ETH zürich

Infrastructure and Operational Influences on Collisions between Trams and Left Turning Cars

Unpublished results

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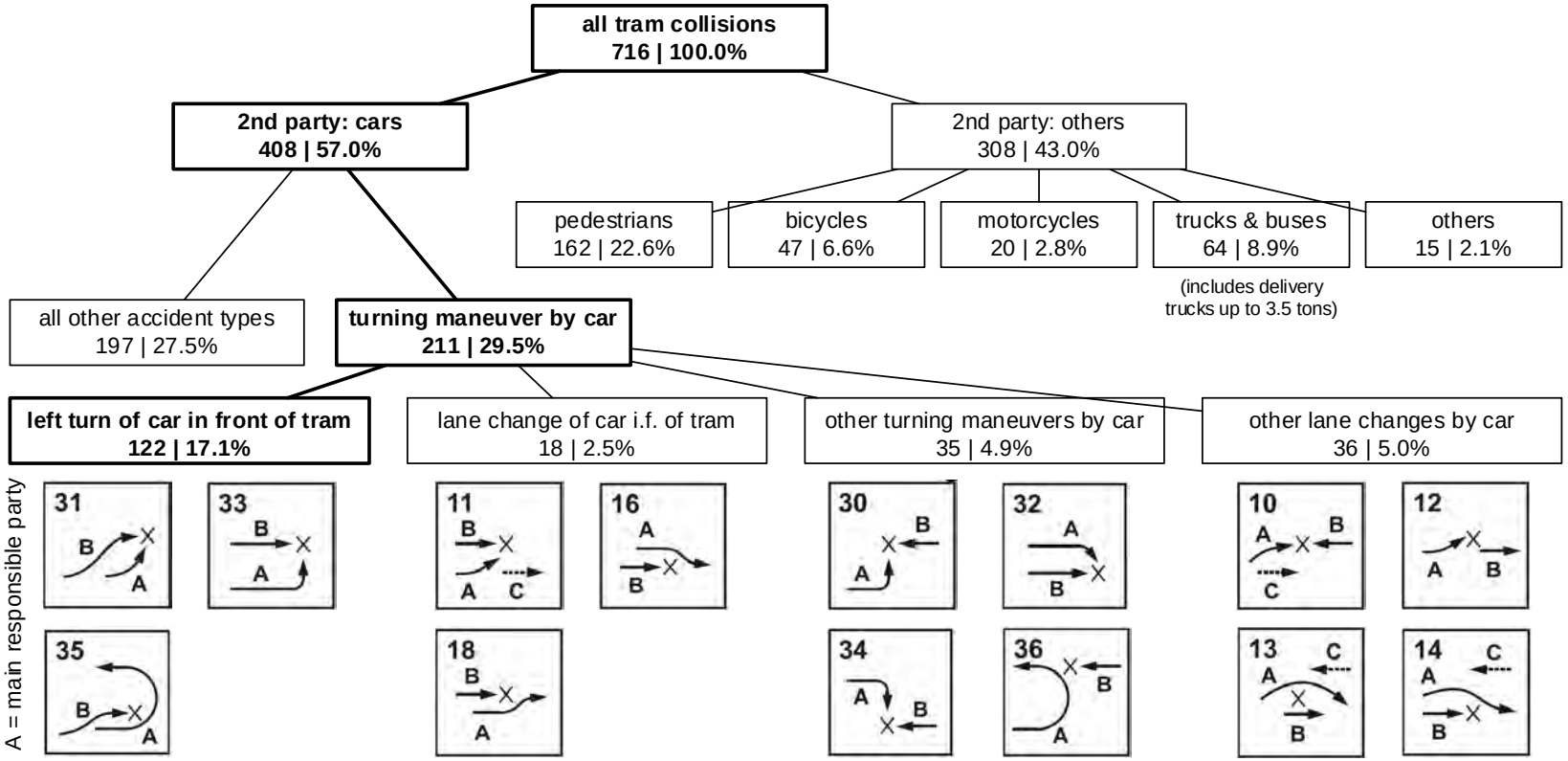
Outline

