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Investigating long-term lifestyle changes: A methodological proposal based on a statistical model

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Abstract

Lifestyles are both a broad and complex object of thought and a key determinant of the sustainability of our societies. A qualitative analysis of future lifestyles offers great freedom to imagine dramatic societal changes and explore paradigm shifts. Performing a quantitative analysis is less straightforward and more conceptually questionable. In this paper we introduce a statistical model that we developed for France to specifically address long-term lifestyle changes and their consequences for the consumption of goods and services, housing demand and demand for mobility, which are key determinants of resource use and emissions. We use national social surveys to identify significant patterns. The model enables us to assess explorative scenarios if lifestyle changes are not too disruptive. In providing an explicit representation of lifestyles at a macroscopic level, it can inform us of the interrelated desirability and sustainability debate.

KEYWORDS

consumption, foresight, lifestyles, model, transition

1 | INTRODUCTION

Since the Rio Earth Summit in 1992, there has been increased recognition of the role of societal changes in achieving a sustainable society. A typical quantitative technical and economic analysis stresses factors such as resource efficiency, carbon content of energy flows, and costs or gross domestic product (GDP), whereas a societal and lifestyle perspective puts the emphasis on the potential for or barriers to a wider diffusion of sustainable practices in a society, and seeks how to increase the engagement of consumers and citizens to reduce their lifestyle footprints while avoiding adverse rebound effects. While lifestyles relate to our ways of "doing," "having," "using" and "displaying" our behavior and all the related products, objects and infrastructures (Røpke, 2009), they are the logical background of our ordinary resource uses and yet remain a broad and complex object of thought. It is therefore essential to understand their role as a lever toward a more sustainable society. Furthermore, when looking forward to 2050 and beyond, we are not irreversibly locked in an unchanging set of social patterns or lifestyle: future decades could either see a move toward a more resource-intensive techno-society, or a society with different degrees of sobriety. Conducted in a qualitative way, an analysis of future lifestyles thus offers great freedom to imagine dramatic changes in societies and explore paradigm shifts. These changes could either result from the spread of various existing behaviors currently considered as marginal, or emerge from original, extensive social movements.

The scientific and systematic treatment of lifestyle is an emerging research field that encompasses several disciplines and multiple concepts. Reacting to the abundance of the literature on consumption, Jackson (2005) challenges the idea that consuming more always increases welfare and puts forward an alternative understanding of consumption as a "social pathology." Beyond its criticism of "utilitarianism," this work supports building a more complex understanding of how needs are formed instead of what is behind conventional consumer preferences. The Stockholm Environment Institute report adopts a more practical, toolbox approach and proposes a transversal description of some key themes and methodologies used to investigate either sustainable alternative lifestyles or, with a more restrictive focus, sustainable consumption (Scott, 2009). A survey by the United Nations Environment Program (UNEP) also provides evidence of differences and similarities in the declared priorities of young adults around the world. Although the sample is not fully representative, this report gives multiple qualitative views on the aspirations associated with the notion of sustainable lifestyle (UN Environment Program, 2011). Similarly, the SPREAD project offers a comparable exercise centered on Europe (Kuittinen et al., 2012), in which participants at several workshops imagined sustainable lifestyles in Europe in 2050 with an annual material footprint target of 8,000 kg per person. The challenge

of supporting sustainable consumption practices is addressed in Jaeger-Erben, Rückert-John, and Schäfer (2015) through a review and typology of several practical examples and, in Shao, Taisch, and Mier (2017), with a focus on making information on product attributes available to consumers for more informed purchase decisions. In the UK, the sustainable lifestyle approach of the Department for Environment, Food & Rural Affairs (Defra) (Eppel, Sharp, & Davies, 2013) provides a strong case of a government department's efforts to understand and promote sustainable behaviors and lifestyles. The proposed segmentation into population groups reveals differences in their willingness to engage in more sustainable behaviors, showing for instance that the two extreme groups of "Positive Greens" and "Honestly Disengaged" are of similar size. In France, the iterative and participative process described by Emelianoff et al. (2012) provides a comprehensive description of five possible future lifestyles by 2050 defined in the PROMOV project. Extended to the world scale, the heterogeneity of societal aspirations and their potential transformative power directly frame the likelihood of a more sustainable future when considered from a global perspective. In De Vries and Petersen (2009), cognitive maps and so-called "worldviews" that encompass individual psychological and socioeconomic drivers of action have been proposed as a qualitative backbone for the specification of contrasted scenarios of future energy needs. However, lifestyle elicitation in the proposed example of The Intergovernmental Panel on Climate Change's narratives remained coarse, which is partly because only generic and broader worldviews related concepts and effects (total population, GDP, aggregated mobility, etc.) are accessible in practice for large-scale world regions.

This overview of the growing and diverse literature on sustainable lifestyles and behaviors illustrates that the challenge is to improve our understanding of the process of the behavior itself, its psychological dimensions (values, meaning) and societal dimensions (social pressure, collective practices) and potential governance schemes. This has been tackled using conceptual frameworks and practical case studies. Quantitative scenarios of future lifestyles have received less attention, mainly due to the absence of a common understanding of the boundaries and meanings of lifestyle. However, the debate on sustainability requires a quantification of resource use and emissions at macroscopic level. Therefore, addressing lifestyle changes raises a methodological question: how can future lifestyles be quantified?

In this paper we propose a numerical model to project alternative social practices (mobility, housing and consumption of goods) in the long term in France. The model is intended as a dialog tool to make assumptions formulated as lifestyle changes in a form that is useable for techno-economic analysis and thus bridges the two approaches. A model cannot of course replace the cognitive, human and imaginative value of workshops, such as the coconstruction workshops cited above. It should be seen as a complementary tool that can superficially explore alternatives.

Longer-term lifestyle transformations have been explicitly proposed by Mont, Neuvonen, and Lähteenoja (2014) for Europe based on visions made by expert groups and a specified sustainability target. The PROMOV project also used a comprehensive qualitative approach to future lifestyles in France that involved an interdisciplinary panel of experts. We adopt a macroscopic perspective on social practices and quantify those using existing large-scale statistical surveys. Compared to the literature on future lifestyles, our aim is to propose a quantitative methodology and use a more systemic framework to explicitly characterize the impact of changing lifestyles on the demand for mobility, housing and goods and services. The main expected contributions are thus a higher level of detail of lifestyle dimensions and the numerical model we propose for an effective implementation. Future lifestyles may combine sustainable and unsustainable patterns. Based on information from recent surveys, our core assumption is that we can anticipate future lifestyles and their impacts by valuing the heterogeneities of observed practices. The proposed methodology leads to explorative scenarios according to the typology of Börjeson, Höjer, Dreborg, Ekvall, and Finnveden (2006), and does not attempt to "predict" future lifestyles. Section 2 presents our statistical approach, Section 3 introduces a concrete test case, and then Section 4 discusses some limitations and implications of our proposal.

