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Mixed-methods approach to studying multiuser perceptions of an interim Complete Streets project in Norway

Miroslav Vasilev [a,*], Ray Pritchard [b], Thomas Jonsson [a]

[a] Department of Civil and Environmental Engineering, Faculty of Engineering, NTNU—Norwegian, University of Science and Technology, 7491 Trondheim, Norway
[b] NORCE Norwegian Research Centre, 4021 Stavanger, Norway

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A B S T R A C T

Research on multiuser perceptions of street environment alterations has been gathering attention in recent years given an increased focus on both sustainable city development and public participation. This study investigated the value of applying a mixed-methods approach to investigating user perceptions of Complete Streets projects. It employed an online survey of 719 users of a case study street in Trondheim, Norway which received an interim infrastructural treatment including a road diet and a separated bicycle path. The survey presented the respondents with manipulated photographs showing the implemented interim design solution and six different potential streetscape configurations in order to explore their street design preferences. Additionally, the use of an integrated mapping application programming interface (API) allowed the participants to place markers with comments along the project map to explain where and why they had felt unsafe in relation to their use of the street before and after the implementation of the interim street modification, although both were collected in the after period. The ability of users' demographic characteristics and transport behavior to explain variations in perceptions and preferences was explored. It was confirmed that the participants favored separated bicycle path designs and that their preferences did not vary considerably among the different user types. The analysis of the distribution of the unsafe points from both time periods helped in the identification of traffic safety issues that might not have been uncovered if only stated preference methodologies were used. Additionally, it was shown that implementing such street alternations as interim projects could be beneficial for the planning process by providing the planners with insights on the way changes to the street environment would be experienced by the users.

1. Introduction

The benefits of shifting the focus in transport planning from private motor vehicles to active travel modes are well-documented and include the reduction of congestion, noise, air pollution, accidents and health issues (Rabl & de Nazelle, 2012; Rissel, 2009; Sælensminde, 2004). Transport planning authorities across the world are attempting to realize such benefits by adopting more holistic approaches which take into consideration the mobility needs and safety of all street users. For example, a growing number of jurisdictions throughout the USA and Canada have adopted a policy framework called Complete Streets (McCann, 2010). Its principles have been incorporated in numerous design standards and applied in specific street enhancement projects of the same name.

One of the techniques commonly applied as part of Complete Streets redesigns is the implementation of road diets, which involves a reduction in the number of traffic lanes and the reallocation of the freed-up space for other modes of travel. This technique has a positive effect on traffic safety of motorists (Burden & Lagerway, 1999; Huang et al., 2002; Pawlovich et al., 2006), while not having major detrimental effects on their travel times and capacity (Burden & Lagerway, 1999; Gudz et al., 2016; Provence, 2009). All of these benefits are well-documented in scientific literature, however, little is known about the effect of road diets on bicycling and walking (Gudz et al., 2016).

Planning and designing street changes that provide optimum transportation opportunities for all transport modes requires an enhanced understanding of the perceptions and needs of different types of users. As pointed out by Vallejo-Borda et al. and Pánek and Benediktsson, the methods for planning and evaluation of bicycle infrastructure such as level of service (LOS), quality of service (QoS) and level of traffic stress

* Corresponding author.
E-mail addresses: miroslav.vasilev@ntnu.no (M. Vasilev), rpri@norceresearch.no (R. Pritchard), thomas.jonsson@ntnu.no (T. Jonsson).

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(LTS) use technical parameters related to the physical environment, while failing to directly consider the subjective knowledge that could be acquired from street users (Pánek & Benediktsson, 2017; Vallejo-Borda et al., 2020). Additionally, the way users perceive their environment can depend on their characteristics and the geographical location (Vallejo-Borda et al., 2020). The emerging approaches, as alternatively called public participation GIS (PPGIS), SoftGIS and emotional mapping, allow respondents to report their perceptions and experienced issues with the help of geospatial tools. Kahila and Kyttä explored the potential of these methods for establishing a link between transport users and urban planners by giving users the opportunity to generate "localized experiential knowledge" through user-friendly, Internet-based crowdsourcing platforms (Kahila & Kyttä, 2009). In a study from Copenhagen, cyclists responded to an online survey where they drew their most recent routes and pinpointed locations of positive and negative experiences along those routes (Snizek et al., 2013). The purpose was to find relationships between the geolocated user experiences and the characteristics of the urban environment, such as the availability of bicycle facilities. In a later study cycling respondents identified points on a map of Reykjavík, Iceland and also added explanatory comments to those locations (Pánek & Benediktsson, 2017). It was found that the survey participants preferred the use of points instead of lines to indicate "negative" cycling experiences. Pánek and Benediktsson also demonstrated that the use of PPGIS tools is an adequate approach to investigate how measures, aimed at improving bicycle transport, are perceived by the users.

