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Research paper

Evaluating the convenience and safety effects of bicycle lanes in Gdańsk

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Abstract: Bicycle lanes are lanes marked on a road and dedicated for exclusive use for cyclists.. Because they combine bike and motor traffic they provide directness and flow. However, a shared use of streets could result in bicycle-car accidents. Following up on the good practice Western countries have in planning cycle infrastructure, Gdańsk has recently introduced bike lanes on a few streets. The aim of the research was to assess the attractiveness and safety of bike lanes as a relatively new and rare solution in Gdansk. The attractiveness was assessed using the multi-criteria method. The data for the assessment came from surveys and fieldwork (inventory, observation of cyclist behaviour, traffic counts). Additionally, safety information was supplemented with police statistics on collisions and accidents. The results show that the level of bike lane usage is rather high (more than 70%). However, 80% of the respondents do not find them as attractive as separated bike paths. The advantages indicated by bike lane users included speed, surface quality, and comfort. Those who avoiding bike lanes have pointed to insufficient sense of safety. The main problems were identified such as speed and volume of motor traffic, width of bicycle lane, surface quality and parking places located next to bike lanes. The conclusions from the research are consistent with the literature. The findings could improve the attractiveness and safety of bike lanes in Gdańsk if implemented by bike infrastructure planners and designers.

Keywords: bike lanes, road safety, attractiveness assessment

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1. Introduction

The decision to use a bicycle and choose a specific route is influenced mainly by criteria of safety, directness, comfort, cohesion and attractiveness [1].

Directness means minimising detours and delay. Comfort can be achieved by minimising delay, ensuring high design speed, reducing the stress of cycling and minimising gradients and differences in elevation. Cohesion means the percentage of origins and destinations that are accessible via a cycling sub-system. An attractive cycling system should be easy to understand, safe for the public, well connected with urban functions and meet the needs of users. Safety is determined by a minimal number of collision points with cars and pedestrians and a uniform speed. Safety may be improved by segregating cycles from motorised traffic. This takes up a lot of space and may lead to real hazards such as side crashes at intersections. In addition, where cyclists use separate cycle roads, once at an intersection they will follow pedestrian traffic lights. This usually makes travel longer on that section and has a negative effect on the perception of comfort, making the bicycle less attractive as a means of transport. To make cycling a more obstacle-free experience cycling should be integrated with cars and cyclists should follow traffic light cycles for motorised traffic.

1.1. State of the art

There are significant differences between how countries and cities view cycling, how they organise cycle traffic and plan and deliver cycling infrastructure. The literature was reviewed to find information about the experience of other countries and cities in the area of cycle lanes and how they are assessed for their practicality. The question was also whether cycle lanes are safe in the first place.

In the US the following are the design options: shared lanes, marked shared lanes, paved shoulders, bike lanes, bicycle boulevards and shared use paths [2]. According to AASHTO, a national agency recommending the technical standards of road and cycling infrastructure for all states [2], cycle lanes can only be used on main roads, collector roads and busy urban roads with lower speeds. The general consideration for motor vehicle design speed is more than 40 km/h. Cycle lanes should not be designed next to perpendicular or angle parking spaces. If that is the case, parking spaces should be long enough for the parking vehicles to not go beyond the designated area. Cycle lane width should be bigger than minimal width where parallel parking is considered because of the risk of hitting a cyclist with the door. An additional safety and intersection conflict analysis is also required.

Australian's Queensland allows cycle lanes only for speed limits below 50 km/h, and recommends them for speeds below 40 km/h [3]. In Canada, Ontario's recommended cycle lanes, both separate and shared with cars, are to be used depending on the road's 85th percentile of speed, daily traffic volume and type of surroundings (rural, suburban, urban) [4]. Some European countries are just as restrictive in recommending cycle lanes. The UK, as an example, looks at the 85th percentile and traffic volume [5]. The differences between the US and Europe can also be seen in cycle lane technical guidelines. Dutch law does not state how wide a bicycle path should be. But even though there are no legal requirements there are some very

strong recommendations where 1.5 m is a minimum width. The American guide states that the desirable width would be 1.8m. The latter suggests that the minimum width of the lane can be even 0.91 m [6, 7]. A number of articles cover cyclist safety in relation to the type of cycle infrastructure. The literature describes a variety of study methods such as analysis of video footage from cycle lane cameras [8], analysis of footage from devices that record images and parameters of cyclist movements [9], surveys of cyclist behaviour and preferences [10], computer visualisations [11] and measurements and observations. Analyses into the safety of cycle lanes produce conclusions that differ from country to country and are not clear-cut. A comparison of cycle lanes and lanes shared by cycles and cars in Canada [12] shows that if well marked and separated, cycle lanes can reduce cyclist injuries by 30% to 90% compared to shared lanes. In addition, this increases pedestrian safety by as much as 50%. Cycle lanes that are too narrow, however, and where traffic exceeds 14,000 vehicles daily, may cause cyclists to behave dangerously [9].

Irish research [10] showed that cyclists are keen to choose direct routes that offer the shortest time to go from origin to destination. They are least keen, however, to use the road, whether on dedicated cycle lanes, bus lanes or car lanes and prefer to ride routes away from the road. Older people prefer to use routes that are separated from cars and pedestrians [11]. A study in New York [13] looked at the effects of separating cycle lanes from cars by introducing parking space and bollards. It was found that cyclist safety improved and injuries dropped by 20–58%. O. Madsen and H. Lahrmann compared five possible cycle routes across signalised intersections to study the number of potential conflicts [8]. It was found that the safest solution for cyclists across such intersections was to use a dedicated cycle path combining cyclist and pedestrian traffic. Dedicated lanes whether shared or with right turns or lanes with a different surface and separated by a low kerb are less safe. Drivers parking on cycle lanes is a separate problem affecting cyclist safety and is frequently covered in the press, e.g. “Rochester has a bike lane problem” [14]. The article presents cycle lane examples, studies and their results to contribute to the discussion about the practicality of cycle lanes, how they are assessed by cyclists and their safety. Case study – the City of Gdansk. Gdansk tends to be one of the most cycle-friendly city in Poland. The authorities aspire to have the bicycle recognised as a mode of transport. Having signed the “Brussels Charter”, the city made a commitment to reach a 15% share of cycling in all trips by 2020. One way to achieve this is to build cycling infrastructure, a policy the city has been delivering for a number of years. One of Poland’s best cycling infrastructures was built in several stages: 1991–2001, 2002–2005 and 2007–2013, as part of Gdansk Cycling Projects. They were the result of cooperation between City Hall and non-governmental organisations [15]. The total cycle road network is 690.8 km long and consists of 121.1 km of dedicated cycle roads, 499.4 km of 30 km/h roads with traffic calming measures. This number includes 51.8 km of contra-flow one way streets and 7.7 km of cycle lanes and 0.7 km of bus and cycle lanes. The other sections comprise pavements where cycling is allowed and shared pedestrian and car roads [16]. Striving to increase the flow of bicycle traffic and increase the attractiveness of the bicycle as a means of transport, as well as the limited space for building separate cycle roads encouraged the authorities of the city of Gdansk to increase the integration of bicycles and vehicles traffic. Under the Mayor of Gdansk’s Regulation [17] the cycle infrastructure design choice should depend on the particular road’s design speed. In

