Conflicts between bikes and trucks in urban areas - a survey of Norwegian cyclists

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Abstract

Several challenges accompany the current growth of bike and truck volumes in urban areas, with traffic safety being one of the most critical concerns. Bike-truck accidents present a direct measure of the safety; however, these are rare events. Furthermore, accident records are subject to several shortcomings. Thus, safety studies should not rely solely on accident analysis, and conducting the additional methods is advisable (e.g. surveys or conflict analysis). This paper discusses the results of a retrospective survey of Norwegian utilitarian cyclists, which collected data about their involvement in conflicts with trucks in urban areas. An online questionnaire was disseminated within major cities in Norway, and 631 valid responses were analysed. The results revealed large numbers of conflicts experienced by cyclists, with the most frequent types of conflicts being (1) truck overtaking bicyclist and (2) right-turning truck vs. straight-riding bicyclist and. Visibility issues were frequently mentioned as the important risk factors. Almost all cyclists blamed truck drivers as the party responsible for the conflict. The distribution of conflict categories differed between major Norwegian cities, which corresponds with the findings of a previous accident analysis. Insights developed are useful to local policy makers both in Norway and abroad, when considering how to plan for increasing numbers of cyclists and trucks in urban areas.

Keywords: Bike-truck conflicts; Survey; Urban areas

1. Introduction

Urban cycling has been gaining significant political support in Norway. Policies have been introduced to encourage and motivate people to cycle, as it contributes to improving health, reducing the negative effects of car traffic, and creating liveable and vibrant cities. The current Norwegian National Transport Plan 2014-2023 has introduced a “zero-growth objective” referring to the use of private motorised vehicles (NTP, 2013). It states that the expected growth in urban passenger transport is to be made by public transport, cycling and walking. The Government aims to increase the cycling share from 4% (year 2013) to 8% by 2023, and set aside significant annual funding of NOK 0,82 billion (≈ EUR 87 millions) towards implementing measures for cyclists and pedestrians. Given such objectives and funding, it is possible to expect a growth of cycling in urban areas, as described e.g. by Pucher et al. (2010).

Meanwhile, the number of kilometres driven by trucks in Norway increased by on average 4.6% annually in the period 2009–2014 (Statistics Norway, 2015), and further growth is expected, particularly on short distances (NTP, 2013). Although numerous innovative city logistic concepts (e.g. urban consolidation centres, off-hour deliveries, bicycle deliveries, crowdshipping) that could reduce freight traffic in the cities, the structure of urban areas is such that trucks are highly likely to be the dominant delivery mode for the foreseeable future (Jaller et al., 2013). Moreover, longer and heavier vehicles are expected to be more frequent on the road network (NTP, 2013). One of the consequences of this development is that cyclists and trucks are sharing urban roads more than ever, which increases the risk of potentially fatal accidents (Davis and White, 2015).

Based on several road safety indicators, Norway is considered one of the safest countries in Europe (ETSC, 2016). The Norwegian safety policy is grounded on Vision Zero approach, which implies that all the traffic safety work should be based on a vision of no fatal or serious injury accidents. Nevertheless, cyclists are facing considerably higher risk in traffic than passengers of motor vehicles (Elvik, 2009). According to the Norwegian Public Road Administration's accident database, STRAKS, 65 cyclists were killed and 6032 suffered an injury in road accidents in urban areas between 2000 and 2014. The frequency and characteristics of accidents between cyclists and motor vehicles are influenced by variety of risk factors and their combinations. These factors relate to humans, infrastructure, environment and vehicles. The most common are age, gender, type of infrastructure and intersection, mass and speed difference between a cyclist and other vehicle/s, visibility, weather, inattention, unpredictable behaviour, errors in decisions, reactions or observations (Kim et al., 2007; Bjørnskau, 2005). The frequency of cycling, particularly the number of encounters between cyclists and motor vehicles have an effect on accident rates, too, because of the negative relation between exposure and risk (Elvik, 2015).

