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The linkage between the lifestyle of knowledge-workers and their intra-metropolitan residential choice: A clustering approach based on self-organizing maps

Amnon Frenkel [a,1], Edward Bendit [a,1], Sigal Kaplan [b,*]

[a] Faculty of Architecture and Town Planning, Technion-Israel Institute of Technology, Haifa 32000, Israel
[b] Department of Transport, Technical University of Denmark, Bygningstorvet 116 Vest, 2800 Kgs. Lyngby, Denmark

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ABSTRACT

This study investigates the linkage between the lifestyle and the intra-metropolitan residential choice of knowledge-workers in terms of home-ownership, location, dwelling size and building type. Data are retrieved from a revealed-preferences survey among knowledge-workers in the Tel-Aviv metropolitan area and are analyzed with self-organizing maps for pattern recognition and classification. Five clusters are identified: nest-builders, bon-vivants, careerists, entrepreneurs and laid-back. Bon-vivants and entrepreneurs differ in their dwelling size and home-ownership, although both prefer the metropolitan core. Careerists prefer suburban large detached houses. Nest-builders and laid-back are attracted to central locations, conditional on the provision of affordable medium-size dwellings.

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1. Introduction

Recently, knowledge-based economy has been recognized as a major driver of economic growth and an important component of the competitive ability of nations and regions (Raspe & van Oort, 2006; Reiner, 2010; Schwartz, 2006). Consequently, regional policy-makers invest in attracting and retaining high-skilled workers as well as in branding their cities' identities as knowledge-cities (Yigitcanlar, Baum, & Horton, 2010).

As knowledge-workers are important to increase regional competitiveness, most studies focus on their inter-regional residential choice. These studies discuss region characteristics for attracting and retaining knowledge-workers such as employment opportunities, housing affordability, regional amenities, accessibility, diversity and equity (e.g., Asheim & Hansen, 2009; Brown & Meczynski, 2009; Clifton & Cooke, 2009; Darchen & Tremblay, 2010; Florida, 2002a; Mathur & Stein, 2005; Niedomysl & Hansen, 2010; Yigitcanlar et al., 2010). The main limitation of these studies is the treatment of regions as homogenous units, thus failing to account for intra-regional competition and knowledge-workers impact on urban development trends within regions (i.e., suburbanization versus core revitalization). Another limitation of these studies is the referral to knowledge-workers as a homogenous population while neglecting the individual lifestyle perspective.

Studies about the residential preferences of knowledge-workers at the intra-regional level are scarce (Tomaney & Bradley, 2007; van Oort, Weterings, & Verlinde, 2003) and reveal contradicting trends regarding their potential impact on urban development. Tomaney and Bradley (2007) present evidence regarding the residence of knowledge-workers in gated-communities. Felsenstein (2002) provides evidence from the US that high-technology workers tend to reside in the suburbs and encourage sprawl. In contrast, van Oort et al. (2003) present evidence that young knowledge-workers prefer to reside in core areas, while knowledge-workers in later life-cycle stages prefer to reside in the suburbs. The main limitation of these studies is that they consider the socio-economic aspects while neglecting the relationship between the lifestyle of knowledge-workers and their residential choice.

This study focuses on the relationship between the lifestyle and the residential choice of knowledge-workers at the intra-metropolitan level. Specifically, this study hypothesizes that lifestyle differences across knowledge-workers are reflected in their residential choice within the metropolitan area. Within this framework, a self-organizing map (SOM) approach investigates the linkage between the residential choice of knowledge-workers in terms of home-ownership, location, dwelling size and building type, and their lifestyle from a multi-dimensional approach, encompassing life-cycle stage, work-role and leisure activities,

* Corresponding author. Tel.: +45 45256559; fax: +45 45936533.
E-mail addresses: amnonf@tx.technion.ac.il (A. Frenkel), bendit@technion.ac.il (E. Bendit), siga@transport.dtu.dk (S. Kaplan).
[1] Tel.: +972 4 829 3956; fax: +972 4 829 4071.

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subject to economic and spatial constraints. The approach allows individuating heterogeneous groups of knowledge-workers and investigating their distinct residential preferences, in order to gain understanding towards resolving the conflicting role of knowledge-workers in inducing both urban revitalization and urban sprawl.

The results of this study are meaningful for real-estate developers and urban policy-makers. From the real-estate perspective, this study sheds light about the location and housing preferences of knowledge-workers, thus helping to face the challenge of catering for the needs of knowledge-workers as clientele who exercise a considerable choice about their location within and across regions. From the policy-makers perspective, knowledge-workers are important as catalysts to revitalization of urban areas, while studies suggest that they have a negative effect in terms of suburbanization and sprawl. Hence, understanding the residential preferences of knowledge-workers is important in order to propose policy measures for attracting and retaining knowledge-workers while mitigating potential suburbanization effects.

The paper proceeds as follows. Sections 2 and 3 present the behavioral framework and the applied methodology. Section 4 describes the data collection. Section 5 details the identification of lifestyle patterns and their linkage to residential choice. Last, Section 6 draws the conclusions and recommends further research.

2. Behavioral framework

This study hypothesizes that lifestyle heterogeneity across knowledge-workers is reflected in their intra-metropolitan residential choice. The lifestyle perspective draws from the multi-dimensional definition of lifestyle by Salomon and Ben-Akiva (1983) as a pattern of behavior conforming to the individual's roles as household member, worker and leisure consumer subject to external constraints. The suitability of this definition to knowledge-workers is in agreement with Kunzmann's (2009) view that the residential location choice of knowledge-workers depends on their socio-economic characteristics, cultural background and activity sector, subject to time and budget constraints. Cumulative evidence from the literature substantiates the relevance of the three roles (i.e., household member, worker and leisure consumer) to the residential choice of knowledge-workers in the following sections.

2.1. The role as a household member

The household member role is strongly associated with residential choice as it is defined by intra-household interactions to satisfy the welfare needs of all household members. The household member role comprises an integral part of the lifestyle of knowledge-workers due to the high proportion of dual-career households. Unlike the traditional breadwinner-housekeeper household, dual-career households face the difficulty of finding two jobs commensurate with the skills of each spouse within a reasonable commuting distance (Costa & Kahn, 2000; van Ommeren, Rietveld, & Nijkamp, 1998). In these households, the residential choice considers wages, residential amenities, commuting time and distance for both workers, career and child care constraints (e.g., Freedman & Kern, 1997; Green, 1997; van Ommeren et al., 1998).

