

Revealing Freight Vehicle Tours and Tour Patterns from GPS Vehicle Tracking and Driver Survey Data

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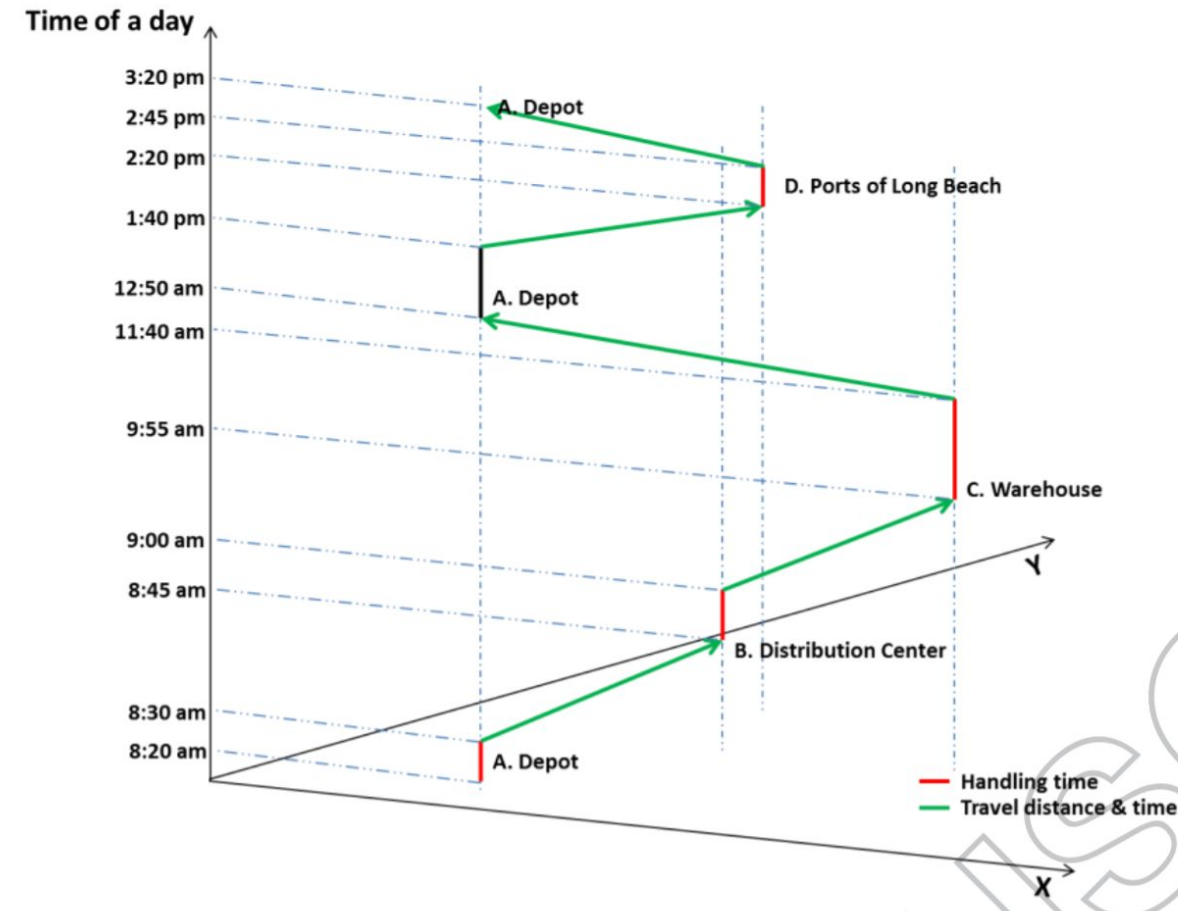
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Contents

- Concepts and motivation
- Method and data
- Results and insights
- Future work

Concepts

- Trip chain & Stop chain for freight vehicles
- Stops
 - Base / depot (A)
 - Intermediate stop / trip-ends (B, C, D)
- Tour (e.g. A,B,C,A)



Source: You et al. (2016)

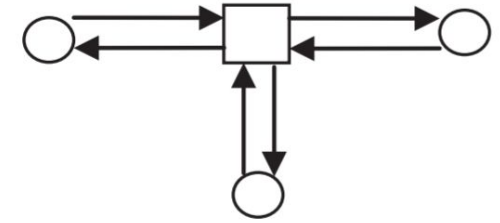
Illustration of a Trip Chain

Past work

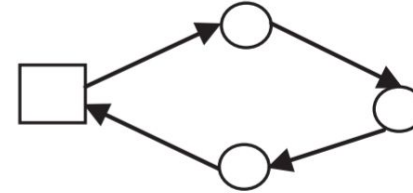
- Most research presents tours already labeled, without detailing the labeling method.
- Research gap identified regarding post-processing methods specific for freight GPS data (except for stop detection).



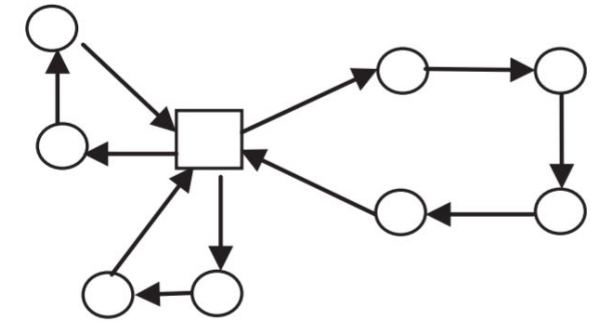
(1) Single Direct



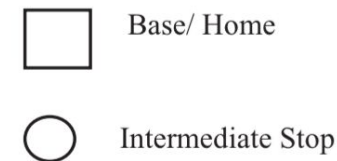
(2) Multiple Direct



(3) Single Peddling



(4) Multiple Peddling

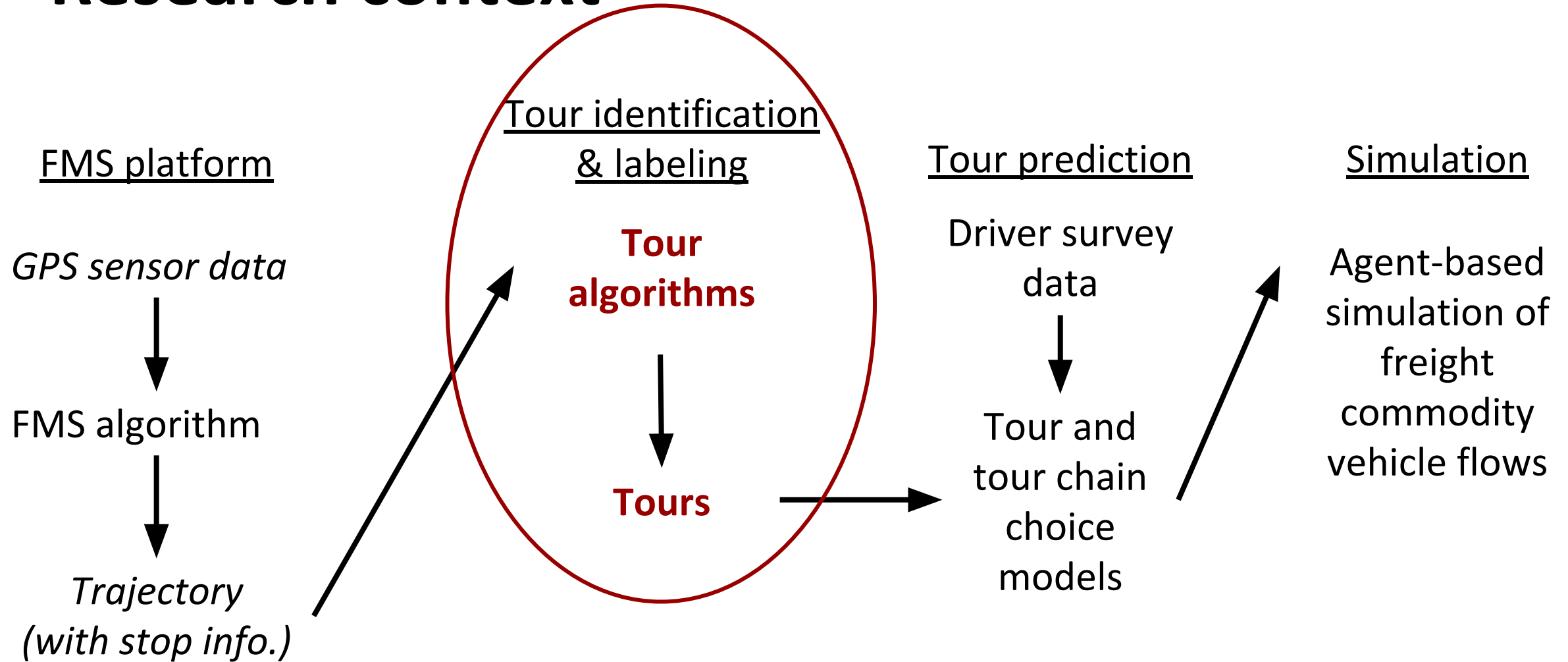


Example of tour patterns proposed in the literature (Ruan et al., 2012).

Motivation

- Model data-driven tour-based goods vehicle behavior in SimMobility Freight.
- Need for algorithm to generate *tour* data from trajectory data.
- Tour-identification and labeling process not been well-established in the past.