Focusing on truck-bicycle accidents (referred as TCA further in the text), a total of 271 occurrences were recorded by the Norwegian police in the period 2000-2014, with 27 cyclists fatally injured. Further, the majority of TCA (80%) and TCA fatalities (85%) were recorded in urban areas. The share of fatal TCA in all fatal cycle accidents in urban areas in Norway (35%) is one of the highest in Europe (Evgenikos et al., 2016). Urban TCA in Norway typically occur at intersections, under low-speed manoeuvres of trucks, during working days and working hours, under good weather-visibility conditions (Pokorny et al., 2017). Existing literature has highlighted that numerous characteristics of TCA are different from other types of bicycle-motor vehicle accidents, particularly regarding the environment of fatal accidents, accident scenarios, severity of consequences, the role of speed, visibility, age and gender of cyclist. While the majority of fatal cycle accidents occurs in rural areas, most of the fatal TCA were recorded in urban areas. TCA are typically very severe - the fatality rate of urban TCA in Norway is more than ten times higher compared to other urban bicycle accidents (Pokorny et al., 2017). This corresponds with findings from the UK, Germany, Denmark or China (Niewoehner and Berg, 2005; Ming et al., 2014; Kaplan et al., 2014). The high severity level of TCA is usually attributed to the mass differences between a vulnerable bicyclist and a truck (Kim et al., 2007), while the speed of a truck is not considered as a significant risk factor(Volvo Truck, 2013). Turning accidents, and particularly those associated with limited visibility around a truck (so-called blind spot accidents), are regarded as the most serious and frequent type of TCA (Johannsen et al., 2015; Seiniger et al., 2015). Female cyclists were found to be overrepresented in TCA (Niewoehner and Berg, 2005; Frings et al., 2012). Specifically in Norway, females were involved in 48% of fatal TCA in urban areas in the period 2000-2014, while regarding other fatal urban cycle accidents, the percentage was 20%. The significant difference was also found for non-fatal accidents (40% vs. 20%). Frings et al. (2012) suggest that gender differences in risk perception could explain this phenomenon. Cyclists involved in TCA are spread over all age groups (Niewoehner and Berg, 2005) and this is true for Norway as well (Pokorny et al., 2017). However, Norwegian data show that older cyclists (over 60) were involved in 10% of urban TCA, while their share in fatal TCA was 26%. This difference suggests the well-known effect of older age on accident severity, mainly because of the human body's increasing vulnerability. Furthermore, age has been shown to affect cyclist behaviour, as older cyclists appreciate pedestrian crossings, signalized intersections and cycle paths significantly more than do younger cyclists (Bernhoft and Carstensen, 2008).

To reduce the risks involved in encounters between trucks and cyclists, it is necessary to have the sufficient knowledge about those encounters, their types and the risk factors involved. Studying TCA is an obvious approach to obtain such knowledge, as accidents are a direct measure of safety and the data are relatively accessible. However, relying solely on accident analysis cannot provide sufficient knowledge (Juhra et al., 2012), as accident data suffer from several constraints. First, TCA are rare events, which makes their statistical analysis challenging (Pokorny et al., 2017). Second, data about accidents involving cyclists suffer from a significant level of underreporting, which depends (amongst others factors) on accident severity (Kaplan et al., 2017). Regarding Norway, it was estimated, that the probability of reporting a bicycle accident is 12% for minor and moderate injuries, 33% for serious injuries, 71% for severe and critical injuries and 100% for fatal injuries (Veisten et al., 2007). As TCA are typically more severe than other bicycle accidents, their level of reporting is probably higher; however, a proportion of TCA is certainly missing in official statistics. Third, the absence of certain data and inconsistency of reporting of TCA were identified within the Norwegian police database (Pokorny et al., 2017).

To compensate for these limitations, the analysis of surrogate measures of safety, including conflicts, has been recognised as an alternative to accident analyses. A conflict is understood here as "an observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged" (Amundsen and Hyden, 1977). The impact of conflicts are associated not with physical harm but can act as a significant psychological deterrent for future cycling (Jachyra et al., 2015; Sanders, 2015), as cyclists are experiencing conflicts in traffic on daily basis and the involvement of trucks in those conflicts is associated with a significant increase of fear (Aldred and Crosweller, 2015).

The current knowledge about traffic conflicts involving cyclists and other vulnerable road users (also referred to as near-accidents or near-misses), was recently summarised by Johnsson et al (2016). Several methods exist to collect and analyse conflicts, i.e. recording (observing) road users' behaviour and consequently identifying the conflicts based on different criterions, using traffic diaries or conducting face-to-face interviews and surveys. Only a few studies have focused on bike-truck conflicts specifically. For example, an observational study from the US (Conway et al., 2013) analysed conflicts on three different configurations of parking and cycle lanes in commercial areas of New York City. During 92 hours of observation, 35 conflict events were recorded.

This paper explores truck-bicycle conflicts from a cyclist perspective within the context of Norwegian urban areas through using a retrospective questionnaire survey. The objectives of this study were to identify the types of conflicts cyclists are experiencing in Norwegian cities; to explore the associations between the conflict types and various background variables, and, more generally, to contribute to filling the knowledge gap regarding truck-bicycle encounters, particularly conflicts.

2. Methodology

A retrospective questionnaire survey was performed focusing on cyclists' involvement in conflicts with trucks, as this type of study design is considered to be appropriate for assessing the interrelation between bicycle safety and infrastructure (Vanparijs et al., 2015). A conflict between a cyclist and a truck was described to respondents as any situation where a cyclist almost collided with a truck, but due to the reactions of the cyclist and/or driver (braking, suddenly changing direction etc.), no accident occurred, the cyclist having merely been threatened. This "user-friendly" definition is a modification of the classical Amundsen and Hydén definition mentioned previously. Referring to the survey, a truck was defined as a large road vehicle used for carrying or pulling goods or materials.

