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# Beyond the Built-up Form / Mobility Relationship: Spatial Affordance and Lifestyles.

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## Highlights

- The concepts of spatial affordance and dwelling regime (prevailing lifestyle) are defined.
- Within a quantitative approach, indicators are used to describe spatial affordance and dwelling regimes.
- Indicators are calculated for spatial units in the metropolitan area of the French Riviera.
- Bayesian Networks are used to infer typologies of place based on spatial affordance and dwelling regime indicators.
- Cross-analysis of the two typologies is performed and new insight on the study area is gained going beyond the built-up form/mobility relationship.
- All combinations of spatial affordance and dwelling regime types are not possible, as concordance relationships bind these two aspects of place.

**Abstract:** The aim of the paper is to explore the interplay of spatial affordance and lifestyles within a metropolitan context. The reorganisation of urban regions in integrated metropolitan areas generates new lifestyles based on hyper-mobility (often in the form of car dependency) and poly-topic practice of space. At the same time, the physical and functional characteristics of urban and rural components of space are modified. Within a quantitative approach, spatial indicators are used to describe the different facets of spatial affordance and of lifestyles of the resident population. The case study is the French Riviera metropolitan area, in south-eastern France. The indicators are used within a Bayesian Network model to identify typologies of place in the metropolitan area. Two typologies are produced. The first one identifies seven classes of spatial affordance ranging from regularly planned, dense and mixed urban cores to less accessible peripheral rural villages under metropolitan influence. The second one looks for profiles of place based on the prevalent lifestyles of its population (dwelling regimes). Once again seven classes are determined, including urban, suburban and metropolitan-rural lifestyles. The correspondence between spatial affordance and lifestyles is later explored to compose a more thorough description of places. The research confirms the need to enlarge the view of the built-up form / mobility relationship, shows the usefulness of the concepts of spatial affordance and dwelling regimes and explores new methodologies for identifying profiles of place. The probabilistic framework of Bayesian Networks proves particularly well suited to capture the fuzzy relationship between spatial affordance and lifestyle.

**Key-Words:** Spatial Affordance, Lifestyles, Dwelling Regimes, Indicators, Bayesian Networks, French Riviera.

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# 1. Introduction

Research on the relationship between built-up form and mobility behaviours in urban space has a long tradition. Transformations in urban morphology, transportation (and communication) networks and mobility behaviours nourish a vast debate on the contemporary metropolis (Wiel 1999, Ascher 1995, Castells 2002). As far as empirical research is concerned, Newman and Kenworthy (1989, 1998) as well as Kenworthy and Laube (1999) first highlighted the role of urban density in a world-wide comparison of metropolitan areas. According to these authors, population density, measured at the metropolitan scale, shapes both transportation offer and average mobility behaviours of city-dwellers. Their researches were seminal and have given rise to several developments (Naess 1995, Giuliano and Narayan 2003, Van de Coevering and Schwanen 2006) as well as harsh critiques due to the aggregate level of the analysis and the simplified conceptual (and empirical) relations among the phenomena (Gordon and Richardson 1989, 1997, Fouchier 1997). Inspired by Newman and Kenworthy's work, international comparisons at the metropolitan level have thus later been conducted in order to better specify the causal chain of the built-up form / transportation / mobility interaction, and to evaluate its overall performance in a sustainable development perspective (Fusco 2004, Le Nechet 2011). Urban densities, transportation offer and accessibility levels have also been studied at municipal level within a given metropolitan area (Camagni et al. 2002). Cervero and Kockelman (1997) investigate the relationship even more locally, distinguishing the relative role of density, functional diversity and urban design within urban neighbourhoods. The impact of the configuration of street networks on modal choice, and more particularly on walking habits, has also been explored through *ad hoc* surveys (Genre-Grandpierre and Foltete 2003, Rodriguez and Joo 2004). On these bases, planners have identified design strategies to foster or hinder different patterns of mobility behaviours (Boarnet and Crane 2001). More generally, mobility survey data open the way to the analysis of the impact of built-up form on mobility behaviours integrating further socio-economic characteristics of the households (Cervero 2002). At this local scale as well, causal links among variables have been better explored (Bagley and Mokhtarian 2002, Handy, Cao and Mokhtarian 2005, Lin and Yang 2009). Research in this field is so vast, that meta-analyses are proposed to summarise results obtained with different variable definitions, methodologies and study areas. Ewing and Cervero (2010), for example, overview research based on regression analysis of mobility behaviours on built-up form parameters over the last two decades.

Advances of empirical research on the connection between built-up form and behaviours from city dwellers have thus identified elasticities of modal choice and destination preferences for different categories of people, as well as transit-inductive, car-inductive and walking- or cycling-inductive morphological arrangements. We think nevertheless that trying to identify the impact of every form element on people's behaviour (which is the very aim of regression analysis) should not be the only research strategy. The different aspects of built-up form overlap among them as well as with other functional and perceived characteristics of the urban space, contributing to a more general "habitat" or "ecosystem" for urban and metropolitan life. A "habitat" is a systemic view of physical, functional and perceived elements of urban morphology, taking into consideration the mutually reinforcing interactions among elements. The concept of overall physical affordance of a given habitat seems to us an appropriate generalization of the mobility-inductive characteristics of specific form elements. At the same time, mobility has to be placed within the broader context of lifestyles and attitudes of city-dwellers (Kaufmann 2000, 2007, Lanzendorf 2002, Urry 2007). Mobility behaviours are part of more general lifestyles reflecting people's habits, attitudes, values and aspirations in urban space. Econometric models are thus starting to address lifestyle-related mobility patterns (Pinjari et al. 2011). Going back to the debate on the contemporary metropolis, we think that spatial affordance and lifestyles can indeed throw new light on the most recent transformations of urban space. The reorganisation of urban regions in integrated metropolitan areas, often referred to as metropolisation process (Ascher 1995, Lacour and Puissant 1999), gives birth to new lifestyles based on hyper-mobility (often in the form of automobile dependency) and poly-topic practice of space (Stock 2004). At the same time, metropolisation modifies the physical and the functional characteristics of the urban and rural components of space and enlarges the usual perimeters of the urban realm.

The aim of this paper is thus to explore the interplay of spatial affordances and lifestyles within a given metropolitan context. The case study of our analysis is the French Riviera metropolitan area, showing important diversity both in physical characteristics and in prevailing lifestyles. The rest of the article will be structured as follows. Section 2 introduces the concepts of spatial affordance, lifestyle, dwelling regime and place. Section 3 presents the case study of the French Riviera and the empirical data of the analysis. Section 4 presents the research methodology, namely spatial indicators and multivariate clustering through Bayesian Networks. Sections 5 and 6 show the results of Bayesian clustering on indicators of spatial affordance and dwelling regime within the French Riviera metropolitan area. Section 7 proposes a cross-analysis of the two typologies of metropolitan space previously identified and explores the empirical correspondence between them. Conclusions, critical assessment and perspectives of future development of the research are presented in Section 8.

## 2. Spatial Affordance, Lifestyles and the Functioning of Metropolitan Space

The concept of affordance was first introduced by Gibson (1979) in ecological psychology. Affordance is the characteristic of an object to suggest its functionality and use through elements that can be directly perceived from its users. Affordance is not simply a physical characteristic of the object, as it also depends from the task to be performed and from the user's capabilities (Jordan et al. 1998). Gibson's definition was later criticised as it relied uniquely on the subject's perception of objects. In real life situations, cognitive processes (both of habitual objects and new ones) play an important role in the subject's ability of projecting possible uses on objects at hand.

For the purpose of geographical analysis, we propose the new concept of "spatial affordance". This is defined as the set of task-relevant characteristics of geographic space in connection with "complex tasks", as they emerge from the practice of a whole population. Our research focuses on inhabiting geographic space (Stock 2004), which is a perfect example of a complex set of actions that people perform within or outside of daily routines: dwelling, going to work, shopping, enjoying leisure time, visiting places on weekends, attributing values and meaning to these activities and to the places involved, etc. Inhabiting is not linked to a simple perception of space (as could be the case for space exploration by tourists). It is a more complex knowledge of the possible uses of space that should be considered. Being mainly concerned with inhabiting urban space (or ex-rural areas in a metropolitan context), we will limit our analysis to the aspects of urban morphology that contribute to spatial affordance. If urban form is defined in its broadest sense, covering physical, perceptive and socio-functional aspects, as proposed by Levy (2005), we think that its descriptors are good descriptors of spatial affordance, as far as they convey to its inhabitants different possible uses of urban space, different ways of "doing with it". Appropriate descriptors of spatial affordance should thus include indicators of visible activities, of centrality functions and of accessibility levels in order to supplement descriptors of physical urban form and housing stock.

The different ways of performing the complex set of actions of inhabiting geographic space do not combine randomly within a given population, but give rise to particular patterns defined as lifestyles. Lifestyles are socially classifiable systems of practices (Bourdieu 1979). By integrating the spatial dimension of lifestyles (places used to perform activities and mobility needed among them), Stock (2004) proposes the concept of "dwelling mode" (*mode d'habiter*) of individuals and households as being more appropriate than lifestyle in geographical analysis. In what follows we will use them as synonyms, which implies that the spatial dimension will always be fully integrated in the concept of lifestyle. When a lifestyle / dwelling mode becomes predominant among the population of a given territory, we can speak of a "dwelling regime" (*regime d'habiter*), i.e. a dominant model for this population of being in relation with geographic space within a territorial unit.

It is tempting to correlate lifestyles and dwelling regimes to the physical and functional aspects of space. This is of course not a simple cause-to-effect relation. Dwelling regimes could be tributary of spatial affordance, and at the same time they could contribute to shape the way space is perceived, used and actually structured by its inhabitants. Place will thus be used as a third, encompassing concept accounting for the association of given spatial affordances and dwelling regimes in a given space. Phenomenologist geographers claim that it is precisely through the meaning conferred by the



actions performed in space that space becomes “place”. According to Relph (1976), place is a unique instance (localised in space) of a pattern composed of physical features, observable activities and human meaning. In our opinion, “place” can precisely be defined by jointly considering its spatial affordance and the lifestyles / dwelling regimes characterising its inhabitants (Figure 1). Physical elements and observable activities within a place are what the spatial affordance of a place is mainly made of: in order to suggest its functionalities, a place must also show how these functionalities are actually put in use by people (Jordan et al. 1998). Sidewalks full of people walking or window-shopping suggest different potential uses than desert sidewalks bordering parking lots, as Jacobs (1961) already remarked. At the other end of the equation, the observable activities of people inhabiting the place and the human meaning assigned to physical elements and activities are the main features of predominant lifestyles (dwelling regimes).

Of course, places are cells within a system of places. A metropolitan area is a rather complex and diversified system of places, allowing dwelling modes that differently combine the spatial affordance of its places. This imposes a subtle distinction on the question of observable activities. The spatial affordance of a given place draws on the observable activities of all the people which are present in it: residents, city-users, tourists, etc. The intense and diverse urban life of a city-centre is thus not the result of its residents only. On the other hand, when characterising the dwelling regime of a place, we are interested in the prevalent dwelling mode of its inhabitants, which could imply mobility within the whole metropolitan area. A suburban commuting dwelling regime, for example, is not just defined by the habit of sleeping at night in a peripheral subdivision, but by precise patterns of visiting employment, shopping and leisure activity centres, often through considerable car mobility, and of giving meaning to residential peacefulness and to the use of a private garden, as opposed to the use of public space in city-centres.

The use of the concept of place has nevertheless the implicit danger of suggesting that unique instances cannot support any generalisation of analysis results. The aim of our research is to overcome this assumption. We will thus, on the one hand, temper the tendency to reduce dwelling regimes to explicatory morphological factors. On the other hand, with the working hypothesis of several distinct classes of spatial affordance and dwelling regimes within a metropolitan area, we will explore the existence of categories of places, allowing some generalisation on the bases of observable regularities.

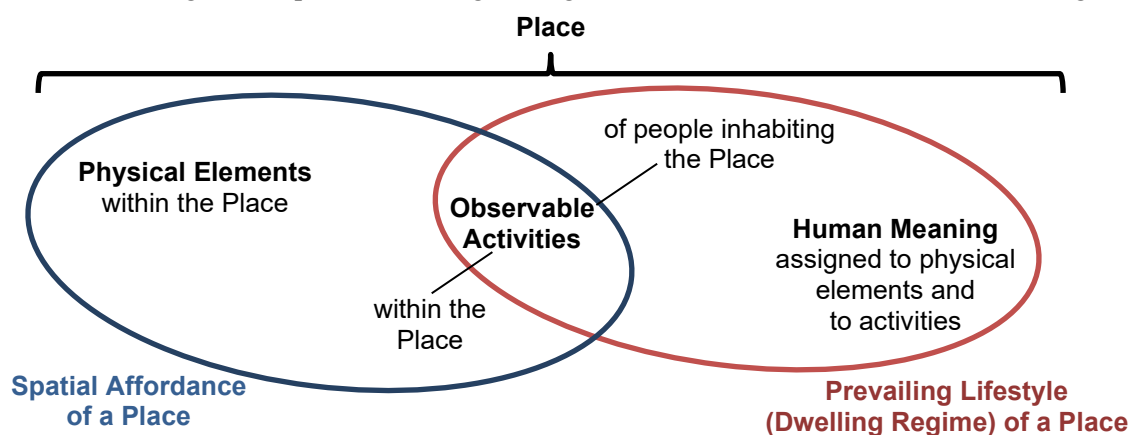


Figure 1. A conceptual framework for Place, Spatial Affordance and Lifestyle/Dwelling Mode.

### 3. Case Study and Empirical Data

#### 3.1 The French Riviera Metropolitan Area

The case study for our research is the French Riviera, in South-Eastern France (Figure 2). It is a polycentric metropolitan coastal region of over one million inhabitants with a strong residential and touristic economic base. Over the last decades, several coastal cities (Nice, Cannes, Antibes, Monaco) and a few minor centres in the close hinterland (Grasse, Vence) have coalesced to give birth to a vast conurbation. New activity areas have also emerged in the interstices of the conurbation, like the technology centre of Sophia-Antipolis and the activity areas in the lower Var valley. The functional

1 influence of the coastal centres of the conurbation goes well beyond the pericoastal area and  
2 encompasses much of the Alpine hinterland, as well as parts of the neighbouring Department of Var  
3 (France) and of the Region of Liguria (Italy), defining a vast metropolitan region (Fusco and Scarella  
4 2008, 2012, 2013). The gradual emergence of this metropolitan area has been accompanied by changes  
5 in mobility patterns of its inhabitants, at different scales and temporal rhythms (Decoupigny and Fusco  
6 2009, Fusco and Scarella 2013). Local authorities are just beginning to realise the increasing extent of  
7 the metropolitan area and of the on-going transformations of mobility behaviours. The previous  
8 household mobility survey of 1998 had already fostered research on our study area. Jourdan (2003)  
9 investigated in a qualitative way questions of centrality and of urban form (mainly density and  
10 functional mix) in connection to urban governance and automobile dependence. Fusco (2006)  
11 proposed a causal analysis of the link between urban form (density, centrality, functional mix),  
12 transportation offer and mobility behavior of the resident population. Nevertheless, these works did  
13 not address in a more systemic way the association of lifestyles with physical and functional  
14 characteristics of space. The latest household mobility survey of 2008-09 is the first to cover the  
15 hinterland, as well as the easternmost part of the Department of Var (although it does neither cover the  
16 Principality of Monaco, nor Italian municipalities). The survey also covers for the first time items like  
17 weekend and residential mobility, along with more traditional themes of daily mobility, motorisation,  
18 dwelling and socio-economic characteristics of the resident population.

19 The metropolisation process is not only a change in mobility behaviours. Physical changes in land-  
20 cover, urban form, commercial offer and activity distribution are essential factors of the emergence of  
21 the new metropolis. The highway network deeply modifies accessibility patterns within the  
22 metropolitan area and this, together with mass motorisation, fosters new suburban developments and  
23 peripheral retail centres. Old villages and ex-rural scattered settlements are also integrated in the  
24 metropolitan system. How are these transformations related to the new metropolitan lifestyles and  
25 mobility behaviours? At the same time, the morphological and functional characteristics within the  
26 metropolitan area are so diverse (traditional urban fabric, skyscrapers, collective housing projects,  
27 suburban subdivisions, old villages more or less accessible from the coast, etc.), just like the  
28 observable lifestyles. Is there a link among these two important aspects of metropolitan, observable  
29 landscapes, physical and functional features on the one hand, human and social features on the other?

30 The concepts of spatial affordance and of lifestyles/dwelling regimes can be used to answer these  
31 questions. Our goal is to identify the variety of places within the metropolitan area of the Riviera.  
32 Within this variety we will look for archetypical categories of places, characterised by consistent (i.e.  
33 recurrent) patterns of spatial affordance and dwelling regimes of people inhabiting them.