2 | METHODOLOGICAL PROPOSAL

2.1 | Surveys as a substrate for a quantitative approach to social practices

Our aim is to investigate the impact of future lifestyle changes on housing demand, the demand for mobility, and the consumption of goods and services. To achieve this goal requires taking a quantitative approach to lifestyles. This is a delicate task given that lifestyles are related to both qualitative and quantitative dimensions, and conceptual and practical dimensions. Lifestyles are multifaceted and marked by our relationships to time, space, others and ourselves (Hérault, 2013). Nevertheless, they have a visible result in individual and collective practices in the broad sense. It is through these practices that we intend somewhat to "capture" lifestyle traits and capture them through data from French national surveys. Most of these surveys are conducted periodically every 5–10 years, providing valuable foresight material.

Five national surveys were used to cover several dimensions of social practices: the population census, the Housing Survey, the National Transport and Travel Survey, the time-use survey and the household budget survey. A short description of their goals, scope, existing editions and sample size is provided in Table 1. We used the latest available edition of each of these surveys (except for the population census) to establish a baseline on current practices.

Each survey includes several variables that directly provide two types of information, that is, information on individual (or household) characteristics and information on their practices. For example, the National Transport and Travel Survey contains a set of variables describing individual daily mobility (e.g., number of trips, distance, means of transport, aim) and a set of variables describing the individual (e.g., gender, age, situation) and his or her household (e.g., size, composition, age of the household reference person). A key step in our approach is to select a set of variables to build a representation of the people and their lifestyles. Table 2 reports the types of variables that we used to address the different lifestyle dimensions and the questions addressed by each set of variables.

TABLE 1 Short description of the five national surveys used

Name	Time use survey	Housing survey	National Transport and travel survey	Household budget survey	Population census
Purpose	To collect accurate information on how individuals use their time	To collect comprehensive and accurate data on the housing stock and the conditions of household occupation	To improve knowledge of mobility of households in France	To study household expenditure and income at a microeconomic level	To ascertain and follow the evolution of the population living in France in its geographic diversity and its evolution
Editions	1966–1967 1974–1975 1986–1987 1998–1999 2009–2010	1955, 1961, 1963, 1967, 1970, 1973, 1978, 1984, 1988, 1992, 1996, 2002, 2006, 2013	1966–1967 1973–1974 1981–1982 1993–1994 2007–2008	1979, 1984, 1989, 1995, 2001, 2006, 2011,	Since 1801 Every 5–9 years from 1801 to 1962 Harmonized data: 1968, 1975, 1982, 1990, 1999, 2006–2012
Edition used to establish a reference	2009–2010	2006 (the latest edition has been available since march 2016 and was not used for the first version of this paper)	2007–2008	2011	2009
Main scope	The survey details how individuals use their time based on a description of two full days by the individual surveyed (use of notebooks)	Nationally, this is the major statistical source to describe the housing stock and the occupation conditions of a household's primary residence. Only ordinary dwellings are concerned	The survey investigates short- and long-distance mobility and the use of individual and collective means of transport	The survey provides detailed data on all kinds of expenditure (including expenditure other than on goods and services; e.g., taxes) and the incomes of individuals and households surveyed (only ordinary households)	The census provides information on population and housing: Gender, age and origin, marital status and place in the household, diploma and place of study, occupation, place of work and mode of transport, previous residence, housing conditions and location
Sample in the last edition	≈28,000 notebooks ≈18,000 individuals ≈12,000 households	≈43,000 households ≈43,000 dwellings ≈110,000 individuals	≈45,000 notebooks ≈19,000 individuals ≈19,000 households	≈41,000 individuals ≈16,000 households	The whole population is concerned

TABLE 2 Types of variables used to build a quantitative representation of "people and their lifestyles" and their availability in each survey

		Survey				
	Types of variables	Time use survey	Housing survey	National Transport and travel survey	Household budget survey	Population census
Who are they?	Age, gender, activity status	+++	+++	+++	+++	+++
With whom do they live?	Household size and composition, incomes	++	++	++	++	+++
Where do they live?	Type of urban space	+++	+++	+++	+++	+++
What do they do?	Frequency of different kinds of activities and time spent	+++		++	+	
Where do they do it?	Location of activities (at home, at work, etc.), to-face or virtual activity	+++		+++		
What do they own?	Ownership of equipment, vehicles, furniture	++	+	+	+++	+
What do they consume?	Volumes of each type of goods and services				+++	
How do they inhabit?	Building type, dwelling size	+	+++	+	+	++
How do they move?	Number of trips, distance and means of transport	+		+++	+	
How do they travel?	Location, frequency, duration			++	+++	

"+++", "comprehensive data are available"; "++", "partial data"; "+", "little information"; empty cell, "no information available".

Our analysis of the surveys gives us the information that is contained in the correlation between variables. For example, people aged 75 years and older make on average half as many weekday trips as the rest of the population (Figure 1). This reflects the process of biological and social ageing, that is, it is more common for people aged over 75 years to experience physical discomfort when moving around and see their social networks shrink. A different lifestyle for this group, characterized by enhanced social participation or physical capability over time, coupled with a change in the population structure could therefore influence total trip demand. Another example is the correlation between size of household and floor space per person in a dwelling (Figure 2). This correlation reflects the process of space sharing, which has a consequence on space needs. To give a concrete application of this process: while several types of room are considered by most people as "necessary" in a dwelling (e.g., kitchen, bathroom, living room), one of these types of room per household is generally considered enough.

