GIS-Based Spatial Analysis for the Integrated Transport-Land Use-Energy Planning: An Application to the Great London Area

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Abstract: This work focuses on examining the possible advantages for the urban sustainability, derived from the integration of transport, land use and energy systems. The main aim is to develop a GIS-based method that can help decision makers, either public or private, improving the economic, social and environmental sustainability of urban areas through an integrated transformation approach. As a result, it was possible to provide a spatial analysis technique based on seven synthetic variables and on the application of a cluster method able to identify the portions of urban areas where investments and urban integrated transformation processes can be more suitable, according to the dynamic relationships among transport, land use and energy systems. The methodology was applied to the Great London Area and lead to significant results: the cluster classes follow the transport railway network evolution within the study area boundary. The paper is organized as follow: in section 1 the integration of transport, land use and energy planning is investigated; following the introduction, in section 2, the GIS-based method is presented, followed by a description of the application to the Great London Area; in section 4, findings of the methodology are explained. In the last section, results and future developments are discussed.

Key ords: Energy consumption, sustainability, transport, clustering, GIS, spatial planning.

1. Introduction

The aim of this first section is to describe the main dynamics of the urban and technological developments, whose complex and fast evolution has requested an increasing focus on the sustainability concept. The close connection between the transport network, the land use and the energy consumption has been highlighted both by the scientific community and research works and by the latest EU and global politics. Furthermore, the role of Geographical Information Systems (GIS) within the field of government of urban and territorial transformations is deeply analyzed.

The development of new sources of energy and new technologies, the need for communication and a deep functional re-organization have determined a territorial transformation process and consequently the evolution of urban areas [1] Over the centuries, the discovery and availability of various energy sources have greatly facilitated the economic development of humanity, for example: inventions such as the steam engine have made possible to increase the availability of energy and to achieve a better quality of life. The transition from an economy and a predominantly agricultural production to an industrial type, characterized by technological innovation, marked the succession of different historical periods, but above all, the evolution of the city [2]. Such transitions have been associated with considerable urban and demographic development phenomena [3,4].

The constant growth of the urban population has determined an increase in the dimension and in the complexity of the urban systems, as a consequence there has been an increment in the demand of needed resources and their development and sustenance [5,6]. Starting from 1987, after the oil crisis and the Brundtland report, the international scientific community, has adopted the concept of sustainable development, with the aim of optimizing the usage of

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the natural resources and develop new technologies, which would better use the renewable energy sources [7].

In 1994 the urban sustainable development has been defined as "the goal of minimizing the natural resources imports and the export of waste, in addition to the maximization in the protection of the natural capital and the local built (monuments and valuable works, comparable to non-renewable resources)" [8]. Sustainability, in the transports sector, has assumed, during time, an own relevance as a reaction to the growing negative impact generated by the private car usage and the expansion of transports system. The complexity in assessing the mobility sustainability, caused by the connections between the transport and other activities which affects the choices and lifestyles of human beings (social interconnection issue), is one of the reason that lead to vagueness of this concept which still lacks of a precise definition [9].

In the scientific context, the interplay between the functional system, the travel demand and the transport supply and, on the other hand, the environmental sustainability is still at an early stage, even though it would be able to reverse the current trends, both in terms of urban congestion and ecological footprint, e.g. GHG emission reduction [10,11,12,13].

The relationship between transport and land use has been widely studied since the 1960s, progressively adding the environment dimension also in the traditional LUTI models [13,14]. Nevertheless, the wide complexity and strict interdependence among these elements [15,16,17] make often difficult assessing and measuring their interactions in an efficient and holistic way [12,18,19,20,21]. In particular, the complexity in obtaining reliable information on energy consumption in a detail scale, the separation between estimating mobility demand models and the use of travel distances as a "proxy" for the assessment of energy consumption [22], can be identified as few of the main factors on which the lack of integrated transport, land use and energy