34

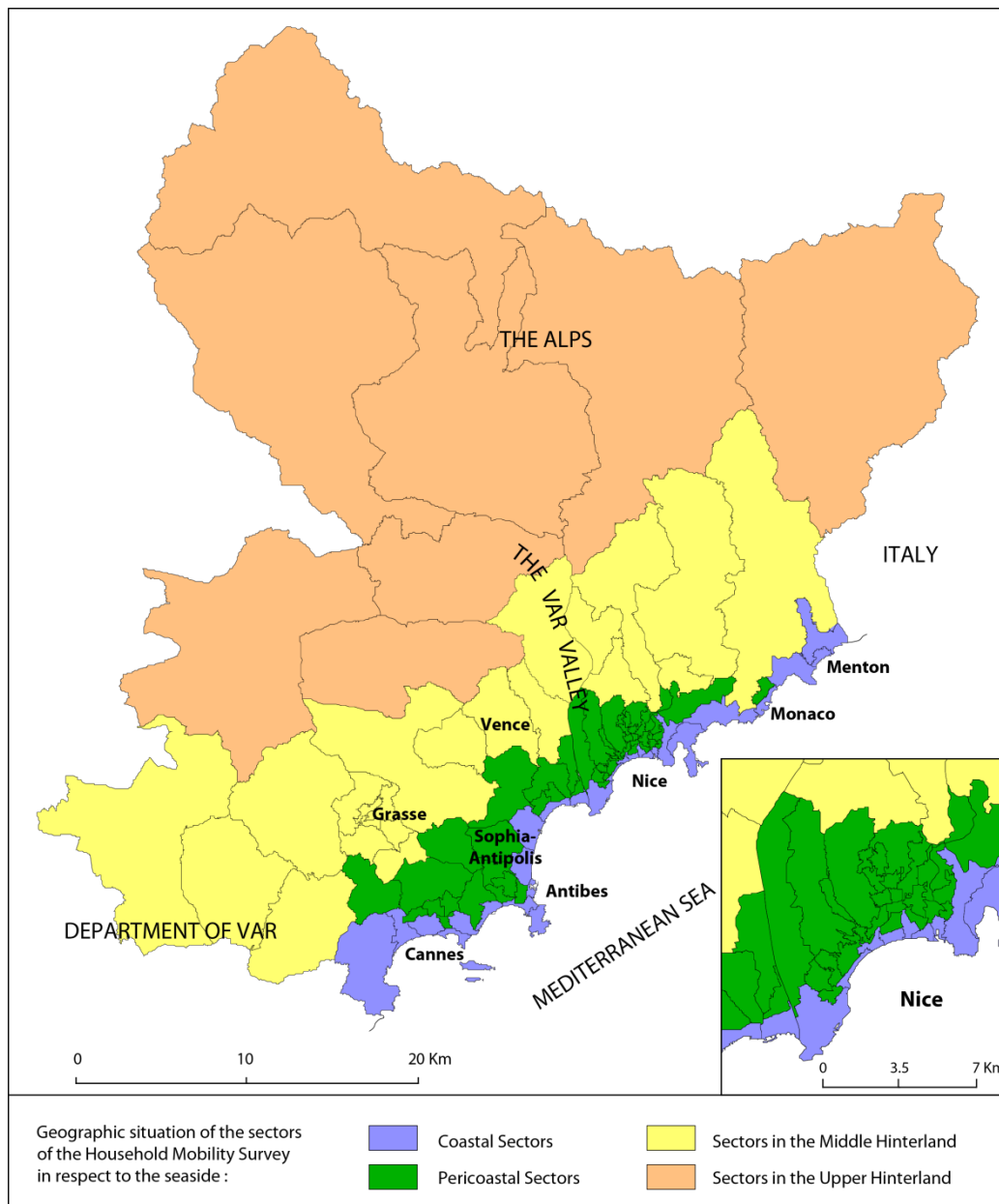


Figure 2. The French Riviera Metropolitan Area

### 3.2 Empirical Data from Multiple Sources

In order to conduct a joint analysis of spatial affordance and lifestyles/dwelling regimes, we need appropriate spatial databases. The 2008-09 Household Mobility Survey (HMS, Conseil Général 06 2009) provides useful information on lifestyles, behaviours, opinions and socio-economic characteristics of the resident population. Housing characteristics are also described in the database, but they are far from covering the different aspects of spatial affordance. Other databases have thus to be used, namely the BD TOPO (issued by IGN, the French National Geographic Institute) a geographic coverage of the study area including buildings and street network at metric precision. The affiliation database of the local chamber of commerce is also used to characterise retail offer. National Census, both in France and Monaco, as well as the *Monaco en chiffres* publication series (Principauté de Monaco 2009), is finally used to quantify items beyond the coverage area of the HMS. The 2008-09 HMS was in fact conducted over 104 survey sectors, 94 of which in a 15 km wide, 50 km long band going from the coast to the middle hinterland. In these sectors, 7539 households were surveyed through a face to face protocol covering all the items of the enquiry. In the 10 most peripheral sectors (upper hinterland and Department of Var), 1461 households were interviewed by telephone over a

smaller number of items. The Principality of Monaco was not covered by the survey at all, but we integrated it in our 105 sectors study area, given its fundamental role in the functioning of the metropolitan area. The combination of all our sources provides a database of several thousand variables covering a much wider spectrum of themes than the one necessary to our analyses. How can we transform this huge quantity of data into valuable information?

## **4. Research Methodology: Spatial Indicators and Bayesian Networks**

### **4.1 From data to indicators**

We clearly need a way to reduce the dimensionality of our possible analyses. This feature selection is theory-driven and has been structured as follows. First, the two concepts of spatial affordance and of dwelling regime have been defined as the composition of more specific facets. Geographic situation in the metropolitan area, built-up morphology, street network morphology, functional morphology (observable patterns of activity), accessibility and housing were thus identified as the main components of spatial affordance; socio-demographic characteristics, daily mobility behaviours, weekend mobility behaviours, residential choice, motorization, opinions and attitudes as the main components of dwelling regimes.

In order to operationalize the description of these components, indicators were calculated for every spatial unit. An indicator is a tool capable of conveying information in a synthetic form on a phenomenon which is more complex and has a wider meaning (Meadows 1998). In its simplest form it is a parameter, or a combination of measured parameters, which is particularly significant in order to understand a phenomenon. Twenty-seven and forty-six indicators have thus been selected and calculated to describe spatial affordance (Appendix A) and dwelling regimes (Appendix B), respectively. In describing spatial affordance, for example, we selected aspects of urban form which are often mentioned in literature to be task-relevant for housing choice, mobility behaviours and other spatial practices of city-dwellers (indicators 4 to 12 in Appendix A). Jacobs (1961), Hillier and Hanson (1984), Hillier (1996) and Habraken (1998) highlight how street network connectivity can influence urban life in connection to human perception of urban space. The relative importance of tree-like structures and of densely meshed networks seem particularly relevant in shaping residential suburban use of space and city-centre mixed use of space, respectively. Instead of using complex indicators of space syntax (as proposed by Hillier 1996), we measured the relative importance of dead ends and crossroads, as well as the average network density within the built-up area (vascularisation indicator) and the local reach of built-up elements (Sevtsuk and Mekonnen 2012). Straightness of connections has been fought by the Garden City movement as incompatible with residential peacefulness and picturesque cityscapes (Hall 2002) but is now recognized as a central feature in space syntax approaches (Hillier 1996). Distances between built-up elements are also paramount in urban proxemics (Hall 1966, Habraken 1998). Lynch (1960) highlights how connections, direct view-lines and spacing shape the perceived cityscape fostering of hindering a sense of place. Architects of the typo-morphology school (Caniggia and Maffei 1979) show how these parameters are the product of given urban cultures and are recognized as such by city dwellers. Land coverage ratio, functional density and built-up density are all commonly used indicators when studying urban form in connection to urban life, perception of urban space, residential choices and mobility behaviours (Jacobs 1961, Cervero and Kockelman 1997, Fouchier 1997, Newman and Kenworthy 1998). More particularly, Berghauser Pont and Haupt (2010) identify land coverage ratio, built-up density and street network density as the three most important urban form descriptors to understand the performance of built landscapes.

The selected 73 indicators are descriptors of each of the 105 spatial units of the metropolitan area. They can thus describe the average value of a given parameter for the population within a spatial unit or, much more often, in order to avoid the filtering power of averages, they quantify the proportion of a given behaviour or of a given morphological characteristic within the spatial unit. Of course, the use of quantitative indicators inevitably reduces and simplifies the complexity of the underlying concepts (both spatial affordance and dwelling regime). Nevertheless we see this as a necessary price to pay in order to bridge qualitative conceptual analysis and quantitative spatial analysis.

## 4.2 Bayesian Network Clustering

The 73 indicators used to describe spatial affordance and lifestyle/dwelling regime are the starting point of a new kind of computer-aided data mining application. Thematic maps of indicators show both redundancy and complementarity among them. Some data are missing, as all indicators cannot be reconstructed for the sectors not fully covered by the face to face survey protocol. A few indicators are qualitative (like the geographical situation within the metropolitan area and the typology of spacing in the built-up fabric). Finally, the indicators are only operational measures of different aspects of two complex concepts: spatial affordance and lifestyle/dwelling regime. As a consequence, any operational description of these concepts through indicators is intrinsically imprecise, sometimes incomplete (not all aspects of the concepts could actually be measured) or contradictory (when indicators point in different directions), in a word uncertain. Uncertainty has thus to be a guiding principle in data mining, both in modelling algorithms and in the interpretation of their results.

In this context, Bayesian Networks (BN) offer an interesting approach for data mining in our database. At the junction between multivariate statistics and artificial intelligence, BN (Pearl 2000, Jensen 2001, Korb and Nicholson, 2004, Pourret *et al.* 2008) are powerful modelling tools in a context of uncertain knowledge. BN were thus used to achieve uncertainty-based multivariate clustering in our database.

In our research design, the clustering protocol has been applied twice: first, to analyse indicators of spatial affordance, and then to analyse indicators of lifestyle/dwelling regime. The guiding principles of this application have already been presented in a prototypical application by Fusco and Scarella (2012). To sum up, the clustering protocol is structured in several phases, coupling supervised and unsupervised learning from the database. The protocol was implemented using the BayesiaLab software (Bayesia 2010).

**Step 1 – Unsupervised Learning of Associations.** The first step is the search of probabilistically strong links among the 27/46 indicators through unsupervised learning of a BN, a classical knowledge discovery application. At this stage, no previous knowledge is entered by the modeller over the BN structure. Despite the small size of the databases (105 records), the SOPLEQ learning algorithm (Jouffe 2002) produced two networks containing fairly robust links from a probabilistic point of view. Given the small data sample, robustness was assessed through 10-fold cross-validation analysis. Even if the BN learning produces a directed graph, no causal interpretation is needed for such a model. The BN just summarizes probabilistic associations among indicators.

**Step 2 – Variable Segmentation.** The two resulting BN define probabilistic distances among variables in terms of mutual information (a classic information theory distance measure between two probability distributions, MacKay 2003). They can thus be analysed by a hierarchical clustering algorithm to detect groups of closely linked variables, which can be ascribed to a more general concept. These are intermediate concepts between the 27/46 individual indicators and the two main concepts of spatial affordance and dwelling regime. Six variable groups could be identified for spatial affordance, reflecting the following concepts: accessibility, geometrical characteristics of the street network, built-up density, housing characteristics, centrality and built-up/network connection. Eight intermediate concepts emerge in the characterization of dwelling regimes: motorisation and opinions about motorisation, daily routines, weekend mobility, modal behaviours within the week, priorities for transportation policies, proximity practices during the weekend, non-constrained mobility and attraction by metropolitan centres. These variable groups correspond only approximately to the components identified *a priori* to organise the database: information embedded in empirical data is used to make variable groups emerge in a bottom-up approach.

**Step 3 – Determining Synthetic Factors.** Latent non-observable variables (factors) are created in order to summarize the information contained in every group of indicators. The number of factor values is automatically determined by segmentation algorithms according to a likelihood maximization approach within a clustering naïve BN architecture. Factors are good summaries of the probabilistic information of the variables: table contingency fit lies between 67% and 89% for 15 of the 16 groups of variables. Individual records of the database can be assigned to values of each factor with very limited uncertainty (always less than 0.05 for dwelling regime and 0.10 for spatial affordance). Links among variables contributing to each factor and high mutual information between variables and factors also make factors robust to addition/suppression of indicators.

**Step 4 – Identifying Profiles that Summarise Factors.** A Bayesian classification of individual records (spatial units) can now be performed using the factors. For each clustering application, a new non-observable variable is added, the spatial affordance of place and its dwelling regime, considered to be the latent causes of the six or eight factors, respectively. Once again, the number of profiles is determined automatically through likelihood maximization. Seven profiles can thus be identified within the French Riviera, both in terms of spatial affordance and of dwelling regime. They resume 80.2% and 72.2% of the probabilistic information of the 6 and 8 factors, respectively. The determination of the optimal number of clusters by the search algorithms is indeed driven by a few parameters entered by the researcher. Clusters are relatively insensitive to the minimum average probability in assigning units (this value was set to 0.9 but the same results are obtained increasing it to 0.95 or decreasing it to 0.8). On the contrary, clusters were constrained to group at least 5% of the spatial units, in order to attain a certain generalization. Had this threshold been lowered to 2% or been set to zero altogether, we would obtain several more clusters, some of which only grouping very few (eventually one) units. Profile interpretation from factor values is nevertheless unpractical. It will be done in the next step of the analysis using the original variables.

**Step 5 – Characterizing Profiles.** Supervised learning of two new BN is now performed in order to characterize profiles of spatial affordance and dwelling regime from the original data plus the newly determined profiles. It is finally possible to interpret the place profiles in terms of probabilities of the combination of values of the original variables. The new BN (having naïve architecture) can precisely be used to infer the characteristics of each profile probabilistically. Profiles don't explain equally well all variables. The latter can then be ranked with respect to mutual information with profiles. Statistical significance is evaluated through a G-test on empirical data. Assuming a 0.05 significance level, only 2 variables only out of 27 for spatial affordance and 6 variables out of 46 for dwelling regime have no significant relations to the clusters. These are rather encouraging results (almost all *a priori* selected variables are significantly associated with *a posteriori* identified clusters), but we cannot exclude that other crucial variables are missing in our feature selection (we can only hope that they would at least partially overlap with the selected ones in terms of mutual information).

The final result of the Bayesian multivariate clustering is thus a double segmentation of metropolitan space. At this level of detail and complexity (105 spatial units, 73 variables), these segmentations could not have been produced by geographical expertise only. It is worth comparing our Bayesian method to more classical factor analysis, with subsequent clustering algorithms (hierarchical or k-means). First of all, intermediate concepts interpretation is much easier than in classical factor analysis: we don't have to interpret linear combinations of empirical variables, but just disjunctive groups of variables. Secondly, interpretation of intermediate factors is not crucial to our analysis. The main goal of summarizing groups of variables in synthetic factors is to avoid information redundancy: factors will contribute equally to the learning algorithm of step 4, regardless of the number of empiric variables they summarize. Thirdly, the main difference with classical clustering algorithms (whether they are performed on empirical variables or on factors) is that these methods try to identify homogeneous clusters based on a multivariate distance function from the cluster centres (however these are defined). This forces units belonging to a given cluster to have more or less the same values on all indicators. On the contrary, Bayesian algorithms maximize cluster likelihood given the empirical data. With this procedure, every cluster is identified by the fact that its members share a few common properties on a subset of variables (and these variables could be different from cluster to cluster). Preferring clusters sharing common properties over homogenous clusters is a crucial choice of our research design: spatial affordance is context dependent (inhabitants of a given area could be attentive only to a subset of the characteristics of this space) and dwelling modes, too, are normally defined by changing subsets of human and behavioural variables.

Finally, in all the phases of the analysis, BN have the advantage of a Bayesian probabilistic approach well suited to capture uncertainty issues. Knowing empirical data (and eventually not knowing them completely given the missing data), BN can calculate the most probable clusters (both in number and content). Sensitivity analysis shows that the addition/removal of a single indicator does not alter the segmentation. At the same time, always within a probabilistic framework, it is possible to study the association of every indicator to clusters as a whole and to every single cluster in particular. Affecting

a single spatial unit to a cluster is also done probabilistically. We can thus evaluate the uncertainty in affecting a spatial unit to a cluster, and identify those sectors, which are “between profiles”. One of the main shortcomings of the Bayesian models, compared to classical regression, PCA or clustering models, is the need to work with discrete variables. Continuous variables in our database were discretized in 4 classes using a k-means algorithm. The resulting models are thus relatively coarse, compared to the precision of classical regression or PCA models. This coarseness is the price to pay for statistical robustness: discretizing variables more finely would have increased more than linearly the number of probability parameters to estimate from data.

## 5. A Typology of Spatial Affordance

BN clustering algorithms identify seven profiles of places in terms of spatial affordance on the French Riviera. Projected in space, the belonging to the profiles regionalises metropolitan space (Figure 4). Profiles are commented in what follows, based on their projection in space and on the probability distributions of the most important indicators (in terms of mutual information with the profile). Probabilistic profiles of spatial affordance are shown in Appendix C. Figure 3 indicates how to read a profile. For the sake of a fluent commentary, we will avoid to constantly quote probability values inferred by the BN model. As a consequence of this editorial shortcut, we will lose some of the probabilistic nuances of BN clustering.

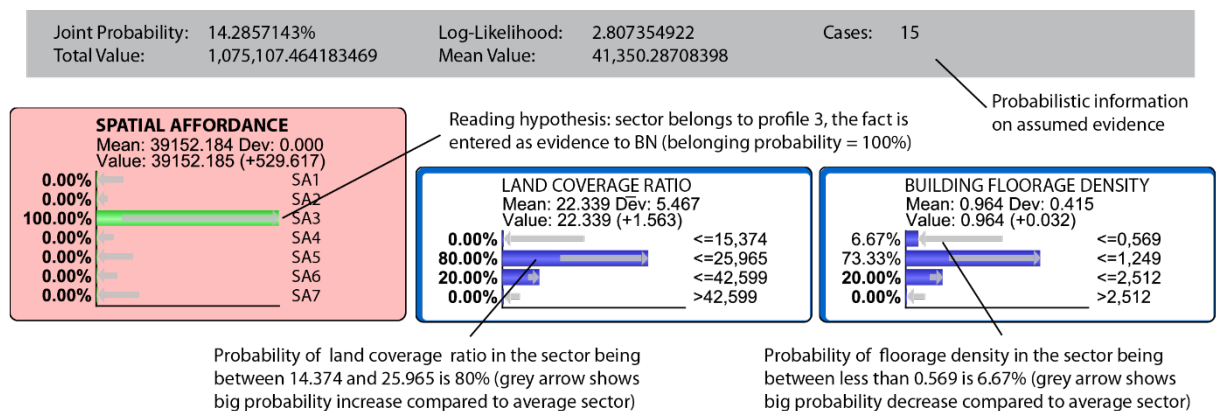


Figure 3 – Bayesian probabilistic reading of a profile.

### Profile SA1: Planned urban cores with meshed, dense and old urban fabric

This profile encompasses 11 sectors which are particularly central within metropolitan space. Morphological indicators play an important role in characterizing spatial affordance. Urban fabric is very dense both in terms of land coverage ratio and in building intensity. Street networks are characterised by frequent intersections, dead-ends are rare, straightness is high: relatively regular planned grid-based urban forms make up this profile, with high levels of local accessibility, suitable to walking and cycling. This, together with high centrality levels and contiguity among sectors, results in high accessibility levels to jobs and schools, both on foot and by transit (a bit less by car). These sectors are full of urban life, being visited by large numbers of city-users during working days, even if slightly less during the weekends. Housing offer is typical of French city-centres: a great majority of collective housing, in old buildings with few big flats and mainly for rental. Sectors in this profile correspond to the city-centres of Nice and Antibes. In Nice, the profile includes pericentral neighbourhoods, too, which share the physical elements of affordance, but not always the observable activities (lower commercial density and presence of city-users). This core of “urban places” in Nice corresponds to the area influenced by the plans of *Consiglio d’Ornato* (Graff 2000) in the 19th century.



