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### Article

# Shared micro-mobility market disturbances: The Polish bike sharing market in light of Z-score analysis

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ORIGINAL ARTICLE

## Shared Micro-mobility Market Disturbances: the Polish Bike Sharing Market in Light of Z-score Analysis

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**Abstract** Urban transportation has changed dramatically in the recent years through the large scale implementation of shared micro-mobility services, especially bike sharing systems (BSS) and electric scooter sharing (ESS). The COVID-19 pandemic brought further changes and uncertainty to this turbulent business environment. In 2020, the major BSS operator in Poland filed for bankruptcy claiming that its problems arise from the COVID-19 pandemic. Market reports and media speculated that BSS business, despite being publicly financed, and considered to be a of part of public transportation system, could be unsustainable in face of the competition from ESS. We used Z-score analysis to investigate if bike sharing systems operators' problems began before or during the COVID-19 pandemic and large scale development of ESS. Our study focuses on the Nextbike company, which held a dominant stake in the Polish BSS market. It also covers two other major Polish operators and includes a German operator for comparative analysis. To complement the quantitative findings from z-score analysis, we have also interviewed representatives of major stakeholders, which deepened our understanding of BSS problems. The results of our research indicate that although the market was affected by the COVID-19 pandemic and growing scooter-sharing competition, the problems of the largest BSS operator were specific to this company, and the entire market was not under the risk of failure.

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Paweł Antonowicz Faculty of Management, University of Gdańsk, ul. Armii Krajowej 101, 81-824 Sopot, Poland E-Mail: pawel.antonowicz@ug.edu.pl **Keywords** Bike sharing  $\cdot$  E-scooter sharing  $\cdot$  Micro-mobility  $\cdot$  Z-score  $\cdot$  Urban transport  $\cdot$  Bankruptcy

 $JEL \ R4 \cdot R41 \cdot R48$ 

#### 1 Introduction

Development of the sharing economy in transport is widely seen as an opportunity for sustainable urban transport development (Bullock et al. 2017; Caspersen and Navrud 2021; Olaru et al. 2021; Strulak-Wójcikiewicz and Wagner 2021). The sharing economy concept emerged after the 2008 financial crisis due to the need of change in the use of resources and in tandem with the Internet development. Firstly, being considered as a niche in economics it has lately emerged as a global trend following the success of two start-ups that became multi-billion dollar international corporations in about five years—Airbnb and Uber (Martin 2016). Also called as "collaborative consumption", the sharing economy is understood as obtaining, giving or sharing the access to goods and services with community-based online platforms' support (Hamari et al. 2016; Möhlmann 2015). Despite the discussion on the sustainability of the sharing economy (Martin 2016), for over a decade it has been seen as an opportunity to overcome some of societal problems such as a hyper-consumption or pollution. The concept became also a part of sustainable transport development, especially in terms of urban mobility, focusing on first and last mile transportation over short distances (Standing et al. 2018).

Micro-mobility is considered to have a special role in the development of future urban mobility, as it is efficient in terms of energy use and low negative external effects (little land usage, noise and pollution) (Abduljabbar et al. 2021; Si et al. 2021; Zakhem and Smith-Colin 2021). Since 2021, it has been also part of the EU urban mobility development strategy to support further development of micro-mobility (European Commission 2021).

Shared micromobility services including the bike sharing systems help to reduce vehicle-kilometres travelled within urbanised areas (Shaheen and Chan 2016). Therefore, they are considered to be environmentally friendly solutions reducing carbon footprint, noise, land use and time loss caused by traffic congestion (D'Almeida et al. 2021; Maas et al. 2022; Wang and Sun 2022). Shared vehicles fully or partially human-powered are also proved to be, as all forms of physical activity are, a remedy for mental and physical health issues (Almallah et al. 2022; Otero et al. 2018; Sanmiguel-Rodriguez 2022).

In the past few years, bike sharing, and recently fast developing e-scooter sharing, have played a decisive role in the development of micro-mobility. However, the sustainability of shared micro-mobility operators' business models is often put into question, as they are highly dependent on public subsidies or are financed by venture capital (Li et al. 2021). As many bike sharing systems (BSS) and Electric Scooter Sharing (ESS) systems collapse, it is important to investigate reasons for their failures in order to be able to counteract them in the future. Unfortunately, there are not many micro-mobility operators' failure studies and most of them analyse the

bankruptcies of Asian BSS (Si et al. 2021). Our study aims to fill this research gap by the analysis of the 2020 crisis in the Polish BSS operators' market. We analyse 3 major Polish BSS operators, but our study focuses on Nextbike Poland-the dominant BSS operator in Poland (with 83% of the market, operating 45 BSS in its peak year of 2018) which filed for bankruptcy in 2020. Nextbike Polska's financial problems forced the company to issue a new series of shares and eventually led to its acquisition by Nextbike GmbH (its German mother company). Nextbike claimed that the major reason for its problems was the COVID-19 lockdown, but as the company had suffered losses before the first wave of the pandemic, it was necessary to assess its financial condition in the previous years. The COVID-19 effect on micromobility usage is a new and evolutive subject of research. Recently some studies examined passengers' behaviour during COVID-19, (Borkowski et al. 2021; Kamargianni et al. 2022; Kellermann et al. 2022). Generally, most of the studies suggest that bike sharing and scooter sharing ridership initially dropped, but in time proved to be more resilient than public transportation (Benita 2021; Wang and Noland 2021; Yan et al. 2021). Still, COVID 19's effects on shared micromobility operators remains largely unknown. We investigated the financial stability of Nextbike Polska, Geovelo and Roovee both before and during the COVID-19 pandemic to find out if the problems of BSS operators in Poland were caused by COVID 19 or had begun before the pandemic.

