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**Conference Paper**

# Dynamic Spatial Confluence of Residential Construction Initiations Autocorrelation in Tel Aviv-Yafo 1976-2003

46th Congress of the European Regional Science Association: "Enlargement, Southern Europe and the Mediterranean", August 30th - September 3rd, 2006, Volos, Greece

**Provided in Cooperation with:**
European Regional Science Association (ERSA)

*Suggested Citation:* Porat, Idan; Shoshany, Maxim; Frenkel, Amnon (2006) : Dynamic Spatial Confluence of Residential Construction Initiations Autocorrelation in Tel Aviv-Yafo 1976-2003, 46th Congress of the European Regional Science Association: "Enlargement, Southern Europe and the Mediterranean", August 30th - September 3rd, 2006, Volos, Greece, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:
https://hdl.handle.net/10419/118321

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# Dynamic Spatial Confluence of Residential Construction Initiations Autocorrelation in Tel Aviv 1976-2003

**Abstract**

Residential Construction Initiation (CI) is an important spatial characteristic of the urban structure and its spatio-temporal change. This research employed autocorrelation analysis of the residential CI data for the suburbs of Tel Aviv which was collected by the Tel-Aviv Municipality and the National Bureau of Statistics of Israel since the 1970s. Autocorrelation results indicated complex spatio-temporal patterns. A Dual Mechanism Model is suggested treating Agglomeration in core sub-quarters versus Spontaneous Regeneration at the other sub-quarters.

## 1. Introduction

Construction Initiations (CI) information represents the addition and renewal of built floor area (FA) according to its land-use and location. Municipalities gather CI information during the planning, approval, and monitoring phases of urban development. Such information, when collected for decades, at the detail level of individual buildings, may provide important insight into the dynamic underlying urban processes. These processes include the following: the formation of city fabrics and patterns, the relationship between actual growth, planning policies and regulations, as well as differences between the spatial dynamics of different land-uses and the urban volumetric changes (Fagan et al., 2001).

This study aims at assessing the spatio-temporal information content in CI data by using a spatial autocorrelation technique based on Moran's *I* statistics (Paez and Scott, 2004). This statistic may help determining whether the distribution of a variable is systematic or random (Ord and Getis, 1995; Anselin, 1995). Such an analysis may reveal growth centers (centricity/policentricity, for example), the association between urban cores and their surroundings, and the characteristics of the pattern of the changes: spatial homogeneity, randomness, agglomeration, which is obviously linked to the driving forces of the urban evolution.

Autocorrelation analysis will then be implemented to the study of CI pattern evolution in the city of Tel Aviv-Yafo (TA), which is a metropolitan core city and is considered a world city in terms of evolution (Kipnis, 2001). This research was facilitated by the fact that CI information was collected by the TA municipality and the Israeli Central Bureau of Statistics (CBS) since the middle of the 1970s.

## 2. Urban structure evolution and autocorrelation analysis

The physical dynamics of urban spatial development has attracted extensive research (e.g., Batty, 2003; Benguigui et al., 2000 Benguigui et al, 2006; Fujita et al., 1999; Makse et al., 1998; Schweitzer and Steinbink 2002). These studies used primarily remote data sets which provide only a limited representation of the urban processes and forms. Remote sensing data is limited in revealing development inside the urban fabric. Urban infill and renewal processes in large mature cities represent a major (and growing) part of the urban spatial development (Adams, 2004). Renewal aspects are difficult to detect from remote sensing images.

Urban evolution is the result of the accumulation of FA. Annual development and cumulative development are two complementary ways of studying urban dynamics. Despite its high information content and availability, it is interesting to note that there is little use of CI FA data in urban morphology and its dynamic change. Furthermore, CI information may facilitate geo-statistical analysis of urban dynamics by providing high spatio-temporal detail.

Spatial statistics has received greater attention in recent years because of the increased availability of spatio-temporal databases and software tools for implementing it within GIS (Herold et al., 2005). It may facilitate the discovery of knowledge through the use of spatial data mining techniques. New knowledge is sought for describing the phenomenological affinity between close locations, pattern characteristics, and spatial structures.

