Some contribution toward Spatial Urban Dynamics

From Relative Attractiveness point of view

Akira UCHINO*, Tetsuma FURIHATA, Nobuhide TANAKA***, Yutaka TAKAHASHI***

**University of Shimane, ***Gakushuin University,

*School of Commerce, Senshu University
2-1-1 Higashimita Tamaku
Kawasaki JAPAN 214-8580
Tel. +81-44-900-7953 FAX +81-44-900-7849
uchino@isc.senshu-u.ac.jp

Abstract:

There was an interesting presentation at ISDC 2004 in Oxford. The title was "Spatial urban dynamics" presented by Peter Sanders and Frank Sanders. They expanded Forrester's original urban dynamics model in terms of spatial point of view. While one of us has been studying Geographic Information Systems (GIS) and applying GIS to consumer spatial behavior. Recently we have got some research results, one of which explains how retailers agglomerate in a city, the other one shows one of the method of calculating relative attractiveness of retail areas. We have been developing a basic SD model treating two shopping areas in Niigata city in Japan, but we are still struggling to make a few modifications on the model in order to turn it into the applied one.

In this paper, we make some contribution toward spatial urban dynamics, firstly discussing the importance of the concept of "attractiveness" in social sciences, secondly showing latest research result on "the attractiveness" outside of system dynamics field and how to take it into spatial urban dynamics, thirdly making constructive comments on Sanders' approach, finally referring to a strong possibility of expanding spatial urban dynamics toward national models and world models.

1. "Attractiveness"

Demand and supply are adjusted by price in market mechanism. But it is true that human being cannot gather all the information about demand and supply in real world and that goods and services in market are not always homogeneous. When we buy a product in a market, we evaluate competitive products, on which differences we put prices. And we sometimes chose a more expensive product because of its better performance. Or we chose a more expensive one because the brand of the product is more powerful, even competitive products are all the same in performance.

> When I wanted to buy a brand-new video camera made in S Company, I visited in a big retail store. Unhappily the video camera was sold out there. But they had another brand-new video camera sold by K Company. S Company was original equipment manufacture so that the video was just same as S Company's. The difference is only the brand name, S Company and K. And the price of K Company's was 50 dollar less than S Company's. In case you chose K's video camera instead of S's? At that time I did not buy K's and went to another shop to find S's.

In this case, the performance of the video cameras are same, the name of them are only the difference. If retail prices are not same, brand power between two companies exists. If S Company is well known international company, can fifty dollar compensate it, or not? In reality it depends on own customer.

Where does a customer buy goods? Shopping style is different from country to country. But we think not only prices but also distance and familiarity of the shops to buy perishables and to satisfy daily needs. How to choose a specialty store, a department store, a shopping mall, or an agglomerated retail area, when we go shopping to get some special goods or to enjoy shopping with our family or a friend? Which area and which shop? When we need some sort of goods, how to choose shops and the shopping route?

Where do we live? Where do we get jobs? Development of a city or a stagnation of it highly depends on migratory flow of population into a city or outside of it, especially high the mobile countries on of living and job changing. In Japan people are relatively stable on working and living, and only a few cases changing both job and house at the same time. It is popular in USA that moving house to adjacent school districts or neighboring cities when kids attain school age to get better educational environment without changing a job, though it is exceptional in Japan.

Prices of goods and services, drawing power of shops and agglomerated retail area [(1)] on shopping, population increases in a city along economic development; there is a similarity between them. We can hypothesize the concept of "attractiveness" that draws a person's attention, attracts a person when making a decision or choosing something.

When we think about products, services, companies, brands, tourist spots, holiday resorts, contents or titles of audio and visual, development and stagnation of cities or areas, immigration between countries, we make a definition of "attractiveness". And if we can treat the concept of "attractiveness" commonly, we have a clear understanding of developing models in social systems. The "attractiveness is one of key concept in social sciences. This is a basic consensus of our joint research. Our first step is focusing on the latest research on "attractiveness" and discussing from system dynamics point of view.

We sometimes use the "quality of life" in social system modeling. We only value it not by quantity measure but by quality measure. The "attractiveness" as well as "quality of life" composes of many factors or elements, changing in every situation. So we define that the "attractiveness" is a power of products, services, and cities or nations that attracts people. But we are not treating the "attractiveness" as a theoretical concept, treating it as a tool of real problems solving.

