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A new methodological approach for retail fabrics in the city.

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Abstract.

Urban retail distribution within the urban space contributes to the vitality and economic prosperity of streets and neighborhoods. Moreover, different retail patterns represent the specific outcome of the surrounding socio-economic fabric. Several models of retail activity distribution have been proposed in the scientific literature of economic geography in order to study the spatial organization of these retail patterns. Despite the large debate about the validity of these models, few empirical based studies have been proposed. Micro retail location data has been the subject of studies from different disciplines; statistic point pattern analysis methodologies have recently been presented as a way to detect spatial concentrations of a point pattern. Yet, concentration is not the only significant aspect defining retail fabric. Form and function represent the two main characteristics identified from the economic geography literature participating simultaneously to the definition of retail districts. In this paper a new bottom-up data-based methodology is proposed in order to assess retail distribution starting from a store point pattern representation on a street network. Theory-based indicators are implemented with geoprocessing approaches, allowing the recognition of morpho-functional patterns. Bayesian Classification methods are then applied to these spatial patterns. Retail fabrics and their spatial organization are identified and described. This methodology is applied in this paper to the real case study of the French Riviera metropolitan region.

Keywords: retail distribution, retail fabrics, geoprocessing, point pattern analysis, Bayesian classification.

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1 Introduction

The presence of retail activity within urban spaces is of paramount importance to street and neighborhood attractiveness: it enhances social and economic exchanges between citizens, contributing to the dynamics of a city (Jacobs 1961, Gehl 1987). Despite the undeniable growing importance of new communication technologies and their impact on citizen behavior, internet is “a pale imitation of [...] real proximity” (Greenberg 1995). The need to exchange goods, services, ideas and knowledge has always been the urban activity *par excellence* (Cachinho 2014). No civilization or settlement through history has never blossomed without the presence of stores (Barata-Salgueiro and Erkip 1996).

Spatial distribution of retailers within settlements reveals information about the socio-economic fabric of the population living and working in those spaces: consumers’ needs and desires are satisfied by the diversity of stores and merchandise offered in a neighborhood (Calchinho 2011). The aggregate choices of consumers, shape the overall patterns of retail activities (Craig, Ghosh and McLafferty 1984). Moreover, the social activity generated by the presence of retailers contributes not only to the concept of safety and control of the urban space (“eyes on the street” Jacobs 1961) but also to the non-monetary concept of gift-value (Greenberg 1995).

Awareness of the role of retail presence in urban space is now a well-established value for practitioners of town/urban planning. Indicators of retail presence have been also incorporated in street/neighborhood measurement for real estate value estimation (i.e. Walk Score in USA¹, CityScan in France², etc.).

Nevertheless, a simple enumeration of stores and businesses within a street, or a given urban space, “doesn’t tell the whole story” (Greenberg 1995). Descriptors of spatial distribution as well as variety of retail typology contribute in different ways to the strength and the appeal of a commercial district. The combination of these characteristics should be interpreted as a local DNA of the socioeconomic fabric representing both the outcome and the determinant of the surrounding urban nature (Craig, Ghosh and McLafferty 1984, Brown 1994, Hillier 1996).

Starting from Central Place Theory, researchers deducted and debated different spatial representations and models of retail distribution within urban settlements (Proudfoot 1937, Burns 1959, Berry 1963, Davies 1974, Brown 1994, Guy 1994 etc.). Constantly evolving technological progresses are modifying and multiplying citizens’ shopping behaviors, with a resulting observable impact in retail distribution and composition within urban spaces (Desse Lestrade 2016). Despite the important heritage of traditional models and approaches still influencing current retail distribution and urban planning policies (Brown 1991, Saraiva 2017), new paradigms need to be investigated in order to consider the impact of modern socioeconomic tendencies. Quantitative urban geography, thanks to ever-growing data availability and powerful

¹ <https://www.walkscore.com/>

² <https://www.cityscan.fr/>

geoprocessing tools is well positioned for the study of urban patterns (Talen 2011) especially on a large scale approach.

The study of retail distribution within settlements (*retailscape*, Cachinho 2014) is not merely a descriptive task. Identifying retail fabric patterns and their spatial configuration represents the first step for the elaboration of new urban planning development and regeneration projects (i.e. Procopiuck and Djalo 2008, Emery 2006, Brunetta and Caldarice 2014 etc.). Furthermore, it might represent an essential variable for locational decision and modeling of retailers.

This paper proposes a new geo-processing methodology for store point pattern analysis on the urban street network. Retail Fabric Assessment (RFA) allows the identification and characterization of urban retail localization patterns in a whole metropolitan area, with a micro-scale bottom-up approach

The paper is structured as follows. Section 2 reviews scientific literature on retail pattern analysis, focusing on the main two representations: hierarchical and post-hierarchical models. Section 3 reviews recent empirical works on retail micro-scale analysis. Considering both theoretical and empirical studies, section 4 specifies the objectives of the methodology proposed in this paper. Section 5 presents RFA methodology: (i) identification of the spatial units and collection of retail information, (ii) geo-statistical and geo-processing protocols to identify significant spatial patterns, (iii) identification and description of retail structures through Bayesian Clustering. The application to the real case study of the French Riviera is discussed in Section 6. Conclusion and perspectives of future work are discussed in the final section.

2 Retail patterns, models

Models of commercial distribution within settlements have been strongly inspired by land-use theories developed at the beginning of the twentieth century (Christaller 1933, Hoyt 1939, Park and Burgess 1925). Proudfoot (1937) transposed the concepts of Central Place Theories (CPT) to the intra-urban retail distribution. Based on detailed studies of several American cities, this author proposed the first spatial representation of commercial structure through the definition of five categories of retail districts: Central Business District, outlying business centers, principal business thoroughfare, neighborhood business street and isolated store clusters. Similarly, CPT have been adapted in Carol's analysis (1960) resulting, here again, in a hierarchical representation of commercial districts on four levels: central, community, neighborhood and local business district.

The most studied and discussed method is the hierarchical model of Berry (1963). The analysis of the business district of Chicago led this author to the identification of three morpho-functional groups: (i) nested hierarchical centers, (ii) commercial ribbons and (iii) specialized areas (Fig.1). Each of these groups is divided in sub-groups considering size and complexity of the retail structure. While the first group follows Carol's fourfold subdivision, the other two groups represent the most interesting advance of Berry's model. Ribbon developments identify those store concentrations with a linear layout alongside highways, routes, urban roads with or without a functional specialization (i.e. home supplies, furniture decoration etc.; motorcar

industry related etc.). Specialized areas represent large areas with a specific retail or service function concentration.