Bicyclists' preference for separation from motorized traffic has been well documented in the academic literature (Heinen et al., 2010; Stinson & Bhat, 2005; Taylor & Mahmassani, 1997; Wardman et al., 1997; Winters & Teschke, 2010), and it is strongly related to their perception of safety (Dill et al., 2014). However, the way users perceive their transportation environment can be influenced by factors outside of the traditionally used technical traffic characteristics such as demographics, socioeconomic and cultural factors (Wahl, 2012). Monsere et al. (2012) explored the perceptions of various users of a newly implemented cycle track and a pair of buffered bike lanes in Portland, US. They found that among cyclists, especially female, safety perception was positively affected, while motorists were more likely to associate the new infrastructure with travel delays and inconvenience. In addition, Monsere et al. distinguished between cycling and non-cycling drivers and pedestrians. For example, it was found that drivers and pedestrians who also used a bicycle, exhibited more positive attitudes towards the street changes than those who did not. Differences in cyclists' perceptions and behavior based on gender were found also in (Dill & Gliebe, 2008; Environics, 1998; Krizek et al., 2005; Tilahun et al., 2007; Twaddle et al., 2010). Additionally, user preferences have also been examined with regards to frequency of cycling (Dill & Gliebe, 2008; Hunt & Abraham, 2007). A way to examine the effect of users' characteristics on their perception of a particular infrastructural measure is to apply the experimental use of manipulated photographs of street environments. This methodology offers the opportunity to control for the co-occurrence of environmental factors and allows for the demonstration of causal relationships (Mertens et al., 2014).

The goal of this paper was to apply a multi-method approach which takes advantage of the strong sides of two different methodologies. The main research objectives were to find out:

- How do different users perceive alternative roadway configurations depicted in manipulated photographs?
- What are the benefits of complementing stated preferences for street layouts with mapping of experienced unsafe locations along an interim street design implementation?

2. Methodology

2.1. Case description

The case study is an interim road diet project implemented on Innherredsveien in Trondheim, the fourth largest urban area in Norway, with a population of 205 000 people (Statistics Norway, 2020). According to the National Travel Survey 2019, the mode split in the city was the following: car trips – 49% (of which 9% as a passenger); public transport trips – 13%; trips by foot – 27%; bicycle trips – 10%; other trips – 1% (Grue et al., 2021).

Innherredsveien is a main arterial east of the city center part of which was rebuilt to an interim Complete Streets project in July 2017. The project included a road diet intervention where the number of traffic lanes was reduced from four to two and a 1.8 km two-way bicycle path was implemented in the freed-up road space. The bicycle path was separated from the traffic lanes by using markings with diagonal cross hatching along 65 % of the project while along the rest of the project a concrete traffic barrier was used (picture A on Fig. 2). Along the northern side of the street new so-called "floating bus stops" were built (Goodyear, 2015). Their design included an elevated platform situated between the traffic lanes and the bike path. Signage prohibiting the use of the street for through-traffic was implemented at one of the intersections (Fig. 1).

2.2. Data collection

This article was based on survey data that included the users' demographics and their feedback on both the implemented facility and on proposed alternative design solutions, whilst in a previous article on the same project the focus was on route and mode choice changes (Vasilev et al., 2018). The interactive survey platform was hosted by the web-application EmotionalMaps.eu (Pánek & Benediktsson, 2017).

The survey targeted residents who had been using Innherredsveien both before and after the street changes took place and was available online between June 11 and August 14, 2018 in English and Norwegian languages. Participants were mainly recruited with the help of 5000 flyers containing a link to the survey, which were mailed to residents in the neighborhood via the local post company (to the eldest member of a given household). Another 1500 unaddressed flyers were distributed to accessible mailboxes of private houses or windshields of parked cars in the neighborhood, whilst another 500 flyers were handed out to street users (mostly cyclists and pedestrians) or left at places where students and employees usually pass through or sit around at the Gløshaugen campus of the university (NTNU). The flyers contained a photoshopped picture of the interim design project depicting solution E from Fig. 2 and a short invitation for participation announcing the opportunity to win 3000 Norwegian crones (approximately 330 USD) in the form of a voucher. The survey was also distributed via social media and the intranet of a university college located on the street of interest (Vasilev et al., 2018).

As part of the survey, respondents who had been cycling at least once per month were presented with manipulated versions of a photograph of a cross-section of the interim project on Innherredsveien depicting both the interim design solution itself and six alternative street layout solutions (Fig. 2). They were asked to rate how safe they would feel cycling on each of the possible street layouts on a scale from 1 to 10 (low to high). The design alternatives were presented simultaneously to the respondents as shown in Fig. 2. The first streetscape configuration (picture A) was acquired from Google Street View and showed the implemented interim design project (Google, 2017). It was used as a base picture from which the alternative solutions were drawn using Adobe Photoshop. In that way, the light conditions, the sky, buildings, and the motorized traffic were the same in all the pictures. The only non-design related differences between alternatives were the images of cyclists and the pedestrians (Skalgubbar, 2020) which were modified