consumption studies depend on. On the contrary, this limited amount of information in the application-experimental field, is offset by a considerable number of documents, guidelines and strategies developed at a legislative level, aimed at optimizing the energy performance of urban systems, in which the transport system "is intended as a joint, integrated and interacting product of the distribution of activities on the territory and of the movement opportunities which the physical and intangible networks offers" [23]. Since the end of the 1990s, the European Union has focused its efforts on identifying innovative solutions for sustainable urban mobility, promoting research and initiatives in various areas, from public transport to traffic management, transport infrastructures to governance of urban transformations. Neither the energy efficiency, nor the policies to promote the purchase of green vehicles have, however, succeeded in countering the growing energy consumption in the transport sector, characterized by an increase of 21% from 1990 to 2010 [24]. The explanation of this apparent contradiction needs to be found in the evolution of individual mobility behaviours. Current trends, in fact, show an increasing use of private cars compared to public transport, an increase in daily trips, kilometres travelled and time spent on journeys [25]. An innovative approach is needed to solve both the "congestion crisis", and to improve the environmental sustainability of urban areas, especially for what concerns the energy consumption. "The interpretation of the space, mobility and energy domains should be seen as an arena's of changing (f)actors-networks in order to understand and create new links beyond the existing borders" [26].

The systemic interpretation of the city has led to the development of urban governance procedures, which allow the overcoming of classical urban planning, no longer able to manage the continuous and fast spatial and functional urban changes. In the last years, the continuous growing of urban system has required the

development and use of new instruments able to analyse it.

Among the technical instruments currently most used in the field of government of urban and territorial transformations, there are the Geographical Information Systems (GIS). From the land-use science point of view, the GIS has been defined as "a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world" [27]. For this purpose, the GIS could not be regarded as a mere software for data processing but on the contrary, it could be a catalyst for new cognitive processes and representation of the urban and territory phenomena. In general, the GIS is configured as an operating environment, within which it is possible to develop a decision support tool for the analysis, transformation and management of the territory [28,29]. The input data for GIS analysis are both geometrical and alphanumerical. GIS tends to be used no longer as an isolate software, but as an instrument able to communicate with other software and hardware dispositive, oriented to the governance of the transformations of the territorial of urban system. This means that GIS is a new knowledge development environment, a space to be modelled, following precise theoretical directions to develop systems that support the decision in the territory planning, a place to design through the development of original algorithms, applications that can solve specific problems and enable better management of territorial complexity [30]. In addition, a further aspect that allows GIS's greater ability to support planning processes is given by the use of tools which combine spatial and statistical analysis [31,32]. Therefore, numerous studies have shown how to use these tools in a GIS environment to get to know in the depth the different urban phenomena in order to support decision-making processes [33,34].

2. Materials and Methods

The proposed GIS-based methodology, that will be

described in the following sections, was applied to the Great London area. The choice of the English capital is motivated by its extension [1] and its own physical-functional characteristics which make it a highly complex urban area and because local authorities have been engaged, for several years, in promoting and implementing urban transformation interventions which aim to an improved sustainability and integration.

A rapidly increasing population (approximately 100,000 people a year) has characterized London metropolitan area and this trend means a rising both of public transport demand, 50-60% increase in trips and up to an 80% increase in rail trips, (Greater London Authority, 2014) and energy demand and carbon emissions (http://www.energyforlondon.org). According to these data and previsions, within the several urban plans and strategies developed during the last fifteen years (e.g. The London Plan 2004, 2008 and 2011, The London Transport Strategy 2010 and 2017, the London Energy Strategy 2011 and 2017), the integration of transport and land use component has been always considered as an opportunity to reach a "good growth" mainly characterized by a compact and environmentally sustainable urban system. Thus, the application of the proposed GIS-based methodology to the Great London area allows to support local public and/or private decision makers in identifying the most suitable areas for integrated transport, land use and energy transformation process.

2.1. Materials

The data used for the application of the GIS-based methodology to the Great London area were collected from the England National Census, in order to refer to an authoritative and open source data. The referring year is 2011, that is the same year of English Census.