2.2. The role as a worker

The work role is fundamental to knowledge-workers and hence forms an integral part of their lifestyle interweave. Knowledge-workers view their work as a career path, leading to better position and financial well-being (Petroni & Colacino, 2008), and a vocation, leading to implicit fulfillment associated with personally defined goals (Correia de Sousa & van Dierendonck, 2010). Consequently, the workplace is an important determinant in the residential choice of knowledge-workers.

The working conditions of knowledge-workers impose constraints on their spatiotemporal behavior. Working conditions include schedule and workplace flexibility, autonomy and accountability, teamwork, management by objectives, and strict deadlines (Correia De Sousa & van Dierendonck, 2010; Florida, 2002b; Peters, Den Dulk, & van Der Lippe, 2009). These working conditions might induce work intensification and blurred boundaries between work and leisure time (Peters et al., 2009) and consequently enhance the importance of the residence proximity to the workplace location.

2.3. The role as leisure consumer

A multi-dimensional leisure activity-pattern consisting of culture and entertainment, sport, home and work is considered relevant to the residential choice of knowledge-workers. Many knowledge-workers participate in culture and entertainment activities as well as in sport activities (Florida, 2002b; van Oort et al., 2003). In addition, knowledge-workers are likely to engage in work-related activities during leisure time, since they are highly ambitious and are infatuated with their work (Florida, 2002b). Last, since knowledge-workers value working at home and are involved in the community (Florida, 2002b), they possibly engage in home-oriented hobbies and organize social gatherings at home.

Different activity-patterns possibly result in different residential choices in terms of location and housing type. Culture and entertainment activities are typically concentrated in the metropolitan core, which is characterized by medium or high building density, cultural diversity and mixed land-use. Sport activities require sport facilities and public open spaces. Social milieu that allows working by communicating and co-creating new ideas naturally exists in the metropolitan core and in knowledge-intensive urban districts. Conducting home activities likely requires a sufficient dwelling size, and active participation in community life is encouraged by a friendly neighborhood environment.

3. Methodology

Following the behavioral framework, this study attempts to (i) individuate heterogeneous groups of knowledge-workers on

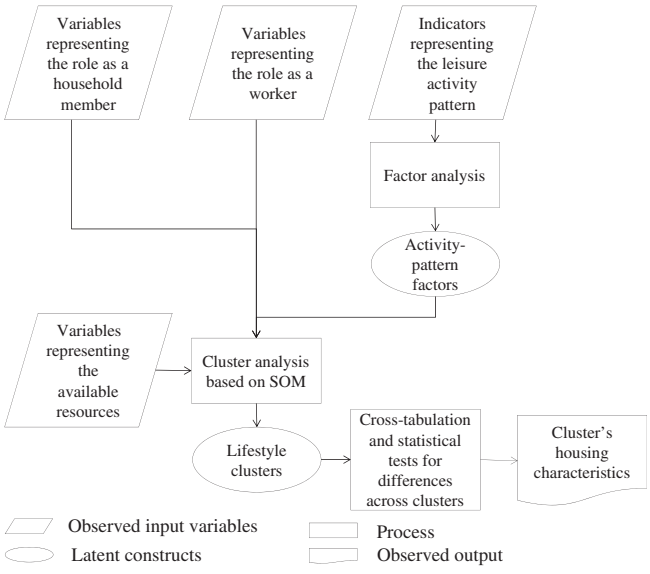

Fig. 1. The methodology applied in this study.

the basis of their multi-dimensional lifestyle composed of their role as household members, as workers and as leisure consumers, and (ii) to investigate the residential preferences of the generated groups. The methodology applied is described in Fig. 1.

The input variables representing the role as a household member are age, marital status, number of children and spouse's workplace location. The input variables pertaining to the role as a worker are education, employment status, work sector (e.g. high-technology or finance), and workplace location. The input variables comprising the role as a leisure consumer form a multi-dimensional activity-pattern consisting of cultural activities, sport activities, home-oriented activities and working overtime. The available resources constraining the residential choice are monthly income and car ownership. Notably, the approach of combining directly measurable variables and latent constructs is analogous to the approach taken by Choo and Mokhtarian (2004) and Schwanen and Mokhtarian (2005) in discrete choice models.

In order to identify population groups based on their multi-dimensional lifestyle, cluster analysis is conducted by means of a two-stage clustering method embedded in the software Synapse (Peltarion, 2010) that consists of SOM followed by neural gas, Bayesian classification and unified distance matrix (U-Matrix) edge analysis. With respect to alternative methods such as frequency analysis or regression models, the chosen approach is advantageous from both the policy and the methodological perspectives. From the policy perspective, the approach is suitable for individuating target population groups with the aim of designing efficient policy instruments for attracting and retaining knowledge-workers, in line with sustainable urban development policies. From the methodological perspective, the approach allows avoiding restrictive a priori assumptions regarding the model structure, the distribution of the variables, and the interdependencies across variables. The two-stage approach has several advantages over a single-stage approach, including reduction of computational cost and noise reduction (Vesanto & Alhoniemi, 2000). The principle of the methodology is illustrated in Fig. 2 and is outlined below.

At the first stage, the Kohonen's SOM algorithm reduces a high-dimensional manifold of N data points (i.e., records of knowledge-workers) onto a two-dimensional array of M neurons (Kohonen, 2001). SOM are a powerful tool for visualizing and investigating lifestyle as a multi-dimensional phenomenon because of their ability to convert complex and nonlinear statistical relationships into simple geometric relationships on a low-dimensional display (Kohonen, 2001). The features of the SOM algorithm, its recent variations and advices for practical application are further detailed by Kohonen (2001). SOM based algorithms have been widely applied in various fields (Kohonen, 2001), including recently the context of regional science. Skupin and Hagelman (2005) showed the usefulness of SOM in exploring temporal demographic trends across spatial data units (e.g., counties) over time. Yan and Thill (2009) used SOM to perform both cross-sectional and temporal analysis of the airline market in the US Arribas-Bel, Nijkamp, and Scholten (2011) employed SOM to explore the key dimensions of urban sprawl patterns in Europe.

