

Geostatistical analysis of urban brownfields in Liverpool city

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Abstract. The article analyses major data of the real estate transactions made in Liverpool during the period 2006/2016 with the urban brownfield dissemination and scope. The author has collected and systematized multidimensional data, studied real estate transaction price changes, layout in the space, interrelations and relation with the urban brownfields during the period analysed in order to use them for the conversion or revitalization. In total, 478 transactions and 2.83 km² of brownfields were systematized. By its size and statistical values, the study volume corresponds to the context of Vilnius city. The aim of the study is to define relationship between attribute data of real estate transaction and spatial distribution on urban brownfields. When conducting a study described in the article, the author applied GIS and MS Excel technologies. A spatial data aggregation method and data pairing method have been applied. The author examined statistical data of real estate transactions by the type of sector in time, carried out their statistical and spatial analysis, identified a relationship between a location and distance from the city centre and calculated their correlative connection with the spread of brownfields in the city.

Keywords: urban brownfields, GIS data mining, territory conversion, real estate, Liverpool, geostatistical analysis

Conference topic: Sustainable Urban development.

Introduction

Urbanization has changed the pattern of urban landscapes and the natural landscape. Evaluations of the spatial and temporal changes of the urban landscape pattern could support the urban expansion analysis commendably. A city as a space where interacts socio-economical, ecological and urban processes meets with complex challenges that are caused by efforts to preserve urban contextuality and by threat of abandoned sites that are calling as brownfields (BF). Experience of Western countries shows that an economical environment and it's potential performs as a catalyst processes of BF regeneration to areas of new a function. Basically, the potential of economical environmental is a reflection of local and foreign investments. Decision making in urbanism and in economy examples of recent years shows that in order to implement right decisions the role of Big data is not enough. For this Smart data must be used. Inadequate evaluation causes a wide range of inconveniences for citizens in long time perspective. For the implementation of the research the due to similarities in scale, demography, social life and availability of data resources with Lithuania cities the author select Liverpool city as a target of research. These cities are featured by differences in functional zones and historical context. The aim of the research is to define relationship between attribute data of real estate transaction and spatial distribution on urban brownfields. In order to compare aggregated statistics of BF and related issues by identifying the root differences of urban environment and economy in both cities. The results allow to determine the essential guidelines of territory and spatial planning for such scale cities as Vilnius or Liverpool. Geostatistical analyses includes a complex evaluation of indicators of economy and urban environment. Packages of open and developed geostatistical data was used in this research.

Geostatistical analysis was implemented by using geographical information system (GIS). Quantitative and qualitative land use/land cover data are widely used in spatial modelling such as land use change analysis, hydrological modelling, health and environment, ecological modelling, city and town planning, public facility management and so on. Raster based Remote Sensing technology provides real world information in quantitative approach and while GIS provides theory and methods that have the potential to facilitate the development of spatial analytical functions and various GIS data models (Lwin, Mizutani 2012). By implementing this way of research the authors prepared thematical data maps that corresponds to the result of the research and revealed the significance of spatial relationship between BF and social, economical and urban environment. Results of the research will ease complex sustainability development that will address to economical growth.

Course of a study

The study provided in this article investigates connections of brownfields in Liverpool city with real estate transaction linkages in time and space. In order to combine these sub-systems, the authors of this work have applied a strictly defined plan of the course of a study (see Fig. 1) which comprises the following 4 parts:

