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Spatial Distribution of High-Rise Buildings within Urban Areas: The Case of the Tel Aviv Metropolitan Region

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Spatial Distribution of High-Rise Buildings within Urban Areas

The Case of the Tel Aviv Metropolitan Region

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ABSTRACT

The spatial aspects of high-rise buildings in the Tel Aviv metropolitan region in Israel are examined, using empirical data gathered through a field survey. A multinomial logit model is employed to test the hypotheses concerning the cyclic model in the development of the metropolitan region. The results support empirical evidence of the dispersal of high-rise buildings in space, indicating an initial process of convergence in the Tel Aviv metropolitan pattern. The study points out that intensive high-rise building is expected to develop extensively in the future, particularly in the core and inner-ring cities. A classic negative gradient pattern is indicated in the dispersal of intensive high-rise building, moving from the core area toward the outskirts of the metropolitan region. In contrast, the classic pattern between center and fringes does not hold within the built-up areas of the cities.

Keywords: High-rise buildings, Metropolitan region,

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1. Introduction

High-rise buildings started to appear on the urban scene in the late nineteenth century and the beginning of the twentieth-century with the construction of giant buildings in the large cities of Northern America, such as New York, Chicago, San Francisco, and Boston (Polledri, 1990; Kanda and Kobayashi, 1991; Krieger, 1999). The high price of land, large demand, and the characteristics of the consumers motivated developers to build tall, massive buildings (Polledri, 1990; Hidenobu, 1995; Willis, 1995; Hudson, 1996; Bogнар, 1997; 1998; Lim, 1998). Although high-rise building is an urban phenomenon well known in many cities around the world, it is surprising to find that only little has been written on the spatial aspect of this phenomenon on a macro scale. There is, as well, an absence of data on the geographical distribution of tall buildings in space. The existing data refer mostly to prestigious building towers that serve as architectural landmarks and monuments (see, e.g., Skyscrapers.com., 2003). Most high-rise buildings still appear in different intensive building clusters and serve a diversity of land uses, which have gained only little research effort from a spatial perspective.

Great importance should be given to the integration of high-rise building in the urban pattern. From an architectural point of view, studies have focused mainly on the design of the tall buildings and their facades (Lollini, 1988; Bonshek, 1990). Accordingly, the effects of the design and placement of the buildings in blocking light and sunshine and on the wind regime have been examined (Aregger and Glaus, 1967; Bosselmann, et al., 1995). Most of the design research deals with building towers, which are considered expressions of the architects' creativity (Goldberger, 1981). The research on urban design focuses, in particular, on the effect of the buildings on the city skyline and scenic sights (Heilbrun, 2000), as well as on symbolic and esthetic values (Appleyard and Fishman, 1977). Their location in space as a major issue has not been investigated.

From a social perspective, studies have tested the implication of tall residential buildings for the daily functioning of their user groups, the relationships that exist among the residents, and the adjustment of high-rise buildings as a living place to different population groups (For example, see the studies of Appleyard & Fishman (1977) and Dornbusch & Gelb (1977) in San Francisco; Yeung (1977) in Singapore;

and Ginsberg & Churchman (1984, 1985) in Israel). The findings point to the importance of investigating the spreading trends of high-rise building in space, particularly when they are dictated by market forces. It could help in identifying market failures and designating a policy in advance in order to reduce negative social costs.

The research on urban pattern in general does not refer to the height dimension. Most researchers have perceived the urban space as a two-dimensional space, which is examined in terms of size, density, and intensity of development (Lynch, 1991; Elkin et al., 1991; Haughton and Hunter, 1994; Breheny 1992, 1997; Williams, 1999; Williams et al., 2000). They did not raise questions about the relationship between high-rise buildings and the urban pattern. An understanding of the spatial distribution of these buildings, the subject of this paper, is common to essential for the design and social and economic aspects associated with high-rise building as an urban phenomenon.

This study analyzes the spatial pattern of high-rise buildings in the Tel Aviv metropolitan region in Israel and identifies the effect of location on the frequency and characteristics of this phenomenon. The intense use of land as expressed by high-rise building is obviously associated with land-price distribution. In this context, the study provides empirical evidence of the dispersal of high-rise buildings in space; it tests this finding in regard to the development phases of the metropolitan region.

The next section of this paper introduces the conceptual framework and the study hypotheses. Section 3 presents the model that was developed to test the spatial aspect of high-rise building. The data and the region investigated are described in Section 4, and the main empirical results are contained in Section 5. Finally Section 6 presents the conclusions.

2. Conceptual Framework and Hypotheses

High-rise buildings tend to concentrate in the center of large cities, where land prices are high (see Alonso, 1964; and Mills, 1972). The reason for this has to do with the high competition for land, which increases the capital-labor ratio at the center compared to the outskirts of the urban area (see Mills and Hamilton, 1994, Ch. 6). Thus, a negative exponential land-rent gradient between the central location and its

fringes is expected. This pattern of development is also found in metropolitan regions, where similar regularities between population densities and land-rent gradients exist (Ingram, 1998). Yet there are not many empirical studies on the association between densities and land rent, and indeed this kind of data is rare (see, in Ingram: Mills and Song, 1977; Ingram 1982; Mohan and Villamizar, 1982). Although we would expect to find high-rise buildings in the center of large cities, we also find them on the urban fringes, especially tall residential buildings (Lawrence, 1996).

Regarding locational considerations in the metropolitan region, there is a need to distinguish between residential and non-residential land uses. Although the distribution of land values (negative exponential land gradient) indicates the importance attributed to locating non-residential uses close to the center, households are more concerned with the quality of the residential area, environmental characteristics, and amenities that affect their choice of location. As a result, they often can secure more desirable land in the fringes, where land prices are lower, than what they would have to pay even for a less desirable location in the core area (Stegman, 1969).

High-rise buildings obviously appeals to a specific group of consumers, not to the whole market. Yet, empirical evidence still shows high diversity among high-rise building consumers. The non-residential high-rise building is considered prestigious; it projects success, and it is an expression of private initiative and technological changes, as well as the personal aspiration of the initiators (Graham, 1988; Lim, 1988; Willis, 1995). Economics is the driving force behind the construction of tall commercial buildings (Ritchie, 1988). These buildings also function as landmarks in the built-up area, making them a prestigious symbol for different organizations (Smith, 1991). In addition, advertising increases the motivation of companies, initiators, developers, and the upper-class population to build tall buildings in order to gain attention (Willis, 1995).

Residential high-rise buildings actually serve a diversity of income groups, despite the doubts raised by sociological studies as to the appropriateness of high-rise buildings in serving medium and low-income classes (Conway and Adams, 1977; Williamson, 1978; Ginsberg and Churchman, 1985). Intensive high-rise buildings (taller buildings) necessarily require expensive construction systems and

maintenance, thereby increasing housing prices (Warszawski 2001). It is reasonable to assume that these high-rise buildings are available to upper-income groups that prefer this type of housing. In contrast, lower high-rise buildings, which are cheaper to construct, are less attractive. They are most often found in areas where medium and low-income groups reside.

