DEVELOPMENT ASYMMETRY OF THE CITY BIKE SYSTEM IN THE UPPER-SILESIAN ZAGŁĘBIE METROPOLIS

Andrzej Hanusik[1]

[1] ORCID: 0000-0001-9696-7344
University of Economics in Katowice
Department of Transport
1 Maja 50, 40-286 Katowice, Poland
E-mail: andrzej.hanusik@ue.katowice.pl

Abstract: *Metropolitan areas are primarily a set of interdependencies, where individual entities significantly influence each other. When assessing the development of individual systems, it is not possible to focus only on one city - all participants of the agreement should be considered. In such large areas, the asymmetry of various solutions is natural, but the main goal of the authorities should be to minimize discrepancies between individual regions. Therefore, the purpose of this article is to analyze the development of the city bike system in the Upper Silesian-Zagłębie Metropolis in terms of its asymmetry. The collected data refers to the population and area of individual metropolitan municipalities, the number of available bikes and the stations for their rental. The data comes from the studies of the Central Statistical Office (GUS) and websites of individual operators. Collected data were first aggregated by a synthetic measure, then statistically compiled using measures of asymmetry and the Kurtosis coefficient. The conducted analysis concerned both - the entire Metropolis and a group of cities that have a city bike system. The results of the analysis show significant discrepancies between the various entities comprising the Metropolis. The situation looks significantly better in case of a group of cities with city bike systems - the development is quite symmetrical there.*

Key words: *bikesharing, sharing economy, regional development, city logistics*
JEL codes: *D16, O12, O18, O22*

1. Introduction

In the modern world, consumer products are more and more available for rent. This is a new business approach, which becomes a stronger alternative to the traditional purchasing model. This situation is possible primarily due to the development of online platforms that allows for easy transaction of lending the goods. What is more, business models based on sharing have a very high ecological potential (the use of items increases while their volume on the market decreases) as well as economic and social benefits - even lower-income people can have access to some goods (Amasawa et al., 2020). The need to look for savings after the economic recession in 2008 can also be seen as the genesis of some models related to sharing economics. Regardless of the genesis of the phenomenon of sharing, it is undeniable that it faces traditional thinking about how to offer and consume resources. One of the concepts directly related to the sharing economy is bikesharing and the city bike system associated with it.

Bikesharing is currently a very fashionable concept, which in a perfect way fits the policy of sustainable development or pro-environmental social trends. It can be stated that Green Economy is becoming a leading paradigm for the development of rich countries - over the past decade many concepts associated with it can be seen, including sectors such as energy, agriculture and transport (Merino-Saum et al., 2020). This situation means, that the number of cities that have a city bike system is growing all the time. Prices for renting bicycles encourage residents to rent for a short time (30-60 minutes on average), and the growing network of docking stations increases flexibility in their returning (Caspi & Noland, 2019). This situation is a signal, both for city authorities and bikesharing operators, that city bike systems are solutions tailored to the needs of modern society, and the development of those systmes will be very dynamic. It also means that various types of city bike operators can be observed on the market - ranging from city authorities, to public providers of mobility solutions (e.g. DB Rent in Germany), private and free market enterprises focused on obtaining the highest possible rate of return (e.g. Velib' in Paris), for non-profit organizations targeted on improving living conditions in the city like Denver B-Cycle (Suchanek & Wołek, 2018).

While the implementation of city bikes in one city is a relatively simple task (although very costly), the development of an efficient and well-integrated bikesharing system in metropolitan areas, consisting of many separate entities, is a real problem. The city bike system is intended to facilitate the "last mile" ride (Zhou et al., 2019), which is often impossible in metropolitan areas - a bike rented in one city should usually be returned within it. It is true that solutions for the integration of systems of various cities are already working, e.g. the Katowice

- Tychy - Chorzów - Sosnowiec - Siemianowice Śląskie agreement, in the future probably also Zabrze will participate (www1), but they do not cover the entire metropolitan area. The development of the whole system is also uneven - some cities have a very large system, while others do not have it at all. The purpose of this article is to evaluate the development of city bike systems in the Upper Silesian - Zagłębie Metropolis. The following research hypothesis has been formulated - in the Upper Silesian - Zagłębie Metropolis a significant asymmetry in the development of city bike systems of individual participants can be observed.