2. Can we get relative "attractiveness" in reality?

There are several theories on spatial distribution in intra-urban retail trade area, Central Place Theory [(2)], Circulatory System Theory [(3)] and Statistical Distribution Theory [(4)]. They partially explain how retailers are distributed or located in cities. Some of them teach us that the current spatial distribution is quite rational. But they cannot explain how retailers in a city develop dynamically.

There have been developed another series of theories, how consumers select a retail shop when they go shopping. Theories on consumers' spatial activity are Retail Gravitation Model [5], Intervening Opportunity Model [6], and Network Model [7]. Especially a Retail Drawing Power Model, a kind of Retail Gravitation Models originally came from Huff's, shows a suitable location of a new retail shop in a city. It is useful in business. These theories can explain retailers' development in a city in some extent.

We have got some research results in order to explain how retailers agglomerate in a city. We compare two simulation results, one condition in a uniform distribution of population, the other radially populated so that we investigate how population distribution affects the spatial structure of retailers' accumulation in a city (Furihata, Uchino, et al., 2003). These simulation models and other existing studies did not use the attractiveness of shopping streets (areas) effectively in consumer choice because the attractiveness of them includes many elements or factors. Of course although some methods such as Drezner and Drezner(1998)[8] consider the attractiveness of shopping areas, these models did not explain dynamically change under time series. So we focus on the "attractiveness", and develop an assessing method that infer retail facility attractiveness from simple data which we can get easily without effort of getting additional data, and simulate using real data on Niigata Prefecture in Japan (Furihata, Uchino, et al., 2004). The paper is written in Japanese so we show a brief paper in English written by one of joint researchers, as attached pdf file.

The paper attached show you that one of the latest researches on "attractiveness" related spatial urban dynamics. In a certain situation we can make a mathematical model using computer simulation and get relative "attractiveness" of agglomerated retail areas. We use mathematical model and computer simulation because of we cannot solve the model mathematically. It is true that we can get relative attractiveness in real spatial analysis. But the condition to get it is very strict. We don't believe we can apply the same method in the urban dynamics.

Forrester (1969) develops urban dynamics model, which shows growth and stagnation of a city, interacting industry, housing and people. The attractiveness of a city is composed of job availability, housing availability, and land availability. Very simple but it is easy enough explaining dynamics of a city. Of course his model is simple so that it has no spatial point of view.

We believe we can treat relative attractiveness as a set of related factors in system dynamics. But when we make an incursion into the spatial analysis, attractiveness increases complexity.

3. "Spatial urban dynamics" by Sanders

The "Spatial urban dynamics" presented by Peter Sanders and Frank Sanders at ISDC 2004 in Oxford is very interesting. They expanded Forrester's original urban dynamics model in terms of spatial point of view.

1) They expand literally original Forrester's urban dynamics model so that they can compare the simulation results.
2) They build "The service industry" into the model. The basic industry is the same as

Forrester's original model. The second type, service industry is location sensitive and consists of one stock because of simplicity. Location sensitive means fluid or mobile character suitable for spatial dynamics.

3) They introduce spatial analysis and use the equation in which the "trip distribution function" is the distance between zone i and zone k to the power 2. They relate the attractiveness of each zone in spatial distribution to the distance between zones.

4) They only show conceptual expanded model in urban dynamics in their presentation but also they suggest there is a project to apply their spatial urban model to Rotterdam, the second largest city in the Netherlands.

We evaluate their model very highly but place it ideal conceptual expanded model in urban dynamics, only the first stage model in spatial dynamics. Because we believe spatial concept in urban dynamics refer to real distance or real trip time between zones.

1) If there is not quite a far away between zones, a part of people living in a zone may commute another zone.

2) If above 1) is true so that some of the zones have more attractiveness on housing comparing to others. Each zone has characteristics and attractiveness, on housing, schools, public facilities, shopping or business.