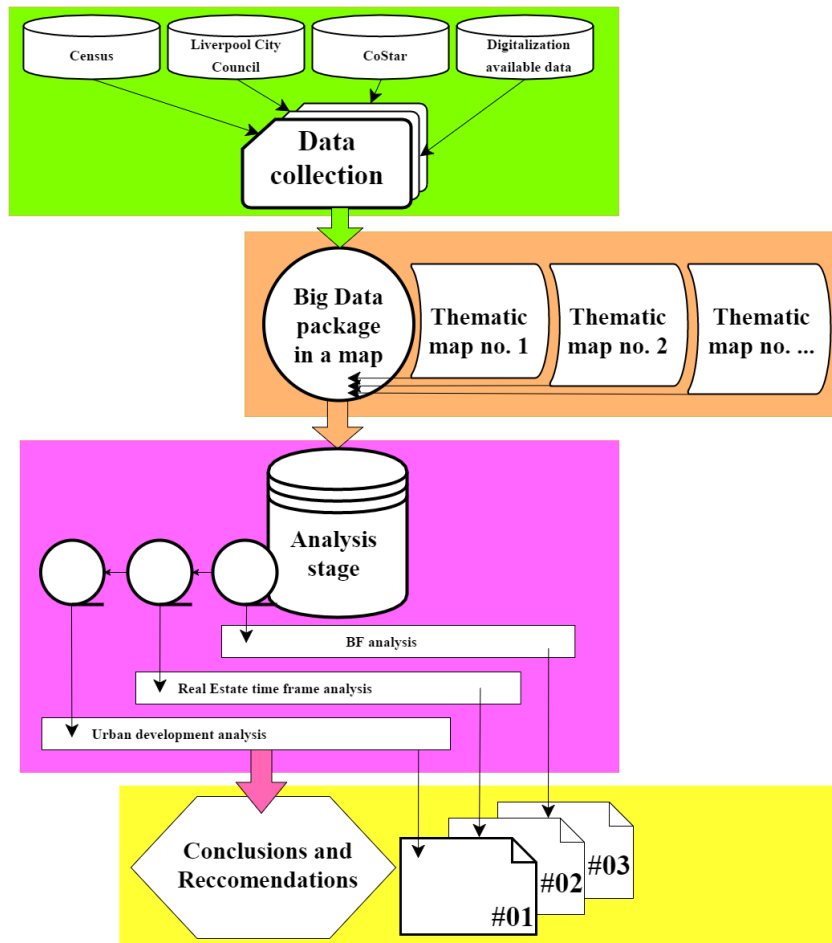


Fig. 1. Plan of a course of a study

All parts of the course of a study were performed consistently by providing fundamental study conclusions and recommendations at the final stage.

Data collection

In this part of a study, the author merged multi-format data from various data sources. Thus, formed databases are suitable for further data processing by applying GIS tools. The major data sources comprising the whole of resources are as follow:

1. Census. This data is used to shape and plan services across the Liverpool city. Understanding the characteristics of population and how it is changing is critical for the planning of employment, health, education, housing, transport and other services (Liverpool City Council 2016). This data source allows to use GIS data collected by the municipality.
2. Liverpool City Council. This resource provides access to planning documents prepared and approved by Liverpool city municipality. The author has paid a special attention to the Liverpool City Region Innovation plan (Liverpool City Region 2016) which defines main guidelines for Liverpool territorial planning by 2020. The author of article re-covered territories which are planned to be developed in this document with spatial data sets of other sources.
3. 2. CoStar real estate registry database. This data resource allowed to digitize and systematize records of real estate transactions in the period 2006/2016. By applying this access, the author systematized all records of industrial, retail and office premise real estate for this period by their dislocation in the city.
4. Other publicly available information. By applying Google Maps, the author digitized areas of 464 brownfields in the territory of Liverpool city. This enabled to identify their overlap with urban city structure and economic environment.

Big Data package in a map

By using the collected data, the author systematized them according to the type of real estate transactions:

- Transactions of objects of industrial purpose (97 units, 20.34%);
- Transactions of retail objects (119 units, 24.96%);
- Transactions of objects of office buildings (261 units, 54.72%).

