EVALUATION OF THE PARKING SYSTEM EFFICIENCY BASED ON THE JADWIZYN SETTLEMENT IN PILA IN THE LIGHT OF SUSTAINABLE DEVELOPMENT

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Resume

The aim of the article is to assess the efficiency of the parking system on the example of the Jadwizyn estate in Pila in the light of sustainable development. For this purpose, an organoleptic test of the use of the parking space was carried out for 7 consecutive days, at three different times of the day (morning, noon, evening) in December and January.

The conducted research has shown that the parking system in the analyzed estate is not effective for the community living in the estate and the sustainable development guidelines were not taken into account during its planning. In the discussed case, it is necessary to introduce changes to the estate's parking policy, for example by implementing new parking solutions in the form of parking automation or building a multi-level structure providing more parking spaces.

1 Introduction and literature review

With the development of the automotive industry and the number of registered vehicles (Figure 1), the needs and expectations of the road infrastructure users also increased, especially those related to parking spaces [1]. The concept of a parking lot is understood as a place intended for parking cars [2]. More precisely, it is a place that allows one to park vehicles that are currently not in motion.

Sustainable development [4-5] is a concept and way of thinking in economics that assumes the level and quality of life at the level guaranteed by civilization. The idea of sustainable development is summarized and presented in the first sentence of the WCED report (also known as the "Brundtland Commission") of 1987 - "Our Common Future". Sustainable development is development that meets the needs of the present without compromising the capabilities of the future. generations to meet their own needs.

Sustainable development supports, protects and restores the health and integrity of the Earth's ecosystem without jeopardizing the ability to meet the needs of future generations [6-7]. It illustrates economic growth that leads to social cohesion and an increase in the value of the natural environment [8-9] and sustainable business as capable of "prospering indefinitely" [10]. The concept of sustainable development [11] covers everyone and everything - it concerns various aspects of human activity and human relations with the environment [12].

A sustainable urban transport system is essential for the proper development of a society and parking is an important element of this. The literature on sustainable parking management systems is extensive and mainly focuses on Park-and-Ride systems [13], planning and use of parklets [14] and the increasingly used Intelligent Transport Systems (ITS) [15-16]. In the case of car parks, the aim is to use them as efficiently as possible [17], with the possibility of introducing new solutions such as shared parking. This idea leads to the most efficient use of parking spaces. The allocation of parking spaces [18-19], the use of shared parking [20-22] and the design of a shared parking platform [23-24] have received much attention in the literature.

Over the years, the approach to parking policy planning and the perception of parking systems in cities has changed. Initially, it was based on transport infrastructure, striving for its greatest functionality, fluidity and capacity. Furthermore, city officials have started to see other important aspects - how existing
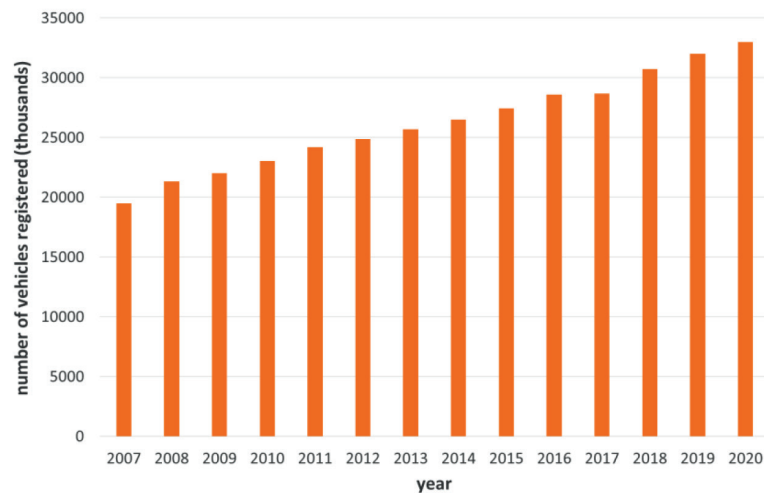
Figure 1 *The number of vehicles registered in Poland in 2007-2019 [3]*

Figure 2 *Location of the town of Pila on the map of Poland [28]*

transport systems and road infrastructure affect the quality of life of city dwellers, are they functional for people with disabilities and businesses and how they affect the environment. To determine whether a city's transport policy is sustainable, it must meet the different conditions [25].

Therefore, it can be concluded that an efficiently operating road infrastructure, which can be described as sustainable, encourages to quit of the most popular means of transport, which is a passenger car and encourages the use of public transport. This, in consequence, is expected to result in a healthier life for the inhabitants and an increase in the cleanliness of cities [26].

There are studies in the literature on urban engineering that confirm that the use of sustainable urban transport has a positive impact on development of cities and satisfaction of their inhabitants. An example is the transport assessment study carried out in the city of Czestochowa, Poland, which implements subsequent steps to improve the road infrastructure in a sustainable manner, encouraging the use of public urban transport. The respondents of the presented study emphasized that the advantages affecting the superiority of passenger car transport over the city transport are greater comfort, destination and shorter travel time. Nevertheless, the respondents were not clearly negative in the context of

public transport, which may lead to conclusions that specific changes in the structure and functioning of this mode of transport could change their opinions and encourage them to use it in the future.

The problems with the road capacity visible on Polish roads allow to conclude that the comfort of traveling by individual passenger transport is still greater than traveling by public means of transport, therefore most road infrastructure users still prefer to travel in this way [26].

In terms of the sustainable development of urban transport, an important element is the parking control system. It includes parking solutions that facilitate the management of available parking spaces, e.g. make it easier for the driver to find a free parking space. Such systems significantly contribute to the more effective use of the parking lot, reducing the time for the driver to find a free space, which is particularly problematic in places with a large parking lot.

2   Materials and methods

The city of Pila is located in the northern part of the Wielkopolska Province (Figure 2) on the border with the Zachodniopomorskie Province. In 2020, Pila
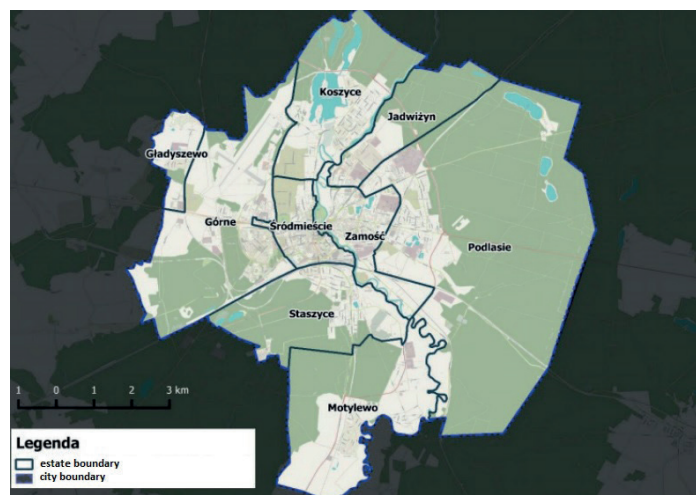
Figure 3 Map of the town of Pila with a breakdown by housing estates [31]

was inhabited by 69.411 inhabitants, which is about 5.000 less than in 2002 when the population was 75.197 [27]. Thanks to the data provided by the Pila City Hall, a downward trend in the number of inhabitants of the city can be observed.