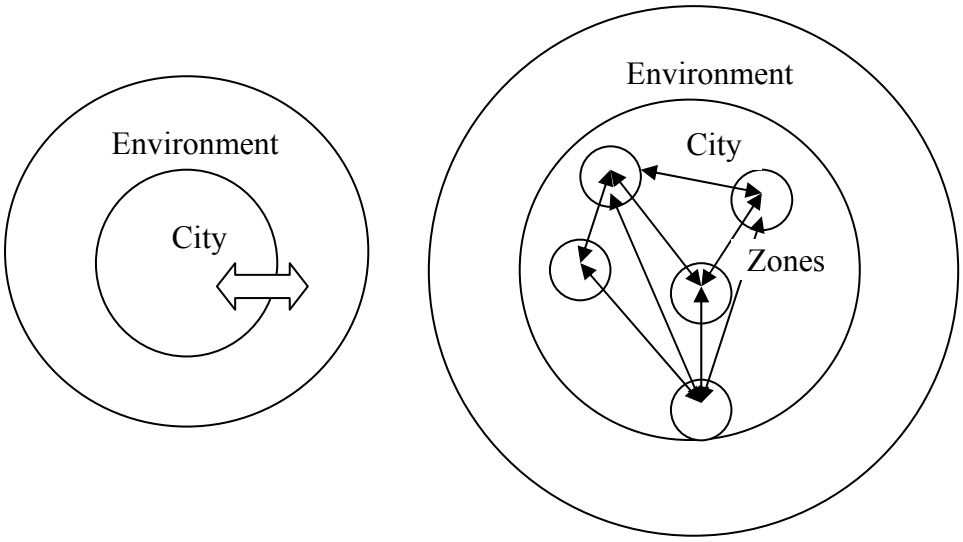

Figure 1. Original urban model and spatial urban model

The attractiveness of a retail facility is a composite index of many attributes. For example, distance or trip time to the retail facility, selection of goods, prices, amenities, parking spaces and so on. Even if we can treat retail areas, shopping center, shopping malls, or huge retail facility, there are so many retailing shops. So we hesitate to treat attractiveness of each small shop. But population as customers only goes shopping. They don't migrate. We cannot compare the complexity of customer behavior and spatial choice modeling to the urban model. The point is that the spatial urban model is enough complex that confuse the model builder.

Forrester's urban dynamics model in 1969 was a fundamental archetype in urban dynamics. Theoretically we discuss his model but in real situation we must make a new model which depicts the real problem we face with.

We think Rotterdam is a big city and zone analysis is effective. If they will develop their model in which each zone has own attractiveness and spatial differences, they will show us a great example to develop spatial urban dynamics model. We are looking forward to their success.

4. Spatial urban dynamics expands widely

Sectors in Sunders' model are areas in a city. But if the sectors truly have spatial character, sectors are like cities in wide area model. If we can treat spatial character reasonably, we have got powerful tools to expand our model widely. Spatial urban dynamics will leads wide area model, national model, and world nations' model. The relative attractiveness of one nation gathers immigrants from other nations. Even if we cannot identify the relative attractiveness, we treat relative attractiveness in system dynamics model and contribute toward improving social problems in the world.

5. Conclusion and Future Research (At the presentation)

In this paper we only discuss,

1) the importance of the concept of "attractiveness" in social sciences,
2) we can define relative attractiveness in a certain condition,
3) evaluate Sanders' approach in spatial urban dynamics,

and

4) refer to a possibility of expanding spatial dynamics toward national wide models.

We must show our experience on spatial analysis concretely so that we are struggling to make a small set of spatial urban dynamics model. The model has 6 sectors. Two has attractiveness of industry area, one has high-class housing, and one has initially large part of underemployed housing. They have locations, distance between sectors. This is for a virtual city but we can show spatial characters through simulation.

As soon as we are ready for the model, we rewrite this paper and surely demonstrate the model in the presentation.

Footnotes

(1) classical shopping streets, districts, intra-urban retail trade area

Retailer shops are commonly classified by the same technical terms. But the situation is slightly different from country to country. There are a few facilities in Japan which we call shopping mall in USA, or shopping center in UK. But classical shopping streets or districts in this paper are slightly different, which sometimes are a mall or an arcade, sometimes line with small shops, department stores, and super market. They expand along the streets, or into a block or blocs in a city. We are discussing them in Japan. We use shopping streets, shopping districts, and shopping or trade area replaceable in this paper.

(2) Central Place Theory

Central place theory originated by Christaller(1966) has been developed in economic geography. This theory was based on classical economic assumptions such as the uniformity of consumers and travel without considering the attractiveness of shopping areas in consumer choice. Nevertheless, it has been widely used to explain the retail hierarchy: a town centre core radiating progressively further out with greater number of district centers, neighborhood centers and finally local centers.

(3) Circulatory System Theory

Circulatory system theory is based on the relationship between transport system and retail centers in urban areas. This theory shows that retail centers configure at the intersection of main arteries, and along the main arteries.

(4) Statistical Distribution Theory

Rogers(1974) presented that spatial distribution of retail facilities(stores) in urban areas conforms the statistical distribution such as a negative binomial distribution.

