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An exploration of multiuser perceptions of a Norwegian Complete Streets modification using interim design strategies

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ABSTRACT

The need for cities worldwide to embrace sustainable transportation alternatives has given rise to innovative planning and design practices such as the use of Complete Streets. This research article presents an approach that utilizes interim design strategies to investigate users' perceptions of Complete Streets modifications and their impact on travel behavior. The study focused on a major street in Trondheim, Norway, where various low-cost interim street changes were implemented to enhance conditions for pedestrians, cyclists, and transit users. These changes involved measures such as a ban on through-driving, a road diet (lane reduction initiative), bicycle lanes with armadillo separators, the deactivation of traffic lights, and parklet installation. Multiuser perceptions of the modifications were explored with the help of 832 online ex-post survey responses from city center residents and street users. Additionally, manual before-and-after counts of cyclists were conducted on the target street and three parallel streets. The findings revealed that employing interim design strategies enables transport planners to gain practical insights into the effectiveness of different Complete Streets measures. This, in turn, facilitates the optimization of roads for diverse travel modes and user needs.

1. Introduction

Over the past two decades, urban and transport planning have witnessed a shift in focus towards more sustainable and holistic approaches, moving away from solely catering to private car users (Delbosc et al., 2018). A key approach that has received considerable attention is the planning of Complete Streets which are designed, operated, and maintained to ensure safe conditions and mobility opportunities for all mode users, regardless of their age and ability (US DOT, 2015). However, accommodating different types of users and purposes within existing street layouts can be complicated as planners have to challenge long-established engineering principles and practices that prioritize cars, often facing opposition of various stakeholders (NACTO-GDCI, 2016; Vasilev et al., 2018).

The National Association of City Transportation Officials (NACTO) suggests that the planning process can benefit from the application of interim design strategies, involving the temporary implementation of small-scale, low-cost street measures that can quickly bring about positive changes (2013). By collecting and evaluating data, the effects of these temporary measures can be demonstrated to the public. Evaluations can involve comparisons with previous conditions using before-and-after studies, with other projects, control sites, or with trends on a city, regional, national and international level (NACTO-GDCI, 2016). These temporary implementations can then be transformed into permanent solutions or modified based on their functional efficiency (NACTO, 2013), offering for the opportunity to select an optimal solution for a specific urban environment. The use of interim design strategies gained importance during the COVID-19 pandemic. Moreover, many experts believe that these measures can play a crucial role in the post-pandemic period as a means of revitalizing cities (Law et al., 2021; Majewska et al., 2022; Thomas et al., 2022).

Research conducted in the United States has yielded positive findings regarding the implementation of Complete Streets projects. These studies have shown various benefits such as higher pedestrian volumes (Shu et al., 2014), a decrease in fatalities despite higher cycling rates (Mooney et al., 2018), improved transit ridership, positive health effects (Brown et al., 2015; Werner et al., 2016), and enhanced gender equity (Jensen et al., 2017). One American study found that the

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implementation of a Complete Streets design can significantly enhance the level of service (LOS) for cyclists and pedestrians, while having a minimal effect on the LOS for motor vehicles (Elias, 2011).

To gather qualitative data on Complete Streets, surveys can be conducted targeting residents, businesses, and other relevant stakeholders (NACTO-GDCI, 2016). In their study, Wahl et al. examined how factors such as gender, age, frequency of usage, and street characteristics affect citizens' perceptions of traffic-related phenomena. They also highlighted the importance of considering the transport mode of street users in future research when assessing their traffic experiences (Wahl et al., 2012).

This paper aims to explore the multiuser perceptions and changes in travel behavior in relation to an interim Complete Streets modification, using a case study from Trondheim, Norway. The street changes that were tested included elements of shared space, particularly the subtype known as "informal streets". In such streets the roadway is designated, but there is a deliberate removal or limitation of conventional regulatory equipment such as curbs and traffic lights (CIHT, 2018). The Complete Streets project was implemented temporarily, enabling the chosen design configuration to be tested in real-world conditions without making permanent alterations. This study aimed to collect user feedback to gain insights into their experiences with the implemented solutions. This facilitated an investigation into the following research questions:

1. How does the use of interim design strategies in the planning process of Complete Streets contribute to understanding users' perceptions of a potential permanent implementation and the expected changes in their travel behavior?
2. How do users' opinions of actual street changes vary based on their mode of transport?

Although numerous papers have been published on the effects of Complete Streets projects, there exists a research gap when it comes to assessing the effectiveness of interim design strategies, specifically their application in evaluating such projects. This paper aims to address this gap by analyzing the multiuser perceptions of an interim Complete Streets project and investigating the resulting changes in travel behavior. Through this analysis, the paper seeks to provide evidence-based insights into the effective utilization of interim design strategies.

The primary contribution of this research paper lies in its ability to offer valuable insights into a politically contentious Complete Streets project, whilst providing recommendations for future redesigns of this kind. This contribution is particularly important as it fills a void in the existing literature, providing guidance for decision-makers and practitioners involved in similar initiatives.

Furthermore, this research goes beyond evaluating interim design strategies and investigates the effects of parklets, traffic lights deactivation, and armadillo bicycle lane separators specifically in Norwegian contexts, which have received limited attention thus far. Additionally, this research paper contributes to the limited literature on the utilization of web-based or digitally drawn route choice analysis to examine the changes in route choices that arise from Complete Streets implementations (Vasilev et al., 2018; Pritchard, 2018).

2. Methods and data

2.1. Case study

The case study street is located in Trondheim, the fourth largest urban area in Norway, with a population of over 205,000 inhabitants (Statistics Norway, 2020). Notably, the 2019 National Travel Survey shows that the bicycle mode share in the city is 10% – the highest cycling rate in the country. Trips made by private motorized vehicles represent 49% of all journeys (of which 9% as a passenger), whilst 27% of trips are made on foot and 13% – by public transport (Urbanet Analyse, 2019).

The interim Complete Streets project was implemented in July 2018 along the entire length of Olav Tryggvasons gate (OTG), the Bakke bru bridge and a short section of Innherredsveien (Fig. 1). OTG is a major street through central Trondheim (shown in green in Fig. 1) and serves as the primary corridor for buses heading towards the train station, located to the north of the central business district and the eastern side of the city, facilitating both city and regional connections. The opening of the Northern bypass road in 2010 (shown in red in Fig. 1) led to a reduction in through traffic on OTG, enabling the implementation of the interim modification. Greener Trondheim, a transportation planning authority in the city, aimed to further reduce car flow through the city center, prioritize sustainable transport modes (public transport, walking and cycling), and create a pleasant urban environment through the modifications to OTG (Greener Trondheim, 2018). This project can be considered a Complete Streets initiative as it sought to offer improved conditions for sustainable transport users and included infrastructural measures typically associated with such initiatives.

The interim Complete Streets modification has undergone several alterations since July 2018. However, this article primarily focuses on the initial configuration that remained largely unchanged until the survey was conducted one year after the project's commencement. The primary measure implemented was a road diet, involving a reduction in the number of vehicular traffic lanes from four to two along most of the project's length (see Fig. 2). Over Bakke bru, the number of lanes was reduced from three to two. While private car users could still access the street, a new traffic regulation was introduced to prevent them from driving the entire length of OTG. Cars were required to turn at the intersecting streets, Søndre gate or Jomfrugata, as depicted in Fig. 1. This deliberate measure limited the possibility of driving through the city center on the east-west axis.