The city covers an area of 103 km² and the population density is 674 people / km² [29]. In 2011, the city consisted of nine districts, the largest was and still is Podlasie (Figure 3). Other districts are: Gorne, Koszyce, Srodmiescie, Gladyszewo, Zamoscie, Staszyce, Motylewo and Jadwizyn, of which auxiliary units of the communes of Jadwizyn, Srodmiescie and Zamosc housing estates were abolished in 2011 [30].

The concept of the city is based on maintaining sustainable development by improving the economy, infrastructure and educational and recreational offer. Pila is the leader of investment attractiveness (Forbes 2007/2008 ranking), it is the most business-friendly city (in 2012, 1st place in the Wielkopolska and the 12th in Poland according to the Newsweek weekly), 16th city in the country in the national ranking of the Self-Government of Sustainable Development conducted under the aegis of the Foundation of the Promotional Emblem TERAZ POLSKA [32].

The Smart City idea is being implemented in Pila, which involves the use of information and communication technologies supporting, among others social integration and sustainable development. According to the development strategy of the city of Pila until 2035, it was planned to modernize car parks in the city, as well as to build a park & ride car park with places for disabled people and nanny with children, kiss & ride parking spaces and a parking lot for bicycles and to build parking information systems. An information and promotion campaign is also planned about the built infrastructure, its values and possibilities of using it, as part of the promotion of sustainable mobility [33].

The Jadwizyn estate (Figure 3) was established pursuant to two resolutions of August 29 and 31, 2006. The estate was also granted the statute at that time.

Nevertheless, the resolutions lost their force due to the new resolution No. XIV / 195/11 introduced on November 29, 2011, which called for the abolition of the auxiliary unit of the Jadwizyn estate. The city authorities argued their move with the residents' lack of interest in initiatives aimed at developing the individual. The inhabitants of the estate showed a lack of support for local government bodies in organizational matters, which resulted in the abolition of the estate in its legal form [34].

Nevertheless, the estate still exists in the social sphere of inhabitants and the city authorities of Pila continue to keep statistics for the indicated area, for example regarding the number of inhabitants. The boundaries of the estate indicated on the city map are still valid as the Jadwizyn estate has not been liquidated in the spatial and functional zone, but has only been deprived of its administrative unit.

According to the data published on the website of the Pila City Hall, 4.564 people lived in Jadwizyn in 2017. Its area is approximately 566.44 ha. This space is dominated by multi-storey residential buildings, although there are detached buildings at Jana and Jedrzeja Sniadeckich Streets. Additionally, also in the south-west part of the estate, which includes ul. Dabrowskiego (from number 92 to 150), ul. Grazyny, ul. Jagiellonska, ul. Jozefa Bema, ul. Kwidzynska, ul. Malgorzaty, ul. Olsztynska, pl. Jagielly, ul. Zelazna, houses only free-standing buildings.

The second, frequently used intersection in the estate is the intersection of Sniadeckich Street with Laczna Street located next to the education building, but no major problems related to the traffic flow have been observed there.

The estate has 63 multi-storey buildings and a total of 899 parking spaces. In the context of the diversity of parking systems, the estate can be described as diverse. There are systems such as private underground car parks and garage spaces on it

At the Jadwizyn estate, one would not meet the
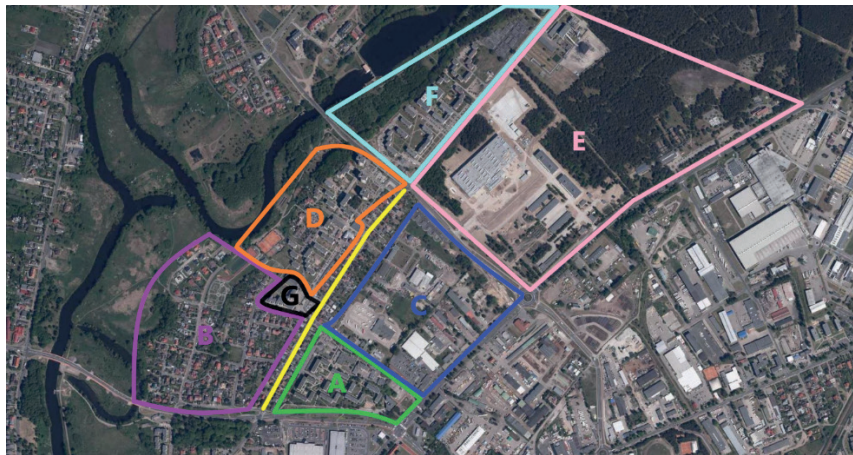
Figure 4 The Jadwizyn estate divided into 8 parking zones [35]

most modern parking solutions that operate in a fully automated manner, but it can be seen that along with newer buildings, among others, underground car parks with a view to making the best use of parking spaces.

3 Research results

The purpose of the research was to analyze the effectiveness of the parking system in the Jadwizyn estate in Pila in the light of sustainable development. The subject of the research were car parks located in the estate at the following streets: Laczna, Dabrowskiego, Grazyny, Jagiellonska, Jozefa Bema, Kwidzynska, Malgorzata, Olsztynska, Jagiely, Zelazna, Krolowej Jadwigi, Sniadeckich and at Aleja Powstancow Wielkopolskich (Figure 4) and the volume flow of vehicles occupying parking spaces at specified intervals, in such a way as to best check the actual efficiency of the currently functioning parking system solutions. Consequently, the research aimed to present a proposal to improve the directions of development of local road infrastructure.

With the help of the presented scientific literature on the subject, it can be noticed the existence of problems related to the failure to adapt to the needs of residential communities regarding parking infrastructure. It is about too large distances between residential buildings and the grouping of parking spaces. Another problem is the outdated road infrastructure, which probably stems from an inaccurate forecast of the number of cars owned by a selected housing estate. As a result, the number of places in a given grouping often turns out to be insufficient to meet the needs of the inhabitants. Moreover, the car parks do not have parking aids, which is another problematic issue. There are also doubts relating to safety issues, such as blocking access roads by incorrectly parked vehicles, as well as mismatching the distance between parking spaces and other objects not related to the parking infrastructure, such as trees, stones or poles, which consequently pose a threat to parking spaces, drivers and other infrastructure users.