In total, the author digitized 478 records of real estate transactions for the period 2006/2016 from CoStar database. The spread of these records in the space is provided in Fig. 2

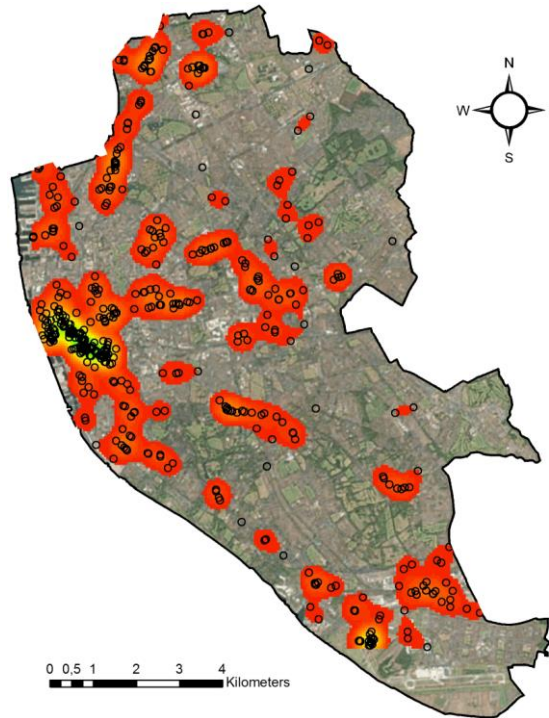


Fig. 3. Spatial spread of real estate transactions during the period 2006/2016 in Vilnius city (compiled by the author)

Each of these records accumulates the following data on a transaction: type of a transaction, date of a transaction, value of a transaction and location in the city. Thus, altogether approximately 2,000 data values on real estate transactions in Liverpool city were collected. Having overlapped this data with the spread of brownfields in the investigative territory, a detailed analysis of the relations between these components provided in the subsequent sections has been carried out.

Analysis stage

Data collected, digitized and systematized by the author were analysed by applying principles of geostatistical analysis, such as spatial data connection, spatial data pairing and connection (see Fig. 4), spatial intersection, etc. Synthesis of these methods and statistical calculations was performed by applying GIS data interchange with MS Excel software package.

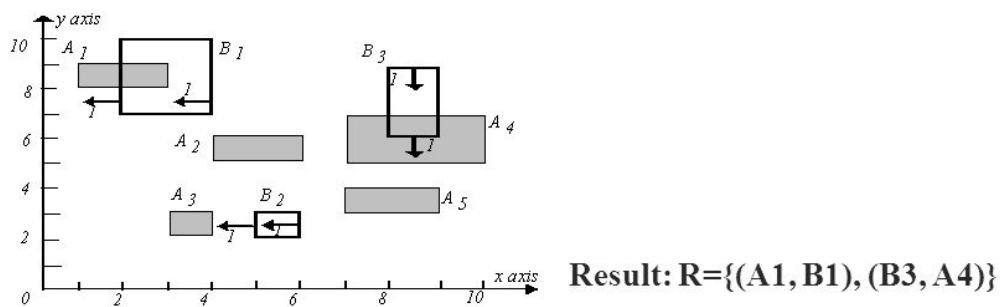


Fig. 3. Schematic diagram of spatial data connection by applying GIS technology (Benkirane 2004)

The final stage of data analysis was performed by making a comparison of multidimensional statistical values, when calculating correlation ratio between separate values, a quantitative and qualitative analysis when responding to the following substantial questions:

- Is there a systematic distribution of values in space?
- Do chosen values described in space correlate with each other?
- What is the variation of scalar data values in time?
- What are the possible assumptions for planning a further city development?

Quantitative Methods and Applications in GIS integrates GIS, spatial analysis, and quantitative methods to address various issues in socioeconomic studies and public policy (Wang 2006). In spatial pattern descriptions, various numerical and statistical descriptions can be obtained to summarize to display.

Researches

The author has conducted 2 complementary research. The research of spread of brownfields investigates a distribution in a selected part of Liverpool city in various spatial and scalar cross-sections. Analysis of real estate transactions of industrial, retail (commercial) and office objects was carried out on the basis of CoStar information system. This allows to investigate historical data and make assumptions for further future scenario.

Brownfields analysis

Vilnius and Liverpool can be characterized by different spatial spread of brownfields in the level of a city. Nevertheless, statistical values defining the spread of brownfields of these cities almost coincide with each other (part of brownfields from a total area and population density, see Table 1).