2. Methodology and Data

The first part of the article is an introduction to research issues. This part uses the method of analysis and criticism of literature, which through a systematic and orderly study of available publications allowed to define the research problem.

The analytical part of the article was based on secondary data from the publication of the Central Statistical Office (GUS), Poland in Numbers website and the pages of individual city bike systems. These data were first collected and aggregated, then the city bike system in the Upper Silesian-Zagłębie Metropolis was analyzed. Data on the population and area of individual municipalities of Upper Silesian-Zagłębie Metropolis were collected, as well as the number of bikes and rental stations availability.

Next step was the data aggregation that it could be comparable. The number of bicycles was correlated with the population of a given municipality (the indicator reflected the number of bicycles per capita), while the number of stations with its area (the indicator reflected the number of stations rented per square kilometer). The data prepared in this way allowed the further analysis.

Next, both indicators were synthesized so that they could be compared. It should be noted that both indicators are stimulants (their values tend to the maximum), so the construction of the synthetic indicator has the form:

$$S_i = \frac{1}{k} \times \sum_{j=1}^{k} \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \times 100\% \quad (1)$$

where:

- x_{ij} – the value of a particular variable;
- $\max(x_{ij})$ – maximum value of the given indicator;

- $\min(x_{ij})$ – minimum value of a given indicator;
- k – number of indicators.

The indicators synthesized in this way allowed for calculating the asymmetry of city bike distribution in Upper Silesian-Zagłębie Metropolis. For this purpose, a classic asymmetry factor based on the third central moment was used. This indicator has the form (Doane & Seward, 2011):

$$nA_{(Si)} = \frac{\sqrt{n(n-1)}}{n-2} \times \frac{\frac{1}{n}\sum_{i=1}^{n}(x_{Si} - mx_{Si})^3}{\left(\frac{1}{n}\sum_{i=1}^{n}(x_{Si} - mx_{Si})^2\right)^{3/2}} \quad (2)$$

where:

- n – number of observations;
- x_{Si} – value of the synthetic indicator for a given municipality;
- mx_{Si} – average value of the synthetic indicator.

However, it should be noted, that in the analyzed case data for the entire studied population (41 communes) were collected, so the formula for the asymmetry coefficient does not have to be burdened with an estimator (Guo & Golam Kibria, 2017):

$$NA_{(Si)} = \frac{\frac{1}{N}\sum_{i=1}^{N}(x_{Si} - mx_{Si})^3}{\left(\frac{1}{N}\sum_{i=1}^{N}(x_{Si} - mx_{Si})^2\right)^{3/2}} \quad (3)$$

where:

- N – population (municipalities belonging to Upper Silesian-Zagłębie Metropolis).

The results of the asymmetry factor calculated in this way can have the following values:

- $NA_{(Si)} = 0$ - symmetrical distribution;
- $NA_{(Si)} > 0$ – right asymmetrical distribution;
- $NA_{(Si)} < 0$ - left asymmetrical distribution.

Next element of the analysis was the calculation of the Kurtosis index, which will allow to determine the degree of concentration of results around the average. The Kurtosis index is based on the fourth central moment. Moreover, it should be noted that the Kurtosis index for

the normal distribution is 3, so in order to simplify the analysis, it was decided to use a measure called the excess (DeCarlo, 1997):

$$nEK_{(Si)} = \frac{n(n+1)}{(n-1)(n-2)(n-3)} \times \sum_{i=1}^{n} \frac{(x_{Si} - mx_{Si})^4}{\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_{Si} - mx_{Si})^2}} - \frac{3(n-1)^2}{(n-2)(n-3)} \quad (4)$$