2.1 Design of the survey

The survey "*Interactions between bicycles and trucks from a cyclist's perspective*" was designed as an online questionnaire with nationwide coverage. The target group included the adults cycling regularly in Norwegian cities for utilitarian purposes, as those were identified from an accident analysis as being the most common type of cyclists involved in TCA (Pokorny et al., 2017). The questionnaire consisted of four sections. Section 1 contained compulsory questions about background variables. Section 2 collected data about conflict types experienced with a truck during the previous 12 months. Depictions of 18 conflict types were presented here and accompanied by their written description. Respondents could mark numerous conflict types they had experienced within 12 months, describe their most recent conflict type in more details or note that they had not experience any conflict at all. Section 3 was comprised of several questions regarding the respondents' experience with an involvement in an accident with a truck. Section 4 allowed the respondents to leave any additional comments and contact information on a voluntary basis. See Tab. 1 for the formulation of the questions, the answer options and the description of variables and their categories.

Table 1. Questions, answers and variables

Question	Possible answers	VARIABLE and its categories (if different from possible answers)	Type of variable
1. What is your age?	Number of years	AGE GROUP: 18-30; 31-40;41-50; 51-60; 60 and more	Quantitative, ordinal
2. What is your gender?	Female; Male	GENDER	Qualitative, dichotomous
3. What is the highest degree of school you have completed?	Basic; Secondary; Bachelor; Master; Doctorate	EDUCATION: Secondary; Bachelor; Master; Doctorate	Qualitative, ordinal
4. Do you have a driving license?	Yes; No	DRIVING LICENSE	Qualitative, dichotomous
5. In what city do you most often ride your bicycle?	Bergen; Kristiansand; Oslo; Stavanger; Trondheim; Other (name)	CITY: Bergen; Oslo, Trondheim; Tromsø; Other	Qualitative, multinomial
6. You use your bicycle mainly for:	Commuting; Transport to other activities; Recreation and sport activities; Other	REASON FOR CYCLING: Utility, Recreation only	Qualitative, multinomial
7. How often do you cycle in the summer? And in the winter?	A few times a day; Almost every day; 2-3 times a week; A few times a month; Never or very seldom	FREQUENCY OF CYCLING: *Infrequently* (a few times a month in the summer and never/seldom in the winter); *Frequent* (2-3 times a week in the summer and a few times a month in the winter); *Very* (at least 2-3 times a week in the winter and at least almost every day in the summer)	Qualitative, ordinal
8. What types of conflict with a truck have you experienced in the last 12 months when riding your bike in the city? (multiple answers possible)	18 different conflict types (from A to R) illustrated with the scheme of each type (see Tab. 7) and further described by the text	NUMBER OF CONFLICT TYPES EXPERIENCED: 0, 1, 2, 3…	Quantitative, ordinal
9. What was the most recent conflict you experienced?	A-R, other; no conflict	TYPE OF THE MOST RECENT CONFLICT	Qualitative, multinomial
		EXPERIENCING A CONFLICT: yes/no	Qualitative, binomial
10. How would you estimate the degree of severity of that most recent conflict?	Slight - only minimal effort needed to prevent a crash; Serious - almost an accident, intensive effort (braking, swerving) needed to prevent a crash.	PERCEIVED SERIOUSNESS	Qualitative, ordinal

11. What factors played the most important role in your most recent conflict with a truck?	I was breaking the traffic rules; I did an unexpected manoeuvre; The truck driver did not see me; The truck driver was breaking the traffic rules; The truck driver did an unexpected manoeuvre	CONTRIBUTORY FACTORS	Qualitative, multinomial
12. As a cyclist, have you experienced any accident with a truck in the last 12 months?	Yes, once; Yes - multiple times; No	INVOLVEMENT IN ACCIDENT: Yes; No	Qualitative, dichotomous
13. Was that accident investigated by the Police?	Yes; No	RECORDED BY POLICE	Qualitative, dichotomous

The questionnaire's link was disseminated through cycling-related social media channels, the main Norwegian municipalities' web pages, cyclist organisations, universities, a hospital and a research institute. The link was active for approximately one month during May-June 2015.