Research context



Exploratory scope

Tour identification

- **Stop-driven**
 - **Purpose**
 - **Location**
- Capacity-driven
 - Loaded
 - Delivered
- Base-driven
 - Declared
 - Identified

Tour labeling

- **“Threshold” method**
 - **Labels individual tours**
 - **Generalizes predominant pattern to day**
- **“Full-day” method**
 - **Aims to label a full day pattern**

Tour-identification methods (stop to tour membership)

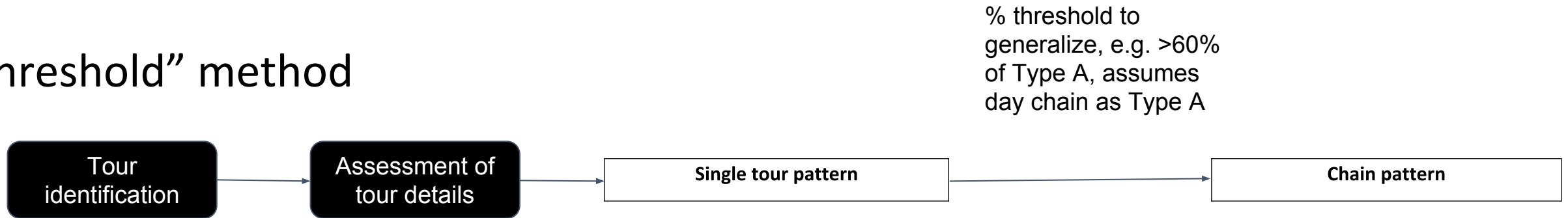
Stop	1	2	3	4	5	7	8
Purpose	P	P	D	D	P	D	P
Base	Yes	No	No	No	Yes	No	No
Capacity Usage (%)	50	100	50	25	75	0	100
Stop-driven tours	1	1	1	1	2	2	3
Base-driven tours	1	1	1	1	2	2	2
Capacity-driven tours	1	1	1	1	1	1	2

Tour identification criteria for *stop-driven method*

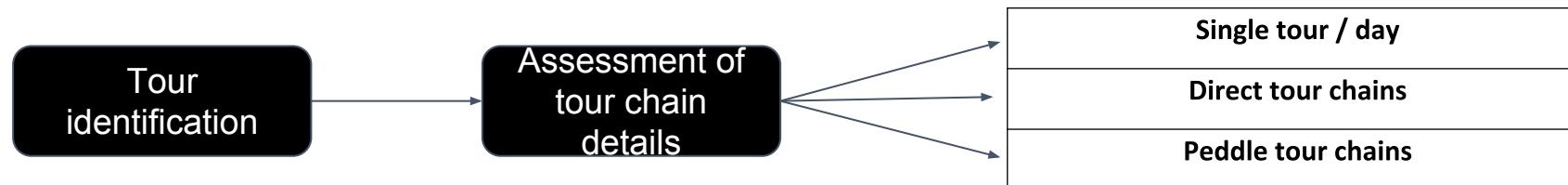
- Pickups following a delivery sequence define new tours.
- Exceptions for long-stops (over 240 mins) or explicit mention of shift end, which force a new tour start for following stop.

Tour labeling methods (what kind of tour)

“Threshold” method



“Full-day” method



Tour and tour-chain patterns



Single tour / day				
Direct	Unloading	Loading	Mixed	Pickups
DIR	UL	L	MX	PT



Direct tour chains			
fixed pickup, fixed delivery	fixed pickup, variable delivery	variable pickup, fixed delivery	variable pickup, variable delivery
FPFD	FPVD	VPFD	VPVD



Peddle tour chains						
fixed pickup, multiple fixed deliveries	fixed pickup, multiple variable deliveries	variable pickup, multiple fixed deliveries	variable pickup, multiple variable deliveries	multiple fixed pickups, fixed delivery	multiple variable pickups, fixed delivery	multiple variable pickups, multiple delivery
FPMFD	FPMVD	VPMFD	VPMVD	MFPFD	MVPFD	MVPMD



Data

Singapore

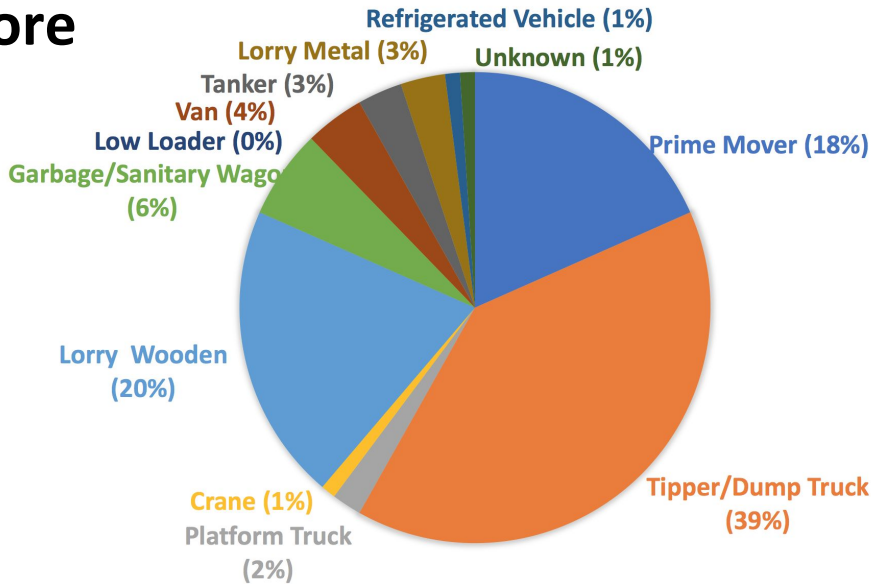
- Singapore-based application of FMS to freight vehicles **(urban)**
- Sample of:
 - 1184 driver (working) days
 - 206 drivers / vehicles

U.S.A.

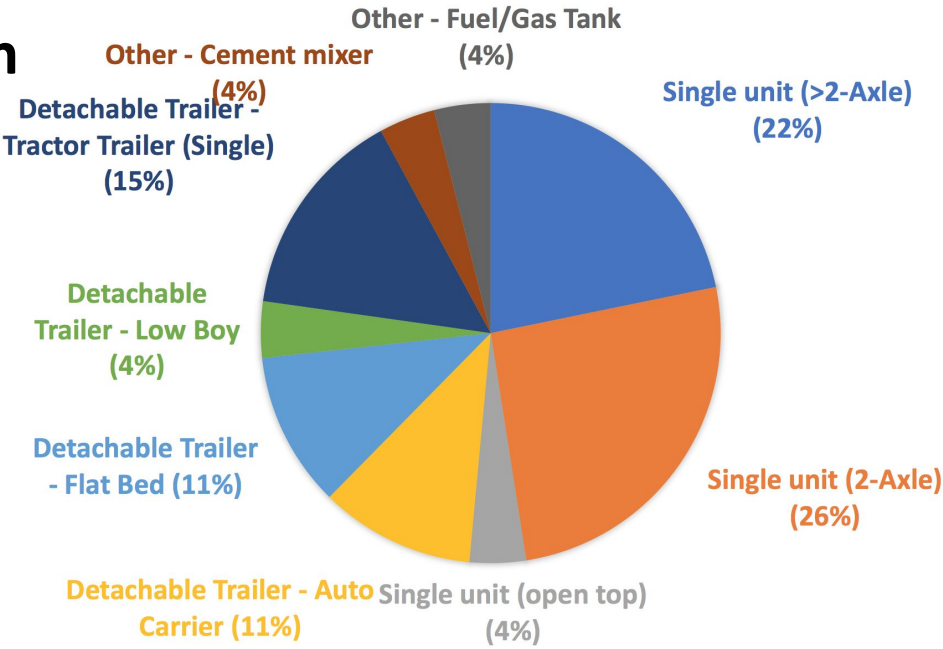
- Boston area application of FMS to freight vehicles **(urban and inter-urban)**
- Sample of:
 - 280 driver (working) days
 - 21 drivers / vehicles