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1 It is worth noting that the Great London refers to an area of 1569 sq km with a population of 7.75 million people (2009) with projections of 8.57 million by 2026 (Greater London Authority, 2011).

Before listing and classifying the data used, the different censorship spatial units used to collect the data in 2011 Census of England are described below, starting from the lower to the higher section:

• Output Area (OA) was created for the output of census estimates. OA represents the minimum geographic level for what the census data are provided. Firstly, they were used in Scotland in 1981, and subsequently across the UK during the 2001 census. Moreover, the OAs are roughly regular shapes and they consist of mainly urban or rural postcodes. They are usually formed by a number of residents that goes from 40 to a 100, which clearly shows that smaller portions were incorporated into larger ones;

• Lower Layer Super Output Area (LSOA) were introduced for the first time in 2004 across the United Kingdom and they were projected to improve the OA's results. They are created by the fusion of different Output Area, usually from 4 to 6;

• Middle Layer Super Output Area (MSOA) were designed as the union of more LSOAs and are characterized by a population of at least 5,000 individuals (7,200 average). They are defined as the surface area censorship type.

For this research, the Output Area level was used, in order to produce as accurate results as possible. In particular, the alphanumeric and geometric data used for this case study were (Table 1):

• Total number of population – used to calculate population density variable: the data were obtained from the NOMIS (Office of national statistics) 2011 governmental website (2011 Statistical Census Bureau) with reference to the 25,054 Output Area of the London Metropolitan Area;

• Total number of Jobs – used to calculate employees density variable: collected by NOMIS 2011 with reference to the Output Area, provide a division by sector but also the total number of employees in the single section;

• Functional Mix - parameter defined as the ratio between the total number of population and the total number of employees);

• Roads Network - used to calculate the walking accessibility at metro stations variable: collected by the open database OSM (Open Street Map) that provides geographic data. Data on all types of road arteries in the reference area were found;

• Urban Rail Network - used to calculate the walking accessibility at metro stations variable: with reference to the single OA, the routes and the locations of public transport stations were found by OSM, with particular attention to the 326 metro stations of London;

• Buildings Energy Consumption - used to calculate both the domestic and non-domestic energy consumption variables: these ones are the only values not found for OAs but MSOAs, as they were the only ones available. They were provided by the National Statistical Office with reference to the 2011 census and divided by domestic and non-domestic consumption;

Buildings location- used to calculate the building-coverage-ratio variable: in relation to the OAs, graphical data on the location of the buildings were obtained.

It worth noting the types of data used. In order to develop this work, no privileged channel has been used to retrieve data, but only sources accessible in open format. In order to ensure the correctness of the data processing, it is necessary to proceed with a cleaning operation of the geographic data to eliminate all non-essential information for the achievement of this work, in particular eliminate the tracts relating to non-pedestrian roads, as it is not the subject of the study.

2.2. Method

The aim of this section is to describe the phases that enabled the implementation of the GIS-based method used for spatial analysis. Thanks to the use of this sequence of operations, it is possible to support public administrations and private individuals in identifying portions of urban areas in which promote investments

Fig. 1 Greater London Area and Tube network.

Table 1 The set of alphanumeric and geometric data use for the application of tool at Great London area.

Data	Types of data	Spatial Unit	Year	Source
Number of population	Alphanumeric	OA	2011	NOMIS
Number Jobs	Alphanumeric	OA	2011	NOMIS
Buildings Energy consumption	Alphanumeric	OA	2011	London Datastore
Urban Rail Network	Geometrical	OA	2011	OpenSteetMap
Roads Network	Geometrical	MSOA	2011	OpenStreetMap
Building location	Geometrical	OA	2011	OpenStreetMap

for the implementation of integrated transport, land-use and energy transformation operations. The proposed GIS-based methodology is divided into four steps (Figure 2). It is based on seven variables, classified into the following four categories: the socio-economic category, which refers to the demographic and employment structure of the population; the land-use category, which refers to the urban morphology; the transport category, that concerns the accessibility levels of the rail network; the energy category, that is related to the urban energy consumption levels (Table 2).