2.2 Analytical methods and hypotheses

Given the existing knowledge on truck-bicycle encounters, several analyses were conducted. The descriptive statistics of the sample were conducted separately for both genders, as female cyclists are typically overrepresented in TCA. Chi-square tests of homogeneity ($p<0.05$) and pairwise comparisons using the z-test of two proportions were applied to compare the differences in distributions among independent background variables. The characteristics of the valid sample were compared with the non-valid sample (the participants who did not complete the questionnaire). Furthermore, the following hypotheses are suggested and tested:

I. The probability of experiencing a conflict with a truck is influenced by the demographics of respondents, particularly by *age* (as older cyclists avoid certain situations/infrastructure), *gender* (possible differences in risk perception), *frequency of cycling* (more cycling increases chance to encountering a truck in the traffic, on the other hand it means more experience in avoiding conflicts), *education* (potential effect of educational degree on risky behaviour) and *city* (differences in transport networks). Binomial logistic regression was performed to ascertain the effects of these variables.

II. The type of most recent conflict is influenced by respondents' independent background variables, particularly by *age*, *gender* and *city* (as described above). Multinomial logistic regression was conducted to test this hypothesis.

III. The number of reported conflict types among the respondents differs for variables *city* and *gender*. Two-sample t-tests were applied to test the hypothesis.

IV. The conflict types differ in their contributory factors and severity (perceived by the cyclists). This hypothesis was tested using chi-square test of homogeneity at $p<0.05$ and pairwise comparisons using the z-test of two proportions.

3. RESULTS

From the survey, a total of 1207 responses were obtained. Respondents who answered that they cycle in more than one city were omitted from the analysis, as it was not clear which city should be assigned the answers. Furthermore, respondents who both stated that they had not experience any conflict in the last 12 months (question #9 in Tab. 1) but also marked one or more conflict types in question #8, were omitted from the analysis as they had likely misunderstood the questionnaire. Those who stated that they cycled exclusively for recreational purposes, were also removed from the sample, as their background characteristics (gender, age, education, city, frequency of cycling) were significantly different from the other respondents (tested by chi-square test of homogeneity at p<0,05 with pairwise comparisons using the z-test of two proportions). Finally, those who had not completed the questionnaire were also removed from the analysis. As a result of the above criteria, 631 valid responses remained for the hypothesis testing.

3.1 Characteristics of the respondents — descriptive statistics

The majority (56,4%) of the valid respondents were male. Almost all respondents (97%) had a driver's licence. A total of 92% of valid responses were received from four cities: Trondheim (n=341), Oslo (n=140), Bergen (n=62) and Tromsø (n=38). Regarding both genders, the age bracket between 31-40 years was the most frequent. Approximately 80% of respondents of both genders cycle almost every day in the summer. In the winter, this share drops to 50% for males and 30% for females. The sample is well educated, as nearly 90% of respondents stated that they have completed some form of university education. Tables 2-5 summarise the selected background variables of the valid sample according to gender.

Table 2. Gender*Age cross tabulation

Gender		Age				
		18-30	31-40	41-50	51-60	over 60
Female	Count	55	86	69	51	14
	% of Total	8,8%	13,6%	10,9%	8,1%	2,2%
Male	Count	54	125	106	52	19
	% of Total	8,6%	19,8%	16,8%	8,2%	3,0%

Table 3. Gender*Education cross tabulation

Gender		Education			
		Secondary	Bachelor	Master	Doctoral
Female	Count	34	116	99	26
	% of Total	5,4%	18,4%	15,7%	4,1%
Male	Count	40	113	164	39
	% of Total	6,3%	17,9%	26,0%	6,2%

Table 4. Gender*City cross tabulation

Gender		City				
		Bergen	Oslo	Trondheim	Tromsø	Other
Female	Count	18	35	191	17	14
	% of Total	2,9%	5,5%	30,3%	2,7%	2,2%
Male	Count	44	105	150	21	36
	% of Total	7,0%	16,6%	23,8%	3,3%	5,7%

Table 5. Gender*Frequency of cycling cross tabulation

Gender		Frequency of cycling		
		infrequent	frequent	very
Female	Count	100	75	100
	% of Total	15,9%	11,9%	15,8%
Male	Count	80	79	197
	% of Total	12,7%	12,5%	31,2%

When comparing the proportions in independent variables between genders, significant differences were found in the following variables:

- *city* (p<0,00001), particularly higher share of female respondents in Trondheim than in Oslo and Bergen
- *frequency of cycling* (p<0,00001), with more males cycling *very frequently*
- *education* (p=0,03), with more males with *Master's* degree, while more females with *Bachelor's* degree

The demographics of the respondents who did not complete the questionnaire (n=470) were compared with those of valid respondents. The "non-valid" respondents typically stopped answering when they reached Section 2, where they were asked to choose all conflict types experienced in the last 12 months. They were possibly deterred by the requirement to go through 18 conflict types' schemes. Another explanation could be that they simply had not experience any conflict with a truck and decided to stop answering. Alternatively, it could be a combination of both reasons. There were significant differences between those two samples in the following independent variables:

- *gender* (p=0,03), including more females within non-valid respondents
- *city* (p<0,001), including a smaller proportion of non-valid respondents in Oslo than in Trondheim and Tromsø
- *education* (p<0,001), including higher proportions of non-valid respondents in lower educational categories (*Secondary, Bachelor*)
- *frequency of cycling* (p=0,002), including the highest share of non-valid respondents in *infrequently* category

Furthermore, eight females and five males stated that they had been involved in an accident with a truck in the past. Almost all of these (12) had occurred in Trondheim. The police had not investigate any of these accidents. The number of conflict types experienced by these 13 respondents was significantly higher compared to those who had not reported any accident.