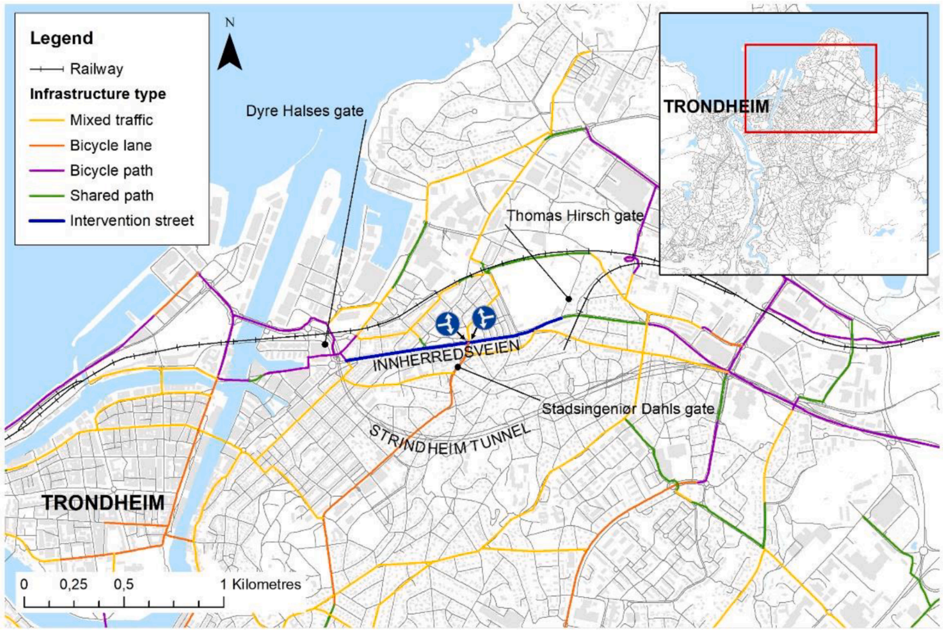

Fig. 1. Location of the interim design project in blue (Vasilev et al., 2018). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

slightly as it was assumed that they would help the respondents to imagine themselves using the depicted solutions. The alternative solutions consisted of two generic types of bicycle infrastructure - a two-way bicycle path on one side of the roadway (pictures A, B, E) and one-way bicycle lanes on each side of the roadway (pictures C, D, F, and G).

The responses to six closed-ended questions were also used in this article. These were related to comfort and safety of cyclists and pedestrians first and foremost, but also to bus passengers and car drivers. Free-text responses with feedback or suggestions about the project were also analyzed to provide context to the closed-ended question responses.

In addition to the rating task, the survey platform also contained an integrated mapping Application Programming Interface (API) which allowed the respondents to geolocate points along the project where they had felt unsafe and to add comments to these points. They could do this in relation to their use of the street both before the implementation took place, approximately one year earlier, and after that, when they had already become accustomed to the changes. It is important to highlight the fact that the data connected to the user experiences in both the before and after periods were collected after the interim street changes had been in place. This meant that the respondents had to recall their safety perceptions from a year earlier and thus the methodology was not a typical before-and-after study.

2.3. Analysis

2.3.1. Statistics

In order to understand more about the perceptions of the different types of cyclists, the subsample was broken down with regards to respondents' frequency of cycling, gender and car usage. The frequency categories were: "infrequent" use of a bicycle (1–3 times per month), "frequent" – 1–3 times per week and "very frequent" – 4 or more times per week. According to their car usage, cyclists were divided in the following way: "driving cyclists" - those using a car at least once per month and "non-driving cyclists" (using a car less than once per month).

A one-way repeated measures ANOVA was conducted to test if there was a significant difference among the mean rating scores that each facility type received. Independent-samples t-tests were performed to compare the rating scores provided by men and women and by driving and non-driving cyclists. A one-way between groups ANOVA was carried out to investigate the impact of the age and the cycling frequency of the respondents on the way they rated the different alternative design solutions. A Tukey post-hoc test was run to find out the exact groups that were significantly different from each other. In the cases where the assumption of homogeneity of variances was violated, a Welch ANOVA test was carried out and a Games-Howell test was used instead of a Tukey post-hoc test.

2.3.2. Qualitative data

The free-text responses were manually coded into different themes, such as preference for one-sided or two-sided design solutions, preference for separation, dangerous situations at intersections, etc., and then the most illustrative comments were presented alongside the other results in order to allow better insight into user perceptions.

2.3.3. Geographic information system (GIS)

The geospatial distribution of reported unsafe points along the interim design project was analyzed by grouping the points into different zones around intersections and links (street sections between junctions). The comments within each zone were categorized and subsequently used to visualize the main safety issues by providing a color-coded pie chart for each zone for pre- and post-intervention street layouts.

3. Results

3.1. Descriptive statistics

Table 1 presents the descriptive statistics for the sample of respondents (n = 719). It can be noted that more than half of the respondents were male (58%), young and employed (77%). The majority of those categorized as cyclists belonged to the group of "very frequent" cyclists (66%). It should be noted, however, that the sample did not reflect the actual distribution of street users in Trondheim as drivers were underrepresented (Vasilev et al., 2018). To reflect on this, the responses were analyzed and presented in the paper by dividing them according to the mode of the users. By doing so, it was taken care for the representativity of the views of all user groups.