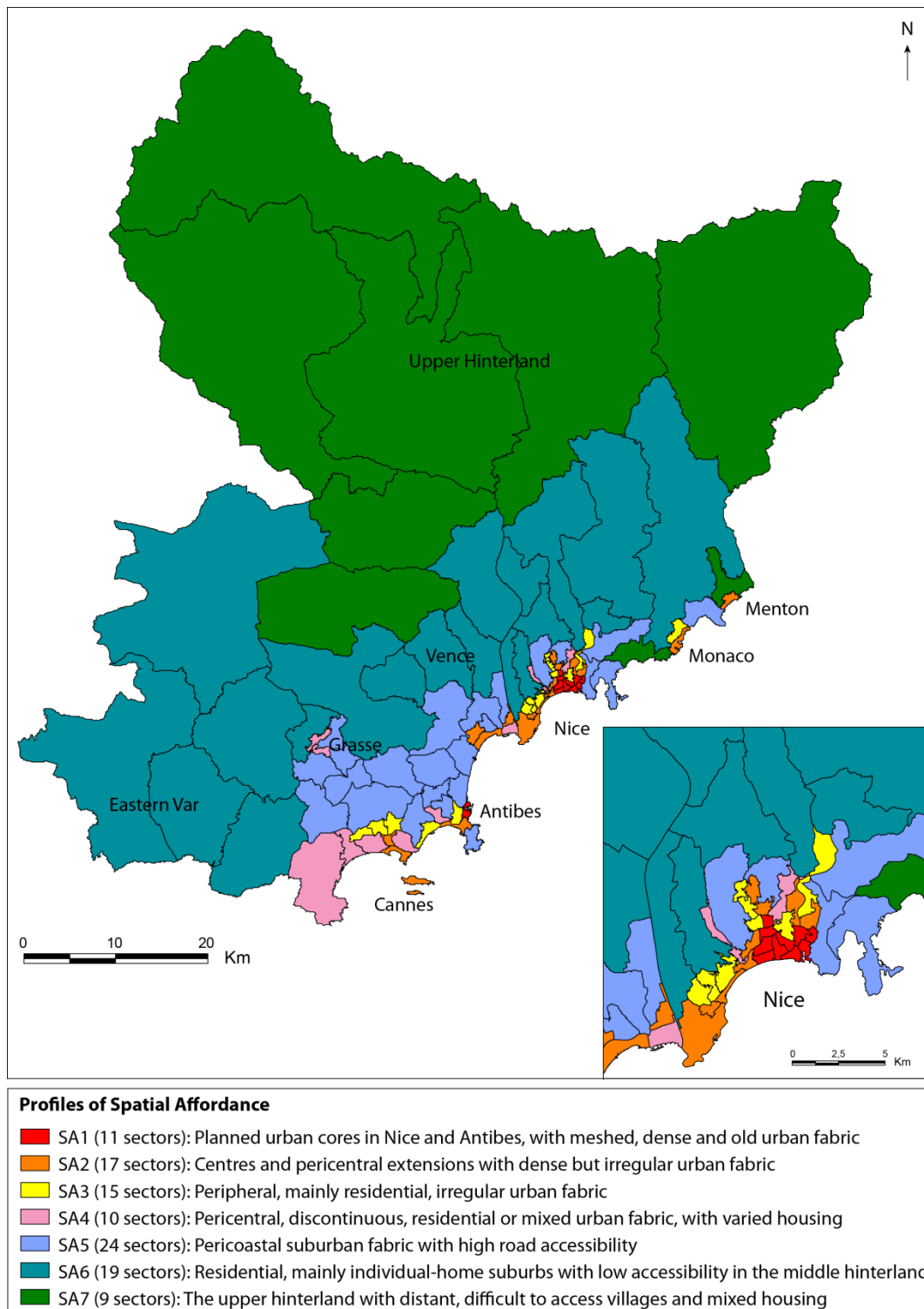


Figure 4 – A typology of spatial affordance in the French Riviera metropolitan area.

### Profile SA2: Centres and pericentral extensions with dense but irregular urban fabric

This profile concerns 17 coastal/pericoastal sectors, strongly characterised by morphological indicators. Like sectors of profile SA1, they present relatively dense urban fabric (both in terms of land coverage ratio and built-up density). Functional density and road accessibility to jobs and schools are also high, and presence of city-users in the typical working day is high (much less during weekends). Prevalence of big collective housing is once again a very likely pattern. Like in other central or pericentral sectors, big flats are underrepresented, small flats overrepresented, the rental offer is important. The urban fabric is mainly continuous, sometimes mixed continuous/discontinuous.



Unlike profile SA1, street network morphologies are more irregular, as the planning effort on these sectors has been less intense. Geographically, these sectors are either the first extensions of the city-centres (in Nice, Antibes, Menton) or city-centres where the planning of urban forms has only concerned scattered fragments (Cannes, Cagnes-sur-Mer, Monaco).

### **Profile SA3: Peripheral, mainly residential, irregular urban fabric**

This profile encompasses 15 sectors around the main urban centres and close to the seaside. They adjoin sectors of profile SA2, but their physical differences with planned urban cores (profile SA1) are even bigger. Sectors in profile SA3 are still relatively continuous, or mixed continuous/discontinuous. But they are more irregular, less vascularised and less dense than profiles SA2 and SA1. Big collective housing represents the majority of main homes, but is not as predominant as in profiles SA2 and SA1. Small flats become a bit less common. What distinguishes the most profile SA3 from profile SA2 is that sectors here are by no means central places, neither in working days, nor in weekends. They are mainly residential places, with very weak retail offer. Some variety characterises the profile: peripheral neighbourhoods in Nice and Cannes are marked by big collective housing; in and around Antibes individual homes are very frequent and big collective housing is limited to 40% of the housing stock. Similarities in spatial affordance can also mask different social content: among peripheral residential sectors in Nice we find both upper-middle class and working-class neighbourhoods.

### **Profile SA4: Pericentral, discontinuous, residential or mixed urban fabric, with varied housing**

This profile groups 10 sectors and is another possible issue of the morphological and functional gradient from profile SA1 to profile SA2: SA3 is morphologically closer to SA2, but SA4 shares some of its functional characteristics. Within profile SA4, mixed urban-suburban fabrics are only moderately dense and mainly discontinuous, even if a few dense and continuous cores can be highlighted. Big collective housing is still very present and built-up density is medium to low. Overall, the housing offer mirrors the average characteristics of the study area, showing a mix of collective and individual housing, small, big and medium-sized dwellings, for rental and owner-occupied. Most of this housing stock was built in the post-war decades and in the 1980s (especially suburban subdivisions). SA4 sectors show medium levels of metropolitan usage and centrality, at least during the typical working day. They are thus functionally mixed, sometimes with a residential predominance, but they are never dormitory communities, like SA3 sectors. Like for profile SA5, car accessibility to jobs and schools is relatively good. Geographically, profile SA4 includes peripheral sectors in the big coastal cities (Nice, Antibes, Cannes), emerging new suburban centres or declining old city-centres (as in Grasse).

### **Profile SA5: Pericoastal suburban fabric with high road accessibility**

With its 24 sectors, this profile (together with profile SA3) characterises most of the pericoastal region. Some sectors within profile SA5 are nevertheless coastal or on the southernmost fringe of the middle hinterland. Morphological indicators are essential in characterising profile SA5. Its sectors show typical suburban fabric (eventually interspersed with urban fragments), mainly discontinuous, sometimes even scattered, with low density and limited land coverage ratio. Local building accessibility for pedestrians is low to medium, as a consequence of low density, low vascularisation and generalized presence of dead-ends in the street network. The housing stock has some prevalence of big dwellings, mainly in individual homes. Accessibility to jobs, schools and commerce is relatively mediocre by transit, but is good to extremely good by car. This is the combined result of relative proximity to coastal cities, good highway links and *in situ* presence of business areas (Sophia-Antipolis, Plan-de-Grasse). Some sectors are more definitely residential: on the coast or in suburban areas around Nice, Antibes and Grasse.

## **Profile SA6: Residential, individual-home suburbs with low accessibility in the middle hinterland**

This profile concerns 19 sectors, almost exclusively in the middle hinterland. The situation plays an important role in characterising the profile, together with accessibility, housing and morphology. Sectors have typical suburban fabric, low or very low density and are made up mainly of individual houses, with very limited rental offer. Low density and strong presence of dead-ends in the street network, together with weak vascularisation, produce very low local accessibility levels for pedestrians. Settlement patterns can include several cores (villages, subdivisions or clusters of houses) separated by agricultural/natural areas. Functional density is low (with a few exceptions in the lower Var valley). Accessibility to jobs, schools and commerce is very limited by transit, and mediocre even by car, making a clear difference from the other suburban profile (SA5). Once again, sectors in the lower Var valley are an exception, having better transit/highway links and important job and service concentrations. Geographically, this profile defines a very homogeneous peripheral metropolitan belt, covering the middle section of the main valleys and a few peripheral sectors in Nice.

## **Profile SA7: The upper hinterland with distant, difficult to access villages and mixed housing**

This last profile is made up of only 9 sectors. Just like profile SA6, the situation is fundamental in order to characterise the profile, together with accessibility and housing indicators. The profile concerns sectors with extremely rough topography, mainly in the upper hinterland and exceptionally in the eastern Riviera. Accessibility to jobs, schools and commerce is typically very low, both by transit and by car (but in the coastal sectors). The housing stock is less peculiar than in profile SA6. The built-up fabric is less dense, with low levels of local accessibility, but individual housing is not prevalent and the size distribution of the dwellings is relatively balanced. This profile is also the most mixed in terms of housing offer (for ownership, for rental on the market, social housing, etc.). The majority of dwellings were built before the war, especially in the old villages. Villages, linear urbanisation along valley roads and a few more recent subdivisions, separated by natural areas are the main landscape pattern. Despite the presence of village cores, functional densities are among the lowest in the study area. A few sectors become important leisure centres during the weekend, attracting many city-dwellers from the coast for outdoor activities.

BN algorithms assign individual sectors to the different profiles with extremely low uncertainty (around 0.01). Only four sectors were assigned to a profile with non-negligible uncertainty (0.1 to 0.3). Uncertainty has a spatial structure: affected sectors are mainly around Antibes and show some proximity between the two pericoastal profiles SA4 and SA5.

The regionalisation induced by this typology of spatial affordance in the French Riviera shows that the coastal and pericoastal regions are a mosaic of places of very different kinds, making up the most heterogeneous section of the metropolitan area. On the contrary, almost all the upper hinterland is grouped in the same profile, just like the middle hinterland (with the exception of its southernmost fringe). A profile of residential sectors, with suburban fabric and high car accessibility, is strongly present in the metropolitan area, mainly in the western section of the Riviera. Finally, a double gradient of typically urban spatial affordances characterises the sequences SA1-SA2-SA3 and SA1-SA2-SA4, with a steady decrease in density, regularity of the urban fabric, centrality and functional mix (in the first sequence), density, regularity of the urban fabric and characteristics of the built-up forms (in the second one). Overall, the further from the seaside the more the situation in relation to the coast plays a role in structuring spatial affordance. Closer to the coast, distances from the city-centres and the highway become more crucial factors. Will these spatial structures also emerge in a typology of lifestyles/dwelling regimes? The next section will deal with this second important aspect of place.

## **6. A Typology of Dwelling Regimes**

Even for lifestyles/dwelling regimes, BN clustering algorithms identify seven profiles of places on the French Riviera. More precisely, profiles define dwelling regimes of metropolitan sectors, that is

predominant lifestyles within their resident population. Once again, the belonging to the different profiles regionalises metropolitan space (Figure 5). Probabilistic profiles of dwelling regime are shown in Appendix D and will be commented in what follows.

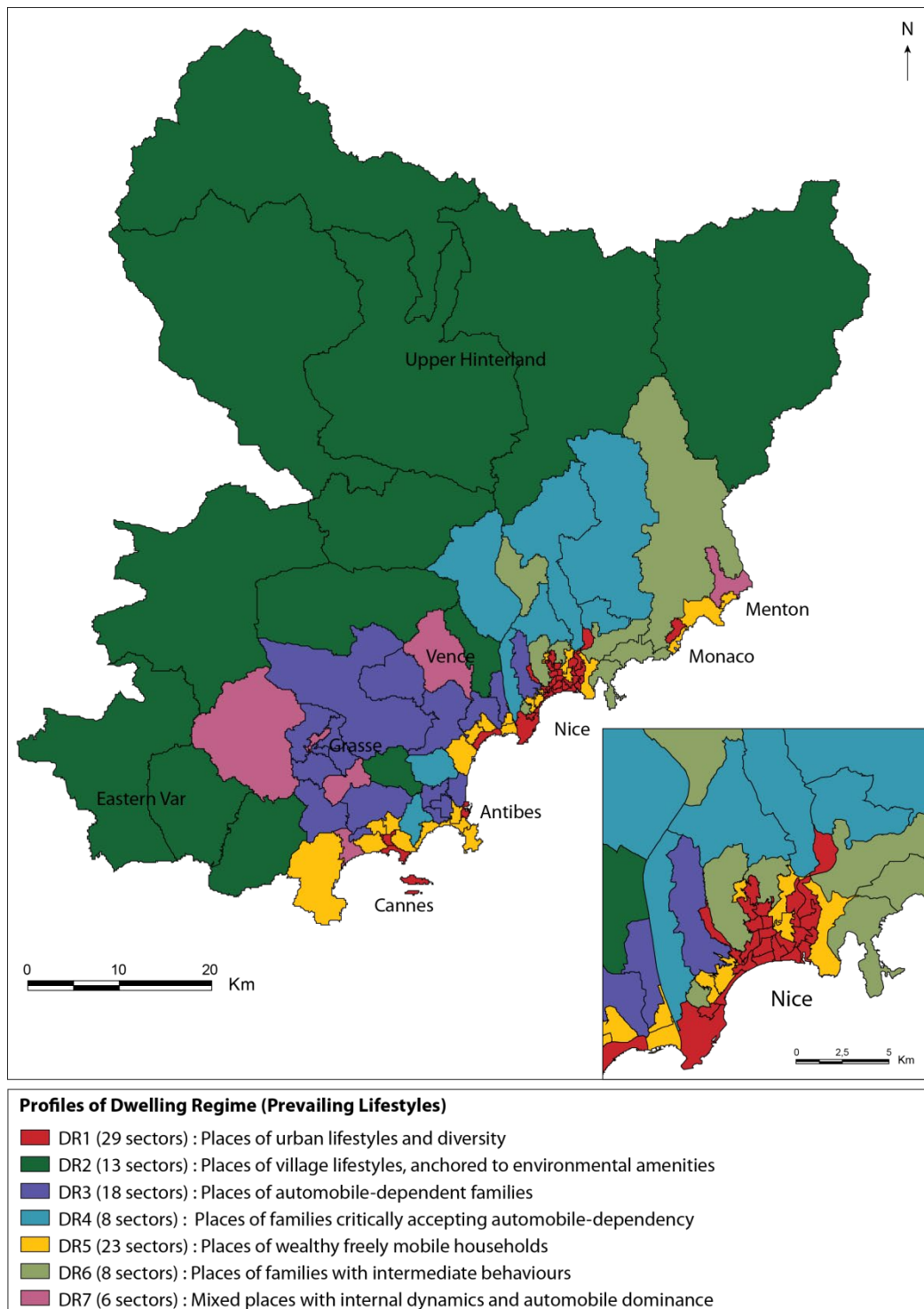


Figure 5 – A typology of dwelling regimes in the French Riviera metropolitan area.

### Profile DR1: Places of urban lifestyles and diversity

It is the modal profile within the metropolitan area, covering 29 sectors. Populations living in these sectors are weakly motorised and have limited practice of car mobility. Conversely, most people walk (sometimes bike), both on working days and on weekends (car mobility is more important on weekends). Owners and tenants balance each other, whereas seniors and people in their fifties living alone

are over-represented. Residents have modal habits which are typical of French city-centres and express positive opinions on modal alternatives to the car, whereas negative opinions on cars and car use are relatively widespread. Globally satisfied with the accessibility levels they enjoy, these urbanites don't see the improvement of the transportation system as a priority. On the contrary, public security is a main concern. On the whole, residents of DR1 sectors tend to be relatively unsatisfied with their housing conditions, are more prone to move and make these sectors net generators of residential mobility within metropolitan space. Nevertheless, these considerations don't hold for all DR1 sectors and some sectors retain their inhabitants more than others. Geographically, this profile concerns the central and the coastal sectors of Nice, Cannes and Antibes, as well as more peripheral coastal sectors.

### **Profile DR2: Places of village lifestyles, anchored to environmental amenities**

This profile encompasses 13 sectors and is profoundly different from the former. The trip domination indicator shows that these territories are relatively autonomous and never dominated by a single metropolitan centre. They are the places of residence for many retirees. Inhabitants are not very mobile, despite good motorisation levels. They are generally satisfied with their housing conditions and living environment; low concerns about insecurity and environmental nuisances witness this widespread satisfaction. In recent years many sectors have become increasingly attractive, confirmed by the high ratio of newcomers and by the low residential emissivity ratio. Residential attractiveness is higher in the middle hinterland and is the lowest in those upper hinterland sectors which do not possess particular leisure amenities. Transportation and poor transit links are nevertheless main concerns for households relying heavily on car mobility. The natural environment is essential for the inhabitants, the desire for natural amenities being an important reason for moving to these sectors. This is also reflected in the widespread practice of outdoor activities. Geographically the profile covers homogeneously the upper alpine hinterland, the sectors of the Department of Var, and, more surprisingly, the sector of Valbonne, home of the Sophia-Antipolis technology centre.

### **Profile DR3: Places of automobile-dependent families**

This profile covers 18 sectors and describes a third distinctive dwelling regime in the French Riviera, the one most closely associated with automobile dependency. Motorisation and modal behaviour indicators have the highest mutual information with the belonging to the profile. DR3 sectors are mainly inhabited by families with children, heavily car-dependent, hyper-mobile and hyper-motorised (which is all the easier as they generally have private parking at home). Although a minority, households of retirees or of people in their fifties living alone are not uncommon in some of the sectors. Of course, car is the most used transportation mode both on working days and on weekends. Mobility flows produced by inhabitants of these sectors create a web among places in the metropolitan area, without being dominated by a single metropolitan centre, reflecting a highly poly-topic practice of metropolitan space. Opinions reflect the predominance of this lifestyle based on high car mobility: households have a positive opinion of the car, of the flexibility and ubiquity it allows, and are not interested in alternatives to it. Geographically, DR3 sectors are situated in the western section of the French Riviera, stretching from the seaside to the southern fringe of the middle hinterland.