However, it should be noted that, as in the case of the asymmetry coefficient, the data for the entire studied population were collected, so the formula for Kurtosis excess does not have to be burdened with an estimator - it will have the form (Kim & White, 2003):

$$NEK_{(Si)} = \frac{\frac{1}{N}\sum_{i=1}^{N}(x_{Si} - mx_{Si})^4}{\left(\frac{1}{N}\sum_{i=1}^{N}(x_{Si} - mx_{Si})^2\right)^{4/2}} - 3 \quad (5)$$

The results of the Kurtosis excess calculated in this can have the following values:

- $NEK_{(Si)} = 0$ – mesokurtic distribution;
- $NEK_{(Si)} > 0$ – leptokurtic distribution;
- $NKE_{(Si)} < 0$ – platokurtic distribution.

Information on the value of Kurtosis excess together with the average value will allow to determine the degree of development of the city bike system in the Upper Silesian-Zagłębie Metropolis.

The next step of the analysis was to re-run the entire research process, this time taking into account only municipalities in which public bike system exist. Such a procedure will allow the assessment of the entire Upper Silesian-Zagłębie Metropolis city bike system and the uniformity of its development in individual municipalities that have decided to invest in this system.

The last element of the analysis was the creation of the resultant index (wSi) for the entire area, which takes into account the population of municipalities with access to city bicycles and those without such access. The indicator was calculated by using a weighted average:

$$wS_i = \left[\left(pa_{\%} \times mS_{i(pa)}\right) + \left(pn_{\%} \times mS_{i(pn)}\right)\right] \times 100\% \quad (6)$$

where:

- $pa_{\%}$ - percentage of the population having access to the city bike system;
- $Si_{(pa)}$ – average value of the synthetic indicator for areas having access to the city bike system;

- $pn_{\%}$ - percentage of the population not having access to the city bike system;
- $Si_{(pn)}$ – average value of the synthetic indicator for areas not having access to the city bike system.

It should be noted that the average value of the synthetic index for areas without access to the city bike system will be 0, so the indicator will have the form:

$$wS_i = \left(pa_{\%} \times mS_{i(pa)}\right) \times 100\% \quad (7)$$

3. Results and Discussion

Upper Silesian-Zagłębie Metropolis does not have a coherent system of city bikes - out of 41 associated cities, only 7 has the appropriate system. In 2018, the holiday pilot program related to the development of bikesharing started in Świętochłowice (residents were given 4 stations and 32 bikes for use), but due to budget cuts, the program was not continued in 2019. Table 1 presents synthetic measures for the development of city bikes in each municipality affiliated to Upper Silesian-Zagłębie Metropolis. The basis for creating the meter were two indicators:

- X_1 - number of stations per square kilometer (in relation to the best result);
- X_2 - number of bicycles per capita (in relation to the best result).

Tab. 1 City bike system in Upper Silesian-Zagłębie Metropolis - synthetic approach

Municipality	X_1: number of stations – synthetic [%]	X_2: number of bicycles – synthetic [%]	**Si [%]**
Będzin	0	0	**0**
Bieruń	0	0	**0**
Bobrowniki	0	0	**0**
Bojszowy	0	0	**0**
Bytom	0	0	**0**
Chełm Śląski	0	0	**0**
Chorzów	100	100	**100**
Czeladź	0	0	**0**
Dąbrowa Górnicza	0	0	**0**
Gierałtowice	0	0	**0**
Gliwice	8,09	19,61	**13,85**
Imielin	0	0	**0**
Katowice	33,32	50,56	**41,94**
Knurów	0	0	**0**
Kobiór	0	0	**0**