Autocorrelation is one of the most used methods for this purpose; it is capable of summarizing the overall characteristics of discrete spatial distributions. Spatial autocorrelation identifies the tendency of variables to display some degree of systematic spatial variation as either random, unified or clustered (Cliff and Ord, 1981). Autocorrelation analysis has been extensively applied within the urban context, most of it socio-economic rather than representing the physical aspects of the urban

fabric. For example, the inter-linkages of socioeconomic variables in Canadian urban clusters were studied by Portnov and Wellar (2005) using Autocorrelation analysis. Interestingly, they found that socio-economic variables tend to have high autocorrelation levels in proximity to the urban cluster core, whereas they are random at a range greater than 20-40 km from the City core. They also found that the effect of clustering on urban growth is not uniform: it is stronger in peripheral urban clusters, whereas in centrally located ones the development levels of neighboring towns are less interdependent. Such clustering patterns may link or evolve to polycentric structures that form focal points for the spatial spread or diffusion. Han (2005) and Paez et al., (2001) have studied urban polycentric development patterns and found, for example, that there is positive autocorrelation in land-values, in which agglomeration of high property values is expressed around vivid primary and secondary centers. Census data of employment and population density distribution in sub-centers of Dijon (France) were found to have a positive autocorrelation, indicating multiple core-periphery gradients throughout the city (Baumont et al., 2003).

The results further justify the extension of spatial autocorrelation analysis to the physical dimension in order to differentiate between levels of spatial association in urban zones, and by that means, to assess structural changes during the evolution of urban patterns. This may help in identifying centripetal or centrifugal processes leading toward agglomeration or disintegration of core areas (e.g., Anas et al., 1998)

Here our aim was to apply this approach in analyzing physical aspects of urban expansion and regeneration, in general and those of CI spread, in particular. An urban built area evolves through individual decisions, spontaneous processes, economic processes, and policy-driven developments. Multi-temporal Autocorrelation analysis may help in differentiating between the processes shaping the urban pattern and thus reveal the effectiveness of the planning policies relative to spontaneous processes.

## 3. Residential development in Tel Aviv-Yafo

Tel Aviv-Yafo (TA) urban development has attracted significant attention in the last two decades (e.g. Alperovich and Deutsch, 2002; Benguigui et al., 2006; Benguigui et al., 2000; Carmon, 1997; Ginsberg, 1993; Kipnis, 1997; Lotan, 2001; Schnell, 1999; Shachar and Felsenstein, 2002). TA is the main and core city of the Tel Aviv metropolitan area, Israel's largest metropolitan region, which serves as the focal

point of its economy and culture. The city was established in 1909 and grew rapidly. By the time of the declaration of Israel's independence, in 1948, its population reached 250,000 residents, and in 1961, it was 386,000, which was TA's most populated year. From that year on, however, TA's population fluctuated, reaching its lowest level of 347,000 residents in 1997, and climbing back to 371,400 residents in 2004 (CBS, 2005).

The total amount of floor area in construction projects that were initiated and the deviation between residential and non-residential CIs are presented in Figure 1. Residential CI levels fluctuated considerably, representing primarily economical and immigration cycles: it decreased by 47% during the 1980s, then increased by 260% during the 1990s and decreased again during the early 2000s by 40% (TA strategic plan, 2002). The major trends shifts of development rates had only minor impact upon the morphology of Tel Aviv metropolitan area which reached a quasistationary mature state in 1985 and after this point the metropolitan morphology hardly changed (Benguigui et al, 2006). The dissimilarity between CI major trends changes and the morphological quasistationary raises a question of the role of CI in the evolution of urban structure.

Our study encompasses the area within TA's municipal borders (53 square kilometers), which are surrounded by cities and municipalities from the east, southeast and north, and by the Mediterranean Sea from the west (see map 1). TA is municipally divided into nine quarters: quarters 1-4 in the north, which are mainly residential areas; quarters five, six, and part of nine are mainly business areas; and quarters seven, eight, and nine are southern residential areas.