Table 1. General statistics of Vilnius and investigated part of Liverpool city and generic statistics of brownfields

	Vilnius	Investigated part of Liverpool city
Area (km ²)	354,78	111,84
Brownfields (%)	2,59	2,53
Average BF size (ha)	0,92	0,67
Density (population/km ²)	1,392	4,230
Population (mln)	≈ 0,494	≈ 0,473
Hot spots	6	5

In this comparison, Hot spots are considered to be locations in the investigated territory in which they are characterized by a significant accumulation of brownfields as compared to surrounding territories. This value varies in time and is identical in Vilnius and Liverpool (see. Fig. 3).

The statistical analysis revealed that statistical data of spread of brownfields of investigated part of Vilnius and Liverpool are identical. Based on this data, further provided conclusions and recommendations and previous research conducted by the author (Bielinskas and Burinskiene 2015, Bielinskas *et al.* 2015) can be applied to cities of Liverpool, Vilnius and Eastern European cities of similar size and sociodemographic profile in Czech Republic, Slovakia, Romania, etc. Spatial analysis revealed that brownfields in Liverpool city are distributed more evenly than in Vilnius. In the investigative territory of Liverpool, BF are concentrated around the central part of the city where there is a predominance of monofunctional territories of commercial purpose. The same phenomenon in the context of Vilnius city was identified in peripheral monofunctional territories of residential and industrial purpose. In the previous works the author identified that monofunctional territories in the city can be characterized by a higher than average criminogenic activity (Bielinskas *et al.* 2014).



Fig. 3. Spread of brownfields of Vilnius and Liverpool in space (compiled by the author)

The author carried out an analysis of spread of brownfields by distribution of BF quantity according to distance from the city centre. A comparative diagram of quantity distribution in cities of Vilnius and Liverpool is provided in Fig. 4.

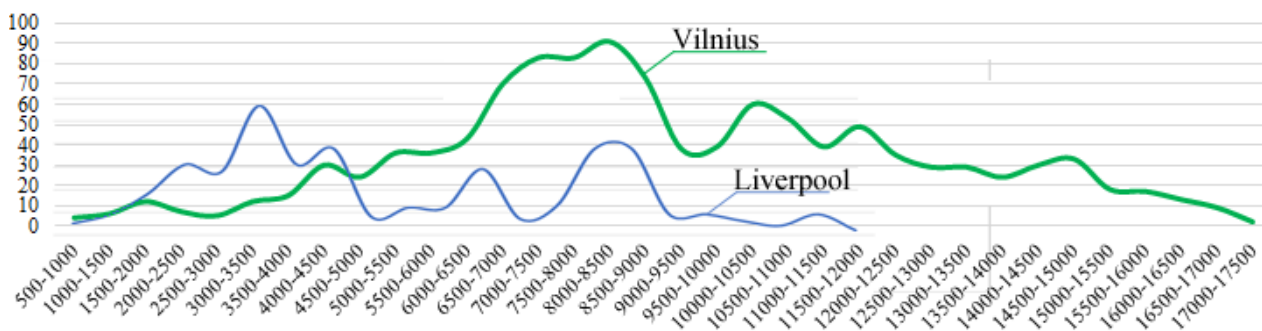


Fig. 4. Distribution of brownfields by distance from the city centre in Vilnius and Liverpool cities (compiled by the author)

A diagram of spread variation reveals major differences between the cities analysed. Contrary to Vilnius city where the biggest quantity of brownfields is situated at 6.5-9.5 km radius of the city centre, in Liverpool the highest spread extremes are identified in 3.0-4.5 km and 7.5-9.5 km distance from a central part of the city. The author makes an assumption that this phenomenon depicts historical processes of a city development and shows the influence of economic fluctuations via the urban city framework. Based on this assumption and knowing that the average area of brownfield in Liverpool is by 2 % less than in Vilnius, it may be suggested that a city development in Liverpool is performed by following economic safeguards against unexpected abandonment of a territory, its buildings and engineering infrastructure. By this and other methods, such as PPP (Roig, Soriano 2015), favourable conditions are created for the investors to develop activities and local infrastructure in new territories in a long-term perspective

Historical analysis of Real estate transactions in Liverpool city

The author was analysing the records of real estate transactions in Liverpool city during the period 2006/2016. The object of research is retail, industrial and office purpose facilities transactions. In his analysis, the author relies on the assumption that all the transactions covering the purposes analysed reflect general liquidity of the city economy and current potential, as well as are related to the brownfield diffusion dynamics. In total, the author systematized 479 real estate transactions. Graphical interpretation of these data is presented in Figure 5.