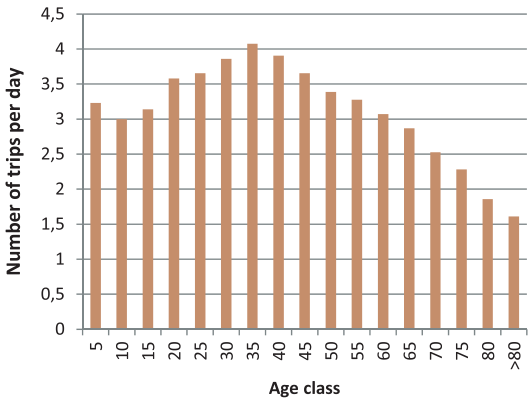

FIGURE 1 Number of trips per age. Data (ource: French National Transport and Travel Survey 2008 [Colour figure can be viewed at wileyonlinelibrary.com]

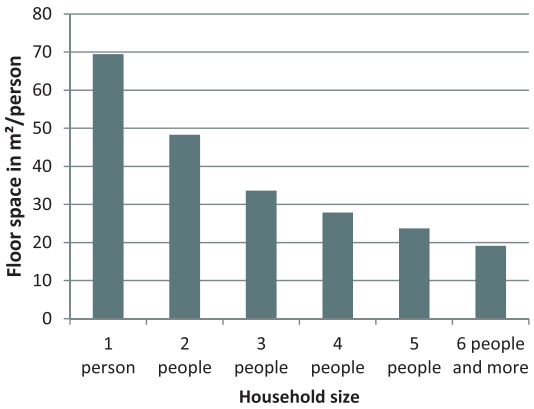

FIGURE 2 Floor space per person depending on household size. Data source: French Housing Survey 2006 [Colour figure can be viewed at wileyonlinelibrary.com]

2.2 | Principle of the modeling approach

A social survey consists of a matrix, where each row represents an individual and each column represents a variable. Some variables might describe individual or household attributes (e.g., age, gender), while others describe practices (e.g., number of trips per day per purpose, time spent at home per day). In its generic form, a cell of coordinates (i, j) contains the value or the modality of the variable j for individual i. Classification methods then allow for the identification of groups of individuals according to the modalities of the variables used as a basis for the segmentation. Finally, we use the correlations between variables of the surveys as a descriptor of social practices. These correlations are thus interpreted as the statistical manifestation of a combination of biological, psychological, cultural, juridical, geographic, demographic or economic processes. They are formalized in correlation matrices illustrated in Figure 3.

In this example, one categorical variable z with k modalities is analyzed in relation to two explanatory variables x and y with m and n

	$z = z_1$	...	$z = z_r$
$\begin{cases} x = x_1 \\ y = y_1 \end{cases}$	$\rho(z = z_1)_{x=x_1 \& y=y_1}$	...	$\rho(z = z_r)_{x=x_1 \& y=y_1}$
...	...	...	...
$\begin{cases} x = x_m \\ y = y_n \end{cases}$	$\rho(z = z_1)_{x=x_m \& y=y_n}$	...	$\rho(z = z_r)_{x=x_m \& y=y_n}$

FIGURE 3 Form of a correlation matrix. The response variable ***z*** is categorical and has ***r*** modalities. ***x*** and ***y*** are the explanatory variables which have respectively ***m*** and ***n*** modalities [Colour figure can be viewed at wileyonlinelibrary.com]

modalities respectively. Each row represents a unique combination of modalities of *x* and *y* in a group, and each column represents one modality of the variable *z*. The cells contain a value *ρ* that is the frequency of a modality for one pair of values (*x*, *y*). If *z* is a categorical variable, the cells contain the percentage for each modality; if *z* is numerical, the cells contain a statistical measure (e.g., mean, percentage of cases between two values). The distribution consistency is checked (Equation 1) for any pair $(i,j) \in \llbracket 1, m \rrbracket \times \llbracket 1, n \rrbracket$:

$$\forall (i,j) \in \llbracket 1,m \rrbracket \times \llbracket 1,n \rrbracket, \sum_{k=1}^{r} \rho(z = z_k)_{x=x_i \& y=y_j} = \mathbf{1} \quad (1)$$

The statistical approach we propose uses dynamic population and practice matrices as lifestyle markers. Its practical starting point is a basic matrix containing a future population pyramid (which is extracted from demographic projections), that is, only two variables are described: age and gender (an indication of the region could be added). The other variables are added one by one thanks to the correlation matrices. Figure 4 illustrates the principle of adding a variable to the population matrix. Here, adding a variable to this matrix increases the number of rows by a factor *r* (*r* is the number of modalities of the added variable, *z*). The population matrix (a) has two variables (*x* and *y*). Analyzing the correlations between *z* (as response variable) and (*x*, *y*) (as explanatory variables) provides the correlation matrix (b). These two matrices are combined to create the population matrix (c) which disaggregates each row of (a) in *k* rows (for the *k* modalities of *z*) using the frequencies of the matrix (b). This elementary operation is included in a sequential process starting from the basic population matrix (population pyramid) and leading to a more comprehensive population matrix including several variables describing the future population and its lifestyles.

Several methods exist to report the correlation between variables, and we opted to use decision trees. First, this method makes it easy to deal with a mix of numerical and categorical covariates. Secondly, the process implemented is extremely flexible, especially regarding the selection of variables taken into account. Decision trees use numerical categorization to build descriptors or predictors from a data source and are commonly used in data mining. In our case, they are used to group individuals with relatively homogeneous practices or situations with regard to a given variable. The practices or situations of each group are then characterized by standard statistical analyses (e.g., mean, distribution). This clear and flexible method also allows us to control the size of the groups formed to ensure their statistical significance. We use the RPART routines (as "Recursive PARTitioning") available in R to build the decision trees (Breiman, Friedman, Olshen, & Stone, 1984; Therneau & Atkinson, 2015).

Figure 5 shows an example of a classification tree and its associated correlation matrix. In this example, the response variable is the living floor space per person. The explanatory variables are the age of the household reference person (5-year classes), the household size (six classes: 1 person, 2 people, 3 people, 4 people, 5 people, 6 or more), the location of the dwelling (four classes: rural area, urban area of less than 100,000 inhabitants, urban area of more than 100,000 inhabitants, urban area of Paris) and building type (two classes: apartment or house). In this example, we have limited the recursive partitioning to eight parts. The most explanatory variable is household size. The sample is split into two groups: single-person-household and others. Each group is then further split into subgroups using the most relevant criteria. Figure 5 also reports the mean and standard deviation of floor space per individual in each group.

(a)

x	y	group size
...	...	...
x_i	y_j	$\alpha_{x=x_i \& y=y_j}$
...	...	...

(b)

	$z = z_1$	...	$z = z_r$
...	...	...	...
$\begin{cases} x = x_i \\ y = y_j \end{cases}$	$\rho(z = z_1)_{x=x_i \& y=y_j}$	...	$\rho(z = z_r)_{x=x_i \& y=y_j}$
...	...	...	...

(c)

x	y	z	group size
...	...	...	...
x_i	y_j	z_k	$\alpha_{x=x_i \& y=y_j \& z=z_k} = \rho(z = z_1)_{x=x_i \& y=y_j} \times \alpha_{x=x_i \& y=y_j}$
...	...	...	...