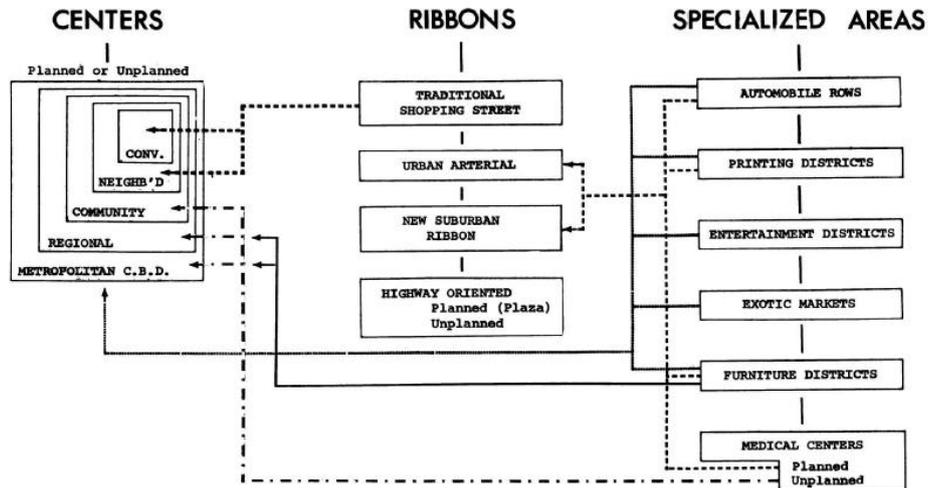


Figure 1 Berry's hierarchical structure of business and commerce. Source (Berry 1963, Table:2)

For about 30 years, this deductive-derived model has been celebrated but also criticized due to its several underlying assumption and implications (Dawson and Sparks 1987). Despite evolutions in the socio-economic settings and in the retail industry Berry's model have been applied by students, town planners and retailers themselves (Brown 1992;1993). Starting from the '80s several research studies identified issues with this model: the incomplete picture of spatial patterns of urban retailing (Potter 1982, Jones Simenson 1987), the assumption of single-purpose shopping behavior (McGoldwick 1984) and single-retail organization (Dowson 1983, Guy 1984), the new development of big box stores out-of-town (Davies 1984) etc. Dawson and Kirby (1980) and Dawson and Sparks (1987) state the inadequateness of Berry's hierarchical model.

Consequently to address these criticisms, several post- and quasi- hierarchical models have been proposed. Brown's (1991) taxonomy represents an interesting evolution of the hierarchical model. The starting point of Brown's classification is based on the identification of two main aspects describing retail districts: the *form* of a shopping area and its *function*. Three types of forms can be recognized: cluster, linear and small isolated concentrations. The function of these agglomerations is then considered: general, specialized or ancillary functions are thus identified. The combination of these two factors, generates a classification matrix composed by 9 groups of commercial districts, extended to 12 when considering planned/unplanned clusters (Fig.2). At the end of his work, the same author highlights some limitations of this method. Firstly, the difficulties in the identification of the 12 classes described by the post-hierarchical model in real case studies. Second, this model represents a static classification which would not be able to recognize changes in the retail configuration.

Finally, Brown highlights that despite its exclusion, “hierarchy still exists and will doubtless continue to exist” (Brown 1991, p377).

While hierarchical models were developed during a period in which city centers represented the socio-economical core of settlements, post hierarchical models emerged during post-war suburbanization.

		FUNCTION		
		GENERAL	SPECIALIST	ANCILLARY
FORM	CLUSTER (Unplanned)	Town and City Centres	Bright Lights District	Sandwich Bars in Financial District
	CLUSTER (Planned)	Megacentre	Speciality Shopping Centre	Shops in Airport Departure Lounge
	LINEAR	Traditional Arterial Route	Ethnic Shopping Street	Hamburger Alley
	ISOLATED	Corner Shop	Carpet Warehouse	Crush Bar in Opera House

Figure 2 Brown's non-hierarchical classification of retail location. Source: Brown(1991,Figure 2)

3 Different approaches to micro retail location

In the previous section, the main theoretical studies from the economic geography have been reviewed. In the last few decades, micro retail location has been the focus of several studies in different disciplines. Within this section, some of these approaches are reviewed in order to identify conceptual and methodological innovations and limitations that should be considered when approaching the retail distribution analysis at the micro scale.

A growing number of quantitative studies in urban geography and urban planning explored the relationships between urban form and socioeconomic characteristics within a city. More particularly parameters of the urban physical environment and retail distribution have been studied considering different morphological components: network configuration (Hossain 1999; Hillier 1993; Omer and Goldblatt 2015; Piovani Molinero and Wilson 2017; Porta 2009; Scoppa and Pepponis 2015; Svetsuk 2012; Van Nes 2001,2005) and morphological analysis of elements such as buildings, parcels, blocks and their spatial arrangement (Joosten and Van Nes 2005; Saraiva and Pinho 2017; Sarma 2006; Yoshida and Omae 2005). While the former group propose an advanced elaboration of proximity, accessibility and centrality-based approaches at the intra-urban level, the latter investigates the influence on retail distribution of the physical layout of the urban space.

Both these paths of research propose a large variety of methodological approaches and techniques highlighting different spatial properties of the urban form. But when it

comes to cross analyzing these properties with retail distribution, the simple density/presence of stores is considered. As discussed in the introduction, the combination of spatial distribution and functional mix at the origin of the retail system should not be reduced to simply counting the number of stores in a given space. Just like built-up density has been criticized as being too simplistic to describe urban fabrics, we need to overcome an oversimplified assessment of retail in the city through the sole parameter of retail density. We thus propose to define the new concept of retail fabrics within the city, taking into account the most characteristic spatial and functional properties of retail distribution patterns within urban space and buildings on the aforementioned theory of retail geography in the city.

Only separate assessments of urban fabrics and retail fabrics might allow in a later phase of analysis, the study of the interrelations between these two aspects revealing the organization of the global form of a complex city as a whole (Levy 2005).