Based on the above observations, obtained thanks to the presented scientific literature and for the needs of the research, a hypothesis is formulated that the parking system operating in the Jadwizyn estate in Pila

Table 1 The structures of separated zones in the Jadwizyn estate of 30.12.2020 - part 1 [31]

Street name	Zone	Age range	Women	Men	Number of multi-family buildings	Number of single-family buildings	Total number of parking spaces
		0-18	61	88			
		19-55	198	229			
Laczna street	A	56-63	58	31	17	0	200
		64 and above	167	124			
		Sum	956				
Dabrowskiego street, Grazyny street, Jagiellonska street, Jozefa Bema, Kwidzynska street, Malgorzaty street, Olsztynska square, Jagielly street, Zelazna street	B	0-18	51	50	0	160	4
		19-55	135	184			
		56-63	35	27			
		64 and above	57	54			
		Sum	593				

Table 2 *The structures of separated zones in the Jadwizyn estate of 30.12.2020 - part 2 [31]*

Street name	Zone	Age range	Women	Men	Number of multi-family buildings	Number of single-family buildings	Total number of parking spaces
Powstancow Wielkopolskich Avenue to Lukasiewicz roundabout, Przeswit street	C	0-18	0	0	0	0	0
		19-55	0	0			
		56-63	0	0			
		64 and above	0	0			
		Sum	0				
Krolowej Jadwigi street	D	0-18	109	128	24	16	273
		19-55	309	321			
		56-63	121	65			
		64 and above	228	185			
		Sum	1466				
Aleja Powstancow Wielkopolskie from the Lukasiewicz roundabout to the height of the production plant, Philips street	E	0-18	0	0	0	0	19
		19-55	0	0			
		56-63	0	0			
		64 and above	0	0			
		Sum	0				
Sniadeckich street	F	0-18	82	97	22	0	337
		19-55	226	235			
		56-63	72	70			
		64 and above	112	102			
		Sum	996				
School at Krolowej Jadwigi street	G	0-18	0	0	0	0	40
		19-55	0	0			
		56-63	0	0			
		64 and above	0	0			
		Sum	0				
Sniadeckich street with buildings along the street	H	0-18	32	38	0	69	0
		19-55	88	91			
		56-63	28	27			
		64 and above	44	39			
		Sum	387				
Sum			2932		63	245	873

is ineffective in relation to the needs of its residents.

The study consisted of observation of the parking infrastructure in the Jadwizyn estate, divided into 8 parking zones, shown in Figure 4. The individual zones cover the following streets:
- Zone A - ul. Laczna.
- Zone B - ul. Dabrowskiego (from number 92 to 150), ul. Grazyny, ul. Jagiellonian. ul. Jozefa Bemq, ul. Kwidzynska, ul. Malgorzaty, ul. Olsztynska, pl. Jagielly, ul. Zelazna.

- Zone C - Aleja Powstancow Wielkopolskich to the Lukasiewicza roundabout, ul. Przeswit.
- Zone D - ul. Krolowej Jadwigi.
- Zone E - Aleja Powstancow Wielkopolskich from the Lukasiewicza roundabout to the height of the Philips production plant, ul. Frits Philips.
- Zone F - ul. Sniadeckich covering the northern zone of the estate, which is characterized by multi-family buildings.
- Zone G - includes a car park adjacent to the school

at ul. Krolowej Jadwigi.

- Zone H - runs through the main street of the estate (Sniadeckich Street), which in this part is characterized by single-family houses.

The research was performed in the periods from November 30 to December 6, 2020 and January 11 to 17, 2021. Each of them lasted 7 days in 3 time intervals: 6.00-8.00, 14.00-16.00 and 21.00-23.00. Measurements made in both dates are characterized by taking into account the following parameters for each zone: total number of parking spaces, the average number of occupied and vacant spaces, including the number of spaces for disabled people, the number of cars parked incorrectly, the number of multi-family and single-family buildings and the number of residents. Data from the Pila City Hall on 30/12/2020 [31] obtained for the purposes of this article, regarding the structures in individual zones, are presented in Tables 1 and 2.

The studied area of the Jadwizyn estate is inhabited by 2.932 residents in 63 multi-family buildings and 245 single-family buildings, which include 873 parking spaces. In order to facilitate research, the estate has been divided into 8 zones: A-H. The description of the zones can be found later in the article. The indicator method [36] was used to analyze the neighbourhood parking system. By default, it adopts three criteria, however, due to the lack of access to restricted parking zones, the subject criterion, which uses the restricted parking zone share index, was not taken into account. Therefore, two criteria were used: subjective and functional, presented in Table 3 and were calculated based on the data presented in Tables 1 and 2. The parking intensity indicator expresses the ratio of the number of parked vehicles to the total number of parking spaces as a percentage and represents the total degree of occupied parking spaces for the examined area. The parking correctness index is also expressed as a percentage, it is the ratio of the number of incorrectly parked vehicles

to the number of parked vehicles. As improperly parked cars are understood all the vehicles in the area of a given test that were left in a manner that deviates from the correct one in a given system, e.g. in a forbidden place, hindering pedestrian traffic, green areas or outside the designated parking stand.

In Table 4 the subjective criterion was presented along with the indicator of the number of parking spaces per 100 inhabitants for each zone. A zero result in zones C and H results from the lack of parking spaces and a zero result for zones E and G due to the zero number of inhabitants.

Moreover, the method of direct systematic observation was adopted in the study [36]. The task was to observe the phenomenon of how residents leave their cars at designated parking spaces, in order to notice the relationship between their behaviour, the functionality of existing parking lots in relation to the needs of residents and the effectiveness of parking systems.

The first zone is inhabited by 956 residents in 17 multi-family buildings with 200 parking spaces and 67 private garages. The zone is presented in Figure 5.

In Table 5 is shown the parking intensity and correctness indicators in zone A for the 1st and 2nd measurement period. The number of parking spaces for the first indicator on individual days at three different times of the day was presented and the correctness of parked vehicles was presented, which means that on November 30, in the evening hours, the number of incorrectly parked vehicles was 5.5% of the total number of parking spaces, i.e. 10 cars in this case. For poorly parked vehicles, cases were counted that took places outside the designated parking spaces, e.g. in a prohibited place. It was observed that some vehicles blocked the access to the dumpster shelters and were left in forbidden places, thus making it difficult for, for example, emergency services to access individual

Table 3 *Criteria and indicators for the evaluation of the estate parking system [36]*

Criterion	Name	Formula
Subjective	The indicator of the number of parking spaces per 100 inhabitants [place / 100 inhabitants]	$W_{B2} = \frac{M_C}{U_C} * 100$
Functional	Parking intensity indicator [%]	$W_{C1} = \frac{P_C}{M_C} * 100$
	Parking correctness indicator [%]	$W_{C2} = \frac{P_N}{P_C} * 100$

M_C - number of parking spaces,

U_C - number of residents,

P_C - number of parked vehicles,

P_N - number of vehicles parked incorrectly.