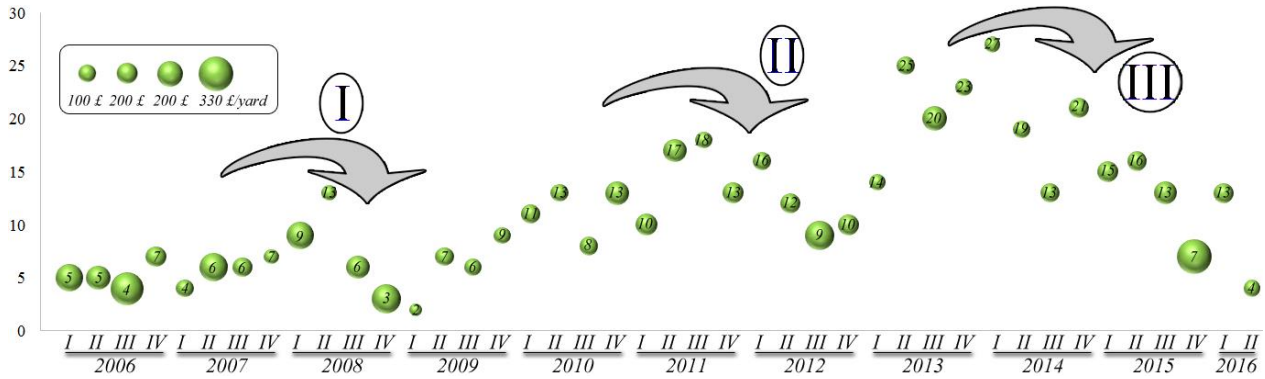


Fig. 5. Summary of real estate transaction frequency distribution by performance year and quarter in Liverpool city (compiled by author)

Graphic interpretation in Figure 4 shows that performed real estate transaction frequency was cyclically changing and increasing in time over the last decade. For this period, based on the data collected, the author determined the quantity growth and decreasing waves for 3 performed transactions.

The first of them took place from 1Q2006 to 4Q2008, while the second one – from 1Q2009 to 3Q2012. And the third one occurred from 4Q2013 to 2Q2014. Graphical interpretation of a cumulative variation of a real estate transaction quantity growth by sector is presented in Figure 6.

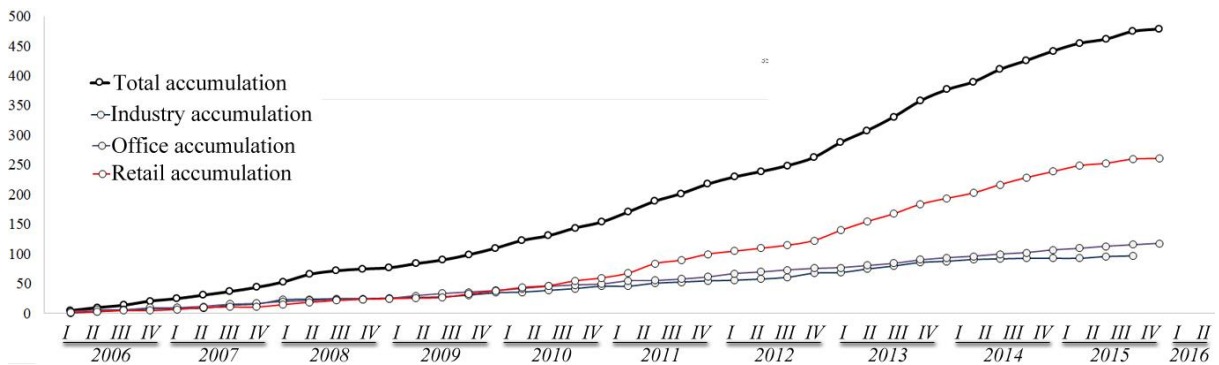


Fig. 6. Graphical interpretation of a cumulative variation of real estate transaction quantity growth by sector (compiled by author)