On the metropolitan level, we suggest that high-rise building dispersal be tested with respect to the cyclic model in the development of the metropolitan region. The “stage urban development” model, first introduced in the 1970s, argues that the city has a life cycle, going from a growing phase to stability or declining stage (see literature review in Roberts, 1991). Hall (1971) suggested a stage model to describe the process of development in the metropolitan regions of England and Wales. The model was based on a comparison of population growth between core and rings. The process begins with the predominance of the core area in population growth rate at the expense of the rings; it continues with a decentralization process in which the core grows less rapidly than the rings and follows with an absolute loss of population, until at the end the whole metropolitan area experiences an overall decline. An important contribution to the recurring cycle of the model was suggested by Klaassen et al. (1981) and followed by Berg et al. (1982): a fourth stage after the declining stage; namely the process of reconcentration. This fourth stage leads to a convergence toward the core, thereby moving to the beginning of a new cycle of the urban development model. The suggested paradigm was based on empirical evidence collected from many metropolitan regions in the developed world. The results point to the urbanization stage as predominant in the 1950s, whereas suburbanization accelerated in the 1960s; the 1970s were considered to be the decade of disurbanization.

Recently, Champion (2001), along with supportive arguments for the model, also raised questions and disagreements about its validity. However, there is no doubt that the stage of disurbanization in some metropolitan regions can be identified according to the definition given by Klaassen et al. (1981) and Berg et al (1982). In this stage, the metropolitan region loses its compact form and sends shoots and islands of built-up areas long distances away from the relatively highly dense core area. A wave of emigration from the center to the metropolitan outskirts occurs and exhibits an edge-

cities pattern (Garreau, 1991)¹. Business centers also tend to split, and a large proportion of the economic activity moves from the core to the outskirts.² Concomitantly, households can enjoy lower housing prices in the urban fringes and still be close to a variety of urban services (Stegman, 1969).

The disurbanization stage may be seen as only a temporary stage in the urban development of any metropolitan region, and is followed by a stage of reurbanization. The originators of the cyclic model admitted that they had no clear evidence at that time of the existence of the fourth stage, the reurbanization stage. Only a few cities were found to be at this stage, and these were small-size rather than the largest cities. Although the researchers anticipated that the beginning of the reurbanization stage would emerge through market forces, they believed in the necessity of a supportive government policy to stimulate the process (Berg, et al., 1982). The hypothetical stage argued that when the residential and employment split reached an unbearable level in regard to the spatial pattern of individuals and firms, a re-convergence of the metropolitan region would start to occur. This process will witness a wide scale of urban rejuvenation in the core and in the inner ring. At this stage, land prices will increase within the core area, particularly in residential areas with environmental quality. The status of an area depends significantly on the socio-economic level of its residents, thereby influencing the price of the dwellings and thus the price of land. This might accompany a turnover of income groups, with the more wealthy seeking the preferred areas in the center and pushing the poor to the outskirts (Stegman, 1969). More recent studies have yielded initial empirical evidence of several metropolitan regions, especially in north Europe, being in the fourth stage of the cyclic model (see the study by Cheshire, 1995, in Champion, 2001, p. 154).

¹ The Federal Transit Administration (in Burchell et al., 1998) reports, e.g., that almost 70% of the total population of 168 metropolitan regions in the U.S.A. in 1950 lived in large cities. In 1990, in contrast, more than 60% of the population of 320 metropolitan regions lived in urban suburbs. Liberty (1999) reported that between 1960 and 1990, the population of 213 urban areas in the U.S.A. grew by 47% while the urban land area increased by 107%.

² According to a report of the Lincoln Institute of Land Policy (in Ingram, 1998), more than half of all urban jobs and three quarters of new office space are located in the suburbs. Most of the trips to work and for shopping in the U.S.A. occur in the suburbs and edge cities surrounding the core cities (Garreau, 1991). Gordon and Richardson (1997) argued that office space in the suburbs had been larger than in the cities since 1984, and the gap was growing.

In places where there is a great demand for developing land, the price of land is expected to rise. If we accept the assumption that the rise in land price has an effect on the readiness of developers and landowners to use the expensive land more efficiently (i.e., building heights), then we would expect that the change in the distribution of high-rise buildings in space would indicate the direction of change in the metropolitan spatial pattern. When the disurbanization process continues to dictate the urban form, we would expect to see an increase in the probability of constructing taller buildings in the fringe. An opposite direction, as manifested by an increase in the probability of constructing taller buildings in the core and the inner ring, may suggest the beginning of the Re-urbanization stage, with the convergence toward the core. An earlier indication of this process will emerge with the supply of detailed plans for taller buildings in the core, prior to the existence of actual data on population changes in the core and the fringe.

At the city level, changes in land-use pattern have occurred with the emergence of the polycentric structure of the built-up area. The spatial distribution of activities, in particular the diffusion of employment to the fringes, reduces the importance of the centrality of land uses. The new spatial pattern that emerges is no longer the classic monocentric city (Alonso's bid rent model). In the beginning, the tendency to sprawl toward the outskirts is a consequence of the area's inexpensive land prices and lower development costs (Meyer and Gómez-Ibáñez, 1981). Thus, the impact of commuting costs on location choice is still expected, yet no longer directed toward the center; more often, it is directed toward the fringes, following employment decentralization or suburbanization. Later, a change in the land-rent gradient occurs, emanating from new centers that have sprawled toward the fringes, that may affect the distribution of high-rise buildings within the built-up area of the city.

In Israel, high-rise buildings started to appear in the urban area in the 1970s, and intensified mainly in the 1990s. This was the result of an accelerated population growth brought on by a massive wave of immigration from the former Soviet Union and the desire of the planning authorities to increase building density in order to

reduce the depletion of available land resources (Alterman, 2002; Frenkel, 2004).³ With the absence of a clear planning policy toward high-rise buildings, the Israeli planning authorities have reacted intuitively to private initiatives, that have been submitted to them for approval. In addition, land prices in Israel, especially within the Tel Aviv metropolitan area, are expected to continue to rise as a result of the rapid growth of the population and the consequent reduction in the stock of land.