The SOM algorithm encodes a high-dimensional manifold of N observations of knowledge-workers onto a two-dimensional array of M neurons (Kohonen, 2001). Each observation x_i ($i = 1,2,\ldots,N$) in the data manifold is characterized by a real vector of K attributes $x_i = [x_{i1}, x_{i2}, \ldots, x_{iK}]^T \in \Re K$ (e.g., socio-economic characteristics, activity-patterns), and each neuron j($j = 1,2,\ldots,M$) in the array is characterized by a parametric real vector of K scalar weights $m_j = [m_{j1}, m_{j2}, \ldots, m_{jK}]^T \in \Re K$. At the initial stage of the algorithm, the scalar weights are arbitrary and can be drawn either randomly or linearly. Next, at each step of the algorithm an observation of a knowledge-worker is randomly chosen from the input data set and the distance between its attribute values and scalar weights is calculated across K dimensions and the neuron with the minimal Euclidean distance is chosen as the "best matching unit" neuron for the chosen observation:

$$m_{bmu} \leftarrow \min_j \left\{ \sum_{k=1}^{K} (x_{ik} - m_{jk})^2 \right\}$$

Following, a "soft-max" rule is applied to update the scalar weights of the best matching neuron and the topographically closest ones. The update rule for the scalar weight of neuron j at step t is as follows:

$$m_{jk}(t+1) = m_{jk}(t) + m_{bmu}(t)(x_{ik}(t) - m_{jk}(t))$$

The function $m_{bmu}(t)$ is a neighborhood Kernel function:

$$m_{bmu}(t) = \alpha(t) \exp\left(-\frac{(r_{bmu} - r_j)^2}{2(\sigma(t))^2} \right)$$

where $\alpha(t)$ is a scalar valued "adaptation gain" ($0 \leqslant \alpha(t) \leqslant 1$), r_{bmu} is the vector of coordinates of the "best matching unit" neuron, r_j is the vector of coordinates of neuron j, and $\sigma(t)$ is a decreasing function of time.

The SOM stage of the process results in each of the M neurons grouping similar observations of knowledge-workers, and in the M neurons being spatially arranged according to inter-neuron similarity. Hence, the SOM plays a substantial role in the clustering process.

At the second stage, cluster analysis is applied to the intermediate layer of M neurons in the SOM to form C clusters of knowledge-workers. The production of C large clusters from the SOM neurons constitutes a refinement of the initial clustering process, primarily for presenting results in a comprehensible manner and directly communicating with decision makers regarding policy. Another benefit of clustering the SOM neurons instead of the records of knowledge-workers is noise reduction since neurons contain data averages, and hence are less sensitive to random variations in the original data (Vesanto & Alhoniemi, 2000). The SOM is clustered to C clusters of knowledge-workers by applying the Neural Gas (NG) algorithm (Martinetz, Berkovich, & Schulten, 1993). The NG algorithm has clear advantages in comparison with other clustering methods (i.e., k-means, maximum-entropy and Kohonen's SOM) in terms of convergence speed and accuracy, while its main weakness is the high computational complexity

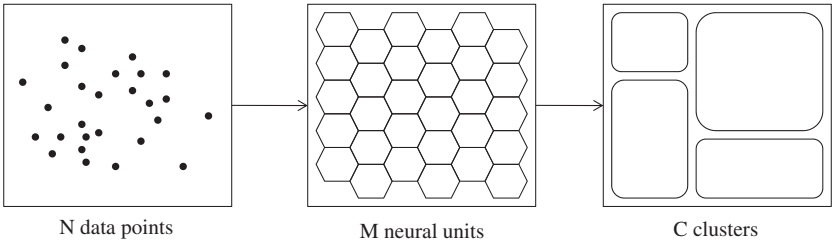

Fig. 2. Two-stage clustering process based on SOM. *Source*: Vesanto and Alhoniemi (2000).

(Martinetz et al., 1993). Consequently, the NG algorithm is applied on the low-dimensional SOM neuron array rather than directly to the records of knowledge-workers, in order to gain fast convergence and low distortion error while mitigating computational complexity.

Once the SOM neurons are clustered with the NG algorithm, the C clusters of knowledge-workers based on their lifestyle are successively sharpened by means of Bayesian classification that combines region-growing/merging with edge detection. The general principle involves a comparison of one neuron with its spatial neighbors, and assigning it to the same class based on statistical similarity measures. The number of clusters is determined according to a Bayesian goodness-of-fit criterion (Lee & Crawford, 2005; Pavlidis & Liow, 1990).

Following the clustering of knowledge-workers based on their lifestyle, feature maps are utilized to visualize and explore the relationship between the different aspects of lifestyle and the residential characteristics, namely home-ownership, building type, dwelling location and size. Notably, the residential characteristics are not taken into account in the cluster analysis, and hence the relationship between lifestyle aspects and residential choice is derived from the data exogenously to the clustering process. Following, the existence of difference among the clusters with respect to their residential choice is investigated by extracting the distribution of chosen dwellings in each cluster and performing Pearson's chi-square test.

4. Data collection

4.1. Research region and population

The research region is the Tel-Aviv Metropolis (TAM) with a classical concentric structure around Tel-Aviv as the core city and three concentric rings spreading eastwards, covering 1518 square-kilometers and hosting 3.0 million inhabitants. The TAM comprises two administrative districts, namely the Tel-Aviv and the Central districts. The Tel-Aviv district, which includes the core and the inner ring, is a continuous urban development characterized by medium residential densities. The Central district, which includes the middle and outer ring, is characterized by satellite cities and suburban communities.

The TAM hosts 86% of the country's high-technology firms and three of its main industries: communication, information technology, and the Internet (Kipnis, 2004). The target population consists of high-technology and finance knowledge-workers who reside and work in the TAM. These sectors provide jobs for 192,600 employees in the TAM, which comprises a considerable share of 19.8% of the total jobs in the TAM (CBS, 2009). The sample was recruited through 1500 relevant firms, whose main facilities are located in the TAM, and covered a wide range of high-technology and financial activity sectors, firm sizes and ages.

4.2. Web-based survey design

The data were collected by means of a revealed-preferences web-based questionnaire that included questions about the housing choice of knowledge-workers, their lifestyle and their constraints. Questions about the housing choice of knowledge-workers investigated residence location, building type, dwelling size and home-ownership. Questions about the role as household member concerned gender, age, marital status, number of children, and the spouse's workplace location. Questions about the role as a worker included education level, workplace location employment sector and status. Questions about available resources concerned monthly income and household's car ownership.

In this study, the role of a knowledge-worker as a leisure consumer is related to the consumption of leisure activities. Measuring perceptions regarding the general activity-pattern was preferred to a traditional 1-day activity travel diary, in order to avoid the problem of under-reporting low-frequency activities and short-distance trips, and to reduce respondents' burden. The measurement of the perceived general activity-pattern was conducted by means of psychometric instruments. Specifically, the aforementioned four activity-pattern dimensions (see Section 2.3) were extracted by means of factor analysis from 27 items concerning the frequency of engaging in activities related to each dimension. The items were rated with a bipolar five-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (5). A pilot survey among 60 respondents and subsequent exploratory factor analysis established the validity of items and scales.