FIGURE 4 Example of adding a variable to the statistical model. [Colour figure can be viewed at wileyonlinelibrary.com]

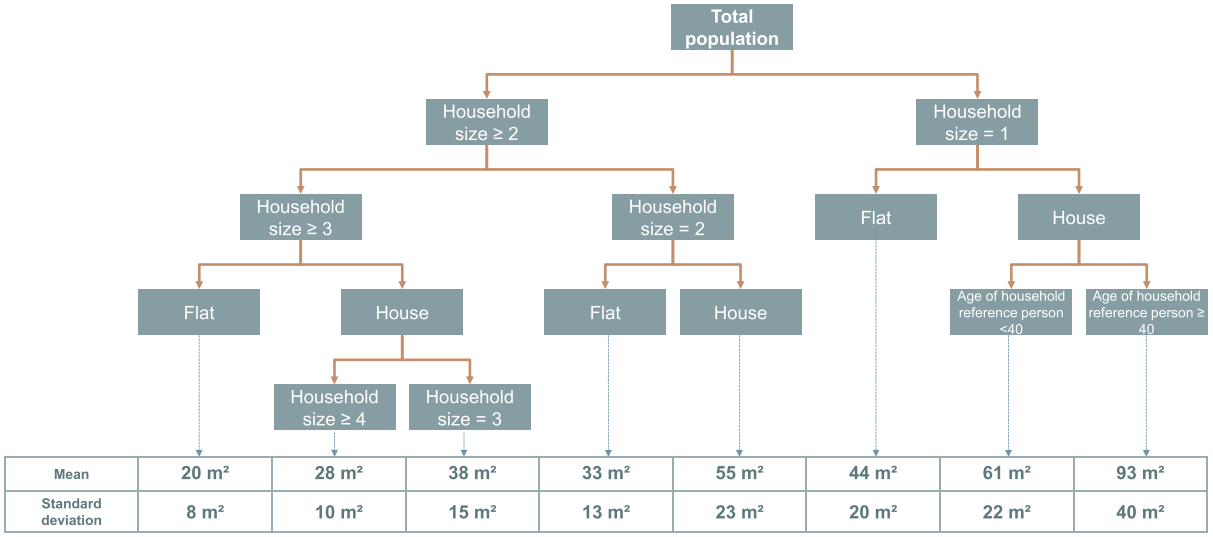

FIGURE 5 Regression tree related to the floor space per person and its associated matrix. Data source: French Housing Survey 2006 [Colour figure can be viewed at wileyonlinelibrary.com]

2.3 | Representing prospective changes in lifestyle indicators

We now turn to the critical question of the dynamics of our lifestyle indicators. Over several decades, different social mechanisms can indeed lead to changes over time in the pattern of aggregated practices in a society (here at national level). The first of these is demographic changes and the reconfiguration of the population structure. While it can be argued that there are as many original lifestyles as there are individuals, we can also identify some age-based groups with relatively homogenous practices. Changes in the relative sizes of these different groups—all things being equal otherwise—would also change the aggregate collection of lifestyles. Population pyramids and revenue distribution are examples of structural elements that will evolve in the future and potentially modify the dependent practices. Secondly, we can include more progressive social changes, such as changing perceptions of societal priorities (e.g., awareness of the environment over recent decades), new social trends such as remote activity (teleworking, teleshopping, teleconferencing) and the development of a leisure economy. Thirdly, some changes are disruptive and can be perceived as radical changes with fast rates of adoption. They can be triggered by unexpected economic crises that dramatically reduce the wealth available to share in a society, or can originate from a massive spread of new forms of social practices enabled by wider access to new social networking capabilities (car ownership, internet access). In our approach they are treated as scenarios. The main principle is to convert narrative assumptions of change into quantitative practice changes in frequency in one or some of the correlation matrices. Figure 6 depicts this simulation process, in which some changes are introduced through the replacement of reference matrices by modified matrices.

3 | TEST CASE ILLUSTRATION

3.1 | Simulating a more urban, virtual and high-tech lifestyle

The methodology described above was applied to illustrate the influence of a range of future lifestyle patterns on housing demand,

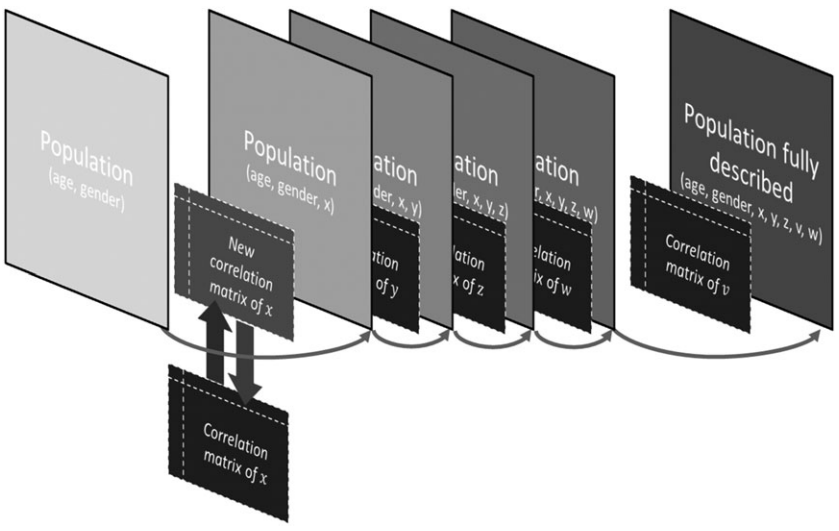

FIGURE 6 Introduction of lifestyle changes in the simulation process. Here, the correlation matrix of ***x*** is changed.

mobility needs and the demand for selected goods in France. Our scope is the year 2050 and includes people living in mainland France and belonging to a household, representing about 92% of the whole population living in the French Republic.

The constructed test case, called "individual and virtual society," describes a shift toward more urban, virtual and technology-oriented lifestyles. It depicts a more performance-centered, individualistic society (Table 3) where the desire for performance and personal development drives most people to live alone, with no constraints from others. To access the most sought-after leisure activities and services, people tend to live in small apartments in large cities. More and more activities are carried out virtually: work, social relations, shopping, and so on. Individuals pay great attention to their home and spend a great deal of time in it. The demographic changes in volume and structure are based on the central projection of the National Institute of Statistics and Economic Studies for 2050 ("Insee projection"). The population increases by 16% compared to 2010, reaching 70.3 million.

3.2 | Induced future housing demand

The simulation process starts with a population matrix of three variables (age, gender, household size) and successively adds seven lifestyle markers as described in Figure 7. The first steps describe the composition of the household, situation and socioprofessional category of its members. These steps impact the choice of location according to the correlation matrix related to the urban unit size range. Figure 8 details the preference transformation for each location type for our test case. Finally, the building type matrix yields the demand for different types of housing according to location and household characteristics.