Sample characteristics

Singapore

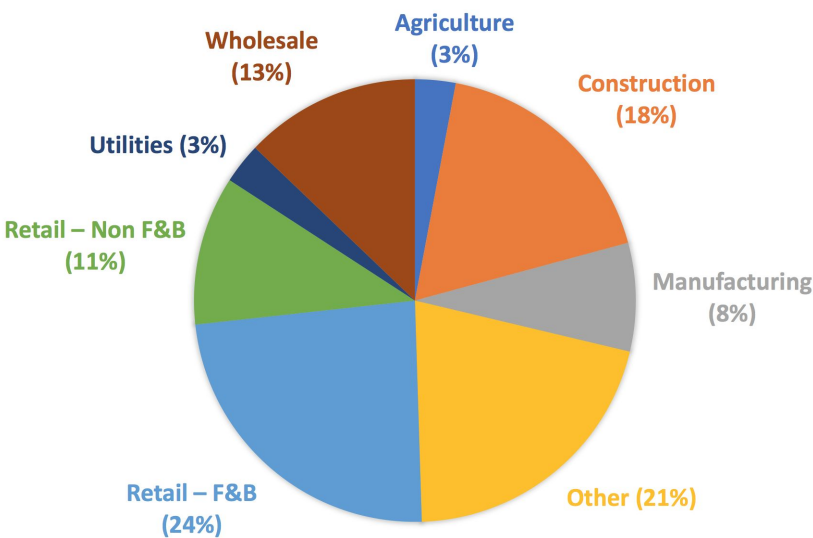
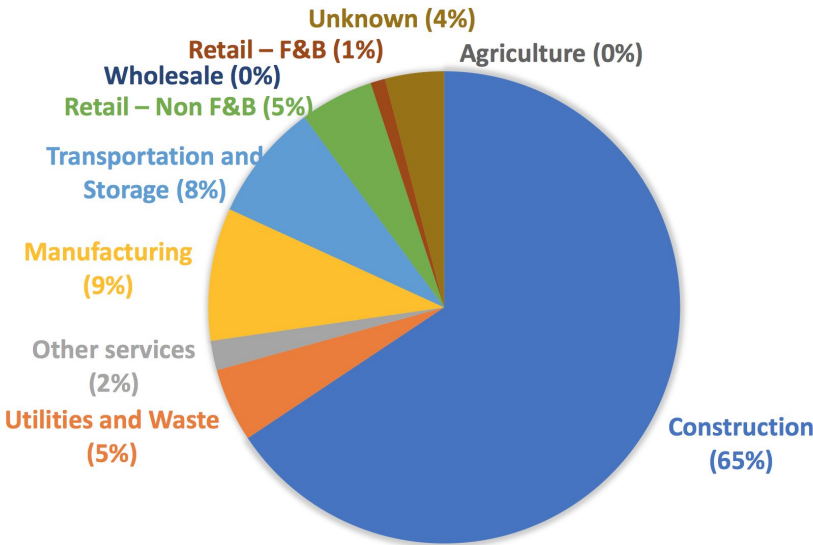