Table 4 *Indicator of the number of parking spaces per 100 inhabitants, divided into zones*

Indicator	Zone							
	A	B	C	D	E	F	G	H
W_{B2} [1 place for 100 people]	20.9	0.7	0	18.6	0	33.8	0	0

Figure 5 *Zone A with marked parking spaces [35]*

Table 5 *Indicators of parking intensity and correctness for zone A*

First measurement									
Indicator [%]	Time	30.Nov	01.Dec	02. Dec	03. Dec	04. Dec	05. Dec	06. Dec	Average
W_{c1}	06.00-08.00	67.5	60.5	64.5	63	66	82.5	85	69.9
W_{c2}		3	0.8	1.6	3.2	2.3	1.8	2.4	2.1
W_{c1}	14.00-16.00	71	77.5	89	81.5	86.5	84.5	84	82
W_{c2}		0.7	2.6	2.8	1.8	1.2	3	3	2.2
W_{c1}	21.00-23.00	90.5	94	95.5	92	93	94.5	96.5	93.7
W_{c2}		5.5	6.9	4.2	3.8	3.2	2.1	4.7	4.3
Second measurement									
Indicator [%]	Time	11.Jan	12.Jan	13.Jan	14.Jan	15.Jan	16.Jan	17.Jan	Average
W_{c1}	06.00-08.00	82.5	79	77.5	76.5	75.5	80	83.5	79.2
W_{c2}		5.5	7.3	4.8	7.9	7.3	6.7	7.9	6.8
W_{c1}	14.00-16.00	92.5	89.5	88	90.5	86.5	88.5	89.5	89.3
W_{c2}		6.7	6.1	6.1	9.7	8.5	6.1	8.5	7.4
W_{c1}	21.00-23.00	94	91.5	94.5	94	92	93.5	96	93.6
W_{c2}		7.9	8.5	7.3	11.5	9.1	8.5	10.9	9.1

buildings. The last column shows the average for a given time of day and indicator. In the second period of the study, an increase in the average intensity in the morning and afternoon hours, as well as a similar result for the evening hours was noticed.

Development of the zone B consists of 160 single-family buildings inhabited by 593 people. Due to the single-family development of the zone, which distinguishes this part of the estate from the rest, the number of parking spaces is limited to 4, located next to the grocery store. The boundaries of zone B are set out in Figure 6.

Table 6 shows the traffic intensity index for the zone B for the 1st and 2nd measurements. Increased use of parking spaces in the afternoon by store customers has been noticed. Incorrectly parked vehicles were

not observed. During the study, it was noticed that residents leave their cars in private parking lots within the property. There are no designated parking spaces for disabled people in this zone and no incorrect parking has been observed. Depending on the time of day, the average number of occupied parking spaces varies from 1 to 2. During the research on the second date, there were no badly parked vehicles and the highest intensity occurred in the afternoon. Comparing the results of the measurements, a minimal increase in parking space in the second period was noticed.

Zone C is the service and retail part of the estate (Figure 7), which consists of the IBI shopping mall, MZK Pila bus depot, car wash, Altvater garbage dump and small local businesses. In this part, there is one parking system with 194 parking spaces, which belongs

Figure 6 *Zone B with marked parking spaces [35]*

Table 6 *Parking intensity and correctness indicator for zone B*

					First measurement				
Indicator [%]	Time	30.Nov	01.Dec	02. Dec	03. Dec	04. Dec	05. Dec	06. Dec	Average
W_{c1}	06.00-08.00	25	25	25	25	25	25	0	21.4
W_{c2}		-	-	-	-	-	-	-	-
W_{c1}	14.00-16.00	50	25	100	25	75	25	0	42.9
W_{c2}		-	-	-	-	-	-	-	-
W_{c1}	21.00-23.00	25	75	25	25	50	50	0	35.7
W_{c2}		-	-	-	-	-	-	-	-
					Second measurement				
Indicator [%]	Time	11.Jan	12.Jan	13.Jan	14.Jan	15.Jan	16.Jan	17.Jan	Average
W_{c1}	06.00-08.00	25	25	0	25	25	50	25	25
W_{c2}		-	-	-	-	-	-	-	-
W_{c1}	14.00-16.00	25	75	50	25	50	50	50	46.4
W_{c2}		-	-	-	-	-	-	-	-
W_{c1}	21.00-23.00	0	25	50	50	50	50	50	39.3
W_{c2}		-	-	-	-	-	-	-	-

to a shopping mall, but it was not included in the study, because it is largely used by residents of other parts of the city and its use is different than in residential areas. An interesting tendency of owners of vehicles from zone A was noticed to leave them outside the designated positions, in the IBI gallery, especially in the place bordering zone A.

Due to the lack of parking spaces, the purpose of which is to leave cars by residents while they are in their place of residence, the test results for the entire zone C

have not been prepared as a vehicle parked incorrectly, because they did not occupy the designated positions (Table 7). Based on the presented results, it can be concluded that in the morning and evening hours there is the largest number of incorrectly parked vehicles by the inhabitants of Zone A.

The zone D is inhabited by 1.466 people. The vast majority of zones are the multi-family buildings, the number of which is 26 (Figure 8). With regard to the single-family housing, it was calculated that there are 16

Figure 7 *Zone C [35]*

Table 7 *Average of incorrectly parked vehicles at particular times of the day*

First measurement								
Time/Data	30.Nov	01.Dec	02. Dec	03. Dec	04. Dec	05. Dec	06. Dec	Average
6:00-8:00	2	3	3	2	1	3	4	2.57
14:00-16:00	0	1	2	2	2	2	3	1.71
21:00-23:00	5	4	4	4	6	5	5	4.71
Second measurement								
Time/Data	11.Jan	12.Jan	13.Jan	14.Jan	15.Jan	16.Jan	17.Jan	Average
6:00-8:00	1	2	3	3	3	2	3	2.43
14:00-16:00	2	2	0	1	2	1	3	1.57
21:00-23:00	6	5	5	3	4	4	4	4.43

buildings of this type in the zone. There are 273 parking spaces in this zone. In this part of the estate there is one local grocery store with 8 parking spaces. There is a church near the grocery store, but it does not have a dedicated parking lot. There are also single garage car parks in the zone, of which there are 55 in total.

A large number of incorrectly parked cars took place on sidewalks, green belts and places with no parking. In the evening hours, one can observe significant difficulties related to the movement of the vehicle in the designated zone, which is related to incorrect parking, presented by the parking correctness indicator in Table 8. It shows that on November 30, in the evening hours, the number of poorly parked vehicles was 14.6% of the number of occupied parking spaces. In this case, it is nearly 40 vehicles parked in prohibited places. This could be due to the start of the weekend and the arrival of more people at home. The high parking intensity index occurs for all the test hours, while the highest result can be observed in the evening hours, along with the highest parking correctness index.