1. Research Question and Relevance
2. Methods
3. Descriptive Data Analysis
4. Regression Results
5. Discussion and Conclusions

Part 1: Research Question and Relevance

Second parties and accident types for collisions between trams and other road users in Switzerland for years 2012-2014



31: collision during left turn with vehicle behind
33: collision during left turn with vehicle behind that drives on separate lane
35: collision during U-turn with vehicle behind

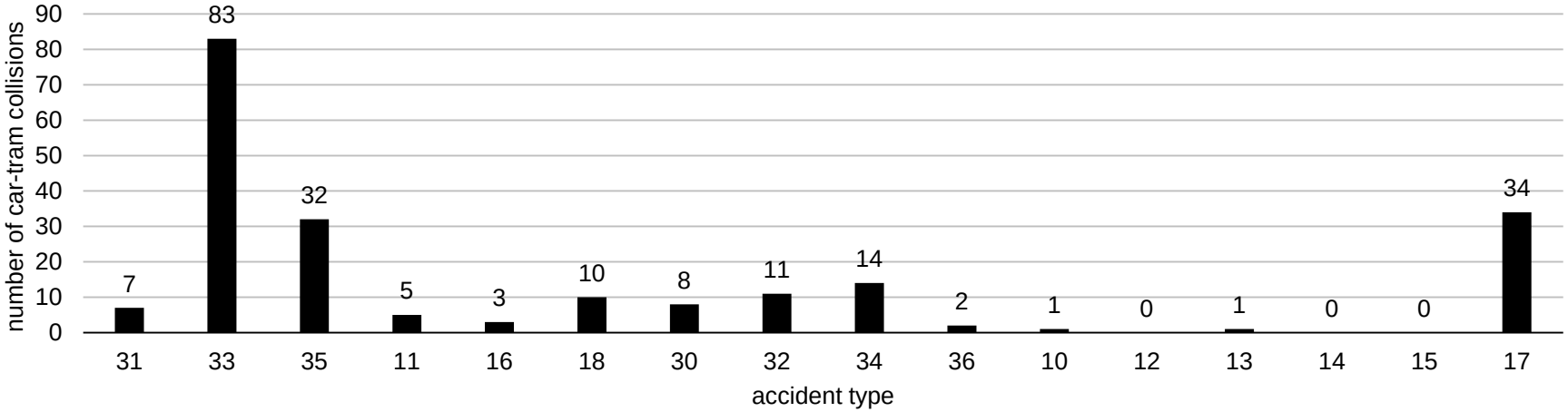
11: collision during overtaking with vehicle behind
16: collision during change to right lane with vehicle behind
18: collision during change to left lane with vehicle behind

30: collision during left turn with oncoming vehicle
32: collision during right turn with vehicle behind
34: collision during right turn with vehicle that drives on seperate lane (both directions)
36: collision during U-turn with oncoming vehicle

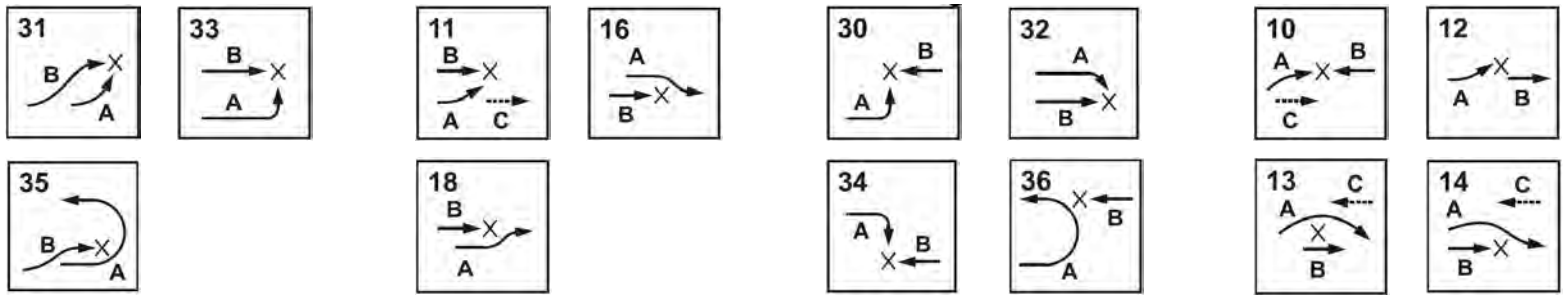
10: collision during overtaking with oncoming vehicle
12-15: collision during overtaking with vehicle in front
17: side swipe collision