Boston



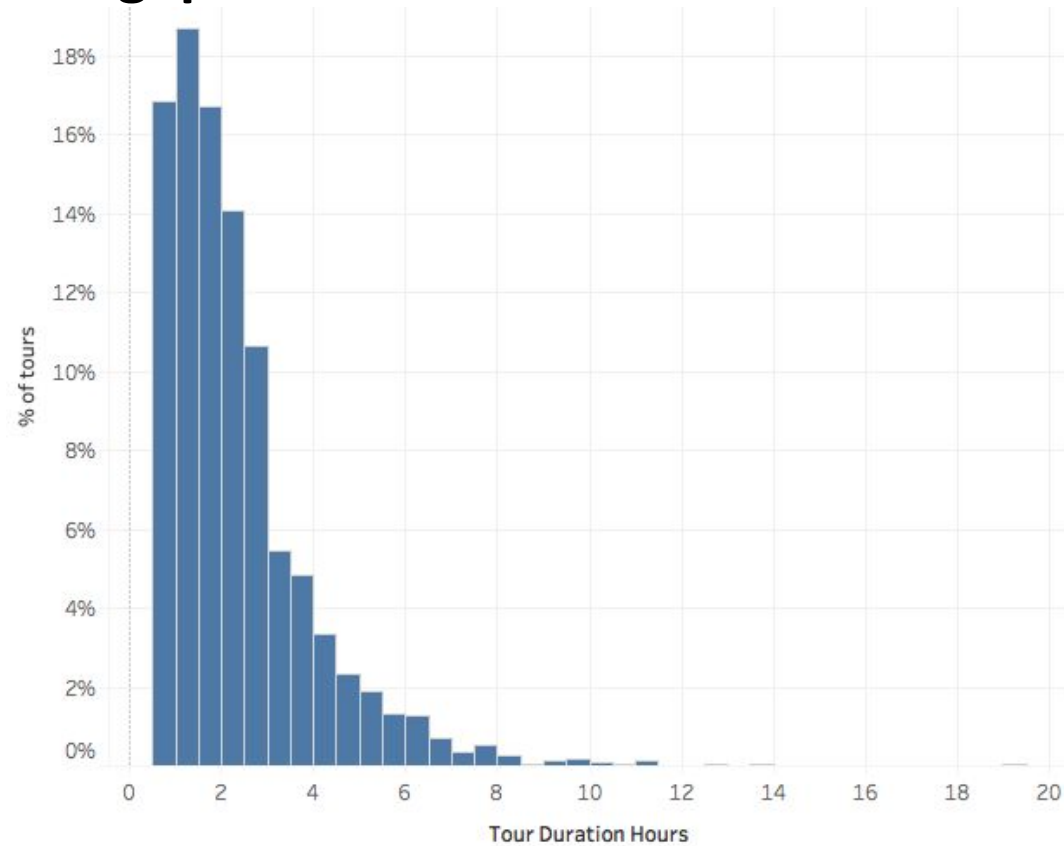
Vehicle type

Industry Served

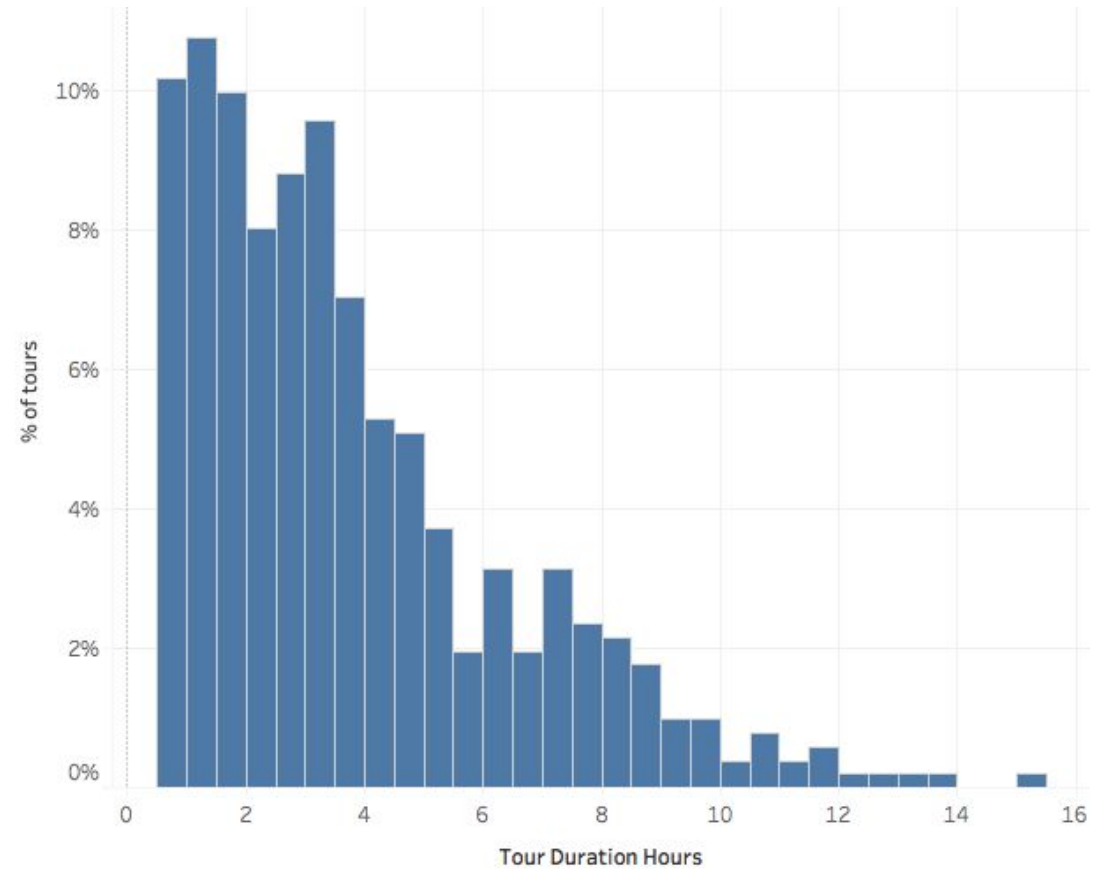


Tour duration

Singapore

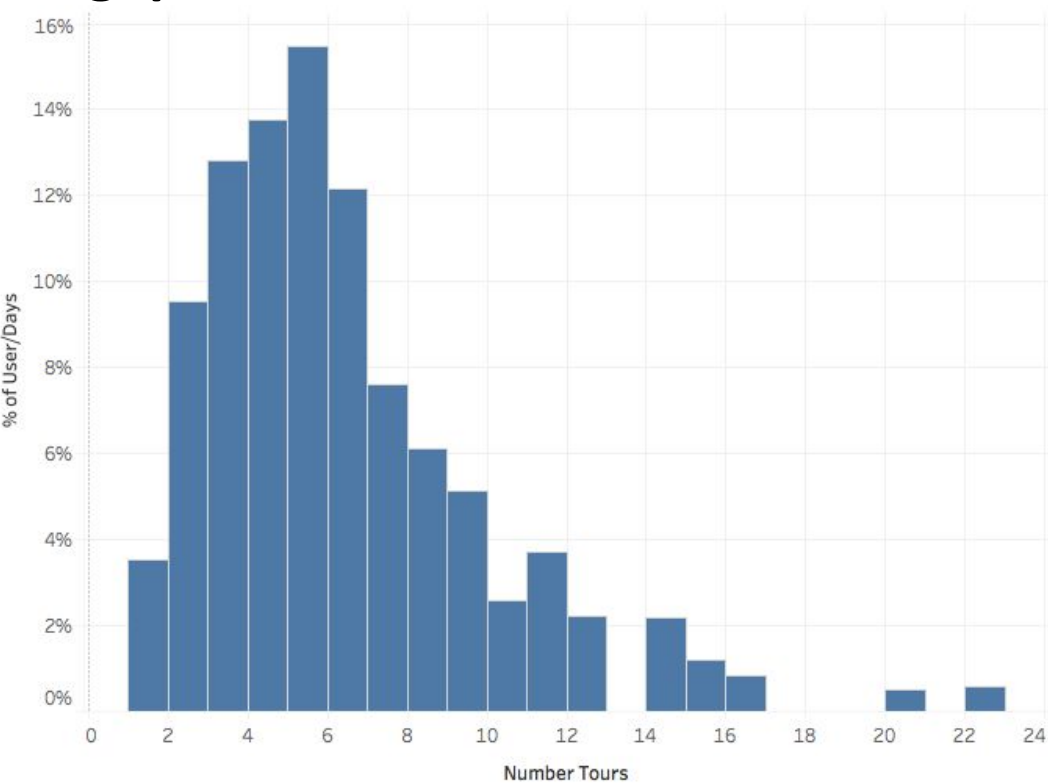


Boston

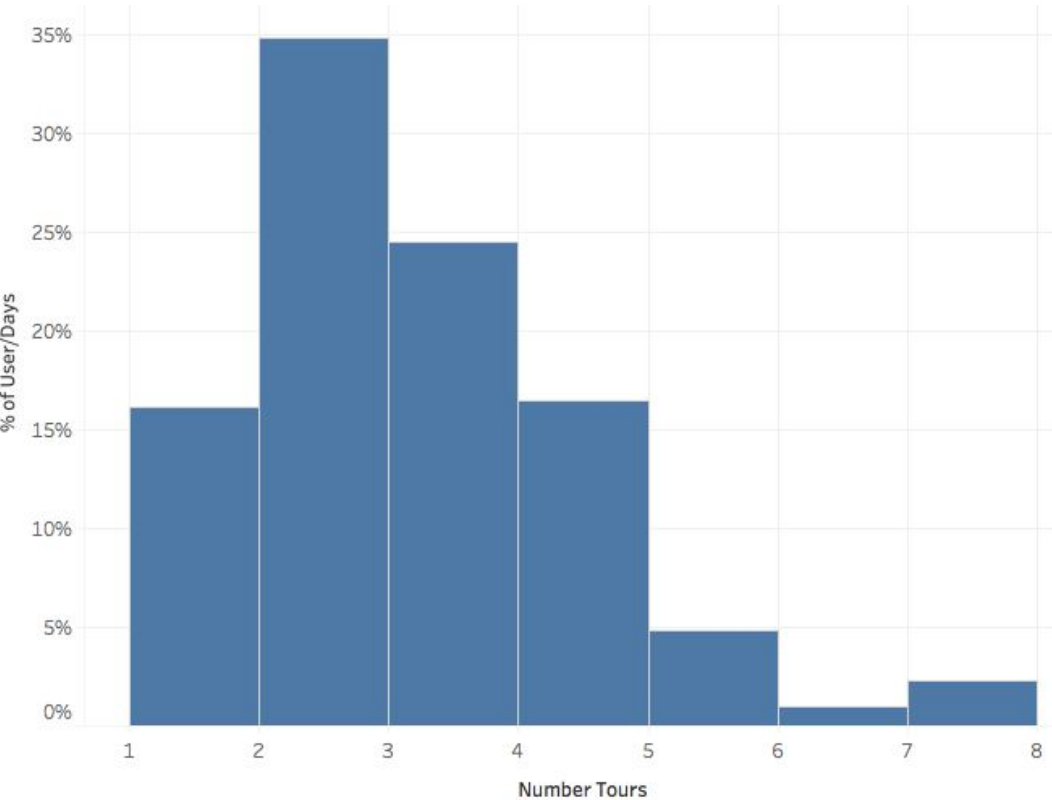


Tours per day

Singapore

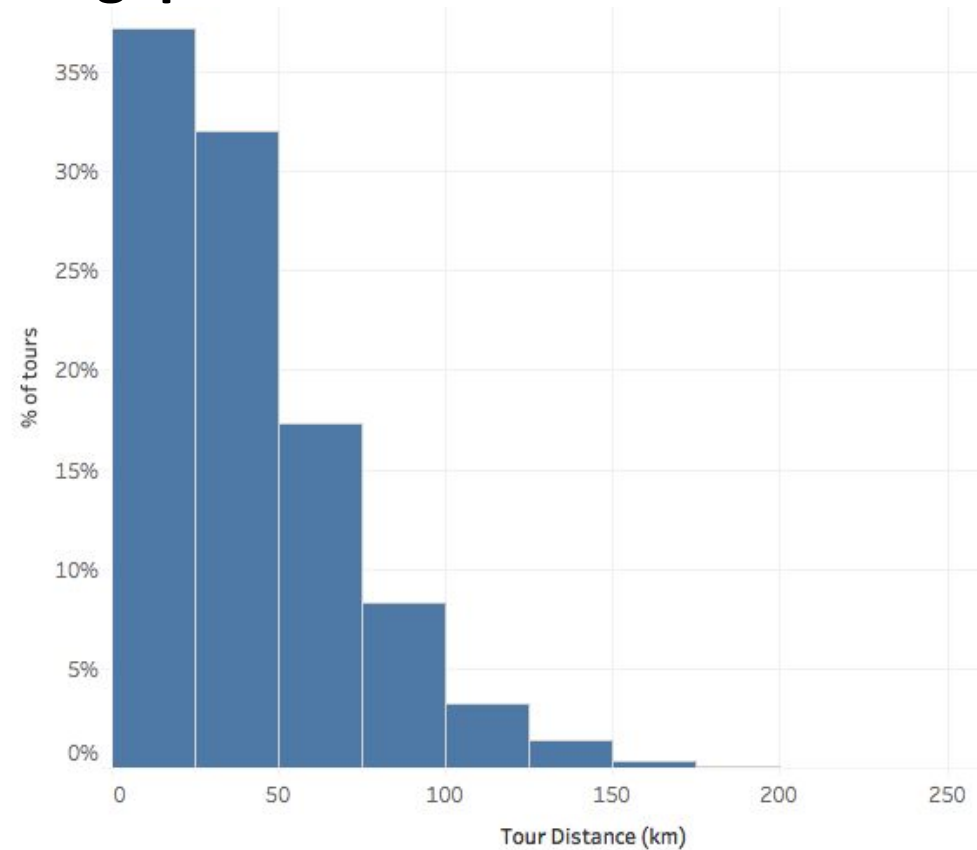


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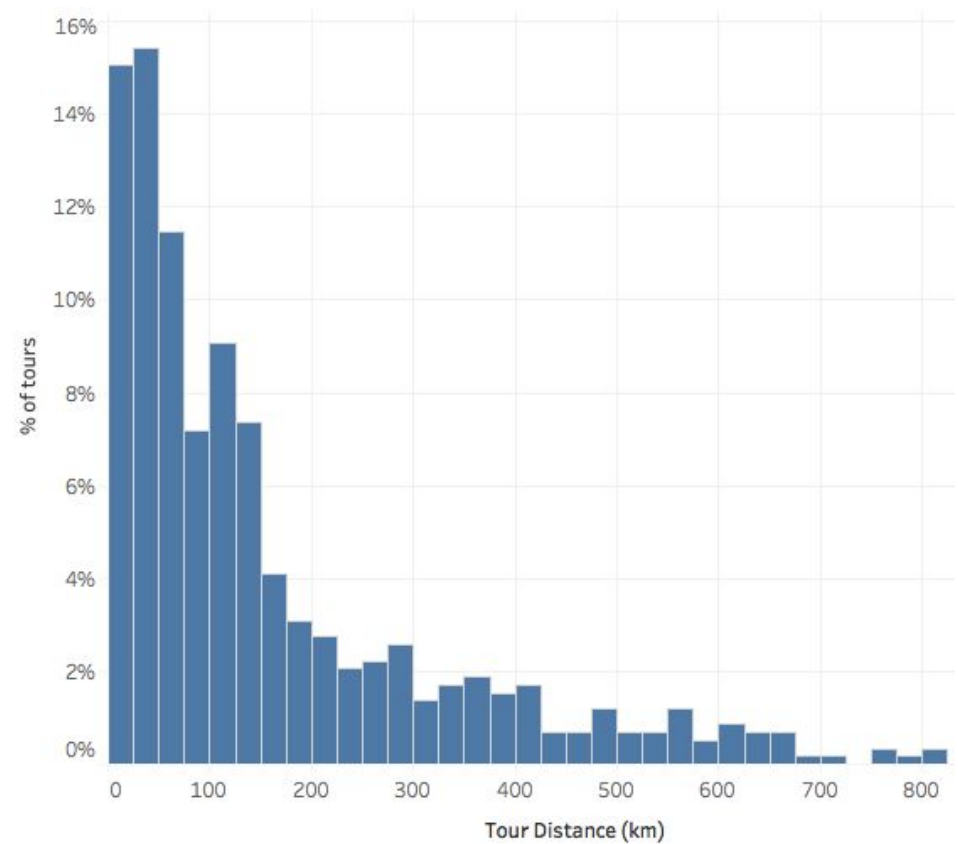