The benefits of a web-based survey design for administration among knowledge-workers are the minimal disturbance to their intensive schedule due to time and location flexibility, and the use of a highly familiar media. The challenge in conducting web-based surveys concerns sample reliability, as the web-based environment provides a high degree of anonymity. In order to control for sample composition, the recruitment of respondents was conducted through human resources offices in knowledge companies, and the workers provided their name and contact details that were verified in a follow-up contact.

5. Results

5.1. Sample characteristics

The survey yielded 1181 questionnaires of knowledge-workers who reside and work in the TAM, and 837 complete records (70.9%) are analyzed in this study.

In terms of respondents' life-cycle characteristics, 71.8% are male, the average age is 38 years (SD = 8.4), 80.4% are married and 74.6% have children. In terms of education and work, 91.9% have an academic degree, 70.7% work in the high-technology sector and 29.2% work in the financial business service sector. In terms of workplace location, 32.7% work in the core, 24.2% work in the inner ring, 32.0% work in the middle ring and 11.1% work in the outer ring of the TAM. Interestingly, 15.9% of the respondents stated that they relocated to their current residential location for work reasons, indicating the importance of workplace for knowledge-workers. The sample is representative of employees in the high-technology and finance sectors in the TAM in terms of gender and age distribution and in terms of the spatial distribution by workplace rings (CBS, 2009).

In terms of car-ownership, 27.8% of the sample own one car per household and 69.4% own at least two cars. The monthly wage in U.S. dollars is below $3300 for 14.1% of the sample, while 25.4% earn between $3300 and $5200, 31.9% earn between $5200 and $7800, and 28.5% earn a monthly wage above $7800. The wage level of the respondents is slightly higher than the average monthly wages of $4100 and $3700 in the high-technology and finance sector, respectively (CBS, 2008).

In terms of residential choice, most respondents (63.7%) are home owners, and in terms of location 28.1% reside in the metropolitan core, 26.2% in the inner ring, 24.8% in the middle ring and 20.9% in the outer ring of the TAM. Among respondents, 38.1% reside and work in the same metropolitan ring, while an additional 28.9% reside and work in adjacent metropolitan rings. The majority of the sample population (69.7%) live in multi-storey buildings,16.4% in small dwellings (up to 60 m^2), 30.2% in medium size dwellings (60–100 m^2), 25.0% in large dwellings (100–140 m^2), and the remaining 28.4% in very large dwellings (over 140 m^2).

5.2. Extraction of activity-pattern factors

As explained in Section 4.2, the role of a person as a consumer of leisure activities was obtained by means of factor analysis of instrumental variables aimed at measuring the perceived general long-term activity-pattern.

Tests of internal consistency and sample adequacy constituted the necessary preliminary conditions for conducting factor analysis and obtaining meaningful results. The Spearman correlation matrix among the indicators provided the input for both the tests and the factor analysis. The activity-pattern items obtained in the survey demonstrate good internal consistency (Cronbach's alpha = 0.742) and appropriate sampling adequacy for performing factor analysis according to the overall Kaiser–Meyer–Olkin measure (KMO = 0.787). Based on Kaiser and Rice's guidelines (Sharma, 1996), at the single item level about half of the items are meritorious (KMO > 0.8), and the rest are middling (KMO > 0.7) or mediocre (KMO > 0.6), as presented in Table 1. The Spearman correlation matrix contains correlations with absolute value between 0.3 and 0.7, and the value of its determinant is 0.001, hence the existence of correlations without multi-collinearity is established. The result of the Bartlett's sphericity test rejects the null hypothesis that the correlation matrix is an identity matrix ($p = 0.000$).

Exploratory principal axis factor analysis with orthogonal rotation (Varimax rotation with Kaiser normalization) produced four factors according to a combination of scree-plot analysis and the Ricolfi measure aimed at conveying as much information as possible while maintaining the parsimony of the model (see Prato, Bekhor, & Pronello, 2005; Ricolfi, 2002). The factor loadings are presented in Table 1. A factor loading threshold of 0.35 served for retaining the items for factor analysis and for factor labeling.

The first factor (F1) relates highly to questions about participating in activities related to culture and entertainment and is labeled "culture-oriented activities". The second factor (F2) concerns dedicating time to outdoor and indoor sport activities and is named "sport-oriented activities". The third factor (F3) involves items related to social activities at home and social involvement in the neighborhood, and hence is identified as "home-oriented activities". The last factor (F4) has high loadings for questions related to working extra hours for promoting one's career and is defined "work-oriented activities".

5.3. Identification of lifestyle patterns

The SOM algorithm employed in this study had an output layer consisting of a 20×20 neural network, in order to avoid forced clustering as a result of a small neural network size with respect to the number of observations in the data manifold. The input variables for the cluster analysis are related to the role as a household member, the role as a worker and the role as a leisure consumer. The available resources that impose constraints on the residential choice are monthly income and car ownership.

Cluster analysis yielded five clusters of knowledge-workers that greatly differ with respect to their lifestyle. The five-cluster solution was chosen on the basis of cluster comprehensiveness, interpretability, and parsimony. Pearson's chi-square test for discrete variables and ANOVA for continuous variables confirmed that the differences among the clusters are statistically significant. The distribution of the features by clusters and the results of the corresponding statistical tests are described in Table 2. The cluster descriptions are outlined below.

Nest-builders (26.5%) are characterized mainly by their family-oriented lifestyle. They are on average in their late thirties, most of them are married and have two children or more. They have a home-oriented activity-pattern, and they do not often engage in cultural and sport activities. They also dedicate the least amount of leisure time for career development relatively to the other clusters. They are salaried employees at either the high-tech or finance sector and they earn medium–high wages. They have the second highest car ownership among the clusters, since about 80% have two cars in the household.

Bon-vivants (19.4%) are young professionals with undergraduate degree, who are salaried employees in the high-tech sector earning low and medium wage levels. Possibly, they are at an early stage of their career. While roughly half of the bon-vivants are married, 75% do not have children. Their leisure time is filled with out-of-home cultural and sport activities, and they do not dedicate much of their leisure time to in-home or work oriented activities.