TA's built up-area has grown from 12 million square meters of FA in 1972 to 22 million in 2002 (TA Strategic Plan, 2002). The 92% increase of the FA during these years consisted of (TA strategic plan, 2002) 5.6 million square meters of residential FA, and 4.4 million square meters of non-residential floor area (industrial, commercial, municipal services, and tourism). The urban residential growth of TA is characterized mainly by the addition of new neighborhoods, especially in the northern part of the city, and renewal processes in the center and southern parts. The new neighborhoods in the north are primarily built of high-rise buildings for the high-level socioeconomic population (Alperovich and Deutsch, 2002). The renewal areas of the city are located in a few specific low and middle class neighborhoods, which were part of urban regeneration programs (Carmon, 1997; Ginsberg, 1993; Lotan, 2001;

Schnell and Graicer, 1993), and spontaneous private renewal processes that took place in the center of the city. Residential development potential (in approval development plans) divided between development rights in vacant areas (40%) which are mainly in the northern quarters, and development rights inside the urban fabric (60%). Furthermore, in most TA quarters the existing residential buildings constitute less then 73% of the total potential (TA strategic plan, 2002).

From the planning perspective, TA had no comprehensive plans or ordinances in its history that set explicit and consistent spatial rules. Instead, planning and construction in TA have had always been subjected to local detailed plans (Alfasi and Portugali,, 2004; Yosikevich, 1997), each referring to a fraction of the city, and to partially outlined plans, which refer to a single aspect (for example the laws governing planning in basements and attics, compulsory parking, compulsory preservation of certain areas, e.g., municipal gardens). However, in 2002 the TA municipality initiated a comprehensive strategic plan that set long-term guidelines for the distribution of different land uses.

The economic and sociological urban dynamics which is present above, is well describe in these current research but the physical aspect of this dynamic development did not attract much attention. The question as to whether the different processes that take place in TA have a recognizable spatial pattern that defines the city's morphology city form is the focal point of this article.

## 4. Methodology

Visual examination of the CI maps and their change over time indicates that the general trends described in the literature explain only a fraction of the overall phenomenon. Autocorrelation analysis of residential CI distributions in TA during the years 1976-2003, may improve our understanding of these complex spatio-temporal patterns, their relationships with urban evolution theories.

Residential CI autocorrelation is expected to be clustered if new development in the northern districts dominate or would tend toward a random/regular pattern if this development is balanced by regeneration in the older parts of TA.

Research questions which follow from these two different spatial options are as follows:

a. What are the annual autocorrelation levels of TA residential CIs, and to what magnitude are these levels explained by the sub-quarters of the highest CIs?
b. What are the accumulative autocorrelation levels of TA residential CIs, and to what magnitude are these levels explained by the sub-quarters of the highest CIs?

In order to assess these questions, we built the research methodology in two main stages:

1) The formation of accumulated (annually cumulative) CI time series: starting the accumulation of CI data for each sub-quarter in 1976 would not obviously reflect the actual total of built-up area and would cause the time series to reflect more the annual rather than the accumulated built-up area. Thus, the 1972 census data provided initial conditions for the further accumulation of the CI data. However, the census data do not contain corresponding differentiations between residential and non-residential FA. Thus, it was decided to use the average ratio from 1976 to 1983 between the residential and non-residential CIs for splitting the 1972 FA data.
2) Autocorrelation analysis was performed for the following time series:
    a. Annual residential CI.
    b. Accumulated residential CI.
    c. Repeating a and b for data representing only those sub-quarters with the highest levels of CI. For identifying these sub-quarters, their relative proportion from the total CI of each year was calculated, and those sub-quarters that consistently received the highest proportions were selected.

The Moran *I* (Moran, 1950) autocorrelation statistics were chosen for this study:

1) $$I = \frac{N\sum_i \sum_j W_{i,j}(X_i - \bar{X})(X_j - \bar{X})}{(\sum_i \sum_j W_{i,j})\sum_i (X_i - \bar{X})^2}$$

where *N* is the number of cases

X is the mean of the variable

$X_i$ is the variable value at a particular location

$X_j$ is the variable value at another location

$W_{ij}$ is a weight indexing location of *i* relative to *j*.

Moran's *I* is positive when there is agglomeration of similar values in a close neighborhood, and negative when they tend to be dissimilar; and approximately zero when the observed values are arranged randomly and independently over space.

