# ANALYSIS OF EPISODES IN URBAN EVENT HISTORIES

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*Contribution to the Metropolitan Study: 9*

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*LIST OF CONTRIBUTIONS TO THE METROPOLITAN STUDY:*

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2. Casti, J. (1983) Emergent Novelty and the Modeling of Spatial Processes. Research Report, RR-83-27. IIASA, Laxenburg, Austria.

3. Lesse, P.F. (1983) The Statistical Dynamics of Socio-Economic Systems. Collaborative Paper, CP-83-51. IIASA, Laxenburg, Austria.

4. Haag, G. and W. Weidlich (1983) An Evaluable Theory of a Class of Migration Problems. Collaborative Paper, CP-83-58. IIASA, Laxenburg, Austria.

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# FOREWORD

*Contributions to the Metropolitan Study: 9*

The project "Nested Dynamics of Metropolitan Processes and Policies" started as a collaborative study in 1983. The Series of contributions is a means of conveying information between the collaborators in the network of the project.

The presentation in this paper has an exploratory character. It introduces the concepts of *event histories* and *episodes* and suggests that episodes may function as a bridging link between (i) statistical analysis and empirical observations, and (ii) non-linear theoretical models of regional change processes. The objective is to approach a principle for organizing observations in such a way that they can shed light on non-linear change processes of interaction subsystems.

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# 1. EVENTS AND EPISODES IN URBAN DYNAMICS

## 1.1 Introduction

Urban growth patterns have exhibited in the past decades dramatic shifts, in both developed and developing countries, and in both market and planned economies. *Steady* growth patterns have evolved into fluctuating development paths. In addition, various subsystems within an urban system display different evolutionary patterns due to differences in adjustment speeds. Urban dynamics is nowadays marked by a complexity that is hard to disentangle by means of conventional analytical tools (see also Johansson et al., 1983).

In the context of fundamental (sometimes drastic) changes in an urban system, it may be fruitful to introduce some new concepts. The first one is an *event*. In formal statistical terms an event is a subset of the sample space, so that the probability of its occurrence can be assessed by means of an underlying probability distribution. Thus an event represents a specific state from a feasible state space, with a certain probability of occurrence in a given time interval. In the framework presented in this paper on urban dynamics, it is especially interesting to focus attention on *changes*. Therefore, an event will be interpreted here as (i) a distinct change in a state variable or (ii) a distinct switch from one change pattern to another with regard to a particular variable or subsystem.

In relation to events, another term may be introduced, viz. *episodes*. An episode in urban dynamics (or in urban history) will be regarded here as a change pattern in urban history that is distinctive and separate from previous patterns although part of a larger series of episodes in urban history. For instance, a steady change pattern or dynamic process may be termed an *episode*. Consequently, an event is a transition from one episode to another. Hence, a switch from fast growth to stagnation or to decline of a certain variable represents events for which observations on this variable can be measured at discrete time intervals. Evolutionary patterns of a dynamic system are then transformed into a series of events such that each is associated with the start of a new episode.1) A whole evolution path is then divided into a series of episodes which describes the urban history. For instance, a change of urban finances from a state of solvency into bankruptcy may be regarded as a transition between two episodes. Urban fluctuations in the past decades may be interpreted as episodic growth patterns. With another time scale, a period of rapid variations forms an episode in contradistinction to a preceding or succeeding period of steady change.

In the sequel of the paper, the notions of events and episodes will be employed to design a formal methodological framework for studying urban evolutionary patterns and variations in those patterns.

## 1.2 Methodological Relevance

In the past decade, many advances in the area of discrete spatial analysis have been made, for instance, by means of logit and probit analysis, generalized log-linear models and soft modeling (see for an extensive survey Nijkamp et al., 1984). As observations on urban events and episodes are often of a discrete

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1) Formally, an event may be either (i) a "new" event leading to a new episode or (ii) a "redundant" event implying the continuation of an episode.

nature, it is clear that discrete data analysis is a powerful tool in studying complex urban systems, witness also the great many applications in this field.

In recent years, especially panel studies and longitudinal data analyses have increasingly come to the fore, particularly in behavioral analyses of disaggregate (spatial) choice behavior (see also Coleman, 1981). Several applications in the area of transportation and residential mobility reflect the potential of panel and longitudinal analysis for studying adequately the determinants of individual episodes in a spatial context.

Modeling long-term processes based on discrete states, however, is far more complicated and is only recently receiving attention in social science research. For instance, discrete-state, continuous-time, stochastic models have hardly been applied in urban and regional research, though some examples can be found in Griffith and Lea (1983). The analysis of event-histories in an urban context deserves, no doubt, more attention, especially because the urban evolution in many countries is exhibiting highly unstable episodes.

### 1.3 Some Illustrations of Industrial Episodes in an Urban Region

A typical example of successive economic/industrial episodes in an urban region would be a transition from a manufacturing region to one dominated by banking and other service activities. The Gothenburg region in Sweden has during this century had the following episodes: textile, shipyard, and automobile industrial dominance. Urban regions with an economy based on the extraction of natural resources, like coal in the Dortmund region, may experience dramatic transitions between growth, stagnation and drastic decline. The Silicon Valley in the San Francisco Bay area provides an example of a "high technology episode" initiated in the second half of the 1960s.

For metropolitan regions one may also observe how a period of creativity and innovation is followed by a period of productivity, expansion and a fading away of the creativity. From this point of view, Jane Jacobs' suggestive story about Manchester and Birmingham in the middle of the last century is revealing (Jacobs, 1970). At that time Manchester was admired by economists and other social scientists for its productivity and efficiency based on large-scale specialization. Birmingham, on the other hand, was perceived as being unstructured with a multiplicity of seemingly unorganized production activities. However, this environment gave rise to a development period characterized by novelty by combination and successful innovations; at the same time Manchester was lagging behind, suffering from its own success during an earlier period. An episode with a concentration on already established innovations logically bears fruit in the form of a transition to a phase with large-scale solutions, increased rigidity with exclusion of activities which might renew the system, and thereby leads to an episode of obsolescence and decline.