Although retail distribution analysis has attracted researchers' attention on national, regional and urban scale since the beginning of the 20th century, micro retail location has been, comparatively, neglected (Brown 1994) mainly because of the lack of precise location information of stores. Consequently, empirical studies have been forced to consider coarser scales at a given spatial unit, often represented by administrative boundaries (Hildago and Castaner 2015) as for example in Beijing (Wang and Jones 2002) and London (Thirstain-Goodwin 2005) retail assessments. These partitions might be at the origins of statistical bias related to the well-known modifiable areal unit problem (MAUP, Openshaw 1984). Aggregate statistics related to administrative boundaries could influence the choice of indicators and the resulting definition of business centrality of settlements. Asides from that, it seems to us that a clearer understanding of the spatial logics of retail distribution in the city should not ignore the main characteristic of urban space for pedestrians and retailers: urban space is a network space, and all administrative subdivision ignore this very nature of urban spatiality.

Davies (1972), in his criticism of the Central Place literature, highlights how the difficulties of defining the extent of centers absorbed the attention of researchers, hindering empirical studies on retail structure typologies. Despite the conceptual clarity of Brown's post hierarchical model (1991) the recognition in the reality of these classes is not easy to study.

Urban planners and practitioners aware of the importance of theoretical models and of the lack of well-established methodological procedures beyond traditional aggregate statistics, adopted classification measures of the urban retail spaces based on expert-based knowledge and observation of the space study under analysis. This practice requires qualitative approaches in order to identify, delineate and adapt theoretical patterns to each real case study. Discussions and criticisms of the obtained spatial partition might arise due to the subjectivity of this procedure.

A systematic, quantitative, bottom-up (even if partially theory-driven) approach for retail distribution assessment at the urban micro-scale is therefore needed for both modeling and assessment purposes. In order to achieve this goal, empirical studies resulting from the economic geography theories need to be combined with methodological works from geo-statistics and point pattern analysis.

Starting from the wide scientific literature discussed in the previous chapter, Guy (1998) proposes data-based classification approaches as an “*essential means of understanding and analyzing relationships in the world of retailing*”. In his review, two main positive aspects are associated to this methodology: firstly, “*logical and appropriate classification provides systematic and well-informed discussions of research in retail geography, whether of development trends, institutional influences, retailer behavior and consumer behavior*”. Secondly, the possibility to compare empirical findings within different spaces, cultures and time periods. Guy’s work provides an interesting discussion with important insights and caveat on classification methods, depending on three main facets of retailing: consumer behavior choice, retail strategy and retail location. While the first two approaches consider intrinsic aspects of stores (type of goods, retail size, ownership etc.), the third aspect is focused on spatial localization of commercial activities within settlements. Yet, no methodological implementation is provided or mentioned.

Mackness and Chaudhry (2011) propose an automatic classification of retail spaces from a large scale topographic database. The authors include spatial variables that consider the configurational disposition of retailers, built-up and non-built-up spaces in order to identify retail parks, shopping malls and agglomeration of high streets. This work represents the first example of classification of retail concentrations considering different aspects of retail configuration. However, it focuses attention only on planned/unplanned concentration including non-retail information (distance from the settlement CBD, parking slot etc.).

Other recent quantitative works on retail patterns present interesting methodological innovations based strongly on spatial statistics and geo-processing algorithms.

Jensen (2006) proposes a local quality indicator of a given retail activity in a specific localization, considering store presence within its surrounding area. This indicator is based on quantitative measures of local spatial attractive/repulsive behaviors between retail categories, based on M statistic (Duranton and Overman 2005, Marcon Puech 2017). This robust statistical method and its developments (Marcon Puech 2009, Lang et al 2016) consider how to evaluate the overall relative spatial concentration of specific categories of industrial sites using micro-geographic data. Jensen’s local adaptation of M statistic represents a first attempt at implementation for the identification of local over/under representation of retail activities and it could be applied in retail pattern recognition.

Two considerations may be made in this respect: firstly, this procedure needs to consider network-based subspaces instead of Euclidean disks to fully take into account the specificities of urban space. Researchers demonstrated how planar techniques can generate false clusters of hot/cold spots when applied to phenomena taking place in a network constrained space (Okabe and Yamada 2001; Yamada and Thill 2004). While M statistic applied to industrial sites on a regional and national scale might not be strongly affected by street network configuration, the same cannot be said when dealing with retail activities within urban spaces. Secondly, retail fabric (as seen in the previous chapter) has been theoretically identified and described not only by its functional characteristics: concentration and spatial configuration (isolated, clustered and ribbon structures) should equally be considered.

Hildago and Castaner (2015) implement a recommender system able to identify missing amenities considering current specialization patterns within neighborhoods. An *ad hoc* clustering algorithm is here implemented starting from a distance based accessibility indicator in order to identify spatial aggregations of amenities. In this work both agglomeration and specialization of amenities patterns are studied, but their analysis is not simultaneously considered. The analysis of the former results in a partition of the space that, despite being endogenous, still imposes constraints on the determination of the latter (similar to what was discussed above for exogenous partitions). The delimitation of neighborhood partitioning impacts the commercial presence and typology mix, influencing the results of amenity typology correlations. Here again, street network constrained space and spatial layout of the retail distribution are not considered

The analysis of density based spatial clustering algorithms applied to retail distribution in the city represent the focus of Dolega Pavlis and Singleton's work (2016). In this paper spatial methods for point pattern clustering identification like k-means, quality threshold, KDE, random walk and density based spatial clustering of application with noise (DBSCAN) are applied and compared. Another variant of clustering analysis of point patterns, is represented by clumping methods. A clump, is defined as "*a set of points on a plane where all the points are within a certain Euclidian distance of at least one other element of the set*" (Roach 1968). Okabe and Funamoto (2000) implemented a Planar Variable-Distance Clumping Method (PL-VCM) able to identify statistical significant clumps at different scales. More recently, the corresponding network-based version (NT-VCM) has been proposed by Shiode and Shiode (2009).