## 5. Results

Figure 2 presents (with a time lag of 4 years) the annual and cumulative amounts of residential CI in each sub-quarter. Visual assessment of these patterns indicated that there are some regions that show consistent patterns, whereas there are parts of Tel Aviv that show unexpected spatio-temporal fluctuations in their CIs. Autocorrelation analysis may further contribute to the interpretation of these observed patterns beyond the insights gained from visual assessment. The following results were obtained from the autocorrelation analysis:

**Residential CI Autocorrelation - Moran *I* statistics:**

Cumulative and annual CI time series differ significantly:

- Residential cumulative Moran *I* values show a steady and linear increase of agglomeration, with moderate and low fluctuations due to the fact that each year introduces a very small amount of CI is introduced relative compared to the accumulated sum.
- Residential annual values fluctuated greatly over an average value of ~0.5 until 1995 and then decreased towards a random distribution in CI patterns.

As discussed previously, the conflict between the cumulative and annual trends calls for an explanation. The observation that the cumulative data represent higher Moran I values compared with to the annual values will be assessed, since as it can be viewed as an anomaly because due to the fact that the cumulative values are composed of annual values.

The trends and fluctuations embedded in the autocorrelation results further strengthen the interpretations gained from the visual assessments of the autocorrelation maps (Figure 3). On the one hand, patterns seem to be simple, following continuous trends, whereas on the other hand, there are extremely high

annual variations. Obviously, such discrepancies between the annual and accumulated data cannot prevail; thus, there is a need to disaggregate the data to reveal those components that may explain these results and may also enable reliable forecasting of future trends.

Both main hypotheses refer to the possible existence of core areas that may dominate the patterns' evolution. These core areas would obviously represent sub-quarters that attracted more build-up than others over the years. Analysis of sub-quarters that consistently represent more than 3% of the annual residential floor area expansion (Figure 4) enabled the identification of two residential cores, one in the north of the city and one in the southeast. These residential cores constitute 55% of the TA area. The amounts of CI in these cores decreased during the research period from an average of 80% to an average of 50%. The autocorrelation analysis was then applied to data representing core area information as is, whereas the other sub-quarters retained a value of zero. The results of this analysis (Figure 4) indicate that the magnitude of CI at core areas is the main source for the relative clustering of the pattern in the accumulated data. This becomes even clearer with the annual Moran *I* results after 1990. Thus, separating the core area data from the total CI contributes to a better understanding of the trends, but it also provides a further indication of the complexity of the phenomenon.

## 6. Discussion

The dynamics of urban development can be quite different when looking from annual or accumulative perspective. Accumulative perspective expresses the patterns inherited, while annual perspective expresses present dynamics which are less consistent. The two perspectives put forward two fundamentally different alternatives for the patterns of evolution. The cumulative effect represents urban agglomeration by which core areas dominate the pattern formation. The annual point of view represents the spontaneous development whereby the new build-up areas spread over the whole TA area.

Both alternative perspectives were found to be partially valid in spatio-temporal analysis. CI agglomeration in northern new neighborhoods was the main spatial urban process until the 1990s'. The contribution of spontaneous random development inside the urban fabric and regeneration increases consistently during the last ten years.

This discrepancy between pattern evolutions led us to describe a Dual Mechanism Model: Cores Agglomeration & Spontaneous Regeneration (CASR). The model is a combination of two elements:

1) A shift from early spread of isolated built-up areas at the early stages of the urban formation, to increased dominance of core areas' evolution in the intermediate stages, and then to the mature phase of homogenous distribution of CIs when most of the urban area has already been built-up. Thus, the annual CIs would start with a random pattern, would increase the dominance of a clustered distribution during the transition (intermediate) phase, and would ultimately end with a homogenous/ random distribution.
2) A delayed shift of the accumulated pattern from a clustered to a random pattern. This delayed shift is explained by
    a. The accumulated weight of the core areas from the initial phases of the town's evolution.
    b. Further growth of the core areas during the transition period is due to the fact that the random spread of CI also contributes to core areas and since they occupy a substantial portion of the town area, they receive a substantial part of the CIs. This portion only gradually decreases during advanced stages of the process.

TA is in the midst of transformation in its spatial development due to the residential development potential inside the old urban fabric. In order to assess the model, we simulated the further addition of spontaneous /random CI to the residential area with two assumptions: (1) a random CI distribution during the following 15 years; (2) a total annual area built in two levels: a moderate level represented by the average for the beginning of the 1980s, and a high level represented by the average of the beginning of the 1990s.

Figure 5 clearly shows that the accumulated CI pattern decreases its clustered appearance from 2005 onwards and will become random sometime during the 2020s.