### **Profile DR4: Places of families critically accepting automobile-dependency**

This profile strongly resembles the previous one, but concerns only 8 sectors. It completes profile DR3 in identifying places mainly inhabited by families with children having car-dependent lifestyles. These families live their car-dependent hyper-mobility in a more critical way. They are thus more concerned by road safety. Even if they have negative attitudes towards alternatives to the car, many households also advocate the improving of transit links. This reveals a potential for changing the modal habits within these territories. Thus, at least on working days, people in DR4 sectors tend to walk and cycle more than in profile DR3. Even more, positive opinions for the car are not always a majority. Finally, observed hyper-mobility patterns are often due to constrained trips (journeys to work or school). Residents are globally satisfied by suburban amenities at reach. Although they are still attractive for new residents, profile DR4 sectors show weak values of replacement rate during the last 5 years. Finally, residents are relatively polarised by a single metropolitan centre in their daily mobility, often

the city-centre of Nice or the new suburban downtown of the lower Var valley. From a geographical point of view, profile DR4 faces and completes profile DR3: it concerns pericentral or peripheral sectors in the middle hinterland in the eastern section of the French Riviera (above all in the hinterland of Nice), with a few exceptions in the West.

#### **Profile DR5: Places of wealthy freely mobile households**

This profile groups 23 sectors whose resident populations are relatively mixed from a demographic point of view but not socially (the upper classes are always overrepresented and there are almost no social tenants). As far as modal habits are concerned, populations of profile DR5 sectors show average behaviours: both hyper-motorisation and non-motorisation are around the average values of the metropolitan area, car use on working days and on weekend has high probability of being important but it is never the only transportation mode (as it often is in profiles DR3 and DR4) and walking and cycling tend to be very important on weekends. Mobility levels are on the average but non-constraint mobility (for leisure, commerce, service, etc.) is particularly high. Geographically, profile DR5 covers coveted coastal and pericoastal sectors, including the capes and hilly areas north of Nice and Monaco.

#### **Profile DR6: Places of families with intermediate behaviours**

Once again, the profile is complementary to the previous one. It concerns a small number of sectors (8) whose populations are averagely mobile. Unlike profile DR5, probabilities are higher for a more important presence of families with children and for a much lesser presence of retirees. Even more than profile DR5, car use and motorisation levels by these populations stick closer to the average levels of the metropolitan area. Possession of transit season ticket is also on the average, and only private parking space is more frequent than in the rest of the study area. Unlike profile DR5 (this aspect is linked to the socio-demographic content of the profile), non-constraint mobility is less important on working days and people tend to shop for food on weekends. Opinions on alternatives to the car diverge within these sectors. Spatially, profile DR6 includes sectors in the East, namely in the hinterland of Nice and Monaco, but also directly on the coast between Nice and Monaco.

#### **Profile DR7: Mixed places with internal dynamics and automobile dominance**

This profile is the least frequent in the study area, only concerning 6 sectors. Their populations are relatively mixed (prevalence of families with children, followed by retirees) and show some diversity in modal habits: the widespread use of car is combined with positive opinions on this transportation mode; at the same time, the use of transit and walking is important on working days, car use becoming more exclusive on weekends. Possession of transit season tickets is on the average. Residential mobility is low, mainly within the sector and is not particularly dependent on the main metropolitan centres. At the same time, on working days just like on weekends, residents are not attracted by any single metropolitan centre. The majority of households are unsatisfied by their housing conditions. Together with local residential movements, this could be explained in two different ways: location is a priority more than intrinsic characteristics of the dwelling or, much more simply, strong constraints (financial, logistical, etc.) play both on housing and location choice. For once, no clear geographic cluster emerges, even if most of the sectors are in the western section of the metropolitan area and include a few secondary urban centres (Grasse, Vence).

Despite missing values, sectors are assigned to profiles with extremely low uncertainty (around 0.01), with a few exceptions. The city-centre of Cagnes-sur-mer is thus assigned to profile DR5 with probability 0.75, with a residual probability of 0.25 of being assigned to profile DR1 (urban lifestyles). This shows well the ambiguous classification of an increasingly residential city-centre having left central activities migrate towards the seaside over the last decades.

On the whole, the regionalisation produced by this typology of dwelling regimes shows homogeneity in the prevailing lifestyles of the most peripheral metropolitan sectors, namely the upper alpine hinterland and the eastern section of the Department of Var. The seaside is marked both by urban lifestyles and by wealthy freely mobile households. The middle hinterland and the pericoastal area are finally segmented by different regimes. These are on average characterised by high (more or less constrained) mobility levels and by prevalence of car mobility (sometimes in the form of car

dependency), more or less accepted and lived with. This segmentation, with a few exceptions, is marked by dividing lines following the main valleys, more or less perpendicular to the seaside.

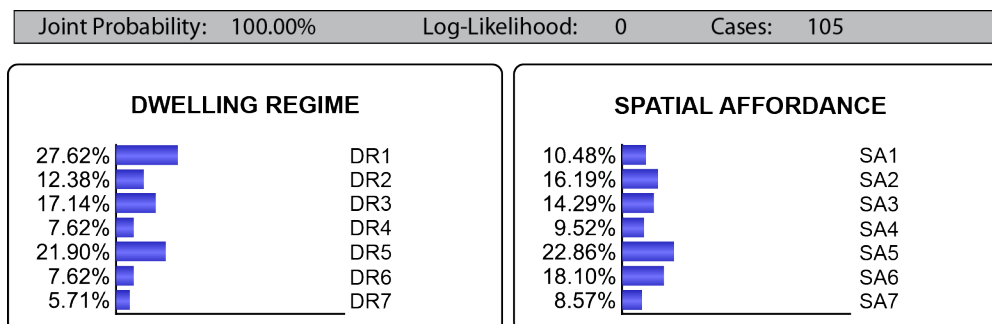


Figure 6: *A priori* probabilities for spatial affordance (SA2-SA5) and dwelling regimes (DR3-DR6).

## 7. Categories of place as combinations of Spatial Affordance and Lifestyles: an Empirical Cross-Analysis

The comparison of the two regionalisations shows sometimes strict correspondence, sometimes just partial overlapping or multiple correspondences between spatial affordance and dwelling regime of places. Nevertheless, not all combinations of spatial affordances and prevailing lifestyles are possible. It is thus interesting to use BN to explore probabilities of association among profiles. Correspondences, even when they are complete, cannot be explained through simple cause-to-effect relations (a given spatial affordance producing the prevailing lifestyle of residents), as territorial phenomena are much more complex. Spatial affordance factors and lifestyles set in over several decades. Once a lifestyle has spread to become a dwelling regime within a place, it can contribute to shape its spatial affordance: building types, housing offer, road and transit links are also the fruit of planning decisions or market behaviours responding to established lifestyles. Furthermore, as the same spatial affordance can correspond to different dwelling regimes, we have to dismiss any determinism of spatial affordance, a possibilistic approach being much more appropriate. Indeed, we will look for categories of places by identifying consistent associations between spatial affordances and dwelling regimes. Statistical consistency will be used as an indicator of “congruence”, following Offner (1993) on the relationship between transportation and territorial development: no simple cause-to-effect but complementarity between phenomena observed in a more complex system behaviour. Once again, BN offer an interesting modelling opportunity. The starting point is the *a priori* probabilities of the different profiles of place within the study area (Figure 6), which will serve as reference point in the cross-analysis.

The first question underlying our analysis is to reveal the dwelling modes which are most probably associated with every kind of spatial affordance. Answering this question means identifying empirically the ability of spatial affordance to be “congruent” with a subset of prevailing lifestyles of the resident population. BN can answer this question with *a posteriori* probability distributions whenever the spatial affordance class is entered as evidence (Figure 7). The second question, mirroring the previous one, is to identify the spatial affordance compatible with a given dwelling regime. We can thus understand the residential attraction exerted by places with different spatial affordance for households attached to a particular lifestyle. Once again, the BN model supplies *a posteriori* probability distributions whenever the dwelling regime is entered as evidence (Figure 8).

The cross-analysis of spatial affordance and lifestyles within the metropolitan area of the French Riviera comes to the following main results:

- First of all, spatial affordance of places with higher density, centrality, functional and social diversity seem to have a real ability to catalyse urban lifestyles within the resident population, showing reduced hyper-mobility and hyper-motorisation and favouring modal alternatives to the car. Profile DR1 corresponds thus with high probability to spatial affordances SA2 and SA1 and only to a lesser degree SA3. The association is perfect between SA1 and DR1. SA2 is also strongly associated with urban lifestyles, but can also be the habitat of less diverse populations (wealthy

freely mobile households of profile DR5). Profile SA3 is compatible with urban dwelling regime DR1, but the latter is neither the only nor the most probable regime associated with it. Some factors of dissatisfaction over quality of life in the city (security, housing conditions) can nevertheless push households with urban lifestyles to move to places which are less compatible with them.

- Secondly, a link exists between car dependent lifestyles and residential suburban fabric. On the one hand, the most car-dependent dwelling regime (DR3) has high probability (over 0.6) of finding its ideal habitat in places with spatial affordance profile SA5, with the second most probable habitat being residential suburban fabric in the middle hinterland (SA6). Car-dependency is thus experienced in a relatively positive way in places closer to the seaside and the highway network, producing high accessibility levels. It starts to be challenged (dwelling regime DR4) in places of the middle hinterland that do not enjoy high accessibility levels (spatial affordance SA6 with probability 0.75). This could incline part of the resident population within these sectors to accept changes in the spatial affordance (namely in terms of urban morphology and transportation links) making space less prone to car dependence. It should be remarked that highly accessible residential suburban fabrics close to the seaside (profile SA5) are compatible with a wide variety of dwelling regimes. If car-dependent DR3 lifestyles are the most probable (0.45), all other dwelling modes (with the exception of urban lifestyles DR1) can become predominant in these places, and more particularly the dwelling mode of the freely mobile wealthy households (DR5).

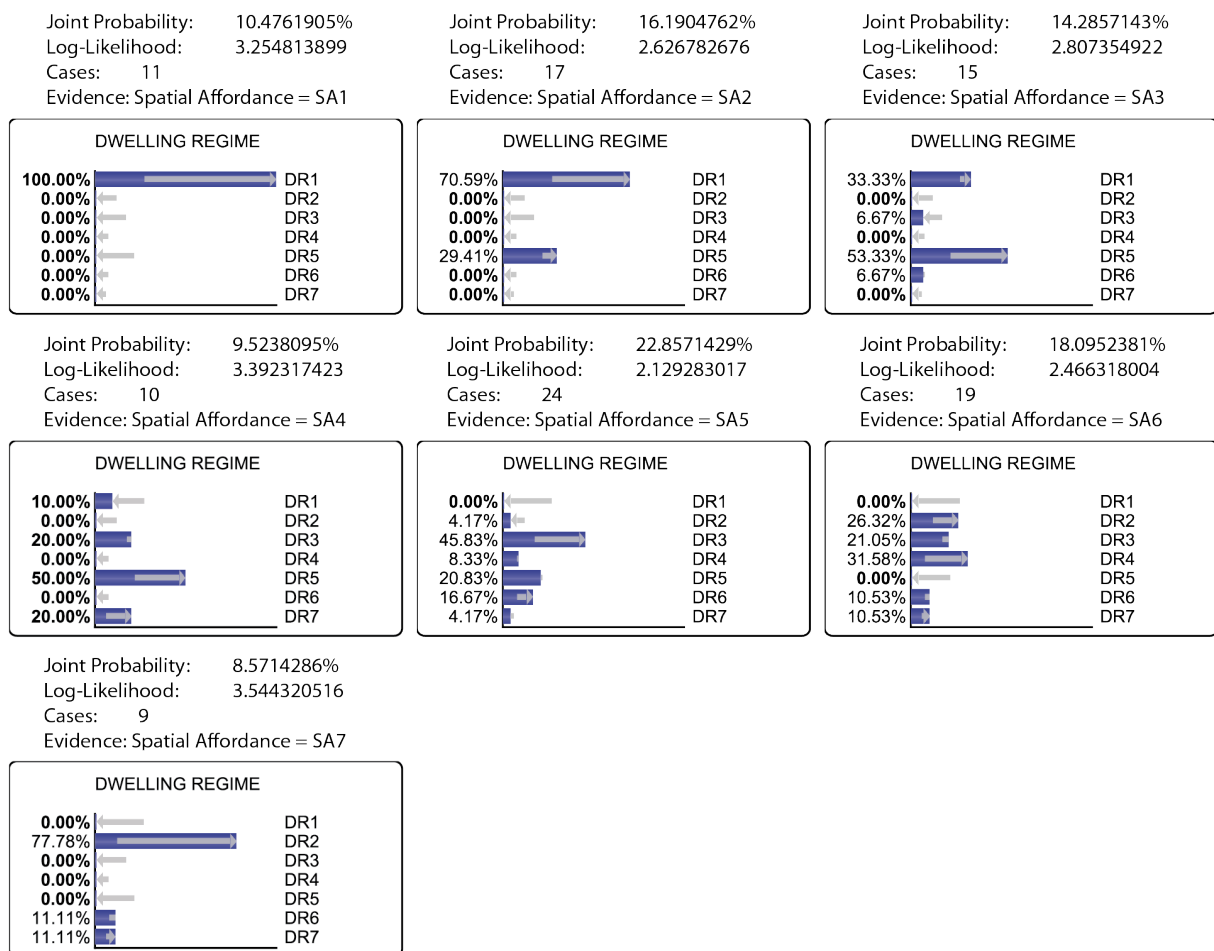


Figure 7: Probabilistic correspondence of prevailing lifestyles with a given class of spatial affordance.



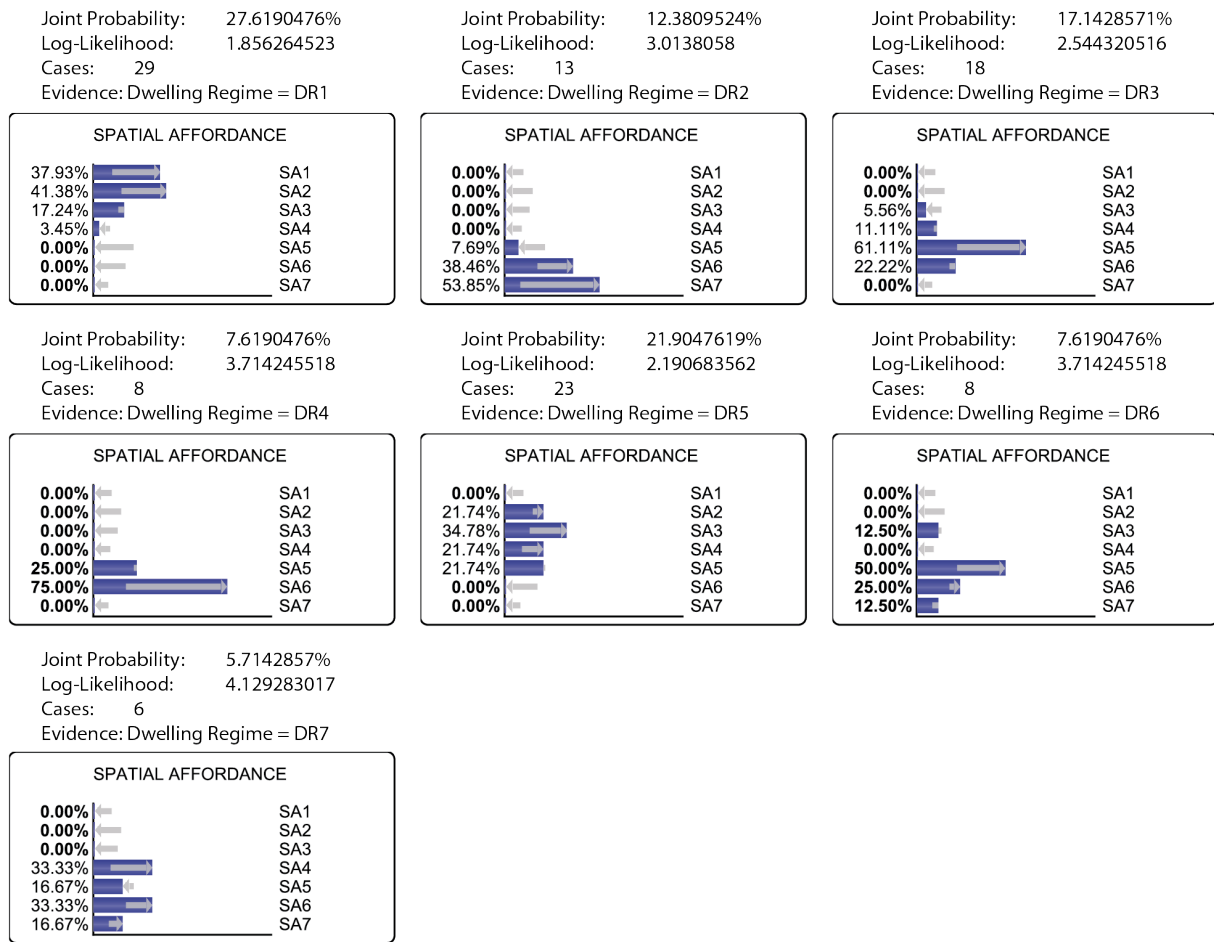


Figure 8: Probabilistic correspondence of spatial affordance with a given class of prevailing lifestyle.

- Thirdly, village lifestyles (DR2) find their ideal habitat in sectors of the middle and upper hinterland (spatial affordance profiles SA6 and SA7). Within these sectors two different fabrics combine: old villages (predominant in SA7) and residential subdivisions (predominant in SA6). What unites these two profiles is the presence of highly appreciated environmental amenities, which is a priority for DR2 lifestyles, but also low accessibility levels by car and transit. Exceptionally, village lifestyles are possible in residential suburban sectors closer to the seaside. The dwelling regime DR2 concerns here more affluent populations (metropolitan-rural), like in Valbonne. The Eastern Var sectors have spatial affordance of residential suburban fabric with relatively good car accessibility but are the habitat for normally more peripheral village lifestyles. Looking for the dwelling regimes most probably associated with spatial affordance types SA7 and SA6, we find that SA7 is almost always associated with village lifestyles (except for the coastal sectors, linked to more mobile DR7 and DR6 regimes). This is not true for residential suburban fabric in the middle hinterland (SA6), which is compatible with a diversity of lifestyles, but urban lifestyles (DR1). This diversity shows that strong car dependency (DR3, DR4) is not the only possible regime in the middle hinterland of the Riviera.
- Finally, one of the main peculiarities of the Riviera is the existence of places with a preponderance of wealthy freely mobile populations (profile DR5). Spatial affordance types compatible with this lifestyle are diverse (SA3, SA2, SA4 and SA5) but have a few common properties. The first three are relatively dense and close to metropolitan centres, enjoying very good accessibility for car, transit and walking. Increasing social diversity to take in households more prone to the use of transit, walking or cycling (students, lower income households) could make these places less dependent on car mobility. When associated with DR5 dwelling modes, pericoastal suburban fabrics (SA5) are highly coveted seaside sectors with expensive individual housing. By reverting our analysis, spatial affordance of types SA3 and SA4 are compatible with different dwelling regimes. The former is associated with wealthy freely mobile populations (DR5 with probability



0.53) as well as with urban lifestyles (DR1 with probability 0.33). The latter can be the habitat for freely mobile populations (DR5 with probability 0.50), for mixed populations with internal dynamics and automobile dominance (DR7 with probability 0.20) and with car-dependent families (DR3 with probability 0.20).

