Analyzing the Reporting Error of Public Transport Trips in the Danish National Travel Survey Using Smart Card Data

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Outline

- Household Travel Surveys and Smart Card Data
- Case of Denmark
- Statistical Analysis
- Conclusion

Household Travel Surveys and Smart Card Data

Household Travel Surveys (HTSs)

- Provide contextual information about travel behavior, travel preferences, socio-economic characteristics, attitudes etc.
- Most travel surveys rely on the respondents' ability to accurately report:
  - Number of trips, origin and destination, departure time, trip duration etc.

"Unfortunately, people are notoriously poor at providing accurate reports of any of this information" Stopher et al. (2007)

- **Recall Bias**: A well-known tendency for respondents to report travel details inaccurately but can it be quantified?

Smart Card Data Vs. Travel Surveys

- Comparison is mostly done at the population/aggregate level
- Underreporting or overreporting of trips based on trip purpose, time of day etc. (Spurr et al., 2018; Chapleau et al., 2018; Egu and Bonnel, 2020)
- Few efforts have been made for individual/disaggregate comparison (Spurr et al., 2015; Su et al., 2022; Riegel and Attanucci, 2014)
- Such studies are mainly limited by time constraints (e.g., one day, different time periods)

Objectives

Literature Gap:

- Lack of exhaustive and comprehensive comparison at the individual level
- Reporting error vs. socio-economic and demographic characteristics

This Study:

- Matches 5 consecutive years of SC data and HTS from Denmark
- Quantifies reporting error of public transport users in the Danish HTS
- Investigates relationships between reporting error and socio-economic characteristics

Case of Denmark

Smart Card – Rejsekort – Data

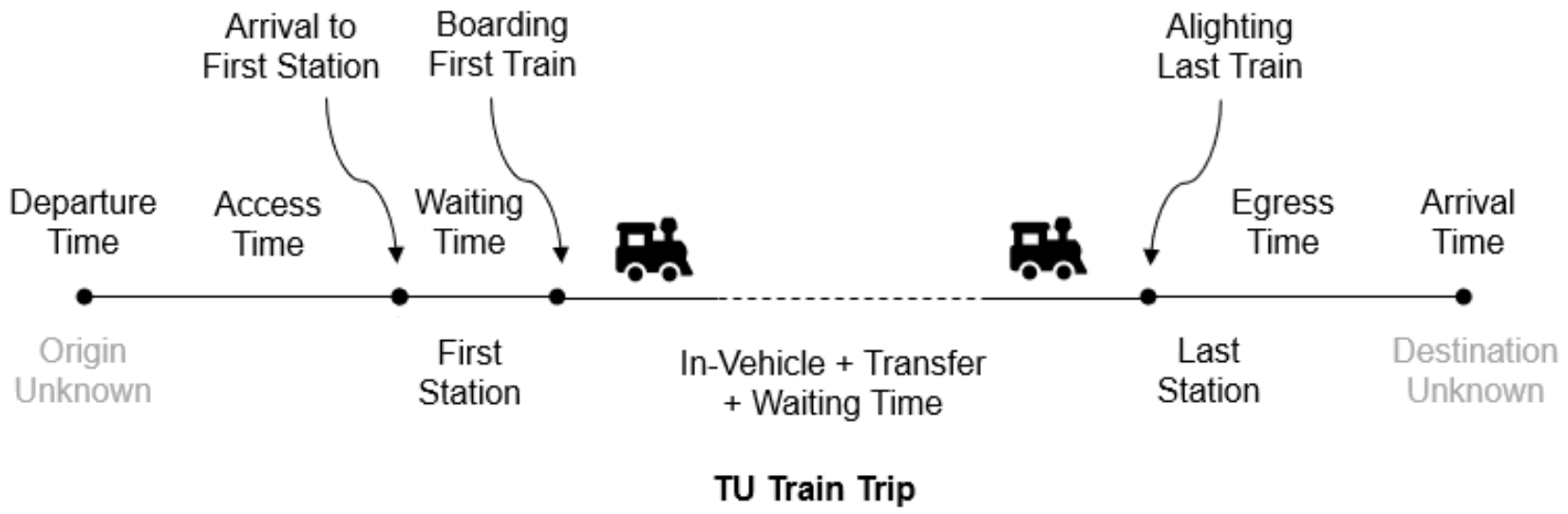
- Rejsekort: nationwide SC system in Denmark
- Passengers tap-in at origins/transfers and tap-out at destinations
- Rejsekort transaction:
  - Type of transaction (tap-in, transfer, or tap-out)
  - Time and location
  - Type of the card
  - Fake card ID (for privacy concerns)