Given this background, several research questions and hypotheses were formulated for empirical testing in this study:

- 1) *The rise in land prices will force developers and landowners to utilize their land more efficiently. Consequently taller high-rise buildings will be constructed.*
- 2) *High-rise buildings, particularly taller buildings, are more prevalent in the center of the metropolitan region in order to utilize the high priced land more efficiently.*
- 3) *At a stage where the metropolitan region will continue to disperse, generating new growth poles at the fringes, the negative exponential land-rent function is expected to flatten out with time. Thus, we hypothesized that *the utilization of land will also intensify at the fringe of the metropolitan region as the construction of high-rise buildings intensifies.**
- 4) *On the other hand, a steeper negative exponential land-rent function at the core may suggest the beginning of the fourth stage of the cyclic model in the development of the metropolitan region. We thus expect to find *the strengthening of clustering of taller high-rise buildings in the center of the metropolitan region.**
- 5) *Under the assumption that land-prices dictate the way land is being utilized, we would expect substitutions between land uses in favor of those that can afford the site (e.g., substituting commercial and business for residential uses). We then would expect to find *high-rise buildings stratified by function following the steepness of their bid rent curves (e.g., commercial and service high-rise buildings**

³ The early 1990s saw the start of a great influx of immigrants from the former Soviet Union. Within a decade, more than one million new immigrants came to Israel; most of them settled in urban communities. This growth, together with a high natural increase (annual rate of 1.5%), has brought about an increase in development needs, which in turn has created heavy pressures to convert open space to land for development. Concomitantly, it raised the issue of the reduction in land resources and the need for better, more efficient uses of land, especially in the cities.

will be located closer to the center of the metropolitan area than will residential high-rise buildings).

- 6) *With time, we would expect that taller commercial/business buildings will creep toward the fringes of the city; on the other hand, taller residential buildings, primarily for the high-income group, will penetrate the center.*
- 7) *More intensive use of land, as indicated by building heights, will take place in high-status areas, whereas less-intensive high-rise building for lower-income groups will take place in less-prestigious areas.*

3. The Model

The model employed in this study examines the effect of different variables on the probability of constructing high-rise buildings in space and their intensity as measured by the height of the buildings. The definition of high-rise building is given in relative rather than absolute terms, and it differs from place to place. Alterman and Zafrir (2001) suggested two concepts commonly used for this definition: the absolute measure refers to a sometimes arbitrary cutoff point; the relative measure refers to some predetermined benchmark that changes with place and time. The present study defines a high-rise building as an intensive form of land utilization. In this study, we adopt the absolute measure of the Israeli Planning and Building Act 1965 -- “a building exceeding 27 meters above the entrance level”, which is equivalent to a building of 10 stories or more. This definition is also used in other places (e.g., Germany; see Aregger & Glaus, 1967).

We assume that the planner/developer sets the building height based on the level of profit expected to be received from the project. The profit is a function of the income that emanates from selling or renting the property and the costs involved in its construction and operational maintenance (in case of renting). Since the location in space affects profitability, the model introduced in this study used location variables in order to estimate their effect on the probability of constructing tall buildings belonging to different height groups.

The initiator's income depends on the consumer's readiness to pay the price for the property, which reflects the benefit that the latter gains from the high-rise building. The model employed in this study uses socio-economic characteristics of the

population residing in the areas of high-rise buildings as explanatory variables. The assumption is that these variables could serve as a proxy measure of the region's prestige, which influences the ability and readiness of the population to pay.

The building costs consist of the construction cost, land cost, financing cost, and risk cost (Warszawski, 2001). Among these elements, land cost, a significant component, is the main factor affected by location. Location theory explains why the proximity to central places increases the consumer's willingness to pay higher prices for land. In addition, studies have shown that the construction cost of a high-rise building is higher than that of a standard building (Steyert, 1972; Newton, 1982; Warszawski et al., 1983; Jaafari, 1988). The intense use (per unit of land) that characterizes high-rise buildings also increases the value of land; consequently, it is reasonable to assume that developers will try to use the land more intensively.

We hypothesized that five groups of explanatory variables influence the probability of constructing the different groups of tall building i (P_i). We propose a general function of the following form:

$$(1) \quad P_i = f(R_{ij}, L_{ic}, U_{ix}, A_{yz}, T_i)$$

In order to test the effect of these variables, a multinomial logistic regression model was employed in the empirical analysis (Pindyck and Rubinfeld, 1981; Ben-Akiva and Lerman, 1985). This multiple-choice model within a set of alternatives assumes three mutually exclusive alternatives of building heights. The specification of the model is given in the following equation:

$$(2) \quad P_i = \frac{\ell^{\alpha_i + \sum_{j=1}^3 \beta_{ij} R_{ij} + \gamma_{ic} L_{ic} + \sum_{x=1}^2 \delta_{ix} U_{ix} + \sum_{y=1}^2 \lambda_{yz} A_{yz} + \phi_i T_i + \varepsilon_i}}{\sum_{i=1}^3 \ell^{\alpha_i + \sum_{j=1}^3 \beta_{ij} R_{ij} + \gamma_{ic} L_{ic} + \sum_{x=1}^2 \delta_{ix} U_{ix} + \sum_{y=1}^2 \lambda_{yz} A_{yz} + \phi_i T_i + \varepsilon_i}}$$

Where:

P_i = the probability of choosing to build a tall building of height group i ; three groups were identified: group 1 with 10-16 floors - P_1 , group 2 with 17-24 floors - P_2 , and group 3 with 25+ floors - P_3 . ($i=1,2,3$).

R_{ij} = a vector of location variable j of tall building i ; four inter-metropolitan locations were identified: location in the core city - R_1 , location in the inner ring - R_2 , location in the middle ring - R_3 , and location in the outer ring - R_4 . ($j=1,2,3,4$).

L_{ic} = a dummy variable referring to the location of tall building of group i within the built-up area of the city: $L=1$ indicates location in the CBD, and $L=0$ location in residential areas outside the city center. This variable allows us to follow changes within the built-up areas of the cities.

U_{ix} = a vector of land-use variable x of tall building of group i ; three land uses were identified: commercial and business - U_1 , mixed uses (mainly commercial and residential) - U_2 , and residential - U_3 . ($x=1,2,3$).

A_{yz} = socio-economic characteristic z of the population residing in the statistical area y , where the tall buildings of group i exist or are proposed to be constructed (age, income).

T_i = a dummy variable referring to the time dimension: $T=1$ indicates a proposed new tall building, and $T=0$ an existing tall building; this variable allows us to follow changes over time.

$\alpha, \beta, \gamma, \delta, \lambda, \phi$ are parameters to be estimated.

ε = error term, so that $E(\varepsilon) = 0$.

Based on location theory and the negative exponential land-rent gradient between the center and the fringes, we would expect a similar decrease in the probability of the appearance of intensive high-rise buildings with respect to distance from the core outwards. If R_1 is the core city and R_4 is the metropolitan fringe, then we would expect that the following relationship would hold with respect to the most intensive high-rise building group (25+ floors):

$$(3) \quad \frac{\partial P_i}{\partial R_1} > \frac{\partial P_i}{\partial R_2} > \frac{\partial P_i}{\partial R_3} > \frac{\partial P_i}{\partial R_4}$$

The reverse relationship is expected to hold for the least intensive group (10-16 floors).