the "System of Cycle Routes for Gdansk" [18] a reference is made to a German study "Cycling Expertise from Germany I-1/2010". It says that new cycle infrastructure should integrate cycling and cars indirectly on cycle lanes for speeds up to 50 km/h. Integration is also to be achieved on roads with traffic calming and a 30 km/h speed and cyclist facilities. The guidelines for choosing a specific type of cycling infrastructure are related to design speed and traffic volume without considering real vehicle speeds or user preferences. There are no studies of Gdansk's cycling infrastructure safety or user satisfaction for the different types of infrastructure. The article is exploring this.

1.2. Goal and scope of the study

The aim of the research was to assess the attractiveness and safety of bike lanes as a relatively new and rare element of Gdansk's infrastructure. The assessment is based on an inventory of existing infrastructure, traffic counts and observations of cyclist behaviour on selected sections. A survey was also conducted with questions about the behaviour and preferences of cycle lane users. The study methods aimed to help answer the following research questions:

1. Are cyclists in Gdansk familiar with cycle lanes?
2. How keen are cyclists to use cycle lanes?
3. What are the advantages and disadvantages of integrating cycling and driving as perceived by the users?
4. What are the criteria that respondents value in assessing the safety and comfort of cycling infrastructure?

The article represents the stages of the research and is organised as follows:

Section 1 presents the experience of cities and towns whose knowledge of cycle lane design and use is greater than that of Poland. The focus is mainly on why cycle lanes are the preferred choice and the technical parameters they should meet.

Section 2 describes research methods such as surveys, fieldwork, statistical analysis and multi-criteria assessment. The section also explains the test site.

Section 3 gives the results of the analysis, surveys and fieldwork grouped into areas related to cyclist sense of safety, cyclist behaviour and preferences and factors that influence cyclist behaviour. In the final part of the section an assessment is made of the sections under analysis and measures for their safety and attractiveness using the multi-criteria analysis method.

Section 4 summarises the study and the answers to the research questions stated in the introduction. The conclusions are discussed in reference to the conclusions of the literature analysis. Finally, recommendations are given of how to assess whether cycle lanes are fit for purpose in a given location.

2. Methods

Selected cycle lanes in Gdansk were assessed for their safety using SEWIK accident data (Accident and Collision Database) [19] over a period of when cycling infrastructure first became available until the end of 2017. The analysis looked at whole sections of selected cycle lanes

with emphasis on intersections. Accident data were analysed and summed up and referred to accident sites (pedestrian crossing, cycle crossing, cycle lane). The attractiveness of cycle lanes was assessed using the multi-criteria method. Thirteen criteria were applied: quality of surface, lane width, condition, facilities at intersections, visibility of cycle lane, flow of cycle traffic versus car and pedestrian traffic, separate cyclist signalisation, slope, presence of car parks along the lane, real vehicle speed, volume of motorised traffic, presence of heavy vehicles and degree of lane usage by cyclists. The criteria were scored on a scale of 0 to 2 meaning negative, acceptable and positive. The criteria were also assigned weights. The results, i.e. weighted average, helped to identify three classes of cycle lane assessment: for the range from 0 to 33.3 the infrastructure is considered unattractive, from 33.4 to 66.3 – medium attractiveness and from 66.4 to 100 very attractive. The data for the assessment came from surveys and fieldwork (inventory, observation of cyclist behaviour, traffic counts). The survey was conducted on a sample of eighty eight people using Facebook. The survey was anonymous and dedicated to people who cycle and are familiar with cycle lanes. The survey results presented in the article should be seen as a pilot test because there were few respondents and they all use the same application which suggests that young people may be overrepresented in relation to older people. The questionnaire consisted of 13 main questions and 6 specific questions all of which were closed and were single or multiple choice questions. The surveys were collected from 5 August 2018 to 8 August 2018.

Fieldwork included making an inventory of cycle lanes (such as type and condition of surface, width, type of separator, degree of maintenance, horizontal and vertical markings, traffic layout at intersections, continuity at intersections), observation of cyclist behaviour and cyclist counts on cycle lanes and on alternative routes. Intersection observations were designed to establish whether cyclists are clear about their situation and whether the current condition of cycling infrastructure allows cyclists to feel comfortable using it. Traffic counts on the lanes and on parallel alternative lanes were one of the criteria for assessing the attractiveness of cycling infrastructure.

Test site

Gdansk's first cycle lanes were introduced in 2010 along the streets of Rajska and Podmłyńska. Today, Gdansk has five sections of cycle lanes at the total of 7.7 km:

(1) along the streets of Rajska–Podmłyńska,

(2) along the streets of Gronostajowa – Myśliwska,

(3) along the streets of Wita Stwosza – Aleja Wojska Polskiego,

(4) along the avenue of Jana Pawła II,

(5) along the street of ul. Jana Kilińskiego.

