planning.* Urban Research & Practice Vol. 4, No. 2, July 2011, 99–122

MICHAEL BATTY, *Complexity And Emergence In City Systems: Implications For Urban Planning,* Malaysian Journal of Environmental Management 10(1) (2009)

Beitske Boonstra, Luuk Boelens,*Self-organization in urban development: towards a new perspective on spatial planning,* Urban Research & Practice Vol. 4, No. 2, July 2011, 99–122

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