DBSCAN and VCM methods represent two interesting and statistically robust exploratory methods for point pattern clustering/clumping identification. The spatial arrangement of a given set of points at different scales is compared to random distributions, in order to detect and extract clustering/clumping information pertaining only to anomalies which means identifying elements that are unlikely to happen by chance. These methods are extremely important when spatial models of the phenomena under study are unknown or not available like road accidents, wildlife fatality, crime etc. In these examples, the determination of significant hot-spots leads to the identification of spatial aggregations where an exogenous cause might be investigated. As seen in the previous chapter the distribution of retails in urban space shows specific functional-form patterns. Despite that many statistical methods proposed in the scientific literature have been applied to retail distribution within cities, these methods always compare observed patterns to random distribution in order to corroborate the simple hypothesis of concentration/dispersion.

From the works reviewed in this section we can sum up with the following observations:

- Classifying retail fabrics in the city should be independent from physical elements of the urban settlements; the two phenomena have to be analyzed and characterized independently if a cross-analysis of the relationship between them is later sought for;

- Imposing exogenous partitions based on clustering/clumping methodologies or even manually derived could bias the results;
- Any fine-grained spatial analysis of the retail function should respect the network-space of the city;
- Data based classification methods are suggested, whose results are more objective and can serve as a basis for comparative analysis and simulation models;
- The analysis of retail distribution cannot be reduced to a simple agglomeration analysis (Guy 1998): form and function should be considered simultaneously.

4 Objectives

The main aspects we try to converge in this methodology are:

- From an expert-based recognition of urban fabric to a bottom-up inferential procedure;
- From individual pattern analysis of functional and spatial characteristics to a theory based analysis comprehensive of both aspects.
- An automatic delimitation of retail fabrics without any preconceived or exogenous partition of the space.

Together with these objectives, some methodological constrains are included:

- Network constrained distances in order to respect the nature of the retail distribution phenomena; as demonstrated by several researchers, Euclidean distances could lead to false detection of spatial patterns.
- Minimal information of retailers required in order to guarantee the reproducibility and adaptability to other case studies.

In order to evaluate the new methodological protocol, we tested it on a real-world case study: the French Riviera metropolitan area, in Southern France (Fig. 3). This area has a population of more than one million inhabitants over 1500 km². This space is a unique conjunction of natural and urban landscapes: the topography, with elevation ranging from the sea level up to 1700 meters of the pre-Alps attracts a strong touristic and leisure presence both during summer and winter seasons. Traditional villages and suburban developments are spread around three high density urban areas. From east to west, we find: Monaco and its skyscrapers, the most densely populated sovereign nation in the world; the urban agglomeration of Nice with a regular meshed core inspired by the Turin model (Graff 200) surrounded by residential, hilly and less tightly planned areas. And finally the urban agglomeration of Cannes-Grasse-Antibes characterized by land irregularity together with the car-centered sprawl development of the lasts 50 years. While historical centers present high concentration of touristic-based stores, peripheral areas collect a great number suburban ribbons and specialized areas scattered along the main connection axes. Another peculiarity is the presence of a strong and dynamic real estate market due to the presence of wealthy tourists willing to buy luxury holiday homes inducing a strong presence of real estate agencies. The combination of all these elements produces a sequence of urban centers and peripheral areas of different sizes and different morphology with an uneven distribution of commercial activities.

This study area will give us the opportunity to test our method and to identify in a bottom-up approach different retail fabrics. Moreover, unlike examples found in scientific literature where often case studies analyzed consider a uniformly urbanized dense area or monocentric cities and metropolis, the French Riviera is a coastal polycentric metropolitan region, with a large number of small and average sized villages and towns. Within this peculiar space, in the last fifty years, a great number of retail configurations have been generated from the combination of spatial layout and specialization/mix properties.

The store data used in this application, counts 33 thousand commercial activities with a surface smaller than 300 square meters and 321 anchor store with a surface greater than 300 m² (2016). Each retail activity is described by its precise localization and a national retail classification code (Nomenclature of the French Activities, NAF) with a direct correspondence to the European and International Classifications (NACE and ISIC). When the store exceeds 300 square meters, the precise extent of its surface is reported. This information is provided by the local Chamber of Commerce ensuring a high degree of quality and exhaustiveness. In this study we will consider a classification of 12 retail categories with few adaptations in order to consider the economical specificities of our case study. The French National Geographic Institute (IGN) provided the geographical information of the street network.

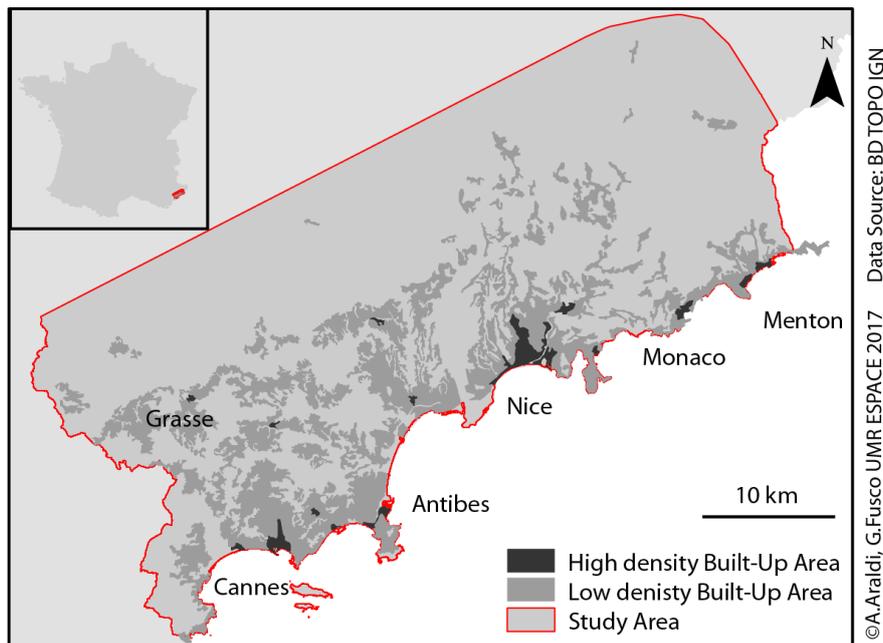


Figure 3 The metropolitan conurbation of the French Riviera, France.