Another threat to the financial results of bike sharing systems operators could be the emergence and popularization of e-scooter sharing systems, which were found to have mostly a competing relationship with bike sharing (Yan et al. 2021). In Chicago, when scooter sharing was introduced, the usage of bike sharing declined (Yang et al. 2021). However, according to Younes et al. (2020), although BSS and scooter sharing systems generally compete with each other in Washington DC, there is a complementary relationship between the usage of scooter sharing and bike sharing for the BSS subscription members (as they may use scooter sharing when there are no bikes available at docking stations). The higher availability of different micromobility systems can lead to its collective competitiveness against other modes of transport. The performance of e-scooters may be better in terms of frequency of usage, but their operators have to face relatively high rebalancing and charging costs (Zhu et al. 2020), therefore making BSS more competitive financially. The aim of the present article is to examine the financial stability of the major BSS operators in Poland-Nextbike Polska SA, Geovelo and Roovee-and to identify the most important reasons for problems that occurred in this sector. We also analyzed Germany's Nextbike GmbH, a leader in the local market, to offer an overview of market conditions in another European country and to provide an international context to our research. Our hypothesis is that Nextbike Polska financial difficulties began before COVID-19 and the wide popularisation of e-scooter sharing in Poland. Therefore, they could not have been caused by these events. To verify this hypothesis, we use the method of z-score analysis.

Table 1	The expansi		tone i ois	Ka DOO III I	oluliu 201	1 2022			
Year	2011	2015	2016	2017	2018	2019	2020	2021	2022
No. of BSS	1	n.d.	n. d.	28	45	44	37	37	37
Bicycle fleet	140	5000	7800	12,000	15,629	20,166	16,962	16,188	16,600

Table 1 The expansion of Nextbike Polska BSS in Poland 2011–2022

Source: (Marynowicz 2017; smartride.pl 2022; teraz-srodowisko.pl 2015)

#### 2 Micromobility Market Competitive Environment

Bike sharing systems in Poland have been in use since 2008. The first system was launched in Cracow and was operated by BikeOne Corporation. Nextbike Polska Corporation was established in 2011 under the license of Nextbike GmbH, existing since 2004 and providing shared mobility services in 150 cities located in 25 countries and 4 continents. The first BSS of Nextbike Polska was launched in Wroclaw in June 2011, and operated with 140 bicycles during the first season (Marynowicz 2017). During the next decade, the bike sharing market in Poland went through a period of expansion, with the leading position taken up by Nextbike Polska (see Tables 1 and 2).

In march 2015, the number of rentals exceeded 6 million since the opening of the first BSS by Nextbike Polska in 2011 (teraz-srodowisko.pl 2015). The number of their BSS and their fleet size increased from 28 and 12 thousand in 2017 respectively, to 45 and 15.6 thousand in 2018. As shown in Table 1, the peak in terms of the biggest number of running systems was reached in 2018. One year later, Nextbike Polska had the biggest fleet to this day (over 20.1 thousand bicycles).

The first e-scooter sharing systems (ESS) in Poland were introduced at the end of 2018 in Warsaw, Wroclaw and Poznan. In the peak of the 2019 season, there were 19 cities with ESS and the size of the fleet reached 11 thousands e-scooters. For the next two years the number of shared e-scooters operators, cities with ESS and their fleet size had grown rapidly. In 2020, there were 12 e-scooter sharing operators in 39 cities providing a fleet of 18.8 thousand vehicles. These numbers increased in 2021, to 60 cities with 46.2 thousands shared e-scooters. As of the end of the peak season of 2022, the ESS were available in 161 cities and the fleet size reached a number of 94 thousands vehicles—double in comparison to the previous year (smartride.pl 2022).

Since 2018, the number of BSS in Poland has risen despite the introduction and rapid development of scooter sharing systems. There were 57 BSS operating in 2018, 69 in 2019 and 2020, 75 in 2021, and 82 in 2022 (as of the peak season). The number of bicycles available for BSS users peaked in 2019, when there were over 24.6 thousand such vehicles in Poland. The Polish BSS fleet size decreased in 2020, probably due to the COVID 19 lockdown, but the number of bicycles went up again and reached 21.6 thousand in 2021, and 23.7 thousand in 2022.