Protected bicycle lanes were incorporated on both sides of the street, starting at the western end of the project at the intersection with Munkegata and extending to the eastern end of Bakke bru (Fig. 1). To separate the bicycle lanes from the traffic lanes, a type of low-level physical barrier known as "armadillos" was initially used (Deegan, 2018). However, the barrier was later removed in November 2018 due to concerns regarding winter maintenance operations. Notably, the bicycle lanes were not connected to any existing bicycle infrastructure on either end of the project, resulting in cyclists needing to ride in mixed traffic when continuing beyond the project's two ends.

The sidewalk on the northern side of OTG was widened, creating space for the installation of several parklets (NACTO, 2013). These parklets featured street furniture, greenery, and bike parking facilities (Greener Trondheim, 2018). The provision of these areas aimed to create attractive place for people to rest while allowing restaurants and cafeterias to serve their clients outdoors. Additionally, the project included the construction of two new bus stops built to an improved standard.

In accordance with the principles of "informal streets", a subcategory of shared spaces, the traffic signals at the intersections of Nordre gate and Jomfrugata, as well as the signals at two pedestrian crosswalks (one near the intersection with Krambugata and another on Innherredsveien), were deliberately deactivated (Fig. 1). This proactive step was taken to improve the bus traffic flow and facilitate pedestrian crossings (Fig. 1). It is important to note that Nordre gate functions as the primary pedestrian street in the city center. Throughout the interim project, traffic lights at the intersections of Munkegata, Søndre gate and Kjøpmannsgata remained operational. For more comprehensive details regarding the changes implemented in the interim design, refer to the consultant report from Rambøll (2019).

2.2. Data collection

This article utilizes data collected from various sources, including a web-based traditional travel survey, a public participation geographic information system (PPGIS) tool, and manual counts of cyclists.

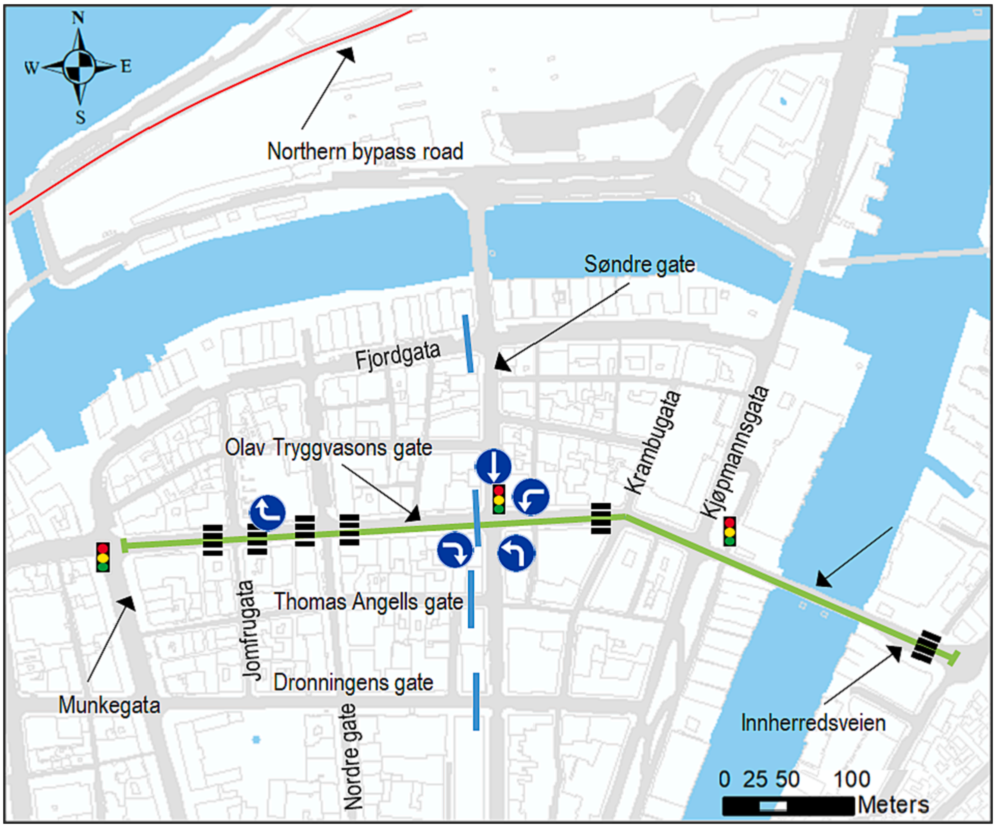

Fig. 1. Location of the street project in the center of Trondheim (in green); new signage; crosswalks that became unregulated; traffic lights that remained in use and counting locations (in blue). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2.3. A web-based traditional travel survey

The primary method of data collection involved gathering of user feedback through a web-based survey, which focused on the interim Complete Streets intervention. The survey was available in both Norwegian and English from June 20 to August 8, 2019, one year after the implementation of the street changes. It consisted of a total of 29 questions and took approximately 20 min to complete, depending on the extent of feedback provided by the respondents. Six of the questions were excluded from the analysis as they were deemed irrelevant to the main research objectives or posed issues with their formulation. Prior approval to conduct the survey and process the user data was obtained from NSD - the Norwegian Centre for Research Data.

A total of 6650 flyers containing a survey link were distributed with the aim of reaching street users. To attract potential respondents, the flyers included a photoshopped picture of OTG depicting a multimodal street layout. Respondents had the opportunity to win a gift voucher worth 3000 Norwegian kroner (approximately 330 USD). The flyers were predominantly mailed to addresses in the center of Trondheim (6,000), while an additional 500 were handed out to street users, mostly pedestrians, public transport users, and cyclists, along OTG. Approximately 150 flyers were left in areas frequented by students and employees near the Gløshaugen campus of the university (NTNU). Online social media groups related to transport and bicycling were utilized to further disseminate the survey, along with university mailing lists (NTNU) and an email sent to the employees of a taxi company. A total of 832 individuals participated in the survey, with different distribution methods resulting in varying response rates. Specifically, 85 respondents received a flyer on the street (17% response rate), 182 found about the survey through social media, 86 were informed by a friend or colleague, 446 received a flyer by post (7% response rate), and 33 selected “other” as their way of obtaining the survey link. Comparatively, the response rates for different distribution approaches were lower than those reported by Monsere et al. (2012), who achieved response rates of 31% and 42% for the two streets for which they had conducted their survey. It is worth noting that the participation rate in the current study may have been higher if the survey had been distributed before or after the summer holidays.

The survey included questions regarding respondent demographics, mode choice, and frequency of street usage, providing background information for investigating user preferences related to the interim design measures. Additionally, responses to an open-ended question from the survey were analyzed.