5 Methodology

Multiple Retail Assessment (MRA) is a three-step protocol for the analysis of retail distribution; it can be summed up as follows:

1. Defining a network constrained catchment area around each event and collecting retail activity information.
2. Identification of retail distribution patterns: (i) configurational properties, (ii) geometrical distribution (iii), local significant prevalence of retail typology;
3. Clustering of relative event-based patterns through Bayesian methods in order to identify and characterize *retail fabrics*.

5.1 Spatial unit

One of the main novelties proposed by this method is the procedural switch in the order of the analysis of traditional approaches. Instead of defining/identifying a spatial partition and analysis in a second phase the retail information within each subspace, MRA collects and analyzes different aspects of the retailscape surrounding each store (steps 1-2), and only afterwards identifies patterns of retail fabric through classification methods (step 3). In other words, the classification is applied on the local external patterns wherein the single element is included by considering its internal characteristics. When we consider for example moving average method, a statistical measure is applied on a spatial or temporal subset of values; similarly, we will apply a spatial moving classification on patterns.

The spatial unit on which MRA methodology is built, is the point representation of stores. Starting from the street network location of each event, we consider the surrounding subnetwork at a given distance r . Within this subnetwork, the number of the total number of stores and of each retail category are considered. This procedure is the starting point of many statistical methods (i.e. Ripley's K and its derivatives kd, m, M etc.) exploring the distribution of points considering a wide range of r . As introduced in the previous chapter, while these methods are used for exploratory data analysis purposes, this methodology is more theory-based. The choice of a network-based application and a short radius r , find their explanation within the store-to-store pedestrian-based movement principle (subject of consumer behavior studies) which represents one of the main motivations of retail agglomeration.

5.2 Form and functioning patterns

Form and function represent the two main components of retail structure identified in the scientific literature. This section presents how these two aspects are conceptualized and implemented through quantitative algorithms based on statistical and geoprocessing methods. Finally, each spatial unit is described by a set of form-function pattern focusing on different aspects of the surrounding retail structure.

In the following description of pattern recognition, three local levels have been separately associated to each indicator, depending on the enclosed information. We refer to them as: street level ($r=150$ m), neighborhood level ($r=300$ m) and community level ($r=600$ m).

The local **Form** of retail activities is described by a set of three indicators:

- ***Distribution*** is based on the total number of stores surrounding each commerce at three local levels. A segmentation based on quantiles is applied to the statistical dispersion of the *distribution* value associated to stores on the overall study area. Instead of a simple count, this statistical discretization informs us about the relative importance of local retail presence. As we can see in Fig.4, the patterns identified illustrates the hierarchical importance of centers at the three given scales.
- ***Agglomeration*** considers the ratio of the number of stores on two different scales: street/neighborhood levels and neighborhood/community levels). This indicator discloses the information on the aggregation of the retailscape at a given level compared to the larger one. In other words, this indicator is able to detect isolated stores and high concentration surrounded by empty/lower concentrations (High-Low distributions) low distributions in proximity of high concentrations (Low-High) and homogenous distribution at both scales (High-High and Low-Low). This triple description is obtained applying the same discretization method used for the previous indicator.
- ***Geometry*** refers to the morphological nature as defined by Berry (1963) This indicator is obtained following the point pattern analysis methodology developed by Araldi and Fusco (2018): this procedure, based on statistical and fractal theories, enables the detection of the local geometrical layout of a point pattern dataset on network. This procedure is implemented as follows: first the total number of stores at different radii are collected. These values are plotted in a log-log graph, obtaining the local cumulative function of stores surrounding each retail. When a linear fit is significant ($R^2 > 0,9$), the slope of this function represents the proportionality factor describing the distribution of stores within the relative subnetwork, from the center of the analysis to the more peripheral links. This factor varies between 0 and a maximum value α_{max} given by the subnetwork dimension. The classification of α , is based on fractal theories: a value close to 0 represents a punctual disposition of retail activities; the prevalence of a linear structure is detected when α is close to 1. Finally, when α is close to the subnetwork dimension α_{max} (hypothetically close to 2, if we consider a planar domain) the presence of retail is pervasive on the considered subnetwork. In this paper, this procedure is here applied at the three aforementioned scales: at the street level, fragmented or linear continuity of stores is detected. At the neighborhood and community level, three geometrical disposition are identified (Fig.5): *pervasive* distribution, when the whole local subnetwork is equally filled by stores. *Linear* distribution describes the presence of a prevalent linear distribution of retails compared to the overall distribution of the point subset. This class represents a quantitative measure of the *ribbons* as defined by Berry (1963): Fig.5(d), shows the detection of both traditional shopping streets within a city center and suburban ribbons in Antibes. Finally, *scattered* store layout is represented by small and fragmented concentrations (punctual concentrations) together with isolated stores.

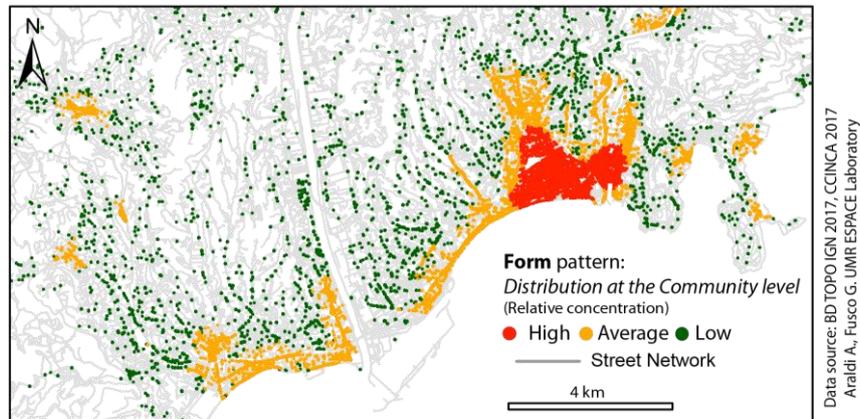


Figure 4 Examples of Form Pattern: distribution at the community level.