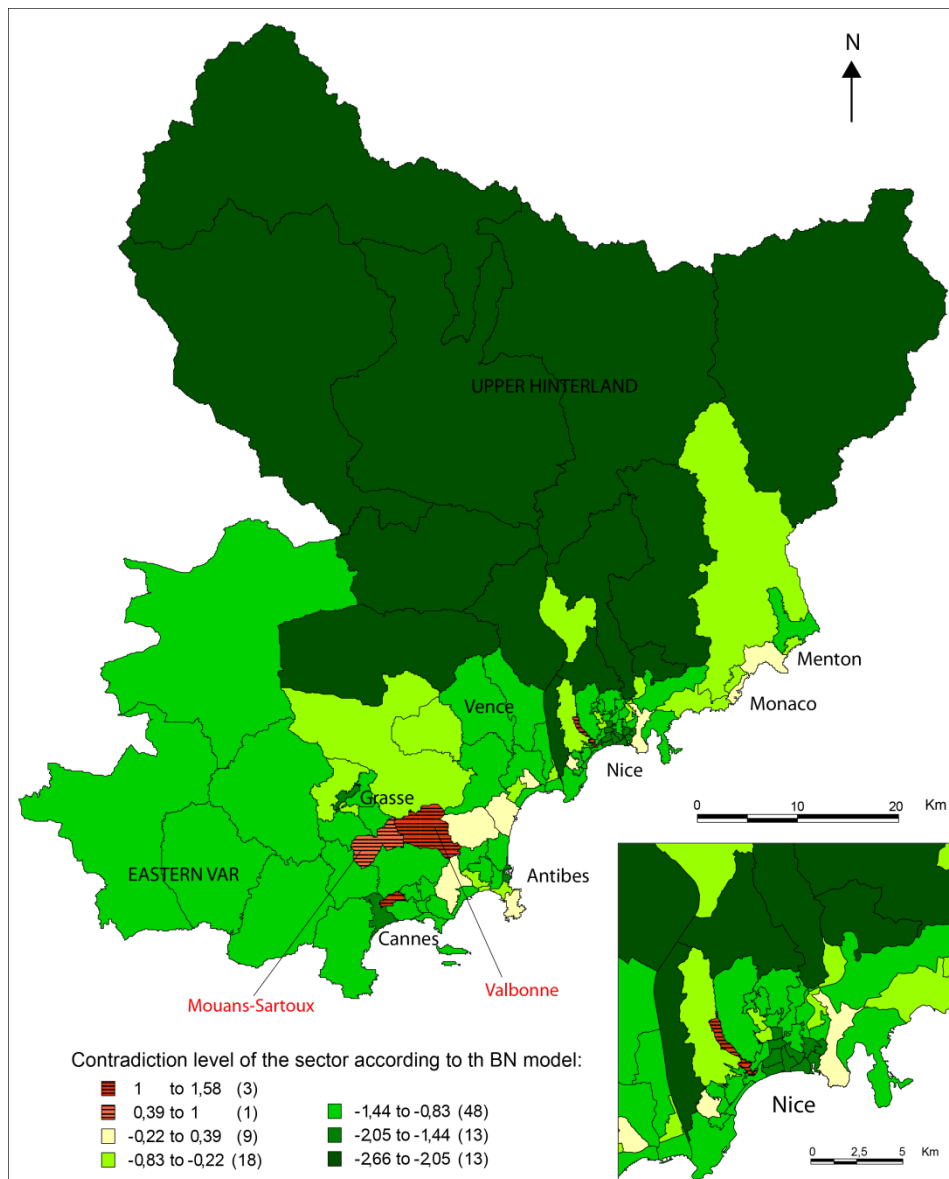


Figure 9: Contradiction analysis in the study area.

Associations between spatial affordance and dwelling regime profiles are the result of statistical regularities that hold within the study area and are reflected in the probability tables of the BN model. It is possible to evaluate the overall relation between the two variables. Their symmetric normalized mutual information is thus 41.84% (meaning that every variable already includes more than 40% of the information content of the other one). By focusing only on the most probable associations between the stochastic variables, the predictive power of the probabilistic model is even higher than this value: dwelling regime can be predicted with 57.14% accuracy from spatial affordance, whereas the latter can be predicted with 47.62% accuracy from dwelling regime, and this without any particular hypothesis of cause-to-effect relation between the variables.

Geographers are often interested both in models and in deviations from models. It is thus possible, thanks to the probabilistic approach, to analyse the contradiction level between the BN model and every sector of the metropolitan space (Figure 9). Contradiction level is the base-2 logarithm of the ratio between the product of independent probabilities for the observed spatial affordance and dwelling

regime profiles for a given sector (no link is supposed to exist between them) and the joint probability expressed by the BN model (where the probabilistic link is assumed). The value is usually negative, as the BN model encodes statistical dependencies that have higher likelihood than the unconnected model. The lower the value, the better the BN describes the relationship between spatial affordance and dwelling regime in the sector. This is for example the case for much of the upper hinterland, for the middle hinterland north of Nice and for the central neighbourhoods in Nice.

A few sectors are nevertheless exceptions to the statistical regularities encoded in the BN model. They are hatched in Figure 9 and have positive contradiction levels. In the western section of the Riviera, the sectors of Valbonne and Mouans-Sartoux are good examples of such exceptions. They have both spatial affordance of type SA5 (pericoastal suburban fabric with high road accessibility), which is typically associated with dwelling modes DR3 or DR5. On the contrary, they show specific patterns of village lifestyles DR7 (Valbonne) and of mixed-population places with internal dynamics and automobile dominance DR2 (Mouans-Sartoux). The BN model can thus indicate both archetypical associations between spatial affordance and lifestyles, which define the most representative categories of place in the study area, and cases where the probabilistic relationships are challenged, suggesting local specificities that characterise different patterns of place.

## 8. Conclusions

Overall, our applications show how it is possible to generalise categories of places (on the basis of profiles of spatial affordance and of dwelling regimes and of some probabilistic relationships between the two). The three BN models provide the generalisations we were looking for, but do allow exceptions, hinting at the existence of a few unique instances of places, whose peculiarities are nevertheless identified and categorized. More generally, BN segmentation allows the search of archetypes of place within an appropriate spatial database. BN can thus be employed to develop a mix of theory-driven and data-driven modelling methodology that echoes the heuristics of the search of ideal types first proposed by Max Weber (1914). The probabilistic framework of BN proves particularly well suited to capture the fuzzy relationship existing between spatial affordance and lifestyles. The data-mining applications were relatively robust and were able to produce elements of knowledge from incomplete databases and imperfect indicators. They were also able to assess the uncertainty of the results.

A few limits in the proposed methodology have to be highlighted. The main weakness of the application is the limited number of case studies (the 105 sectors of the Household Mobility Survey in the French Riviera), which sometimes resulted in over fitting and/or in the creation of profiles of places with intermediate characteristics, very few sectors and dubious generalization aptitude. A second weakness concerns the quality of the indicators used. Noisy values for some indicators are mainly the result of the uneven definition of spatial units: sectors in the coastal cities are much smaller and are fairly well described by our indicators, whereas sectors in the hinterland are generally much bigger and are characterised by wider inner diversity both in terms of spatial affordance and of dwelling modes. Spatial unit definition was unfortunately imposed by the main source of data (the household mobility survey) and could not be modified without losing statistical reliability.

Of course, the data-driven application does not follow a purely inductive data mining approach: concepts were created with a background of theoretical assumptions and indicators for these concepts were later sought for. Indeed, the conceptualisation behind indicators selection and measurement contributes to the robustness of the analysis. As far as the concepts are concerned, the research confirms the need to enlarge the view of the built-up form / mobility relationship. More particularly, it shows the usefulness of the concepts of spatial affordance and of dwelling regime (prevailing lifestyles). Both terms of the analysis (spatial affordance, on the one side, and dwelling regime, on the other) emerge as systemic characteristics of places. The different aspects of built-up form overlap among them as well as with other functional and perceived characteristics of the urban space, contributing to a more general “habitat” or “ecosystem” for urban and metropolitan life, well captured by the concept of spatial affordance, to which we gave a first operationalization. At the same time, mobility behaviours were placed within the broader context of lifestyles of metropolitan populations, reflecting their habits, attitudes, values and aspirations in the metropolitan space. Finally, place itself,

characterised both by spatial affordance and dwelling regime, was always considered as an elementary cell within the relational space of the metropolitan area. On the bases of these concepts and of the BN methodology, we produced a better understanding of the spatial segmentation of the metropolitan area of the French Riviera. Several issues usually raised within urban sustainability policies (like car dependency, urban sprawl, hyper-mobility vs. lack of mobility, etc.) appear as facets of more complex relationships between spatial affordance and lifestyles and impact differently the sectors of the metropolitan area. These relationships cannot be reduced to simple cause-to-effect and policies aiming at curbing or fostering particular phenomena (be it car dependency or urban densification) should take into account these complex relationships shaping places.

Further developments of the proposed methodology could open new perspectives for planners wishing to understand and to solve crucial issues of urban sustainability in a metropolitan context. First of all, further empirical studies following the proposed protocol of analysis will be welcome in order to generalise the results we found on the French Riviera: it could then be possible to identify even more consistent connexions between spatial affordance and dwelling regimes in metropolitan contexts.

Social morphology issues could be better integrated in the analysis, enriching both the characterisation of spatial affordance (housing, availability of service, quality of public space, planning policies, etc.) and dwelling modes. Other essential sustainability issues of metropolitan development could then be addressed, namely residential segregation (selective gentrification and pauperisation of places within the metropolitan area), with the associated impacts on mobility behaviours and dwelling regimes.

Description of spatial affordance of places should also be enriched by ad-hoc surveys, exploring the cognition of metropolitan space and of its characteristics by its inhabitants. Perceived and objectively measured spatial characteristics could then be cross-analysed. This is a direction of research already exploited by sociologists of transportation (Kaufmann 2000) using more qualitative protocols than our Bayesian approach.

In a different perspective, typologies could be produced for “trajectories” of places, following their evolution over time in terms of spatial affordance and dwelling regime. By reconstructing trajectories of places within a given metropolitan area over several decades, we could improve our understanding of the role of the metropolisation process on observed patterns of change. This could also open the way to metropolitan strategic foresight and scenario building in the light of the probabilistic relations describing the trajectory of places within the metropolitan area.

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## Appendix A – The 27 Indicators of Spatial Affordance

### Geographic Situation within the Metropolitan Area

1. SITUATION: Situation with respect to the seaside (coastal, pericoastal, middle hinterland, upper hinterland)
2. CENTRALITY: Visiting ratio during working days (incoming trips / resident population, homebound trips are excluded)
3. WEEKEND CENTRALITY: Visiting ratio during weekends (incoming trips for leisure activities and shopping / resident population)

### Morphology of the Built-Up Fabric

4. LAND COVERAGE: Land coverage ratio within the built-up area
5. FUNCTIONAL DENSITY: Functional density ratio (jobs + education places + resident population / built up area)
6. BUILT-UP DENSITY: Building floorage density within the built-up area
7. TYPICAL SPACING: Typical spacing between built-up elements (A = 5-20 m, B = 28-113 m, C = 160-1280 m, the two most significant values are considered resulting in spacing typologies like AA, AB, BC, etc.)

### Morphology of the Street Network

8. VASCULARISATION: Vascularisation of the built-up area by the street network (lengths of street segments / built-up area)
9. DEAD ENDS: Share of degree 1 nodes in the street network
10. CROSSROADS: Share of nodes with degree 4 or more in the street network
11. LOCAL REACH: Local accessibility to built-up elements (nb of built-up elements within 2 km on the street network)
12. STRAIGHTNESS: Normalised straightness of the street network within a 2 km radius (average ratio between Euclidean distance and network distance when connecting all buildings closer than 2 km)

### Socioeconomic Morphology

13. SOCIAL MIX: Social diversity measured on the housing occupation status (relative entropy index compared to average distribution in the study area)
14. FUNCTIONAL MIX: Functional diversity (relative entropy index compared to average distribution in the study area)
15. RETAIL RESIDENTIAL MIX: Balance between retail and residential functions (retail surface / 1000 inhabitants)

### Accessibility

16. ROAD ACCESSIBILITY JOBS: Road accessibility to jobs and education places (< 30 minutes on the road network)
17. TRANSIT+WALK ACCESSIBILITY JOBS: Transit + Walking accessibility to jobs and education places (< 30 min on the transit network + walking)
18. ROAD ACCESSIBILITY RETAIL: Road accessibility to retail activity (retail surface < 30 minutes on the road network)
19. TRANSIT+WALK ACCESSIBILITY RETAIL: Transit + Walking accessibility to retail activity (retail surface < 30 minutes on the transit network + walking)

### Housing

20. INDIVIDUAL HOUSING: Share of individual housing in the housing stock
21. FLATS IN BUILDINGS: Share of flats in high- to medium-rise buildings (more than 3 floors) in the housing stock
22. SMALL FLATS: Share of one- and two-room apartments in the housing stock
23. BIG DWELLINGS: Share of dwelling with at least 4 main rooms in the housing stock
24. RENTAL HOUSING STOCK: Share of dwelling for rental (both social housing and private sector) in the housing stock
25. OLD DWELLINGS: Share of dwelling built before 1949 in the housing stock
26. POST-WAR DWELLINGS: Share of dwelling built between 1949 and 1974 in the housing stock
27. 80s-90s DWELLINGS: share of dwelling built between 1982 and 1990 in the housing stock

## Appendix B – The 46 Indicators of Dwelling Regime

### Socio-demographic Characteristics of Households

1. COUPLES CHILDREN: Share of couples with children within the resident households
2. SINGLES >50: Share of singles aged 50 or more within the resident households
3. EXECUTIVES: Share of executives and professionals within the resident population aged 6 or more
4. WORKERS EMPL: Share of workers and employees within the resident population aged 6 or more

1	5. RETIREES: Share of retirees within the resident population aged 6 or more
2	6. OWNERS: Share of households owning their main home
3	7. SOCIAL TENANTS: Share of households living in subsidized social housing (HLM tenants)
4	<b>Daily Mobility Habits of Households</b>
5	8. METRO DOMINATION WD: Share of trips towards the dominant metropolitan centre on working days
6	9. INTERNAL WD: Share of internal trips on working days
7	10. IMMOBILITY: Share of resident population not leaving their dwelling on working days
8	11. HYPER-MOBILITY: Share of hyper-mobile residents (more than 4 trips / day) on working days
9	12. SOFT MOBILITY: Share of soft mobility (pedestrian or bicycle trips) to and from the survey sector
10	13. CAR MOBILITY: Share of car or motorbike trips to and from the survey sector
11	14. NON-SYSTEMATIC MOB: Share of non-systematic trips (motives commerce, service, leisure, etc.) by the
12	resident population
13	<b>Weekend Mobility Habits of Households</b>
14	15. FOOD WE: Share of resident population shopping for food on weekends
15	16. HOME LEISURE: Share of home leisure activities among weekend leisure activities
16	17. OPEN-AIR LEISURE: Share of environmental / open-air leisure activities among weekend leisure activities
17	18. METRO DOMINATION WE: Share of trips towards the dominant metropolitan centre on weekends
18	19. INTERNAL WE: Share of internal trips on weekends
19	20. SOFT MOBILITY WE: Share of pedestrian or bicycle trips to and from the survey sector on weekends
20	21. CAR MOBILITY WE: Share of car or motorbike trips to and from the survey sector on weekends
21	<b>Residential Mobility and Motivations</b>
22	22. RESIDENTIAL ROOTING: Share of households living in the sector from before 1988
23	23. RESIDENTIAL TURNOVER: Share of newcomers (households having moved in the sector after 2005)
24	24. FINANCIAL CONSTRAINT MOVING IN: Share of households mentioning financial constraint among the reasons
25	for having moved in the sector
26	25. BIGGER DWELL MOVING IN: Share of households mentioning the need of a bigger dwelling among the
27	reasons for having moved in the sector
28	26. SUBURBAN AMENITIES MOVING IN: Share of households mentioning the desire of suburban and exurban
29	amenities among the reasons for having moved in the sector
30	27. SUBURBAN AMENITIES DISSATISFACTION: Share of households mentioning the lack of suburban and
31	exurban amenities as housing dissatisfaction factor in the sector
32	28. DWELL QUALITY DISSATISFACTION: Share of households mentioning poor dwelling quality as housing
33	dissatisfaction factor in the sector
34	29. HOUSING SATISFACTION: Share of households satisfied with their housing conditions in the sector
35	30. INTERNAL RESIDENT MOVES: Share of residential inflows from households already living in the sector
36	31. RESIDENT MOVES N-C-A: Share of residential inflows from households previously living in Nice, Antibes or
37	Cannes
38	32. RESIDENT MOVES OUT OF METRO: Share of residential inflows from households previously living outside the
39	metropolitan area
40	33. RESIDENTIAL EMISSIVITY: Residential emissivity ratio (population moving out of the sector between
41	2003 and 2008 / resident population in 2008)
42	<b>Household Equipment for Transportation</b>
43	34. NON-MOTORIZED: Share of non-motorized households (households having no motor vehicle)
44	35. HYPER-MOTORIZED: Share of hyper-motorized households (households having at least one motor vehicle
45	per person aged more than 14)
46	36. PRIVATE PARKING: Share of motor-vehicles enjoying private parking space / garage at night
47	37. SEASON TICKET: Share of population aged 5 or more having transit season ticket and no driver licence
48	38. NO SEASON TICKET NO LICENCE: Share of population aged 5 or more having neither transit season ticket and
49	nor driver licence
50	<b>Opinions on Local Life and Mobility</b>
51	39. POSITIVE OPINION CAR: Share of resident population having positive opinions on the car
52	40. POSITIVE OPINION CAR ALTERNATIVE: Share of resident population having positive opinions on alternatives
53	to the car (transit, walking, cycling)
54	41. SECURITY PRIORITY: Share of resident population thinking that public security is a priority for improving
55	quality of life
56	42. TRANSPORT PRIORITY: Share of resident population thinking that transportation is a priority for
57	improving quality of life
58	43. EMPLOYMENT PRIORITY: Share of resident population thinking that employment is a priority for
59	improving quality of life

44. ROAD SAFETY PRIORITY: Share of resident population thinking that road safety is a priority for improving mobility of people
45. TRANSIT PRIORITY: Share of resident population thinking that transit is a priority for improving mobility of people
46. POLLUTION PRIORITY: Share of resident population thinking that noise and pollution are a priority for improving mobility of people

## Appendix C – The Probability Profiles of Spatial Affordance Clusters

Reading key: variables are listed in descending order of mutual information with the considered cluster. Only the most important 23 variables are shown. Colours regroup variables according to underlying synthetic factor.