Careerists (18.5%) are highly skilled professionals who, for the vast majority, hold a master or a doctoral degree. They are salaried employees in the high-tech sector, possibly in key roles or in research and development, since they earn very high wages. Their leisure activity-pattern tends to be workaholic, as they mainly

Table 1
Leisure activity-pattern factors.

Item	KMO	F1	F2	F3	F4
Promoting my career is currently the most important thing in my life	0.712	0.145	0.027	−0.069	**0.451**
I participate in many conferences and professional courses	0.765	0.239	0.073	0.173	**0.399**
I work until late in the evening and also on weekends	0.648	0.043	0.035	−0.019	**0.692**
I am highly available for my employer outside of my work hours	0.682	−0.017	0.038	0.049	**0.680**
I frequently go to restaurants and coffee shops	0.844	**0.625**	0.055	−0.045	0.093
I frequently hang out in discotheques, bars and clubs	0.835	**0.462**	0.066	−0.146	0.033
I frequently go to the theater and music shows	0.855	**0.637**	0.121	0.141	0.058
I frequently go to operas and concerts	0.795	**0.393**	0.158	0.144	0.081
I frequently go to museums, exhibitions and galleries	0.836	**0.541**	0.123	0.188	0.082
I frequently go to courses and seminars	0.837	**0.373**	0.057	0.204	0.166
I frequently go to the cinema	0.873	**0.609**	0.138	0.041	0.087
I enjoy living in an urban area that offers abundance of opportunities and population diversity	0.791	**0.623**	0.032	−0.179	0.036
I prefer to live in a quiet neighborhood	0.704	0.150	0.042	0.405	0.070
I frequently gather with friends at home	0.824	0.142	0.316	**0.377**	−0.072
I like to walk around the neighborhood	0.810	−0.065	0.190	**0.434**	0.036
I like to work in the garden, design the house or engage in other hobbies at home	0.834	−0.024	0.040	**0.720**	−0.036
I have social relations with my neighbors	0.661	−0.097	0.049	**0.723**	0.011
I am socially involved in my community	0.658	**−0.374**	0.095	0.266	0.102
I frequently dedicate time to outdoor sport activities	0.765	0.121	**0.795**	−0.038	0.080
I frequently jog of walk in parks and public open spaces	0.844	0.105	**0.685**	0.142	−0.009
I frequently use sport facilities near my residence	0.887	0.107	**0.528**	0.124	0.151
I frequently engage in outdoor activities in parks, gardens and open spaces	0.816	0.078	**0.400**	0.276	−0.089
I frequently engage in outdoor sport activities such as cycling	0.815	0.103	**0.735**	0.054	0.086

Note: Factor loadings over the threshold of 0.35 are presented in bold.

Table 2
Cluster characteristics.

Variable	Cluster	Categories (%)				Test statistics
Age		Mean	St. Dev.			ANOVA: F = 55.92; *df* = 4; sig. = 0.000;
	Nest-builders	39.6	7.6			*N* = 837
	Bon-vivants	31.8	4.6			
	Careerists	42.9	7.0			
	Entrepreneurs	40.9	10.7			
	Laid-back	35.7	7.2			
	Entire sample	38.1	8.4			
Marital status		Non married	Married			χ^2 = 247.4; *df* = 4; sig. = 0.000;
	Nest-builders	5.9	94.1			*N* = 837
	Bon-vivants	56.2	43.8			
	Careerists	5.2	94.8			
	Entrepreneurs	37.1	62.9			
	Laid-back	1.7	98.3			
	Entire sample	19.2	80.8			
Number of Children		None	One child	Two children	More than two children	χ^2 = 524.1; *df* = 12; sig. = 0.000;
	Nest-builders	0.0	8.1	48.6	43.2	*N* = 837
	Bon-vivants	74.7	22.2	3.1	0.0	
	Careerists	0.0	4.5	39.4	56.1	
	Entrepreneurs	37.1	9.7	21.8	31.5	
	Laid-back	26.4	37.4	21.3	14.9	
	Entire sample	25.4	16.5	28.4	29.6	
Spouse's workplace location		Core and Inner ring	Middle and outer ring	Unknown		χ^2 = 325.5; *df* = 8; sig. = 0.000;
	Nest-builders	48.6	33.3	18.0		*N* = 837
	Bon-vivants	40.7	6.8	52.5		
	Careerists	40.0	0.6	59.4		
	Entrepreneurs	41.1	15.3	43.5		
	Laid-back	22.4	71.8	5.7		
	Entire sample	38.9	27.5	33.6		
Education		High-school and Diploma	B.Sc.	M.Sc. and Ph.D.		χ^2 = 42.9; *df* = 8; sig. = 0.000; *N* = 837
	Nest-builders	7.7	45.9	46.4		
	Bon-vivants	12.3	57.4	30.2		
	Careerists	5.2	31.0	63.9		
	Entrepreneurs	10.5	51.6	37.9		
	Laid-back	5.7	51.7	42.5		
	Entire sample	8.1	47.4	44.4		
Employment status		Salaried employee	Self-employed			χ^2 = 484.8; *df* = 4; sig. = 0.000;
	Nest-builders	95.9	4.1			*N* = 837
	Bon-vivants	98.1	1.9			
	Careerists	100.0	0.0			
	Entrepreneurs	28.2	71.8			
	Laid-back	99.4	0.6			
	Entire sample	87.8	12.2			
Workplace location		Core	Inner ring	Middle ring	Outer ring	χ^2 = 134.9; *df* = 12; sig. = 0.000;
	Nest-builders	49.5	27.5	16.2	6.8	*N* = 837
	Bon-vivants	27.2	22.8	42.6	7.4	
	Careerists	11.6	24.5	47.7	16.1	
	Entrepreneurs	47.6	31.5	12.1	8.9	
	Laid-back	24.7	15.5	42.5	17.2	
	Entire sample	32.7	24.1	32.0	11.1	
Work sector		Finance	High-tech			χ^2 = 272.6; *df* = 4; sig. = 0.000;
	Nest-builders	54.3	47.7			*N* = 837
	Bon-vivants	0.6	99.4			
	Careerists	0.5	99.5			
	Entrepreneurs	67.7	32.3			
	Laid-back	29.3	70.7			
	Entire sample	29.3	70.7			
Culture-oriented activity-pattern		Mean	St. Dev.			ANOVA: F = 26.4; *df* = 4; sig. = 0.000;
	Nest-builders	2.05	0.86			*N* = 837
	Bon-vivants	2.77	0.95			
	Careerists	1.89	0.84			
	Entrepreneurs	2.59	1.01			
	Laid-back	2.16	0.90			
	Entire sample	2.26	0.96			
Sport-oriented activity-pattern		Mean	St. Dev.			ANOVA: F = 2.9; *df* = 4; sig. = 0.020;
	Nest-builders	2.36	1.10			*N* = 837
	Bon-vivants	2.76	1.17			