With the continuing rise in land prices that is expected in Israel, especially in the Tel Aviv metropolitan region, if P_3 is the probability of constructing tall buildings belonging to the most intensive group (25+ floors), then we would expect that the derivative of P_3 with respect to time will be positive; i.e.,

$$(4) \quad \frac{\partial P_3}{\partial T} > 0$$

In regard to the cyclic model in the development of the metropolitan region, the continuation of the disurbanization stage will encourage the dispersal of high-rise buildings to the outskirts in a greater intensity than occurred in the past. However, the

beginning of the reurbanization stage suggests an opposite trend; thus, increasing the probability that the most intensive group of high-rise buildings will appear in the core area at a greater intensity than in the past; described in the following equation (in group 3):

$$(5) \quad \frac{\partial P_{3,R_1}}{\partial T} > \frac{\partial P_{3,R_2}}{\partial T} > \frac{\partial P_{3,R_3}}{\partial T} > \frac{\partial P_{3,R_4}}{\partial T} > 0$$

With a negative exponential land-rent gradient between the core and the fringes of the metropolitan region, where P_{i,U_1} , P_{i,U_2} , and P_{i,U_3} are the probabilities of commercial and business tall buildings, mixed-use tall buildings, and residential tall buildings, respectively, from group i , and R_j is the inner division of the metropolitan region with respect to the distance from the core area, we would expect that

$$(6) \quad \frac{\partial P_{i,U_3}}{\partial R_j} < \frac{\partial P_{i,U_2}}{\partial R_j} < \frac{\partial P_{i,U_1}}{\partial R_j} < 0$$

When the classic negative exponential land-rent gradient between the center of the city and its fringe begins to change, we would then expect that commercial and business tall buildings, as well as mixed-use buildings, will diffuse in time into residential neighborhoods outside the CBD. In contrast, a penetration of intensive high-rise residential buildings into the CBD is expected, reflecting the changes in the status and prestige of these rejuvenated areas.

Population attributes were also included in the model in order to examine their effect on the presence of high-rise buildings in the region. Since our dataset does not include information about the direct users of the buildings or, obviously, about those who will reside in the proposed buildings, a set of socio-economic characteristics of the population residing in the area was included in the model. For this purpose, we used the Central Bureau of Statistics division of the cities' built-up areas into statistical areas. The data on the population's socio-economic characteristics were taken from the 1995 Israeli Census of Population.

In regard to the appropriateness of apartments in high-rise buildings for the middle and high-income classes, if P_1 is the probability of choosing a less-intensive high-rise building (10-16 floors) and P_3 is the probability of choosing the most intensive high-rise building (25+ floors), we would expect that:

$$(7) \quad \frac{\partial P_1}{\partial A_{i1}} < 0 \text{ and } \frac{\partial P_1}{\partial A_{i2}} < 0; \quad \frac{\partial P_3}{\partial A_{i1}} > 0 \text{ and } \frac{\partial P_3}{\partial A_{i2}} > 0$$

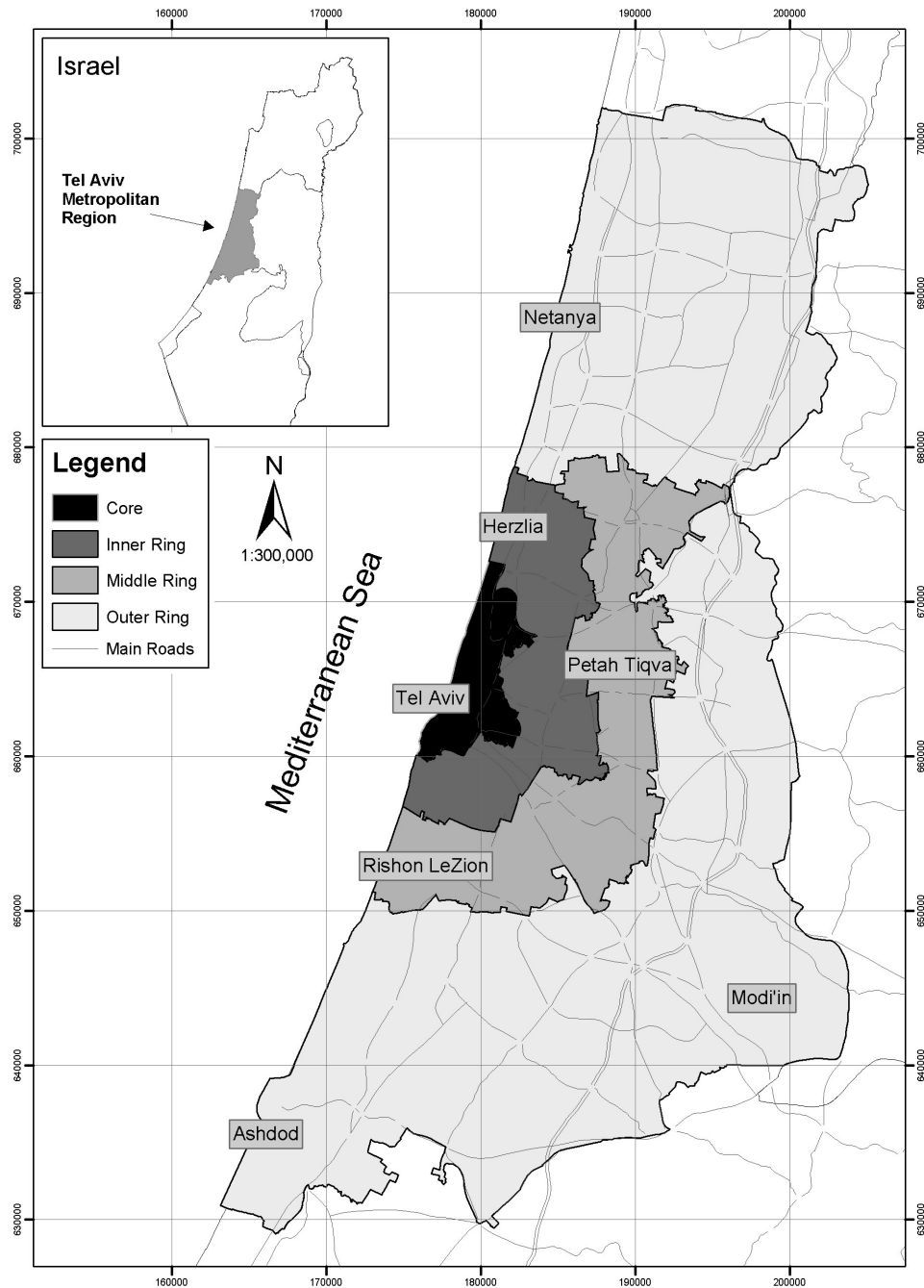
Where A_{i1} is an indicator of the average age of the population; and A_{i2} is an indicator of the socio-economic level, measured by the income level of the population.