The selected variables were chosen because they have the most considerable influence on the energy consumptions [11,34,35]. The three fields (transport, land-use and energy) were studied through seven synthesis variables that allowed to analyse their mutual interactions, in order to encourage the transformations of integrated portions of urban area, aiming to a greater sustainability.
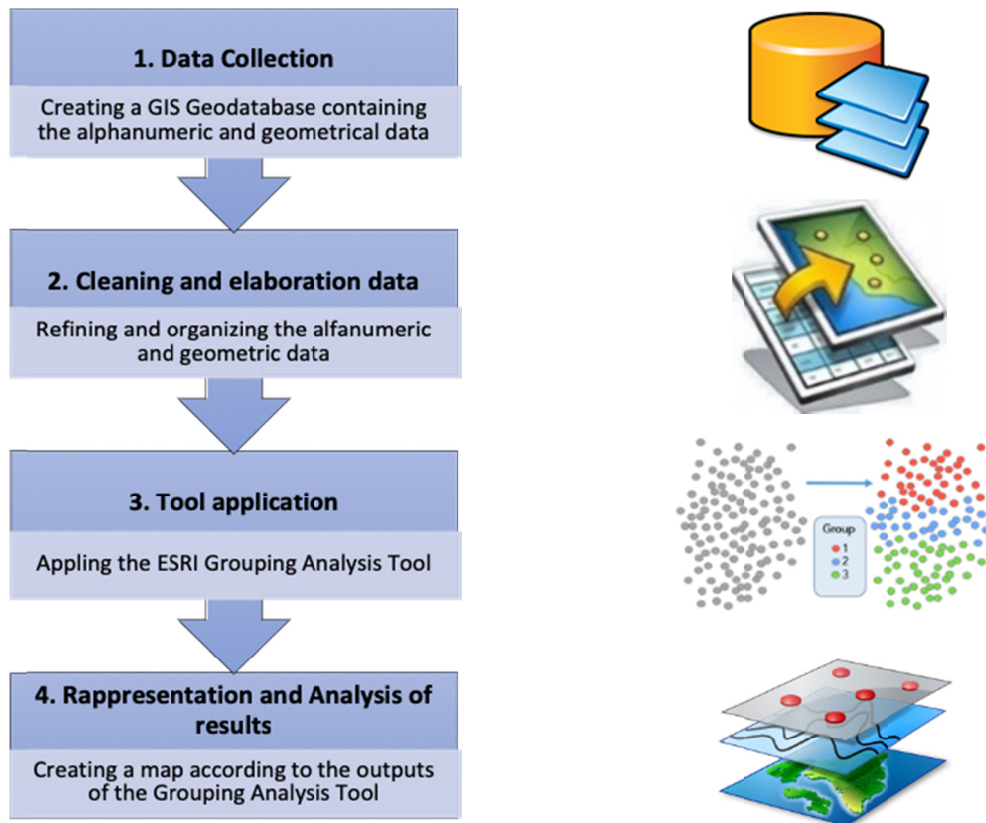
Fig. 2   The workflow of GIS-based method.

Table 2   The list of the selected indicators.

ID	Category	Indicator
1	Socio-economic	Population density
2	Socio-economic	Employees density
3	Socio-economic	Functional Mix
4	Land-Use	Building Coverage Ratio
5	Transport	Walking Accessibility at metro stations
6	Energy	Domestic energy consumption
7	Energy	Non-domestic energy consumption

The measurement of each of these variables was performed using both alphanumeric and geometric data, whose systemization was possible thanks to the associative, computational and representation skills of the GIS. Furthermore, the data belong the Open Data category, which are information collected in the database form "whereby public administration should be open to citizens, in terms of transparency, but also through the use of new information and technologies" [36].

It is worth noting that all listed values should be referred to the most suitable census section for the study or for the one available. The Census section refers to the minimum territorial unit of measurement corresponding in most cases to one block, or part of it, and is used in relation to socio-economic data.