## 2. URBAN DYNAMICS AS AN EVENT-HISTORY

### 2.1 Urban Dynamics as Multi-Faceted Events

Urban dynamics is related to a structure with spatial and temporal coordinates. This structure presupposes relationships between phenomena in space and time, so that complex, multi-faceted and nested patterns of a geographical structure of cities may emerge, sometimes leading to discontinuous space-time trajectories of the variables involved.

Consequently, due to large fluctuations caused by dissipative structures affecting the homogeneity and isotropy of space and time, the geographical structure of cities may become unstable and even exhibit bifurcations (cf. Turner, 1980). Especially if the subsystems of an urban system (like transportation, housing, industry, or facilities) are intertwined in a non-linear dynamic way with differences in the successive rates of change, unexpected switches in the change paths may take place (cf. also Haag and Weidlich, 1983). Urban episodes of a stable evolution may turn into new events (sudden shocks, for example) for the urban economy, so that the evolution of a city can be described by means of its event-history.

Given the complexity involved in describing and analyzing urban dynamics, it is extremely important to pay special attention to the *driving forces* or *key factors* of the space-time trajectory of an urban system. Key factors may be regarded as those stimuli that drive the space-time trajectory of an urban system (or of its components) without being affected in the same time period or in the same geographical area by endogenous variables describing the state of the system (or its components). There are various ways to identify such key factors of an urban system:

- an analysis of the *functional* structure of a model describing the system by focusing special attention on *predetermined* (exogenous and lagged endogenous) variables. This is the usual procedure in conventional economic modeling.
- a *causality* analysis of the interwoven structure of a complex urban system by identifying the autonomous nodes of such a system by means of *graph-theoretic* approaches (e.g. by calculating the causality degree of the urban system or of some of its constituents) (see Blommestein and Nijkamp, 1983).
- a *mathematical* analysis of the Boolean structure of an urban system by trying to triangularize the system in order to derive a nested or multi-level structure exhibiting the successive driving forces (see van der Hee et al., 1979).
- a formal analysis of the *dynamic* structure of an urban system, in order to identify the probability of dissipative patterns to emerge, so that internal dynamic interactions (for instance, different transition rates for intertwined phenomena) may be identified as "change generators" for the space-time trajectory of an urban system. Especially in the latter, more dynamic-oriented interpretation of key factors, the above-mentioned notions of episodes and events play a meaningful role, as then co-evolution or incongruencies of episodes and events may also be analyzed more precisely and related to the existence of singularities and the possibility of bifurcations (see also Haining, 1983).

Finally, the analysis of urban episodes and events has to take into consideration the impact of *constraints* on the emergence of urban events. Here three distinctions can be made (see also Nijkamp, 1983):

- *threshold* conditions: constraints acting as necessary conditions before an urban episode can be changed and a new event takes place
- *bottleneck* conditions: constraints that preclude the continuation of an urban episode, so that without a removal of these constraints a new urban event would come about.
- *synergistic* conditions: coupled constraints that are mutually dependent, so that a removal of the one constraint has only an effect if also the other one is eliminated.

These three types of constraints are extremely relevant in an urban dynamic context: cities need a minimum endowment with facilities before they can really start growing (the threshold phenomenon); the growth of cities may draw to a close if agglomeration diseconomies (congestion, for example) arise (the bottleneck phenomenon); and cities will only have a balanced development if there is a fine tuning of private productive capital and public overhead capital (the synergistic phenomenon; see also Hirschman, 1958). These issues will be further taken up in the next subsections.

## 2.2 Industrial Dynamics as an Event-History

In this study we may refer to industry as all kinds of production such that the output is delivered also to markets outside the urban region; this means that the selling price is determined by factors external to the region. The viability of such production activities is then affected by the capability in the urban region of delivering the output at prices which do not exceed those of external competitors.

The establishment of a new production activity represents an event which eventually gives rise to a specific industrial episode with certain genetic characteristics. Such an event may be founded on an innovation generated within the region or it may be based on imported production knowledge (imitation) (see also Davies, 1979). The continuation of the production requires a gradual adaptation of the productivity to the evolving standard of external competitors. This may take the form of a successive development of the product attributes as a means to retain a market share without reducing the output price. Also when some product development occurs the overall development is frequently dominated by attempts to increase the production scale as a means of raising the productivity and thereby augment the ability to supply at a lower relative price.

Increased production scale has a multitude of effects. It increases the regional specialization and this may also attract associated production activities. However, increased scale also implies a certain degree of exclusion of activities competing for the same inputs like specific types of labor force, land, infrastructure facilities, etc. Although increased scale, with few exceptions, is accompanied by a qualitative improvement of the production process, there is usually a technological limit for the scale-dependent increase of productivity (see Wibe, 1982). Therefore, the marginal returns to scale are decreasing as the scale rises. As a consequence, increased production scale and specialization finally represents a dead end with stagnation and a loss of flexibility due to the specialization. In this way a process of gradually intensified specialization represents a typical industrial episode created by the interaction between (i) external competition and market demand, and (ii) internal responses in the form of increased production scale.

This interaction between the urban production system and external competitors may be modeled as an endogenous process within the frames of a product cycle theory (see Andersson and Johansson, 1984). In this theory the diffusion of production knowledge to new competitors is assumed to be more easy as the production scale grows with associated reduced requirements on the labor force competence. Thus altogether the economic development of a region or a city can be characterized by a variety of episodes, each of which is brought about by exogenous or endogenous events.