4. The Data

The empirical examination of high-rise buildings in this study took place in the Tel Aviv metropolitan region, which is considered the largest and most central metropolitan region of Israel. The metropolitan region's borders as defined by the Tel Aviv Metropolitan region master plan (Lerman and Shachar, 1998) encompasses the Tel Aviv District (with the city of Tel Aviv as the core of the metropolitan area and the inner ring cities), the Central District (middle and outer ring cities), and the city of Ashdod (which belongs to the Southern District) on the southern outskirts of the region (see Map 1).

The Tel Aviv metropolitan region has a sum total of 1,518 square km. constituting 7% of the total area of Israel. A total of 2.88 million people resided in 2002, within these borders constituting 43.5% of the total Israeli population. In the last decade, the population growth rate in the region was 2.2% annually (C.B.S., 2003). The area with the highest population growth rate of the different metropolitan parts in the 1970s was identified as the inner ring. In the 1980s, this growth wave moved to the middle ring; and in the 1990s, it characterized the outer ring. Therefore the process of development demonstrates the continuous decrease in the relative population size of the core area (the city of Tel Aviv), which encompassed 36% of the total population of the region in 1961 and only 12.5% in 2002 (C.B.S., 2003). In contrast, since the 1980s, the proportion describing all the rings has increased in relative, as well as in absolute terms, especially the middle and outer rings. As such, the population center of gravity is moving from the metropolitan's central parts to its outskirts. This situation fits the third stage of the cyclic model as identified in many metropolitan regions in the Western world (Klaassen et al., 1981; Berg et al., 1982).

Map 1. Division of the Tel Aviv Metropolitan Region into Rings



The Tel Aviv core area and the inner ring are characterized by a high level of specialization in finance and business activities (more than double the national average rate), and they function as a financial and administrative center at the national level. As a consequence, these regions are characterized by the highest land pieces in

Israel. The Tel Aviv metropolitan economy has exhibited accelerated growth, especially in the first half of the 1990s, which was expressed by the increasing labor, in the rate of employment, and in gross domestic product. In particular, the growth in foreign direct investment (FDI) in the high-tech industry during this period was impressive (Shachar, 1997).

The high price of land pushed developers and land owners to utilize the expensive land intensively, especially in the core and the inner ring. The appearance of high-rise buildings which have increased in these areas, is a sort of expression of the efficient use of the expensive land. A field survey that was conducted in Israel in 2001⁴, in which most high-rise buildings (above 10 floors) were mapped, shows that 71% of all high-rise buildings are located in the Tel Aviv metropolitan region (Frenkel, 2002). The empirical analysis for this study was based on 22 cities within the borders of the Tel Aviv metropolitan region. The existing inventory contained 1,506 tall buildings. In addition, data were collected from the Planning and Building District Committees⁵ on all detailed outline schemes that proposed high-rise buildings. The planning inventory contained 670 tall buildings. Therefore, the complete data set used for the analysis included 2,176 tall buildings, arranging in height from 10 to 68 floors. Most of the buildings (1,678) contained 10-15 floors; 352 buildings, 16-24 floors; and 146 buildings had 25+ floors.

The buildings were divided according to their location within the metropolitan region. For this purpose, the division of the Tel Aviv metropolitan areas into sub-regions (rings) as suggested by the metropolitan's Master Plan was adopted (see Map 1). The buildings were also divided according to their location in the urban built-up areas of the included cities: CBD vs. neighborhoods outside the city center. In regard to land uses, the buildings were divided among residential, commercial and business, and

⁴ We conducted this survey within the framework of the research project, "An Examination of High Rise Building." This project was funded by the Planning Authority of the Ministry of the Interior in order to conduct a broad, multi-disciplinary examination of high-rise building and to recommend ways of coping with the approval of plans and requests for building permits that include high-rise buildings. The project was a cooperative venture between the Center for Urban and Regional Studies and the National Building Research Institute both at the Technion-Israel Institute of Technology. The survey, which was conducted in all Israeli cities and in towns where high-rise buildings were observed at that time (41 cities), encompassed most of the tall buildings (above 10 floors) in those cities.

⁵ Three of the six Israeli Planning and Building District Committees were relevant: the Tel Aviv District Committee, the Central District Committee, and the Southern District Committee.

mixed-use buildings (mostly a mix of residential and commercial uses). Table 1 presents the distribution of data frequencies.

Table 1: Distribution of buildings in the sample

Variable	<u>Existing buildings</u>		<u>Proposed buildings</u>		<u>Total</u>	
	N	Percentage	N	Percentage	N	Percentage
Location in metropolitan region						
Location in core city	333	22.1	99	14.8	432	19.9
Location in the inner ring	237	15.7	74	11.0	311	14.3
Location in the middle ring	361	24.0	278	41.5	639	29.4
Location in the outer ring	575	38.2	219	32.7	794	36.5
Total	1,506	100.0	670	100.0	2,176	100.0
Location in the city						
Location in the CBD or employment centers	93	6.2	130	19.4	223	10.2
Location in neighborhoods	1,413	93.8	540	80.6	1,953	89.8
Total	1,506	100.0	670	100.0	2,176	100.0
Uses						
Commercial and business	101	6.7	123	15.3	224	10.8
Mixed	58	3.9	76	11.3	134	6.1
Residential	1,347	89.4	471	70.3	1,818	83.1
Total	1,506	100.0	670	100.0	2,176	100.0

Source: The study field survey, 2001.

5. Empirical Results

In the model employed in this study, the least-intensive buildings group (10-16 floors) is used as the reference group, for which all the coefficients are 0. In order to examine the hypotheses, the model was calibrated to test the main effect of the above-listed variables, with additional interaction among the explanatory-category variables. The complete expression of the model is given in Equation 8 (for a full definition of the variables, see Equation 2):

$$(8) \quad P_i = f(R_{ij}, L_{ic}, U_{ix}, A_{yz}, T_i, V_{ix})$$

Where the interaction is:

$$V_{ix} = U_{ix} * T_i$$

The multinomial logit results are presented in Table 2. The results show that most of the variables contribute significant explanatory power to the model.

All metropolitan-location variables positively associated with the most-intensive high-rise group (25+ floors). The reduction in the coefficients when moving from the core toward the outer ring is clear within this group of buildings. However, in the second

group of buildings (17-24 floors), we received a negative association with location in the core area and a positive and reduced association with the location when moving from the inner ring to the middle ring. Apparently, the tallest buildings substitute for the lower buildings in the core, pushing them to the inner and middle-ring cities.