Accident numbers: Federal Roads Office, accident statistics (*16*)
Accident type icons: Federal Roads Office (*17*)

Second parties and accident types for collisions between trams and other road users in Switzerland for years 2012-2014



A = main responsible party



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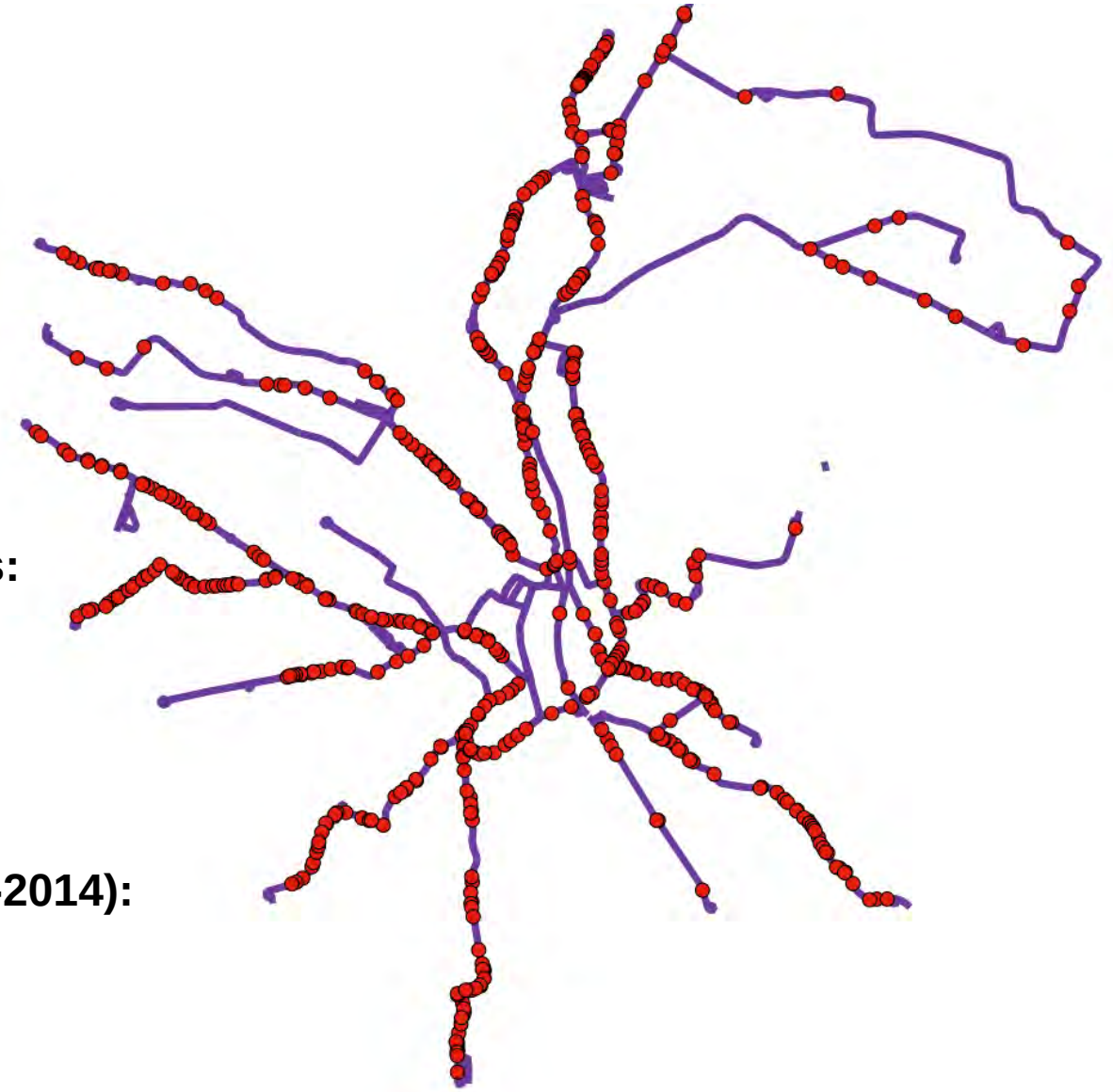
Research gap / goal