### 2.3 Interaction Between Infrastructure and Industrial Episodes

The typified or stylized version of industrial development in the preceding subsection can be enriched by the case in which the expanding industry provides a breeding place from which employees leave and initiate new production based on acquired ideas and experiences. To which extent this latter process takes place depends critically on how the infrastructure develops. Infrastructure is regarded here as the stock of public capital that is supplied to regions or cities as a complement to productive capital in order to increase the efficiency of production (see Biehl et al. 1982; and Hirschman, 1958).

The time scales of industrial and infrastructure capital may differ considerably. Many of the extensive infrastructure systems for transportation and communication are created:

- under conditions of indivisibilities
- with long gestation lags, and
- with inbuilt technological rigidities

This implies that the turnover time of the industrial production equipment and technical solutions may be considerably shorter but more flexible than that of the infrastructure systems. Under these conditions the development of facilities and service systems as well as the provision of land becomes subordinated to the production that dominates the urban region. Two aspects are important: (i) if infrastructural development lags behind, incongruencies may arise and this may hamper the development of expanding activities, and (ii) if the design of the service systems becomesbiased in favor of expanding activities, they will not provide a fertile environment for new potential production activities.

It is important to observe that attempts to interlink industrial and infrastructural development in a conditional probability setting may require an aggregation or clustering approach. For example, when studying a single industrial activity or sector a subset of infrastructural systems may be grouped together, and their compound development may constitute an episode from the viewpoint of the industrial sector. Reciprocally, the development and episode of a certain infrastructure subsystem may be linked with an episode constituted by the aggregate change path of a whole set of clustered industrial sectors.

## 3. STATISTICAL ANALYSIS OF EVENT-HISTORIES

The study of spatial dynamics already has a long history. First attempts at describing space-time trajectories can be found in conventional *space-time geography* (see for instance, Hägerstrand, 1970), in which the evolution of a spatial system and its actors was described in continuous space at both an aggregate and disaggregate level.

The next stage meant a more formalized focus on *location-allocation* problems. This episode in the history of analyzing spatial dynamics was inter alia based on dynamic programming and optimal control theory. The majority of these models was aggregate in nature.

Then more emphasis was placed on *discrete spatial* models encompassing distinct choice issues, for instance, in transportation, labor market and housing market analysis (see, among others, Clark, 1983; van Lierop and Nijkamp, 1984; and Leonardi, 1983). These models are mainly disaggregate models and do not analyze the behavior of the system as a whole or its subsystems.

In recent years, much attention has also been paid to *panel studies and longitudinal data analysis*, in which the intertemporal evolution of distinct events is analyzed on the basis of discrete time intervals (see also Coleman, 1981). Most of these techniques and models focus on micro events.

Finally, the most recent development can be found in the area of *event-history analysis* (see Hannan and Tuma, 1984; and Tuma and Hannan, 1984). Event-history analysis serves to study changes and transitions in qualitative variables. It is based on information on sequences and timing of transitions and is regarded as a new tool in analyzing causal hypotheses regarding qualitative spatiotemporal data.

In both sociology and demography event-history design has recently become an important analytical tool, so that it is worthwhile to investigate its potential for studying spatial dynamic systems. In the social sciences transition problems have often been described by means of *Markov models*, which are usually purely descriptive, without an explicit treatment of causal relations.

The underlying assumption of stationary processes is, however, not very valid, while the use of panel data in social dynamics research is not always appropriate (due to identification and consistency problems). Therefore, event-history design may be meaningful, as has been demonstrated in biostatistics and reliability theory. Spatiotemporal examples of event-history design can be found inter alia in studies dealing with the dynamics of the labor markets (cf. Tuma and Robins, 1980), of marital status (cf. Hannan et al. 1978) and migration patterns (cf. Sandefur and Scott, 1981).

In general, an *event-history* (or sample path observation) plan records relevant information on all changes in a state variable within some observation period, so that this method may be especially suitable for studying discrete changes in the evolution of a phenomenon. An *event-history* w over a certain period $[\tau_1, \tau_2]$ can be represented as:

$$w[\tau_1, \tau_2] = \{y(t);\ \tau_1 \le t \le \tau_2\} ,$$

where y(t) is the qualitative value (occurrence or not, for example) of a variable under consideration at time period t. Clearly, y(t) may take any distinct value from the state space Y, i.e., $y(t) \varepsilon Y$.

This can be exemplified as follows. Suppose an urban system can adopt 3 different stages, viz. urban growth (episode 1), urban decline (episode 2) and urban stagnation (episode 3). Then an episodic representation of the urban history may lead to a sequence of specific growth paths as illustrated in Figure 1.

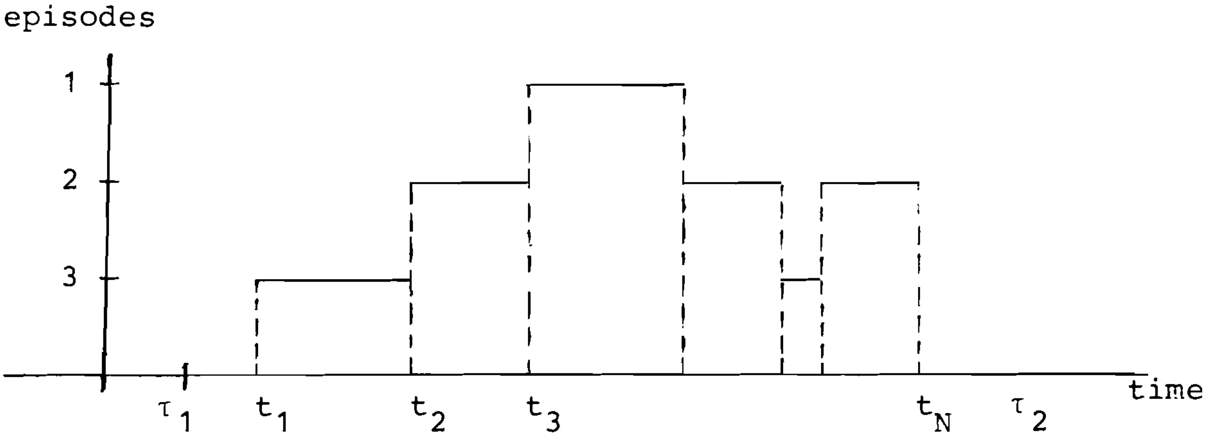

Figure 1. A representation of urban episodes.