The results of the analysis showed that since 2011 the number of retail real estate transactions was rapidly growing. This phenomenon resulted from a sharp economic environment potential growth as a result of creation of favourable conditions for small businesses. This led to reuse of brownfield and buildings therein by resurrecting old commercial facilities or converting old buildings into commercial areas and buildings.

The analysis of the transaction price changes during the period analysed revealed that retail objects are the most expensive. Over the last decade, the average transaction value of this purpose objects per square yard made £175.7, while office purpose transactions reached £103.7, and industrial purpose transactions amounted to only £40.3 (Fig. 7).

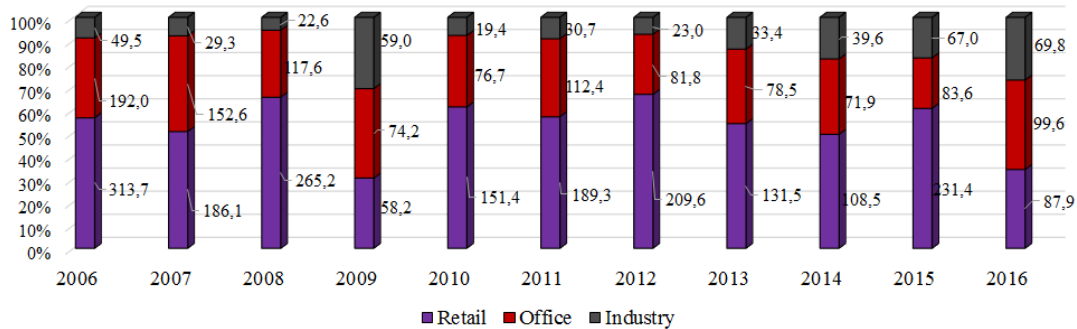


Fig. 7. Graphical interpretation of the average value of real estate transactions per square yard by sector during the period 2006/2016 in Liverpool city (compiled by author)

The analysis of price changes demonstrated that the retail (commercial) market is the most sensitive to the market. During the period 2006/2016, standard deviation of this sector transactions per square yard was £125.4, while office purpose transactions amounted to £38.2, and industrial purpose transactions made only £18.3. Retail purpose object transactions were valued most in 2008 and 2012.

The author estimates that during the period analysed real estate transactions of maximum value were made when purchasing or using existing buildings or brownfield for conversion into office purpose objects or constructions. The average transaction value in this sector during the period analysed amounted to £4.60 million, while retail objects - £2.22 million, and industrial purpose objects made only £1.78 million.

Interaction between Real estate transactions and spatial distribution of Urban brownfields

Having carried out the foregoing analyses, the author conducted data of real estate transactions with a spatial database of brownfields in Liverpool city. Having compared a dislocation of analysed transactions by sectors and brownfields in Liverpool city, the author has ascertained a mutual spatial connection between these components. One of the most significant values defining this reciprocity is a spatial analysis of a distance from the city centre (see Fig. 8).