In addition some of the major intersections such as Hucisko and Podwale Grodzkie – Błędnik have cycle lanes that link into other cycle routes. The safety and attractiveness of Gdansk's cycle lanes was studied on sections where traffic is the busiest: avenue of Jana Pawła II (Fig. 1a), the streets of Rajska–Podmłyńska (Fig. 1b).

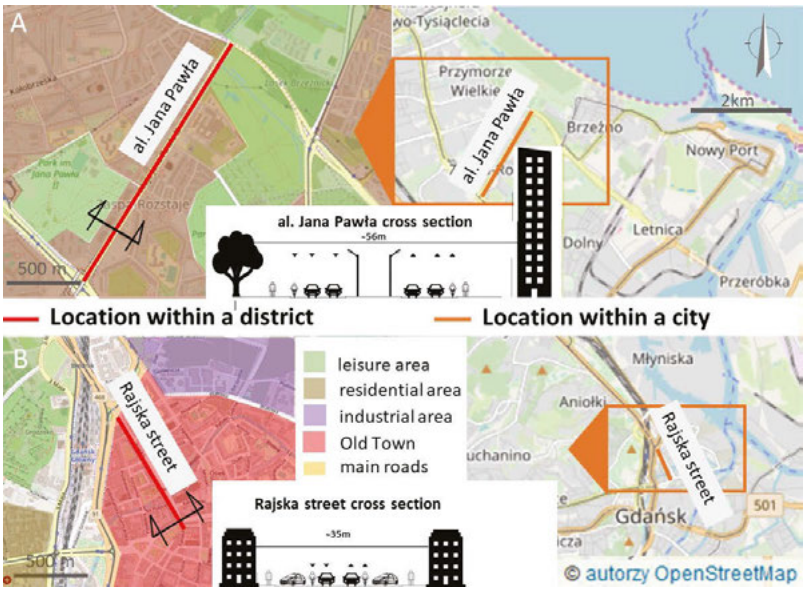

Fig. 1. Location of Gdansk's cycle lanes (www.gdansk.pl, google.com) and street cross-section of analysed roads (streetmix.com)

3. Results

3.1. Results of the stock taking

Rajska–Podmłyńska

The cycle lanes in the streets of Rajska–Podmłyńska were completed in 2011. Located on both sides of the road, they are 550 m long, 150 cm wide and are separated from the road with a white broken line. The road is in poor condition (surface defects, cracks, uneven surfaces), horizontal markings are faded and invisible (Fig. 2b, 2c). The weight restriction in Rajska street applies to vehicles above 8 tonnes. Traffic volume is about 9,000 vehicles/24 h.The street is situated in the historic Główne Miasto and carries a speed limit of 30 km/h. To ensure compliance, additional traffic calming measures are used: narrower road cross-sections and a raised pedestrian crossing near the Madison Shopping Centre. Peak-hour congestion also helps to reduce speeds. From the east Rajska links into three streets: Gnilna, J. Heweliusza and Katarzynki. From the west there are two streets: J. Heweliusza and Na Piaskach (Fig. 1a). On transverse roads cycles follow the general rules of traffic. There is an advanced stop line in J. Heweliusza from the east. There is on-street parking, mostly at an angle and parallel on a short section, in Rajska street from the Podwale Grodzkie intersection to the Podwale Staromiejskie roundabout (Fig. 2a).

Rajska street includes a pedestrian strip with busy traffic, sections of narrower road and surfaces in mostly poor condition. Pedestrian crossings have lowered kerbs. The cycle lane begins at the Błędnik interchange (Figure 3a) where it links into a cycle crossing. It ends with a small roundabout at the intersection with the street Podwale Staromiejskie (Fig. 3b).

Fig. 2. Cycle lane Rajska–Podmłyńska: a) side parking b) uneven surface c) cracked surface

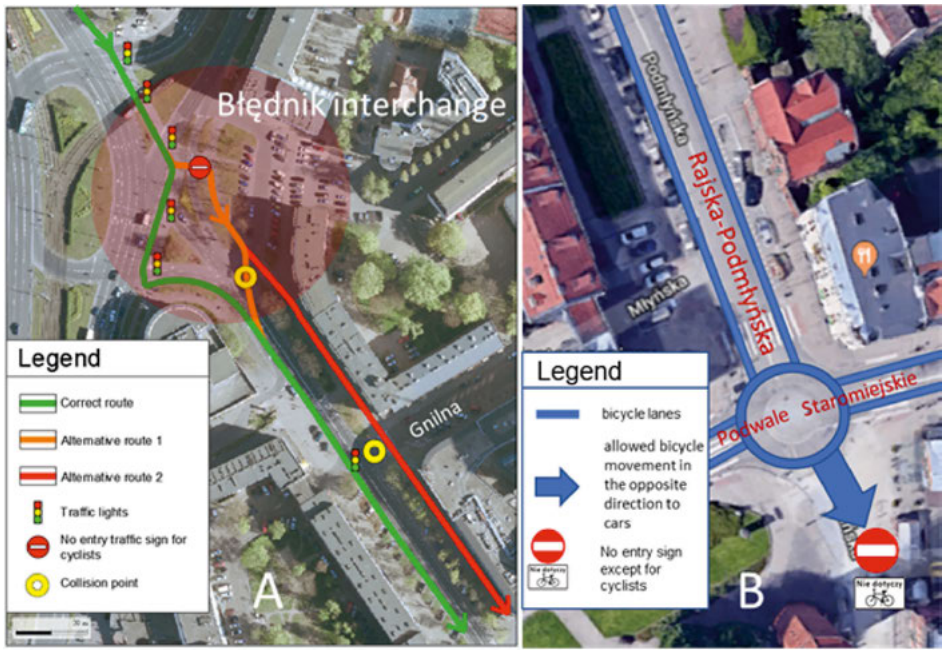

Fig. 3. Cycle lane Rajska–Podmłyńska: a) routes chosen by cyclists when entering the cycle lane at the Błędnik flyover b) expected way of cycling at the end of the street towards the Old Town

Jana Pawła II avenue

The cycle lanes in Jana Pawła II street were completed in 2016. Located on both sides of the road, the lanes are 1500 m long and 150 cm wide. Except for intersections, car parks and bus bays, the cycle lanes are separated from the road with a thick white and solid line which means that going across it is not allowed. Advanced stop lines and intersection crossings

are additionally marked in red (Fig. 4c). Each intersection is preceded with a sign to inform left-turning cyclists how they should do it.