3.2 Hypothesis I: likelihood of a conflict

A total of 381 valid respondents had experienced at least one conflict (54,5% of female and 64,9% of male respondents), while 250 had not experienced any conflict A binomial logistic regression was performed to ascertain the effects of *age*, *gender*, *education*, *city* and *frequency of cycling* on the likelihood that respondents had experienced a conflict with a truck. The binomial logistic regression model (p=0,206) explained 3,1% (Nagelkerke R^2) of the variance in conflict experience and correctly classified 61,0% of cases. Of the five predictor variables, only *gender* was statistically significant (as shown in Table 6). The odds of experiencing a conflict are 1,4 times higher for males as opposed to females.

Table 6. Results of binomial logistic regression model

Variables	B	S.E.	Wald	df	Sig.	Exp(B)	Variables	B	S.E.	Wald	df	Sig.	Exp(B)
gender	0,345	0,170	4,134	1	0,042	0,413	city	-0,070	0,087	0,655	1	0,418	0,932
age			2,081	4	0,721		education			2,920	3	0,404	
age(1)	-0,355	0,414	0,734	1	0,392	0,701	education(1)	0,538	0,359	2,243	1	0,134	1,713
age(2)	-0,143	0,394	0,131	1	0,717	0,867	education(2)	0,345	0,291	1,404	1	0,236	1,412
age(3)	-0,061	0,399	0,024	1	0,878	0,941	education(3)	0,445	0,285	2,435	1	0,119	1,560
age(4)	-0,313	0,417	0,563	1	0,453	0,731	Constant	0,380	0,534	0,507	1	0,476	1,463
frequency			2,738	2	0,254								
frequency(1)	-0,322	0,200	2,573	1	0,109	0,725							
frequency(2)	-,210	0,208	1,018	1	0,313	0,811							

3.3 Hypothesis II: most recent conflict type

Multinomial logistic regression was performed to determine the effects of *age*, *gender*, *frequency of cycling* and *city* on the type of the most recent conflict experienced by respondents. There were 18 conflict types presented to the respondents (see Tab. 7). Note that Norway is right-hand traffic country and cyclists are allowed to cycle on sidewalks provided they give way to pedestrians. Respondents were asked to mark the particular type of conflict that they had most recently experienced. For further analysis, 18 conflict types were merged into five categories, according the truck’s manoeuvre:

1. *Right turn*: the truck is turning right, while the cyclist is going straight ahead on the right side of the truck (either on the road or on a separated infrastructure parallel to the road).
2. *Left turn*: the truck is turning left, while the cyclist is going straight ahead on the opposite side of the road (either on the road or on a separate infrastructure parallel to the road).
3. *Straight – Intersection*: the truck is moving perpendicular to the cyclist, who is either crossing the road within the intersection (e.g. on a zebra crossing) or riding within the intersection.
4. *Straight – Section*: the truck makes a passing/overtaking manoeuvre of a cyclist riding in the roadway
5. *Other*: other types of conflict, specifically described by the respondent (e.g. conflicts related to parked trucks)

The counts of reported most recent conflict categories and the frequencies of particular conflict types are shown in Table 7. The most frequently reported conflict category was *straight-section* conflicts, followed closely by *right turning* conflicts. The most frequent conflict type occurred when a cyclist was overtaken by a truck on the road section (17,1% of all conflicts). The distribution of conflict categories in four cities with most respondents is shown in Table 8.

Table 7. Conflict categories, conflict types and their frequencies within the whole sample (n=381)