Figure 9 shows the size and composition of the housing stock resulting from the simulation. The preference for living alone results in a need for about 67% more dwellings than in 2010. In comparison, a simple scaling factor applied to the total population would lead only to an increase of 16%. Furthermore, growth is asymmetrical and combines fewer houses (in rural areas) with more (small) apartments in big cities. This growth is a key factor of resource use for the construction sector.

Regarding surface, which is a key determinant of energy use for heating, cooling and lighting, two effects influence the results. On the one hand, the preference for urban and metropolitan areas contributes to reducing the floor space per person due to the higher pressure on space and on the housing market in dense areas. However, this effect is more than compensated for by changes in cohabitation practices. Thus, a reduced share of space contributes to a significant increase in the mean floor space per person and a large increase in the total floor space needed (+37%).

3.3 | Induced demand for specific goods

We now consider the impact of our future lifestyle assumptions on consumption of goods and services through the demand for cars, household appliances, digital equipment, computer equipment and audiovisual products. Three new types of variable are added to the previous simulation process to simulate the demand for these goods (Figure 10). Compared to the current situation, the main lifestyle changes that could affect this demand are: household composition, which reflects mutualization at household level; the location of dwellings, which determines the need for cars to move around; and changes in the age structure of the population.

The durable goods covered by the Household Budget Survey are well established in contemporary society and contribute significantly to the global material footprint. While disruptive technological innovations could make them obsolete, they are an integral part of our practices and activities (leisure, productive work and domestic work). Figure 11 shows that for these goods a significant reduction below current levels is not attainable without dedicated policies or disruptive changes. Here, demographic growth and changes in cohabitation

TABLE 3 Summary of assumptions on lifestyle changes

	2050 lifestyle change scenario "Individual and virtual society"	
	Qualitative description	**Quantitative assumptions**
Demography	INSEE projection – central hypotheses	Population growth: +16% The number of people aged 65 years and over has almost doubled since 2010 (from 10.5 to 19.6 million, from 17 to 27%). Theshare of people aged under 15 years is almost stable (from 18% in 2010 to 16%)
Household composition, relations with others	More individual society Single-person households are the norm	40% of the population live in a single-person household in 2050 (14% in 2010); 14% live in households of four or more (39% in 2010). See also Table A1
Location of dwelling	Very strong attraction to metropolitan areas to the detriment of rural areas in particular	9% of the population live in rural areas in 2050 (23% in 2010); 25% in the urban unit of Paris (16% in 2010); 45% in other urban units of more than 100,000 inhabitants (30% in 2010). See also Table A2
Location of activities, relationship to space	Most of the time at home The share of virtual activities increases	The share of activities outside the home increases: From 8 to 40% for work (workers), from 22 to 40% for studies (students), from 35 to 18% for leisure (all), and is divided by 3 for shopping (all)

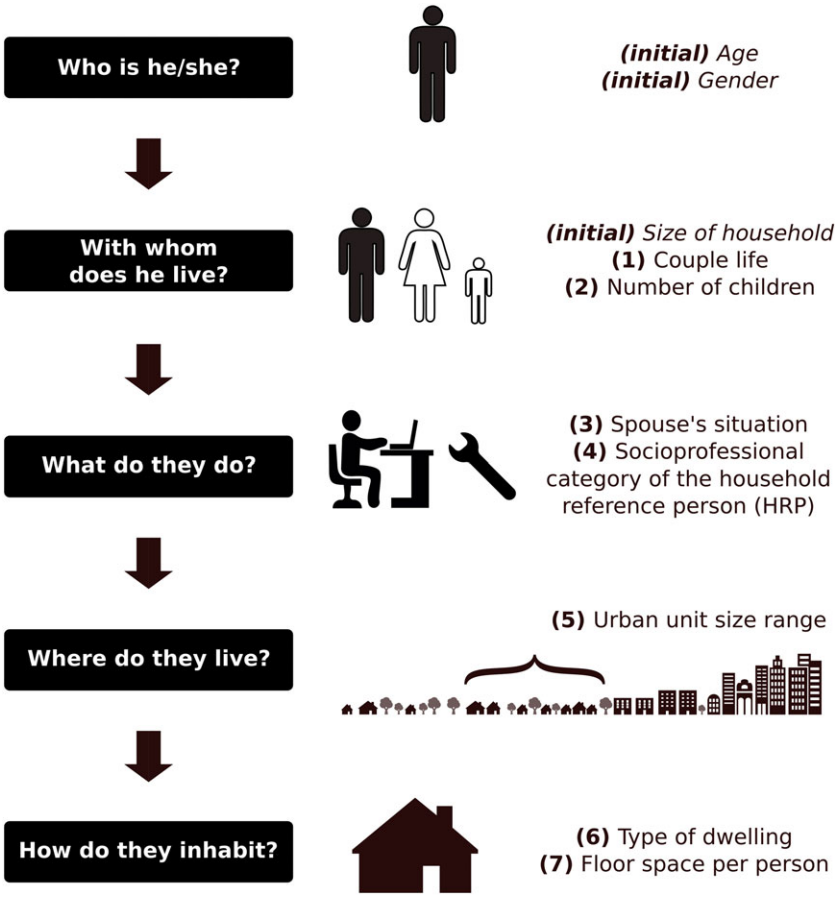

FIGURE 7 Lifestyle markers specification process for housing demands [Colour figure can be viewed at wileyonlinelibrary.com]