Danish National Travel Survey – TU Data

Year	Reported Rejsekort Trips in TU	Nb of Respondents	Respondents with 2 trips/day	Respondents with 3 trips/day
2018	732	427	223	24
2019	786	442	255	28
2020	681	388	216	19
2021	664	374	218	24
2022	887	485	296	33
Total	3,750	2,116	1,208	128

- Only those with 2 or 3 trips per day are matched: 1,336 respondents with 2,800 trips

Matching – Respondents with Train Trips



$\Delta T_{n,First\_St_i}$

$\Delta T_{n,Last\_St_i}$

Absolute time difference:

$$\Delta T_n = \sum_{i=1}^{I_n} \Delta T_{n,First\_St_i} + \sum_{i=1}^{I_n} \Delta T_{n,Last\_St_i}$$

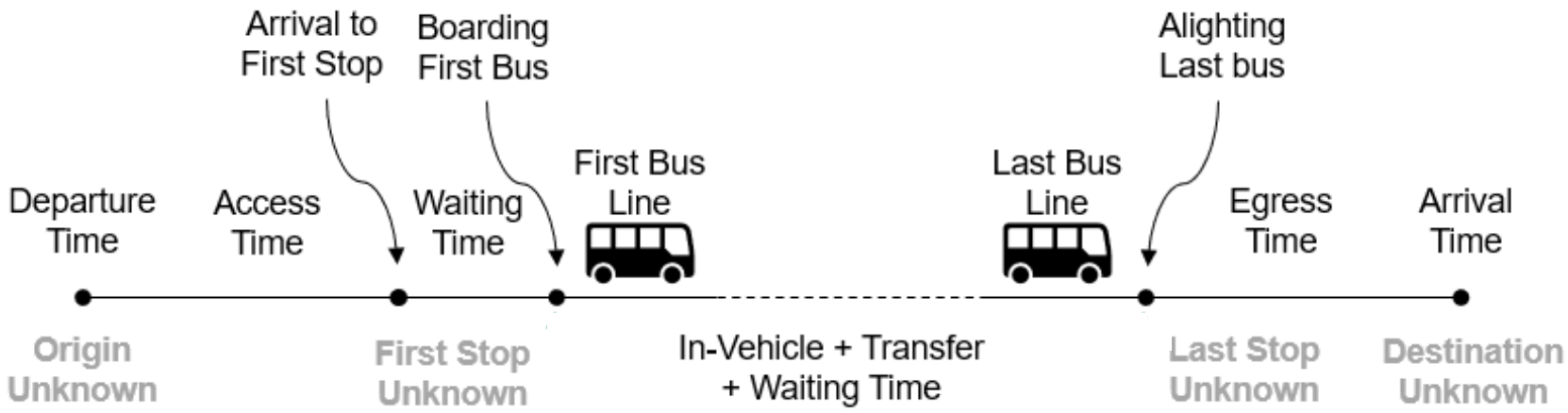
Matching – Respondents with Train Trips

- Given an individual n who reported I_n: $\{2,3\}$ trips by train on a specific day
- Get the names of the first and last stations of each trip from TU data
- Find I_n: $\{2,3\}$ trips in the Rejsekort data made by the same Rejsekort card that match the names of the stations
- Compute ΔT_n: absolute time difference between Tap-in/Tap-out times from Rejsekort data and Arrival to first/last stations from TU data of all trips

$$\Delta T_n = \sum_{i=1}^{I_n} \Delta T_{n,First\_St_i} + \sum_{i=1}^{I_n} \Delta T_{n,Last\_St_i}$$

- If there are more than 1 match ➔ select the one with the smallest ΔT_n

Matching – Respondents with Bus Trips



- Bus lines are used in the matching process instead of station names
- Mixed trips: combination of the train (stations) and bus (lines) matching processes

Matching Results

Year	Individuals with 2 or 3 trips in the TU Data	Matched individuals	% of Matched individuals
2018	257	169	68.42%
2019	283	217	76.68%
2020	235	165	70.21%
2021	242	176	72.73%
2022	329	215	65.35%
Total	1,336	942	70.51%

- 507 individuals with train trips
- 304 individuals with bus trips
- 131 individuals with mix trips