There are no residential buildings in zone E. There are a facility of the military unit and the Municipal Heat Engineering. These centers have 6 and 13 parking spaces, respectively, which are probably used only by employees of the centers (Figure 9). It is worth noting that there are no dedicated parking spaces for disabled people, despite the fact that the car parks are located near two workplaces.

In Table 9 the parking intensity index for zone E was taken into account together with the average for each of the three times of the day. Due to the lack of incorrectly parked vehicles, the correctness index was not calculated. The discussed zone is characterized by the highest parking intensity in the morning, probably due to the hours in which employees of nearby workplaces work.

The zone F (Figure 10) includes only multi-family residential buildings. Their number is 22. There are 337 parking places for this number of buildings. Due to the newer housing development of two buildings, they also have underground garages for use by residents. Underground garage car parks are available only to people who have them, which made it impossible to take them into account in the study. There are also 180 single garage car parks in this zone, which are monitored and entry to their area is prohibited, which is preceded by a no-entry sign, excluding people with garage spaces.

Figure 8 *Zone D with marked parking spaces [35]*

Table 8 *Indicator of intensity and correctness of parking for zone D*

Indicator [%]	Time	30.Nov	01.Dec	02. Dec	03. Dec	04. Dec	05. Dec	06. Dec	Average
First measurement									
W_{c1}	06.00-08.00	63.4	60.8	66.7	62.3	61.5	80.2	84.6	68.5
W_{c2}		12.7	10.2	7.7	9.4	8.9	7.3	7.8	9.2
W_{c1}	14.00-16.00	87.9	90.1	84.6	93.4	85.7	85.7	90.5	88.3
W_{c2}		10.8	9.8	12.1	8.2	10.3	11.5	8.1	10.1
W_{c1}	21.00-23.00	95.2	94.9	97.1	94.5	96.3	97.1	99.6	96.4
W_{c2}]		14.6	8.5	11.3	14	10.6	12.1	12.9	12

Indicator [%]	Time	11.Jan	12.Jan	13.Jan	14.Jan	15.Jan	16.Jan	17.Jan	Average
Second measurement									
W_{c1}	06.00-08.00	79.9	75.8	72.9	79.9	82.1	76.9	76.2	77.7
W_{c2}		11	8.2	12.1	6	8.5	10.5	9.1	9.3
W_{c1}	14.00-16.00	88.3	90.5	89	84.2	88.3	86.8	90.5	88.2
W_{c2}		5.8	10.5	11.5	10	11.2	14.8	10.9	10.7
W_{c1}	21.00-23.00	92.7	91.2	93.8	90.8	94.5	96	97.1	93.7
W_{c2}		12.6	12.9	10.2	10.9	12	15.6	13.6	12.5

The indicators of the occupied parking spaces intensity and the correctness of parked vehicles for zone F are presented in Table 10, showing the variable number of cars on different days, taking into account three tests during the day. The highest number of parked vehicles was recorded in the evening hours; however, it is worth noting that the indicator in the afternoon hours is also high for both analyzed periods of time. Comparing the test results, an increase in the index was noted in the morning and evening hours and a slight decrease in the evening hours for the second period of the study.

Zone G is a part of the estate (Figure 11), where the education building is located, "Queen Jadwiga". The building includes a parking lot with 43 parking spaces.

The main assumption is that the car park is to be used by the employees of the facility to park vehicles during their work, as well as for parents who take their children to school or come to meetings with teachers. It is worth noting that during the study, the school institution conducted remote classes for its students, so it was not fully used by their parents and other people.

In Table 11, the intensity index in zone G was marked, the parking correctness index was not included, because during the tests, no irregularities related to leaving the vehicles were observed and the highest intensity of parking was recorded in the evening hours in both cases. Comparing the research results, it can be stated that for each time of the day an increase in

Figure 9 *Zone E with marked parking spaces [35]*

Table 9 *Indicator of intensity and correctness of parking for zone E*

First measurement									
Indicator [%]	Time	30.Nov	01.Dec	02. Dec	03. Dec	04. Dec	05. Dec	06. Dec	Average
W_{c1}	06.00-08.00	63.2	63.2	73.7	63.2	57.9	26.3	21.1	52.6
W_{c2}		-	-	-	-	-	-	-	-
W_{c1}	14.00-16.00	21.1	26.3	42.1	31.6	26.3	15.8	10.5	24.8
W_{c2}		-	-	-	-	-	-	-	-
W_{c1}]	21.00-23.00	5.3	15.8	15.8	26.3	26.3	15.8	0	15
W_{c2}		-	-	-	-	-	-	-	-
Second measurement									
Indicator [%]	Time	11.Jan	12.Jan	13.Jan	14.Jan	15.Jan	16.Jan	17.Jan	Average
W_{c1}	06.00-08.00	47.4	68.4	57.9	57.9	68.4	63.2	52.6	59.4
W_{c2}		-	-	-	-	-	-	-	-
W_{c1}	14.00-16.00	15.8	21.1	31.6	26.3	21.1	5.3	15.8	19.5
W_{c2}		-	-	-	-	-	-	-	-
W_{c1}	21.00-23.00	10.5	10.5	10.5	5.3	10.5	15.8	5.3	9.8
W_{c2}		-	-	-	-	-	-	-	-

parking intensity was recorded in the second research period.

The zone H was separated for the purposes of the study (Figure 12) in order to separate the residential buildings belonging to it from other zones, because the adjacent single-family houses are directed towards the main Sniadeckich Street starting from zones A and B and continuing to the end of zones F and E, adjacent to each of the zones described above. The division is aimed at increasing the correctness of the research by subtracting the number of inhabitants of zone H from the inhabitants of other zones, because they park only on their properties, the entrance to which is from the main street. The number of buildings per zone is 69.

For the H zone, no table was prepared containing data from the research carried out from 30/11/2020 to 6/12/2020, because the zone did not have any parking spaces and the residents of this zone parked their vehicles on their properties with single-family houses.

The conducted research was aimed at assessing the effectiveness of the parking system at the Jadwizyn estate in Pila in the light of sustainable development. At the very beginning, it is worth noting that the study was carried out during the SARS-CoV-2 coronavirus pandemic, which significantly limited the movement of the population since the introduction of the epidemic and preventive measures limiting the spread of the virus. The situation could have contributed to an increase in the intensity of the use of parking lots due to the transfer of many works from stationary to remote mode (the so-called home office) and due to the limitation or closure of some workplaces, or staying in home quarantine in accordance with the government's recommendations. Therefore, the tests in the first period were carried out on November 30, 2020 after lifting some restrictions, including opening of shopping malls, however operating under the sanitary regime limiting the maximum number of customers.