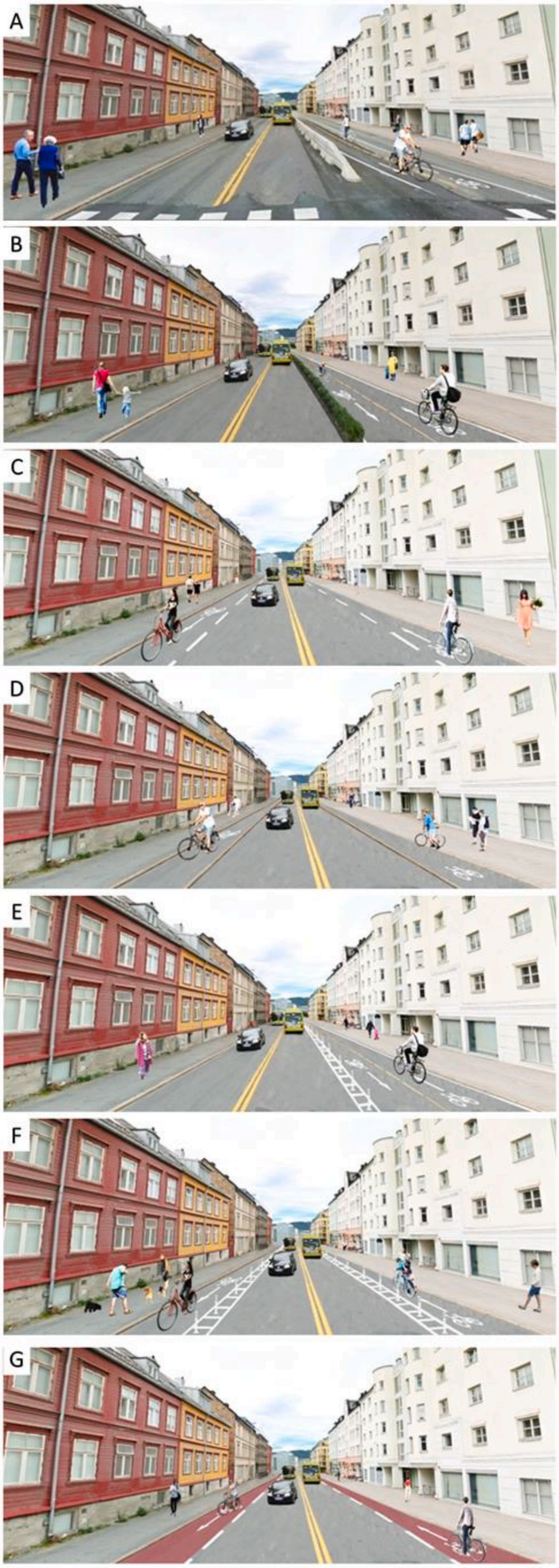

Fig. 2. Design solutions. A – A bicycle path separated with concrete blocks (the implemented solution); B – A bicycle path separated with planter boxes; C – Standard bicycle lanes; D – “Danish” curb-separated bicycle lanes; E – A bicycle path separated with bollards; F –Bicycle lanes separated with bollards; G – Bicycle lanes in red. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1
Descriptive statistics for the total survey sample.

Variable	Category	Frequency	%
Gender	Male	415	57.7
	Female	304	42.3
	Total	719	
Age	<30	242	33.7
	30–39	229	31.9
	40–54	168	23.4
	>54	79	11.0
	Total	718	
Mode	Pedestrians	647	29.8
	Bicyclists	570	26.3
	Public transport users	519	23.9
	Car drivers	434	20.0
	Total	2170*	
Frequency of cycling	Infrequent	64	11.2
	Frequent	131	23.0
	Very frequent	375	65.8
	Total	570	
Occupation	Employed	552	76.8
	Student	116	16.1
	Not occupied	50	7
	Total	718	

*The total number for mode is larger than the total number of respondents as users could select multiple mode.

3.2. Feedback on the manipulated photographs

In total, 570 respondents rated the manipulated photographs according to how safe they would feel cycling on each of the streetscape configurations on a scale from 1 to 10 (low to high). Table 2 presents the mean rating score that each solution received, together with the distribution of the scores in terms of the users’ cycling frequency and gender. The solutions were ranked in the table from least to most safe (low to high score). It was found that there was a statistically significant difference between all the mean rating scores that each facility type received ($p < .005$), except between those for solutions F and E. The distribution of the mean scores according to motor vehicle use is not displayed as no statistically significant differences were found between the ratings given by the driving ($n = 342$) and the non-driving cyclists ($n = 228$). This lack of significant difference meant that being a driver in addition to using a bicycle did not influence the perception of the different solutions.

Gender seemed to have little effect on the way the solutions were rated, except for the two most protected solutions – A and B ($p < .05$) where women’s were statistically significantly higher than men’s. None of the depicted alternative solutions received significantly different rating scores across the different age groups at the 5% confidence level. This meant that age had no significant influence on the way the respondents perceived the solutions and the respective distribution of scores was, therefore, not displayed in the table. The cyclists’ rating scores for each solution except for solution A were statistically significantly different among infrequent, frequent and very frequent cycling groups. However, it was found that frequency of cycling has not affected the order in which the designs were ranked.

3.2.1. Two-way bicycle path solutions on one side of the street

Overall, it can be noted that the visualizations that depicted solutions with a two-way bicycle path on one side of the street received a higher total rating than those showing bicycle lanes on each side of the street, although it can be argued whether this was due to the type of solution itself or due to the more solid separations that were depicted on the two-way alternatives. At the same time it has to be mentioned that bicycle lanes separated with solid barriers from the traffic lanes is not a standard solution in Norway (one of the reasons for this being that they would hinder snow removal during winter times). So in a way solid barriers which seem to be a preferred option for cyclists are more relevant in

Table 2
Rating score distribution according to cycling category.