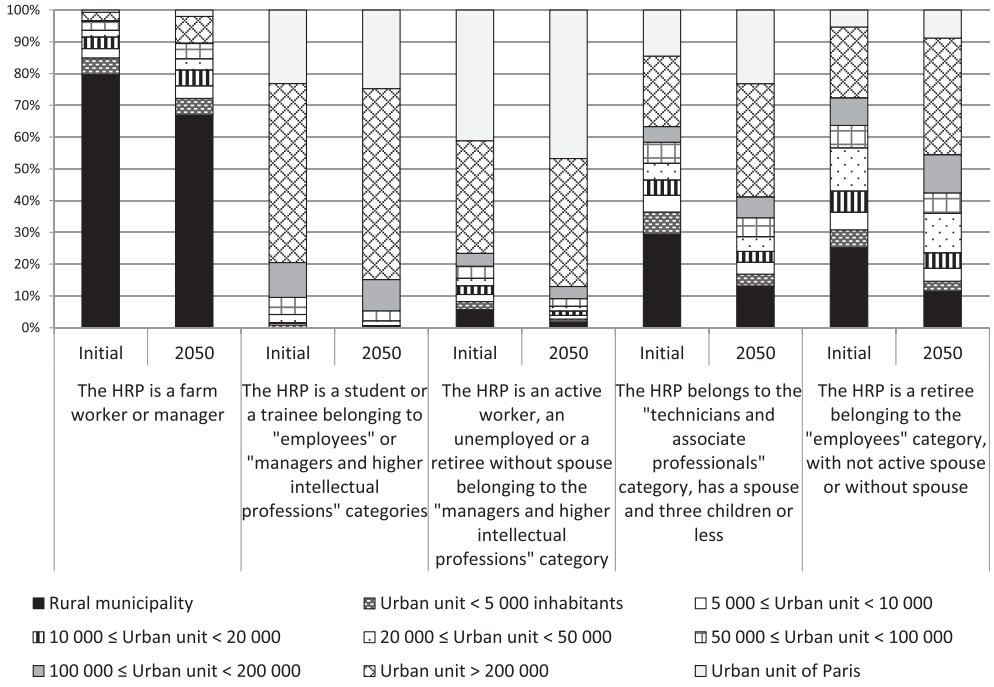

FIGURE 8 Representation of transformations in the preference for each location type in 2050 for five groups of population.

practices are the main explanations for increased demand. Therefore, although this is mitigated by a reduction in the mean size of dwellings (in particular for appliances and audiovisual products) and by the aging population (in particular for digital equipment), the simulated scenario does not indicate a path toward material sobriety.

The selected lifestyle assumptions also have a significant effect on the size of the car stock (Figure 12). Here, two contradictory effects are combined: the downsizing effect of household location in metropolitan areas where cars are less necessary is more than compensated for by the reduction of car sharing at household level due to the

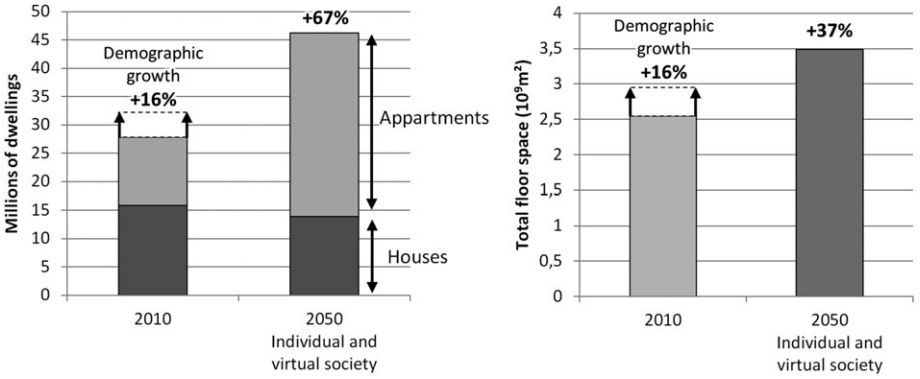

FIGURE 9 Size and composition of the housing stock for the current situation and the investigated scenario (number of dwellings and total floor space).

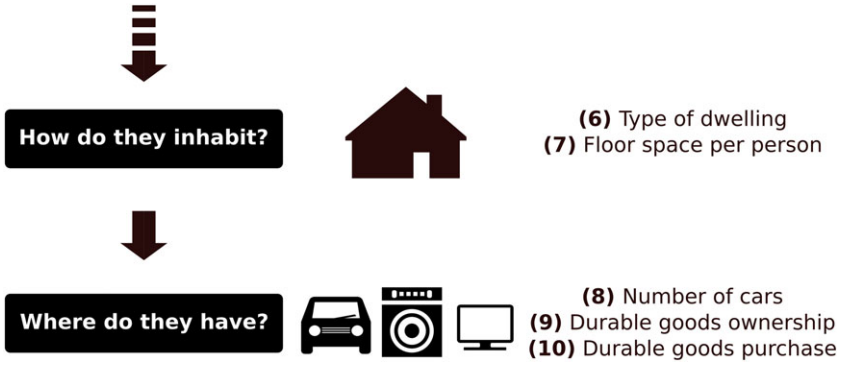

FIGURE 10 Simulation process and markers leading to the demand for specific goods [Colour figure can be viewed at wileyonlinelibrary.com]

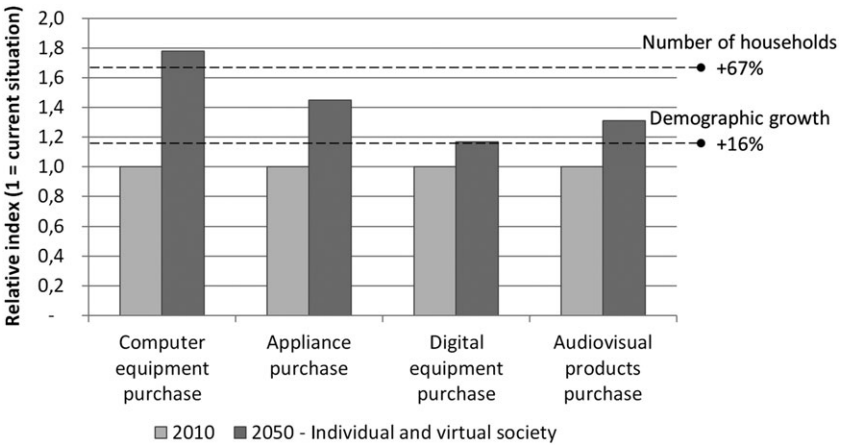

FIGURE 11 Consumption of four types of durable goods in the current situation and the investigated scenario (using relative quantitative index).

substantial increase in the number of households and a more individualistic approach.

3.4 | Induced needs for short-distance mobility

Trips are not performed for themselves but to reach a desired location to perform an activity of interest. Individual mobility is responsible for most of the environmental impacts of the transport sector. In this section, we consider social practices regarding short-distance mobility (and associated purposes) as lifestyle markers. In addition to changes in the location of households and in the use of time due to the aging population, the simulation process also considers changes in relationship to space (Figure 13).

For our test case, information and communication technologies change our relationship to space, leading to new arbitrages between real and virtual activities (work, leisure, learning, shopping). Most people prefer spending more time at home.