Table 2 (*continued*)

Variable	Cluster	Categories (%)				Test statistics
	Careerists	2.60	1.17			
	Entrepreneurs	2.55	1.27			
	Laid-back	2.52	1.17			
	Entire sample	2.54	1.17			
Home-oriented activity-pattern		Mean	St. Dev.			ANOVA: F = 11.1; *df* = 4; sig. = 0.000; *N* = 837
	Nest-builders	3.46	1.03			
	Bon-vivants	2.83	0.94			
	Careerists	3.36	0.99			
	Entrepreneurs	3.13	0.95			
	Laid-back	3.10	0.96			
	Entire sample	3.20	1.00			
Work-oriented activity-pattern		Mean	St. Dev.			ANOVA: F = 18.0; *df* = 4; sig. = 0.000; *N* = 837
	Nest-builders	3.07	0.99			
	Bon-vivants	3.09	1.00			
	Careerists	3.62	0.88			
	Entrepreneurs	3.49	0.93			
	Laid-back	3.22	0.94			
	Entire sample	3.27	0.98			
Monthly wage in US dollars		$\leqslant$3300	3300–5200	5200–7800	$\geqslant$7800	χ^2 = 180.7; *df* = 12; sig. = 0.000; *N* = 837
	Nest-builders	10.4	36.0	32.9	20.7	
	Bon-vivants	22.2	36.4	31.5	9.9	
	Careerists	0.6	5.2	32.3	61.9	
	Entrepreneurs	23.4	20.2	21.0	35.5	
	Laid-back	17.2	23.6	38.5	20.7	
	Entire sample	14.2	25.4	31.9	28.4	
Car ownership		None	One car	Two cars	More than two cars	χ^2 = 153.1; *df* = 12; sig. = 0.000; *N* = 837
	Nest-builders	0.9	16.2	80.2	2.7	
	Bon-vivants	6.2	59.9	32.1	1.9	
	Careerists	0.0	11.0	82.6	6.5	
	Entrepreneurs	4.8	29.8	58.9	6.5	
	Laid-back	2.9	26.4	67.8	2.9	
	Entire sample	2.7	27.8	65.6	3.8	

engage in work-related and in-home activities. They are on average in their forties, married and the vast majority has two children or more. They mostly work in the inner and middle rings and have the highest car ownership level among the clusters.

Entrepreneurs (14.8%) are mostly self-employed professionals who earn high wages. Forty percent holds a graduate degree and more than two-thirds are employed in the finance sector. They are mostly in their forties, and two-thirds of them are married with children. They mostly work in the core and inner metropolitan rings, and have a high car ownership level, although lower than the careerists or the nest-builders. Their activity-pattern tends to be workaholic, but on average they prefer out-of-home cultural and sport activities over in-home activities.

Laid-back 20.8% are on average in their mid-thirties, they are married and most of them have either no children or only one child. They are salaried employees, of whom 70% work in the high-tech sector. Most of them hold an undergraduate degree and their wage distribution ranges between low and medium–high wages. They seem to have a balanced leisure activity-pattern, as they are moderately engaged in each activity type relatively to other clusters.

5.4. The linkage between lifestyle and residential choice

Following the clustering procedure, the observations of knowledge-workers are arranged according to their coordinates in the array of neurons, and the average values of their features for each neuron can be plotted on two-dimensional maps in a manner analogous to geographical maps. The clusters, lifestyle aspects, home-ownership, building type, dwelling size and location across the sample are visualized as feature maps in Fig. 3. Notably, while the lifestyle aspects served as input to the clustering process, the visualization of the residential choice in terms of home-ownership, building type, dwelling size and location is the output of the cluster analysis.

The feature maps reveal the linkage between the different aspects of lifestyle and the residential characteristics, by looking at the same coordinates across different features and detecting matching or opposite patterns in terms of colors and shades across map areas. For example, observing the lower left-hand corner of the feature maps reveals that renting small apartment in the core area is positively associated with young age, being single and without children, being a salaried employee, high engagement in culture-oriented activities, earning low wages and having a low car-ownership. In contrast, observing the upper middle section of the feature maps shows that owning a large detached house in the suburbs is positively linked to married couples at their forties who have children, high education level, workplace in the high-tech sector in the suburbs, workaholic activity-pattern, high income and high car ownership.

The distribution of dwelling unit characteristics differs across clusters and the difference is statistically significant at the 0.05 level.

The two clusters with the highest home-ownership rate are the careerists (81.9%) and the nest-builders (78.8%), while the bon-vivants have the lowest rate (34.0%). The difference across clusters is significant at the 0.01 level (χ^2 = 109.1, *df* = 4, Sig. = 0.000).

The cluster with the highest share of residents in multi-storey buildings is by far the bon-vivants (90.1%), while a relatively high-share is also found for the laid-back (77.0%). The cluster with the lowest share is the careerists (49.0%), who prefer detached houses. The difference across clusters is significant at the 0.01 level (χ^2 = 71.2, *df* = 4, Sig. = 0.000).

The clusters with the highest share of residents in large and very large dwellings are the careerists (81.3%) and the nest-builders (72.9%), while the lowest share is found by far for the