Table 2: Multinomial logit results

Explanatory Variable	<u>Buildings with 25+ floors</u>		<u>Buildings with 17-24 floors</u>	
	Parameter Estimate	Std. Error of Estimate	Parameter Estimate	Std. Error of Estimate
Constant	-13.149	1.35665*	-3.657	0.41101*
<u>Main effect:</u>				
Location in core city (R ₁)	4.910	1.07147*	-0.621	0.32058***
Location in the inner ring (R ₂)	4.182	1.06125*	0.791	0.19846*
Location in the middle ring (R ₃)	3.052	1.04058*	0.402	0.16647**
Location in the CBD (L=1.0)	0.799	0.44720***	-0.219	0.31560
Commercial and business (U ₁)	4.841	0.76077*	1.145	0.84754*
Mixed uses (U ₂)	4.395	0.76422*	2.588	0.44114
Proposed buildings (T ₁)	5.343	0.57812*	1.621	0.15279*
Average age of the population in the region	0.067	0.01942*	0.028	0.01223**
Percentage of residents who earn twice the average income	0.051	0.02055**	0.023	0.00979**
<u>Interactions (V_{ix}):</u>				
U ₁ *T ₁	-3.911	0.73981*	-3.144	0.60063*
U ₂ *T ₁	-4.059	0.87935*	-0.735	0.59680

N=2,055

* Significant at the 1% level.

** Significant at the 5% level.

*** Significant at the 10% level.

The base alternative is a high-rise building with 10-16 floors.

The log-likelihood value is 1249.07. All the differences in -2 log-likelihoods between explanatory variables in the final model and a reduced model are significant at the 99% level.

All metropolitan-location variables positively associated with the most-intensive high-rise group (25+ floors). The reduction in the coefficients when moving from the core toward the outer ring is clear within this group of buildings. However, in the second group of buildings (17-24 floors), we received a negative association with location in the core area and a positive and reduced association with the location when moving from the inner ring to the middle ring. Apparently, the tallest buildings substitute for the lower buildings in the core, pushing them to the inner and middle-ring cities.

In contrast, location in most of the regions (except the outer ring) has a statistically significant negative influence on the probability of constructing the lowest group of

high-rise buildings (10-16 floors) in an opposite pattern than the most intensive group. The results confirm our second hypothesis, apparently following the negative exponential land-rent function that exists between the center and the fringe.

As expected, intense land use, in particular with buildings with 25+ floors, will increase significantly over time (they received the highest positive coefficient value in the model; see Table 2). This could be the result of a future expectation of a rise in land prices, especially in the center of the Tel Aviv metropolitan region.

For demonstration purposes, we introduced the direct influence of location in the metropolitan region. Since location and time were defined in the model as category variables, the effect of a variable's category change on the probability of constructing building group i in the region was calculated (using the estimate parameters obtained by the model). Direct influences were measured in terms of calculated probabilities (Δp 's), using the following equation (Peterson, 1985):

$$(9) \quad P = \exp(L_1)/[1+\exp(L_1)] - \exp(L_0)/[1+ \exp(L_0)]$$

Where:

L_0 = probability value obtained in the multinomial logit model before a change of one unit in the independent variable x_j ;

L_1 = probability value obtained in the multinomial logit model after a change of one unit in the independent variable x_j (e.g., L_0+b_j).

When calculating the direct influences, the continuous variables in the model (A_{yz}) remain constant by using the mean values of the population attributes in each of the regions examined.

The direct influences were demonstrated by computing, for each explanatory variable across the different groups, a simple arithmetic average of the probabilities obtained. This was done with the provision that this average did not represent a probability of real cases, since the composition of the groups was not identical and the average value of one group could be radical in another group. However, it is possible through this simple average to present clearly the change in the trends associated with the research hypotheses. In order to support the general outcomes given by the average probabilities, we also introduced the trends in regard to real values that were obtained in selected groups commonly used in the regions.

The results, presented in Figure 1, confirm our hypothesis. There is a significant increase in the probability that high-rise buildings with 25+ floors will appear in the future in all the regions, except in the outer ring. As expected, an opposite trend emerges in the lowest group (10-16 floors). In the figure, the distances between the metropolitan rings are given in proportional terms indicating the average distance between the core area and all the other rings in the Tel Aviv metropolitan region.

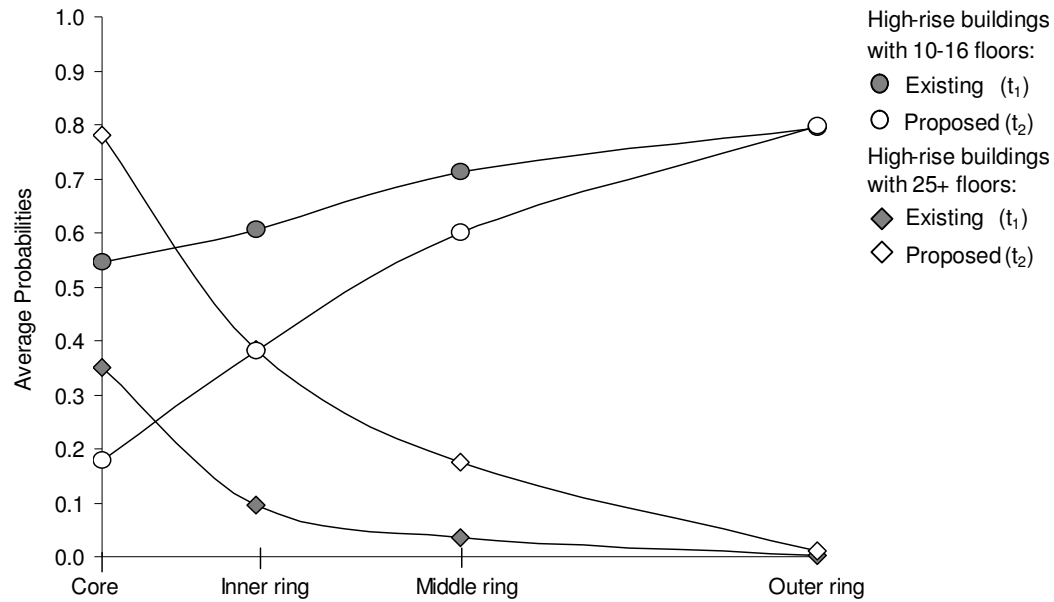


Figure 1. Average probabilities of existing and proposed high-rise buildings, by region

The rise in the curve steepness between T_1 and T_2 with respect to the most intensive group (25+ floors) along the core-outer-ring axis, points to the strengthening of intensive high-rise building construction and its convergence toward the core area. The opposite trend was obtained with respect to the lowest group (10-16 floors). This finding is interesting in light of the cyclic model (Klaassen, et al, 1981; Berg et al., 1982). The negative exponential function in the intensive high-rise building (Figure 1) indicates a reduction in the intense use of land with distance from the center. The increase in the expected steepness in the future could be interpreted as an indicator of the beginning of the transition from disurbanization (third stage) to reurbanization (fourth stage), according to the cyclic model. In this stage, we expect to see a re-convergence of the metropolitan region emerge on a wide scale of urban rejuvenation,

especially in the core and the inner ring. These parts of the metropolitan region are going to benefit from re-building and intensified dense development.