- 898 individuals with 2 trips
- 44 individuals with 3 trips

➔ 1,928 trips

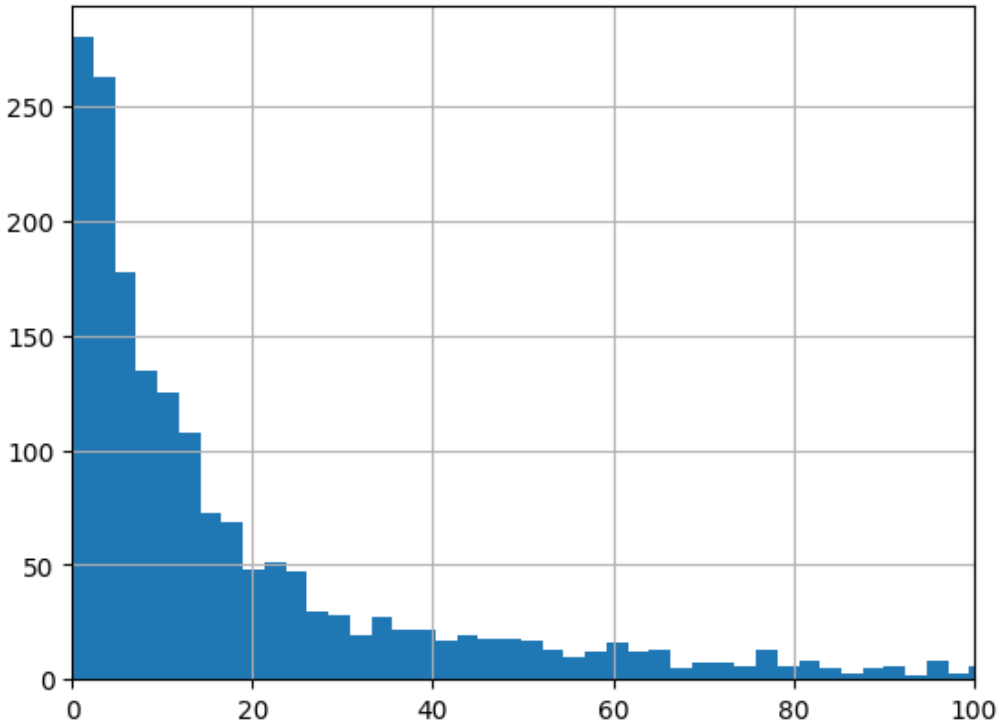
Unmatched Trips – Possible reasons

- People reporting incorrect train/metro stations or bus lines
- Potential data entry mistakes by interviewers
- People forgot to tap-out at the alighting station/stop

Statistical Analysis

Checking Normality

- Dependent variable of interest: time difference at the first stop/station $\left(\Delta T_{n,First\_St_i}\right)$



$\Delta T_{n,First\_St_i}$ in minutes

- Non-normal data ➔ non-parametric tests
- Median: 11.34 minutes
- Interquartile Range (IQR): 28.14 minutes
- Temporal resolution in the TU survey: 5 mins

Mann-Whitney U-Test

		Count	Mean	Std	25%	50% - Median	75%	IQR
Gender	Male	856	37.09	64.10	4.68	13.33	41.71	37.03
	Female	1,072	31.30	65.85	3.75	10.17	25.39	21.64
	P-value					0.000***		
Day Type 1	Weekdays	1,623	33.38	64.58	3.83	11.00	31.57	27.73
	Weekends	305	36.49	68.00	5.72	13.23	37.15	31.43
	P-value					0.015**		
Day Type 2	Weekdays	1,502	32.11	62.83	3.82	10.78	29.67	25.85
	Weekends & Holidays	426	40.09	72.39	5.61	13.61	40.63	35.02
	P-Value					0.000***		

** significance at the 95% level of confidence
*** significance at the 99% level of confidence

Mann-Whitney U-Test

		Count	Mean	Std	25%	50% - Median	75%	IQR
Interview Type	Internet	424	22.85	48.96	2.85	7.23	18.33	15.48
	Telephone	1,441	37.14	69.06	4.68	12.72	36.60	31.92
	P-value					0.000***		
Schedule Flexibility	Fixed	1,447	33.28	67.00	3.88	10.78	28.92	25.03
	Flexible	418	35.37	59.141	4.55	14.59	39.65	35.10
	P-value					0.002***		
Location	Zealand & Funen	1,610	35.42	66.62	4.52	12.31	34.63	30.10
	Jutland	318	26.06	56.43	2.95	7.63	21.19	18.24
	P-value					0.000***		