According to Tab.3, the data were used to measure the seven selected variables and then they were put into the Geodatabase. The Geodatabase plays a key role in collecting the above data, where all class features, tables, and any files related to the data were stored. A standard spatial unit was introduced to solve problems

related to the ineffectiveness of the spatial reference units over which the above data are available. The hexagonal cell, which is the minimum space unit in which the study area is subdivided, has mainly hexagonal and square shape with a side that may have dimensions previously selected by the user based on the area to be analysed.

In literature, the use of a hexagonal cell rather than the square is advised when dealing with connectivity problems and when the identification of shorter paths is needed for calculating travel distances. The reason lies in the geometry of the cell itself: on the same side, the hexagonal cell has a smaller distance from the center to the side of the cell and also greater connectivity with the surrounding cells, unlike the square cell that is only in contact with the four neighbouring. Moreover, the hexagonal cell provides a greater aesthetic and accuracy in computing and showing th results, rather than the square cell.

In order to start with the GIS method, preliminary steps were needed to combine the constructed and the censorship reference section. The intersect command was used since it calculates a geometric intersection of the input files, the functions or portions of functions overlapping in all layers or parts of them are written in the same output function. Then, within the same censorship section, the buildings footprint was calculated in square meters. The intersect command is repeated this time for the hexagonal cells and for the output of the previous intersect, in order to define the portions of buildings belonging to the single cell and the relative proportionality coefficient between the total area of the single building and the surface portion of the single cell. The join command (typically used to add the fields of one table to those of another through a common attribute) allowed to link the data previously collected with its buildings through the common hexagonal cell of belonging. The latter statement does not apply, however, to the geographic data relating to the geographical location of the roads. For the previous mentioned, it is necessary to build and validate the

topology: collection of rules, together with a set of tools and modification techniques, allows the geodatabase to develop more accurate geometric models. The topology is then stored in the geodatabase as one or more relationships that define how the features of one or more feature classes share the geometry. In general, the topology serves as a description of how feature classes can be spatially linked. To build and validate topology, it is important to "purge" the map from graphic and geometric errors.

After the "cleansing" of the geographic data, the network is created. The latter is created from source features, which can also contain simple rows and dots, and stores the connectivity of the above source features.

The network is essential for the construction of service areas, which represent the actual user network paths within the reference area, relative to the proximity to a subway station or to any previously defined public transport tool. The range of a point of interest, valued through these service areas, is chosen in advance and often corresponds to the maximum walking distance, ranging from 500 up to 2,000 meters.

After calculating all the indicators for each hexagonal cell, the values have been normalized from 0 to 1, according to previous studies. These normalized data represented the input elements for the last step of the GIS-based method, which is the use of an ArcGIS cluster statistics tool. Clustering techniques refer to a multivariate data analysis procedure that aims to select and group the homogeneous elements on the basis of their mutual distance, in a multidimensional space [37].

Multivariate analysis has been applied to research field such as the area analysis with great validity, given the fact that it is able to process and summarize considerable quantities of information and data linked by complex interdependencies [38,39,40], a characteristic of territorial phenomena, which are complex to control. Therefore, the purpose of this statistical methods is in line with that of the present

research, based on the study of the dynamic relations between transport, land use and energy components.

In particular, the spatial analysis algorithm (geoprocessing) by ArcGIS Desktop "Grouping Analysis" (Spatial Statistics) allows to create homogeneous clusters of territorial areas with similar characteristics based on the variables calculated starting from the collected Open Data. Given the nature of the study so far, it is considered appropriate to use, amongst others2, grouping analysis. The latter defines the number of clusters using the statistical indicator Caliński Harabasz pseudo F statistics which is a relationship that reflects the resemblance within the group and the difference between the groups [15]. Based on the values of this indicator, which will be higher for distinct clusters, the tool creates a minimum tree (dendogram) that represents the results of the hierarchical agglomeration classification. In this inverted tree graph, for each grouping, the best solution is the one which maximizes both the similarity within the group and the difference between the distinct groups. The allocation of each input data to a cluster is done by using the k-means algorithm. The latter is an alternative algorithm that, at each step, minimizes the sum of the distances (Euclidean distances squared) of the n points from the centroid of the belonging cluster. Ultimately, the Grouping Analysis tool groups the common data according to their position, allowing to identify the exact values for the population, employees, energy consumption, coverage ratio and functional mix for a given number of areas.