The effect of location and time on the probability of the second height group of tall buildings (17-24 floors) is also significant and positive, except in the core area. Nevertheless, the effect is weaker in comparison with the previous group (Table 2).

The changes in the actual probability represented by two different frequent groups support the tendency presented above. In the first group, represented by tall commercial and business buildings with 25+ floors in the CBD, the gap between the probabilities in time is 0.29 in the core area, gradually reducing to only 0.019 in the outer ring. In the second group, representing the tall residential buildings located in the neighborhoods, the changes are more acute, from 0.60 to 0.004.

Additional support of the hypotheses in this context is given by the results of the effect of building use and location. Tall buildings with 25+ floors are more likely to have commercial and business uses or to serve mixed uses than residential. The positive and statistically significant results support the assumption that land-price dictates the way land is utilized within the Tel Aviv metropolitan region and confirm our hypothesis. Figure 2 presents the direct influences with respect to these variables.

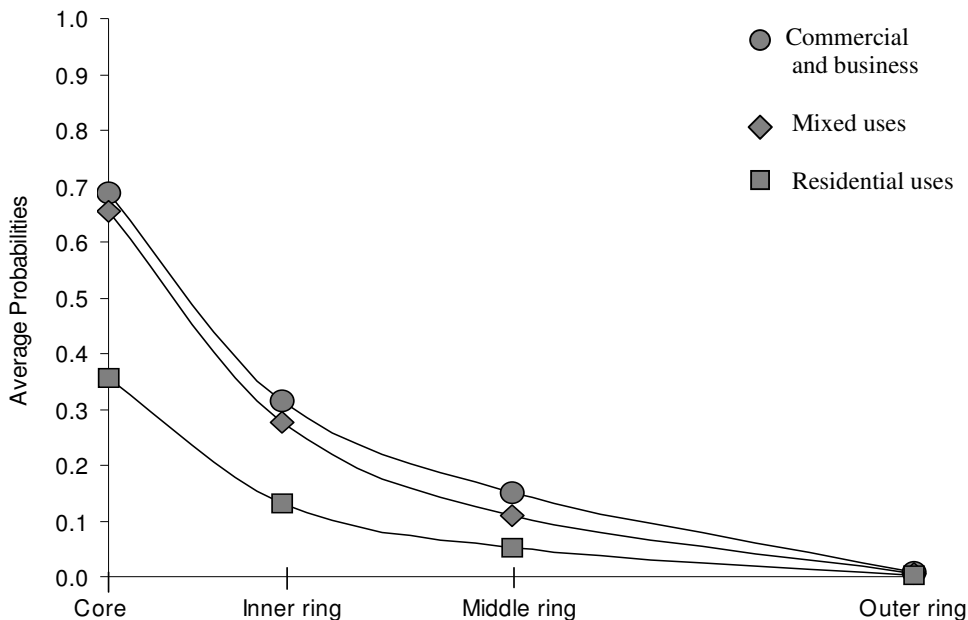


Figure 2. Average probabilities of high-rise buildings with 25+ floors, by use and region

An examination of the influence of the interaction between building uses and time (V_{ix} in Table 2) shows a strong and negative statistically significant effect of time on commercial and business uses and an even stronger effect in regard to mixed uses. This expected change in the future points to a prominent alteration in the construction of tall residential buildings, in particular in the core area. In contrast, the mixed-use high-rise buildings will receive only minor changes in their probability over time (Figure 3). This result is interesting in light of the findings of an opinion survey conducted in Tel Aviv (Churchman, 1998) that indicates significant objection to mixed uses in tall buildings. The change in the probabilities with respect to tall commercial and business buildings will be the highest in the inner ring, indicating the sprawl of this kind of uses from the core area to the inner ring.

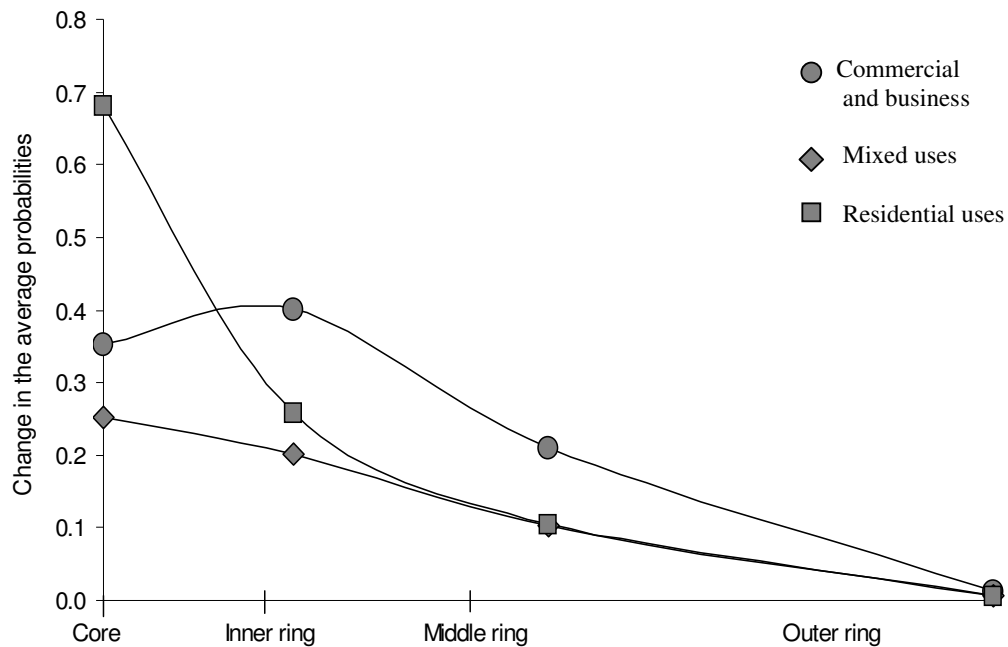


Figure 3. Changes in the average probabilities between proposed and existing high-rise buildings with 25+ floors, by use and region

Location in the CBD within the built-up area of the cities was found to have a positive effect on the probability of constructing the most intensive group of high-rise buildings. However, it appears to be less effective and less statistically significant than the other category variables tested by the model (Table 2). The calculated direct influences show, as expected, radical changes in the different locations within the

built-up area of the cities in the future. Today, the presence of residential high-rise buildings with 25+ floors is almost negligible in any location. In contrast, it is more likely that this type of buildings will be constructed in the future not just in the CBD, but in the outlying neighborhoods, as well (Figure 4). On the one hand, the CBD will more likely see in the future an increase in commercial and mixed-use high-rise buildings. On the other hand, a penetration of commercial and business high-rise buildings is more likely to appear in exclusive residential areas in the future. In the past, the location of intensive high-rise buildings fit the classic negative exponential land-rent function between the center of the city and its fringe. However, as hypothesized, the future will see a distortion in the classic trends, with the penetration of additional intense use of land outside the cities' centers.