## 7. Summary and conclusions

This study examined Tel Aviv Yafo residential spatial development from the years 1976 to 2003. Novel aspects of this research are related to autocorrelation analysis of CI data in annual versus accumulative forms and core versus non-core

build-up categories. Importantly, we showed that FA additions form relatively complex spatio-temporal patterns that are not referred to explicitly in the existing urban studies of TA. Our findings suggest a Dual Mechanism model of Cores agglomeration & Spontaneous Regeneration in residential development in Tel Aviv. This model represents the ratio between two main processes of agglomeration in urban cores on the one hand and free regeneration development on the other hand, processes which acts simultaneously in TA.

By simulating the continuation of existing annual autocorrelation trends, a continuous process was formed representing expected transitions from a clustered pattern in the accumulated data to the dominance of a random spread. Such a random spread may be attributed mainly to a spontaneous regeneration in residential development in Tel Aviv. Although there is increased awareness of the role of regeneration in the city's built-up structure, its pattern is relatively unknown. Furthermore, the magnitude of this phenomenon throughout the city had not attracted much attention in the professional literature. Yet this result is meaningful for a better understanding of TA's development, and again, it is a phenomenon that had not been analyzed previously in the literature. Such a random spread also reflects the lack of explicitly implemented town planning policies; in a way it conforms with the spontaneous urban regeneration. In conclusion, autocorrelation analysis of different profiles of CI information (annual versus accumulative forms and core versus non-core) resulted in a better understanding of TA's built-up area evolution and allowed significant new insights into the spatial processes taking place.

Future extension of this research needs further expansion of the CI databases in terms of the urban extent (to include other cities in the Metropolis), the CI land-use categories and the spatial resolution. Finally, the results obtained in this research must be analyzed with reference to the sociological and economical processes that drive them.

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**Figure Captions**

Map 1: Tel Aviv-Yafo quarters and sub-quarters

Figure 1: Construction Initiations amounts in Tel Aviv Yafo 1976-2003, in residential distribution

Figure 2: Annual (a) and Cumulative (b) maps for residential construction initiations for 1976 - 2003 (with a time lag of 4 years)

Figure 3: Annual and cumulative autocorrelation for residential construction initiation in the years 1976 – 2003

Figure 4: Autocorrelation analysis of all residential sub-quarters & for core residential sub-quarters in annual and cumulative distribution

Figure 5: Extrapolation of accumulative autocorrelation for homogeneous residential construction initiations distribution