Type of solution*	Infrequent (n = 64)	Frequent (n = 131)	Very frequent (n = 375)	Men (n = 342)	Women (n = 228)	All cyclists (n = 570)
Standard bicycle lanes (C)	3.92[b]	4.23	4.76[b]	4.58	4.50	4.55[d]
"Danish" bicycle lanes (D)	4.44[b]	5.06	5.55[b]	5.32	5.29	5.31[d]
Bicycle lanes in red (G)	4.94[c]	5.34[c]	5.99[c]	5.68	5.80	5.73[d]
Bicycle lanes separated with bollards (F)	5.67[c]	5.76[c]	6.48[c]	6.24	6.19	6.22
A bicycle path separated with bollards (E)	5.73[c]	6.08[c]	6.63[c]	6.43	6.36	6.40
A bicycle path separated with planter boxes (B)	7.41[b]	7.96	8.28[b]	7.92[a]	8.38[a]	8.11[d]
A bicycle path separated with concrete blocks (A)	8.00	8.30	8.56	8.30[a]	8.65[a]	8.44[d]

[a]An independent-samples *t*-test showed that mean score is significantly different between men and women ($p < .05$).
[b]A one-way ANOVA/Welch test showed that mean score is significantly different between cyclists' types ($p < .05$). The infrequent cyclists differed from the very frequent cyclists ($p < .05$). [c]A one-way ANOVA showed that mean score is significantly different between cyclists' types ($p < .05$). The very frequent cyclists differed from the infrequent cyclists ($p < .05$) and frequent cyclists ($p < .05$). [d]A one-way repeated measures ANOVA showed that the mean score was significantly different among the different solutions ($p < .005$).
*See illustrations of the alternative solutions in Fig. 2.

combination with two-way solutions. The implemented solution with a two-way bicycle path separated with concrete blocks (solution A) received the highest rating, which may indicate a preference amongst users for the as-built scenario rather than the alternative illustrations. Throughout the rest of this section quotes from the answers to the open-ended question were used to add context to the general findings.

One of the positive comments related to the implemented bicycle path that also pertains to two-way solutions in general is cited below:

- "The advantage of having a two-way bicycle path on one side of the street is that it is perceived as more spacious and allows for overtaking of other cyclists, taking into consideration that the speeds of normal and electric bicycles can vary." (cyclist, female, 30–40 yo)

There were also some respondents who commented on the negatives related to this type of solutions, such as: collision risk at intersections or accessibility issues due to positioning of the bicycle infrastructure on one side of the roadway.

- "Having both directions of cyclists on one side of the street creates many potentially dangerous situations. It's much simpler to ride in the roadway, fewer rules and traffic user groups to take into consideration." (cyclist, male, 20–30 yo)

With regards to the type of separation between two-way bicycle paths and traffic lanes, it can be observed that the more substantial/solid the separation was, the higher the rating score that the solution received. The three most preferred solutions A, B and E separated cyclists from traffic lanes with concrete blocks, planter boxes and bollards respectively. Many respondents expressed a desire to have a physical separation.

- "The bicycle path should be facilitated with a physical separation from the traffic lanes so that it is perceived as safe by everyone and such that dirt, slush and ploughed snow from the roadway does not end up on the bicycle path." (cyclist, male, 50–60 yo)

Some of the respondents had concerns about the aesthetics of the implemented concrete barrier separation and about the difficulty it created for them when crossing the street. Additionally, it was suggested that having a solid barrier encouraged the motorists to maintain higher speeds and that it obstructed the drivers' view of cyclists on the bicycle path.

- "I hope that the permanent solution will not include large walls between the traffic and the bicyclists such that the cars and the buses drive slower and one can cross Innherredsveien at more places." (cyclist, male, 40–50 yo)

3.2.2. Bicycle lane solutions on both sides of the street

As mentioned earlier, the bicycle lane solutions on both sides of the road received a lower total rating than the two-way bicycle path treatments, although it was uncertain whether it was due to the type of the treatment (one-sided versus two-sided) or due to the type of the separation. Some respondents commented on the positives of having bicycle lanes, particularly in relation to the traffic rules, mobility and accessibility:

- "Two-way paths like the implemented one should not be used because of the problems they create at intersections. The advantage of having bicycle lanes on each side of the roadway is that drivers have to yield to cyclists when crossing a bicycle lane on their right." (bicyclist, female, 30–40 yo)

A similar trend towards a preference for a greater separation was also found for the treatments consisting of two-sided bicycle lanes, although the "Danish" raised curb bicycle lanes received a lower score than the treatment with bicycle lanes in red. With regards to the bicycle lanes in red, some of the participants in the current study expressed their positive attitude towards them and the use of red surfacing for bicycle infrastructure in general. In some of the comments this was mentioned in relation to making the bicycle path more conspicuous, particularly at bus stops.

- "The bicycle path has to be marked in such a way that the pedestrians waiting at the bus stops are aware of the path and look around before crossing it. A bicycle path in red makes the traffic situation more understandable for everyone." (cyclist, female, 30–40 yo)

3.3. Geolocated points of user-perceived traffic risk

Table 3 below presents the total number of unsafe locations indicated by the respondents in the mapping API for each time period. The number

Table 3
User generated points and comments.

	Before	After	Total
Total number of points (including those without comments)	529	464	993
Points along the project (including those without comments)	470	374	844
Points along the project (with categorizable comments)	247	306	553

of points along the project and the number of meaningful comments that could be categorized are also included.