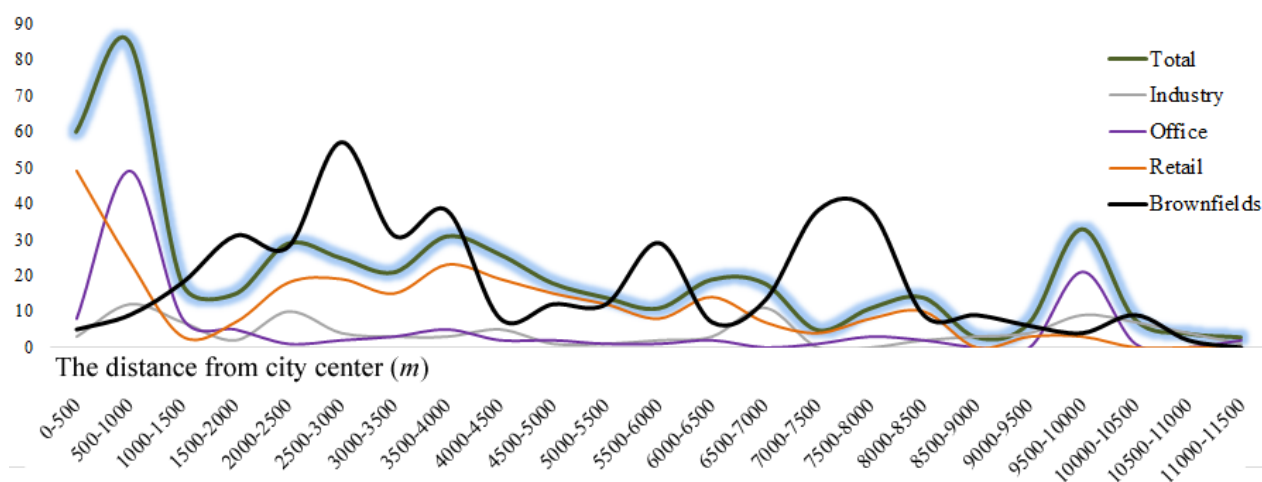


Fig. 8. Distribution of real estate transactions by sector and ratio of brownfields according to the distance from the city centre (m) in Liverpool city (compiled by the author)

The author has calculated that coefficients of correlation of real estate transactions by sector provided in Table 2 exist between their place in the city and distance from the city centre.

Table 2. Correlation coefficient of real estate transactions by sector between a location of these territories and brownfields and a distance from the city centre

	Retail	Office	Industry
Correlation coefficient	-0.72	-0.34	-0.20
Strength	Strong	Weak	Very weak

It has been ascertained that the strongest relationship exists in a retail trade market. This result allows to raise a hypothesis that a development and economic potential of small business and other commercial purpose objects directly depend on the actual distance from the city centre. This phenomenon evidences a polycentric efficiency of the city development model. Residential areas are serviced in small trading places which are evenly distributed in densely populated territories.

By applying this method, the author has calculated the relationship between real estate transactions by sector and spread of brownfields in the city. This relation is expressed in calculated correlation coefficients provided in Table 3.

Table 3. Correlations of coefficients between a location of real estate transactions by sector and spread of brownfields in the city

	Retail	Office	Industry
Correlation coefficient	0.12	-0.16	-0.21
Strength	Strong	Very weak	Weak

The author found out that a relationship between a location in the city of real estate transactions of all types and a spread of brownfields is weak. The positive relation has been calculated only for the objects of retail trade. This shows that a spread of small business objects is directly related to a recycling of far-gone brownfields by converting them and implementing their revival with the attraction of small private capital.

Geographical advantages (David *et al.* 2010), as well as the implementation of environmental policies and funds (University of Tsukuba 2012) by the federal and state governments, encourage the redevelopment of brownfields.

While performing a spread of real estate transactions of all types for the period 2006/2016 with an existing spread of workplaces in Liverpool city, a direct spatial relation between these values has been identified, which is seen in Fig. 9.