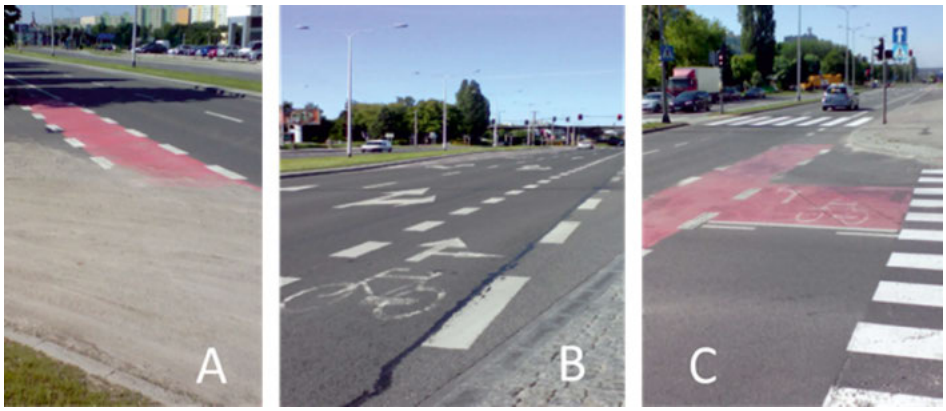

Fig. 4. Cycle lane in Jana Pawła II: a) pools of sand b) horizontal markings far away from one another c) advanced stop line and cycle crossing marked in red

The horizontal marking on the lanes is in good condition and fairly spaced (Fig. 4b). While the surface is in very good technical condition, there are periodical problems with cleanliness as a result of sand deposits (Fig. 4b).

Jana Pawła II avenue is situated in a residential area which has a speed limit of 50 km/h. Because the road is wide and there are no means of traffic calming, the 85th percentile of speed is more than 61 km/h. The road's wide cross-section with two lanes in each direction encourages higher speeds. The traffic volume is about 20,000 vehicles/24h.

Cycle lanes begin at the intersection of Jana Pawła, Dywizjonu 303 and Startowa streets and are a continuation of separated cycle roads. They terminate at the Czarny Dwór intersection where it is up to the cyclist how they will continue cycling. The choice is between general traffic rules, a cycle road or pavement, depending on what direction they are going.

Along Jana Pawła there are a number of points for merging with other traffic, including one grade-separated intersection with the city's main artery of Rzeczypospolitej, two full signalised intersections with collector streets of Meissnera and Leszczyńskich, one one-sided intersection with a collector street of Powstańców Wielkopolskich and about a dozen local streets and entries from the residential area and car parks.

There are parking spaces on parallel streets, separated from the cycle lane by a green belt and pavement with very few parallel parking spaces.

When the cycle lane was completed, the original cycle road along the street was closed. Cyclists can use the pavement but pedestrians have priority.

3.2. Safety – analysis of accident data and results of observations

Fourteen incidents were recorded in the SEWIK database (Table 1) between 2010–2017 in the Rajska – Podmłyńska section. The majority happened on the intersection. With no details of

the accidents known, it is not clear whether the accidents took place at the pedestrian crossing or cycle lane. The road section with the highest number of accidents [8] has a curve and a car park exit (Fig. 3). Four accidents were recorded at car parks that run at an angle to the road edge (Figure 3). A stationary vehicle was hit which was probably a parked car.

In Jana Pawła II from July 2016 until the end of 2017 one accident was recorded in SEWIK (Table 1).

Table 1. Collisions in Rajska–Podmłyńska and al. Jana Pawła

Intersection / street	Number of incidents	Type of incident
Rajska–Podmłyńska (from June 2010 till the end of 2017)		
Gnilna	4	side crash of vehicles ×4
Rajska	8	side crash of vehicles ×7, hitting a stationary vehicle
Podwale Grodzkie	1	side crash of vehicles
Katarzynki	1	side crash of vehicles
Podwale Staromiejskie	1	side crash of vehicles
al. Jana Pawła (from July 2016 till the end of 2017)		
Jelitkowski Dwór	1	side crash of vehicles

Police data are complemented with observations of cyclist behaviour. This is to get a better understanding of why certain sites carry or may carry a higher risk.

Three high-risk sites were identified in Rajska street. Cyclists using the orange path (Figure 3) are at risk of crashing into cars leaving the parking space and using Rajska street. Such manoeuvres require cyclists to watch for vehicles coming from three directions of which one is from behind the cyclist. The second dangerous site is the Rajska – Gnilna intersection (Figure 3). The majority of cyclists riding on the pavement use the pedestrian crossing to cross the street which is illegal. With parallel parking on both sides of Gnilna street, drivers have limited visibility of cyclists approaching the crossing. Statistics shows that the next high-risk site includes sections of the cycle lane running along angle parking spaces. Drivers leaving the parking space cannot see cyclists using the cycle lane. In addition, turnover at city centre car parks tends to be high.

In the Jana Pawła II area there was one collision within 1.5 year in Jelitkowski Dwór street. There are parallel parking spaces not far from the Jelitkowski Dwór intersection. Because the demand for parking exceeds the supply, drivers break the rules and park at an angle. As a consequence, cars occupy parts of the cycle lane and limit visibility when leaving the parking space. Another potential risk was identified on the street – there are sand deposits on both intersections causing the risk of skidding and loss of balance.

Perception of safety – as assessed by cyclists, survey results

The level of safety is a normalised quantitative measure which uses incident statistics calculated over time, road length or number of cyclists. The perception of safety, however, is something users assess and may differ from the safety levels expressed with numbers. The

perception of safety was assessed from the survey. When asked where people feel safer on a straight section, 69% of respondents picked cycle road and only 14% said it was on a cycle lane. Others marked "difficult to say / it depends". Among respondents who used a cycle lane running along parking spaces, 75% confirmed they did not feel at ease. Among 45 respondents who would choose the pavement given the choice of pavement and cycle lane, 16% explained that they felt safer on the pavement as opposed to the cycle lane. At the same time among 43 respondents who would choose a cycle lane over a pavement on a straight section, 42% said they would feel safer on a cycle lane.