Lędziny	0	0	**0**
Łaziska Górne	0	0	**0**
Mierzęcice	0	0	**0**
Mikołów	0	0	**0**
Mysłowice	0	0	**0**
Ożarowice	0	0	**0**
Piekary Śląski	0	0	**0**
Pilchowice	0	0	**0**
Psary	0	0	**0**
Pyskowice	0	0	**0**
Radzionków	0	0	**0**
Ruda Śląska	0	0	**0**
Rudziniec	0	0	**0**
Siemianowice Śląskie	31,13	39,31	**35,22**
Siewierz	0	0	**0**
Sławków	0	0	**0**
Sosnowiec	7,92	15,17	**11,55**
Sośnicowice	0	0	**0**
Świerklaniec	0	0	**0**
Świętochłowice	0	0	**0**
Tarnowskie Góry	0	0	**0**
Tychy	6,18	11,09	**8,64**
Wojkowice	0	0	**0**
Wyry	0	0	**0**
Zabrze	7,18	8,84	**8,01**
Zbrosławice	0	0	**0**

Source: own elaboration based on: (www2; www3; www4; www5; www6; www7; www8; www9)

The analysis shows that the development of the city bike system in Upper Silesian-Zagłębie Metropolis is very uneven. Chorzów is the best in the metropolis, which can serves as a benchmark for other cities. The development of bikesharing is therefore very asymmetrical - the asymmetry coefficient for the analyzed case is 4.32, which indicates a very strong right asymmetrical distribution, and thus the uneven development of the entire system. In order to specify the degree of system development, the distribution of values around the average was assessed. The Kurtosis excess obtained during the analysis is 19.50 - it is a result stating a very strong leptokurtic distribution (the distribution is more slender than the normal distribution, ergo - greater concentration of values around the average). This Kurtosis excess result combined with a low average synthetic index (mS_i = 5.35%) shows that the system is in

a very early stage of development. The obtained result was also confirmed by the structure of cities with and without a city bike system - 34 areas without systems versus 7 areas with such system.

The analysis was supplemented by the determination of the above coefficients only for cities in which city bike systems are developing. This approach is justified by the fact that many municipalities included in GZM are relatively small entities in which the development of their own bikesharing system would be unprofitable. Upper Silesian - Zagłębie Metropolis is a very diverse area, strongly monocentric in nature, where the main strength is constituted by several of the largest cities (polycentric agglomeration). 7 cities with a city bike system cover about 25.7% of the metropolitan area and account for 49.3% of the population of the entire agglomeration (about 1,160,000 people). Table 2 presents the synthetic indicator for the development of city bikes limited only to cities where such system develops.

Tab. 2 City bike system in Upper Silesian-Zagłębie Metropolis according to the municipalities possessing it - synthetic approach

Municipality	X_1: number of stations – synthetic [%]	X_2: number of bicycles – synthetic [%]	**Si [%]**
Chorzów	100	100	**100**
Gliwice	2,03	11,82	**6,93**
Katowice	28,94	45,77	**37,36**
Siemianowice Śląskie	26,60	33,43	**30,02**
Sosnowiec	1,86	6,95	**4,41**
Tychy	0	2,47	**1,24**
Zabrze	1,07	0	**0,54**

Source: own elaboration based on: (www2; www3; www4; www5; www6; www7; www8; www9)

The conducted analysis shows that the development of the city bike system limited only to cities having such system (not to the entire Metropolis) is more homogeneous. The asymmetry coefficient for the analyzed group is 1.42, which is 67.2% lower than for the entire Metropolis. The right asymmetrical distribution of the city bike system of individual cities can still be observed, but this is not as extreme. The situation is similar in the case of Kurtosis excess, which value is 0.70 - almost 28 times lower than in the case of the entire Metropolis. This is a weak leptorkurtic distribution, but it is still a greater concentration of values around the average than in the case of normal distribution. The average synthetic indicator for the analyzed case is 25.79%, which in relation to Kurtosis excess still shows the poor development of the entire system - ideally the average value of the synthetic index should be 100%, so it can

be assumed that cities with a city bike system have its average development potential at the level of about 74.21% (assuming the benchmark as a development target).