** significance at the 95% level of confidence
*** significance at the 99% level of confidence

Sensitivity Analysis

		Cut-off point									
		All data		200 mins		100 mins		60 mins		30 mins	
		Count	Median	Count	Median	Count	Median	Count	Median	Count	Median
Gender	Male	856	13.33	804	12.00	720	10.63	622	8.63	463	6.47
	Female	1,072	10.17	1,006	9.23	950	8.44	880	7.84	708	6.29
	P-value		0.000***		0.000***		0.000***		0.028**		0.353

* significance at the 90% level of confidence
** significance at the 95% level of confidence
*** significance at the 99% level of confidence

Kruskal-Wallis H Test

		Count	Mean	Std	25%	50% Median	75%	IQR
Mode	Train	1,029	34.26	63.54	4.65	12.70	36.60	31.95
	Bus	622	33.08	66.21	3.77	9.69	26.60	22.84
	Mixed	277	34.21	68.63	3.93	10.50	24.10	20.17
	P-value					0.006***		

*** significance at the 99% level of confidence

Sensitivity Analysis

		Cut-off point									
		All Data		200 mins		100 mins		60 mins		30 mins	
		Count	Median	Count	Median	Count	Median	Count	Median	Count	Median
Mode	Train	1,029	12.70	971	11.72	908	10.7	808	9.66	567	6.95
	Bus	622	9.69	582	8.85	529	7.85	482	6.92	414	5.73
	Mixed	277	10.50	257	9.22	233	7.82	212	7.32	190	6.41
	P-value		0.006***		0.002***		0.000***		0.000***		0.085*
Year	2018	347	14.68	322	11.63	296	10.73	262	9.13	180	5.88
	2019	444	12.00	410	10.63	381	9.40	345	8.15	282	6.81
	2020	336	11.22	314	9.58	296	8.90	263	7.83	205	5.60
	2021	362	11.28	347	11.00	321	10.05	293	8.85	232	6.97
	2022	439	10.12	417	9.68	376	8.29	339	7.43	272	6.31
	P-value		0.161		0.285		0.11		0.15		0.35
Position in Family	Single	659	13.33	602	12.00	550	10.41	500	9.67	373	6.95
	Older in Couple	391	11.42	377	10.85	353	9.68	303	8.15	232	6.29
	Younger in Couple	461	9.28	439	8.83	409	7.82	387	6.98	317	6.00
	Child < 25 years	417	11.02	392	10.35	358	8.92	312	7.51	249	6.45
	P-value		0.003***		0.029**		0.025**		0.112		0.658

* significance at the 90% level of confidence
** significance at the 95% level of confidence
*** significance at the 99% level of confidence

Wilcoxon Signed-Ranks: 1st Trip vs. 2nd Trip

	Count	Mean	Std	25%	50% Median	75%	IQR
All data							
1st Trip	898	32.11	64.42	3.78	10.23	30.99	27.22
2nd Trip	898	35.88	66.03	4.57	12.64	34.31	29.74
P-value					0.002***		

*** significance at the 99% level of confidence

Primacy Effect?

Sensitivity Analysis

	Count	Mean	Std	25%	50% Median	75%	IQR
Cut-off point – 200 mins							
1st Trip	842				9.38		
2nd Trip	842				11.60		
P-value					0.003***		
Cut-off point – 100 mins							
1st Trip	781				8.37		
2nd Trip	781				10.28		
P-value					0.007***		
Cut-off point – 60 mins							
1st Trip	703				7.08		
2nd Trip	703				9.23		
P-value					0.002***		
Cut-off point – 30 mins							
1st Trip	551				5.63		
2nd Trip	551				7.40		
P-value					0.001***		

*** significance at the 99% level of confidence

Findings

More Accurate	Less Accurate
Women	Men
Younger in couple	Older in couple
Fixed schedule	Flexible schedule
Weekdays	Weekends & holidays
Internet-based surveys	Telephone-based surveys
Bus trips	Train/Metro trips
Jutland	Zeeland & Funen
1st trip	2nd trip

Conclusion

Conclusion

- Findings highlight the importance of individual-level comparison between SC data and travel surveys
- Better understanding of reporting errors and their connections to different socio-economic & demographic characteristics
- It is hoped that this analysis could help:
  - Improve design of travel surveys and data collection
  - Account for reporting errors/biases when using travel survey data
  - Offer insights underlying the psychology of travel recall by survey respondents

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Thank you!

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