Each jump from the one episode to the next one may be called an event n (n=1,...,N) in the urban history. Thus altogether, there are N events in the urban history of Figure 1. These events take place at time periods $t_1$, $t_2,\ldots,t_N$, so that the event-history of the city from period $t_1$ onward can be represented as follows:

$$w(t_1,\tau_2) = \{(t_1,y_1)\ ,\ (t_2,y_2),\ldots,(t_N,y_N)\}$$

According to Hannan and Tuma (1984), there are three different possibilities to define statistical measures for assessing the probability of the occurrence of events:

(a) *survivor function:* defines the probability that an event takes place after time $t_n$, given the initial conditions $w_n$: $\mathrm{Prob}[T_{n+1} \geq t_n | w_n]$. This probability can be estimated by means of maximum likelihood methods.

(b) *waiting-time distribution function:* defines the probability that a certain event will take place based on the cumulative distribution function for the waiting time (i.e., length of intervals between successive events): $\mathrm{Prob}[U_n < t | w_{n-1}]$. Here maximum likelihood methods can also be employed.

(c) *hazard function:* defines the probability of having an event at time t in terms of failing by means of a hazard rate, given that the hazard (event) has not occurred before time t. The hazard can be defined in terms of a corresponding survivor function, and can be estimated by means of a maximum likelihood technique.

An important element in event-history analysis is not only the estimation of the probability that an event takes place (implying a different state of the system), but also *which* new state will be attained. Such a situation of conditional probabilities can also be illustrated as follows. Suppose that the growth of an urban subsystem is markedly reduced or stops. The succeeding potential events may be stagnation or decline. Moreover, a decline episode may or may not be coupled with an expansion phase in another subsystem. The possibility of such interdependencies illustrates the importance of a problem- or hypothesis-determined classification of events, i.e., how subsystems are aggregated or clustered in order to define a variable for which episodes are examined.

Event-history analysis may in particular be used to define causality relationships between

(i) event probabilities and explanatory variables,
(ii) probabilities of simultaneous (coupled) events.

For discrete data, this type of enquiry may rely on log-linear model specifications so that positive probabilities (or positive transition rates for events) are ensured (see, for example, Arminger, 1984).

It is important to observe the time-hierarchical relation between events and episodes. A growth curve like the one in time interval $(t_0, t_1)$ in Figure 2 may be treated as a series of repetitions of the same event at all points in time within the interval. In the second interval $(t_1, t_2)$ another episode is identified, once again built up by repeated events of continuing the episode.

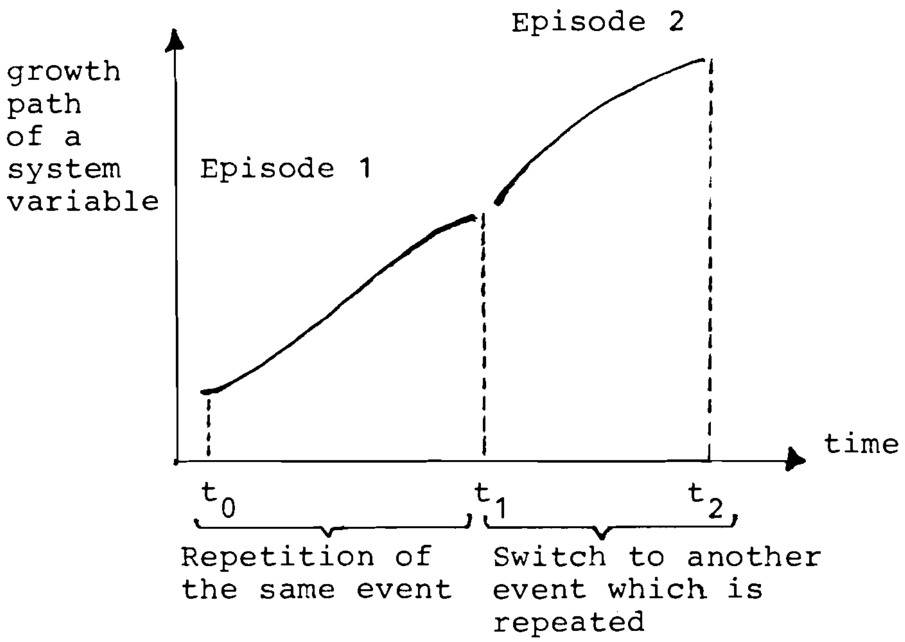

Figure 2. Illustration of events and episodes.

The probability of an event or the transition rate for events in the figure are clearly distinct from the rate of change that characterizes the episode.

Further extensions of event-history analysis can be found in higher-order (nested) dynamics, in which the transition rates may also become time-dependent. In such cases, logistic specifications may be used (see Hannan and Tuma, 1984, for further details).

Problems of spatiotemporal auto- and cross-correlation can also be taken into account, especially in the framework of Lisrel V models for discrete variables (see Folmer, 1984).

So far the *spatial* aspects of event-history analysis have hardly been treated. Even in panel and longitudinal analysis the spatial dimension has not been covered in a fully satisfactory way. Event-history analysis may be an extremely important methodology for studying urban dynamics as it:

- collects information on the sequence and timing of events in the urban evolution
- provides a potential for testing causal hypotheses in a dynamic urban system marked by discrete events
- allows the inclusion of qualitative spatial data in stochastic process models for urban dynamics

## 4. INTERACTION BETWEEN INDUSTRIAL AND INFRASTRUCTURAL EPISODES

### 4.1 The Breeding Place Principle

As discussed in subsection 1.3, the composition of activities in an urban region forms an environment that may give birth to new varieties of old activities as well as qualitatively new activities (innovations). The Birmingham example illustrates novelty by combination based on richness of non-mature (young) activities. The Silicon Valley type of innovation development exemplifies a process in which new ideas drop out of successful firms, as a result of employees leaving their workplaces to start up new firms. In this way successful firms breed new firms which eventually become strong competitors.