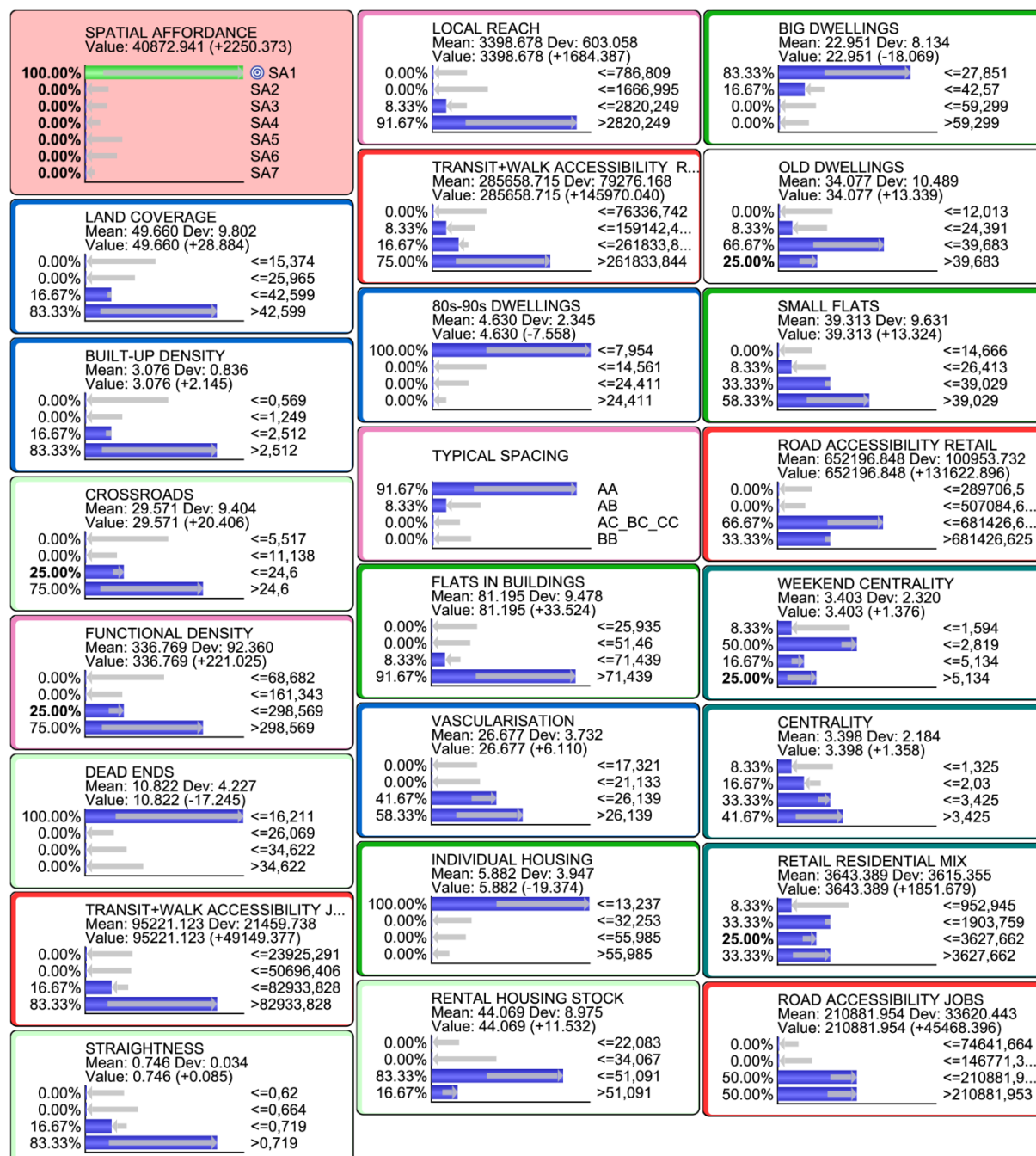


Figure C1 – Probabilistic profile of cluster SA1 - Planned urban cores with meshed, dense and old urban fabric.



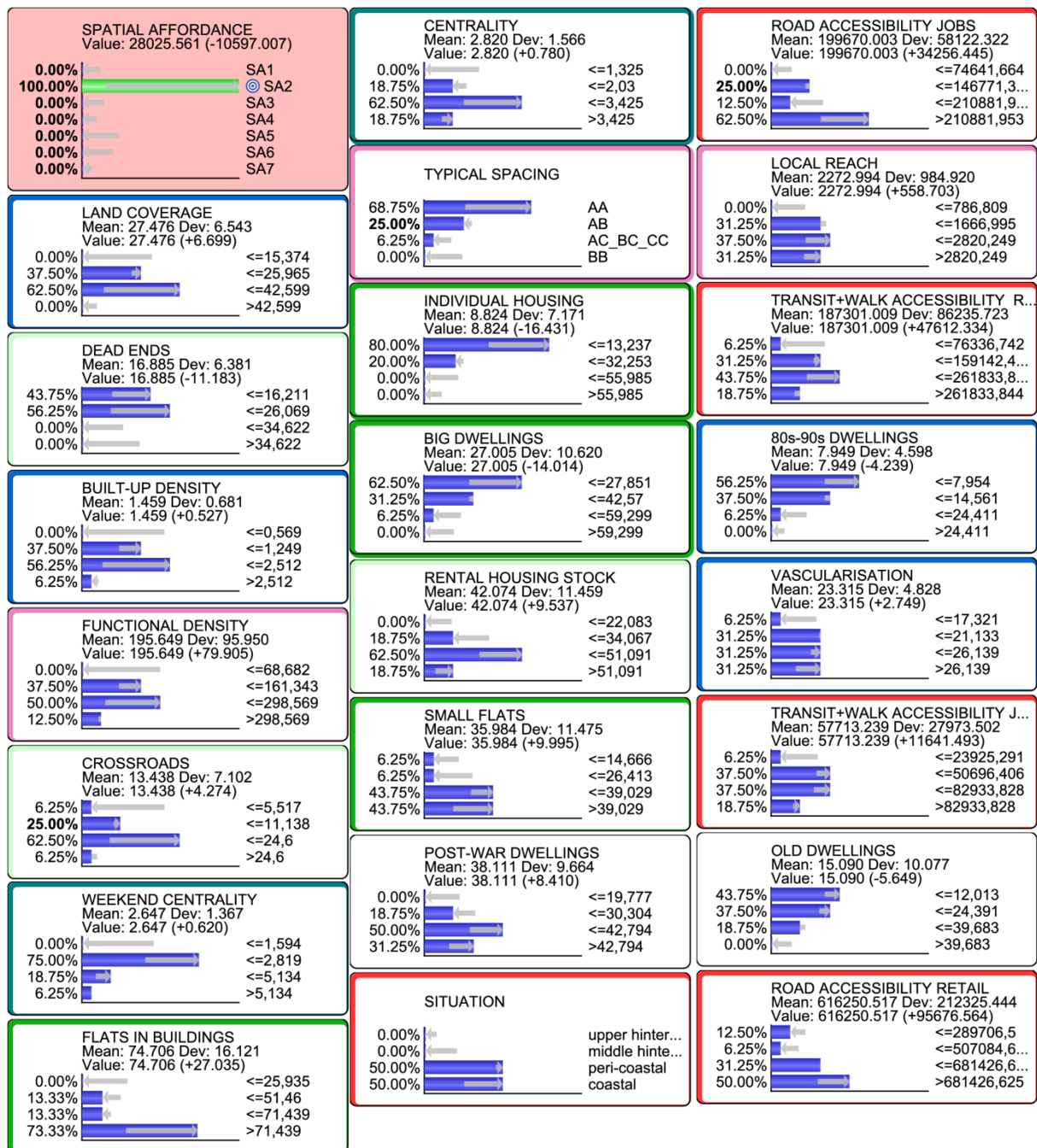


Figure C2 – Probabilistic profile of cluster SA2 - Centres and pericentral extensions with dense but irregular urban fabric.

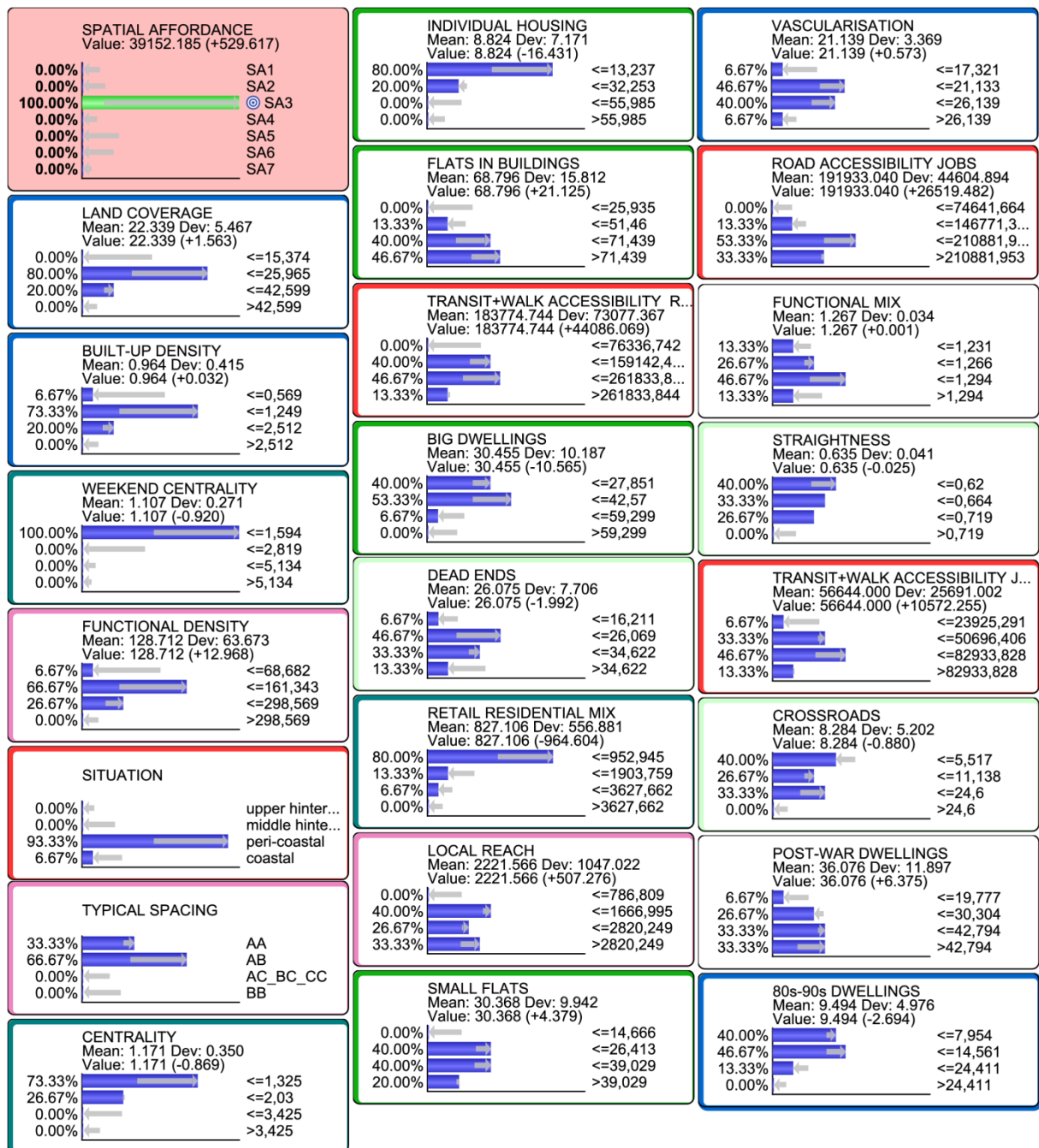


Figure C3 – Probabilistic profile of cluster SA3 - Peripheral, mainly residential, irregular urban fabric.

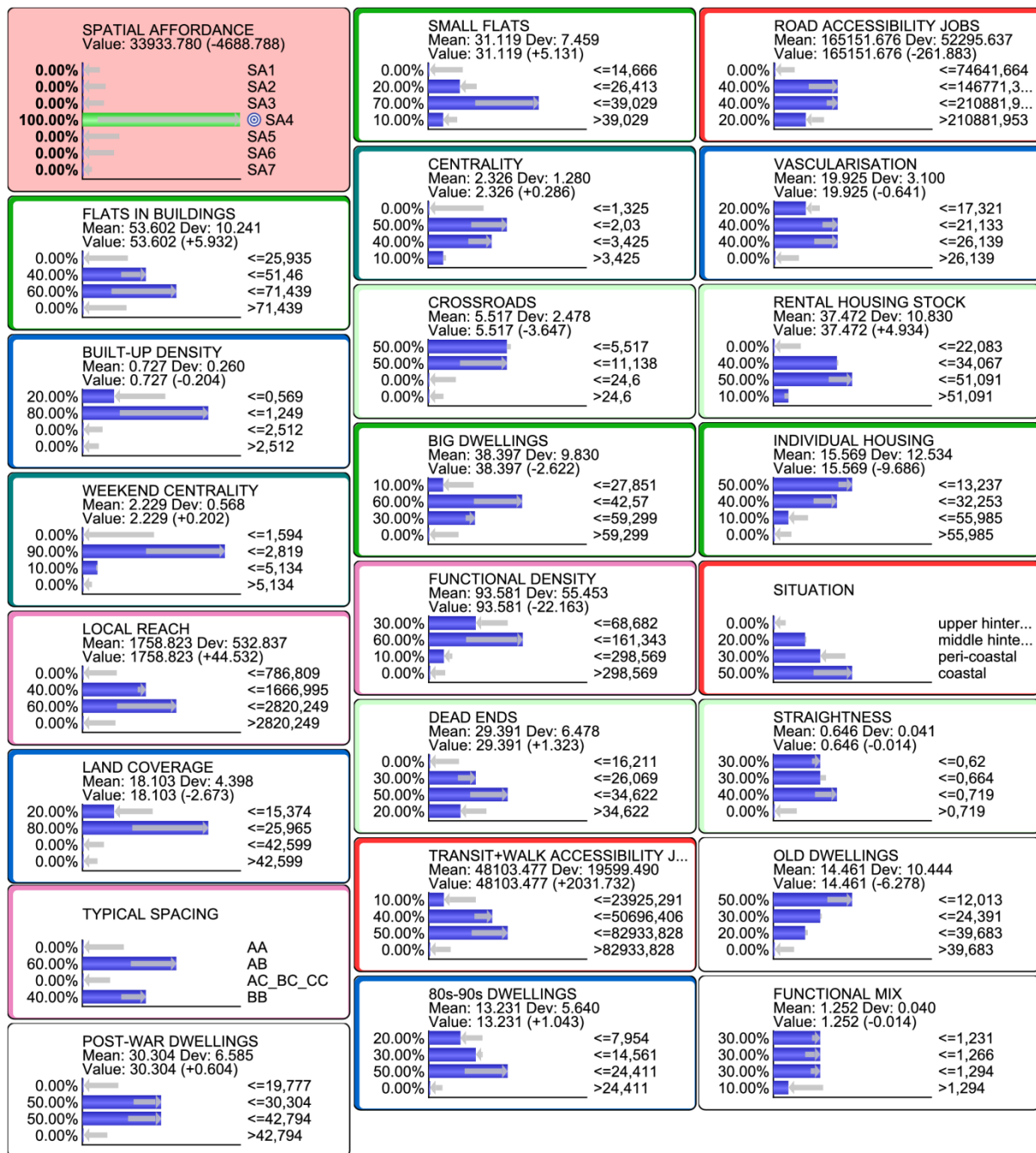


Figure C4 – Probabilistic profile of cluster SA4- Pericentral, discontinuous, residential or mixed urban fabric, with varied housing.

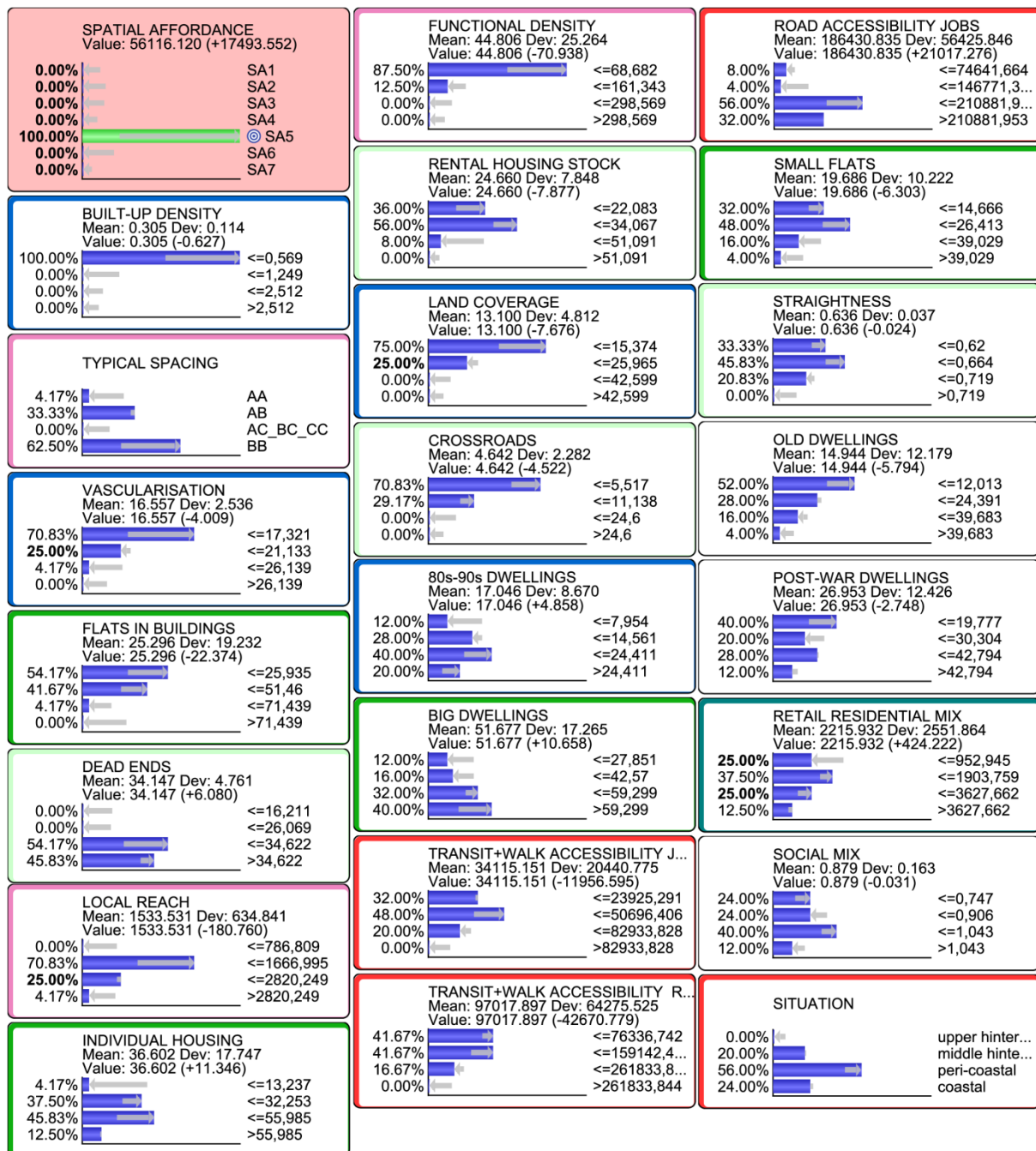


Figure C5 – Probabilistic profile of cluster SA5- Pericoastal suburban fabric with high road accessibility.