The distribution of the survey through social media groups focused on cycling could have contributed to an overrepresentation of cycling respondents. It is also worth noting that cyclists were the primary beneficiaries of the project, which might have motivated them to participate and express positive opinions. Steps were taken to address and minimize these potential biases. As mentioned earlier, respondents were asked to provide information about their various characteristics, allowing for a stratification of the sample based on the transport modes they used. This approach enabled the analysis of responses specific to each mode, helping to mitigate the potential impact of overrepresentation of cycling respondents. Further details on the analysis of the user responses can be found in section

2.4. Analysis

2.4.1. A public participation geographic information system (PPGIS) tool

To better understand changes in cyclists’ actual travel behavior resulting from the interim modifications, a revealed preference technique called participant-recalled route choice, as described by Pritchard (2018), was applied. The survey incorporated an integrated mapping application programming interface (API), allowing respondents to draw

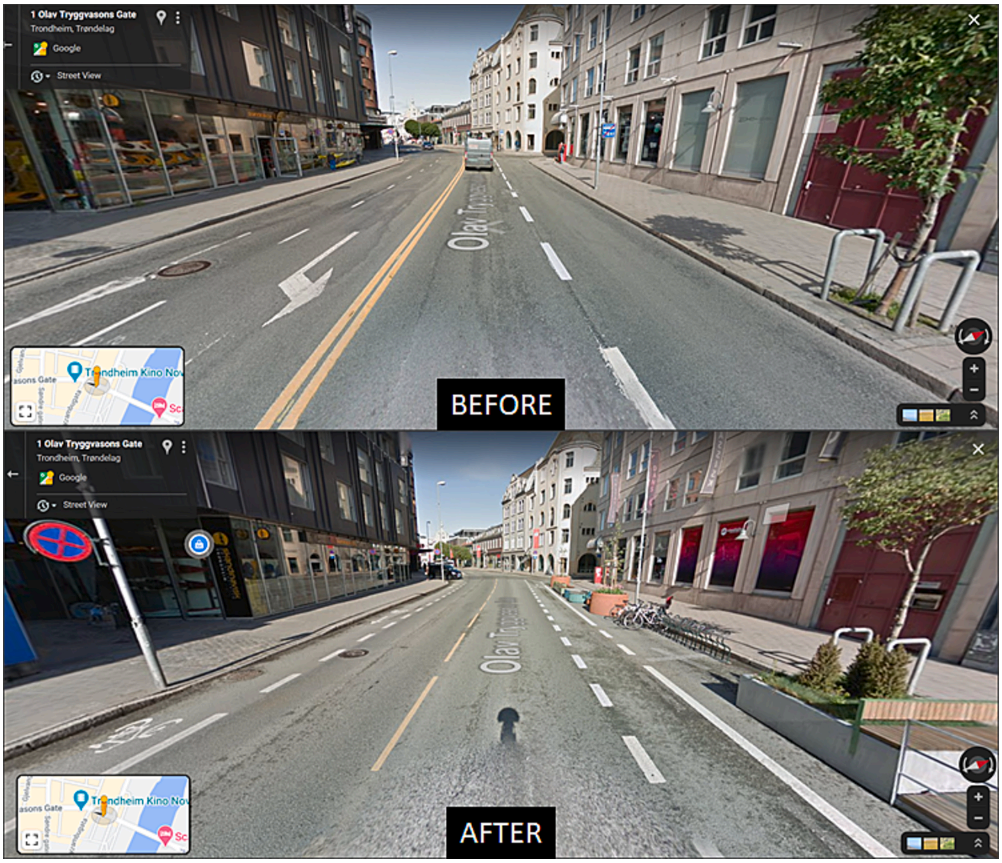

Fig. 2. Street profile of Olav Tryggvasons gate before and after the implementation of the Complete Streets project in 2018. Source: (Google, 2017; 2019).

the routes they had been using most often within the area of the Complete Streets project both before and after its implementation. This mapping tool had been previously tested in a similar study of another main street project in the same city (Vasilev et al., 2018) and has been applied internationally in practical projects and research endeavors (Pánek & Benediktsson, 2017). This type of tool, which involves residents mapping geospatial data, is commonly referred to as public participation GIS (PPGIS).

2.5. Manual counts

The research team collaborated with the consultancy Rambøll to conduct manual counts of cyclists on OTG and three parallel streets at the street sections marked in blue in Fig. 1. These parallel streets were selected because they, along with OTG, serve as direct routes for cyclists traveling across the city center on the East-West axis, allowing for comparison of the distribution of the through bicycle traffic before and after the street changes. The counts took place during peak travel times on May 29 and 30 in 2018 (before the street changes) and on September 11 and 12 (during the interim design period). The registrations on Fjordgata, Thomas Angells gate and Dronningens gate were carried out during the morning rush hours (07:00 to 09:00) and the afternoon rush hours (15:00 to 17:00). The counts on OTG were conducted for one hour per rush hour periods (08:00 to 09:00 and 15:00 to 16:00) on the same days.

2.6. Other data sources

The consultancy Rambøll prepared an evaluation report that not only collected data on cycling numbers as mentioned in the above paragraph but also encompassed a comprehensive range of short-term effects observed during the initial six months of the interim design project, spanning from July 2018 to January 2019 (Rambøll, 2019). This report was independent of the current study, except for the manual counts conducted on the three streets parallel to OTG. The current paper also references the findings of a master student's thesis, which focused on the impact of traffic lights deactivation at the intersection between OTG and Nordre gate on public transport and pedestrians (Ravnåmo, 2020).

2.7. Analysis

Survey participants were asked about their frequency of using different transport modes along OTG during the summer half of the year (April to October) before and after the street changes. A respondent was categorized as a user of a specific mode on OTG if they had used that mode at least once per month. To account for the fact that respondents could use multiple modes along OTG, multimodal categories were created. For example, the "walking cyclists" category included respondents who walked and cycled on OTG at least once per month. Other categories were formed in a similar way, allowing exploration of user preferences and travel behavior changes across various modes. Participants had the opportunity to comment on survey issues and provide feedback on the project. They were coded into main themes discussed in this paper. Selected translated themes and comments were presented to provide contextual understanding of user attitudes.

The routes drawn by the participants, depicting their most common trips in the treatment area, were mapped, and aggregated along the case study street and nearby areas of central Trondheim. Only the routes of bicyclists were examined since they were the primary beneficiaries of the street changes in terms of reallocated space. In cases where respondents drew multiple routes, only the most easily map-matched route per time period was considered for analysis. Routes that clearly deviated from the street network were excluded. QGIS was used for the map-matching which involved the creation of a 10 m buffer around each

Table 1
Descriptive statistics of the survey sample.

Variable	Category	Frequency	%
Gender	Male	440	52.9
	Female	392	47.1
	Total	832	100
Age	16–29	420	50.5
	30–44	216	26.0
	45–64	153	18.4
	≥65	43	5.2
	Total	832	100
Occupation	Student/Trainee	285	34.3
	Employed part-time	62	7.5
	Employed full-time	428	51.4
	Parental leave	5	0.6
	Retiree	33	4.0
	Unemployed/Disabled	19	2.3
	Total	832	100
Mode distribution "before"	Drivers	297	
	Non-cycling drivers	192	
	Cycling drivers	105	
	Non-walking drivers	39	
	Walking drivers	258	
	Cyclists	287	
	Non-driving cyclists	182	
	Walking cyclists	270	
	Non-driving pedestrians	438	
	Non-cycling pedestrians	426	
	Non-cycling public transport users	371	
	Non-walking public transport users	65	
	Total	832*	
Mode distribution "after"	Drivers	193	
	Non-cycling drivers	115	
	Cycling drivers	78	
	Non-walking drivers	30	
	Walking drivers	163	
	Cyclists	349	
	Non-driving cyclists	271	
	Walking cyclists	326	
	Non-driving pedestrians	557	
	Non-cycling pedestrians	394	
	Non-cycling public transport users	325	
	Non-walking public transport users	52	
	Total	832*	

* The total number of respondents is 832. However, many respondents have used more than one mode along OTG so the total number would be much higher if the numbers in the different categories are summed up.

road segment to account for slight variations in the drawn routes' centroids. For each segment buffer, the sum of intersecting lines was calculated and then joined back to the route network using unique buffer numbers. A map illustrating the change in the number of bicycle trips taken before and after the intervention on each street segment was generated. This analysis was done for a subset of participants who had provided satisfactory routes for both time periods, with at least one of the routes had been made by bicycle.