Figure 10 *Zone F with marked parking spaces [35]*

Table 10 *Indicator of intensity and correctness of parking for zone F*

Indicator [%]	Time	30.Nov	01.Dec	02. Dec	03. Dec	04. Dec	05. Dec	06. Dec	Average
				First measurement					
W_{c1}	06.00-08.00	52.2	50.1	54.9	54.3	47.2	68.2	72.4	57.1
W_{c2}		3.4	1.2	5.4	2.2	1.3	2.6	2.9	2.7
W_{c1}	14.00-16.00	81.3	76.3	81.9	68.8	73	77.4	85.5	77.7
W_{c2}		4	2.3	2.2	1.3	1.2	1.5	3.1	2.2
W_{c1}	21.00-23.00	86.6	87.8	84.6	88.7	82.8	84.9	86.9	86.1
W_{c2}		4.8	5.1	3.5	4	2.9	4.2	3.8	4

Indicator [%]	Time	11.Jan	12.Jan	13.Jan	14.Jan	15.Jan	16.Jan	17.Jan	Average
				Second measurement					
W_{c1}	06.00-08.00	60.2	58.8	52.5	56.4	55.2	71.2	74.5	61.3
W_{c2}		3.4	2.5	5.1	3.2	2.2	4.2	6.4	3.8
W_{c1}	14.00-16.00	73.6	77.7	76.6	79.8	81	78.3	85.2	78.9
W_{c2}		4	3.1	3.1	2.6	3.3	4.9	2.8	3.4
W_{c1}	21.00-23.00	84.6	86.4	84.3	84	85.8	88.4	87.2	85.8
W_{c2}		6.7	6.9	5.6	3.5	4.5	6	5.1	5.5

On the other hand, the tests in the second period, on January 11-17, 2021, took place after the announcement of further restrictions prohibiting the normal operation of such facilities as shopping malls and gyms. Table 12 compares the average parking intensity indicators for each of the zones in the first and second study periods.

The test results are presented collectively in Table 13 and 14 for both studies, simultaneously gathering all the zones of the Jadwizyn estate. They contain intensity indicators. Each research day is divided into 3 time periods in which the research was carried out. The higher the intensity index, the more parking spaces have been occupied. The average daily intensity was calculated for each test day. At the end of the statement, the correctness index was given in the form of an arithmetic mean, taking into account the entire period

of testing of a given table, whereas in Table 15 is the intensity index with the average for each of the 3 series of time intervals for the entire test period. This allows one to visualize the intensity that occurs at certain times of the day. A1 means the 1st measurement, A2 means the 2nd measurement, etc.

The analysis of the research results (Table 12) allows to state that zone D together with zone A had the highest parking intensity indicator. This is due to the highest number of multi-family buildings in these zones. In addition, these buildings have old buildings that are not equipped with, for example, underground parking spaces and the size of the existing parking lots is not adapted to the current needs of residents. Zone D was characterized by the greatest use of parking spaces in the afternoon and evening hours. It is worth

Figure 11 *Zone G with marked parking spaces [35]*

Table 11 *The intensity and correctness index for zone G*

First measurement									
Indicator [%]	Time	30.Nov	01.Dec	02. Dec	03. Dec	04. Dec	05. Dec	06. Dec	Average
W_{c1}	06.00-08.00	12.5	12.5	10	17.5	10	25	30	16.8
W_{c2}		-	-	-	-	-	-	-	-
W_{c1}	14.00-16.00	22.5	17.5	22.5	20	22.5	35	27.5	23.9
W_{c2}		-	-	-	-	-	-	-	-
W_{c1}	21.00-23.00	32.5	30	27.5	35	32.5	40	40	33.9
W_{c2}		-	-	-	-	-	-	-	-
Second measurement									
Indicator [%]	Time	11.Jan	12.Jan	13.Jan	14.Jan	15.Jan	16.Jan	17.Jan	Average
W_{c1}	06.00-08.00	27.5	30	22.5	30	20	32.5	37.5	28.6
W_{c2}		-	-	-	-	-	-	-	-
W_{c1}	14.00-16.00	20	27.5	27.5	27.5	37.5	40	35	30.7
W_{c2}		-	-	-	-	-	-	-	-
W_{c1}	21.00-23.00	32.5	35	32.5	40	35	45	47.5	38.2
W_{c2}		-	-	-	-	-	-	-	-

Table 12 *Average rate of parking correctness for the two research periods*

Indicator	Time	Zone							
		A	B	C	D	E	F	G	H
W_{c1} [%]	30.11-06.12.2020	81.9	33.3	-	84.4	30.8	73.6	24.9	-
	11.01-17.01.2021	87.4	36.9	-	86.5	29.6	75.3	32.5	-

noting that this zone is inhabited by the largest number of inhabitants, which accounts for half of the entire estate.

Although the zone D is inhabited by 1.466 people, zone F has more parking spaces by 64 parking spaces. Additionally, zone F has 137 more parking spaces than zone A, despite the similar number of inhabitants. The largest number of parking spaces in zone F is the result of the renovation of local car parks by the city authorities, thus increasing the number of available spaces. While in zones D and A, there are only old, dense buildings that prevent creation of new places, which

could involve the construction of parking spaces in close proximity to residential buildings and their windows and this would be against Polish law.

Comparing the three zones with the highest number of inhabitants, A, D and F, the last one was the one that recorded the lowest number of occupied zones at any time of the day. This is due to the largest number of parking spaces per 100 inhabitants; in this case it amounts to almost 34, where for zone A it is almost 21 and for zone D more than 18 parking spaces per 100 people. In addition, zone F has the latest development compared to the rest of the estate zones, making it easier
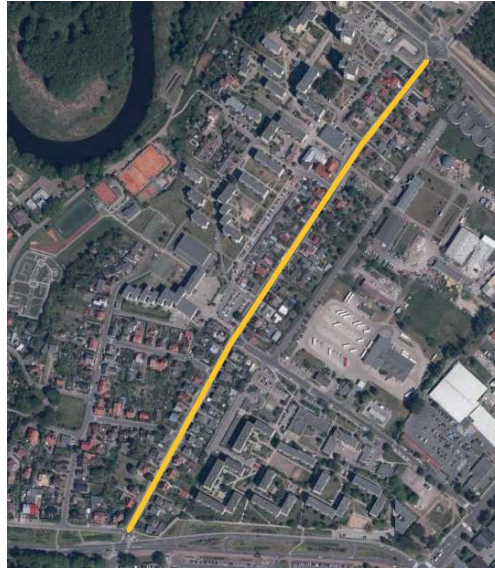
Figure 12 *Zone H [35]*

Table 12 *List of indicators for all the zones of the Jadwizyn estate during the study period from 30/11/2020 to 06/12/2020*