Fig. 3 below shows the distribution of the geolocated points indicating the locations considered to be most unsafe by the users. The pie charts summarize the most common issue categories noted by respondents for ten different zones – five at street links (2, 3, 5, 7 and 9) and five at intersections (1, 4, 6, 8 and 10). The points corresponding to each zone are indicated using alternating white and gray color. Points beyond the immediate area of Innherredsveien are not shown in Fig. 3. The overrepresentation of the cyclists versus car drivers has probably influenced the results of the mapping task. However, when it comes to perceived safety, the opinions of the vulnerable road users were considered to be of greater importance than those of the drivers as cyclists are usually the ones who get injured in an accident.

The pie charts provide information about five issue classes which resulted from the aggregation of 15 more detailed categories of user comments shown in Table 4. Only three selected zones are included in the table and only the most frequently commented issues are discussed in the following text. The zones were selected based on whether they contained relatively more issues that could be relevant in other contexts in relation to bicycle path implementation.

Overall, the change in the distribution of points between the two periods indicated a "shift" in the relative perceived unsafety from the street links to the intersections (Fig. 3). While in the before period only 40% of the points were added at intersections, in the after period this increased to 62%. The latter was on account of a general decrease in the number of places where the respondents felt unsafe along street links. The observed decrease in the number of points along street links could be due to the improved conditions for both cyclists and pedestrians after the separated bicycle path was implemented considering the fact that 65% of the cyclists had been using the sidewalk in the before period (Vasilev et al., 2018). In addition, the sidewalks that cyclists and pedestrians had to share in the before scenario along Innherredsveien are narrow, an issue which was noted in 44% and 27% of the comments related to Zones 2 and 3 respectively (Table 4). The difficult sidewalk conditions in the before period were also reflected in the percentage of comments related to interactions between cyclists and pedestrians – 15% in Zone 2 and 23% in Zone 3.

The alternative for cyclists in the before period had been to share the traffic lanes with motorized vehicles, something associated with unsafety by 15% and 18% of the respondents with regards to their experiences with using Zone 2 and 3 respectively. These findings were confirmed by responses to the closed-ended questions, where the cyclists and pedestrians were asked how safe/comfortable they felt both before and after the street changes. Table 5 provides the percentage of respondents who felt moderately or very safe/comfortable in each period. Asked if they were satisfied with the increased separation between bicyclists and other vehicles, 86% of drivers answered positively, which also confirmed the beneficial effect of the bicycle path (not shown in Table 5).

With regards to Zone 3, more survey participants have commented on issues related to interactions between bicyclists and pedestrians at bus stops in the after period (32%) compared to the before period (7%). This is probably due to the new design of three of the bus stops along the stretch which according to many of the respondents has led to conflict situations between cyclists and bus passengers. Responses to a separate question on this specific issue revealed approximately equal percentages of respondents who meant that the risk of collisions between bus passengers and cyclists had increased or decreased. This is likely because the bus stops were not optimally designed for such interactions in the

Fig. 3. Geographic aggregate category distribution of the marked unsafe points immediately adjacent to the Road Diet project. a) before b) after.

Table 4
Detailed categories of user comments.

Aggregated	Detailed	Zone 2, %		Zone 3, %		Zone 6, %	
		Before	After	Before	After	Before	After
Interactions - bikes and peds	At bus stops	0	4	7	32	0	2
	General	15	13	23	8	0	0
	At crosswalks	0	0	0	2	0	2
Interactions - bikes and cars	–	15	4	18	2	47	5
Safety - others	Interactions - bikes and bikes	0	0	1	5	0	0
	Interactions - cars and peds	15	13	3	37	13	0
Infrastructural issues	Lack of bike signal	0	0	0	0	0	18
	Narrow sidewalk	44	4	27	5	7	0
	Traffic rules	2	29	0	3	27	68
	Bike path	0	21	0	0	0	0
	Accessibility	10	4	20	2	7	2
	Place making issues	0	4	1	0	0	0
General comments	Negative - drivers	0	4	0	5	0	2
	Positive - intersections	0	0	0	0	0	0
	Positive - bike signal	0	0	0	0	0	0
Total, *n*		41	24	74	62	15	44

Table 5
Safety/comfort perception.

Users	Before	After
Cyclists	33%	94%
Pedestrians	55%	86%

before situation either in which bus passengers had to wait on the narrow sidewalk which was shared with the majority of cyclists.

- “As a cyclist one has to be alert for pedestrians who are getting on/off a bus the way the bus stops are designed now.” (cyclist, female, 55–65 yo)

Only one of the intersections along the interim design project (except for the one at Zone 1 which has been closed for cyclists with a barrier), the one at Zone 4, received fewer points in the after period (40 points) compared to the before situation (81 points). The probable reason for the improvement in the perceived safety at this intersection is the implementation of a bicycle traffic signal, something which has likely made the traffic situation more predictable than at the other intersections. The intersections in both Zones 6 and 8 received considerably more points related to the after period (Fig. 3). As shown in Table 4, 68% of the expressed concerns regarding Zone 6 were related to confusing traffic rules and 18% pointed out the lack of a bike signal. The following quote illustrates this issue:

- “The intersections along the whole street should be designed as uniformly as possible so that they are easily understandable. Traffic lights for cyclists should be used so that nobody is confused about the right of way.” (cyclist, female, 30–40 yo)

4. Discussion

This article aimed to document the user perceptions of an interim design project through multiple approaches. The discussion addresses the results from the manipulated photograph ratings, the geospatial distribution of unsafe points and the free-text responses from users.