A chi-square test was conducted to examine the difference between the response frequencies of specific user categories and the overall sample of respondents for most the survey questions discussed in the paper. To assess the statistical significance of changes in bicycle volumes on each street segment, an independent two-sample *t*-test was conducted

Table 2
Mode choice changes on OTG.

Transport mode	Before	After	Change
	#	#	%
Cyclists	287	349	+ 22
Non-driving cyclists	182	271	+ 49
Non-driving pedestrians	438	557	+ 27
Non-cycling drivers	192	115	− 40

using the results obtained from manual bicycle counts.

3. Results

3.1. Survey results

3.1.1. Descriptive statistics

The descriptive statistics of the sample are presented in Table 1 below. The respondents were fairly balanced in terms of gender, although there was a slight male predominance (53%). However, as demonstrated by Vasilev et al. (2022), the responses regarding interim Complete Streets projects do not significantly vary between age groups. The sample consisted predominantly of young respondents, with half of the respondents falling within the 16–29 age group. It is worth noting that due to the multimodal categorization of users, where individuals could belong to multiple categories, the sum of all the categories listed below exceeds the sample size (n = 832).

3.1.2. Route and mode choice changes

The analysis of the multimodal categorization of users, as shown in Table 1, reveals a noticeable mode shift towards cycling and walking in the post-implementation period. Specifically, the number of cyclists has increased by 22%, "non-driving cyclists" have seen a significant rise of 49%, while"non-cycling drivers" have experienced a decline of 40% (Table 2). Additionally, there has been a 27% increase in "non-driving pedestrians".

A total of 579 routes were drawn by respondents regarding their travel in the area of interest, both before and after the street changes. From this dataset, a subset of cyclists who had drawn mappable routes in both periods, with at least one route made by bicycle, was selected for mapping, resulting in 172 routes from 86 individuals.

Fig. 3 illustrates the change in the number of bicycle trips per segment between the two time periods, using only the bicycle routes (n = 123) out of the previously mentioned 172 routes. Segments where the number of trips increased after the street changes are represented in green, while segments with a decrease in the number of trips are depicted in red.

The analysis reveals that bicycle trips along OTG have shown the most significant increase, while the bicycle use on parallel Fjordgata, Thomas Angells gate and Dronningens gate has decreased. Intersecting streets with OTG have generally experienced a slight increase in bicycle usage.

3.1.3. Street preference for bicycle lanes

Shortly before the survey distribution, city authorities were considering removing the temporary bicycle lanes on OTG and instead implementing a bicycle path on a parallel street to the north, Fjordgata. Survey respondents were asked whether they would support this proposal, and the response options were designed to allow them to choose which street(s) they believed should have a bicycle facility: OTG only, Fjordgata only, both streets, or neither of them. Table 2 presents the various response options and the preferences of all respondents, including different subcategories of users selected based on the likelihood of having differing opinions.

The majority of respondents (49%) expressed a preference for bicycle infrastructure to be available on both streets. The options of having

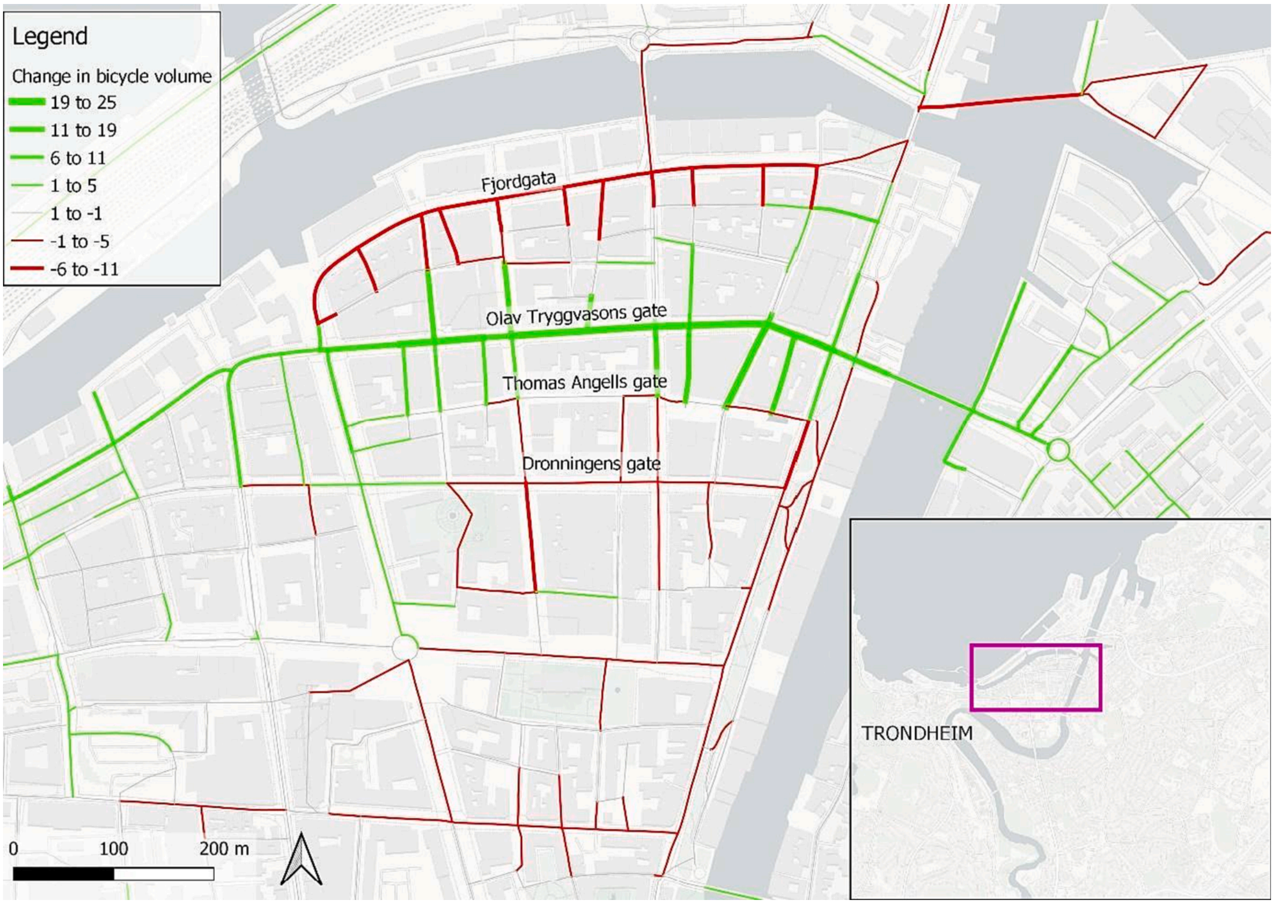

Fig. 3. Change in bicycle trips per street segment by bicycle subsample (n = 86).

cycling infrastructure on either OTG or Fjordgata received nearly equal support, with 21% and 20% favoring each respectively. In the subset of "non-driving bicyclists", there was a preference for bicycle infrastructure on both streets. However, the existing street situation with cycling infrastructure only on OTG received twice as much support compared to the alternative of having a bicycle path solely on Fjordgata. This suggests that the "non-driving cyclists" highly value the presence of bicycle lanes on OTG as it provides them with better accessibility to the city center. In contrast, a bicycle path on Fjordgata would route them along the northern periphery of the center, potentially resulting in detours for users crossing or traveling to the city center. This preference is reflected in Theme 1, which is illustrated by an example user comment.