(5) Gravity Model

The origin of gravity models dates back to well-known `The law of gravitation' proposed by Reilly(1929). A general equation of the models is follows:

$$P_{ij} = \frac{A_j R_{ij}^{-1}}{\sum_{k=1}^{m} A_k R_{ik}^{-1}},$$

where P_{ij} is the probability that a consumer i purchases at a shopping destination j, A_j is the attractiveness of a shopping destination (store) j, R_{ij} is the resistance measure perceived from the consumer i's shopping trip to the destination j such as the distance and time. According to an above gravity model the probability that a consumer i patronizes a shopping destination (store) j is proportional to its attractiveness and inversely proportional to the resistance measure. By the definition of the attractiveness and resistance measure on the above equation, many gravity models are formulated. In the representative model proposed by Huff(1962), for instance, the attractiveness and resistance measure substitute for the retail sales floor area of shopping destination (store) and distance between the origin i and the destination j.

(6) Intervening Opportunity Model

Stouffer(1940) who is a sociologist proposed an intervening opportunity model. The fundamental idea of this model is follows: the probability that a consumer chooses a store proportional to the purchase opportunity served by its store and inversely proportional to the total opportunity from the consumer's origin to its store. This model comes to the conclusion that the distance and time between the consumers' origin and the destination are not fundamental to explain for consumers' behavior but the spatial order of stores is a most important factor.

(7) Network Model

Network model developed by White and Ellis(1971) captures consumers' behavior as flows in network configured by arteries and public transportation. The network consists of nodes such as consumers' origin and the destination(stores) and arcs connected the nodes. This model defines some assumptions to flows in the network, and estimates the outflow(the number of consumers or total sales volume in each stores) based on the inflow(the number of consumers or total expenditure in its consumers' origin).

References

Alfeld, Louis E. & Alan K. Graham (1976), *Introduction to Urban Dynamics*, Wright-Allen Press.

Alfeld, Louis E. (1995), Urban Dynamics – The first fifty years. *System Dynamics Review*, Vol. 11, No. 3, pp.199-217.

Christaller, W. J.(1933) Die zentralen Orte in Soddenutchland, (W.H. Woglom and W.F. Stolper, Trans ed., *Central Places in Southern Germany*, Englewood Cliffs, New Jersey: Prentice Hall, 1966).

Drezner, T. and Z. Drezner(1998) On Assessing the Attractiveness of Retail Facilities, *Communications of the Operations Research Society of Japan*, Vol49, No.4, 2004.(in Japanese).

Forrester, Jaw W. (1969) *Urban Dynamics*, Wright-Allen Press.

Furihta, T., A. Uchino, Y. Takahashi and N. Tanaka (2003) Simulation for Configuration of Retail Agglomerations Considering the Interaction between Retail Facilities and the Distribution of Population, *Journal of Japan Society of Business Mathematics*, Vol.25, No.2, pp.151-163 in Japanese.

Furihta, T., A. Uchino, and N. Tanaka (2004) Hierarchical Destination Choice and Retail Agglomerations: A simulation, *Journal of Japan Society of Business Mathematics*, Vol.26, No.2, pp.17-34 in Japanese.

Huff, D.L.(1962) *Determination of Intra-Urban Retail Trade Areas*, Publication of Retail Estate Research Program, Graduate School of Business Administration, Division of Research.

Mass, Nathaniel J. ed. (1974) Readings in Urban Dynamics: Volume 1, Wright-Allen Press.

Nakanishi, Masao (1983) *Theory and Measurement of Retailing Drawing Power*, Chikura Press (in Japanese).

Reilly, W.J.(1929) Methods for the Study of Retail Relationships, *University of Texas Bulletin*, No.2944.

Rogers, A.(1974) *Statistical Analysis of Spatial Distribution*, London:Prion Ltd.

Sanders, Peter & Frank Sanders (2004) Spatial urban dynamics – A Vision on the future of urban dynamics: Forrester revisited, *The Proceedings in ISDC 2004 in Oxford*.

Schroeder III, Walter W., Robert E. Sweeney & Louis E. Alfeld (1975) Readings in Urban Dynamics: Volume 1, Wright-Allen Press.

Stouffer, S.A.(1940) Intervening Opportunities; a Theory Relating Mobility and Distance, *American Sociological Review*, Vol.5, 845-867.

White, L.A. and J.B. Ellis(1971) A System Construct for Evaluating Retail Market Locations, *Journal of Marketing Research*, Vol.8, pp.43-46.