Tour distance

Singapore

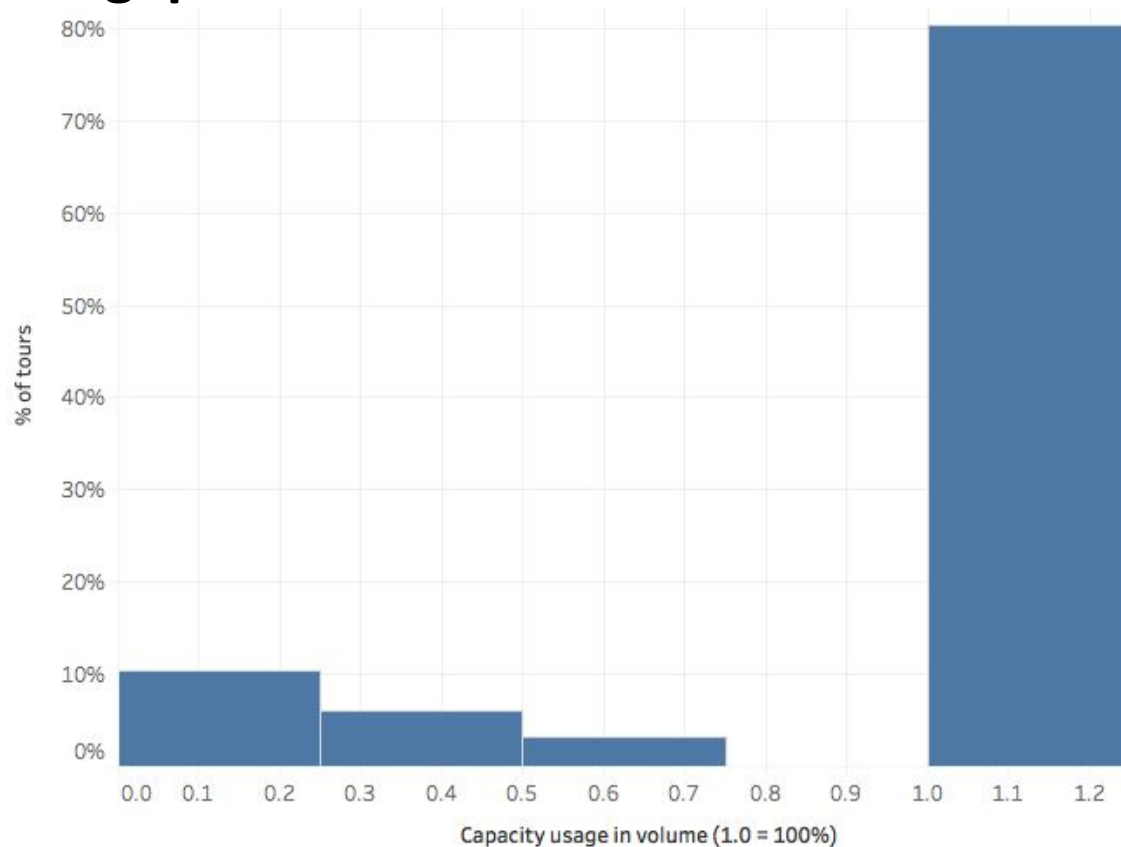


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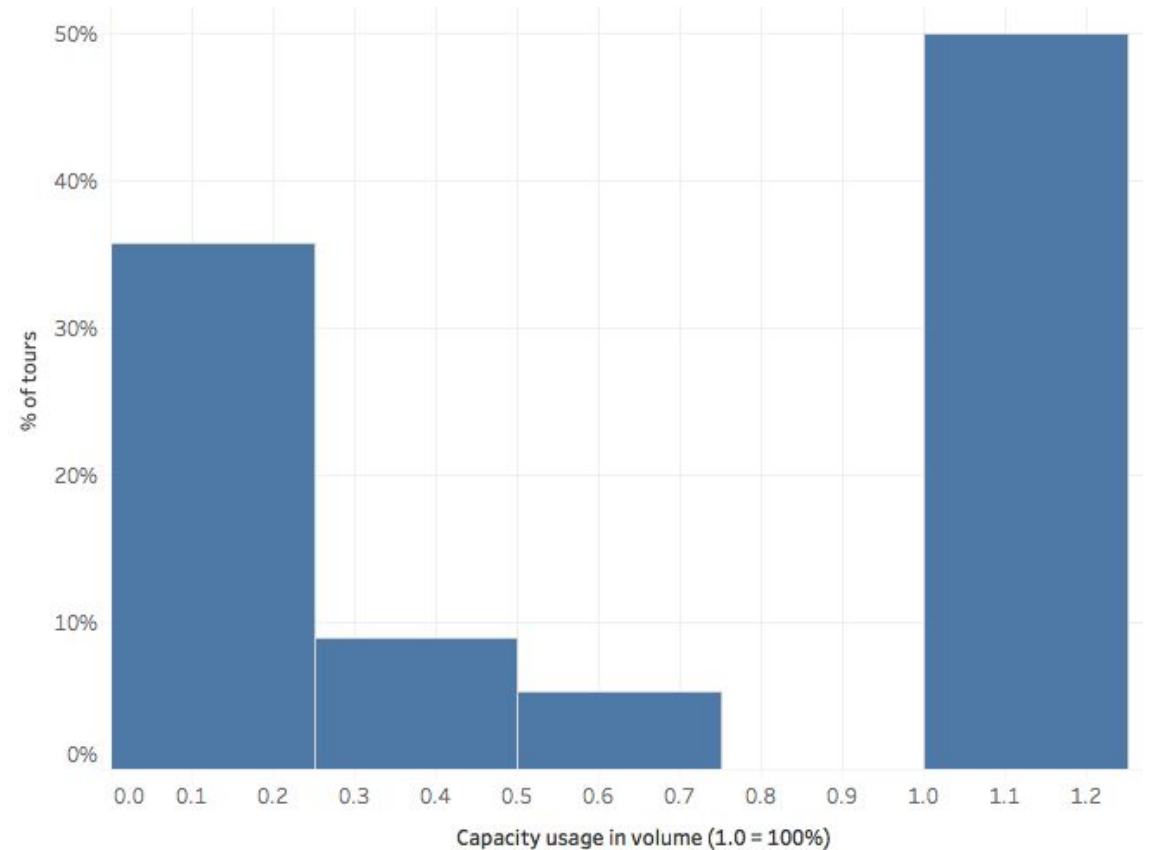