Theme 1: Fjordgata is a detour for bicyclists.

- "A bicycle street in Fjordgata would be too far away from where people travel and stay in the center." (driver, male, forties).
- "It is irrelevant for me to use Fjordgata when I am cycling from Bakke bru to somewhere in the southwest part of the city center. It would result in a significant detour and longer travel time compared to my previous route before the implementation of the OTG project. I prefer using Thomas Angells gate instead of the former OTG or the proposed Fjordgata (even with bicycle infrastructure). What matters most to me is a fast and safe road." (bicyclist, male, thirties).

When considering the "non-bicycling drivers", the preferred options were either having no bicycle infrastructure (31%) or having infrastructure exclusively on Fjordgata (30%). These drivers expressed their disapproval of the traffic restrictions on OTG and suggested implementing bicycle infrastructure on alternative streets like Fjordgata. This sentiment is reflected in Theme 2, and illustrated by two quotes from respondents:

Theme 2: Move cyclists to other streets.

- "Let OTG be a street where the bus moves quickly, and pedestrians and cyclists can use Kjøpmannsgata and Fjordgata." (all modes user, female, fifties).
- "I think it would be better to enforce traffic restrictions on Fjordgata and reverse the traffic measures in OTG. Cyclists should be accommodated in Fjordgata and Thomas Angells gate instead." (driver and public transport user, male, thirties).

3.1.4. Deactivation of traffic signals

The survey posed a question to respondents regarding their agreement with the statement that deactivating certain traffic lights had improved traffic conditions for all street users. The responses, presented in Table 3, are analyzed collectively and by user group.

Considering the distinct viewpoints of drivers who are also pedestrians compared to drivers who have not walked along the case study street, it was anticipated that variations in responses would arise between the two driver groups. The "walking drivers" expressed less disapproval compared to "non-walking drivers". However, it should be noted that the reliability of this comparison is diminished due to the limited number of respondents (30) in the "non-walking drivers" category.

The majority of motorized users favored keeping the standard traffic lights setup on the street."Non-driving cyclists" held a contrasting view, with the highest proportion (45%) expressing support for the traffic signal changes among all user sub-categories. On the other hand, pedestrian opinions regarding the measure were evenly split, despite the expectation of clear support due to reduced waiting time at crosswalks.

Table 3
User preference for the parallel street to be facilitated with bicycle infrastructure.

Type of Users	None[a]	Only on OTG[b]	On both streets[c]	Only on Fjordgata[d]	Total
All	10% (n = 84)	21% (n = 175)	49% (n = 407)	20% (n = 166)	100%
Non-driving bicyclists*	2% (n = 6)	22% (n = 59)	65% (n = 175)	11% (n = 31)	100%
Bicycling drivers	13% (n = 10)	24% (n = 19)	40% (n = 31)	23% (n = 18)	100%
Non-bicycling drivers*	31% (n = 36)	15% (n = 17)	24% (n = 27)	30% (n = 35)	100%

[a] None = No, I am against cycling infrastructure on any of the two streets.
[b] Only on OTG = No, I prefer cycling infrastructure only on OTG.
[c] On both streets = Yes, but I would like cycling infrastructure to be available on both streets.
[d] Only on Fjordgata = Yes, I would prefer cycling infrastructure on Fjordgata instead of on OTG.
* By using a chi-square test, a statistically significant difference was found between the response frequencies given by the particular user category compared to the response frequencies by the whole sample of respondents ($p < 0.05$).

Among public transport users, a larger proportion expressed negativity towards the deactivation of the traffic signals, which is likely associated with traffic congestion and delays, as highlighted in Theme 3.

Theme 3 revolves around the regulation change and focuses on delays experienced by buses and other traffic. According to several respondents, these delays were attributed to pedestrians frequently crossing at the newly unregulated crosswalks.

Theme 3: Delays for vehicles.

- "The fact that the traffic lights are switched off for most of the day leads to many single crossings at the pedestrian crossings, especially at Nordre gate, which further slows down public transport." (public transport user, female, twenties).

Survey participants highlighted that chaotic situations had arisen between motorized vehicles and pedestrians crossing the street, resulting in deterioration of the safety conditions. Other sources also raised similar safety concerns. Feedback from the bus operator highlighted instances of bus passengers and pedestrians running across the street, both at crosswalks and elsewhere (Rambøll, 2019). The evaluation report by Rambøll also noted that bicyclists were cycling over the crosswalks without dismounting, disregarding the right of way according to Norwegian rules, and at high speeds. Furthermore, the master's thesis reported that approximately 15% of the pedestrians crossed the street outside designated zebra crosswalks (Ravnåmo, 2020). Many pedestrians in the present study also reported incidents of drivers failing to yield to crossing pedestrians, as illustrated in Theme 4:

Theme 4: Safety.

- "I want traffic lights regulation so that conflicts between buses and pedestrians can be avoided. This comment is made from the perspective of being both a bus driver and a pedestrian." (all modes user, female, fifties).
- "My biggest problem is crossing the street as a pedestrian since the buses do not stop even though one stands in such a way that it is obvious that they want to cross. One almost must force their way across." (public transport user, male, twenties).

Additionally, participants highlighted the impact of deactivating traffic lights on individuals with disabilities and the elderly. This issue is addressed in Theme 5 and exemplified by the following quotes:

Theme 5: Problems with universal design.

- "I think there is a lack of good facilities for people with visual impairments. Once I saw a blind person who did not know when to cross the street as the traffic lights have been deactivated, and they do not produce a signal." (public transport user, male, twenties).
- "I see more and more people who run like crazy in front of buses and old people who do not dare to cross the street when the traffic lights are deactivated." (bicyclist, female, fifties).

Furthermore, the master's thesis found that pedestrian crossing times at the intersection with Nordre gate were significantly shorter when the traffic lights were off compared to when they were activated (Ravnåmo, 2020). This explains the presence of positive feedback regarding the initiative, which is reflected in Theme 6 and exemplified by the following quoted:

Theme 6: Positive attitudes toward deactivating traffic lights.

- "I think turning off the traffic lights at pedestrian crosswalks makes the street less of a barrier for pedestrians. I think it is more comfortable to cross the street when you don't have to wait that long and can better adjust to the traffic." (public transport user, female, twenties).

3.1.5. *Removal of the parklets*

Prior to the distribution of the survey, the city authorities were contemplating the removal of the parklets, which were part of the interim design on OTG, to make room for either bicycle lanes or traffic lanes. Table 4 provides a summary of respondents' opinions regarding this proposal.

In terms of the preferred alternatives, 48% of all respondents approved of replacing the parklets with bicycle lanes, while only 10% preferred traffic lanes. Consistent with expectations, the "cycling drivers" displayed a higher level of support for converting the parklets into cycling lanes compared to the "non-cycling drivers". Interestingly, among "non-cycling drivers", a higher percentage (43%) preferred the implementation of cycling lanes rather than traditional traffic lanes (29%).