Nextbike Polska lost part of the market to its competitors after 2018–2019, as the number of its systems decreased from 45 to 37 in 2020–2022. Also its fleet size has shrunk after the 2019 peak (20.2 thousand bicycles) reaching less than 17 thousand bicycles in 2020–2022. As Nextbike Polska keeps its position in the Polish big

Table 2 Poli	ish bike shar	ing market	structure												
Year	2018			2019			2020			2021			2022		
Operator:	Bicyle fleet	Market share (%)	No. of BSS												
Nextbike	15,629	83.0	45	20,166	81.8	44	16,962	85.6	37	16,188	74.7	37	16,602	70	37
Geovelo	160	0.8	2	630	2.6	8	655	3.3	11	613	2.8	9	170	0.7	2
Roovee	150	0.8	4	530	2.1	6	962	4.9	16	1910	8.8	25	2867	12.1	30
Freebike (BikeU)	2150	11.4	I	2358	9.7	I	066	5.0	I	2680	12.4	4	2775	11.7	Ś
Blinkee	100	0.5	1	100	0.4	1	I	0.0	I	18	0.1	1	I	0.0	I
Filfri (Com- drev sp. z	150	0.8	Н	150	0.6	1	150	0.8	-	250	1.2	7	185	0.8	170
Acro	500	2.7	1	700	2.8	1	70	0.4	1	I	0.0	I	I	0.0	I
PKP Mo- bility	I	0.0	I	I	0.0	I	35	0.2	1	I	0.0	I	I	0.0	I
Bolt	I	0.0	I	980	4.1	9									
Roler	I	0.0	I	147	0.6	1									
Total	18,839	100	57	24,661	100	69	19,824	100	69	21,659	100	75	23,726	100	82
Source' (smai	tride nl 202	2)													

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cities with large number of bicycles, its market share measured in the fleet size is still significant—70% in 2022, but it went down from 74.7% in 2021, 85.6% in 2020, and 81.8% in 2019. During this time new bike sharing operators emerged and started to deliver their services in smaller towns and residual areas. In 2018, there were only 12 systems not managed by Nextbike Polska, but in 2021 this number rose to 38 systems (in contrast to 37 operated by Nextbike Polska) (smartride.pl 2022). As shown in Table 2, the market leader started losing its competitive advantage to Geovelo and Roovee.

There are several major differences in the business model of different BSS operators. Most of Nextbike's fleet are station based bicycles (that can be rented or returned in the docking stations). Roovee uses free-floating bicycles that can be parked anywhere in the limits of a designated area (though in some cases specific locations may be preferred by lower prices). Roove uses a single application for all its systems, whereas Nextbike created separate applications for each system it manages. This allows Roove users to rent bicycles not only in their hometown but also when they travel to other cities. Geovelo uses free-floating bicycles, but requires users to return them in parking locations marked with geofencing. As there is no specific infrastructure required for this kind of parking locations, the company can flexibly change them according to the needs of users without any cost. In this way a significant number of parking places can be maintained at no cost. Additional parking spaces can be temporarily created in case of big social events. Additionally, in most of the Roove and Geovelo systems, users have to pay for each ride from the very first minute of usage, in contrast to Nextbike's systems, where usually the first 10 to 20 min are free of charge. This way, the revenues of Roove and Geovelo depend on the number of rides rather than on municipal subsidies.

The main source of revenues for Nextbike Polska were always contracts with the municipal authorities of the big Polish cities for the distribution of bicycles and maintenance of BSS. Other revenues of Nextbike include (Nextbike Polska 2022):

- revenues from dedicated bicycle stations available to private recipients (shopping malls, office buildings);
- revenues from the sale of advertising space on bicycles;
- other commercial revenues (provision of infrastructure, commercialization of the user base);
- rental fees.

In 2021, contracts with municipal authorities generated 82.3% of total revenues (Nextbike Polska 2022). Rental fees do not constitute an important part of the Nextbike revenues because of the pricing strategy of the majority of BSS that is enforced by the contracts with the cities. As a major objective of municipal authorities is to maximize bicycle ridership, Nextbike and Roovee rents them for free for the first 15 to 30 min (depending on the BSS and contracts). Additional fees are charged when this time is exceeded. This may be one of the reasons why Nextbike used to achieve a higher trips per day per bicycle (TDB) indicator than other operators (Bieliński et al. 2019). Geovelo uses a different pricing strategy, as it requires payment from the first minute of the rental, but offering also membership that allows for two one-hour rides per day (paid per month, three months or annually).

In November 2019, Nextbike GmbH invested PLN 11 million in Nextbike Polska S.A. In this way the German partner acquired a 45.1% share in the capital and reached 51.7% of votes at the general meeting, overtaking the majority stake in the company from the Polish company Larq (Janos 2019).

On 31 March 2020, in Poland under the regulation of the Council of Ministers the use of bike sharing systems was prohibited due to the pandemic threat. The ban lasted until 6 May 2020, and therefore the BSS services lockdown was about 5 weeks long. What is important, at that time no prohibition of other shared micromobility services usage was introduced (gs24.p 2020). Nextbike Polska appealed for a mass participation in public consultations with the Ministry of Health to report the need to urgently restore the possibility of using BSS (nextbike.pl 2020a). The company also addressed open letters to the Prime Minister and the Minister of Health underlying the advantages of shared bikes in terms of the reduced risk of contamination, especially in comparison to the other public transport services (nextbike.pl 2020b).