The analysis of the manipulated photograph ratings provided a better understanding of the users’ preferences for both the implemented street configuration and for six alternative solutions. Additionally, the effect of the users’ characteristics on their preferences was explored. Users preferred a greater physical separation regarding both the solutions with bicycle lanes and those with two-way paths, which corroborates the results of earlier studies that used photographs/illustrations (McNeil et al., 2015; Sanders, 2016; von Stülpnagel & Binnig, 2022; Winters & Teschke, 2010) or other types of methodologies (Foster et al., 2015). With regards to the solution that received the highest rating score, the one using concrete blocks, it should be noted that such a separation is usually not a preferred option for permanent street designs and was only permitted because the case study was an interim project which was intended to have a high degree of reversibility. If only those solutions that could possibly be considered for implementation in a permanent redesign are to be taken into account, the most preferred design would be the bicycle path separated with planter boxes. This would have been similar to the findings by McNeil et al. (2015) where the use of planter boxes as a buffer was found to be the most preferred solution. Likewise, Mertens et al. (2016) found that a cycle path separated from the traffic lanes using a hedge was significantly more attractive for respondents than a cycle path separated from the traffic with a curb.

The standard bicycle lanes were rated lowest in the current study, which is understandable given that they do not provide any physical protection from the traffic. This finding was in alignment with the results in (Sanders, 2016) where striped bicycle lanes were found to be the least preferred amongst the investigated solutions that involved dedicated space for cyclists. McNeil et al. (2015) asked respondents to rate four alternative kinds of bicycle infrastructure and found that a striped bike lane was less desirable than bollards separating car and bicycle traffic – a finding that matches the results in this paper. Red bicycle lanes were rated higher than the curb-separated “Danish” lanes, even though that the latter offers a form for physical protection. This is probably because the bicycle lanes in red is a standard treatment in Norway, while the other solution is not. Cyclists in Trondheim and many other Norwegian cities have experience using lanes that have red surfacing and associate them with increased feeling of safety and comfort (Bjørnskau et al., 2016; Karlsen & Fyhri, 2020; Oma, 2012). At the same time the “Danish” bicycle lanes solution was available only in a handful of streetsin Trondheim (at the time of the data collection) and been listed in the Norwegian design standards more than three years after the data collection took place. McNeil et al. (2015) came to a similar conclusion regarding their finding that the solution with plastic flexposts was rated higher than two other types of facilities that the respondents were not as familiar with.

Motor vehicle use, age and gender were not found to have had a significant effect on the way the different solutions were rated by the respondents (except gender’s possible effect on the scores for solutions A and B). The statistical difference between the ratings of men and women with regards to solutions A and B can possibly be explained by the fact that these two solutions offered the greatest protection from motorized traffic and were, therefore, appreciated by the female respondents who are usually more concerned about their safety while cycling than the male ones (Dill & Gliebe, 2008; Krizek et al., 2005; Monsere et al., 2012). The lack of significant effect of motor vehicle use was partly in support of the results by Sanders (2016) who found that non-bicycling drivers, bicycling drivers and non-driving bicyclists had similar roadway design preferences to one another. In a Belgian study, Mertens et al. (2014) found no moderating effects of gender and age on the relationship between different manipulated environmental features in streetscape photographs and the invitingness of the depicted streetscapes for transportation cycling. In a similar fashion, the results of the current study indicate that the improvements to the street environment could encourage residents to cycle more, irrespective of their gender and age.

Users' cycling frequency was positively correlated with the scores given to the alternative street designs (except for solution A). Frequency of cycling, however, was not found to have affected the order in which the solutions were ranked. This corresponds to the results in (Sanders & Judelman, 2018) where cyclists' preference for more separation from the traffic was not found to depend on their frequency of cycling.

Given that the respondents were asked about a street that they had used and that one of the solutions they rated was actually implemented along the project had provided them with the opportunity to pay attention to the negatives connected to this type of separation and to one-sided solutions in general. According to McNeil et al. (2015), reported experiences with actual infrastructure ensure a better understanding of the way cyclists would perceive a given type of facility. They found that reported comfort scores by cyclists in the actual facilities they were intercepted in were substantially lower than the scores they gave to hypothetical solutions with similar type of separation (McNeil et al., 2015). One of the potential explanations provided in that paper was that the use of real-life infrastructure involves not only street links but also elements such as intersections that could often present additional challenges to the comfort of riders. It was also suggested that the real-life traffic volume and speed of motorized vehicles could be different from what the respondents perceive when looking at a photograph of such conditions. The methodology in the current study built on those ideas and involved feedback on the overall user experience with the street aimed at acquiring a more complete picture of the way a given street solution would be perceived in reality. Some of the issues mentioned further in this section could not be uncovered if the methodology relied only on the feedback related to the street design alternatives at a single cross-section of the street.