Figure 5 Form Pattern: Geometry at the street (a), neighborhood (b) and community (c) level. This indicator allows the identification of significant ribbons in both suburban and central areas as illustrated in Antibes agglomeration (d)

All form indicators are based on the total store count at different radii. In order to identify the functional characteristics of a commercial district, the number of store for each retail family is now analyzed. The local **Functioning** of a retail distribution is described by three indicators:

- ***Retail category variety*** is described by the number of retail types presents within the neighborhood distance. This indicator, also called *richness* in segregation studies, represents the amplitude of the commercial offer enabling a multi-purpose shopping behavior. Lower values of variety might represent both specialized areas and small convenience/street-corner developments.
- ***Retail category prevalence*** aims in the identification of significant patterns of specific function concentrations. As in Jensen (2006), this indicator is based on the local implementation of the *M* index (Marcon 2006): it is obtained as the ratio between the total number of a specific store category and the total number of stores within a neighborhood distance. In order to evaluate its significant higher or lower prevalence, this ratio is then compared to the average of the ratios obtained considering each event of the point pattern analyzed. A double one-tailed binomial test is then applied with a confidence level of 0.95¹. The results of the application of this methodology to each group of the 12 retail typologies identify statistical High, Low and Not Significant patterns of functional prevalence (Fig.6). As for the *agglomeration* indicator, the patterns of *retail category prevalence* represent a relative measure based on the overall distribution within the space study analyzed. Twelve retail categories are considered (*Retail category prevalence* Tab.1).

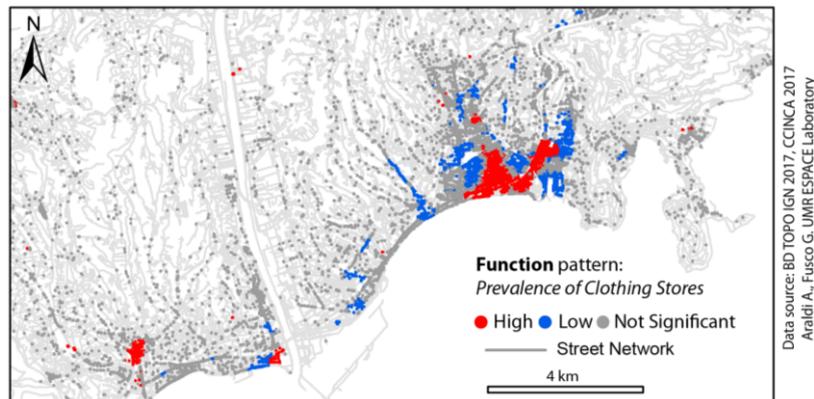


Figure 6 Example of Function Pattern: prevalence of clothing stores.

- ***Anchor store category prevalence***. This group of indicators has been introduced in this analysis to consider the presence of anchor stores in the retail ecosystems. The

¹ As discussed in the scientific literature, a Monte Carlo randomization of the points around each center of the analysis would be the best practice in order to evaluate the correct local statistical significance of the “prevalence test” identified within our methodology. The implementation of one thousand Monte Carlo randomizations around 33 thousand center of analysis, considering the street network domain would be required for our case study.

importance of these *magnet/attractor* stores (Davies and Bennison 1978, Brown 1994) requires a specific group of indicators able to identify their influence on small and average retail fabrics and also those “out-of-town” store configurations, missing in the hierarchical models. The statistical analysis of category prevalence applied above for small and average sized retail surfaces, is reiterated here considering large surfaces presence. The spatial influence of these anchor stores covers wider spaces compared to small retailers; the implementation of the prevalence measure is thus implemented at the community level. Significant concentrations of large stores might be found in both suburban specialized/ribbon structures and in more central areas influencing the presence of small and average retailers in their surrounding space. Six typologies of retail activities are analyzed (*Anchor store category prevalence* in Tab.1)

Table 1 Form and Function measures implemented in Retail Fabric Assessment (RFA) methodology. Patterns are identified through the analysis of the spatial/statistical distribution of retail landscape measurements

<i>Aspect</i>	<i>Indicator</i>	<i>Pattern</i>	
Form	<i>Distribution</i>	Total number of stores within 150 meters	Relative high/average/low store presence at the street level
		Total number of stores within 300 meters	Relative high/average/low store presence at the neighborhood level
		Total number of stores within 600 meters	Relative high/average/low store presence at the community level
	<i>Agglomeration</i>	Ratio n. stores 150 m / n. stores 300 m	H-L, L-H, constant agglomeration between street and neighborhood levels
		Ratio n. stores 300 m / n. stores 600 m	H-L, L-H, constant agglomeration between neighborhood and community levels
	<i>Geometry</i>	Spatial layout of stores within 150 m	Fragmented / continuous stores lay out at the street level
		Spatial layout of stores within 300 m	Scattered-Linear-Pervasive stores lay out at the neighborhood level
Spatial layout of stores within 600 m		Scattered-Linear-Pervasive stores lay out at the community level	
Functioning	<i>Variety</i>	Number of retail categories within 300 m	High / average / low retail variety at the neighborhood level
	<i>Retail category prevalence</i>	Ratio between the n° of stores of category(i) and total n° of stores within 300 meters	Prevalence of food stores
			Prevalence of clothing stores
			Prevalence of furniture related stores
			Prevalence of vehicle related stores
			Prevalence of bar and restaurant
			Prevalence of hotels
			Prevalence of bank and insurance services
			Prevalence of real estate agencies
			Prevalence of informatics and communication stores
			Prevalence of beauty and health services/stores
			Prevalence of reparation services
			Prevalence of culture and leisure services/stores
	<i>Anchor store category prevalence</i>	Ratio between the surface of anchor stores of category(i) and total surface of anchor stores within 600 meters	Prevalence of food anchor stores
Prevalence of clothing anchor stores			
		Prevalence of furniture related anchor stores	
		Prevalence of vehicle related anchor stores	
		Prevalence of home related anchor stores	
		Prevalence of culture and leisure anchor stores	

5.3 Recomposing and characterizing Retail Fabrics: Bayesian Classification

In order to identify retail fabrics, we still have to combine the results of the geostatistical and morphology patterns.

Clustering approaches aiming at achieving high intra-cluster homogeneity based on variance minimization on the values of all the indicators are not well fitted for this task.

Bayesian inference method is based on conditional probabilities (Duda 2001, Haking 2001); this method tries to minimize the probability of error in a decision, by associating to each individual the most probable outcome. The advantage of this method is its ability of identifying classes based on subsets of indicators that could determine a specific class. Fusco (2016) proposes Bayesian clustering to identify groups of individuals sharing a few key characteristics, which could vary from one group to the other. As observed by Mackaness and Chaudhry (2011), Bayesian clustering methods in retailing studies might be a good option considering the fuzzy and incomplete knowledge of the domain.