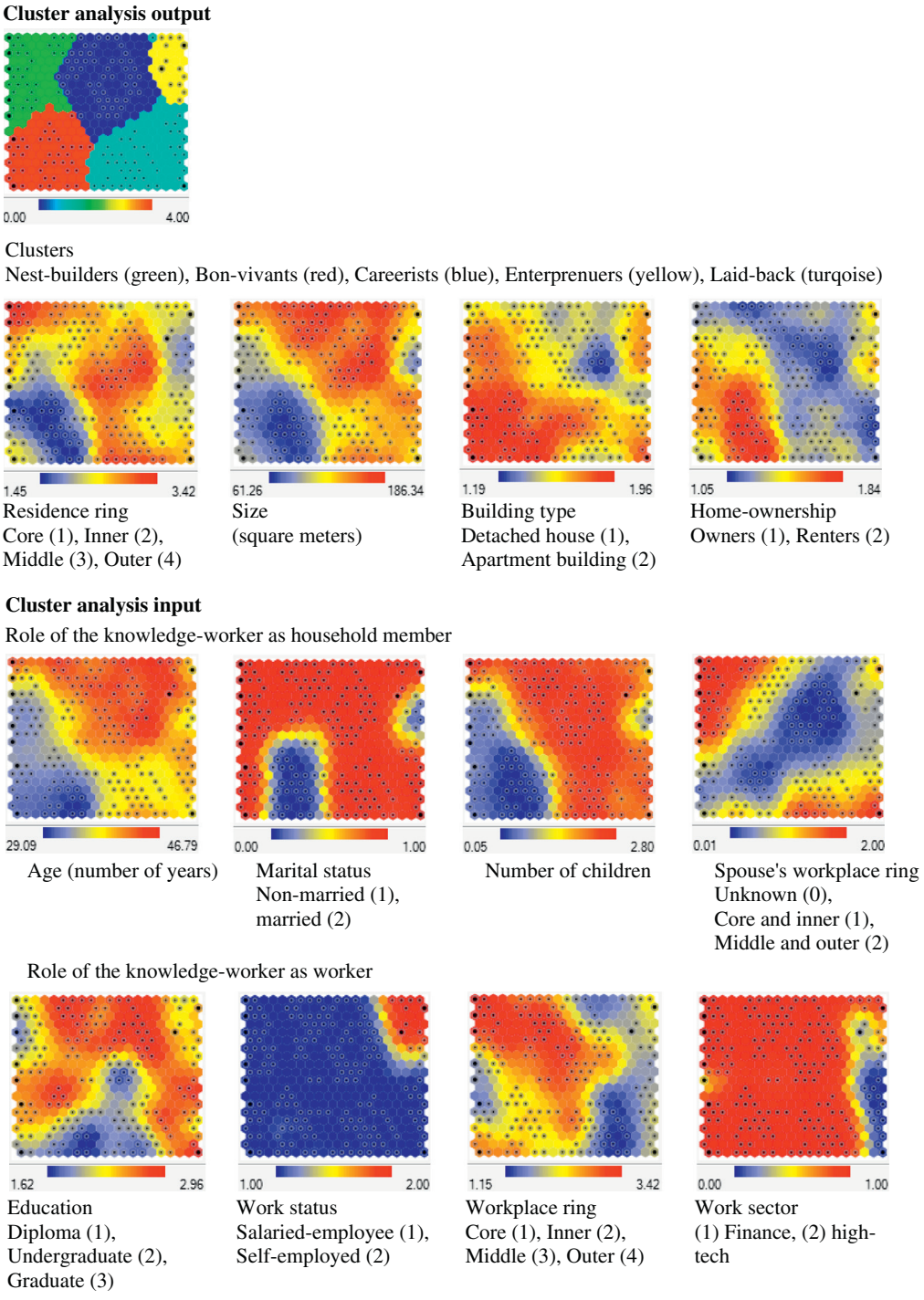

Fig. 3. SOM visualization results.

bon-vivants (13.6%). The difference across clusters is significant at the 0.01 level ($\chi^2 = 263.4$, $df = 12$, Sig. = 0.000).

The two clusters with the highest share of residents in the core and inner ring are the bon-vivants (72.9%) and entrepreneurs (70.2%), while the cluster with the lowest share is the careerists (43.9%). Almost half of the nest-builders (46.0%) and laid-back (46.0%) reside in the core and inner ring. The difference across clusters is significant at the 0.01 level ($\chi^2 = 95.1$, $df = 12$, Sig. = 0.000).

Table 3 depicts the distribution of residential choices across clusters in terms of location, home-ownership and building type.

The most popular residential alternative for nest-builders is an owned apartment regardless of the location, and the second most popular alternative is an owned house in the middle and outer ring. For bon-vivants, the most popular option is a rented apartment in the core and inner ring, followed by an owned apartment in the same location. For careerists, the most popular residential alternative is a detached house in the middle and outer ring, although an owned apartment in the core and inner ring is the second most popular option. For entrepreneurs, the most popular option is an apartment (either rented or owned) in the core and inner ring, followed by a detached house regardless of its location. For laid-back, the most popular alternatives are a rented apartment in the core and inner ring and an owned apartment in the middle and outer ring.

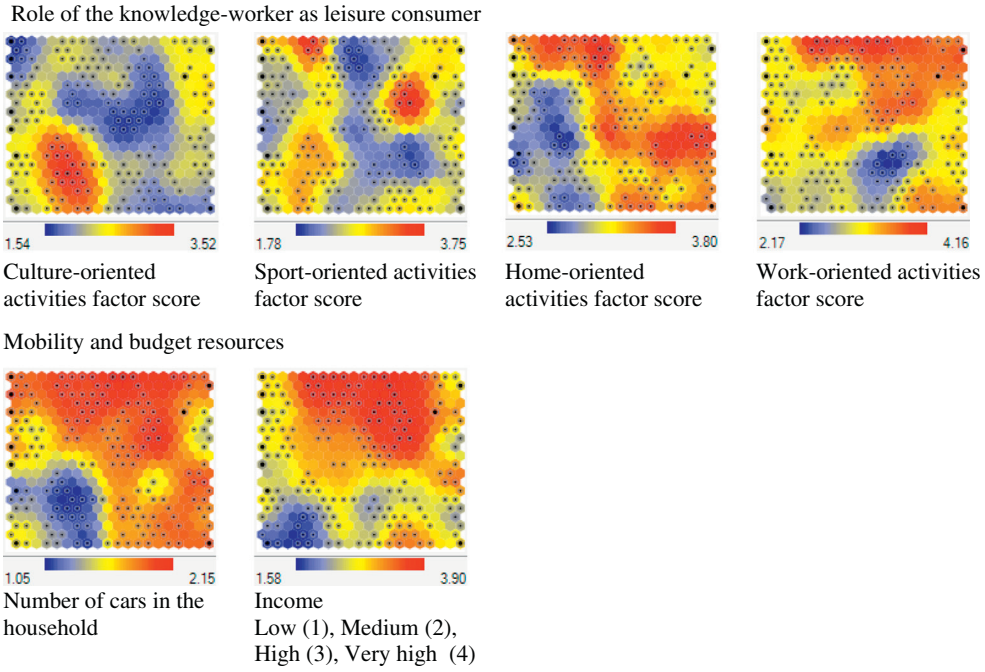

Fig. 3. (*continued*)

Table 4 presents the difference in distribution of location and dwelling sizes across clusters. The difference is statistically significant at the 0.05 level.