Identify factors that influence the occurrence of left-turning car-tram collisions with a quantitative analysis

Part 2: Methods

Approach

- Identify all left turning car-tram **conflict points**:
  - **Trace** entire tram networks of Zurich and Basel (Switzerland) using OpenStreetMap maps and Google Maps aerial pictures and street view
  - **Mark** every location where a left turn across the tramway is possible and has a destination (either a road or a local facility) as a conflict point in a GIS software (per direction)
- For each conflict point, **collect data** on dependent and predictor variables
- Use this dataset for a **regression analysis**



Number of conflict points:
Basel: 247
Zurich: 546
Total: 793

Number of left-turning car-tram collisions (2010-2014):
Basel: 32
Zurich: 93
Total: 125

Regression Models

$$E[collisions_i] = g^{-1}\left(\beta_0 + \sum_j \beta_j X_{i,j}\right)$$

$$E[collisions_i] = \beta_0\, Q_{Tram}^{\beta\_Q\_tram}\, Q_{Car}^{\beta\_Q\_car}\, exp\left(\sum_j \beta_j X_{i,j}\right)$$

Dependent variable	no. of left-turning car-tram collisions (collisions/5years)
Traffic volume	car traffic volume on road with tramway (AAWT) tram traffic volume (trams/h in peak)
Road type	*car turning onto (yes=1, no=0)* main road minor road driveway, shop, gas station, parking, etc.
Speed	modelled car speed on road with tramway (km/h) operational tram speed (km/h)
Tramway layout	*tramway lane just before conflict point (yes=1, no=0)* separated, no violation possible (fence, high curb, etc.) traversable separation (curb, grass track, etc.) special texture, lines, marks mixed use (lane separation as for cars) lateral tramway position in road (yes=1, no=0)
Intersection layout	left turn lane (yes=1, no=0) *angle of turning road relative to tramway (yes=1, no=0)* less than 60° (soft turn) between 60° and 120° (approx. right angle) more than 120° (sharp turn)
Intersection control	traffic light (yes=1, no=0) left turn restriction (yes=1, no=0)
Road network	no. of intersections within 250m radius (along tram axis)
Tram network	within 80m of tram stop (yes=1, no=0)
Road geometry	in curve with radius < 50m (yes=1, no=0)

Conflict Point Identification

Conflict point = “a location where the paths of two motor vehicles […] queue, diverge, merge, or cross each other” (Robinson et al. p. 104)