A specialization-based breeding process like the recent micro-electronic development in the San Francisco Bay area or in New England has been driven by a situation in which demand is growing faster than the supply of output. If such a situation is combined with a continuing inflow of a knowledge-intensive, competent and creative labor force, it allows for a repeated split (multiplication) of successful organizations. As soon as any of these requisites disappears successful organizations will prevent splitting, increase the specialization and thereby more efficiently exclude the emergence of novelties outside the organization (see also the principle of competitive exclusion formulated by Sonis, 1983).

When agglomerations are large enough, the growth of successful organizations can follow a path along which a variety of simultaneous specialization is retained, which is an environmental prerequisite for continuing novelty by combination. In this latter case a scale-effect delays the movement towards the stage at which specialization leads to spatial exclusion.

Another basic requisite with regard to product and process development is related to infrastructure characteristics of the region. There must be an inflow and internal breeding of knowledge and knowledge-intensive employment categories. And this is related to the R & D institutions and R & D investments in the region.

## 4.2 Challenge-and-Response Principle in Urban Dynamics

The historical, often irreversible growth patterns of cities exhibit a heterogeneous nature that can be ascribed partly to locational conditions (see subsection 4.1), partly to endogenous mechanisms in the functioning of an urban system. Events such as the rise and disappearance of cities can only be understood if we are able to provide an endogenous explanatory framework for transition processes in urban dynamics. Examples can be found in the traditional Schumpeterian lines of thought (see for instance, Thomas, 1972) and in the more recent paradigms of self-organization (see for instance, Allen and Sanglier, 1979). Most of these theories however, provide an *internal* explanation of dynamics without relating the dynamics to external developments.

In this regard, it may be useful to refer to Toynbee's *challenge-and-response* principle (see Toynbee, 1961), in which the author demonstrates that the historical development of societies is determined by the way in which they react to (internal and external) challenges. Decline and disappearance is then determined by lack of adequate response (relative to the response of others). In our terms, it means that the transition of the one urban episode to another one is dependent on the nature of responses in urban planning and policy making in order to meet internal and external challenges.

*Internal* challenges may be subdivided into:

- *existence of threshold values* related to endowment of infrastructure, labor force competence and scientific knowledge;
- *lack of innovation:* if the urban production system is "driving to maturity" new production structures, new institutional arrangements and new urban patterns are needed. Such a renewal process needs support from social overhead and R & D capital (see Nijkamp, 1983);
- *existence of bottlenecks:* if the urban economy is reaching a saturation phase, the drive to maturity is drawing to a close due to capacity constraints (congestion, old infrastructure, lack of R & D activities, etc.) (see for a formal approach to this phenomenon based on individual discrete choice models, Miyao and Shapiro, 1981). Then drastic events such as the construction of new infrastructure, the design of a new physical planning and the introduction of advanced technology are necessary.

The above-mentioned challenges and responses for the episodes of an urban history are represented in Figure 3.

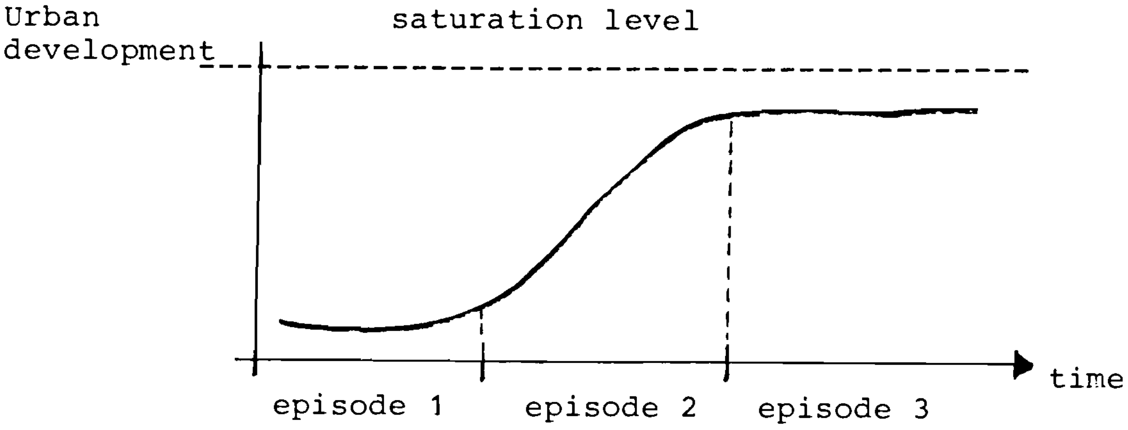

Figure 3. Episodes in a challenge-response view of urban history.

*External* challenges may be subdivided into the following categories:

- *progress of other cities:* in general, an urban economy is small compared to the national or international economy, so that cities have to compete with each other on a nationwide or international market as far as their exports are concerned. The economic success of a city is then determined by its export-base orientation. If other cities grow faster, investors/decision makers in a city k will receive signals about where and how to direct their efforts in order to keep pace or catch up with the development in other urban regions (by imitation or creation of adequate production facilities). These "jealousy" type signals may stimulate city k to be more innovative, if its relative position with respect to others is weakening;
- *lack of coordination:* in an interwoven economy, public policy needs a coordination of policy measures between cities in a spatial system. In an economy with a decentralized institutional structure, coordination of policies can be frustrated by autonomous spatial entities (cities, for example) that use their power to reinforce their position in the national economy or to force policy makers to provide them with more advantages than others.