Date	Time	Zone								
		A		B	D		E	F		G
		W_{c1} [%]	W_{c2} [%]	W_{c1} [%]	W_{c1} [%]	W_{c2} [%]	W_{c1} [%]	W_{c1} [%]	W_{c2} [%]	W_{c1} [%]
30.Nov	06.00-08.00	67.5	3.0	25.0	63.4	12.7	63.2	52.2	3.4	12.5
	14.00-16.00	71.0	0.7	50.0	87.9	10.8	21.1	81.3	4.0	22.5
	21.00-23.00	90.5	5.5	25.0	95.2	14.6	5.3	86.6	4.8	32.5
	Average	76.3	3.1	33.3	82.2	12.7	29.8	73.4	4.1	22.5
01.Dec	06.00-08.00	60.5	0.8	25.0	60.8	10.2	63.2	50.1	1.2	12.5
	14.00-16.00	77.5	2.6	25.0	90.1	9.8	26.3	76.3	2.3	17.5
	21.00-23.00	94.0	6.9	75.0	94.9	8.5	15.8	87.8	5.1	30.0
	Average	77.3	3.4	41.7	81.9	9.5	35.1	71.4	2.9	20.0
02. Dec	06.00-08.00	64.5	1.6	25.0	66.7	7.7	73.7	54.9	5.4	10.0
	14.00-16.00	89.0	2.8	100.0	84.6	12.1	42.1	81.9	2.2	22.5
	21.00-23.00	95.5	4.2	25.0	97.1	11.3	15.8	84.6	3.5	27.5
	Average	83.0	2.8	50.0	82.8	10.4	43.9	73.8	3.7	20.0
03.Dec	06.00-08.00	63.0	3.2	25.0	62.3	9.4	63.2	54.3	2.2	17.5
	14.00-16.00	81.5	1.8	25.0	93.4	8.2	31.6	68.8	1.3	20.0
	21.00-23.00	92.0	3.8	25.0	94.5	14.0	26.3	88.7	4.0	35.0
	Average	78.8	2.9	25.0	83.4	10.5	40.4	70.6	2.5	24.2
04.Dec	06.00-08.00	66.0	2.3	25.0	61.5	8.9	57.9	47.2	1.3	10.0
	14.00-16.00	86.5	1.2	75.0	85.7	10.3	26.3	73.0	1.2	22.5
	21.00-23.00	93.0	3.2	50.0	96.3	10.6	26.3	82.8	2.9	32.5
	Average	81.8	2.2	50.0	81.2	9.9	36.8	67.7	1.8	21.7
05.Dec	06.00-08.00	82.5	1.8	25.0	80.2	7.3	26.3	68.2	2.6	25.0
	14.00-16.00	84.5	3.0	25.0	85.7	11.5	15.8	77.4	1.5	35.0
	21.00-23.00	94.5	2.1	50.0	97.1	12.1	15.8	84.9	4.2	40.0
	Average	87.2	2.3	33.3	87.7	10.3	19.3	76.9	2.8	33.3
06.Dec	06.00-08.00	85.0	2.4	0.0	84.6	7.8	21.1	72.4	2.9	30.0
	14.00-16.00	84.0	3.0	0.0	90.5	8.1	10.5	85.5	3.1	27.5
	21.00-23.00	96.5	4.7	0.0	99.6	12.9	0.0	86.9	3.8	40.0
	Average	88.5	3.3	0.0	91.6	9.6	10.5	81.6	3.2	32.5
Average		81.9	2.9	33.3	84.4	10.4	30.8	73.6	3.0	24.9

Table 13 *List of indicators for all the zones of the Jadwizyn estate during the study period from 30/11/2020 to 06/12/2020*

Date	Time	Zone								
		A		B	D		E	F		G
		W_{c1} [%]	W_{c2} [%]	W_{c1} [%]	W_{c1} [%]	W_{c2} [%]	W_{c1} [%]	W_{c1} [%]	W_{c2} [%]	W_{c1} [%]
11.Jan	06.00-08.00	82.5	5.5	25.0	79.9	11.0	47.4	60.2	3.4	27.5
	14.00-16.00	92.5	6.7	25.0	88.3	5.8	15.8	73.6	4.0	20.0
	21.00-23.00	94.0	7.9	0.0	92.7	12.6	10.5	84.6	6.7	32.5
	Average	89.7	6.7	16.7	86.9	9.8	24.6	72.8	4.7	26.7
12.Jan	06.00-08.00	79.0	7.3	25.0	75.8	8.2	68.4	58.8	2.5	30.0
	14.00-16.00	89.5	6.1	75.0	90.5	10.5	21.1	77.7	3.1	27.5
	21.00-23.00	91.5	8.5	25.0	91.2	12.9	10.5	86.4	6.9	35.0
	Average	86.7	7.3	41.7	85.8	10.5	33.3	74.3	4.2	30.8
13.Jan	06.00-08.00	77.5	4.8	0.0	72.9	12.1	57.9	52.5	5.1	22.5
	14.00-16.00	88.0	6.1	50.0	89.0	11.5	31.6	76.6	3.1	27.5
	21.00-23.00	94.5	7.3	50.0	93.8	10.2	10.5	84.3	5.6	32.5
	Average	86.7	6.1	33.3	85.2	11.2	33.3	71.1	4.6	27.5
14.Jan	06.00-08.00	76.5	7.9	25.0	79.9	6.0	57.9	56.4	3.2	30.0
	14.00-16.00	90.5	9.7	25.0	84.2	10.0	26.3	79.8	2.6	27.5
	21.00-23.00	94.0	11.5	50.0	90.8	10.9	5.3	84.0	3.5	40.0
	Average	87.0	9.7	33.3	85.0	9.0	29.8	73.4	3.1	32.5
15.Jan	06.00-08.00	75.5	7.3	25.0	82.1	8.5	68.4	55.2	2.2	20.0
	14.00-16.00	86.5	8.5	50.0	88.3	11.2	21.1	81.0	3.3	37.5
	21.00-23.00	92.0	9.1	50.0	94.5	12.0	10.5	85.8	4.5	35.0
	Average	84.7	8.3	41.7	88.3	10.6	33.3	74.0	3.3	30.8
16.Jan	06.00-08.00	80.0	6.7	50.0	76.9	10.5	63.2	71.2	4.2	32.5
	14.00-16.00	88.5	6.1	50.0	86.8	14.8	5.3	78.3	4.9	40.0
	21.00-23.00	93.5	8.5	50.0	96.0	15.6	15.8	88.4	6.0	45.0
	Average	87.3	7.1	50.0	86.6	13.6	28.1	79.3	5.0	39.2
17.Jan	06.00-08.00	83.5	7.9	25.0	76.2	9.1	52.6	74.5	6.4	37.5
	14.00-16.00	89.5	8.5	50.0	90.5	10.9	15.8	85.2	2.8	35.0
	21.00-23.00	96.0	10.9	50.0	97.1	13.6	5.3	87.2	5.1	47.5
	Average	89.7	9.1	41.7	87.9	11.2	24.6	82.3	4.8	40.0
Average		87.4	7.7	36.9	86.5	10.9	29.6	75.3	4.2	32.5