Limited to: car-tram conflicts

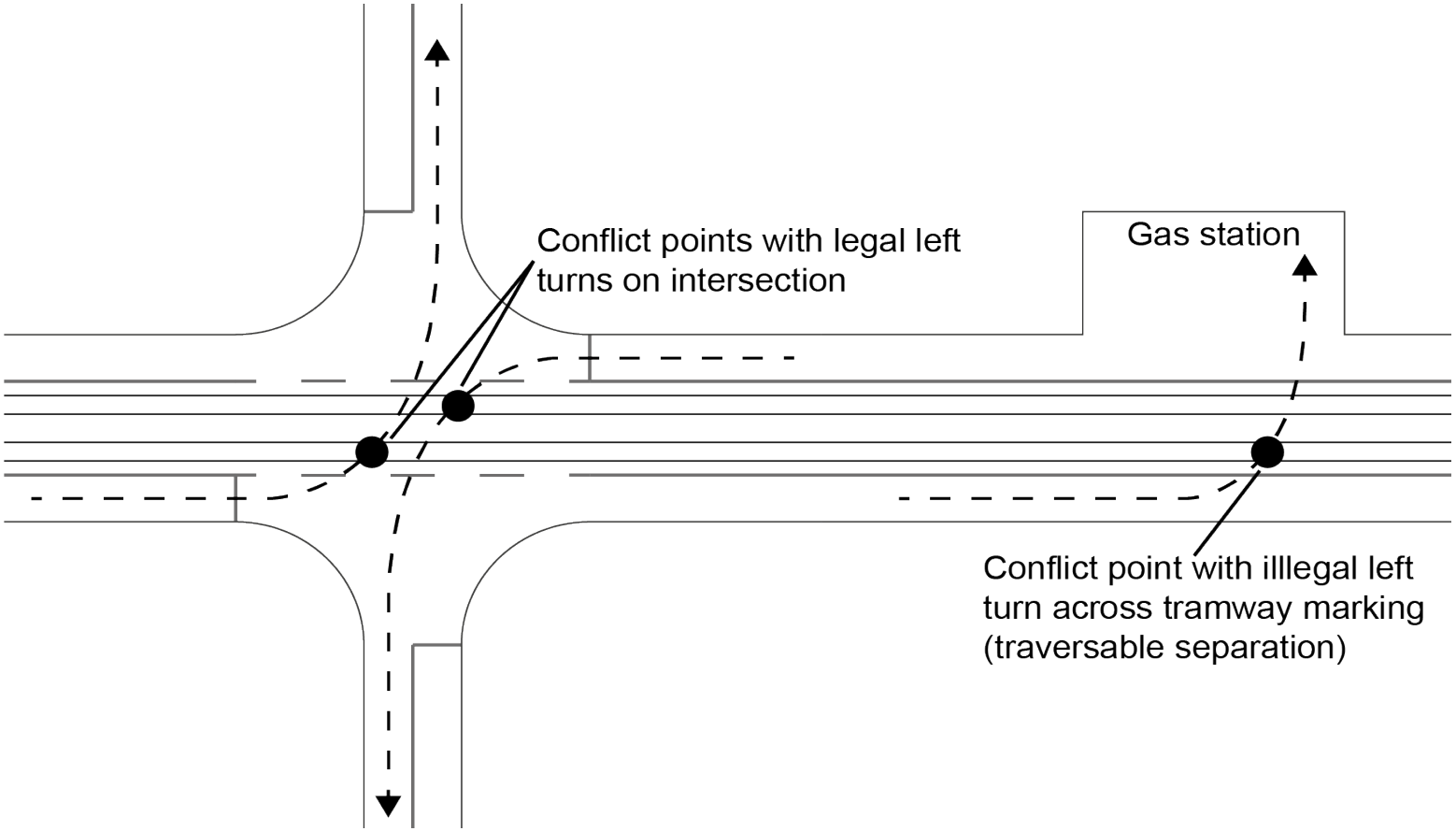
Of those, only consider crossing conflicts between cars and trams that initially drive in the same direction

Respective crashes = “left turning car-tram collision”