3.3. Cyclist behaviour – survey and fieldwork results

To understand how cyclists use cycle lanes, surveys and fieldwork were used (measurements and observations).

Survey results

Surveys were filled out by cyclists. There were questions about respondent profile, their cycling activity (57% of respondents cycle daily or almost daily, 34% cycle often) and experience of using cycle lanes (84% near where they live or when they travel, 64% use cycle lanes daily or often, 2% do not use cycle lanes and 11% use them sporadically but try to avoid them and others use cycle lanes rarely). The questions were about all of Gdansk's cycle lanes.

The answers suggest that the most frequently used lane is in Jan Pawła II street with more than half of the respondents using it (53%). The lane along Rajska–Podmłyńska streets is also very popular with 40% of respondents using it.

There were questions designed to understand cyclist behaviour. One asked whether cyclists use cycle lanes if available. A clear majority, 72% said yes, 8% said no and 20% said "it depends". The propensity to use cycle lanes if alternative routes are available (cycle road, pavement) was studied separately for intersections and straight sections.

When asked about whether, given the choice, they would choose a cycle lane over a pavement on a straight road section, a clear majority of respondents (55 answers, $n = 88$) said they would choose a cycle lane; nine people, however, said additional conditions would be required. Eight people chose the pavement, of which four expected additional conditions. Apart from that 25 of respondents ticked "conditions" without specifying the type of infrastructure they would be using. This means that 57% of respondents were clear about the infrastructure they would choose and 43% made their choice of infrastructure dependent on traffic and pavement conditions or on cycle lane condition, which was rarer.

At intersections which have a cycle lane and cycle road the majority of respondents chose the cycle road. The next most frequent answer was "depends on where I will feel more comfortable at a particular intersection (due to traffic volumes and cycle lane visibility)" which means that 23% of respondents base their choice on safety. 17% of cyclists would choose a cycle lane or simply whatever is faster.

When both a cycle lane and pavement are available, a clear majority choose the cycle lane irrespective of how fast they can cross the intersection. A similar number of respondents also said they would choose a specific type of infrastructure depending on how comfortable or safe they will feel.

Fieldwork results

Observations were carried out on sections between intersections and at intersections. Cyclist behaviour observations and cycle traffic counts at the Rajska-Heweliusza intersection (Fig. 5, Table 2) showed that: the cycle lane is used by most cyclists coming from the Błędnik flyover towards Podwale Staromiejskie street (93% in the morning and 88% in the afternoon) and those going towards Błędnik (77% in the morning and 87% in the afternoon), the pavement at the Madison Shopping Centre is used sporadically by cyclists coming from the Błędnik flyover towards the Old Town (4% in the morning, 3% in the afternoon) and it is used more often by cyclists going towards Błędnik (22% in the morning, 13% in the afternoon), the pavement across from the Madison Shopping Centre is rarely used by cyclists coming from the Błędnik flyover towards the Old Town (3% in the morning, 9% in the afternoon) and is not used at all by cyclists going towards the Błędnik flyover.

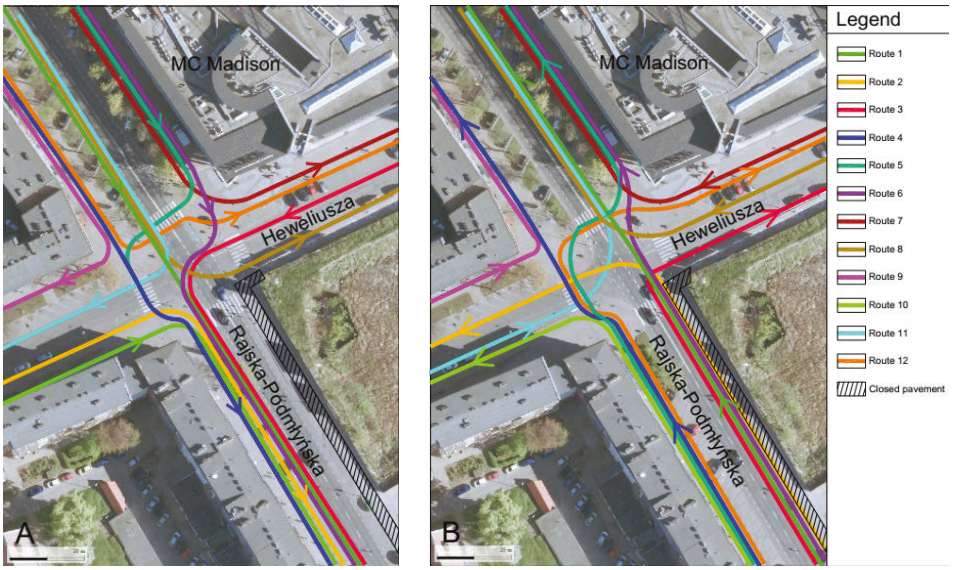

Fig. 5. Cyclist routes: a) towards the Old Town, b) towards the Błędnik flyover

By riding on the pavement along the Madison Shopping centre in the direction of Podwale Staromiejskie street, cyclists can bypass 2 of 5 traffic lights which they would encounter going from the Błędnik flyover to Rajska street and using cycle crossings at the Rajska and Podwale Grodzkie intersection (Fig. 3, green line). Cyclists have to stop at least four times at traffic lights. To avoid the time loss, cyclists use the no-entry cycle crossing (Fig. 3, orange line) which is dedicated for cyclists coming out of Rajska street. They then use the next pedestrian crossing to go to the cycle road and avoid two stops as a result. The third option (red line) continues out of the orange route on the pavement to the Gnilna intersection or further on to the Jana Heweliusza intersection. As a result, the total of three traffic lights can be bypassed.