The latter, given the number of groups to be created, looks for a solution where all the features of each group are as close as possible to each other. The "similarity feature" is based on the set of attributes specified for the analysis fields parameter and can incorporate spatial properties or space-time properties.

When spatial constraints are specified, the algorithm uses a minimum spanning tree to find natural clustering.

When no spatial constraint is specified, the analysis tool uses a K Means algorithm.

All cluster analysis algorithms can be classified as NP-hard. This means that the only way to ensure that a solution perfectly optimizes both the similarities within the group and the differences between groups is to try every possible combination of the features you want to group. It is clearly demanding to ensure an optimal solution, and it is also unrealistic to try to identify a pooling algorithm that best fits all possible data scenarios. The latter may be in different shapes, sizes and densities, can include a set of symmetries and units of measurement. This explains why various cluster analysis algorithms have been developed over the last 50 years. Consequently, it is suitable to use ESRI Grouping Analysis as a tool that combines the statistical analysis with advantages of the geographical software.

Through its application, it was possible to process all the selected input data. The above extension groups common data based on their location, in order to identify the exact values for the population, employees, energy consumption, coverage ratio, and functional mix for a given number of areas.

As first step, the tool requires the creation of 10 groups to get a first report, and also the desire to find the exact number of optimal groups. This first stage is essential for this very reason, thanks to the potential of the tool to be able to evaluate the exact number of groups in which to divide the study area. In this study case, the optimum number was 6 groups, because of the input data used. Additionally, the tool outputs are graphically formatted (as a feature class within the ArcMap software), also in the form of reports to easily analyse and interpret the alphanumeric results.

In conclusion, the GIS-based method allows to classify the study area according to the statistical relationships among transport, land use and energy variables, based on the actual data of end-use electric energy consumption.

3. Results

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2 An overview of all ESRI cluster tools is available at: http://pro.arcg is.com/en/pro-app/tool-reference/spatial-statistics/an-overview-of-the-mapping-clusters-toolset.htm

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The results provided by the GIS-based method allow to draw significant conclusions about the Great London area. Looking at the map where the various distributions of the six classes are represented (Figure 3), it is easy to notice the significance of the subway in the Great London area as the classes follow the evolution of the rail transport network.

By analyzing Figure 3, however, it is possible to draw more precise conclusions about individual groups. The first value given to us is that of the general average of the various classes: from this one can notice the greater influence of the functional mix on the other variables with R^2 value of 0.8835, while the smaller one is the accessibility with 0.6690. However, it may be noted for all high value R^2 variables.

As regards the different groups, the following features are characteristic:

• Group I "Residential accessibility areas"- It refers to 6,600 cells and represents the area around the

territory defined as the "city". It has higher values than average in all respects. In particular, due to the centrality of the group, there is a very high accessibility value. In addition, from energy consumption, employees and population values, much higher than the average, it is possible to understand the importance of the above-mentioned class;

• Group II "Accessible suburbs"- It covers 10,213 cells of the total and in particular it can be described as the area where the most suburbs metro stations are present. From the map it is possible to note that group II refers exclusively to this type of territory. Specifically, as foreseeable, it presents values of the relevant accessibility (0.6657), while the rest of the values are very close to the average values;