In May 2020, the management board of Nextbike Polska decided to submit an application for opening an accelerated Compulsory Settlement procedure and filed for bankruptcy, claiming that the main reason for this was problems that had occurred because of the COVID 19 lockdown (Forbes 2022).

The German bike-sharing market saw significant growth from 2017 to 2020. In 2017, the market value was \$ 47.46 million. This increased to \$ 52.92 million in 2018, a growth of 11.5%. The market value continued to rise in 2019 to \$ 53.50 million, a modest 1.1% increase. A notable surge occurred in 2020, with the market value jumping to \$ 74.63 million, a 39.5% increase from the previous year (Statista 2023). This substantial growth was likely influenced by the COVID-19 pandemic, which encouraged more individual and socially distanced transportation options. In contrast to Polish authorities, the German government encouraged bikesharing, which led to higher revenues in the sector. Nevertheless, Nextbike GmbH was acquired by Tier Mobility in November 2021. Tier is a Berlin-based start-up, e-scooter, and e-moped operator (Bellan 2021). In this way, Nextbike Polska has eventually become a subsidiary of Tier. Because of the connection between Nextbike GmbH and Nextbike Polska, the acquisition of the German company by scootersharing startup Tier Mobility—which may have indicated that despite market growth, Nextbike GmbH struggled with financial liquidity-and the leading role of Nextbike GmbH in the German bike-sharing market, we have chosen Nextbike GmbH for our supplementary analysis to add more international context to the study.

#### **3** Data and Methods

Holistic assessment of the economic and financial condition of enterprises is possible through the traditionally carried out ratio analysis (financial, economic) or through an aggregate view, such as Z-scoring. The authors of this study opted for analytics based on classification methods (Balicki 2009) in the form of the Linear Discriminant Analysis (LDA) that was introduced into the statistical methods theory by British geneticist and statistician: Ronald Aylmer Fisher (1890–1962) (Antonowicz 2015; Box 1978; Kotz et al. 2004; Krishnan 1997; Savage 1982, 1976). Using a set of LDA

Discriminant model results by year							
Company	2018 2019		2020				
Z <sub>7 INE PAN</sub> (Mączyńska, 2004)							
NEXTBIKE POLSKA S.A.	0.22	-3.06	-4.15				
Interpretation of results	not at risk of	at risk of bankruptcy	at risk of bankruptcy				
ROOVEE S.A.	No data	2.91	2.45				
Interpretation of results	No data	not at risk of	not at risk of				
GEOVELO SP. Z O.O.	No data	8.36	7.20				
Interpretation of results	No data	not at risk of	not at risk of				
NEXTBIKE GMBH (GERMANY)	-2.74	-1.70	-4.03				
Interpretation of results	at risk of bankruptcy	at risk of bankruptcy	at risk of bankruptcy				
	Z <sub>HCP</sub> (Hamrol e	t al., 2004)					
NEXTBIKE POLSKA S.A.	1.58	-1.04	-2.23				
Interpretation of results	not at risk of bankruptcy	at risk of bankruptcy	at risk of bankruptcy				
ROOVEE S.A.	No data	4.21	1.82				
Interpretation of results	No data.	not at risk of bankruntcy	not at risk of bankruptcy				
GEOVELO SP. Z O.O.	No data	4.28	3.25				
Interpretation of results	No data	not at risk of bankruntev	not at risk of bankruptcy				
NEXTBIKE GMBH	0.77	1.59	-1.14				
Interpretation of results	not at risk of bankruptcy	not at risk of bankruptcy	at risk of bankruptcy				
	ZBP1 (Prusal	k, 2005)					
NEXTBIKE POLSKA S.A.	-0.76	-3.01	-3.62				
Interpretation of results	at risk of bankruptcy	at risk of bankruptcy	at risk of bankruptcy				
ROOVEE S.A.	No data	1.87	0.80				
Interpretation of results	No data.	not at risk of hankruntev	not at risk of bankruptcy				
GEOVELO SP. Z O.O.	No data	1.53	0.50				
Interpretation of results	No data	not at risk of hankruntey	no interpretation				
NEXTBIKE GMBH	-2.80	-2.19	-4.22				
(GERMANY) Interpretation of results	at risk of bankruptcy	at risk of bankruptcy	at risk of bankruptcy				
Z <sub>A(1968)*</sub> (Altman, 1968)							
NEXTBIKE POLSKA S.A.	0.81	-0.48	-1.33				
Interpretation of results	at risk of bankruptcy	at risk of bankruptcy	at risk of bankruptcy				
ROOVEE S.A.	No data	2.94	2.04				
Interpretation of results	No data	no interpretation	no interpretation				
GEOVELO SP. Z O.O.	No data	3.88	3.83				
Interpretation of results	No data.	not at risk of bankruptcy	not at risk of bankruptcy				
NEXTBIKE GMBH (GERMANY)	0.78	1.02	-0.01				
Interpretation of results	at risk of bankruptcy	at risk of bankruptcy	at risk of bankruptcy				

Fig. 1 Synthetic z-scoring of Polish BSS operators in the years 2018–2020 using selected models of discriminant analysis—Z <sub>7INE PAN</sub>, Z<sub>HCP</sub>, Z<sub>BP1</sub>, Z<sub>A(1968)</sub>—general approach. Source: own elaboration

methods that were proved to be the most adequate and relevant for the Polish market (Antonowicz 2010a), we have been able to combine various areas of traditional financial analysis into one synthetic assessment, taking into account in particular the examination of such (usually separately assessed) areas as: liquidity, debt service capacity, profitability, productivity, and activity and turnover. Thanks to the adopted research methodology, we have managed to assess the competitiveness potential (as well as the de facto business model) of Nextbike Polska S.A. against its close competition and Nextbike GmbH (its German mother company).