Capacity at first pickup stop of tour

Singapore

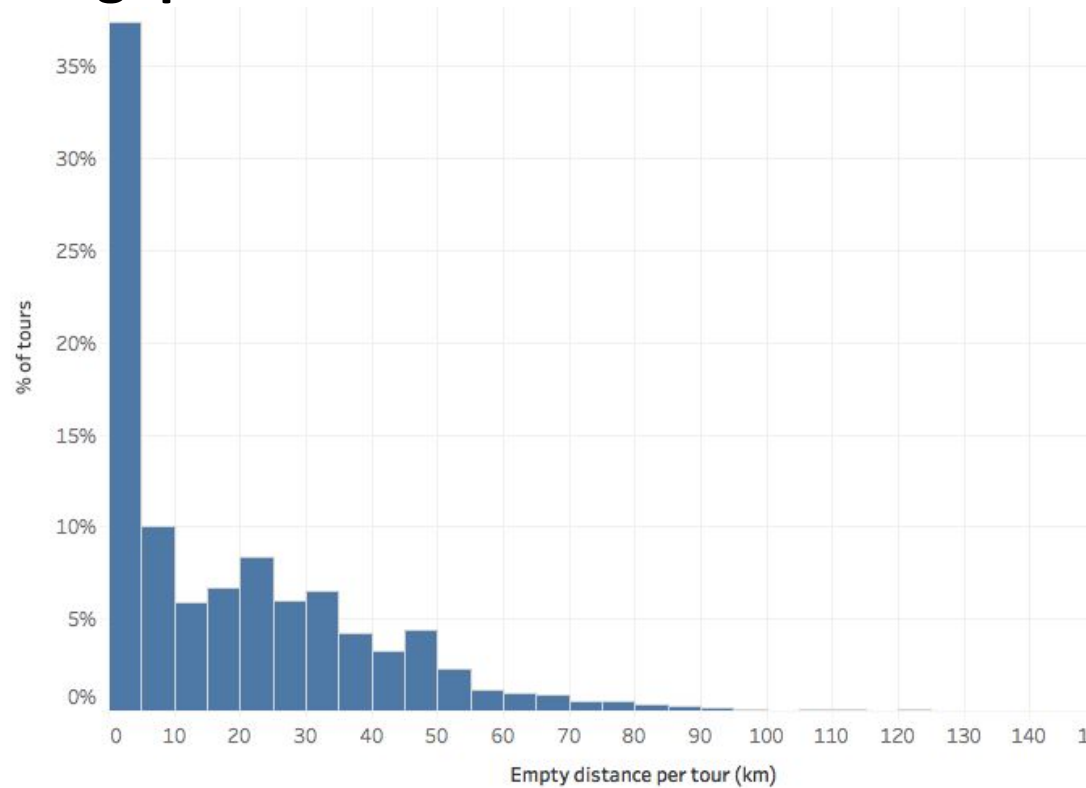


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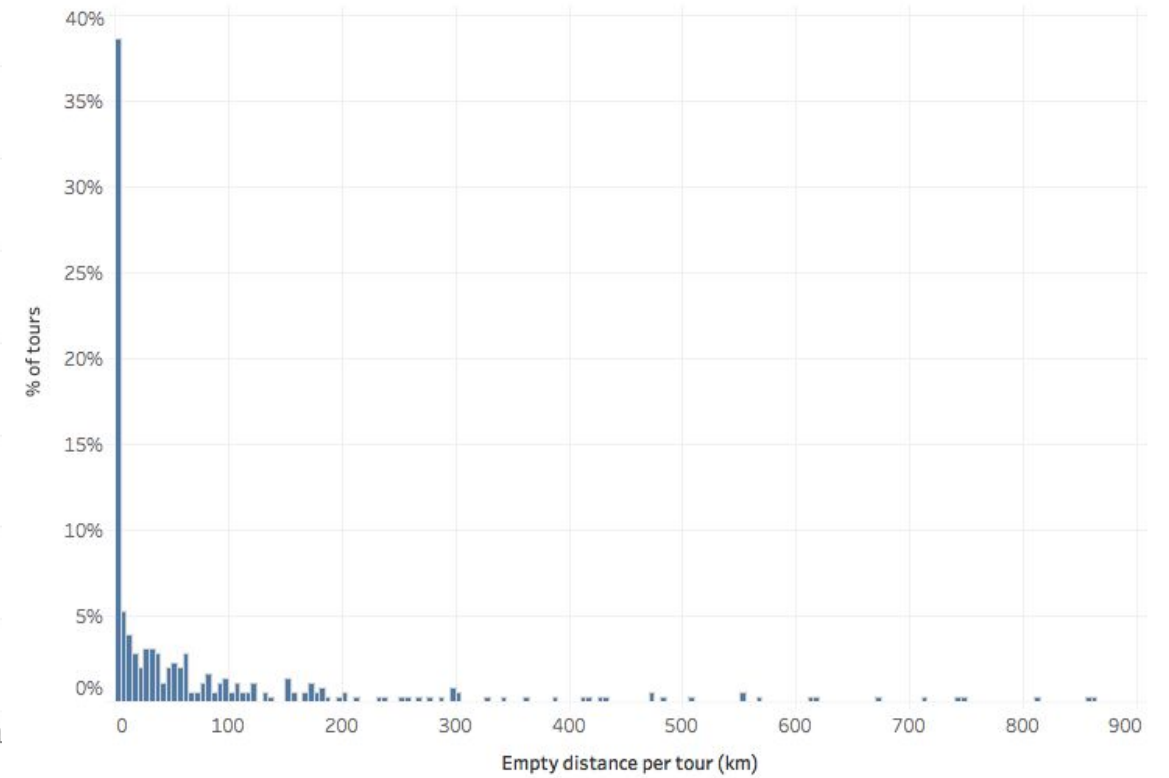