In total both directions are used by a similar number of cyclists which suggests that the route is mainly used by commuters for their daily trips by bicycle to destinations in Główne Miasto. It was also assumed that cyclists who use the bicycle as a means of transport are experienced

Table 2. Number of cyclists coming from the direction of the Błędnik flyover

	towards the Old Town			towards the Błędnik flyover		
	Morning	Afternoon	**Sum**	Morning	Afternoon	**Sum**
Route 1	120	68	**188**	**65**	**137**	**238**
Route 2	6	8	14	3	9	12
Route 3	1	6	7	6	6	12
Route 4	4	7	11	2	4	6
Route 5	6	2	8	5	3	8
Route 6	31	29	60	10	15	25
Route 7	15	13	28	5	8	13
Route 8	4	1	5	6	20	26
Route 9	2	2	4	0	1	1
Route 10	1	67		2	7	9
Route 11	3	1	4	0	3	3
Route 12	1	1	2	1	1	2
Route 13	0	2	2	–	–	–
SUM	**194**	**146**	**340**	**105**	**250**	**355**

riders. The pavement at the Madison Shopping Centre was a frequent choice by cyclists coming from the Błędnik flyover and taking a left turn into Heweliusza street. This made the turning manoeuvre easier and eliminated the need for cyclists to intersect with drivers.

Observations of cyclist behaviour at the Błędnik intersection were compared against the SEWIK data. The results show that those using alternative cycling infrastructure rather than the dedicated infrastructure can be more at risk of a collision or accident. (Fig. 3).

The research and observations in Jana Pawła II street shows that many cyclists continue to use the pavement. The cycle lane was used by less than 40% of cyclists (Fig. 6, Table 3). Cycle

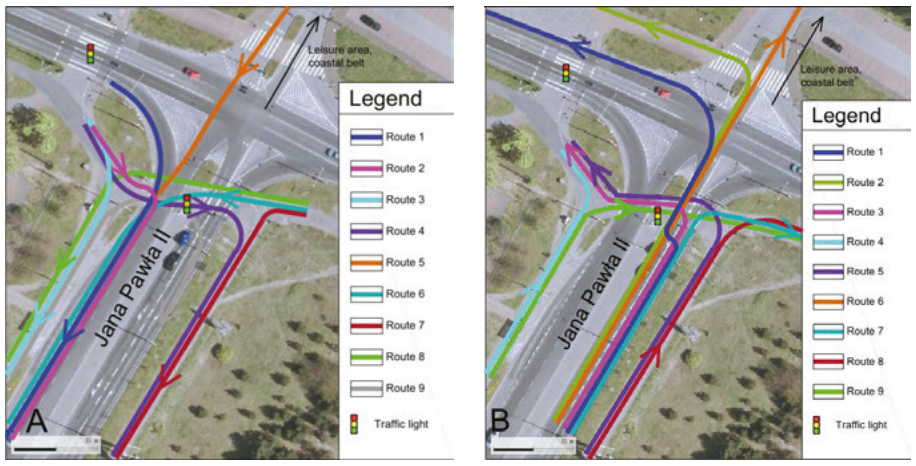

Fig. 6. Cyclist routes a) entry into Jana Pawła, b) exit from Jana Pawła

traffic in both directions was not symmetrical (Table 3). There were 29% more cyclists entering Jana Pawła II street from the direction of the leisure grounds than exiting the street. There were more cyclists in the afternoon, possibly the result of tourist traffic or people coming back from the seaside routes.

Table 3. Number of cyclists coming from the direction of Jana Pawła street

	entry into Jana Pawła street			exit from Jana Pawła street		
	Morning	Afternoon	**Sum**	Morning	Afternoon	**Sum**
Route 1	13	79	92	**0**	**1**	**1**
Route 2	10	40	50	1	1	2
Route 3	16	57	73	26	41	67
Route 4	11	25	36	28	46	74
Route 5	7	1	8	17	18	35
Route 6	5	10	15	8	9	17
Route 7	9	8	17	11	7	18
Route 8	8	9	17	5	6	11
Route 9	0	3	3	9	7	16
SUM	**79**	**232**	**311**	**105**	**136**	**241**

Cyclist preferences

The survey was the main tool for understanding cyclist preferences. Respondents were asked to assign weights to the factors that help them assess cycle routes. Each of the 11 criteria could be assessed on a scale of 1 to 5, where 5 means a very significant factor and 1 is the last important factor. The answers make it clear that cyclists primarily appreciate:

- continuity of cycle routes – i.e. infrastructure as a whole rather than a system of many unconnected sections;
- flow of traffic – i.e. as few stops for traffic lights as possible;
- directness – i.e. the infrastructure is maximally close to trip generators and destinations.

The survey asked cyclists what makes them choose a cycle lane or not. There were general objections to cycle lanes voiced by 36% of respondents who named poor safety (46%), lack of clear information about left-turns (34%) and longer time to ride on a cycle lane (20%) as the main reasons. 84% of respondents identified the general features of cycle lanes that made them use the lanes. The answers show that cyclists who use cycle lanes appreciate the good surface (29%), speed of cycling (28%) and separation from pedestrians (27%).

The next group of questions focussed on how respondents compared the cycle lane with pavement at an intersection or on a straight section.

As regards straight sections, of 45 people who did not want to use a cycle lane and preferred the pavement for their route, 28 identified heavy vehicle traffic and high car volumes. The next choices for cyclists were “I feel safer on a pavement” (16 answers), “poor condition of cycle

lane surface" (14 answers) and "poor visibility of cycle lane" (13 answers). Parking facilities along streets (picked by 6 respondents) and the weather (1 answer) were the least relevant.

For 43 people who opted for a cycle lane on a straight section, the main advantages of cycle lanes included; going faster (50 answers) and better comfort compared to the pavement (39). The third most frequent answer was "the pavement is too narrow or crowded" (41 answers) which may suggest that they were hoping to use the pavement but did not because the pavement was less attractive than the cycle lane. In addition 42% of all respondents feel safer on a cycle lane than on a pavement.

Cycle lanes at intersections are more often chosen (56%) than pavements and pedestrian crossings (18%). 24% of respondents relate their decisions to how comfortable they subjectively feel in each individual case.

The answers to questions about reasons for their choice suggest that cyclists do not use cycle lanes at intersections because of the traffic (29 answers) and heavy vehicles (23 answers). This affects user comfort and sense of safety. 49 people said they prefer to use a cycle lane at intersections stating comfort (48 answers), speed (38 answers), dedicated cycling infrastructure (41 answers) as the reasons why.