The impacts are illustrated in Figures 14 and 15. Despite demographic growth, the virtualization of society is the main explanatory factor for the drastic reduction in short-distance mobility (−31% expressed in number of trips). In this scenario, our hypothesis does not consider any rebound effect linked to a resource given that the virtualization is the result of a desire to stay at home. The aging population amplifies

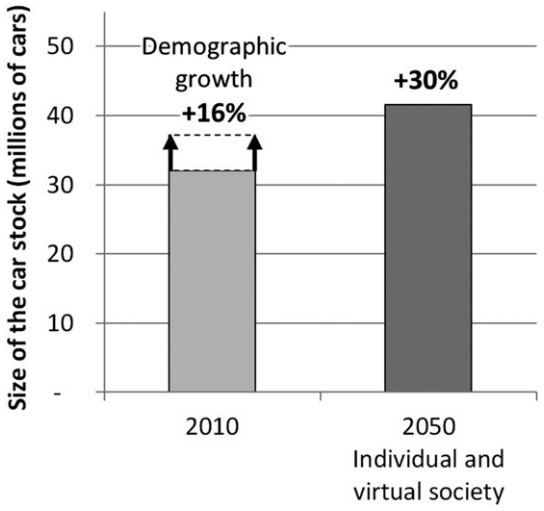

FIGURE 12 Size of the car stock for current situation and the investigated scenario.

this reduction in intensity of practices. However, altering this lower intensity of practices with further assumptions on good health and "socially reconnected ageing" could be a potentially disruptive change. This topic is beyond the scope of this paper, but Moisescu (2014) and Lumme-Sandt (2011) illustrate this better aging with the potentially disruptive evolution of an old-age lifestyle. In addition, the distance traveled is slightly reduced due to the more urban society (Figure 15).

Here a parallel with the private car stock indicates that while owning a car remains a strong individual aspiration, the increased virtualization does not translate this aspiration into regular use. In this "private car for fewer trips" world, the material and energy footprint of transportation could be less correlated.

4 | DISCUSSION

Lifestyles provide the overarching societal and conceptual framework to discuss how the way we occupy our space, consume, move or interact drives our demands for a wide range of services in the long run. The statistical model proposed in this paper aims to infer the quantitative and macroscopic consequences of lifestyle changes. It provides a multidimensional framework based on a set of variables to simulate the future population and its lifestyles. This was illustrated with a test case in which French society evolves toward a more individualistic, urban and high-tech version. We consider here some of its implications and limitations, first regarding analysis of practice, and second regarding the more conceptual ambition to approach lifestyles.

In using bottom-up assumptions formulated at a more societal level, the proposed methodology is systemic and can help capture simultaneously positive or negative influences of anticipated changes for each sector. When a population changes in volume, structure and cohabitation practices, then housing demand and consumption of goods may increase faster than the population (albeit at different rates), while an increased share of virtual activities could have a positive impact on short-distance mobility demand. Note that the transition to a more urban lifestyle does not involve a one-to-one transfer between the extreme cases of rural areas and dense urban centers. Indeed, it may also involve a shift to cities of small to medium size. This

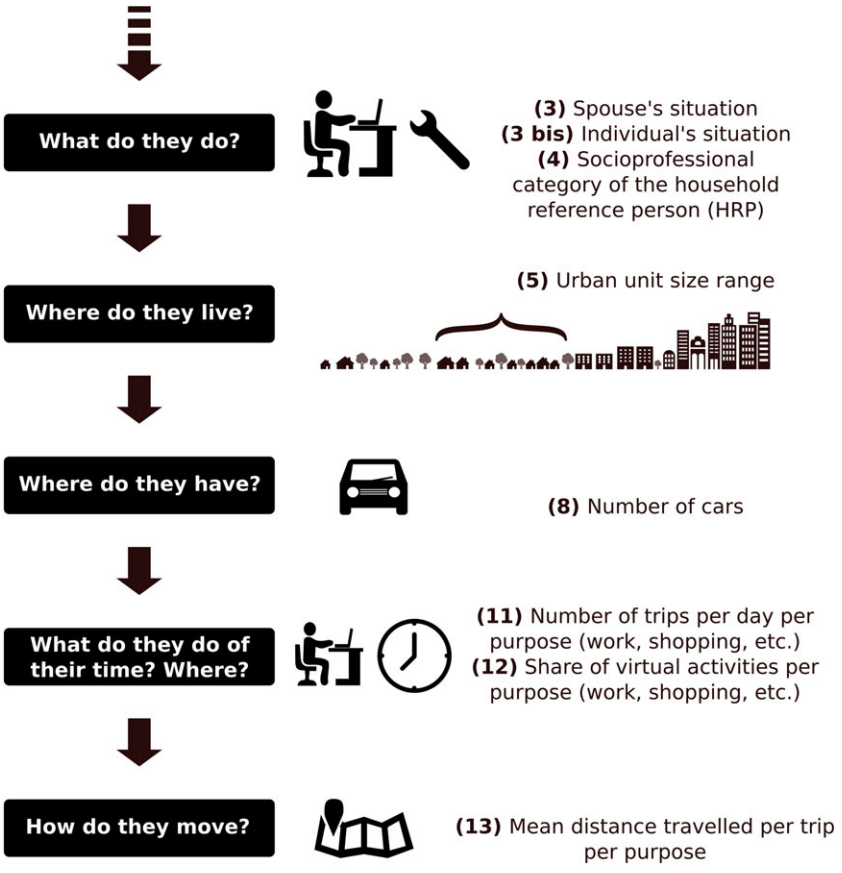

FIGURE 13 Simulation process and markers leading to the demand for short-distance mobility [Colour figure can be viewed at wileyonlinelibrary.com]

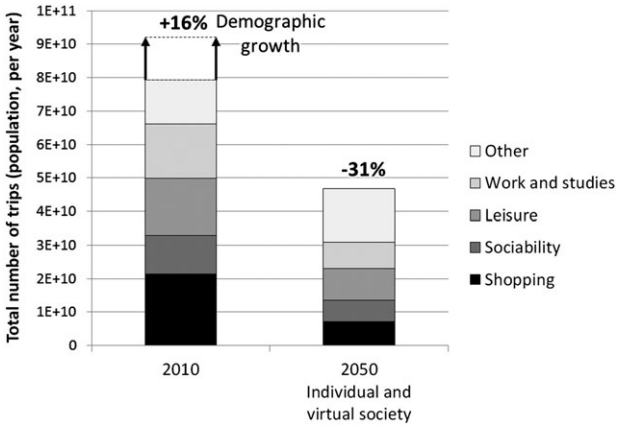

FIGURE 14 Total number of trips per year in the current situation and the investigated scenario.

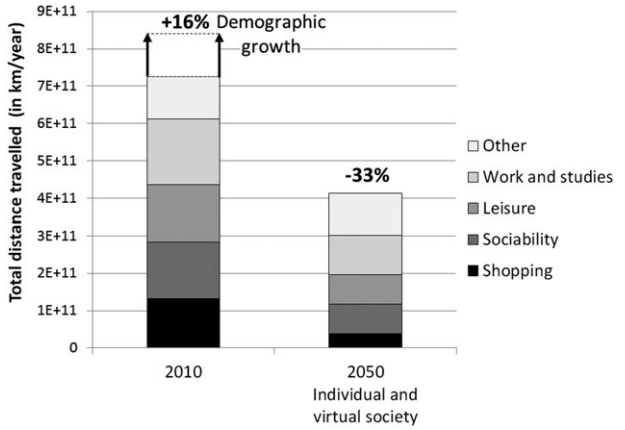

FIGURE 15 Total distance traveled per year in the current situation and the investigated scenario.

need for a systemic and more nuanced description is the first implication of the proposed methodology.