• Group III "Green Areas" - It refers to 15,043 cells and covers the outer areas of the map, in fact it has values far below average values in all aspects, in particular the value of employees density (0.0000) and
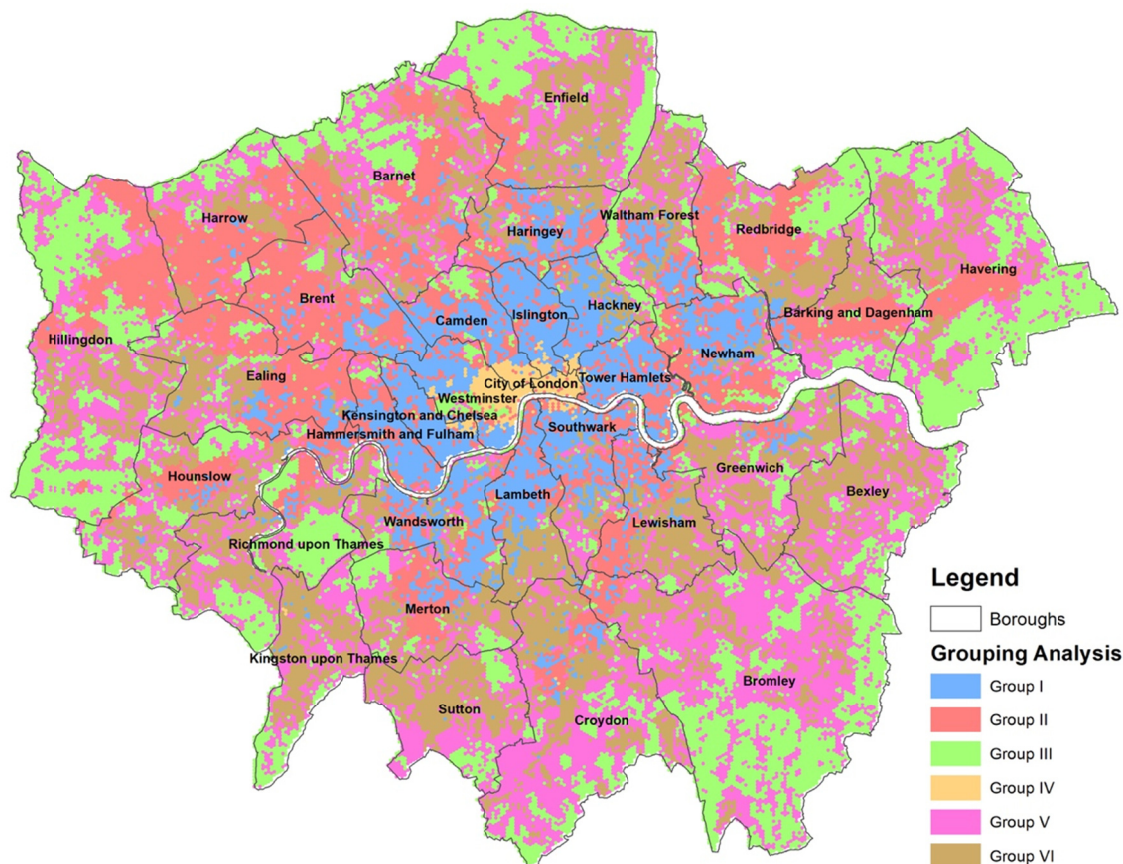

Fig. 3   Great London Area according to the Grouping Analysis results.

Table 3   Summary of the Cluster Analysis.

Group	N° cells	Standard Distance
I	6,600	0.3164
II	10,213	0.2107
III	15,043	0.1974
IV	564	0.3521
V	15,367	0.2000
VI	14,484	0.1643

Table 4   Some numeric results obtained by the application of ESRI Grouping Analysis at the Great London Area.

Indicator	Average	Standard deviation	R^2
Functional Mix	0.1819	0.1094	0.8835
Population density	0.1068	0.1161	0.7585
Employees density	0.0818	0.0921	0.7572
Building Coverage Ratio	0.1298	0.1208	0.7426
Domestic energy consumption	0.0876	0.0883	0.7484
Non-domestic energy consumption	0.0177	0.0430	0.6978
Walking Accessibility at metro stations	0.2454	0.3089	0.6690

the population density (0.0001). Represent the group with the lowest values;

• Group IV "City core" - It refers to the "city" area only covers 564 cells. As foreseeable possesses the highest value of accessibility (0.8413) given the centrality. In general, all values are high compared to the average ones, with reference to non-domestic consumption due to the high concentration of work activity.