In addition, the review of selected sections showed that cycle lanes may lose some of their attractiveness because they are too narrow making overtaking more difficult. As a result, respondents were asked whether cycle lanes should be wider. 64% said yes, 20% said no and 16% did not have an opinion.

Assessment of cycle lane attractiveness

Selected cycle lanes were assessed for their attractiveness and safety. The criteria drew on the results of field observations and surveys. Weights were assigned to the individual criteria as the weighted average of scores. Criteria which were not on the survey's ranking list were assigned their respective weights based on article (20). The criteria were scored on a scale of 0 to 2 meaning: a negative, acceptable and positive effect on the assessment of cycle lane comfort and attractiveness. Cycle lane assessment for a specific criterion is the product of weights and the score. The maximum summary score of a cycle lane is 100 points. Three classes of the final cycle lane score were defined: scores ranging from 0 to 33.3 – the infrastructure is considered unattractive, from 33.4 to 66.3 – medium attractive, from 66.4 to 100 – attractive. Table 4 shows the scores and results.

Based on the criteria both cycle lanes can be considered to have medium attractiveness. Completed three years ago, the cycle lane in Jana Pawła street received more points than the Rajska–Podmłyńska cycle lane that has been in operation for nine years.

The cycle lane in Jana Pawła street has good signage (vertical and horizontal markings, additional colour markings at intersections) with intersections equipped with cyclist facilities (advanced stop lines, cyclist signalisation) to help with a safe transition across the intersection and safe left turns. There are also alternative solutions such as cyclist crossings. The final assessment of the cycle lane is negatively affected by the heavy traffic and high real speeds of vehicles.

Rajska street real speeds are much lower. In this case the cycle lane assessment is lower due to the quality of the infrastructure. The lane is only made up of two white lines along the road edge. The road surface is in poor technical condition (uneven surface, cracks, potholes).

Table 4. Attractiveness score of selected cycle lanes

Criterion		Al. Jana Pawła II		ul. Rajska–Podmłyńska	
	weights	points	score	points	score
Quality of surface	4.1	2	8.2	0	0
Width of cycle lane	3.6	1	3.6	1	3.6
Dirt	4.1	1	4.1	0	0
Intersection facilities	3.8	2	7.6	0	0
Cycle lane visibility	3.4	2	6.8	1	3.4
Flow of cycle traffic compared to cars and pedestrians	4.2	2	8.4	2	8.4
Separate traffic lights	3.3	1	3.3	0	0
Slope	3.2	2	6.4	2	6.4
Presence of parking along the lane	3.5	1	3.5	0	0
Speed of cars	3.8	1	3.8	2	7.6
Traffic volume	4	0	0	1	4
Presence of heavy vehicles	4	0	0	2	8
Is the cycle lane used by cyclists	5	1	5	2	10
SUM OF POINTS (max. 100)			60.7		51.4

As a result, cyclists have to concentrate overly on the infrastructure rather than on traffic. In addition, there is angle parking along the street with a strong turnover rate. As vehicles back out of the spaces, visibility of the cycle lane is insufficient causing a risk of collision and cyclist uncertainty. In addition, there are no cycle facilities at the intersections. With nothing to suggest how to turn left from the right lane, cyclists are more inclined to use the pavement which is wide enough from the Podwale Grodzkie intersection to the Jana Heweliusza intersection and can successfully compete with the cycle lane. If used properly, the cycle routes in Rajska street would involve frequent stops at traffic lights. The exit is not marked at all and involves having to use the cycle road or pavement in the area of the pedestrian crossing.

4. Discussion and conclusions

The conclusions from the research are consistent with the literature [11, 14]. They have answered the research questions about the experience of using bicycle lanes in Gdansk and how lanes are assessed by cyclists.

Although bicycle lanes in Gdańsk are a recent development and are only available on a few streets, they are well known to cyclists (85% of cyclists are familiar with cycle lanes). 72% of respondents identified speed and surface quality as factors that encourage them to use cycle lanes. Cycling experience was not found to have any major effect on cycle lane usage.

Car drivers, however, are more likely to use cycle lanes thanks to their driving experience and knowledge of traffic rules. Site surveys confirmed that 77–93% of cyclists have used bicycle lanes. The results varied depending on type of street, time of day, cycling direction and availability of an alternative road. For instance, part of the bicycle lane on Rajska street (close to the Błędnik intersection) was less attractive than other connections because it is time-consuming. As a result, cyclists choose to use the pavement. Sense of safety was the next factor indicated by respondents as crucial. 70% of cyclists felt more secure on separated cycling paths than on bicycle lanes. The determination of the objective relation between the safety level of bicycle lanes and cycling paths requires further study. Poor safety was the reason most often mentioned (80%) by those who never used bike lanes (28% of all respondents).This problem applies to Jana Pawła street with relatively high traffic speeds and volumes. In the literature the speed limit [7] or actual operating speed V85 [8] appeared to be the essential reasons for designating bicycle lanes. In Gdańsk the choice is determined by design speed. On the Jana Pawła street the V85 speed exceeded 60 km/h, which explained the low sense of safety of cyclists. Another important safety factor [6, 7] and its separation from the car lane [16]. While Gdansk's bicycle lanes are consistent with the majority of the recommendations presented in the literature, there are some deviations. Design practice states that bicycle lanes cannot run along parking places, especially when parking is at an angle or perpendicular. Unfortunately, this rule was not followed in Gdańsk. These and other minor shortcomings result in the low user assessment of the attractiveness of the traffic lanes and may lead to conflict situations between cyclists and vehicles or pedestrians such as collisions or accidents. It is necessary to clarify Gdansk guidelines for the development of bicycle infrastructure, taking into account good practices, local conditions and user preferences.

Author contributions

The authors confirm contribution to the paper as follows: study conception and design: R. Okraszewska; data collection: K. Kijewska; analysis and interpretation of results: K. Kijewska, R. Okraszewska, J. Wachnicka; draft manuscript preparation: R. Okraszewska. J. Wachnicka, M. Mikusova. All authors reviewed the results and approved the final version of the manuscript.