**Map 1: Tel Aviv-Yafo Quarters and Sub-quarters**

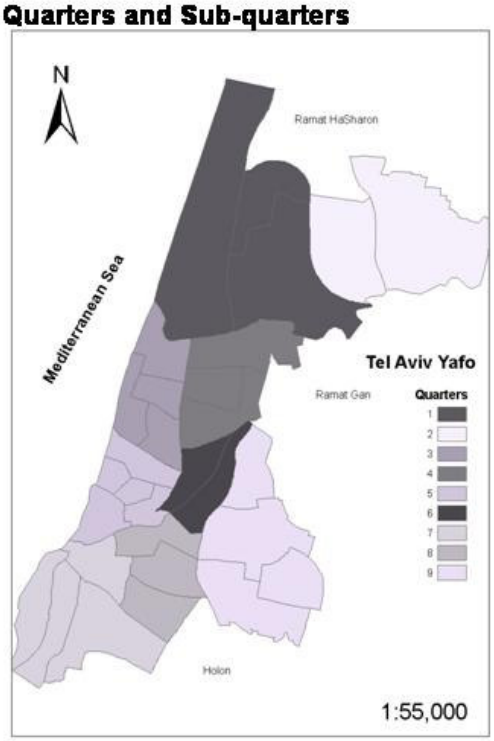



**Figure 1: Construction Initiations amounts in Tel Aviv Yafo 1976-2003, in Residential & non-Residential distribution**

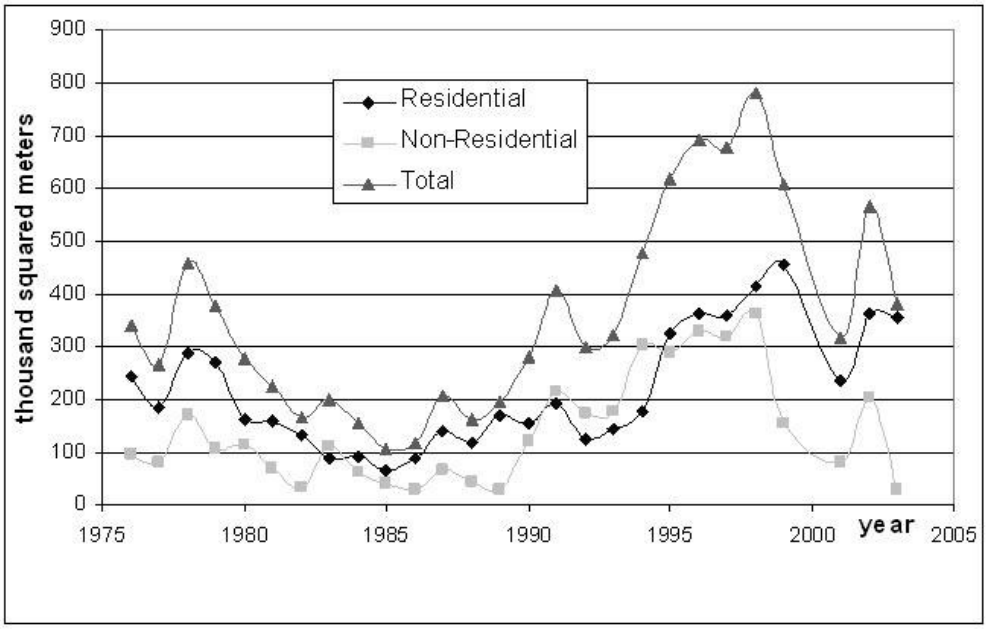


**Figure 2: Annual (a) and Cumulative (b) maps for Residential construction initiations for 1976 - 2003 (with a time lag of 4 years)**