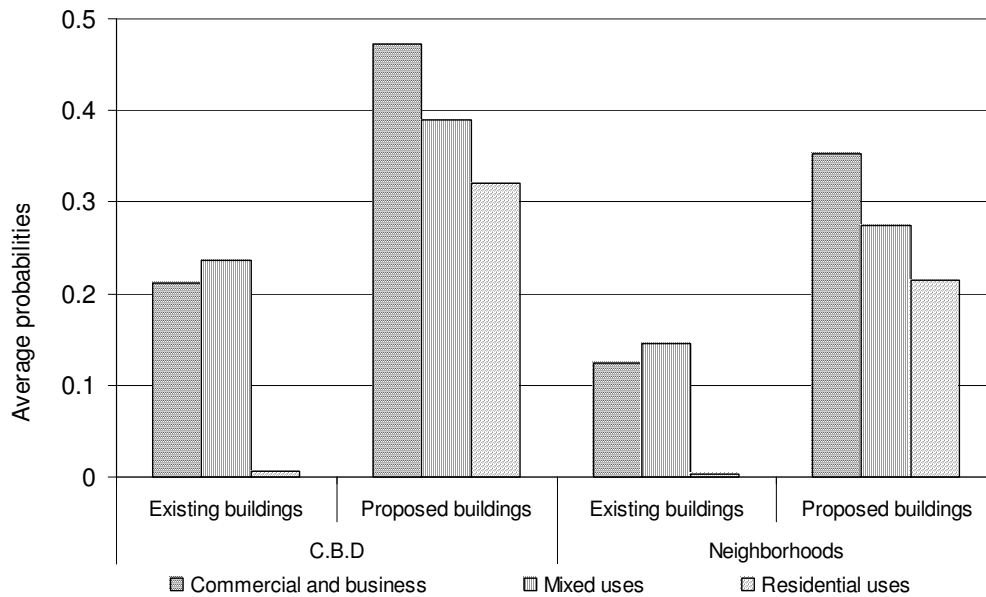


Figure 4. Average probabilities of high-rise buildings with 25+ floors, by use, location, and time

The relationship between a population's socio-economic characteristics and the distribution of high-rise buildings in the region was examined in the model by using continuous variables: average age of the population and the level of income as measured by the percentage of residents who earn twice the average income. The results show a positive and statistically significant effect of these two variables on the more intensive groups of high-rise buildings with 17+ floors. The positive effect is stronger in the most intensive group (25+ floors); there is less effect, though still

statistically significant, in the second group (17-24 floors). Taller buildings are more likely to be constructed in regions where a wealthier and older population resides. With respect to the literature's report on the adjustment of wealthy population without children to residing in high-rise buildings, the results obtained in regard to the Tel Aviv metropolitan region consider the adjustment to be positive.

In contrast, a significant and negative effect of the age and income level was obtained in regard to the lowest group (10-16 floors). As expected, this kind of buildings is more common in areas with younger and a less wealthy population, the result of free-market forces. The authorities should pay attention to these findings in regard to the consequences as reported in the literature on the negative implication of high-rise buildings for populations belonging to the middle and lower classes. In particular, the implication is severe for the outskirts and for neighborhoods isolated from community services, parks, employment zones, commercial services, and an efficient public transportation system. According to Lawrence (1996), these places have a more negative, acute effect on residents' living in high-rise buildings. Isolation exacerbates the social segregation of mono-parental families, the unemployed, the elderly, and youth.

6. Conclusions

High-rise building has become a more common phenomenon, especially in metropolitan regions. However, the spatial aspects of this urban phenomenon have hardly been studied, mainly because of the lack of empirical data. The spatial dispersal of high-rise buildings has significant implications for the function and the urban morphology of the built-up area. The location of high-rise buildings and their characteristics were determined in Israel until recently by free-market forces, which could cause housing market failures and, therefore, disrupt the existing land-use pattern of the urban fabric.

This paper presented empirical data based on an extensive survey of high-rise buildings in the Tel Aviv metropolitan region. The empirical results obtained in the study may help the planning administration by enriching their knowledge of this urban phenomenon, and of its current and future spatial dispersal. It supplies sufficient evidence of the variables that affect the construction of tall buildings in

space. The study tested the dispersal of high-rise buildings in a region as an indicator of changes in the evolution of the metropolitan region pattern.

We found that in the Tel Aviv metropolitan region, particularly in the core and the inner ring, a significance increase is to be expected in the future in the construction of tall buildings with 25+ floors. The strengthening of diffusion trends of intensive high-rise building from the core area to the outskirt is not expected. The disurbanization stage that has characterized the Tel Aviv metropolitan region since the 1990s apparently did not lead to significant increases in land prices in the fringe, since there is no evidence of an increase in the intense use of land there. On the contrary, the strengthening of the negative gradient of high-rise building intensity between the core and the outskirts, as expected in the future, indicates the initial process of a convergence in the Tel Aviv metropolitan pattern, one that fits the Re-urbanization stage of the cyclic model in the development of the metropolitan region.

Within the urban built-up areas of the cities, we find an indication of the disruption of the classic structure between center and fringes. The diffusion of the very intensive tall commercial buildings into exclusive residential areas outside the city center is to be expected in the future. The planning authorities should give attention to the implications of such a trend for the land-use pattern in residential areas in order to avoid causing undesirable harm to the gentle fabric of land uses there. In contrast, the model also expects the entrance of intensive tall residential buildings into the CBD of cities. This trend may have positive implications for city centers, as it could bring more variety to high-rise buildings, cause a rejuvenation of the aging centers of large cities, and create a more balanced urban structure.

We identified a positive tendency in the location preference of residential buildings belonging to the two more-intensive groups (17+ floors), which is for areas where an elderly and wealthy population resides. The results indicate, as well, a tendency to construct residential buildings belonging to the least intensive group -- those with a less prestigious height (10-16 floors) -- in areas populated with lower socio-economic classes. These buildings tend to deteriorate in time and to become slums as reported in the literature. This tendency, which is the direct consequence of free-market forces, should be regulated by planning policy in order to avoid socially and physically negative implications for the urban fabric.

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