References

[1] R.H. Groot, "Design manual for bicycle traffic". The Netherlands: Ede: CROW, 2007.

[2] AASHTO, "Guide for the Development of Bicycle Facilities". Washington DC: American Association of State Highway and Transportation Officials, 2012.

[3] G. Morbey, "Technical Requirements". in Data quality for decision makers, Wiesbaden: Springer Gabler, pp.47–54, 2013, DOI: 10.1007/978-3-658-01823-8_3.

[4] Ministry of Transportation of Ontario, "Ontario Traffic Manual – Book 18 – Cycling facilities". Ontario: Queen's Printer for Ontario, 2014.

[5] Department for Transport, "Cycle infrastructure desing". Local Transport Note 01/20, Great Britain: The Stationery Office, 2020.

[6] E. Kwong et al., "Lessons from The Netherlands". The Health Service Jurnal, vol.11, pp.123-143, October 2013.

[7] P. Jones et al., "International Cycling Infrastructure Best Practice Study: Report for Transport for London". London: Transport for London, 2014.

[8] T.K.O. Madsen and H. Lahrmann, "Comparison of five bicycle facility designs in signalized intersections using traffic conflict studies". Transportation Research Part F: Traffic Psychology and Behaviour, vol. 46, Part B, 2017, pp. 438-450, DOI: 10.1016/j.trf.2016.05.008.

[9] Garcia et al., "Effects of road geometry on the interaction between cyclists and 2 vehicles on two-lane rural highways". in the 5th International Symposium on Highway Geometric Design, pp. 1–17, 2000.

[10] B. Caulfield, E. Brick, and O.T. McCarthy, "Determining bicycle infrastructure preferences – A case study of Dublin". Transportation Research Part D: Transport and Environment, vol. 17, no. 5, pp. 413–417, 2012, DOI: 10.1016/j.trd.2012.04.001.

[11] J. Van Cauwenberg et al., "Older adults' environmental preferences for transportation cycling". Journal of Transport and Health, vol. 13, pp. 185-199, 2019, DOI: 10.1016/j.jth.2019.03.014.

[12] Ministry of Transport, "Safety Measures for Cyclists and Pedestrians Around Heavy Vehicles". Canada, 2018.

[13] Department of Transportation, "Chicago Streets for Cycling Plan 2020". Chicago, 2012.

[14] B. Dahlberg, "Rochester has a bike lane problem". 2019. Avaliable on line: https://www.wxxinews.org/post/rochester-has-bike-lane-problem (accessed on 13 July 2018).

[15] R. Okraszewska, K. Grzelec, and J. Kazimierz, "Developing a cycling subsystem as part of a sustainable mobility strategy: the case of Gdansk". Scientific Journal of Silesian University of Technology. Series Transport, vol. 92, pp. 87–99, 2016.

[16] "Cycling map – Rowerowy Gdansk", avaliable online: https://www.rowerowygdansk.pl/mapa-rowerowa (accessed on 09 Jun 2018).

[17] Mayor of the City of Gdańsk, "Ordinance No. 432/12 regarding the introduction of technical standards and the principles of planning, designing and organizing bicycle traffic on public and internal roads, which are under the permanent management of the Road and Greenery Board in Gdańsk", Gdańsk, 2012.

[18] Gdansk Development Office, "Bicycle route system for Gdańsk – SteR", Gdańsk, 2011.

[19] SEWIK, "Accident and Collision Records System". Police Headquarters in Poland, www.sewik.pl, (accessed on 25 July 2018).

[20] J. Cerberek and T. Podciborski, "Metoda oceny atrakcyjności sieci ścieżek rowerowych wraz z jej weryfikacją na wybranych obiektach badawczych". Logistyka, vol. 4, pp. 5323–5329, 2015.

Ocena wygody i bezpieczeństwa użytkowania pasów rowerowych w Gdańsku

Słowa kluczowe: pasy rowerowe, bezpieczeństwo ruchu drogowego, ocena efektywności

Streszczenie:

Pasy rowerowe to wyznaczone na jezdni pasy przeznaczone do wyłącznego użytku rowerzystów. Włączając ruch rowerowy w przekrój drogi zapewniają rowerzystom bezpośredniość i płynność podróży. Jednak wspólne korzystanie z jezdni przez rowerzystów i kierowców stwarza zagrożenie kolizji rower-samochód. Niemniej, wzorując się na dobrych praktykach w planowaniu infrastruktury rowerowej w krajach zachodnich, w Gdańsku wprowadzono pasy rowerowe na kilku ulicach miasta. Celem opisanych w artykule badań jest ocena atrakcyjności i bezpieczeństwa pasów rowerowych, jako rozwiązania stosunkowo nowego i ciągle jeszcze rzadko stosowanego w Gdańsku. Do oceny atrakcyjności zastosowano metodę wielokryterialną. Dane do oceny pozyskano z ankiet i badań terenowych (inwentaryzacji, obserwacji zachowań rowerzystów, pomiarów ruchu). Dodatkowo informacje dotyczące bezpieczeństwa uzupełniono o dane z policyjnego systemu ewidencji kolizji i wypadków. Uzyskane wyniki pokazują, że poziom wykorzystania pasów rowerowych w Gdańsku jest wysoki (ponad 70%). Jednak według 80% respondentów nie są one tak atrakcyjne, jak wydzielone ścieżki rowerowe. Użytkownicy pasów rowerowych najczęściej wskazywali wśród zalet prędkość, jakość nawierzchni i komfort. Osoby unikające pasów

rowerowych jako powód wskazywały niewystarczające poczucie bezpieczeństwa. Jako główne problemy identyfikowały prędkość i natężenie ruchu samochodowego, szerokość ścieżki rowerowej, jakość nawierzchni oraz miejsca parkingowe przy ścieżkach rowerowych. Wnioski z przeprowadzonych badań są spójne z tymi opisanymi w literaturze. Wnioski z badań mogą przyczynić się do poprawy atrakcyjności i bezpieczeństwa pasów rowerowych w Gdańsku, jeśli zostaną wdrożone przez planistów i projektantów infrastruktury rowerowej.

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