The careful theory-driven feature selection of our analysis justifies the use of a naïf Bayesian classifier on the 27 morpho-functional indicators. As in Araldi and Fusco (2017), the Bayesian classification is applied on pre-segmented indicators resulting from geostatistical analysis and morphological-based segmentation, instead of raw indicator values. Bayesian clustering of categorical values which, in their turn, summarize the statistical significance of spatial patterns defined on a street network. Using different random seeds, 1000-step random walks explored the solution space to obtain optimal Bayesian clustering of our spatial units. The search constraints were a minimum cluster content of 2% of the spatial units, a minimum average probability of assignment of units to each cluster of 0.9 and a maximum of 25 clusters. The optimal score (combining log-likelihood of the clustering solution given the data and a penalization for the increasing number of clusters) was found for the 19-cluster solution. A successive refining phase of the 19-cluster solution was carried out by imposing this fixed number of clusters to the 6 random walks. The best result shows a contingency table fit score of 67.77%.

The relatively important number of classes identified by the Bayesian clustering is a consequence of the variability given by the set of indicators and their internal distribution. A correct number of classes is not determinable *a priori*. As observed by DeLisle (2005) a “*dynamic tension between too few and too many classes*” exists when applying classifications to retail activities. Only unambiguous, meaningful and measurable metrics could lead to a comprehensive classification.

6 Results and Discussion

The main result of the Bayesian Classification is represented by the assignment of each individual store to its most probable cluster. In addition, a rich set of probabilistic information is provided to the analyst in order to identify and to describe each class. For example, the profile of a given class could be analyzed through the relative

importance of each indicator and its values. Describing the precise profile of each retail fabric obtained goes beyond the aim of this paper. In this section the attention is given to the spatial arrangement of these patterns showing important recurrences of these structures of retail fabric within the study area.

Within the French Riviera conurbation, four main centers are identified: (from east to west) Menton, Nice, Antibes and Cannes. Stores within these cities, show a highly concentrated, continuous and pervasive pattern. This spatial *form* distribution represents the necessary condition allowing functional grouping of stores. The coalescence of nucleated facilities within these cities, might find its causes in historical, economic, social, urban characteristics. For example, in all the historical centers of these cities two classes identify a retail fabric composed by small stores related to the high level of tourism-related activity: the first (RF1) show a concentration of restaurants and clothing while the second (RF2) is more related to cultural and leisure activity. Both these retail fabrics do not include large surface stores, probably due to the physical urban constraints. Other concentrations recognizable in all these cities are the clothing oriented districts (RF3) and the service oriented districts (RF4). Individual characteristics of each city result in specific patterns: the west side of the clothes district in Nice shares the urban space with a significant concentration of real estate agencies (RF5). A similar behavior is noticeable within the core of the clothes district of Cannes, where banks, insurances, real estate agencies and clothing department stores coexist. (RF6) Fig.7

When the extension of the city core is important, as in Cannes and even more in Nice, these nucleated specializations are surrounded by a more residential retail fabric characterized by a high variety of retail categories, the absence of clothing department stores and the presence of large food stores. This retail fabric is defined by two classes: despite the fact that the functional characterization remains the same, one class (RF7) is characterized by a continuous linear distribution and concentration on main axes (RF6, urban retail ribbons) while the second (RF8) presents fragmentation along the streets. Fig.8

When considering smaller cities and community-level agglomerations, the reduced extension of their cores does not allow the retailers to give birth to functional clusters. The retail fabric of these settlements (RF9) is characterized by high variety of small stores, prevalence of food, clothing, health/beauty stores and few large food stores. This retail nucleated fabric is typical of small-sized cities as Saint Laurent du Var, Cagnes sur Mer, Vence, Mandelieu, Beaulieu. Fig.8.1

Outside the core of both larger and smaller cities, suburban residential ribbons spread in different directions following the main road axes or constrained by the topography of the site (RF10). Within these linear configurations, a good mix of small retail activity is observable, combined with the presence of food, vehicle, bricolage large surfaces. These residential ribbons alternate with service oriented ribbons: both share the same form characteristics while the second presents more services and the absence of large stores (RF11). These two ribbon configurations are the commercial backbones for more locally scattered/fragmented retail fabrics (RF12 and RF13).

Small isolated historical villages within the French Riviera, represent another attractive destination for tourists. The commercial offering within villages as Eze, Saint Paul de Vence, Valbonne etc. is highly concentrated mainly based on restauration, with an average variety of retail offered and no big stores. The same retail fabric (RF14) is identified around the marinas of Menton, Saint Laurent du Var, Golfe Juan, Nice (east side) and in small villages on the coast like Juan le Pin, Villefranche and Cros-de-Cagnes, (old fishing villages, now local touristic hot spots) Fig.8.2

Two classes represent specialized areas in suburbs where big box stores and shopping malls are predominant. The shape and configuration of these patterns is strongly defined by the topography. The retail family (RF15) is composed by isolated concentrations of stores attracted by food anchor stores and vehicle related retailers; (RF16) presents a ribbon shape and it is more specialized on furniture, clothes, leisure retailing and it attracts small home-related stores. These two specialized retail fabrics could be found isolated or at the extremities of residential ribbons. Fig.8.3