### 4.3 Illustration of Subsystem Interactions

We may illustrate some of the processes discussed in preceding sections with the help of the following prototype model (compare Batten, 1982):

$$\dot{v}_i = \mu_i v_i [N_i - v_i - \varepsilon_i v_j] - \gamma_i v_i \; ; \; i,j = 1,2 \qquad (1)$$

where $v_i$ denotes production of type i with $\mu_i$ and $\gamma_i$ as entry (expansion) and exit (depreciation or removal) rates, respectively. $N_i$ represents a given upper limit on the production level $v_i$. When $\varepsilon_i \geq 0$ for i=1,2, the $\varepsilon$-coefficients will reflect the competition between the two types of production. A negative $\varepsilon_i$ signifies that sector i is positively stimulated by the growth of the other sector. With this model we may consider various types of episodes.

Suppose that at time $t < t_o$ we have $v_1(t) > 0$ and $v_2(t) = 0$. Then we consider the occurrence of entry as an event, identified by $\dot{v}_2(t_o+\tau) > 0$ as $\tau \geq 0$. Such an event is characterized by the episode attached to it. Three cases will be discussed here.

> *Case 1: Exclusion through competition for the same resource.* In this case we let 1 and 2 refer to different kinds of output, and we let $v_1$ and $v_2$ be located in the same region. They compete by using the same available land, infrastructure and labor force. $N_1$ and $N_2$ represent the upper limits of these resources.

For this case we may illustrate exclusion of $v_2$ due to specialization in $v_1$ as

$$\begin{aligned} &\varepsilon_1 \leq 0 \ , \ \varepsilon_2 \geq 0 \\ &N_2(t) = M(t) - N_1(t) \end{aligned} \qquad (2)$$

where M(t) is the aggregate limit on total output of the firms at hand.

As long as $\dot{N}_1 \geq 0$ and $N_1$ is close to M(t) there is no room for $v_2$ to grow. Then $v_2$ can only expand if M(t) expands. If $\varepsilon_1$ and $\varepsilon_2$ are both positive and $N_1(t) + N_2(t) = M(t)$ a stagnating M(t) implies that one of the following episodes occur (i) $v_2$ is pushed back to zero or (ii) $v_2$ will in the course of time squeeze $v_1$ out of the system and reduce it to zero as described in Figure 4. This type of exclusion may be significantly delayed if the infrastructure and labor supply continues to grow so that $\dot{M} > 0$.

> *Case 2: Competition for the same market.* In this case we let 1 and 2 represent two substitutes competing for the same market, i.e.,

$$\begin{aligned} &M(t) = N_1(t) + N_2(t) \\ &\varepsilon_1 > 0 \text{ and } \varepsilon_2 > 0 \end{aligned} \qquad (3)$$

Suppose that $v_2$ survives. Then just as in the preceding case $v_1$ will gradually be extinguished if M(t) is stagnating. In this case we must distinguish between two extremely different episodes. If both $v_1$ and $v_2$ are located in the same region, we have a process of regional renewal. However, if $v_2$ is located in a second region, rhe reduction of $v_1$ also brings about a regional decline.

> *Case 3: Synergistic reinforcement.* Let $v_2$ represent a new type of "infrastructure support" for the production $v_1$, and let $\varepsilon_1$ and $\varepsilon_2$ both be negative as an expression for mutual reinforcement.

According to (1), case 3 will allow for explosive growth if $\varepsilon_1$ and $\varepsilon_2$ are constant. In order to illustrate the balance problem between production and infrastructure support and vice versa, we may write for $i,j = 1,2$

$$\varepsilon_i = - \max \{\alpha_i, 1 - \exp \{v_j - \beta v_i\}\} \tag{4}$$

as an example of a general relation $\varepsilon_i = \varepsilon_i(v_i,v_j)$. The function in (4) emphasizes that when $v_j > \beta v_i$ the synergetic effect is reduced to $\alpha_i \geqslant 0$; this means that $v_j$ stimulates $v_i$ stronger when $v_j$ is below the balance level $\beta v_i$ than when it exceeds this level.

Altogether, a model with a structure of (1) is able to generate a wide variety of episodes for a dynamic system.

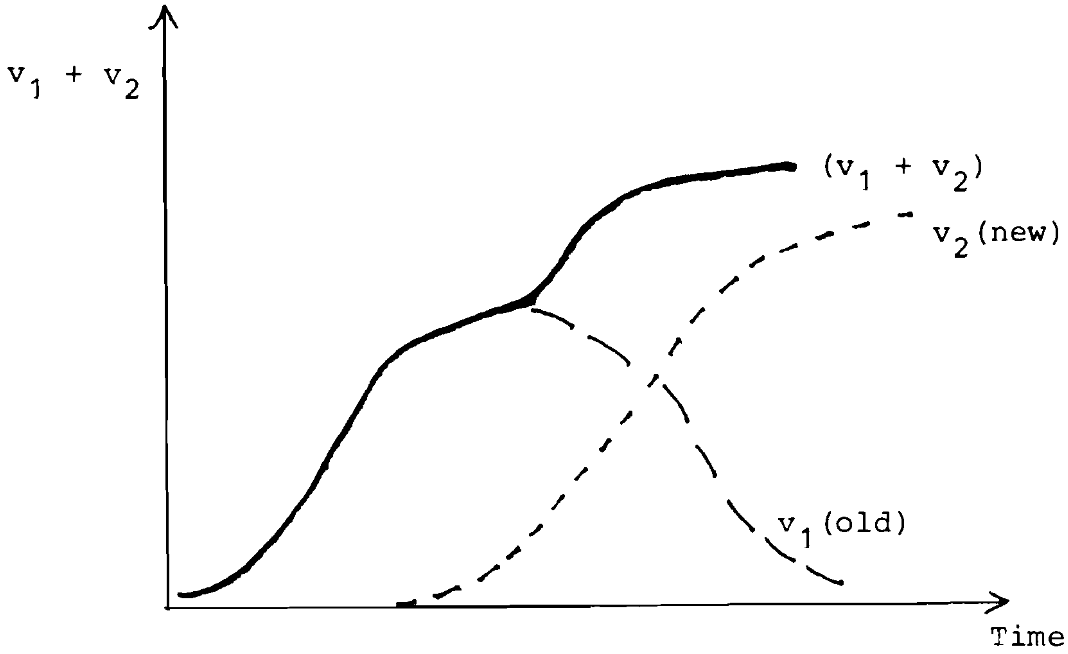

Figure 4. Introduction of a new activity and phasing out an old.