Surprisingly, more pedestrians favored the removal of the parklets compared to those in favor of retaining them. In fact, negative comments about the parklets were prevalent among participants, citing concerns about their appearance and the inconvenience of sitting on a busy street. This sentiment is captured in Theme 7, as exemplified by the following user comment:

Theme 7: Negativity towards the parklets.

Table 4
User agreement regarding traffic signal changes.

Type of user	Agree	Disagree	Neutral	Total
All users	38% (n = 317)	45% (n = 375)	17% (n = 140)	100%
Non-walking drivers*	20% (n = 6)	67% (n = 20)	13% (n = 4)	100%
Walking drivers*	30% (n = 49)	54% (n = 88)	16% (n = 26)	100%
Non-driving cyclists	45% (n = 122)	37% (n = 101)	18% (n = 48)	100%
Walking cyclists	42% (n = 138)	40% (n = 131)	18% (n = 57)	100%
Non-driving pedestrians	43% (n = 237)	41% (n = 228)	16% (n = 92)	100%
Non-cycling public transport users	38% (n = 122)	47% (n = 154)	15% (n = 49)	100%
Non-walking public transport users	37% (n = 19)	50% (n = 26)	13% (n = 7)	100%

* By using a chi-square test, a statistically significant difference was found between the response frequencies given by the particular user category compared to the response frequencies by the whole sample of respondents ($p < 0.05$).

- “The street furniture is totally unnecessary, it is ugly, just a hindrance. It’s naive to expect anyone to sit there for a “nice break“ amidst the fumes and dust of passing buses. I have rarely seen anyone actually using the furniture, so I strongly believe it should be removed to improve accessibility.” (bicyclist, female, twenties).

The bus operator suggested relocating the furniture closer to the building facades to address concerns regarding obstructed views for drivers. This suggestion aims to improve visibility and mitigate the potential for drivers to have limited sight of cyclists and pedestrians, as mentioned in the evaluation report by Rambøll (2019).

3.1.6. Armadillo bicycle lane separators (zebra delineators)

The respondents were presented with a series of statements regarding the bicycle lanes and the lane separators known as armadillos or zebra delineators as depicted in Fig. 4. They were asked to indicate their level of agreement with these statements.

The participants’ responses to the presented statements are provided in Table 5. It is important to note that the third statement was exclusively presented to respondents who reported cycling at least once per month. Therefore, only subsets of cycling users are included in the table. A significant proportion of the respondents expressed neutrality towards the statements. Among the “very frequent cyclists”, who were the most satisfied with the armadillos, there was a decreased tendency to request additional physical separation compared to other cyclists. No statistically significant differences were found in the responses between different sub-categories compared to the overall sample.

Theme 8 captures users’ feedback regarding the necessity of having a physical barrier between the bicycle lanes and the traffic lanes on OTG. The following quote exemplifies their concerns.

Theme 8: Need for a physical barrier.

- “It is difficult to cycle on OTG because there is no barrier separating the bicycle lane from the traffic lanes. They are very close to each other, and it makes me feel very unsafe while cycling.” (public transport user, male, fifties).

3.1.7. Drivers’ perceptions

Table 6 presents the questions that were posed to respondents who use a car along OTG at least once per month. The results reveal that a higher percentage of drivers (43%) disagreed with the statement that the bicycle lanes had resulted in improved safety conditions along OTG, as opposed to those who agreed (35%). Furthermore, a majority of drivers (55%) expressed a negative attitude towards the overall street changes.

Negative comments from drivers mainly focused on previously mentioned concerns such as delays and conflicts with crossing pedestrians, as reflected in Themes 3 and 4. Theme 9 captures general negative feedback about the project, highlighted by the quote below.

Theme 9: Reduced car accessibility.

- “OTG is a major thoroughfare in the city. Transport of goods and some car traffic must be able to pass efficiently. Closure of traffic lanes is experienced as suffocating for business and urban development. The bicycle lanes appear to be almost empty during most of the day. Trondheim is not a big city and does not require bike lanes like Amsterdam (driver, male, fifties).

3.2. Bicycle counts

Table 7 presents the hourly bicycle count volumes during peak hours. Table 8..

The key finding of the counts is that the number of cyclists on OTG has more than doubled (+112%) ($p < 0.05$). Conversely, the bicycle volumes on the three parallel streets to OTG showed a slight decrease, but this difference was not statistically significant. It is worth mentioning that there were variations in weather conditions between the “before” and “after” counts. During the “before” period, it was sunny with temperatures of up to 16 °C, while during the “after” registrations, temperatures were up to 9 °C and it was partly sunny/rainy (Rambøll, 2019). An analysis of past manual counts, as presented in (Rambøll, 2019), revealed that daily bicycle traffic to and from the city center remained relatively stable between 2015 and 2018. It is important to note that the results from the manual counts provide only an indication of the potential change in the number of cyclists. However, these counts are discussed in conjunction with the route and mode choice changes in the following section, and they prove valuable in that regard.

4. Discussion

Throughout the presented subsections, the users’ opinions, and changes in travel behavior in response to the implemented interim Complete Streets measures are extensively discussed. The findings contribute to addressing research question 1 as they emphasize the advantages of employing interim design strategies. Furthermore, the investigation effectively addresses research question 2 by revealing contrasting preferences among different types of respondents regarding each of the examined street changes. These preferences are closely linked to the modes of transportation that the respondents have been

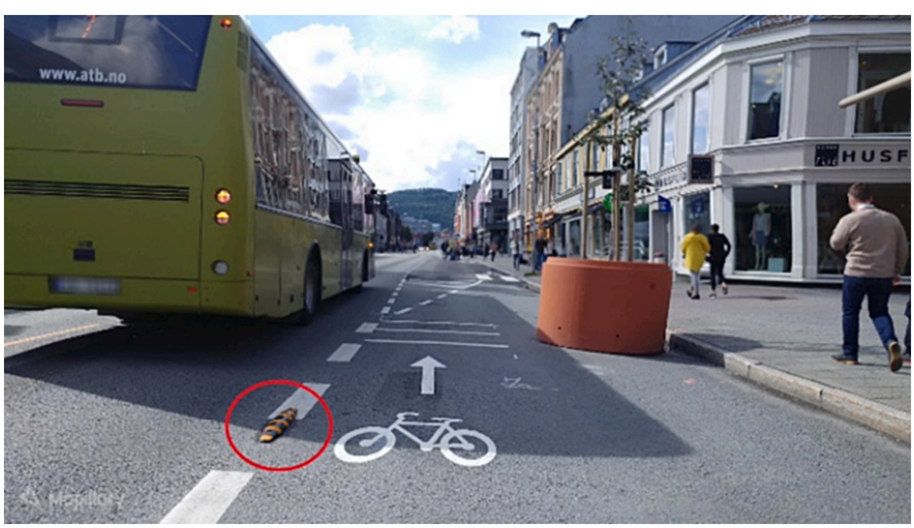

Fig. 4. Bicycle lane separated from traffic lane by armadillos (zebra delineator). Source: (Mapillary, 2018).

Table 5
User opinions regarding the temporary parklets.