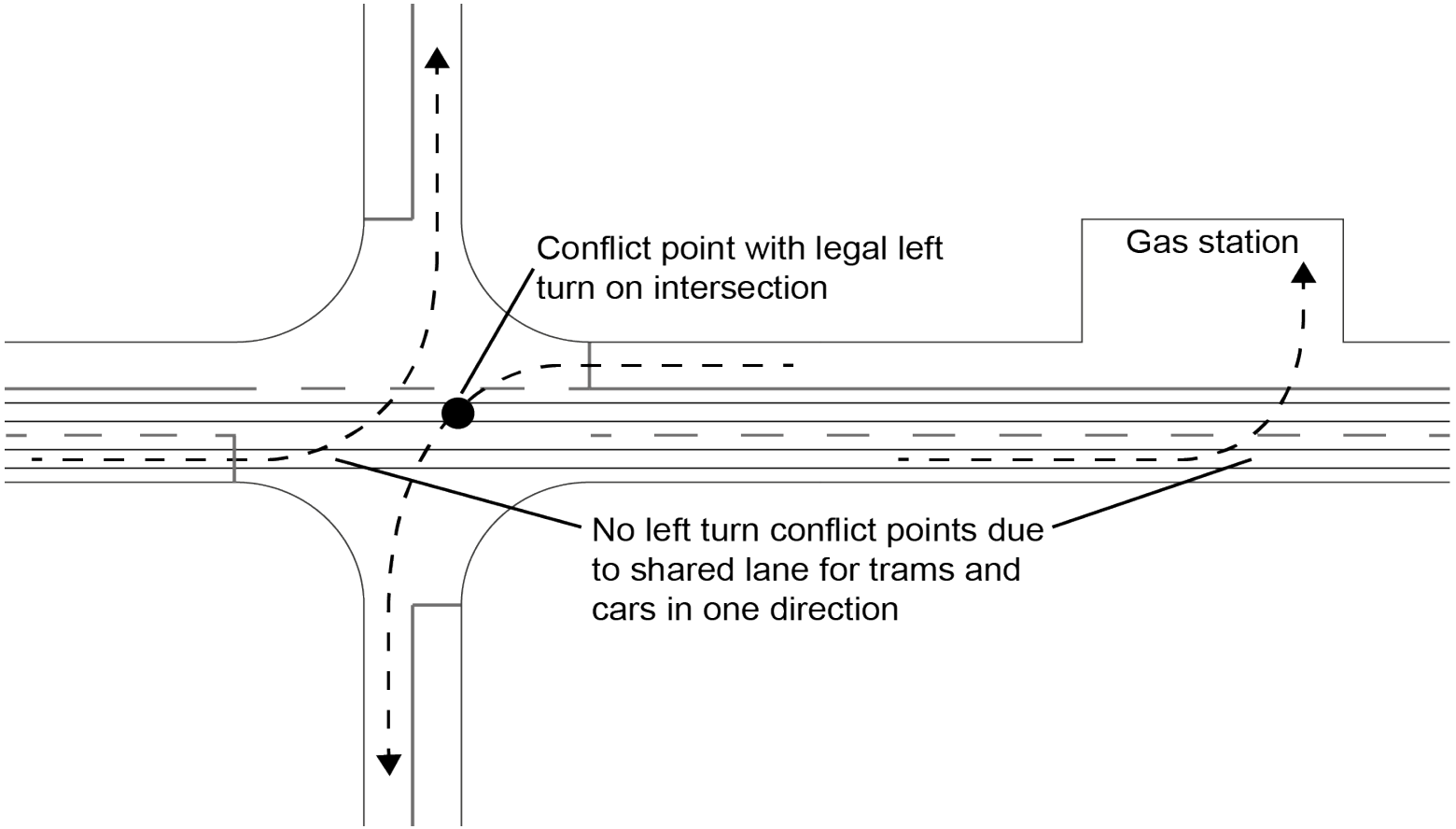
Not considered:

- crossing conflicts with oncoming trams
- diverging conflicts with trams driving in the same direction in the same lane

Conflict Point Identification with seperate lane



Conflict Point Identification with mixed lane




Hofwiesenstrasse / Brunnenhofweg


36
Hofwiesenstrasse / Brunnenhofweg

Hofwiesenstrasse (dir. Radiostudio)

Hofwiesenstrasse / Seminarstrasse


Winterthurerstrasse / Riedtlistrasse


Winterthurerstrasse / Riedtlistrasse

Winterthurerstrasse / Riedtlistrasse

Universitätsstrasse / Sonneggstrasse

Universitätsstrasse / Sonneggstrasse

Universitätsstrasse / Sonneggstrasse

Weinbergstrasse / Riedtlistrasse

Limmatstrasse / Hafnerstrasse


Seilergraben / Mühlegasse


Limmatstrasse / Gasometerstrasse


MIGROS
Limmatstrasse / Gasometerstrasse


Museumstrasse (dir. Sihlquai)


Museumstrasse (dir. Sihlquai)