Empty distance per tour

Singapore

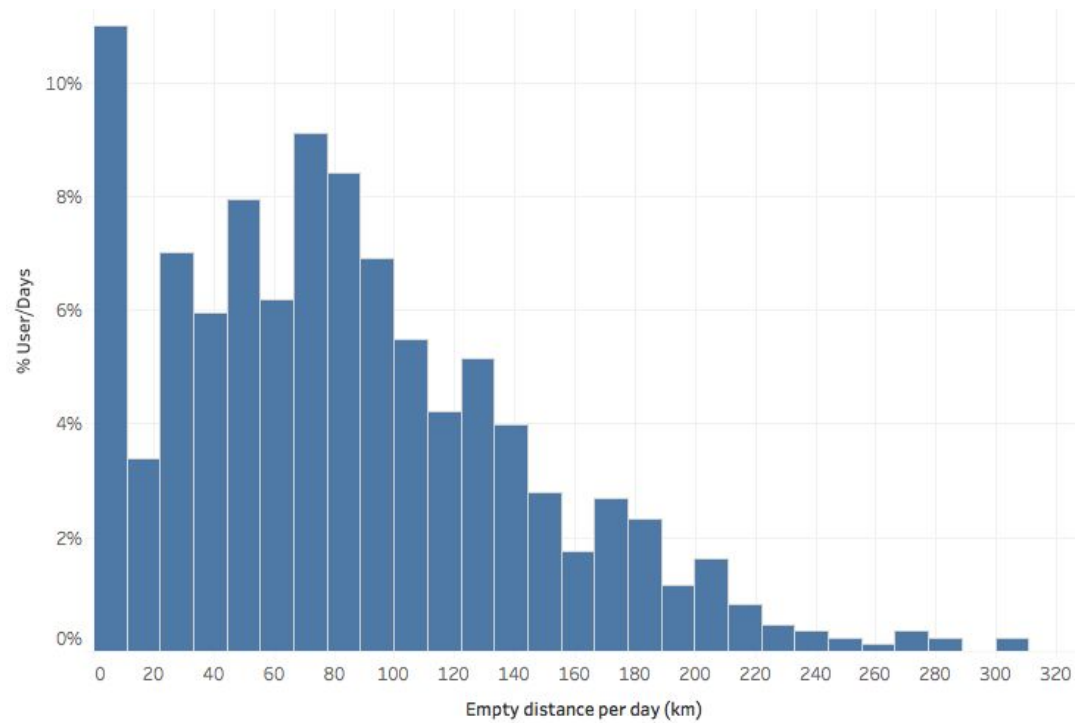


Boston

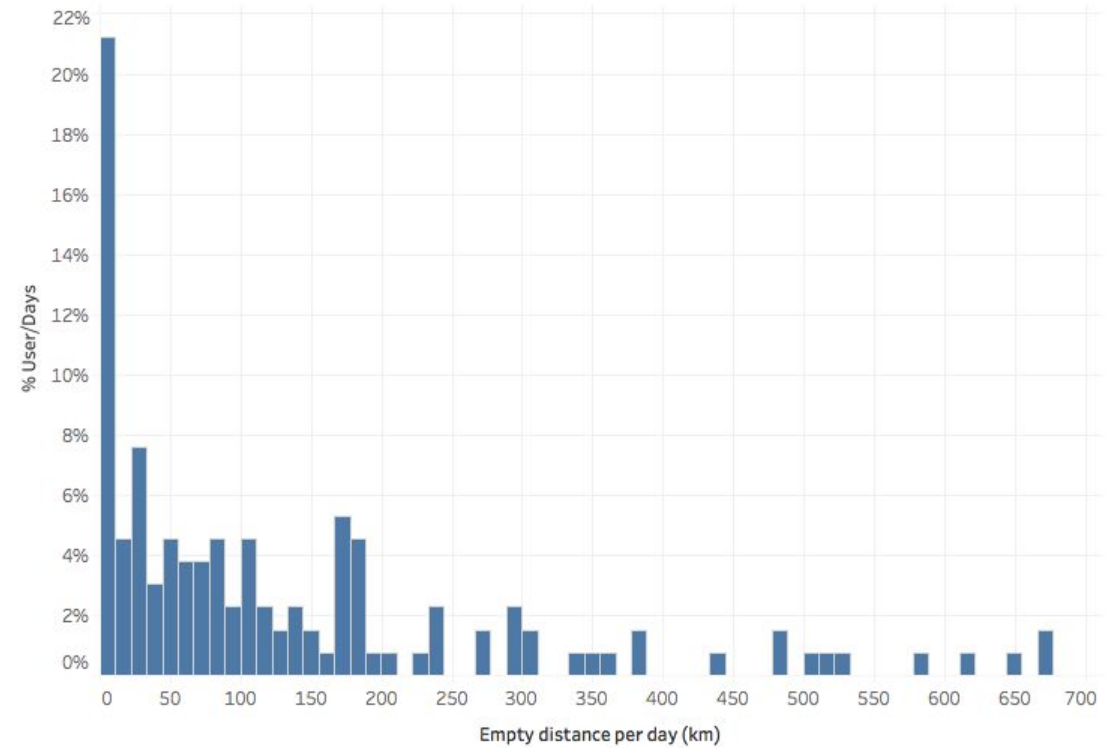


Empty distance per day

Singapore

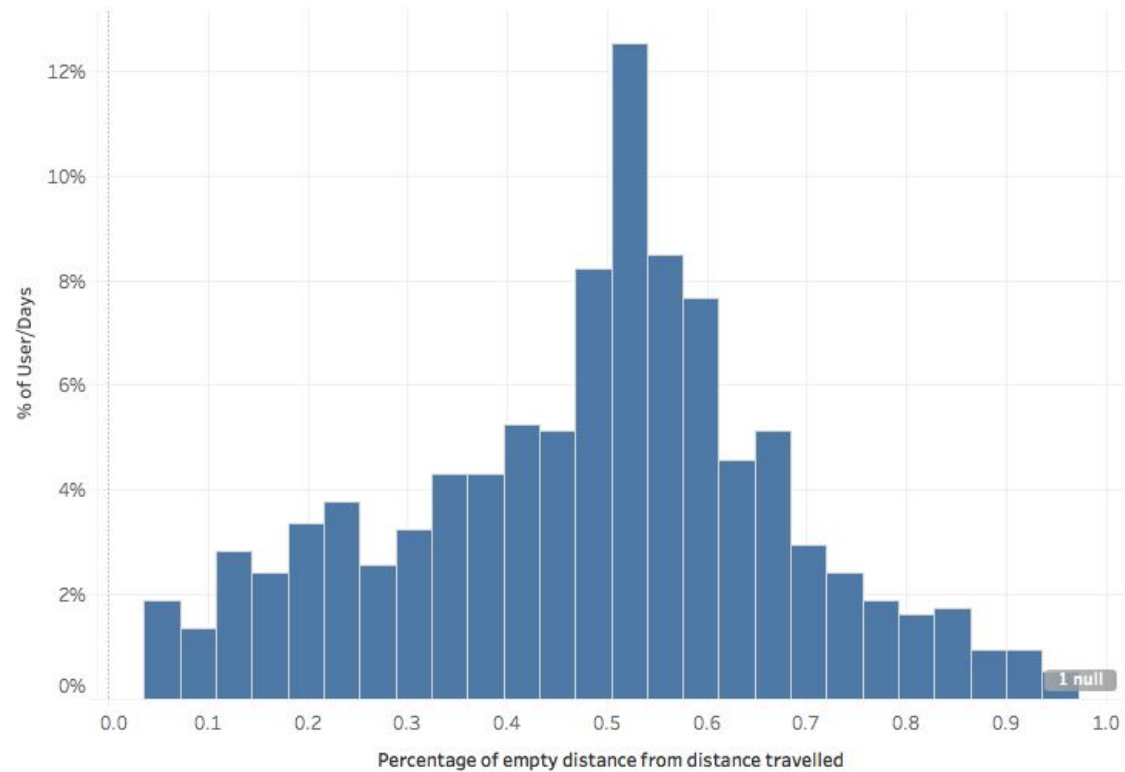


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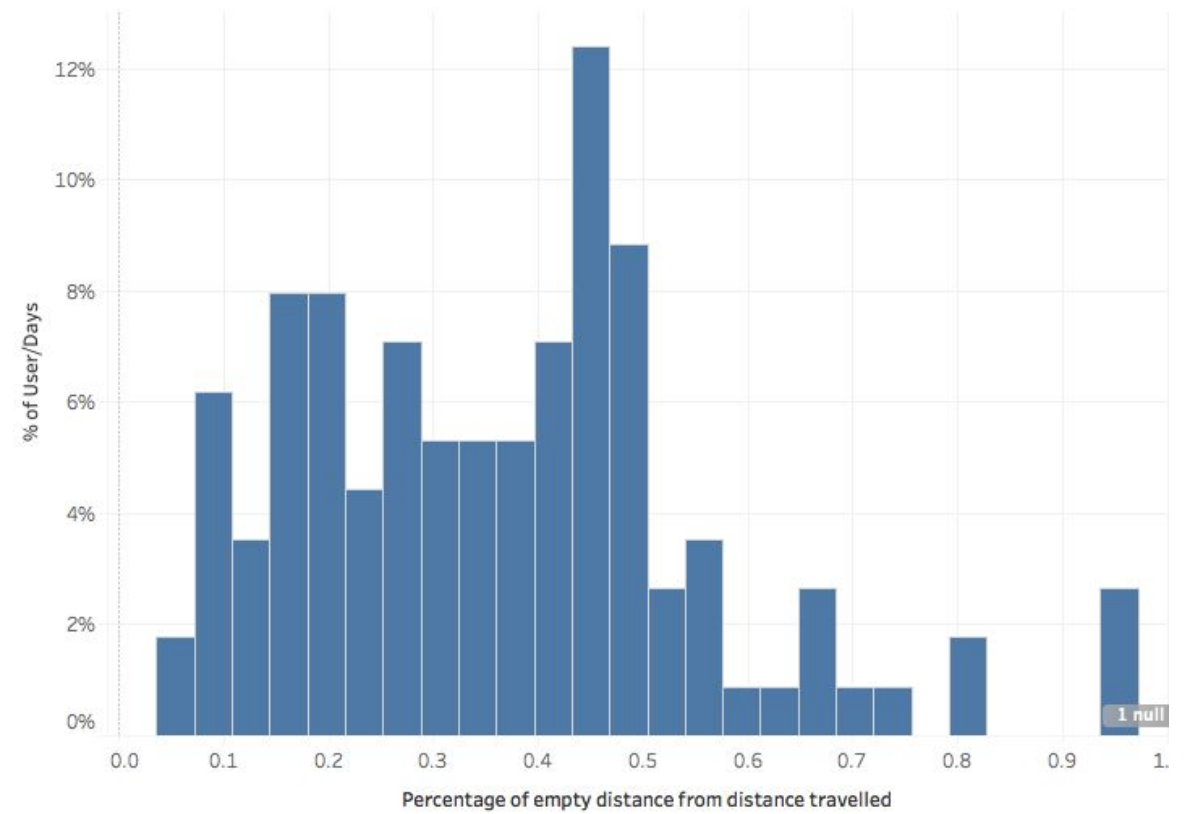


Empty distance % from distance travelled

Singapore



Boston



SG data - Tours & tour chains

- Full-day method achieved slightly better classification rate (88% vs 84%)
- Most vehicles perform direct trips with varying locations across the day (40%)
- Algorithm application limited by data validation process, requiring post-processing & assumptions -> **research gap(!)**

Threshold method (60%)

	Threshold method (60%)		Full-day method	
	Single	Chain		
DIR	70%	74%	DIR	7%
			FPFD	7%
			FPVD	13%
			VPFD	5%
			VPVD	40%
			VPMFD	0%
			FPMFD	0%
UL	6%	6%	FPMVD	3%
			VPMVD	5%
			UL	3%
			MVPFD	0%
			MVPVD	1%
L	2%	1%	L	0%
MX	1%	1%	MX	2%
PT	14%	2%	PT	1%
NA	7%	16%	NA	12%

BOS data - Tours & tour chains

- Full-day method achieved slightly worse classification rate 74% vs 77%.
- Predominant single tour days, likely due to inter-urban operations.
- Higher share of pickup-only tours possibly due to inter-urban movements going over single days and survey errors.

Threshold method (60%)			Full-day method		
DIR	Single	Chain	DIR	8%	
			FPFD	0%	
			FPVD	2%	
			VPFD	1%	
			VPVD	16%	28%
	UL	34%	VPMFD	1%	
			FPMFD	0%	
			FPMVD	5%	
			VPMVD	11%	
			UL	19%	36%
L	6%	5%	MVPFD	0%	
			MVPVD	2%	
			L	2%	4%
			MX	1%	
			PT	4%	
MX	2%	1%	NA	26%	
PT	24%	3%			
NA	13%	23%			

Conclusions

- Tour identification algorithm leads to sensible results on several tour-level indicators
- No major differences between labeling stop chains from an individual tour or whole day perspective.
- Whole day perspective allows further insight into operations: non-negligible percentage of vehicle/days ($\frac{1}{2}$ SG, $\frac{1}{3}$ US) demonstrated variable pickup locations, challenging assumptions of pickup location(s) as base.
- Algorithm development must incorporate robustness to several data issues (wrong/nonsensical validation, missing stops, etc.).

Future Work

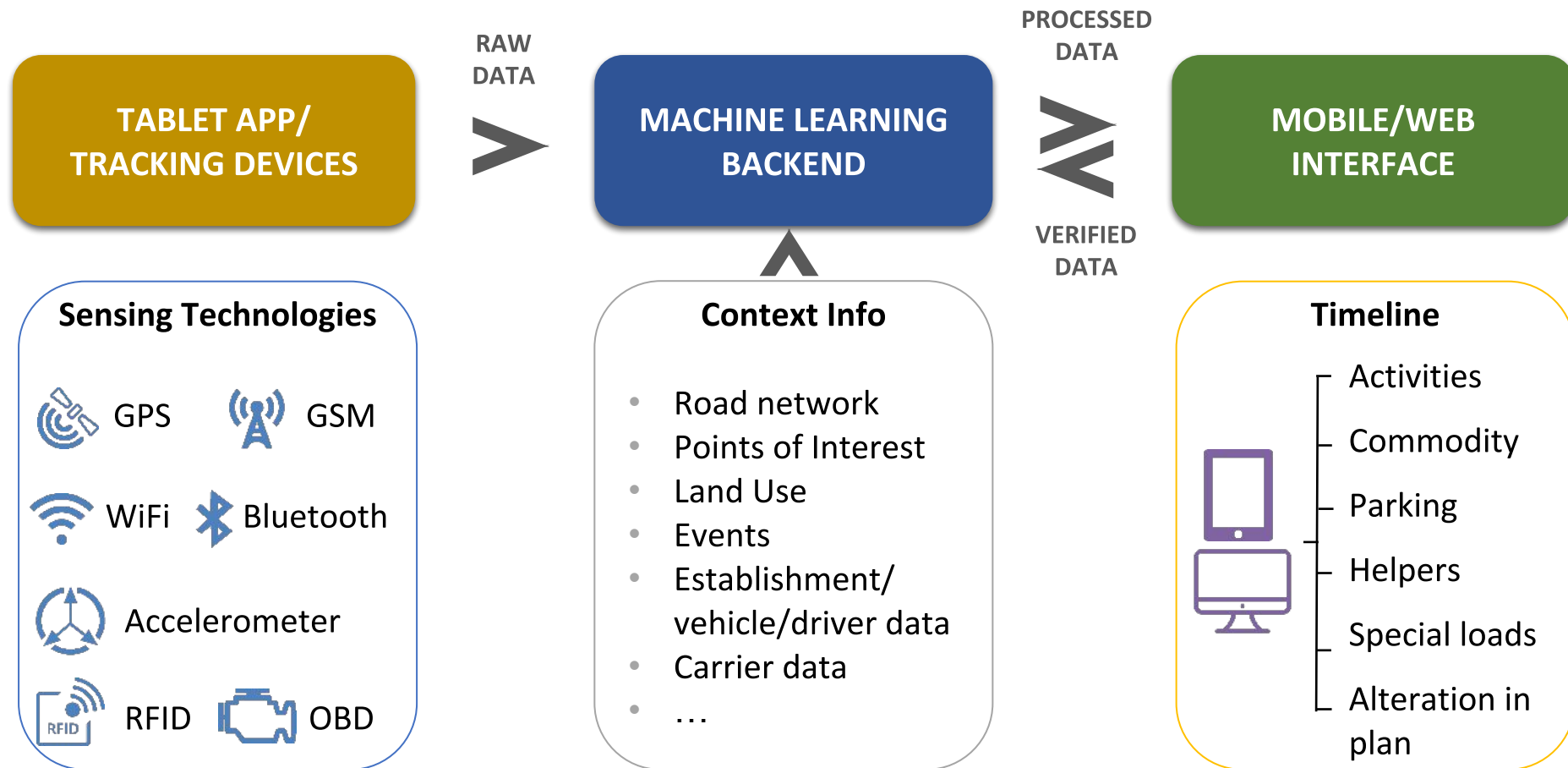
- Explore respondent-declared and algorithm-identified “bases”.
- Compare algorithms to identify freight vehicle tours from stop chains (capacity-driven, base-driven)
- Day-to-day patterns, tour typology and topology.
- Robustness of application to other vehicle types / industries (LGV)
- Tour and tour chain choice modelling and incorporation into agent-based simulations.