Type of user	Should be removed to make way for cyclists	Retain parklets	Should be removed to make way for cars	Neutral responses	Total
All users	48% (n = 402)	29% (n = 238)	10% (n = 86)	13% (n = 106)	100%
Non-cycling drivers*	43% (n = 49)	15% (n = 17)	29% (n = 34)	13% (n = 15)	100%
Cycling drivers	53% (n = 41)	24% (n = 19)	13% (n = 10)	10% (n = 8)	100%
Walking drivers*	45% (n = 74)	20% (n = 32)	21% (n = 35)	14% (n = 22)	100%
Non-driving cyclists*	53% (n = 144)	33% (n = 89)	0% (n = 1)	14% (n = 37)	100%
Non-cycling pedestrians	44% (n = 174)	30% (n = 117)	13% (n = 53)	13% (n = 50)	100%
Non-driving pedestrians*	48% (n = 266)	34% (n = 191)	5% (n = 29)	13% (n = 71)	100%

* A chi-square test revealed a statistically significant difference ($p < 0.05$) between the response frequencies of the particular user category and the overall sample of respondents.

Table 6
Cyclist opinions of the armadillos (zebra delineators).

Statements	Contributes to effective separation[a]			Better than white paint[b]			Safer if more solid barrier[c]		
Agreement	Agree	Neutral	Disagree	Agree	Neutral	Disagree	Agree	Neutral	Disagree
Cycling drivers (n = 78)*	46%	18%	36%	51%	21%	28%	70%	13%	17%
Non-driving cyclists (n = 271)*	42%	27%	31%	56%	27%	17%	76%	11%	13%
Infrequent cyclists (n = 151)*	42%	24%	34%	52%	29%	19%	75%	13%	12%
Very frequent cyclists (n = 67)*	57%	21%	22%	60%	25%	15%	64%	15%	21%

[a] Effective separation = The zebra delineator contributes to the effective separation between bikes and motorized vehicles.
[b] Better than white paint = I would prefer the zebra delineator as a separation rather than just standard white paint.
[c] Safer if more solid barrier = I would feel safer cycling if motor vehicles were physically separated by a more solid barrier than the zebra delineator.
* By using a chi-square test, NO statistically significant difference was found between the response frequencies given by the particular user category and the response frequencies by the whole sample of respondents ($p < 0.05$).

Table 7
Drivers' perceptions of the project.

Statements	Agree	Disagree	Neutral
"Do you agree that the bicycle lanes have made driving safer (the chance for accidents has decreased)?"	35% (n = 68)	43% (n = 83)	22% (n = 42)
"As a driver, do you agree that the project has been positive as a whole?"	30% (n = 58)	55% (n = 107)	15% (n = 28)

using along OTG.

The sample appeared to have a higher proportion of cycling respondents compared to the mode distribution in the overall population of Trondheim. Stratifying the analysis by road user type was conducted to address potential bias resulting from the skewness in the sample. Presenting results for each road user type, rather than averaging them, aimed to provide a comprehensive and accurate representation of preferences within each group. Sufficient respondent numbers in each mode group ensured reliable results.

4.1. Street preference for bicycle lanes

To determine the user preferences for the street/streets where bicycle facilities should be placed, a combination of approaches was employed, facilitated by the application of interim design strategies. This included a PPGIS methodology, manual counts, and a stated preference survey question.

The manual bicycle counts showed that the bicycle volumes along OTG more than doubled as a result of the street changes, while the volumes along the three parallel neighboring streets marginally decreased (between 2 and 9%). The analysis of user-drawn bicycle routes corroborated these findings, showing increased bicycle travel on OTG (19–25 more bicycle trips per segment) and a decrease on the parallel streets (1–11 fewer bicycle trips per street segment).

The stable bicycle volumes to and from the city center between 2015 and 2018 further supported the hypothesis that the increase in bicycling on OTG was partly due to a change in the route choice of cyclists attracted by the improved conditions along the street. Similar findings were observed in a study of a similar project in the east of Trondheim (Vasilev et al., 2018) and a conversion of on-street parallel parking to a contraflow bicycle lane in Oslo (Pritchard et al., 2019). Another contributing factor to the increase in cycling on OTG is the observed shift in mode choice, as discussed in Section 3.1.1. above.

The increased interest among bicyclists in using OTG provides valuable context for interpreting their responses to the stated preference question. Among "non-driving bicyclists," twice as many respondents

Table 8
Results from the bicycle counts.

Street	Period	Morning	Afternoon	Total
Fjordgata[a]	Before	83	154	237
	After	87	133	220
	Change	4.80%	−13.60%	−7.20%
Thomas Angells gate[a]	Before	40	80	120
	After	39	70	109
	Change	−2.50%	−12.50%	−9.20%
Dronningens gate[a]	Before	96	119	215
	After	82	128	210
	Change	−14.60%	7.60%	−2.30%
Olav Tryggvasons gate (OTG)[b]	Before	30	29	59*
	After	63	62	125*
	Change	**110%**	**113.80%**	**111.90%**
Total	Before	249	382	631
	After	271	393	664
	Change	8.80%	2.90%	5.20%

[a] Parallel streets; Morning: average per hour 07–09; Afternoon: average per hour 15–17.
[b] OTG; Morning: 08–09; Afternoon: 15–16.
* An Independent two-sample *t*-test revealed a statistically significant difference ($p = 0.00$) in counts on OTG between the two periods. No statistically significant difference was found on the other three streets (Fjordgata – $p = 0.21$; Thomas Angells gate – $p = 0.23$; Dronningens gate – $p = 0.40$).

expressed a preference for bicycle infrastructure on OTG rather than on Fjordgata, with a majority supporting infrastructure on both streets. In contrast, "non-bicycling drivers" preferred to have bicycle infrastructure exclusively on Fjordgata or on neither of the streets. This result is likely to be more reliable compared to stated preference survey question in other studies because the respondents in this case have firsthand experience using the implemented design solution, enabling them to make more informed comparisons.

4.2. Deactivation of traffic signals

Drivers were predominantly against the deactivation of traffic light signals. This can be attributed to the increased delays and conflicts with pedestrians and cyclists at unregulated crosswalks, as highlighted in their free text responses. The deactivation could have been more successful if the volume of pedestrians crossing the street had been lower. In contrast, "non-driving cyclists" showed a higher inclination in favor of the traffic light deactivation, likely due to reduced travel time.

Given that the pedestrians' crossing times were found to have halved when the traffic lights were deactivated, it is evident that the lack of clear approval or disapproval of the measure among the "non-driving pedestrians" may be attributed to their heightened feeling of unsafety. This feeling arises from the chaotic and hazardous situations that have been reported at the crosswalks in the aftermath of the traffic light deactivation. Studies conducted by (Kelly et al., 2011; Panter et al., 2014) have highlighted the significance of safe crossing opportunities for pedestrians, while research by Firth (2011) and Singleton and Wang (2014) has specifically emphasized the importance of crossings regulated with traffic lights in enhancing pedestrians' perceived safety. For example, Elvik (1997) conducted a study on Norwegian motor vehicle drivers at zebra crossings, which reported an average yield rate of only 53%. More recent investigations involving 16 crosswalks in Oslo and Trondheim found an average yielding rate of 80–85% (Høye et al., 2016; Høye & Laureshyn, 2019). When considering pedestrians' safety, it is crucial to pay close attention to the challenges faced by blind and elderly pedestrians when crossing the street. The World Health Organization's "Age-friendly cities" guide emphasizes the importance of pedestrian crossing lights with visual and audio signals for the elderly (WHO, 2007). Furthermore, documented evidence indicates that uncontrolled or informal crossings can pose safety risks for blind, partially sighted, and disabled pedestrians (Firth, 2011; Guide Dogs, 2012; Norgate, 2012). Additionally, a large proportion of the public transport users expressed opposition to the changes in the regulation, likely due to reported bus delays resulting from frequent pedestrian crossings.