For the purpose of this study, cooperation with one of the largest business intelligence agencies in Europe (InfoVeriti Polska ltd.—whose shareholder is Info Veriti Capital Investments Ltd. in London) was initiated. This enabled us to obtain financial statements (the balance sheet and profit and loss account) of all the analysed companies for a period of at least 4 years preceding the current assessment period (i.e. 2017–2020).

Based on our previous research, we have selected the most effective early warning models for the Polish companies against potential insolvency (Antonowicz 2010b, 2008), constituting a uniform platform for comparison of BSS operators remaining in strict competition (Nextbike, Roovee, Geovelo see Fig. 1). We have used four scoring models that were developed in different research units (Table 3). Thanks

[1] Z <sub>7 INE PAN</sub> (Mączyńska 2004)	$Z_{7 INE PAN} = 9.498 \times POA/TA + 3.566 \times E/TA + 2.903 \times (NP + A)/TD + 0.452 \times CA/CL - 1.498$ POA—Profit (loss) on Operating Activities   TA—total assets   E—Equity   NP—Net Profit (loss)   A—Amortization   TD—Total Debt   CA—Current Assets   CL—Current Liabilities
[2] Z <sub>HCP</sub> (Hamrol et al. 2004)	$\begin{split} &Z_{HCP} = 3.562 \times NP/TA + 1.588 \times (CA-S)/STL + 4.288 \times (PS + LTL)/TA + 6.719 \times PS/S - 2.368 \\ &NP-Net Profit (loss)   TA-Total Assets   CA-Current Assets   S-Stocks   \\ &STL-Short-Term Liabilities   LTL-Long-Term Liabilities   PS-Profit (loss) on \\ &Sales   S-Sales \end{split}$
[3] Z <sub>BP1</sub> (Prusak 2005)	$\begin{split} &Z_{BP1} = 6.5245 \times POA/TA + 0.1480 \times OE/STL + 0.4061 \times CA/STL + 2.1754 \times POA/S - 1.5685 \\ &POA & Profit (loss) \text{ on Operating Activities   TA & Total Assets   CA & Current Assets   OE & Operating Expenses   STL & Short-Term Liabilities   S & Sales \end{split}$
[4] Z <sub>A(1968)</sub> * (Altman 1968)	$\begin{split} &Z_{A(1968)} = 1.2 \times (CA\text{-}STL)/TA + 1.4 \times NP/TA + 3.3 \times (GP + FE)/TA + 0.6 \times EC/TL + 1.0 \times S/TA \\ &Current Assets  STL_Short-Term Liabilities   TA_Total Assets   NP_Net Profit (Loss)   GP_Gross Profit (loss).  FE_Financial Expenses   EC_equity   TL total liabilities   S_Sales \end{split}$

 Table 3
 Methodology of selected (for the needs of the research process) models of discriminant analysis, aimed at a holistic (scoring) assessment of the economic and financial condition of enterprises

#### Source: own elaboration

\* The Altman model, due to the modification of the method of calculating two indices, may show different predictive properties compared to the base model from 1968. The retained earnings variable (originally suggested by Altman) has been replaced with Net Profit (loss). Additionally, the market value equity variable has been replaced by book value equity. In the EBIT calculations the gross profit has been adjusted for financial expenses. The above transformations result from different accounting standards, which make it impossible to calculate the Altman model for Polish entities according to the formula originally provided by the author to the use of multiple scoring models, it was possible to objectify and confirm the obtained results, which made the conclusions of the research even more reliable.

In the methodology of early warning systems, universal models are often applied to assess the economic and financial status of corporations, particularly within the international marketplace. These models are not necessarily developed or tested within the boundaries of a single economy or country. An illustrative example of the global application of these models is seen in the work of E.I. Altman. However, to maintain a uniform comparative basis, we utilize not only E.I. Altman, but also Polish models for comparing Nextbike GmbH with Polish companies.

An additional confirmation of the results from the application of these models was the evaluation of the valuation of shares in Nextbika Polska Sp. z o.o., which was carried out in the same research period.