# 5. URBAN EPISODES ILLUSTRATED BY A SIMPLE MODEL

## 5.1 Multi-episodes in a Logistic Growth Process

In the past decade, modeling qualitative economic changes based on nonlinear self-organizing or adaptive processes has increasingly received attention (see, for instance, Allen and Sanglier 1979, Batten 1983, Day and Cigno 1978, Dendrinos 1980, and Nijkamp and Schubert 1983). The major aim of these contributions has been to understand the functioning of complex dynamic systems by means of models that have a relatively simple structure.

In this section we introduce a model which will help to illustrate some further aspects of urban episodes. We start with a simple model to which more details are added in steps. Also the initial version of the model is able to generate a multi-episode history.

We consider a model of a sector in an urban system. As a limiting case we may conceive this sector as the whole production system of the urban economy. The increase of value added (at given prices) is assumed to depend on investments and capacity removals in the following way:

$$V(t+1) - V(t) = \alpha(t)I(t) - \xi(t)V(t) \tag{5}$$

where for period t, $V(t)$ is value added, $I(t)$ investments, $\xi(t)$ depreciation or removal of old capacity in terms of value added, and $\alpha(t)$ the relation between investments and new production capacity.

Assume that investments are driven by a simple acceleration behavior so that

$$I(t) = \kappa(t)V(t) \tag{6}$$

where $\kappa(t)$ may be thought of as the investment share of current production; although $\kappa(t)$ generally will oscillate around a constant value or a trend, we are treating it as a constant.

As the production grows the demand for labor will also grow, and this will push labor costs upwards. Growing production may also imply increased competition on markets outside the region.

This implies that old production capacities with less modern production techniques will be obsolete and removed, to be replaced eventually by modern and more efficient technologies. Such a vintage process may be reflected in terms of value added as follows:

$$\xi(t) = \lambda * V(t) \tag{7}$$

which together with (5)-(6) yields

$$V(t+1) = V(t)[1+\alpha(t)\kappa(t) - \lambda * V(t)] \tag{8}$$

Difference equations of this simple type have in the past decade been used several times to analyze the dynamics of complex systems (see, e.g., Beaumont et al, 1980; May, 1974; Li and Yorke, 1979; Nijkamp, 1983; Nijkamp and Schubert, 1983; and Wilson, 1981).

Before adding new components to this model, we first describe some dynamic properties of the process in (8). It adheres to a family of logistic growth processes which has been extensively analyzed by May (1976). With a normalized scale such that $0 < V(t) < 1$, and with $\alpha(t) = \alpha$, $\kappa(t) = \kappa$, we may distinguish the following cases:

*Case 1:* $\alpha\kappa < 0$; in this case V(t) will gradually be reduced to zero which implies extinction of the sector in the long run.

*Case 2:* $0 < \alpha\kappa < 2$; in this case there is a stable equilibrium point, and a steady state solution is guaranteed.

*Case 3:* $2 < \alpha\kappa < 3$; in this case we may obtain various kinds of oscillatory solutions ranging from cyclical to chaotic behavior as $\alpha\kappa$ increases within the given interval.

A shift from case 1 to case 2 would represent an event giving rise to a new episode. With regard to case 3, variations in $\alpha\kappa$ may generate qualitatively new episodes.

### 5.2 External Influences

The challenge-and-response principle discussed earlier implies that external conditions may influence the change process in the urban region. For production which is exported and/or has to compete with imports from other regions the relative cost level is of vital importance. We may use $c(t)$ and $\hat{c}(t)$ to denote the relative cost levels of the region with old and new production techniques. Then the willingness to invest is expressed by $\kappa(\hat{c}(t))$, and the depreciation rate becomes $\xi(c(t))$[1]. In this case equation (8) is transformed to:

$$V(t+1) = V(t)[1+\alpha(t)\kappa(c(t)) - \xi(\hat{c}(t))] \qquad (9)$$

Moreover, a region which is lagging behind its surrounding neighbors may imitate them and import production knowledge from its environment. In order to reflect this we may let $\alpha(t)$ change in response to the discrepancy between an aspiration level $V^*(t)$ and the regional production level $V(t)$ so that

$$\alpha(t) = \bar{\alpha} + \alpha^*(V^*(t) - V(t)) \qquad (10)$$

where $V^*(t)$ represents the production level (e.g. per capita production) in the relevant environment of the region.

The above remarks about external influences indicate that when interactions between the region and its enviroment are considered, the occurrence of new events will be much more likely and frequent than in a closed system. This becomes obvious if we insert (9) and (10) into (8), and observe that $\hat{c}(t)$ and $c(t)$ in (9) will depend on the change processes both within the region and in its environment.

### 5.3 A Core-Ring Configuration

In this sub-section, an attempt will be made to extend the previous model in order to demonstrate how different space-time episodes of urban histories can emerge. Without loss of generality, we will assume the existence of two technologies each having its own productivity. In addition, we will also assume a segmented (i.e. dual) supply of labor as a production input.

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1) Observe that $\hat{c}(t)$ and $c(t)$ are affected by the same regional wage level.

Furthermore, it will be assumed that the agglomeration concerned may be split up into a core and a ring (see also van den Berg et al. 1982). Due to congestion and physical inertia the technology in the core may be less flexible, while in the ring new industrial technologies may flourish.