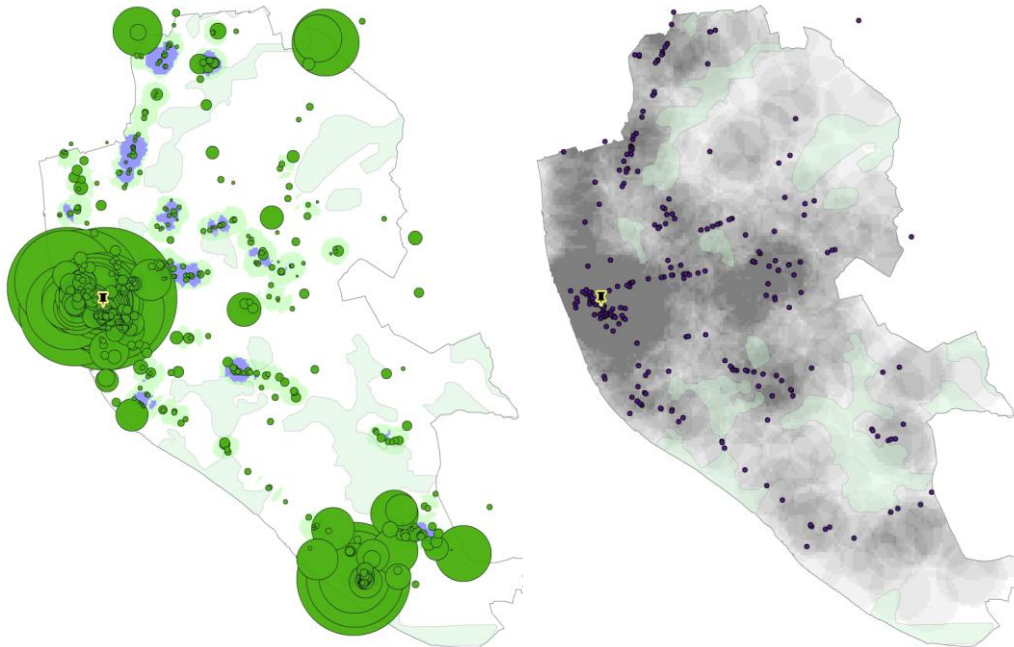


Fig. 9. Generalized distribution of real estate transactions by place in the city by indicating a proportional size of transaction value (left) and distribution of workplaces in Liverpool city (right) (compiled by the author)

When processing attributive spread data of real estate transactions in the city with the help of GIS technologies, the author found out that Liverpool city has 4 large concentric poles of these transactions (see Fig. 6). This is a central territory of the city, northern docks of the city, industrial areas in the north-eastern and south-eastern part of the city and densely populated territories in the south-eastern part of the city.

It has been found out that a major part of retail trade objects is located at the main street axes of the city. These city streets perform a connecting function between city places which are the most densely populated and characterized by the largest concentration of workplaces. In such locations, the economic environment is the most stable, therefore, real estate transactions in the market of retail trade in such places is a frequently encountered phenomenon. In such case a rule of LLL (Location, Location Location) is applied when an economic potential of the object is directly dependent on space and location of its serviced territory (Meirleir 2011).

Conclusions

The author, whilst conducting a detailed historical analysis of real estate transactions and geostatistical analysis of spread of brownfields in Liverpool city, has found the following:

- Vilnius and Liverpool are characterized by the same statistical values defining a spread of brownfields in cities;
- From year 2011, a number of real estate transactions of retail trade has begun to grow rapidly. This phenomenon was affected by an immediate growth of potential of the economic environment due to a creation of favourable conditions for small business;
- Within a period 2006/2016, the author identified quantity increase and fall waves of 3 fulfilled transactions;
- Retail trade objects are valued as the most expensive. The average value of transactions of this purpose during the last decade for a square yard is £175.7;
- A market of retail trade (commercial purpose) is the most sensitive for the market. The standard deviation of prices for a square yard of transactions of this sector within the period 2006/2016 is £125.4, whereas a deviation of office purpose transactions amounted to £38.2, and of industrial purpose transactions is only £18.3;
- A relationship between a location in the city of real estate transactions of all types and a spread of brownfields is weak. The positive relation is calculated only for objects of retail trade;
- Liverpool city has 4 large concentric poles of these transactions (a central territory of the city, northern docks of the city, industrial areas in the north-eastern and south-eastern part of the city and densely populated territories in the south-eastern part of the city).

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Contribution

Authors are welcome to declare any involvement in writing a manuscript (e.g. conception and design of the work, acquisition of data, or analysis and interpretation of data, drafting the article or revising it critically for important intellectual content, etc.).

Disclosure statement

Authors are required to include a statement at the end of their article to declare whether or not they have any competing financial, professional, or personal interests from other parties.

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