Hönggerstrasse / Dorfstrasse

Limmattalstrasse (direction Schwert)

Part 3: Descriptive Data Analysis

Dependent variable	no. of left-turning car-tram collisions (collisions/5years)	**0.1576**
Traffic volume	car traffic volume on road with tramway (AAWT)	**7927**
	tram traffic volume (trams/h in peak)	**26.02**
Road type	*car turning onto (yes=1, no=0)*	
	main road	**0.1929**
	minor road	**0.3985**
	driveway, shop, gas station, parking, etc.	**0.4073**
Speed	modelled car speed on road with tramway (km/h)	**43.15**
	operational tram speed (km/h)	**44.28**
Tramway layout	*tramway lane just before conflict point (yes=1, no=0)*	
	separated, no violation possible (fence, high curb, etc.)	**0.1955**
	traversable separation (curb, grass track, etc.)	**0.0517**
	special texture, lines, marks	**0.2219**
	mixed use (lane separation as for cars)	**0.5309**
	lateral tramway position in road (yes=1, no=0)	**0.0668**
Intersection layout	left turn lane (yes=1, no=0)	**0.1349**
	angle of turning road relative to tramway (yes=1, no=0)	
	less than 60° (soft turn)	**0.0467**
	between 60° and 120° (approx. right angle)	**0.8979**
	more than 120° (sharp turn)	**0.0555**
Intersection control	traffic light (yes=1, no=0)	**0.2585**
	left turn restriction (yes=1, no=0)	**0.1942**
Road network	no. of intersections within 250m radius (along tram axis)	**6.622**
Tram network	within 80m of tram stop (yes=1, no=0)	**0.4489**
Road geometry	in curve with radius < 50m (yes=1, no=0)	**0.0315**

Left-Turning Car-Tram Collisions (2010-2014) vs. Conflict Point Rates

Characteristic	Basel	Zurich	Total	Zu/Ba
network length in km	84.5	82.4	166.9	0.98
mil. train revenue km (5 years)	48.2	65.6	113.8	1.36
left turning car-tram collisions (5 years)	32	93	125	2.91
left turning car-tram conflict points	247	546	793	2.21
conflict points / network km	**2.92**	**6.63**	4.75	**2.27**
conflict points / mil. revenue km (5 years)	**5.12**	**8.32**	6.94	**1.62**
collisions (5 years) / network km	**0.38**	**1.13**	0.75	**2.98**
collisions (5 years) / mil. revenue km (5 years)	**0.66**	**1.42**	1.10	**2.14**
collisions (5 years) / conflict points	**0.13**	**0.17**	0.16	**1.31**