**a**

Annual

78 83 87 91 95 99 2003

**b**

Cumulative

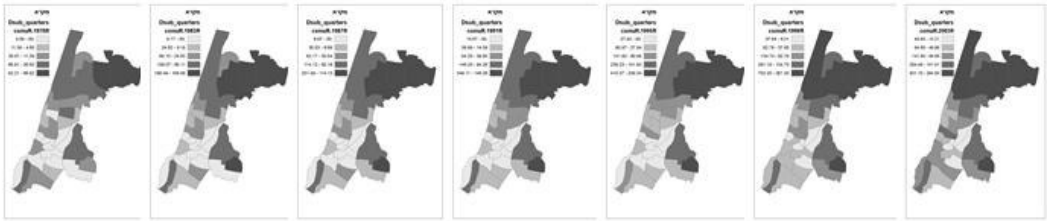


**Figure 3: Annual and Cumulative autocorrelation for Residential construction initiation for 1976 – 2003**

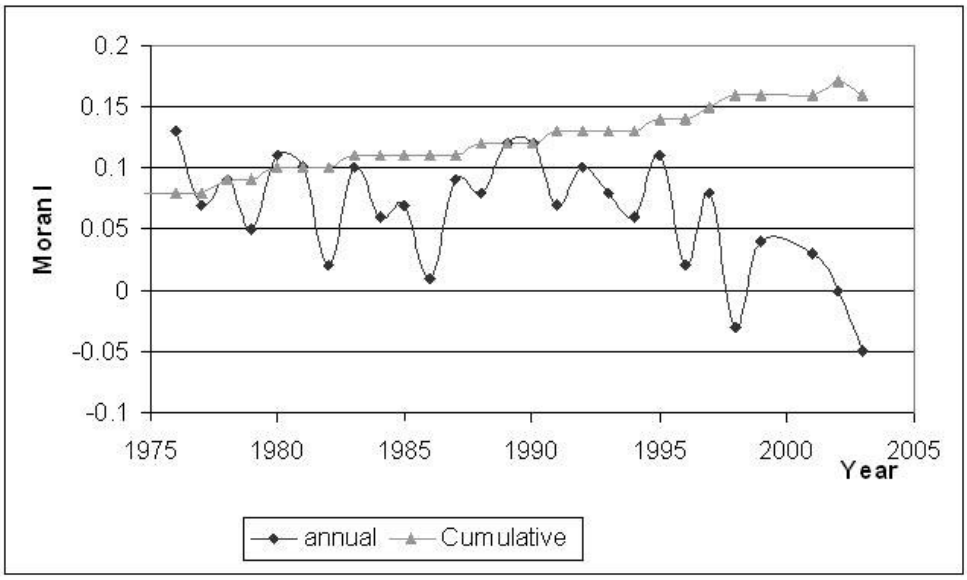
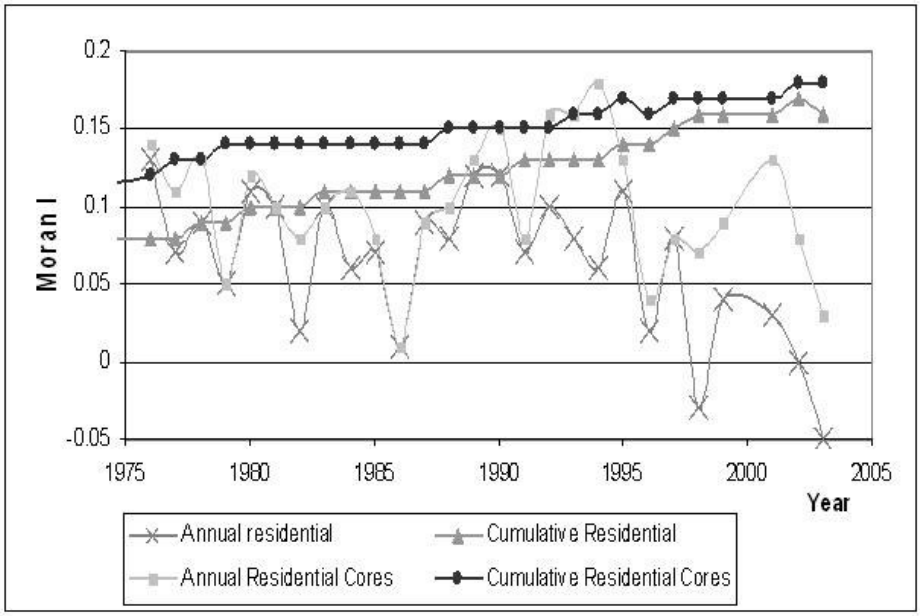


**Figure 4: Autocorrelation analysis of all residential subquarters & for core residential subquarters in annual and cumulative distribution**



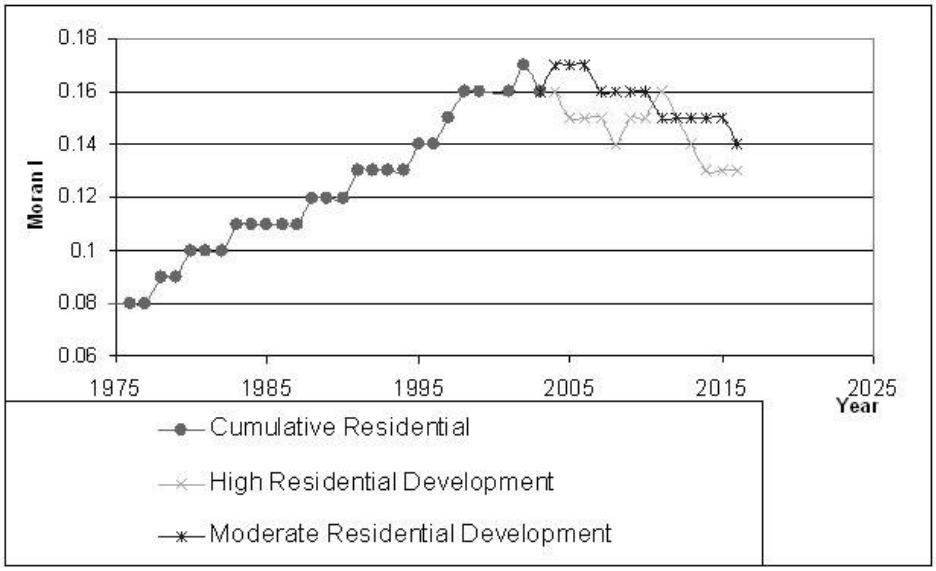


**Figure 5: Extrapolation of accumulative autocorrelation for homogeneous Residential construction initiations distribution**