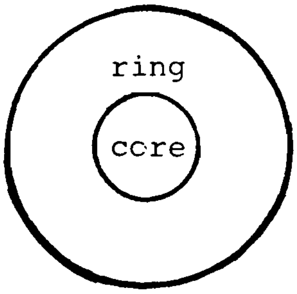

Figure 5. Urban agglomeration with a ring and a core.

Clearly, the assumption of one core and one ring is not strictly necessary; other spatial configurations may also be existent. The main argument is that different areas may favor different technologies. In particular, the availability of space will be different in the two zones, and this implies non-identical technology opportunities. Moreover, as a result of past history the technologies will in general have different vintage structures and different adjustment speeds.

The overall growth of the sector (or the entire production system as a limiting case) may be obtained as the sum of the growth in the two zones so that

$$\Delta V(t+1) = \Delta V_1(t+1) + \Delta V_2(t+1) \tag{11}$$

Let $\Delta L(t) = \sigma V(t)$ denote the labor force available for new employment in period t+1 for the whole urban region, and let $\Delta L_i(t) = \sigma_i V_i(t)$ be the same kind of supply in zone i. Given this, suppose that the zonal wage level $\omega_i(t)$ is affected by the tension in the labor market in such a way that

$$\omega_i(t) = \omega_i + \mu_i \Delta L_i(t)/\Delta L(t) \tag{12}$$

The change in $\omega_i(t)$ can be expected to affect the willingness to invest and the depreciation or removal rate so that $\kappa_i(t) = \kappa_i(\omega_i(t))$ and $\xi_i(t) = \xi_i(\omega_i(t))$. As a simple example we may assume that

$$\kappa_i(\omega_i(t)) = \bar{\kappa}_i - \lambda_i \sigma_i V_i(t)/\sigma V(t) \tag{13}$$

$$\xi_i(\omega_i(t)) = \bar{\xi}_i + \beta_i \sigma_i V_i(t)/\sigma V(t) \tag{14}$$

This yields for i = 1,2

$$\Delta V_i(t+1) = V_i(t)\{\alpha_i(t)\bar{\kappa}_i - \bar{\xi}_i - \sigma_i V_i(t)/\sigma V(t)\,[\lambda_i+\beta_i]\} \tag{15}$$

which constitutes a model with a similar basic structure as the one in subsection 5.1. However, (1) constitutes a coupled system such that the development in the ring will have repurcussions in the core and vice versa. Also, the two zones may show diverging change patterns and adjustment speeds. Hence, in the general case there will be one distinct episode in each zone.

## 6. A SPACE-TIME CORE-PERIPHERY MODEL

The urban episodes discussed in Section 5 can be aligned more closely to a space-time model involving the core-periphery structure. Then an intriquing spatial competition can emergy by assuming both <u>intra</u>-urban (core <u>and</u> periphery) competition and <u>inter</u>-urban competition (or combinations of both) (see also Figure 6).

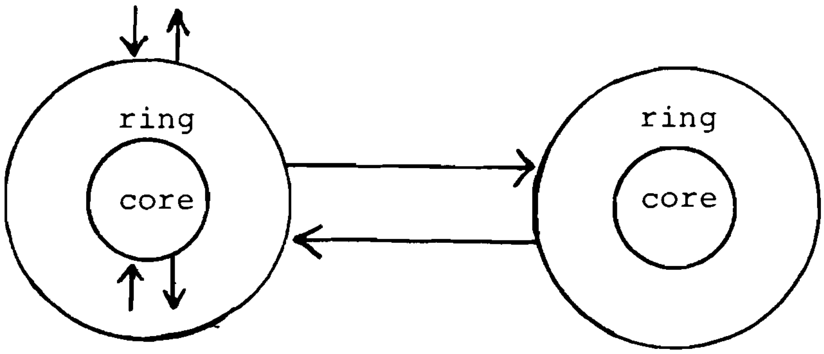

Figure 6. A system of cities.

Then, several interesting cases can be distinguished, for instance, pure core-ring episodes (growth, decline, restructuring), interactive episodes with the outside workd (sudden impacts of energy price, e.g.), 'internal' episodes (related to technological change or substitution processes, e.g.), etc. Differences in urban growth trajectories may also be related to various resource constraints or demand limits in specific cities.

For instance, the coupling of economic development in either the core-ring pattern (intra-urban) or the city-city pattern (inter-urban) will be especially strong if we focus on the same type of production with two competing locations (either within one city or between two cities). In order to illustrate this we may return to the continuous model in (1) and rewrite it as follows:

$$\dot{V}_i = \alpha_i(t-\tau)I_i(t-\tau) - \xi_i(t) \tag{16}$$

$$\alpha_i(t)I_i(t) = \mu_i(t)V_i(t)[N_i(t)-V_i(t)-\varepsilon_j V_j(t)] \tag{17}$$

$$\xi_i(t) = \gamma_i V_i(t)\sigma_i V_i(t)/\sigma V(t) \tag{18}$$

where $(N_i - V_i - \varepsilon_j V_j)$ expresses the market size which is yet uncaptured. This situation is likely to provide a natural investment stimuli. In terms of our earlier formulations we then have

$$\alpha_i\kappa_i = \mu_i(N_i - V_i - \varepsilon_j V_j) \tag{19}$$

and $N_2 + N_1 = M$, with $M \geq 0$.

In a manner analogous to that in previous sections, again the stability conditions for this more complex spatial system can be analyzed.

## 7. FINAL COMMENTS

In this paper we have introduced the concept of episodes and related their emergence to a stochastic framework according to which episodes are generated and exchanged as parts of urban event-histories. With the help of some model examples we have also tried to illustrate how episodes may be modeled and how, in an urban region, they may form a nested network of change processes. In this perspective the concept of episodes could be thought of as an intermediary between theoretical models and empirical observations. In particular, this concept may help to develop a principle for organizing observations in such a way that they can shed light on nonlinear change processes in interacting subsystems.

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