To identify the reasons behind the success or failure of certain bike and scooter sharing companies that could impact their financial stability and profitability, we have additionally conducted three interviews with representatives of key stakeholders. These interviews included two former employees of operators and one representative from a municipal organization responsible for the implementation of bike-sharing systems. The first interviewee was Jakub Michałowski, a manager with several years of experience in the micromobility market in Poland, including working with companies such as Blinkee.city and Bird. The second interview was with Paweł Orłowski, the former president of Nextbike Poland, and Dominik Makurat, a court expert in the field of the implementation and operation of public bicycle systems, who also served as a former employee of the metropolitan association responsible for implementing the largest e-bike sharing system in Poland's Tricity metropolis in 2019.

#### 4 Results

To examine the financial stability of the major BSS operators in Poland and verify the hypothesis that the problems of the major company on this market—Nextbike Polska's problems—began before the COVID-19 pandemic and the wide popularization of e-scooter sharing in Poland, we have used the multidimensional assessment of discriminant analysis. The results of this analysis for the 2018–2020 period are presented in the matrix in Fig. 1. Using all four of the most effective early warning models for the Polish economy: Z<sub>7INE PAN</sub>, Z<sub>HCP</sub>, Z<sub>BP1</sub>, and (the only foreign model created by E.I. Altman)—Z<sub>A(1968)</sub> gives similar results. The unambiguous results obtained for the last two years of the analysis from all the discriminant analysis models used, indicate that Nextbike in terms of its economic and financial condition from 2019 was comparable only to bankrupting enterprises on the Polish market. The result obtained by using the most accurate model (Z<sub>7INEPAN(NXB;2018)</sub>=(-3.06), that is,1 505% less compared to the previous period) definitely indicates a significant deterioration of the economic and financial situation already in 2019.

Contrary to the results of Nextbike, Goovee and Geovelo were classified as companies in good economic and financial condition (Z  $_{7INEPAN(ROOVEE; 2018/2019)}$ = +4.21 / +1.82; Z  $_{7INEPAN(GEOVEL0; 2018/2019)}$ = +8.36 / +7.20). Nevertheless, the multidimensional

assessment of all these entities in the analysed period presented a deterioration of their financial situation as all of the results of early warning models show lower values. The effects of COVID-19 are visible, but it did not threaten the existence of the BSS market. One factor potentially impacting the financial outcomes of all entities within the market was the inability to adjust the pricing structures of bikesharing services. These prices were constrained by long-term contractual agreements with municipalities that provided subsidies for BSS operations in Poland. The combination of rising costs and the inability to adjust prices likely exacerbated the challenges faced by bike-sharing system operators in Poland. However, modelling results clearly indicate a definitely worse assessment of Nextbike compared to its competitors.

To provide a broader, international context for our study, we incorporated a z-score analysis of a leading company on the German and European bike-sharing market, Nextbike GmbH. The company was established in 2004 in Leipzig, Germany and operates its micromobility systems in over 300 cities worldwide (Vitkauskaitė and Vaičiukynaitė 2020). As mentioned previously Nextbike GmbH holds a stake in the Polish company Nextbike Polska.

Unexpectedly, the financial stability of Nextbike GmbH during the study period appeared precarious. Three out of four early warning models employed in our discriminant analysis indicated that the company faced bankruptcy risk in 2018 and 2019, with all models confirming this risk for the year 2020. This financial instability may have precipitated the acquisition of Nextbike GmbH by Tier Mobility in 2021, likely as a strategic measure to ensure its continued financial stability.

The z-scores of Nextbike GmbH deteriorated significantly in 2020, suggesting that the COVID-19 pandemic adversely affected not only the Polish but also the German bike-sharing markets. This decline in z-scores highlights the broader impact of the pandemic on the micromobility sector, emphasizing its vulnerability to global crises.

In addition to the z-score analysis we have also analysed the valuation of Nextbike Polska shares on the stock exchange to see how it compared with the market and if the company's problems began with COVID-19. Geovelo and Rovee could not be compared as these companies are not listed in the stock exchange. The valuation of the stock of a listed company is a good barometer of the investor sentiment, which directly assesses the prospects of a business model.

During the analysed period 01/2018–06/2022 (see Fig. 2), the shares of Nextbike Polska (NXB) decreased their value by over 95% as a result of a negative investment sentiment. Compared to the NCIndex it is a very big decrease in the value of stocks. In the same period, the NCIndex grew significantly, reaching the peak and consolidation in the period 01/2021–01/2022, after which—similarly to all world indices—it started a consistent sell-off (after the invasion of Ukraine by Russian forces). This tendency was noticeable both in the USA (S&P, DJ, NASDAQ) as well as in the geographically proximate German market (DAX), not to mention of course the Russian and Chinese indices. When analysing NXB shares volatility in the context of the capital market in Poland, apart from the NCIndex, it is also worth comparing the blue chip WIG20 index. In the analysed period WIG20 was characterized by an even lower level of volatility than the NCIndex—see Fig. 2.



**Fig. 2** Share prices of Nextbike Polska S.A. in the period from 01/01/2018 to 30/06/2022 against the indices: WIG-20\* (Warsaw Stock Exchange) and NCIndex\*\* (Newconnect). Source: own elaboration. \*WIG20 is the stock exchange index of the 20 largest joint-stock companies listed on the Warsaw Stock Exchange. The base date for calculating the index is 04/16/1994, while its base value is 1000 points. \*\*NCIndex is the NewConnect Polish stock index, the base date of which is August 30, 2007, and the base value of which is 1000 points. This index covers all companies introduced to trading on NewConnect. The number of free-float shares of each listed company exceeds 10%, and the value is at least PLN 1 million

This analysis allows for a very negative assessment of investors' moods in relation to the NXB business model.