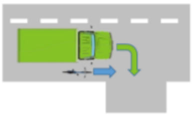
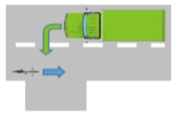
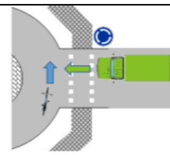
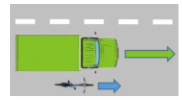
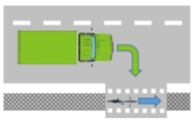
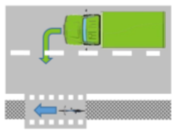
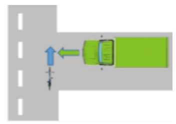
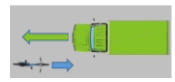
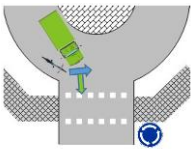
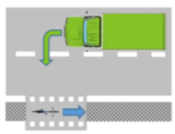
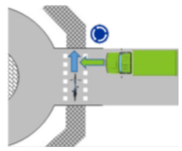
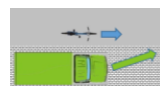
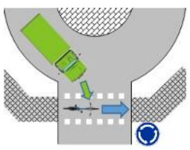
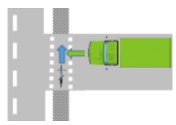
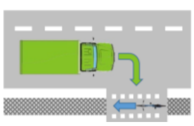
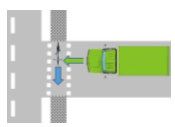
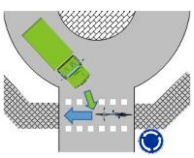
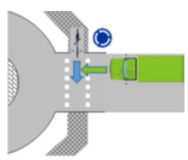
Right turn (n=111; 29,1%)	Left turn (n=22; 5,8%)	Straight – intersection (n=102; 26,8%)	Straight – section (n=118; 31%)	Other (n=28; 7,3%)
 12,9%	 2,9%	 11,5%	 17,1 %	
 9,2%	 1,6%	 5,2%	 8,9%	
 3,4%	 1,3%	 3,1%	 5,0%	
 2,4%		 2,9%		
 1,0%		 2,5%		
 0,2%		 1,8%		

Table 8. Distribution of conflict categories among the cities

City		Conflict category				
		Right turn	Left turn	Straight intersection	Straight section	Other
Bergen	Count	4	5	7	23	4
	% within City	9,3%	11,6%	16,3%	53,5%	9,3%
	% within Conflict cat.	4,0%	23,8%	7,4%	21,7%	15,4%
Oslo	Count	32	5	24	30	3
	% within City	34,0%	5,3%	25,5%	31,9%	3,2%
	% within Conflict cat.	31,7%	23,8%	25,5%	28,3%	11,5%
Trondheim	Count	61	10	56	43	16
	% within City	32,8%	5,4%	30,1%	23,1%	8,6%
	% within Conflict cat.	60,4%	47,6%	59,6%	40,6%	61,5%
Tromsø	Count	4	1	7	10	3
	% within City	16,0%	4,0%	28,0%	40,0%	12,0%
	% within Conflict cat.	4,0%	4,8%	7,4%	9,4%	11,5%

Multinomial logistic regression was performed to test the effects of *age*, *gender*, *education* and *city* on the *conflict category* for the sample of responses from cities Bergen, Oslo, Trondheim and Tromsø (n=348). Among the selected variables, only *city* was found to be significant (p=0,005). See tables 9 and 10 for more details.

Table 9. Multinomial logistic regression model-fit information

	Model Fitting Criteria	Likelihood Ratio Tests		
Model	**-2 Log Likelihood**	**Chi-Square**	**df**	**Sig.**
Intercept Only	520,113			
Final	470,1700	49,943	40	0,135

Table 10. Likelihood Ratio Tests

	Model Fitting Criteria	Likelihood Ratio Tests		
Variable	**-2 Log Likelihood of Reduced Model**	**Chi-Square**	**df**	**Sig.**
Intercept	470,170	0,000	0	.
City	498,543	28,373	12	0,005
Gender	473,076	2,905	4	0,574
Age	483,051	12,880	16	0,681
Frequency of cycling	472,845	2,674	8	0,953

Pairwise comparisons using the z-test of two proportions showed that there were significant differences in the *right-turn category* between Bergen-Oslo and Bergen–Trondheim (less *right-turn* conflicts in Bergen for both comparisons); and in the *straight-section* category between Bergen-Trondheim (more *straight-section* conflicts in Bergen).

3.4 Hypothesis III: total number of conflict types

As each respondent could also check off all conflict types experienced in the last 12 months, the numbers of conflict types experienced by each respondent in each city could be compared. Note that this number does not suggest anything about the frequency or entire number of conflicts experienced by a respondent, as any one type of conflict can be experienced several times, a factor, which is not covered by the survey. There was a significant difference in the mean number of conflict types according to *gender*, as males reported 2.77 and females 1.94 conflict types. Regarding the variable *city*, a significantly lower number of conflict types was reported in Trondheim than in Oslo and Bergen. However, note that there were more female respondents in Trondheim.