Table 14 *Cumulative intensity indicator for all the zones of the Jadwizyn estate*

Indicator	Time	Zone															
		A1	A2	B1	B2	C1	C2	D1	D2	E1	E2	F1	F2	G1	G2	H1	H2
W_{c1} [%]	06.00-08.00	69.9	79.2	21.4	25	-	-	68.5	77.7	52.6	59.4	57.1	61.3	16.8	28.6	-	-
	14.00-16.00	82	89.3	42.9	46.4	-	-	88.3	88.2	24.8	19.5	77.7	78.9	23.9	30.7	-	-
	21.00-23.00	93.7	93.6	35.7	39.3	-	-	96.4	93.7	15	9.8	86.1	85.8	33.9	38.2	-	-
	Average	81.90	87.40	33.30	36.90	-	-	84.40	86.50	30.80	29.60	73.60	75.30	24.90	32.50	-	-

to leave cars, e.g. thanks to underground parking lots that belong to new multi-family buildings.

The highest percentage of incorrectly parked cars was in zones A, D and F. It was observed that incorrectly parked cars were most often located in close proximity to residential buildings and therefore often made it difficult to move around parking lots, e.g. by obstructing other vehicles and garbage arbors, leaving narrow passages that forced users to perform additional manoeuvres with the vehicle in order to park or leave the parking lot. The available parking spaces in the evening hours were most often located far from the places of residential buildings, which was an inconvenience for the residents and they preferred to leave the vehicle in the wrong place, rather than park it correctly. It is worth mentioning that some of the cars parked incorrectly did not hinder the movement of other vehicles and pedestrians, standing in unused places, e.g. neglected parts of sidewalks, which due to their width are able to accommodate several vehicles.

In zone B, despite the lack of public parking spaces intended for residents, there were no incorrectly parked vehicles and parking spaces under the local store were used mainly by the store's customers. It follows that the lack of publicly available parking solutions is the result of the residents of the zone having parking spaces on private properties, which fully covers their needs. Moreover, zone B, due to its distance from multi-family housing, is not an interesting place to leave a vehicle for people living in other zones. The situation of the H zone is similar, because here we are also dealing with single-family houses, which have parking spaces on the property and the residents of these houses do not need to leave their cars in public parking spaces available throughout the estate.

Zone G, despite having a car park, which was originally intended for use by employees of the educational institution, was used mainly in the afternoon and evening hours, most likely by residents of the nearby zones A, D and H. This is the result of an insufficient number of places in the zones mentioned, especially at times when the largest number of residents spent their time at home. It is worth taking into account that due to the situation related to the prevailing pandemic, school classes were held mainly remotely, which could result in a decrease in the intensity of parking spaces used in this area in the morning.

Zone E has parking spaces located at workplaces. It can be concluded that the car parks located in this zone are used only by plant employees, as indicated by the highest traffic hours. The largest number of parked cars was between 6 AM and 8 AM and with each subsequent hour of testing, their number decreased. The evening average number of cars parked in this zone was the lowest. No incorrectly parked vehicles were observed, which allows to conclude that the parking spaces are sufficient to meet the needs of employees or that they also have parking lots at their disposal at the workplace.

Despite the failure to carry out the research for the entire C-zone due to the purpose of the parking system to meet the needs of the mall's customers, during the research for the rest of the estate, it was noticed that the C-zone car park, which belongs to the "IBI" shopping center, was filling up in the evening hours when the gallery was closed. These cars remained there until the very morning, which may indicate that the residents of the estate, especially zone A, decided to leave the car in the parking lot belonging to the store due to the insufficient number of parking spaces in their zone. Another issue indicating such a possibility is the drivers leaving their cars in parking spaces located as close as possible to zone A.

Summarizing the collected conclusions, evaluation of the effectiveness of the parking system allows to conclude that the discussed system is insufficient in individual zones of the Jadwizyn estate, in particular for zones A and D, where the situation prevailing during the research allowed for the practically complete use of available parking spaces, especially in the form of the parking intensity indicator in the second observation period, which increased on average by 5.5 % for zone A and by 2.1 % for the second zone. This is particularly evident when comparing the data from the first and second dates. The observed increase in parking space in the second period of the study results from the imposed restrictions, related to, inter alia, with the closure of large-format stores and shopping malls. This limited the swinging movement between the place of work, education and trade and the place of residence. The situation allowed to "test" the efficiency of the parking systems existing on the estate.

Referring to the idea of sustainable urban transport, it can be stated that the parking system at the Jadwizyn estate does not fit in with this transport policy. First of all, the infrastructure was created with the current needs of the inhabitants of that time in mind and not for the long-term use. At the same time, it confirms that no analyses, concerning the condition of the infrastructure and the increasing interest in means of individual communication, had been carried out before. Moreover, the fact that drivers spend a lot of time driving around the neighbourhood in order to find a vacant place is contrary to the assumption of sustainable urban transport, which aims to reduce the negative effects caused by the excessive movement of combustion vehicles.

4   Conclusion

The conducted research made it possible to notice that the problem of urban aging is not a problem faced only by large agglomerations, but also by smaller cities and towns. The technical progress that took place in the automotive world was not foreseen at the time when the Polish architecture was reconstructed after World War II, the effects of which are still felt by

drivers of vehicles involved in road traffic [37]. The basic conclusion regarding the ineffectiveness of the Pila car park in the Jadwizyn estate also concerns the archaic structure of the existing systems, which do not meet the expectations and needs of residents, contributing to their general dissatisfaction. This is a problem especially visible in periods when the public spends a lot of time in their home areas (holidays, pandemic restrictions, weekends).

However, attention should be paid to difficulties that occurred during the examination. By examining the intensity of the car park and its demand, authors were not able to determine whether each parked vehicle belongs to people living in multi-family buildings, visitors or families living in single-family buildings.

Using the research, it was possible to assess the effectiveness of the parking system that exists in the Jadwizyn estate in Pila and to refer to the idea of sustainable development with the presented results. The conducted study proved that the system is not effective for the community living in the estate and allows to draw a conclusion that changes in the parking policy of the estate should be made, for example by implementing new parking solutions in the form of parking automation or building a multi-level structure providing more parking spaces. Continuation of the research in the field presented would certainly help to implement even more accurate solutions that would result in implementation of the most effective parking systems, tailored both to the structure of the estate and the needs of its residents, this type of research could be carried out with help of a survey conducted among residents.

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