The synthetically discussed results of the volatility of stock values—from the perspective of the capital market, as well as the results of the study with scoring models—clearly lead to the same conclusions. We pay attention to this, because it is not a rule. For example HERTZ—ticker: HTZ listed in the US NASDAQ—a global car rental company—during the COVID-19 period was experiencing financial problems and was finacially declining. Nevertheless, investment in that company became an excellent speculative field both for individual investors and investment funds. There are many examples of such situations, when the valuation of shares is radically low, but the assessment of the business model is so far-reaching that the company becomes the subject of an increased volume of transactions, which, however, was not the case with Nextibke. The decrease in the value of Nextbike Polska shares began before ESS could impact the revenues of the company, and long before the pandemic lockdowns that were claimed to be the major reasons for Nextbike's failure.

Interviews with representatives of stakeholders were conducted with the purpose of shedding light on the issues of bike sharing that led to financial instability, providing insights into how BSS operators and municipalities can adapt in response to these problems.

Jakub Michałowski emphasized that one major disadvantage for bike-sharing companies is the inflexibility of contracts typically signed with municipal authorities. Many cities require a precisely defined number of bicycles to be available on the streets throughout the year or season. In contrast, companies operating without public

Aspect	Insights	Weight*
Infrastructure	Inflexible contracts with municipal authorities limit operational flexibil- ity, increasing operational costs	5
Safety	Vandalism and theft are major concerns for e-bike sharing, GPS tracking and preventive measures are essential	4
Coverage	Accurately estimating demand and building sufficient infrastructure is crucial for successful implementation	3
Costs	Competitive pricing is essential for user attraction and financial viability	2

 Table 4
 Summary of interviews with experts on limitations of BSS causing financial instability

Source: own elaboration

\* The higher the weight, the greater the emphasis of the issue from the experts' perspective.

subsidies are more flexible, often utilizing complicated algorithms and/or artificial intelligence to predict demand for sharing services based on various factors such as time of day, season, weather conditions, and more. This flexibility allows them to provide bicycles and scooters when and where needed, preventing excessive wear and tear of the shared bicycle fleet and reducing costs. Contracts mandating a specific number of bicycles, irrespective of actual demand, make subsidized operators less cost-effective.

Witold Orłowski said that one of the major problems with e-bike sharing is connected with vandalism and theft, as it is hard to estimate and often specific for some districts of the cities. He has underlined that Nextbike took some precautions in that matter, for example GPS tracking installed not only in frames of the bicycles, but also in batteries (which often fall prey to thieves). He also mentioned a particular type of vandalism, involving the deliberate act of dropping bicycles into waterways and water reservoirs, such as rivers and ponds. As a result of this treatment, e-bicycles are not only completely destroyed, but they also pose a threat to the natural environment. To prevent such incidents, e-bike and e-scooter sharing companies prohibit the return of vehicles in places near water reservoirs and on boulevards. This level of flexibility and preventive action can contribute to lower operational costs and higher financial efficiency, but requires consultation of these rules with municipal authorities.

Dominik Makurat mentioned that a significant challenge in implementing bikesharing systems may be accurately estimating the adequate supply of vehicles, building service and charging capacities. Municipal contracts often specify the precise number of vehicles to be delivered and maintained, making it crucial to provide a sufficient number of bicycles. Underestimating demand for bike-sharing can lead to difficulties in maintaining a fleet due to rapid deterioration, particularly relevant to e-bike sharing that requires battery charging, significantly increasing operational costs without proportional revenue growth, as subsidies are typically based on the number of bicycles maintained rather than the number of trips.

The summary of expert interviews was presented in the Table 4.

#### 5 Discussion and Conclusions

Nextbike Polska claims that its financial problems originated in the governmental lockdown of its bike sharing systems; however, our results show that Nextbike's financial problems began long before the pandemic and therefore could not be the major reason for its failure. Moreover, other competitors on the Polish bike sharing market—Roovee and Geovelo—were not at the risk of insolvency.