3.5 Hypothesis IV: contributory factors and severity

A total of 273 respondents provided their opinion on a contributory factor for the occurrence of their most recent conflict. The differences between contributory factors, conflict categories and background characteristics of respondents were tested. The visibility factor (*truck driver did not see a cyclist*) was reported significantly more frequently in *right-turn* conflicts than in *straight-section* conflicts. Furthermore, the factor *truck driver broke a traffic rule* was reported more often in the *straight-section* than in the *right-turn* category. Female respondents reported significantly more frequently the contributory factor *truck driver did not see a cyclist*.

A total of 342 respondents tried to estimate the conflict's severity. 272 respondents estimated their conflict as slight ("it did not require so much effort to avoid collision") and 70 as severe ("nearly collision, a lot of effort required to avoid collision). There was no significant difference found in the proportion of slight/severe conflicts within the conflict categories.

3.6 Limitations to the interpretation of the results

Several limitations that are typical for a retrospective type of study must be taken into consideration when interpreting the cycle survey's results:

- The survey's response rate cannot be estimated, as the number of people exposed to the survey is unknown.
- The sample is not random. It is possible that cyclists who were involved in a conflict with a truck or who were interested in road safety in general were more attracted to the survey. The number of recorded conflicts is thus perhaps overrepresented due to such a self-selection bias.
- Several areas of bias regarding the self-reporting of conflict can be recognised. For example, there are personal biases involved in the interpretation of conflicts as every respondent has different perceptions and margins of safety. Additionally, there is likely a bias arising from errors in the respondents' understanding of a conflict, even if the definition of conflict was repeated within the survey several times. Furthermore, bias from self-reporting of unpleasant/risky behaviour could have occurred (Nævestad et al., 2014).
- Subjective reports are vulnerable to the influence of recall biases (Schleinitz et al., 2015). The ability to remember a conflict decreases with time from the event (Bernard et.al., 1984). The ability to remember likely differs among respondents and is influenced by the severity of the event (Brener et al., 2003).

- Lack of exact exposure data limits the ability to control the data for exposure, which is partly taken into account within the "frequency of cycling" variable.

4. DISCUSSION

4.1 The sample

The characteristics of valid respondents clearly show that the desired target group, adult cyclists who cycle regularly in urban environments for utilitarian purposes, responded to the survey. The survey sample also appears to be generally representative of the Norwegian cycling population. The proportion between genders in the whole sample corresponds with the National Travel Survey 2013/2014 (Hjorthol et al., 2014), as Norwegian males cycle slightly more than females (they account for 55% of daily bicycle trips). However, the sample shows significant gender differences in particular cities. The majority of respondents were from Trondheim (54%), amongst whom 56% were female. Meanwhile in Oslo and Bergen, the sample contained less females – 25% in Oslo and 29% in Bergen. Such a discrepancy is likely caused by the different places of recruitment to the study between the cities. The majority of valid respondents belong to the 31-40 age bracket and have completed higher education. The sample was slightly younger than the national statistics. According the National Travel Survey, cyclists within the 25-54 age bracket (regardless of gender) make 51% of daily bicycle trips and 58% of bicycle kilometres travelled, and adults who cycle have typically completed a university education. Interestingly, there were significant differences between the individuals who did not complete the questionnaire and those who did.

4.2 Reported conflicts

The results of the survey revealed that 60% of 631 respondents experienced at least one conflict with a truck in the past 12 months. 20% of the conflicts were estimated by the respondents as serious. Such numbers may not appear significant compared to "everyday" occurrence of conflicts with other road users, however, the severity of potential accidents and truck-bicycle conflicts requires recognising them within road safety consideration.

Male cyclists reported conflicts more frequently than females, and, according to the results of the binary regression model, *gender* is the only significant variable explaining if a respondent experienced a conflict or not. Still, more than half of female respondents reported a conflict with a truck. Nevertheless, it is not possible to conclude if female cyclists are as overrepresented in conflicts with trucks as they are in accidents, because there is no relevant data about females involvement in conflicts with which to compare these findings.

Concerning the survey, 13 respondents reported an accident with a truck. Majority of these (8) were females, which supports the overrepresentation of female cyclists in TCA found from the accident analysis (Pokorny et al, 2017). Furthermore, none of those accidents were investigated by the police. This finding confirms previous research, that underreporting is a major issue for bike-truck accidents.