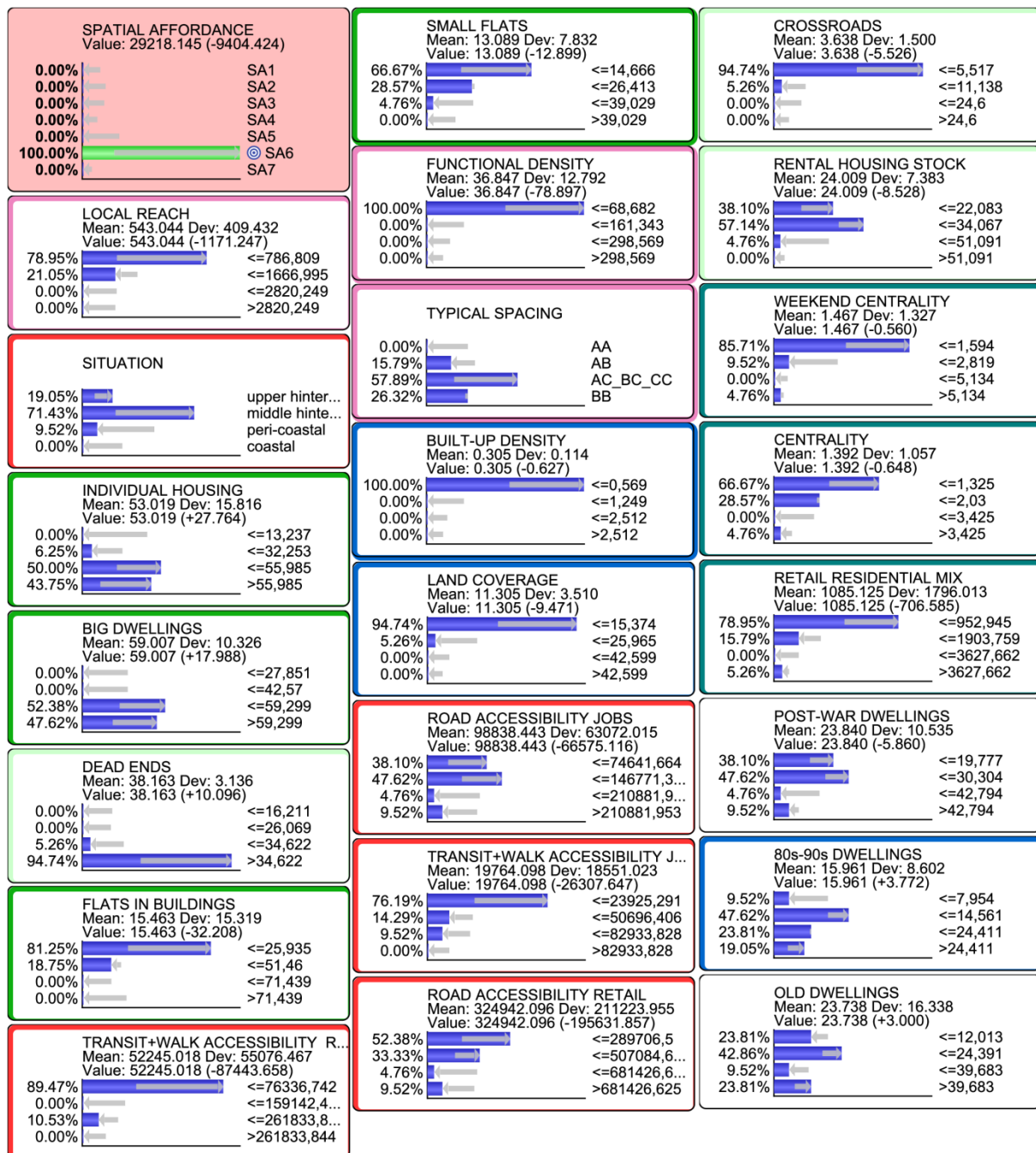


Figure C6 – Probabilistic profile of cluster SA6 - Residential, individual-home suburbs with low accessibility in the middle hinterland.

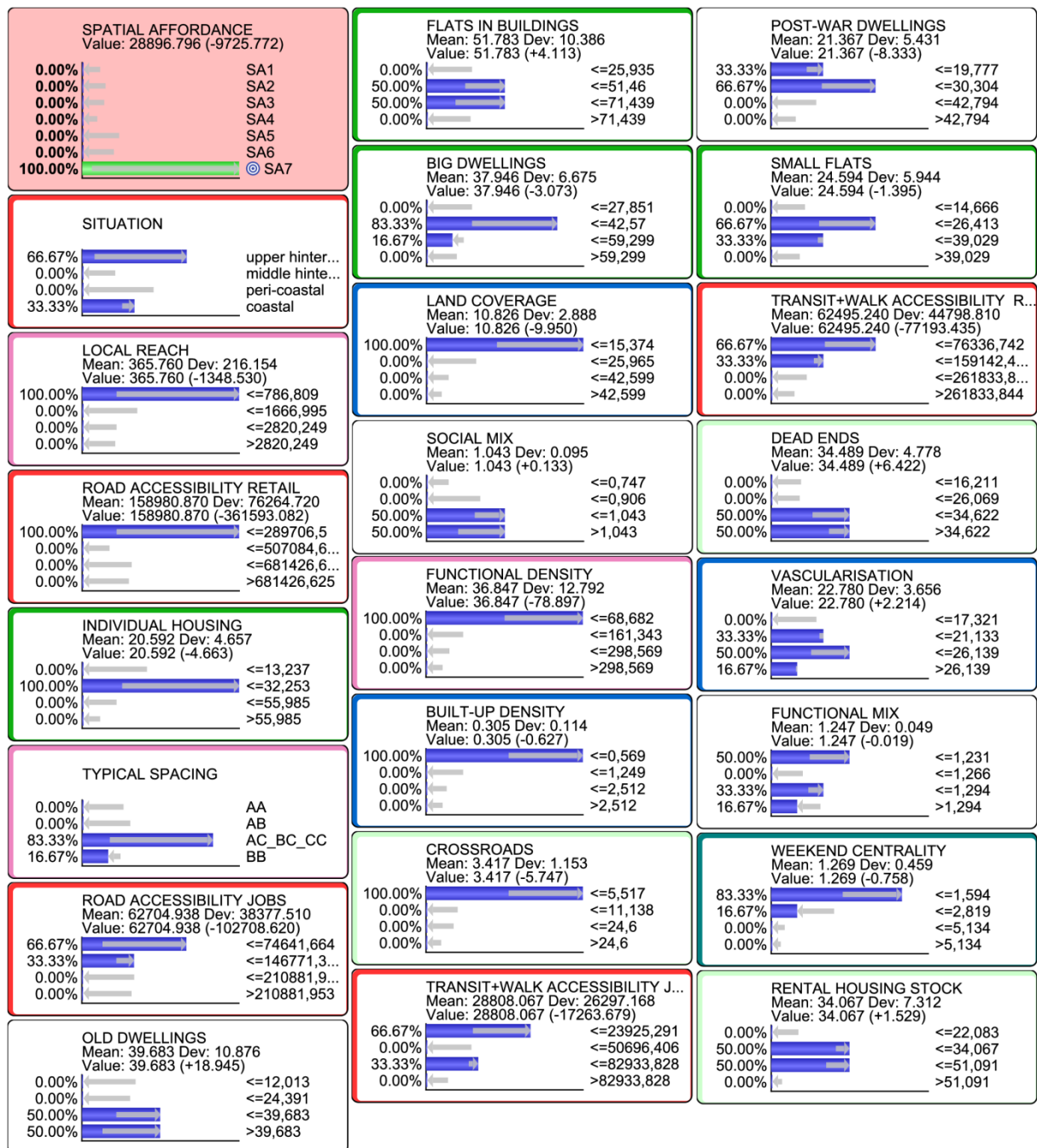


Figure C7 – Probabilistic profile of cluster SA7 - The upper hinterland with distant, difficult to access villages and mixed housing.

# Appendix D – The Probability Profiles of Dwelling Regime Clusters

Reading key: variables are listed in descending order of mutual information with the considered cluster. Only the most important 23 variables are shown. Colours regroup variables according to underlying synthetic factor.

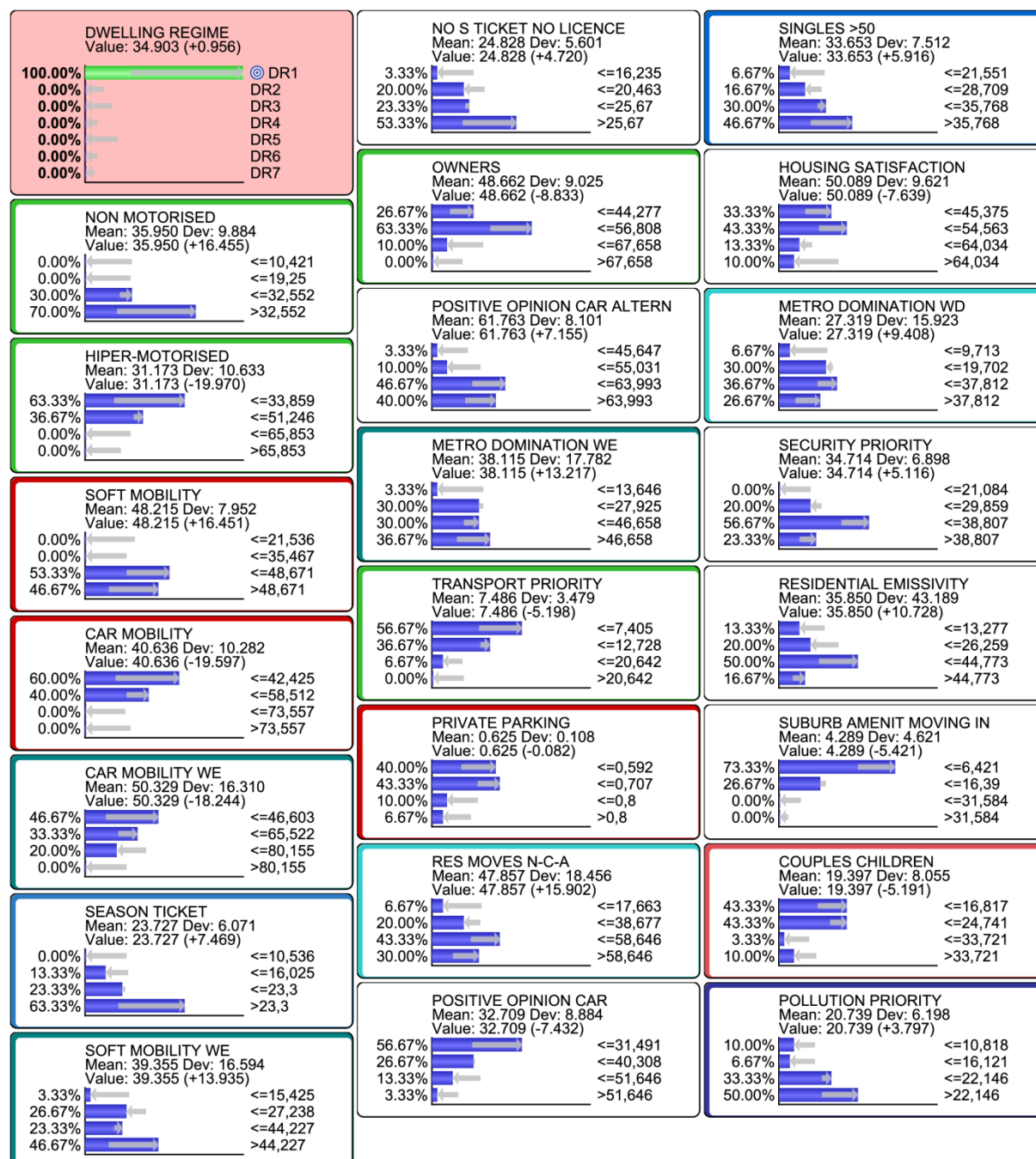


Figure D1 – Probabilistic profile of cluster DR1 - Places of urban lifestyles and diversity.

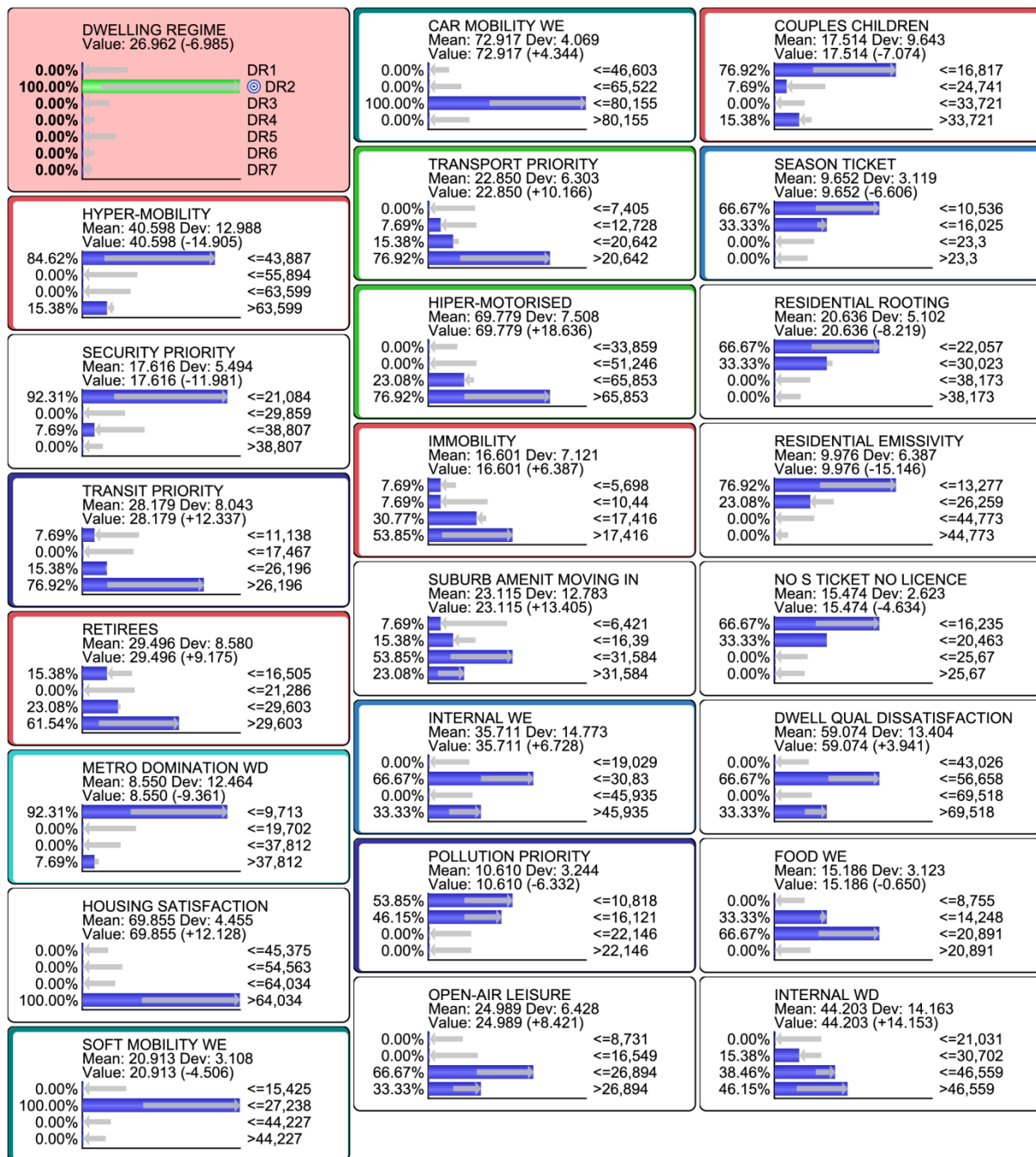


Figure D2 – Probabilistic profile of cluster DR2 - Places of village lifestyles, anchored to environmental amenities.