Referring to the bike sharing literature we can find some studies that seek reasons for BSS bankruptcies. Some articles indicate that theft and vandalism of the bicycles may lead to the unforeseen rise of costs and therefore lead to an operator's insolvency (Laa and Emberger 2020; Makurat and Wojewódzka-Król 2019). However Nextbike already had over 10 years of experience in the Polish market when its problems occurred and did not report any growth in the number of stolen or damaged bicycles in its financial statements or media reports. In fact, all BSS operators face this kind of difficulties and are able to calculate the risk of this kind of events, treating it as part of the usual operational costs. However, in some cases regulations imposed by municipal authorities to tackle the problem of vandalism can lead to bike sharing operators' problems. In Vienna, operators were required to pay a penalty fee for damaged bicycles that were not removed in a timely manner, making their operations unprofitable (Laa and Emberger 2020). Also in China increasing governmental regulations along with insufficient and unreliable financing led to the bankruptcy of many bike sharing companies. (Reddick et al. 2020). Although the governmental lockdown of bike sharing in Poland led to diminished revenues from advertising activities, it did not lead to a blockage of the main source of revenues for BSS operators in Poland, which are municipal subsidies (in 2021, Nextbike's financial statement revenues from private clients accounted for 17.7% of revenues (Nextbike Polska 2022)). In fact, BSS operators still received most of that money without having to cover fleet maintenance costs. Moreover, the Chinese market is much different to the European and Polish ones. In China, most of the BSS are privately financed and there are many competitors in every city, which in the past years led to over-saturation of the market and the insolvency of many BSS (Zhao et al. 2020). In Poland, there is usually only one BSS operator in each city, and they are mostly publicly financed. In the case of Nextbike Polska all the BSS were financed by municipal authorities. This also contradicts the claims expressed in industry and media reports that bike sharing could be losing its market to scooter sharing services (Mobilne Miasto 2020; Wiewiora 2021). Although scooter sharing services have been found to be at least to some extent competitive to BSS (Liu and Lin 2022; Yang et al. 2021), as sources of financing of these two modes of transportation in Poland differ it couldn't be a major reason for Nextbike Polska's problems. Additionally, our results show that Nextbike's financial decline started before the wide popularization of e-scooter sharing in Poland. Moreover, e-scooter competition would affect also other companies on the Polish market and our results show that other Polish BSS operators existence was not threatened. The total number of shared bicycles in Poland is rising despite the ESS competition. This indicates that BSS and ESS can co-exist in one country. Nextbikes major problems may have originated in its engagement in the ambitious and unconventional project of Meyo, in which over 4 thousand of the shared e-bikes were to be delivered to one of the Polish municipalities in 2019. Back then, if successful it would be the largest e-bike sharing system in the world. The company managed to deliver only over one thousand of the e-bikes and was not able to provide adequate maintenance to this system (Bieliński et al. 2021, 2020). This failure resulted in multimillion losses for Nextbike Polska and has been mentioned in its financial statement as one of the major reasons for its lower revenues (Nextbike Polska 2021). This would ideate that managerial decisions and involvement in risky projects, and not only COVID 19 have been the major reasons for Nextbike's financial instability. We conclude that BSS problems in Poland had endogenous reasons and were connected with managerial decisions taken by the one leading BSS operator rather than the exogenous impact of COVID 19. Results from early warning discriminant models indicate that the bikesharing service (BSS) operators sector, while not generally at risk of insolvency, did experience financial setbacks due to the COVID-19 pandemic and expansion of scooter sharing services. Additionally, our analysis of Nextbike GmbH, a prominent player in the German micromobility market, reveals significant financial instability during the period under study. The application of early warning models in discriminant analysis demonstrated a considerable risk of bankruptcy for the years 2018, 2019, and 2020, culminating in the company's acquisition by Tier Mobility in 2021. This strategic acquisition was likely a necessity to preserve financial stability amid adverse conditions. Additionally, the significant decline in z-scores for the year 2020 underscores the profound impact of the COVID-19 pandemic on the micromobility sector, affecting both the German and Polish markets. These findings highlight the sector's susceptibility to global economic disruptions and emphasize the need for robust strategies to mitigate such risks in the future.

Interviews with stakeholders led to conclusions about solutions to universal problems applicable not only to bike-sharing systems in Poland but also in other markets. One major conclusion is that subsidy contracts between operators and municipal or regional authorities should be flexible, allowing operators to control fleet size based on actual demand for sharing services. This flexibility could significantly reduce costs by minimizing bicycle exposure to elements, theft, and vandalism.

The difference between Nextbike Polska and its two major competitors, is that Roove and Geovelo are more flexible in terms of using free-floating bicycles rather than station-based. They also have the ability to move virtual stations to different locations based on changes in demand and temporary transportation needs associated with city events like concerts and other gatherings. Additionally, as Roove and Geovelo's revenues are more dependent on bicycle usage rather than municipal subsidies, they have implemented policies to attract more users, such as offering one application for several systems. As the interviews revealed, this kind of flexibility is not possible under the strict rules of the municipal contracts signed by Nextbike Polska. A similar problem occurred with its German parent company. While the German bike-sharing market grew, Nextbike GmbH was at risk of insolvency from 2018 to 2020 and was eventually acquired by Tier Mobility, which primarily operates a scooter-sharing service and is not bound by municipal contracts. In recent years, Tier Mobility and other micromobility companies operating in Germany have added free-floating e-bikes to their e-scooter fleets, leading to the growth of the bike-sharing market but also creating competition for Nextbike GmbH. This shows that operators should collaborate closely with municipal authorities to negotiate flexible rules for the safe and responsible usage of bicycles, including areas for returns and station locations. Contracts should promote not only fleet availability but also efficiency (measured by the number of trips or other desired factors) and the creation of value added for users.

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Conflict of interest T. Bieliński, A.B. Ważna and P. Antonowicz declare that they have no competing interests.

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