4.3 Conflict types

The most frequently reported conflict type was *being overtaken by a truck* on a road section. *Right-turning truck vs. straight-riding bike* in the same direction was reported as the second most frequent type. This result is surprising, as right-turning accidents (or left in the UK) are considered to be the most frequent accidents in other studies, both in abroad (Volvo Truck, 2013; Niewoehner and Berg, 2005) and in Norway (Pokorny et al.,2017). When considering *city*, overtaking conflicts were most frequent in Bergen, while right-turning conflicts were frequent in Oslo and Trondheim. This difference regarding *city* is supported by the results of multinomial logistic regression that showed significant effect of this variable on conflict category. There are several factors that could explain these differences, e.g. variances in local transport policies, safety culture, traffic characteristics (e.g. frequency of cycling and truck volumes), or different layouts of cycle networks between the cities. The frequency of overtaking conflicts could be associated with both narrow streets and lack of dedicated cycling infrastructure (lack of separation). For example, in Trondheim, the streets are relatively wide (Nordström and Manum, 2015), which when combined with a larger network of separated cycle infrastructure, could contribute to less overtaking/passing conflicts experienced by cyclists in Trondheim. A higher amount of segregated infrastructure could relate to higher percentage of right-turning conflicts in Trondheim, as cyclists' visibility and higher speeds could be an issue. See Table 10 that demonstrates the indicators within the cities, which may influence the frequency of conflict types.

Table 11. Comparison of main cities

Indicator	**Trondheim**	**Oslo**	**Tromsø**	**Bergen**
Bicycle modal share of all trips (Hjorthol et al., 2014)	8,6%	5,0%	4,3%	3,1%
Municipal population 2017 (Statistics Norway, 2017)	191 000	669 000	75 000	279 000
Typical cycling infrastructure	More separated infrastructure and wide streets. Relatively well connected network outside city centre.	Bicycle lanes along some major arterials, but mostly mixed traffic. Good offering of footpaths and shared paths outside the inner city.	No bicycle-specific infrastructure and only very limited shared path facilities. Common for significant snow conditions to last for up to 4 months, covering road markings.	Almost entirely mixed traffic in inner city with some infrastructure along arterials.
Kilometres of municipal shared cycle/pedestrian paths per 1000 inhabitants, data year 2012 (Haagensen, 2013)	0,9	1,7	0,2	0,4
Satisfaction with bicycle infrastructure available - survey response: satisfied or very satisfied (NCF, 2016)*	40,9% (n=249)	23,5% (n=801)	18,4% (n=49)	16,6% (n=169)
Satisfaction with bicycle network connectivity - survey response: satisfied or very satisfied (NCF, 2016)*	14,9% (n=248)	4,9% (n=792)	8,0% (n=50)	4,8% (n=168)
Combined NCF ranking for city cycling conditions among a total of 30 cities (NCF, 2016)*	7	16	22	25
Yearly investment in walking/cycling infrastructure (in millions of kroner)	110 (Strand et al., 2015)	280 (Oslo municipality, 2015)	20 (Melsås, 2017)	44 (Strand et al., 2015)

**Norwegian Cyclists' Federation (NCF) '[Being a] cyclist in your city' survey 2016 [unpublished detailed results].*
Note: Majority of respondents are members of the cyclist organisation and responses are thus not very representative of the entire cycling population (63% in Trondheim and 80-84% across the other cities). Females underrepresented (24% female respondents in Bergen and 30-33% in the other cities). The NCF sample had relatively few respondents under 30 years of age (6%) compared to the retrospective questionnaire for this study.

4.4 Contributory factors

Visibility issues were the most frequent contributory factor for *right turning* conflicts, which corresponds with the findings of several studies stating that reduced vision (likely connected to blind spots and external visibility obstructions) is one of the important risk factors in right-turning accidents (e.g. Johannsen et al., 2015; Seiniger et al., 2015). While there are many factors associated with poor visibility, improper infrastructure layout is one significant contributor. Breaking a rule was reported most often in the *straight-section* category, which could relate to vehicles failing to maintain a safe passing distance from cyclists. Almost all cyclists blamed truck drivers for the occurrence of the conflict.

5. CONCLUSION

Analysis of less severe events in traffic, such as conflicts, has the potential to provide additional knowledge to the understanding of truck-bicycle encounters. Despite its limitations, the retrospective survey of conflicts delivered valuable insight into cyclists' coexistence with trucks from the cyclists' perspective. The results of this research show that cyclists are relatively often experiencing conflicts with trucks, particularly those relating to trucks' overtaking and turning manoeuvres. If these conflicts develop into an accident, the consequences can be very severe. Accidents, and likely conflicts, can also impact cyclists' perceptions of traffic risk, which can affect whether and how frequently people cycle. Within Norway, such an effect can be detrimental to goals associated with large increases in the bicycle mode share.

The expected growth in both of bicycle and truck traffic in urban areas carries important safety concerns. Currently, a range of safety measures and policies exist, aimed at reducing the risks associated with truck-bicycle encounters. These measures address all aspects of the transport system, including vehicles, infrastructure, operations, and regulations. A better understanding of truck-bicycle encounters and recognition of risk factors involved in these encounters can provide evidence-based knowledge to policy makers and planners as they develop such measures to account for expected increase in urban freight and bicycle traffic within growing urban areas. The significant variability in types of truck-bicycle conflicts between major Norwegian cities highlights the need for carefully considering local conditions, when proposing safety measures and policies.

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