Nest-builders and laid-back tend to value both location and size. However, nest-builders show stronger preference for larger dwelling size. Bon-vivants and entrepreneurs tend to value central residential location, although entrepreneurs reside in larger dwellings. Careerists generally prefer large and very large dwellings over smaller dwellings, and their most popular alternative is a very large dwelling unit in the middle and outer rings.

6. Discussion and conclusions

This study suggests a conceptual behavioral framework that relates the lifestyle of knowledge-workers from a multi-dimensional perspective to their residential choice at the intra-metropolitan level. The empirical results of this study confirm that the residential choice of knowledge-workers within the metropolitan area in terms of location, building type and dwelling unit size is related to their lifestyle encompassing life-cycle stage, work-role and leisure activities, subject to economic and spatial constraints. The importance of this issue derives from the envisioned role of knowledge-workers in contradicting urban development trends, namely urban revitalization versus suburbanization, and their role as highly mobile real-estate clientele.

The results indicate that knowledge-workers who have different lifestyles have significantly different residential preferences in terms of home-ownership, location building type and dwelling size.

Nest-builders exhibit strong preference for home-ownership and large dwellings, and it seems that their main reason for locating in the suburbs is housing affordability. The residential patterns of nest-builders considering their budget constraints indicate their willingness to allocate a large budget share to housing in agreement with their home-oriented lifestyle.

Bon-vivants typically rent small or medium apartments in the core and inner ring. Clearly, location in the core and inner ring is the most important aspect to them. Moreover, bon-vivants may actually prefer rented dwellings since there are "no strings attached". Likely, the choice of bon-vivants is guided by their preference to frequently engage in outdoor cultural and entertainment activities, which are most frequent in the core, as well as their young age, small household size, and budget constraints.

Careerists display a strong preference for residing in the middle and outer ring, and to owning very large apartments and detached houses in the middle and outer rings. Interestingly, careerists seem to follow the residential pattern of high-technology workers in the US (see Felsenstein, 2002). Careerists who reside in the core and inner ring prefer owning rather than renting a dwelling, regardless of the building type. Possibly, careerists seek economic stability and hence invest their conspicuous wealth in their residence as a real-estate asset, and possibly regard their residence as a status symbol.

Entrepreneurs, similarly to bon-vivants, show a strong preference for residing in the core and inner ring, although they tend to be home owners of large dwelling units, due to alleviated budget constraints. Although careerists and entrepreneurs are similar in their socio-economic characteristics and workaholic activity-pattern, their residential choice differs in location and home-ownership. The difference is likely related to the workplace location, and to the stronger preference of entrepreneurs for culture and entertainment.

Although similar in their average age and wage distribution to nest-builders, laid-back have weaker preference towards home-ownership, large dwellings and detached houses. The difference in the residential choice can be explained from the multi-dimensional lifestyle perspective, considering the smaller household size and the non home-oriented lifestyle of laid-back in comparison with nest-builders.

The results of this study suggest a direction towards resolving the conflicting role of knowledge-workers in inducing both processes of urban revitalization and urban sprawl. On the one hand, knowledge-workers are envisioned as a catalyst to revitalization and regeneration of urban core areas (Kunzmann, 2009; Lee, Burfitt, & Tice, 2009). On the other hand, knowledge-workers are

Table 3
Distribution of dwelling location, home-ownership and building type across clusters.

Residential alternative		Group (%)						
Location	Home-ownership and building type	Nest-builders	Bon-vivants	Careerists	Entrepreneurs	Laid-back	Entire sample	
Core and inner ring	Rented apartment	11.7	51.9	7.1	29.0	25.9	24.1	$\chi^2 = 203.6$; $df = 28$; sig. = 0.000; $N = 837$
	Owned apartment	26.1	19.8	23.9	25.0	15.5	22.1	
	Rented house	2.3	1.2	0.6	3.2	1.1	1.7	
	Owned house	5.9	0.0	12.3	12.9	3.4	6.5	
Total core and inner ring		45.9	72.8	43.9	70.2	46.0	54.4	
Middle and outer ring	Rented apartment	2.7	7.4	3.9	5.6	8.0	5.4	
	Owned apartment	23.4	11.1	14.2	8.9	27.6	18.0	
	Rented house	4.5	5.6	6.5	4.0	5.2	5.1	
	Owned house	23.4	3.1	31.6	11.3	13.2	17.1	
Total middle and outer ring		54.1	27.2	56.1	29.8	54.0	45.6	
Total		100.0	100.0	100.0	100.0	100.0	100.0	

Table 4
Distribution of dwelling location and size across clusters.

Residential alternative		Group (%)						
Location	Size	Nest-builders	Bon-vivants	Careerists	Entrepreneurs	Laid-back	Entire sample	
Core and inner ring	Small	2.3	39.5	1.3	17.7	15.5	14.3	$\chi^2 = 302.1$; $df = 28$; sig. = 0.000; $N = 837$
	Medium	17.6	28.4	12.9	25.8	20.7	20.7	
	Large	17.1	4.3	14.8	9.7	5.7	10.8	
	Very large	9.0	0.6	14.8	16.9	4.0	8.6	
Total core and inner ring		45.9	72.8	43.9	70.2	46.0	54.4	
Middle and outer ring	Small	.0	6.2	.0	3.2	1.7	2.0	
	Medium	7.2	12.3	4.5	7.3	16.1	9.6	
	Large	18.9	4.9	14.8	5.6	22.4	14.2	
	Very large	27.9	3.7	36.8	13.7	13.8	19.8	
Total middle and outer ring		54.1	27.2	56.1	29.8	54.0	45.6	
Total		100.0	100.0	100.0	100.0	100.0	100.0	

viewed as contributors to encouraging urban sprawl (Felsenstein, 2002). The results of this study suggest that knowledge-workers should not be viewed as a homogenous unit with respect to their potential role in inducing urban and regional processes. Bon-vivants and entrepreneurs bear potential to form part of gentrification processes, due to their tendency to reside in the core and inner ring of the metropolitan area. In contrast, careerists are the most likely to induce urban sprawl due to their strong preference to reside in very large dwelling units and detached houses in the metropolitan fringe. Nest-builders and laid-back knowledge-workers can be attracted to reside in the metropolitan core, conditional on the provision of affordable dwelling units of adequate size. In order to establish this direction, research is needed regarding the impact of knowledge-workers with different lifestyles on urban sprawl in terms of location, land consumption and the derived requirement for new built-up area versus infill and land use intensification in existing built textures.

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