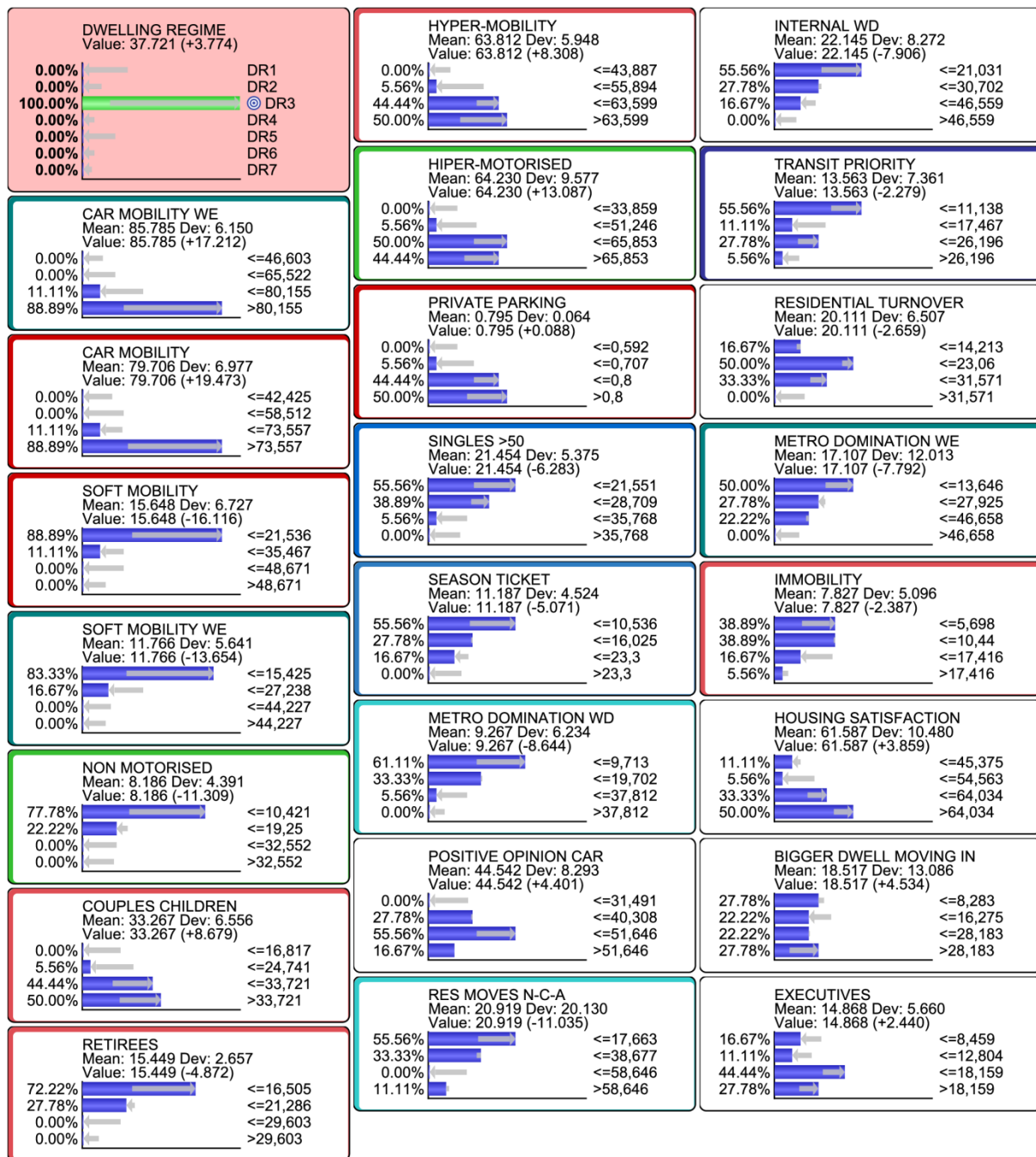


Figure D3 – Probabilistic profile of cluster DR3 - Places of automobile-dependent families.

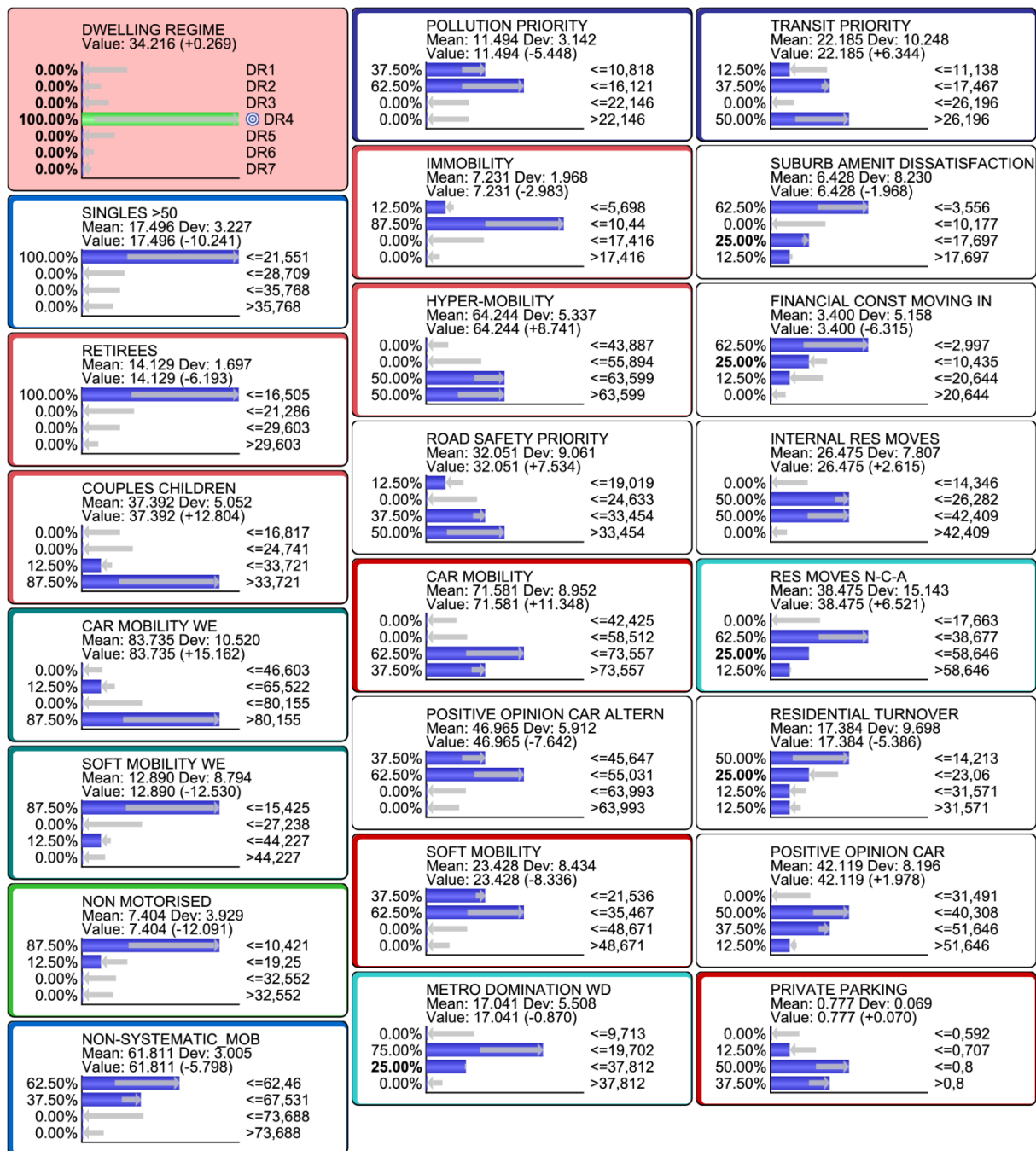


Figure D4 – Probabilistic profile of cluster DR4 - Places of families critically accepting automobile-dependency.

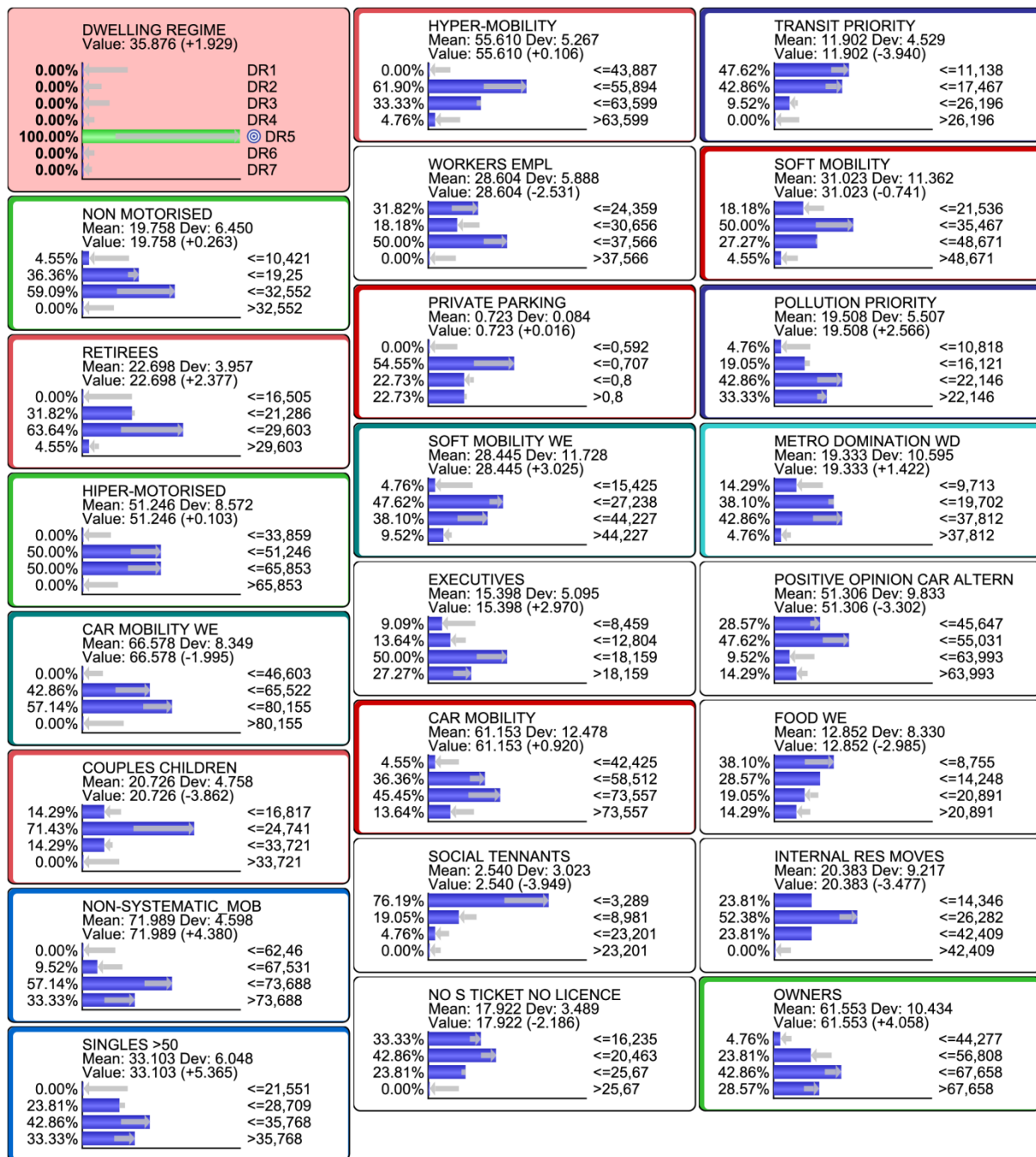


Figure D5 – Probabilistic profile of cluster DR5 - Places of wealthy freely mobile households.

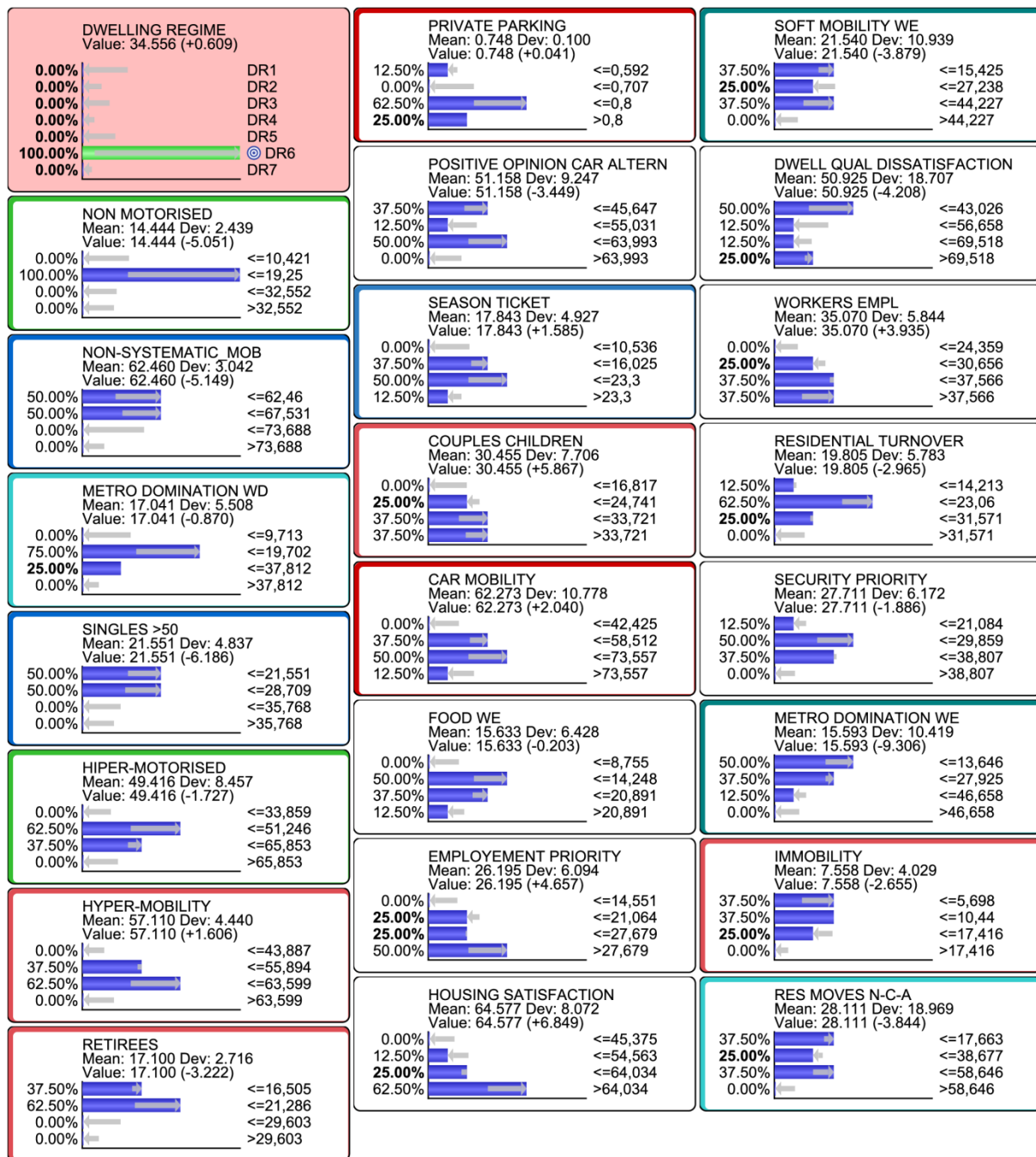


Figure D6 – Probabilistic profile of cluster DR6 - Places of families with intermediate behaviours.



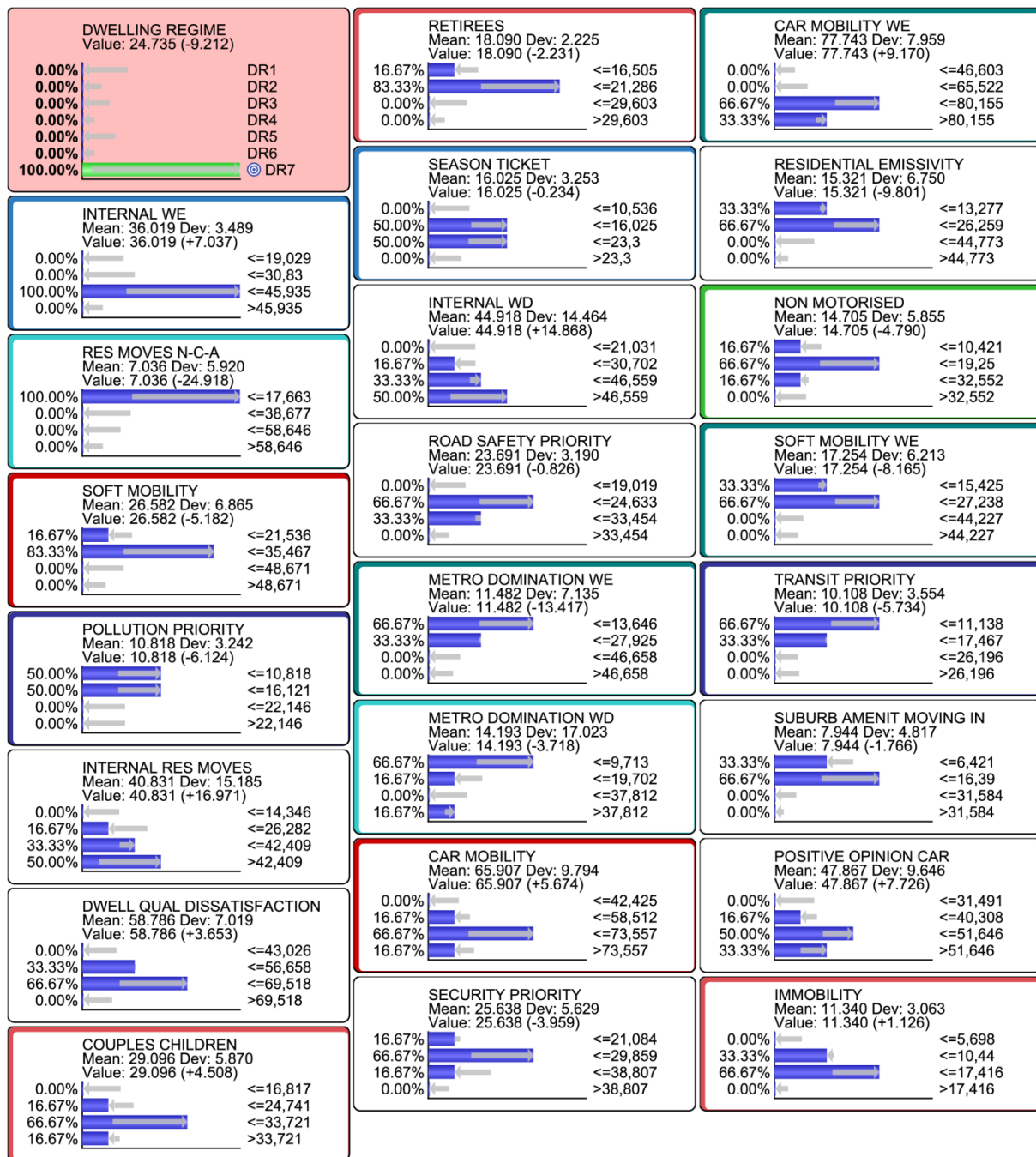


Figure D7 – Probabilistic profile of cluster DR7 - Mixed places with internal dynamics and automobile dominance.