• Group V "Developing areas"- It refers to 15,367 cells with the majority of normalized values lower than the average values. The value of accessibility is very low due to the lack of connection to the metropolitan network (0.0664). In addition, values such as those relating to the population and, above all, domestic and non-domestic energy consumption tell us about the low living and working density of the area;

• Group VI "Poorly developed areas"- It refers to 14,484 cells with the majority of normalized values higher than the average. In particular it includes the non-covered area of some metro stations therefore has much lower accessibility than the average (0.1041). Conversely, for values such as functional mix, coverage ratio, density of population and employees are slightly higher than the average.

4. Discussion and Conclusions

In recent decades, the occurrence of extremely variable and mutually changing events and phenomena, which are difficult to trace back to one cause, is causing high levels of congestion that particularly affect urban systems. It is almost always difficult to read and interpret, accompanied by the inability to control and manage complex phenomena due not only to the inadequacy of the procedures adopted but also to the use of inappropriate tools [42].

Current patterns of urban and social development are incompatible, as they are based on indiscriminate consumption of natural resources. The devastating effects generated by the continuous production and transformation of goods obtained without an organic impact assessment can no longer be pursued. Consequently, the need to limit the consumption of such resources in a sustainable way is one of the central issues within the strategies and policies adopted by most international governments.

As part of the governance of urban and territorial transformations, one of the components that in recent decades is particularly important for livelihood and development of urban systems is energy.

Urban systems play a key role in improving

economic, social and environmental sustainability, as the positive effects that can be generated by the implementation of effective urban transformation policies can significantly improve environmental quality [34]. Hence the main aim of the paper is to identify and study spatial analysis techniques that help decision makers, either public or private, improving the sustainability of urban areas through specific actions.

At the end of the work, the following results have been achieved:

• Through the state of the art, it was possible to identify the need to intervene in improving urban areas and making them more sustainable. From the scientific literature emerges the need to use an integrated transport-land use-energy approach through which effective results can be achieved [43]. Also, it was possible to identify a set of variables that are strongly related to urban sustainability;

• A spatial analysis method was developed in the GIS environment, which, thanks to a series of geoprocessing operations and the use of a standard reference unit (100m side hexagonal), allowed to compute the set of variables by statistical analysis [44,45];

• The Application to the Great London Area allowed to analyze the spatial variation of the set of indicators in order to evaluate the distribution of the variables across the whole area and also to evaluate any relationships between variables in order to increase sustainability. In particular, the GIS-based method showed that the Accessible suburbs (Group II) appear as the most suitable areas for investments and related improvement of urban sustainability, according to its high accessibility, employees density and slightly higher energy consumptions, than the average values.

The GIS-based method is characterized by a holistic view of urban dynamics and can provide insights for investors, either public or private, and decision makers to exploit more sustainable transformation process based on the nexus transport-land use-energy. This

figures particularly significant at a time when both national and local policies are tackling the thorny challenge of implementing actions able to encourage economic investments by privates aiming to a bigger economical social and environmental sustainability.

Nevertheless, given the new insights offered by this work, some limitations and future research development may be identified. First, the set of the variables used could be extended, for example by referring to energy transport uses, in order to improve the effectiveness of the developed spatial analysis method. It could also be useful to apply the method to other case studies by selecting urban contexts with rail transport and others with prevalent public road transport. In addition, with regard to the London study case, the results obtained using the census data for 2011 and those related to recent surveys could be compared, in order to identify evolutionary trends and possible improvements.

Finally, the method is based on a GIS statistical tool and therefore further improvements in this direction could consist in comparing its results to the ones obtained through the use of other specific statistical software in order to evaluate/attest the reliability of this tool.

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