The adopted description of practices and lifestyle markers assumes a partial reproduction of past or current patterns as reflected in existing social organization and behaviors. As a guiding paradigm, this choice has conceptual implications regarding simplification and its ability to simulate lifestyle changes. This is illustrated by the following concrete discussion points.

Our housing demand module focuses on the choice of household location and does not account for new constraints from the supply market, which is implicitly assumed to adjust, creating no more frictions on the desired demand than today. An analysis of the corresponding processes by Genesove and Han (2012) for the United States shows that the average buying and selling time on the market is approximately 2 months for their panel, which could support the simplifying assumption of perfect liquidity for a long-term analysis. However, the correspondence between buyers' initial wishes and the actual transactions is not estimated. The complexity of the housing market is further demonstrated by Hiller and Lerbs (2016), who provide evidence that prices on housing markets are geographically affected by the demographic structure of Germany. While some of these effects might be captured in the socioeconomic characteristics of households, the corresponding levers are not explicit in the scenario formulation process, and existing frictions are invariably propagated in the future. Thus, the lifestyle implications of instruments (rents, prices, public infrastructures, macroeconomic conditions) that influence supply cannot be directly simulated in the proposed model.

More evidence can also be found in modeling generational effects on practices for a given age group (Büttner & Grübler, 1995), which could lead to different behaviors at the same age not accounted for in the test. Using the proposed methodology, a progressive shift in time for a given age group could be simulated by, for instance, changing the practice matrices for people aged over 75 years to progressively match those observed today for people over 65 or 60 years. Interesting discussion points would be the magnitude of this effect for each service or consumption function, the time lag and intergenerational influences. A retrospective example for France is provided by Recours, Hebel, and Berger (2008), who describe changes in expenditure shares between generations for various goods.

More limitations are encountered when investigating disruptive elements that are not observed today even in the form of weak signal. They were partially treated in the analysis linking an increase in virtual activities to changes in expressed mobility needs. This was modeled in our test case by the share of activities performed in or outside the home. However, in practice, the link between the virtualization of activities, a society using more intelligent transport systems, and future mobility demand is more complex and includes, for instance, potential rebound effects due to improved traffic conditions. Furthermore, the potential disruptive effect of autonomous cars, which will probably feature in a virtual and high-tech future, was not considered. Will this technology lead to fewer cars, less attractive public transport, more traffic or more urban sprawl? This is a fairly recent research topic, and for the sake of clarity, we did not include it in our statistical approach. A relevant analysis by Gruel and Stanford (2016) on this topic uses qualitative interviews and a dynamic representation system to conceptually discuss some of the impacts of autonomous vehicles on a transport system. Their work describes three cases combining vehicle change, mobility change and ownership model change.

Finally and more fundamentally, the perception of lifestyles using the variables reported in surveys remains a simplification. As expressed by several authors, a more complete expression of lifestyles should include the role of values, motivations, life events and leaders. Ahuvia, Carroll, and Yang (2006) describe the limitation of quantitative methods and show how a consumer culture theory approach could for instance improve our understanding of the sociological and historical dimensions of lifestyles. The analysis by Misra and Stokols (2012) considers the effect of virtual activities on the relationship to space or social networking using a richer conceptual framework. Regarding mobility demand, the work by Clark, Lyons, and Chatterjee (2016) highlights the role of life events in generating tension or dissatisfaction that can ultimately lead to the decision to buy a car as an adaptive measure. All of these contributions take the description of lifestyle-associated processes much further than the scope of the statistical and quantitative model proposed here. Using our modeling paradigm, we are unable to endogenously simulate the effects of lifestyle

changes triggered by less visible drivers (values, motivations or culture).

In approaching lifestyles with a restricted number of variables, the social mechanisms at play are necessarily simplified. Mimesis in the sense of inherited structure of practices provides a partial answer, because the clustering approach integrates multiple original and isolated behaviors in a more stable statistical observation. However, this argument itself reaches its limits when very disruptive practices are considered. A purely statistical approach must then be complemented with dedicated sociological analysis when available, or with coherent narratives about the disruptive assumptions.

5 | CONCLUSIONS

Future lifestyle patterns are a central yet complex dimension for assessing the different options available to our societies regarding both desirability and sustainability. Related changes are commonly described in broad conceptual terms and expressed using a high level of abstraction. Adequate transcription methods toward more practical outcomes are then needed. This study proposes a quantitative approach to project alternative social practices related to mobility, housing and consumption of goods in the long term. Foresight as a means to inform the debate and decisions is thus applied to question the broad idea of lifestyle changes in the frame of resource use and emissions issues, which require dealing with quantifiable objects. The proposed methodology is explorative and aims at providing a consistent explanatory environment to consider contrasted future lifestyles in either sustainable or unsustainable ways. The main expected contributions are two-fold. Firstly, the selected set of representative dimensions of lifestyles (ten dimensions and their associated variables) can support explicit and high heterogeneity in social markers and practices while being compatible with the statistical knowledge readily embedded in existing social surveys. This could help translate the big picture of the storyline for a particular group of scenarios, often described qualitatively using metalevel concepts related to broader values or socioeconomic orientations into more concrete lifestyle markers. Secondly, the statistical method described is a proposal to effectively quantify the intensity of practice for each marker while capturing some of their systemic interactions.

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APPENDIX

TABLE A1 Dynamics of size of households for the three scenarios: B, business as usual; I, individual and virtual society; S, social link society

	2010	Average annual rate	2030	2050
1 person	14%	+2.70%	27%	40%
2	28%	+0.30%	30%	31%
3	19%	−0.60%	17%	15%
4	22%	−2.50%	15%	8%
5	11%	−2.50%	8%	4%
6 and more	6%	−2.70%	4%	2%

TABLE A2 Dynamics of location of the households for the three scenarios, expressed in percentage of households in each area

	2010	Average annual rate	2030	2050
Rural municipalities	23%	−2.30%	16%	9%
Urban unit of fewer than 100,000 inhabitants	30%	−0.90%	26%	21%
Urban unit of more than 100,000 inhabitants	30%	+1.00%	38%	45%
Urban unit of Paris	16%	+1.10%	21%	25%