The change in the distribution pattern of the marked unsafe points between the two periods and the provided feedback allowed for the identification of problems related to the implemented temporary design. The finding that users had felt relatively less safe at intersections in the after period is backed up by previous research. For example, in a study conducted in Montreal, Canada, bicycle users perceived intersections with bidirectional cycle tracks twice as negatively as they perceived either similar protected facilities midblock or intersections with painted bicycle lanes (Wexler & El-Geneidy, 2017). Snizek et al. found that a shorter distance to intersections and signaled intersections in particular was associated with a higher chance for a negative cycling experience, which they suggested was the result of conflict risk at such locations (2013). According to Elvik et al., more than 80% of all accidents involving a bicyclist found in official accident reports are collisions with cars, and most of them happen at intersections (2009). In a *meta*-analysis of 13 studies on the safety of bicycle tracks (separated on-street two-way bicycle paths), he found an 11% decrease (significant) in the number of bicycle accidents along road sections and a 24% increase (significant) at intersections (a non-significant total increase of seven percent in bicycle accidents) (Elvik et al., 2009). Elvik concluded that bicycle tracks do not increase the safety for cyclists, as the bicycle accidents were found to transfer from road sections to intersections. He theorized that the physical separation between cyclists and motorists along road sections possibly makes those user groups less alert to each other at intersections. Similarly, in a before-and-after evaluation of accidents in relation to the implementation of bicycle tracks in Copenhagen, Denmark, Jensen found a statistically significant increase of 24% of injuries at intersections and a decrease of 13% at links (10% increase in total) (Jensen, 2008). The analysis of the geospatial data contributed also to uncovering of safety issues related to interactions between the users that included safety concerns at bus stops. Snizek et al. came up with similar conclusions in their study where a greater distance to bus stops was associated with an increased chance of a positive experience (2013). According to them, this was due to conflicts between cyclists and bus passengers that cross the bicycle facility.

5. Conclusions

In this article a mixed-methods approach was used to investigate transport users' perceptions in relation to the implementation of an interim road diet project and potential alternative street layouts. The approach helped to identify several safety issues that might not have been uncovered if only a stated preference methodology had been used.

The findings confirmed that the users' preferences for bicycle solutions did not vary substantially among different mode users and according to cyclists' characteristics, which is an important consideration when public feedback is sought in the urban planning process. The user ratings of the manipulated photographs indicated a preference for facilities separated from the motorized traffic preferably as two-way bicycle paths situated on one side of the street. However, the additional analysis with the help of a PPGIS tool showed that these types of solutions can cause uncertainty at intersections when implemented in practice. The post-implementation increase in the number of users that felt unsafe at intersections without dedicated bicycle signals was indicative of the need for safer permanent street design providing clarity about right of way. Another safety issue found through the PPGIS tool was related to users' interactions during the test period, in particular, conflict situations at bus stops. In the reality of municipal planning in which there are limited resources, the PPGIS methodology can be preferable to the time-consuming process of creating and analyzing manipulated photographs. It has to be noted, though, that the analysis of open-ended questions could be quite time-consuming, and this should be considered for practical applications.

There are already known advantages of using interim design to the transport planning process such as achieving improvements for the public in a relatively short period of time and their reversibility. This study found that the PPGIS methodology can be a useful evaluation tool for land use and transportation planners in the context of interim street design processes. The implementation of an interim project is a resource demanding initiative in itself and requires careful planning. The same applies for the use of a PPGIS tool to collect data on user preferences. However, the potential benefits of the two approaches in terms of achieving better solutions with regards to improved user safety and mobility far outweighs the alternative of implementing a permanent solution that might not be well accepted by some of the transport mode users.

Overall, the results showed that transport planners should think in a holistic way in order to optimize the final outcome for all users and can benefit from the combined use of interim design strategies and PPGIS methodologies. The main benefit of this approach is that planners are able to get insights on the way changes to the street environment are experienced by the public and use such insights in the development of a permanent street design.

6. Limitations

There are some limitations in this study which should be noted. The project was temporary in its nature and there was a disagreement amongst politicians about its implementation due to concerns about traffic chaos when the four-lane street was converted to two-lanes, not least for the buses. Thus, some respondents may have wanted to express their support for the implemented street change initiative and give this solution a higher ranking than otherwise would have been the case. At the same time, the application of an interim redesign has certain advantages when PPGIS evaluation methods are used and the benefit of the acquired insights can outweigh the potential bias mentioned above.

Cyclists and pedestrians were overrepresented in this study compared to the drivers. This is partly a result of the recruitment procedure and potentially because the vulnerable road users were more enthusiastic to respond to the survey as they were the main beneficiaries of the street changes (Vasilev et al., 2018).

Another limitation of the methodology applied in this study was the fact that users were asked to recall their perceptions of using the street before the street changes took place, more than a year ago. People likely remember more vividly their more recent unsafe experiences and this could have biased the findings to some degree. Future studies should consider the application of a longitudinal study design at the various planning and implementation stages to improve result reliability, although this would require a larger initial sample to ensure sufficient numbers of respondents across all time periods.

CRediT authorship contribution statement

Miroslav Vasilev: Conceptualization, Data curation, Funding acquisition, Writing – original draft, Visualization, Investigation, Methodology, Project administration, Formal analysis. **Ray Pritchard:** Conceptualization, Visualization, Investigation, Methodology, Formal analysis, Writing – review & editing. **Thomas Jonsson:** Supervision, Formal analysis.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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