The lack of a clear preference for the use of traffic signals amongst pedestrians, coupled with the more pronounced negativity expressed by public transport users towards the deactivation, suggests that the traffic light deactivation measure has not achieved the project's goal of improving conditions for sustainable transport modes. Considering the prevailing negative attitudes of motorized users, it can be concluded that the deactivation of traffic lights in the 2018 Complete Streets trial should not be recommended as a permanent measure. This example of a measure that did not serve its initial intent provides evidence supporting the application of interim design strategies in the planning process of street design alterations, which contributes to addressing research question 1. It is worth noting that achieving satisfactory outcomes without traffic lights may require reducing the street's traffic volumes, while still ensuring it remains the main public transport route through this part of the city center.

4.3. Removal of the parklets

The majority of the respondents, regardless of the transport mode they have been using, expressed a preference for substituting the parklets with bicycle lanes. User comments indicated that this preference stemmed from the inconvenience of sitting near heavy traffic and the perceived unattractiveness of the parklet furniture. The negative feedback from drivers regarding the safety of the bicycle facility and the overall project can also explain the preference for removing the parklets. However, it should be noted that the conclusions drawn about parklets in this study, along with the other measures, may not be generalizable, as the same intervention could yield different results in other locations. Street furniture can play a significant role in shaping the social dynamics of a street, especially during a shift towards a more pedestrian-friendly and less car-oriented environment. Given the importance of street furniture, it is advisable to conduct further research to understand the factors that influence the acceptability of parklets and similar interventions.

The unexpected preference of "non-cycling drivers" for cycling lanes may be attributed to the survey design, as they might have focused only on the option of parklet removal and overlooked the alternative of substituting them with traffic lanes. Randomizing the order of the answer alternatives in the online survey could have mitigated this potential source of error. The fact that both groups of pedestrians largely agreed that the parklets should be replaced with bicycle lanes indicates a low acceptance of temporarily implemented parklets on OTG. The use of interim design strategies once again proved to be timely, as the findings regarding the implemented parklets in this specific project contradicted the primary purpose of such facilities.

4.4. Armadillo bicycle lane separators

A higher proportion of cycling respondents agreed with the statement that the armadillos had contributed to the effective separation between the cyclists and the motorized vehicles and that they would prefer to retain them. This aligns with earlier studies indicating that light segregation facilities, which can be overrun by cars, are usually considered to increase cyclists' perceived safety (Transport for London, 2014) and lead to more cycling (Chris Monsere et al., 2014). However, cyclists indicated that they would feel even safer if a more substantial separation had been employed. Several studies also highlight that vertical separators, such as bollards, concrete blocks and planters, which cannot be easily crossed by motor vehicles, offer higher levels of both objective and perceived safety compared to designs with less physical protection (Koorey et al., 2013; Chris Monsere et al., 2014; Transport for London, 2014). The greater support for armadillos among "very frequent" cyclists compared to other user groups may be because these cyclists are generally more comfortable even without physical protection (Damant-Sirois et al., 2014; Dill & McNeil, 2013). Notably, the respondents' firsthand experience with the assessed facility lends greater credibility to the results, distinguishing this study from those that relied on hypothetical surveys, as seen in the case of (McNeil et al., 2015).

4.5. Drivers' perceptions

A larger proportion of drivers believed that the bicycle lanes on OTG did not enhance safety for driving along the street. Furthermore, most drivers expressed negative views toward the Complete Streets project as a whole. Among "non-bicycling drivers", the two most preferred alternatives were to have no bicycle infrastructure on any streets (31%) or to only have facilities on the parallel street, Fjordgata (30%). Similar findings were reported by Monsere et al. (2012), who observed that motorists in Portland, US, often associated newly implemented bicycle infrastructure with travel delays and inconvenience, particularly among drivers who did not cycle.

Limitations.

The primary focus of this study was to explore the effect of a specific interim Complete Streets project on users' perceptions and behavior. It is important to note that the study did not address the perceptions related to a permanent solution, as the street changes were implemented temporarily.

The rush hour counts conducted on OTG and the three parallel streets were limited to a duration of two days during each observational period, providing only an indication of cyclist numbers. However, the results obtained through other methods employed to analyze cyclists' route choices corroborated the overall findings regarding route choice changes.

Another factor to consider is the recall bias associated with the task of asking survey participants to draw the routes of their most common trips from a year earlier. This bias could potentially impact the accuracy of the drawn routes. To mitigate this, a cohort study could have been employed, where the same respondents would have been surveyed both before and after the implementation of the interim street project. However, one can assume that there would be a degree of participant drop-out between survey waves, resulting in a lower total number of responses compared to the current study, given the same recruitment efforts. Alternatively, two separate cross-sectional surveys could have been conducted, but this approach would not have allowed for surveying the same respondents.

The length and complexity of the entire survey, which included additional questions not used in this article, may have led to respondents answering hastily. Future evaluations can address this issue by implementing a more focused and concise survey that hones in on specific issues. These surveys can be guided by insights gathered from pre-survey focus groups, allowing for a more targeted and efficient data collection process.

5. Conclusions

The goal of this article was to explore the value of interim design strategies in the planning process of Complete Streets modifications. The application of this approach in the current case study proved highly beneficial, considering the context-specific nature of Complete Streets measures. By implementing temporary street changes and closely observing behavioral shifts and user acceptance, valuable insights were gained regarding their functionality and overall user acceptance. This approach allowed for the examination of route and mode choice changes through a survey and on-site bicycle counts.

The noteworthy increase in cycling and walking, as well as the changes in cyclists' route preferences towards the interim design project, hold significant importance. These outcomes provide further justification for the implementation of Complete Streets projects.

Moreover, the use of interim design strategies provided the opportunity to explore user preferences regarding the selection of streets for bicycle infrastructure implementation. The acquired knowledge enables timely adjustments that align with the actual street conditions, making it easier for the planners to balance the interests of various stakeholders. Additionally, it allows for the incorporation of innovative and untested solutions for bicyclists and pedestrians, aligning with the comprehensive principles of Complete Streets designs. Interim design strategies facilitated the examination of user opinions on specific infrastructural measures tested in the project such as deactivation of traffic signals, allocation of roadway space for parklets, implementation of armadillo bicycle lane separators. Overall user perceptions were assessed using a combination of closed-ended and open-ended survey questions. The study also revealed that users' perceptions and opinions toward Complete Streets implementations are strongly influenced by their choice of transport mode. Notably, cycling respondents exhibited a more positive attitude toward the implemented measures when compared to car drivers. Therefore, it is important for planning authorities to ensure appropriate representation of all (potential) user subgroups when conducting surveys regarding implemented street changes. This knowledge can be useful not only for city planners and practitioners but also for researchers.

It is important to acknowledge that the practical insights regarding the measures tested in this study may not apply in different case studies due to the influence of local conditions on the effectiveness of the measures. However, the findings demonstrate the broader implications of employing interim design strategies for the field of urban transportation planning and design. These strategies can be relevant and applicable to other cities and countries, as many of the challenges encountered by planners and policymakers in promoting Complete Streets are universally shared.

Declaration of generative AI and AI-assisted technologies in the writing process:

During the preparation of this work the authors used ChatGPT in order to improve the English language of the paper. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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CRediT authorship contribution statement

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

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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