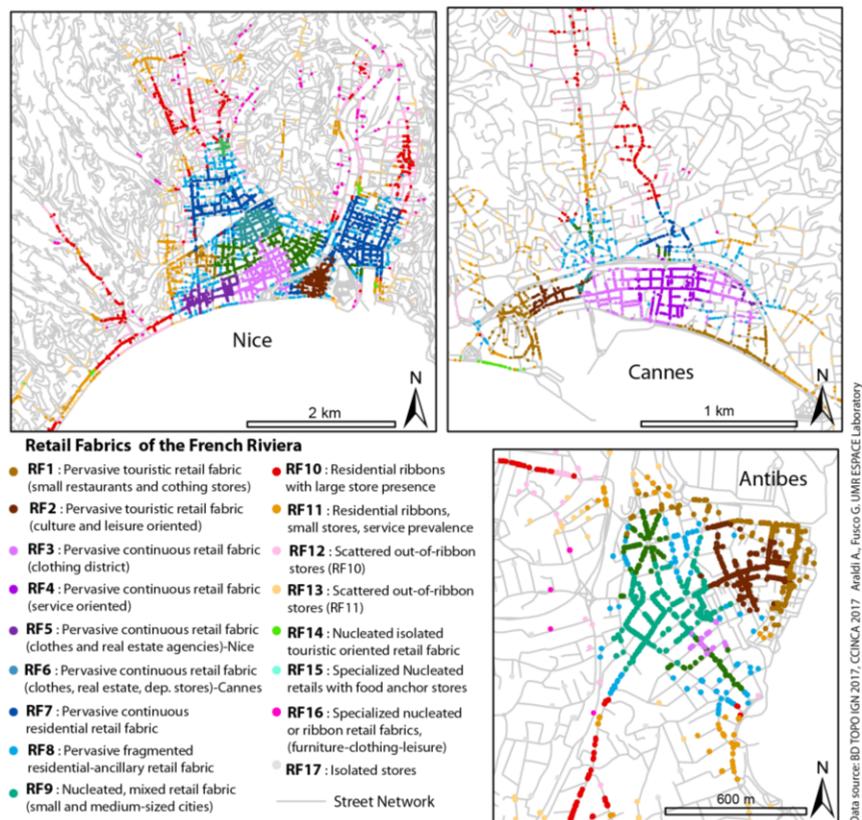


Figure 6 Retail Fabric Assessment (RFA) results: classification of the retail distribution within the core of three cities of the French Riviera (Nice, Cannes and Antibes)

Finally, 2 classes identify isolated stores (RF17) and those stores within a close distance (600 meters) to the retail fabrics described above but without any morpho-functional specific characteristic.

The results discussed in this section are of course linked to the indicators of the analysis. Slightly different results could also be obtained from different parametrizations, or implementation procedures on the same indicators. The attentive theory-based selection and implementation of each indicator adopted in this paper, as well as the results on the case study of the French Riviera, suggest the MFA as a promising robust method for the assessment of retail distribution analysis.

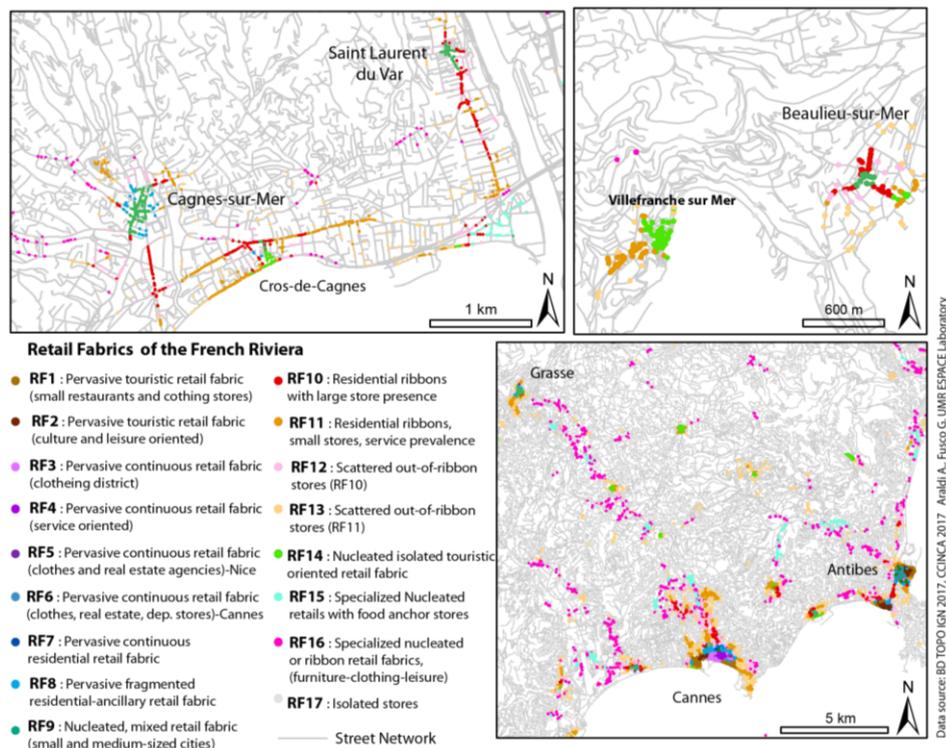


Figure 7 Retail Fabric Assessment (RFA) results: classification of the retail distribution of average-sized cities (ex: Cagnes-sur-Mer, Grasse etc.), isolated touristic villages (Villefranche-sur-Mer, Cros-de-Cagnes etc.), and specialized suburban districts within Grasse-Cannes-Antibes conurbation

7 Conclusions and Perspectives

We proposed a multi-step geoprocessing approach to identify retail districts in a vast metropolitan area. It integrates a theory-based matrix of morpho-functional indicators taking into account the micro retail location, network-constrained geo-statistics and Bayesian clustering. The method proved successful in identifying retail district typologies and their spatial arrangements in the real-world case of the French Riviera metropolitan area, even if the clustering results deserve a more attentive analysis from an economic geographical perspective. The heterogeneity and polycentrism of the coastal region analyzed proved the capacity of MFA method to detect a wide range of commercial districts providing a complete commercial analysis for both central and peripheral areas. From a more methodological point of view, the probabilistic content of the Bayesian clustering should be better exploited to identify uncertainties in the knowledge of retail district spatial organization.

RFA presents several methodological innovations allowing a vast range of applications. Future works might consider the application of this procedure to a time series of retail data in order to study the spatial evolution of commercial districts. The rise and blight of commercial spaces could be studied with a more dynamic approach.

The bottom-up procedure removes the store district delimitation problem and consequently, the need of an *a priori* definition and classification of retail. This allows the identification of new form of commerce resulting from current socio-economic and retail organization evolutions.

The robustness of RFA method, based on its quantitative and objective approach, might allow the comparative analysis of different case studies. It could bring new insights in the scientific discussion for the elaboration of new commercial distribution models.

The assessment of the retailscape could be used in retailer and consumer behavior geographic studies. For example, in agent-based modeling (Zhu 2015), this information might represent an environmental variable influencing the decision of the agents.

Finally, the cross analysis of these results with urban fabric parameters, street accessibility and centrality etc., might highlight interrelations between settlement form and commercial functioning. This is a particularly important perspective within our research.

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