Part 4: Regression Results

Variable	Poisson	NB (full)	NB (forward selection)	ZINB (full)	ZINB (forward selection)
count model:					
(Intercept)	-4.354 (1.99) *	-5.75 (2.017) **	-4.271 (1.184) ***	-2.402 (2.946)	-2.382 (0.929) *
log_Q_car	0.083 (0.152)	0.179 (0.152)		-0.205 (0.196)	
log_Q_tram	**0.684 (0.254) ** **	**0.694 (0.253) ** **	**0.612 (0.238) * **	0.793 (0.389) *	**0.646 (0.245) ** **
turning_onto2	-0.117 (0.332)	0.047 (0.344)	0.03 (0.312)	-0.413 (0.339)	
turning_onto3	**-1.014 (0.43) * **	**-0.784 (0.426) . **	**-0.767 (0.377) * **	-0.234 (0.46)	
car_speed	-0.009 (0.016)	-0.012 (0.016)		-0.045 (0.017) **	
tram_speed	**0.037 (0.017) * **	**0.042 (0.016) ** **	**0.038 (0.014) ** **	0.072 (0.023) **	
lane_separation2	-0.024 (0.283)	-0.003 (0.279)		0.741 (0.353) *	
lane_separation3	-0.663 (0.664)	-0.625 (0.632)		-0.733 (0.664)	
lane_separation4	-0.293 (0.4)	-0.153 (0.395)		-0.232 (0.444)	
left_turn_lane1	**0.927 (0.352) ** **	**0.732 (0.366) * **	**0.62 (0.321) . **	1.258 (0.503) *	**0.597 (0.295) * **
light1	-0.345 (0.338)	-0.204 (0.337)		-0.141 (0.32)	
restriction1	-0.492 (0.376)	-0.521 (0.35)	**-0.567 (0.325) . **	-1.608 (0.43) ***	**-0.674 (0.326) * **
Intersections	-0.022 (0.033)	-0.004 (0.032)		-0.036 (0.04)	
stop1	**-0.956 (0.254) *** **	**-0.847 (0.25) *** **	**-0.863 (0.245) *** **	-0.912 (0.35) **	**-0.848 (0.238) *** **
angle1	**-0.854 (0.363) * **	**-0.775 (0.417) . **	**-0.845 (0.402) * **	0.197 (0.436)	**-0.839 (0.38) * **
angle2	-0.653 (0.502)	-0.611 (0.561)	-0.702 (0.544)	-0.725 (0.45)	-0.741 (0.512)
curve1	-0.899 (1.234)	-0.737 (1.056)		-1.468 (1.067)	
lateral1	0.329 (0.493)	0.274 (0.49)		-0.361 (0.706)	
zero model:					
(Intercept)				3.457 (6.975)	11.136 (3.77) **
log_Q_car				-0.86 (0.445) .	**-0.81 (0.35) * **
log_Q_tram				0.143 (0.947)	
turning_onto2				-1.25 (0.867)	-1.406 (1.252)
turning_onto3				0.998 (1.098)	1.354 (1.121)
car_speed				-0.108 (0.04) **	
tram_speed				0.104 (0.067)	**-0.109 (0.046) * **
lane_separation2				1.793 (0.946) .	
lane_separation3				-1.178 (2.998)	
lane_separation4				-0.438 (1.279)	
left_turn_lane1				2.168 (1.364)	
light1				-0.57 (0.858)	
restriction1				-5.836 (3.236) .	
Intersections				-0.011 (0.094)	
stop1				-0.105 (0.768)	
angle1				3.975 (1.542) **	
angle2				-17.29 (2288.152)	
curve1				-17.462 (4120.734)	
lateral1				-1.519 (1.682)	

Variable	Poisson	NB (full)	NB (forward selection)	ZINB (full)	ZINB (forward selection)
Θ		0.593 (0.203)	0.578 (0.197)	3.833e+4 (1.057e+59)	1.031 (1.672)
Goodness of fit:					
ll	-338	-327	-330	-308	-325
AIC	714	694	682	695	676
R^2	**0.124**	**0.081**	**0.073**	**0.134**	**0.088**
R_{adj}^2	0.075	0.028	0.045	0.027	0.054

The significance codes for the z-test of the model coefficients are the following: *** for a p-value below 0.001, ** for a p-value below 0.01, * for a p-value below 0.05, and . for a p-value below 0.1

Part 5: Discussion and Conclusions

Conclusions

- Caution with inference; models have important limiations:
  - no turning car traffic volume data
  - non-negligible correlation between predictors
- More precise data could improve predictive power, (left-turning traffic volumes, signal type and synchronization, intersection geometry)
- Low R^2 → important portion of variability in the data is not explained by the predictors
  - left turning car-tram collisions not only depend on infrastructure and operational factors: drivers' and vehicles' characteristics matter, as well as accident circumstances such as weather or time of day

Conclusions

- Costly analysis, limited predictive power: is it worth it?
- On the other hand: until now, these relationships have not been examined statistically, it was “only” expert knowledge…
- Other countries have better data!
- Thinking about layout trade-offs offers new insights (mixed section vs. more conflict points, speed vs. accident frequency) – operation vs. safety?

Thank you

Sources and Acknowledgments

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Accident data: Bundesamt für Strassen ASTRA, Strassenverkehrsunfall-Statistik

Network load: Timetables 2015

GIS analysis conducted with QGIS, Version 2.12.3

Statistical analysis conducted with RStudio

Photographs: C.M. Marti