The last element of the analysis is the creation of a resultant indicator of the relative development of city bike systems. The values included in the indicator were percentage of the population that has access to city bikes, together with information about the average value of the synthetic indicator for this area and the percentage of the population without access to the city bike system (in this case the average value of the indicator is 0). The value of the resultant synthetic index was 12.71%, which means that according to the benchmark for the best city, the city bike system in the Metropolis can be further developed by 87.29%.

4. Conclusions

Upper Silesian - Zagłębie Metropolis does not have a coherent and well-developed city bike system. However, it should be noted, that this is a relatively new creation, which has very high development potential. What is more, the concept of city bikes is still a relatively new idea, which may suggest that it will develop dynamically in the future. Modern social trends related to the so-called "green" lifestyle, limiting the carbon footprint and actions to improve the quality of life in cities also support the bikesharing concept - the city bike system is perfectly in line with the assumptions of these concepts.

The structure of the indicator allows to compare different urban areas, which makes a possibility to create one combination for several urban areas in Poland or in the world. One may argue with the legitimacy of calculating the index per administrative unit, because in this case the actual importance of the given commune in agglomeration structures is not taken into account. However, supplementing the analysis with another element, related to the development of the system only in areas that have solutions in the field of bikesharing, and determining the significance of these areas in the structures of the Metropolis, largely eliminates this problem, because allows to reflects the actual access to bicycles in in relation to the entire population of the analyzed area.

References

Amasawa, E., Shibata, T., Sugiyama, H. & Hirao, M. (2020). Environmental potential of reusing, renting, and sharing consumerproducts: Systematic analysis approach. Journal of Cleaner Production, Vol. 242, 1-3.

Caspi, O. & Noland, R. B. (2019). Bikesharing in Philadelphia: Do lower-income areas generate trips? Travel Behaviour and Society. Vol. 16, 143.

DeCarlo, L. T. (1997). On the Meaning and Use of Kurtosis. Psychological Method, Vol. 2, No. 3, 292-307.

Doane, D. P. & Seward, L. E. (2011). Measuring Skewness: A Forgotten Statistic? Journal of Statistics Education, Vol. 19, No. 2, 6-7.

Guo, Y. & Golam Kibria, B. M. (2017). On Some Statistics for Testing the Skewness in a Population: An Empirical Study. Applications and Applied Mathematics: An International Journal, Vol. 12, Issue 2, 726-728.

Kim, T. H. & White, H. (2003). On More Robust Estimation of Skewness and Kurtosis: Simulation and Application to the S&P500 Index. UC San Diego: Department of Economics, UCSD, 3.

Merino-Saum, A., Clement, J., Wyss, R. & Baldi, M. G. (2020). Unpacking the Green Economy concept: A quantitative analysis of 140 definitions. Journal of Cleaner Production, Vol. 242, 1-2.

Suchanek, M. & Wołek, M. (2018). The Relations Between the Bikesharing Systems and Public Expenditures. Cluster Analysis of the Polish Bikesharing Systems. New Research Trends in Transport Sustainability and Innovation, Springer Proceedings in Business and Economics, 37-39.

Zhou, J., Jing, C., Hong, X. & Wu, T. (2019). Winter Sabotage: The Three-Way Interactive Effect of Gender, Age, and Season on Public Bikesharing Usage. Sustainability, Vol. 11, 1-3.

Online sources

(www1) https://dziennikzachodni.pl/rower-miejski-w-siemianowicach-slaskich-nextbike-od-29042019-gdzie-sa-stacje-ile-kosztuje-wypozyczenie-roweru-stawki-na-2019/ar/c1-14088453

(www2) http://www.polskawliczbach.pl

(www3) https://kajteroz.pl/

(www4) https://gliwickirower.pl/

(www5) https://citybybike.pl/

(www6) https://siemianowickirowermiejski.pl/

(www7) https://sosnowieckirowermiejski.pl/

(www8) https://tyskirower.pl/

(www9) https://zabrzanskirowermiejski.pl/