Acknowledgements

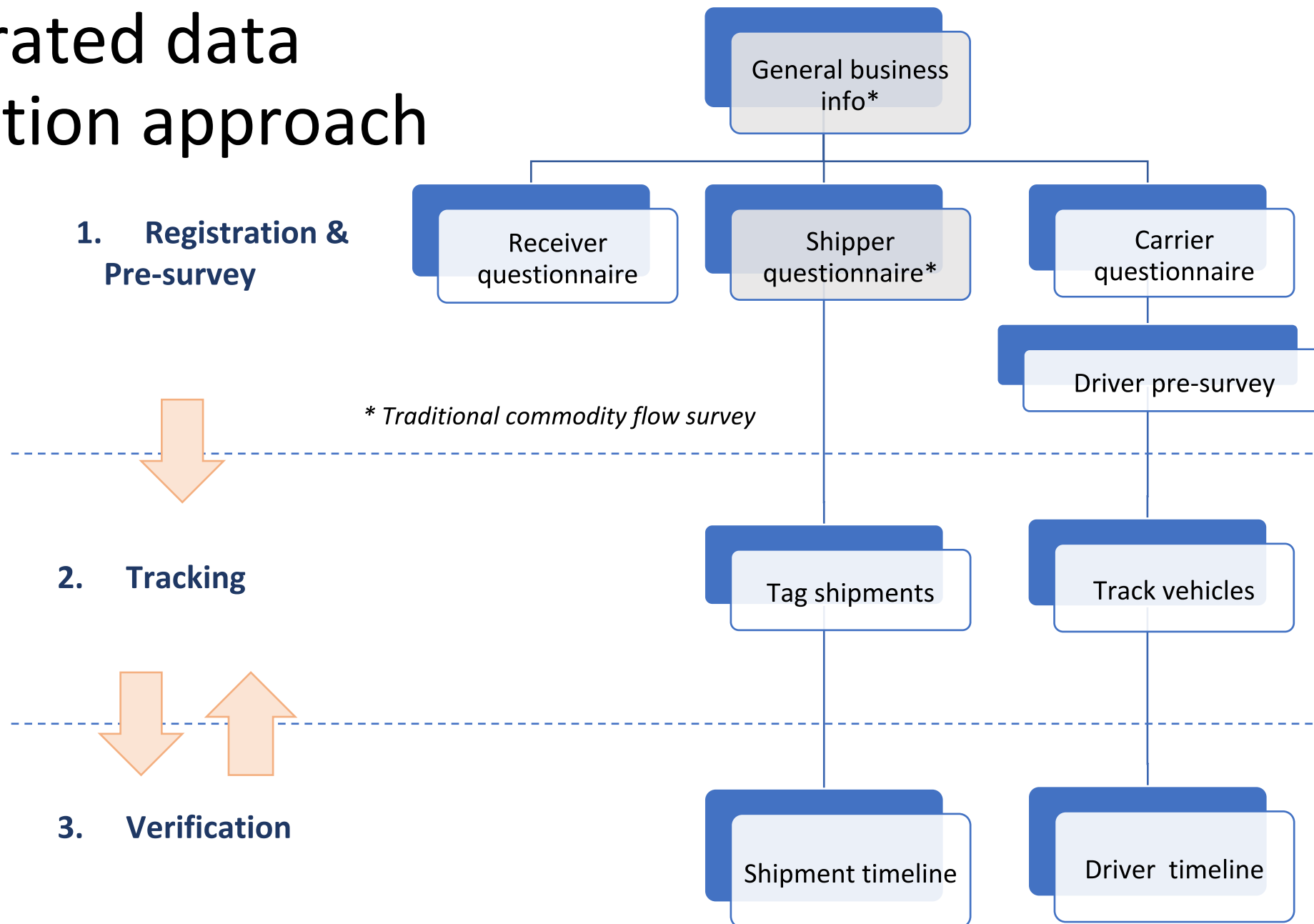
- Federal Highway Administration(FHWA) Exploratory Advanced Research Program, Future Freight and Logistics Survey:integrated data collection using mobile sensing, wireless communication and machine learning algorithms, Contract No. DTFHG115C00033
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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) only.

Future Mobility Sensing (FMS)



Integrated data collection approach

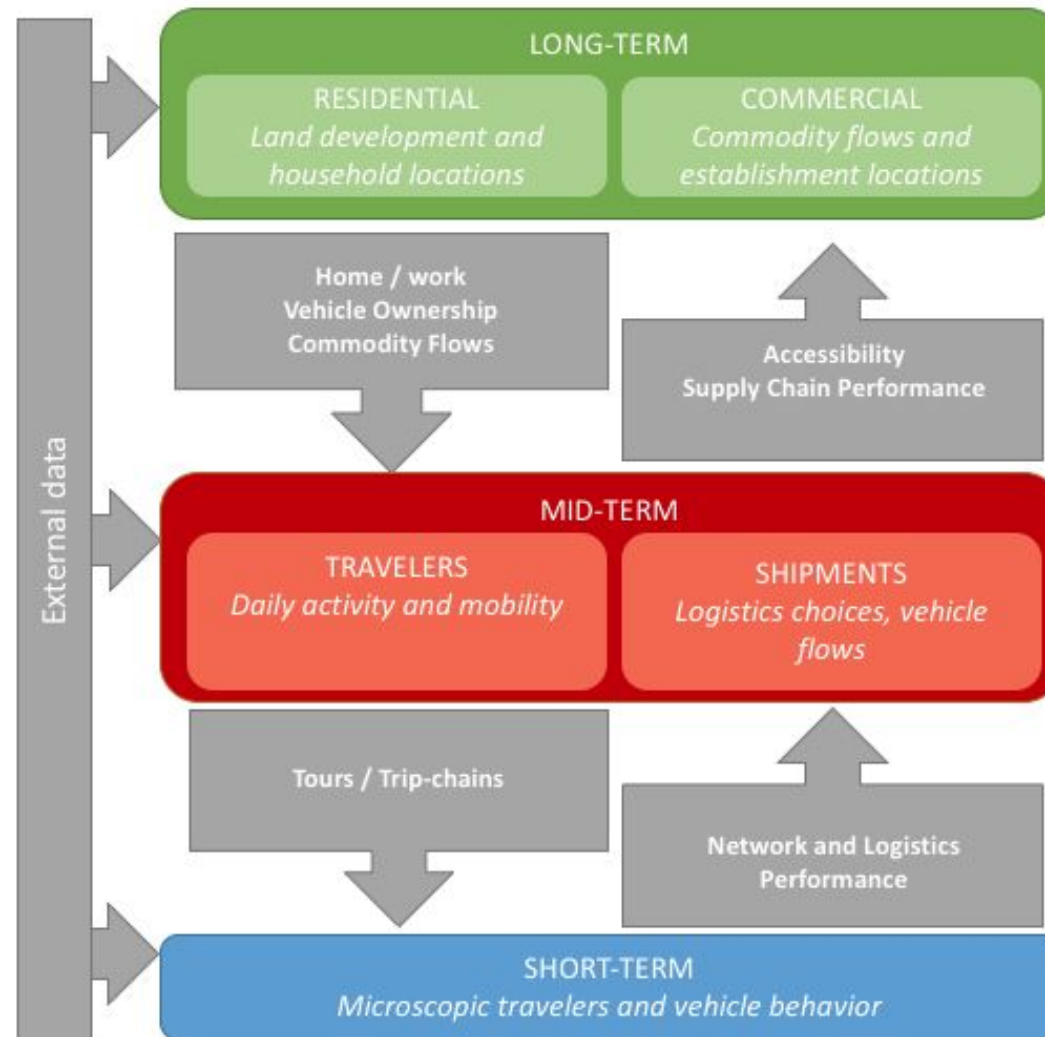


Data collection plans

	Survey	Time	Sample
US	Inter-city truck driver survey	2014	<ul style="list-style-type: none"> • 89 drivers, 2991 days of data (2067 days verified)
	Truck driver survey pilot	2016	<ul style="list-style-type: none"> • 28 drivers, 650 days of data (442 days verified)
	Shipment tracking pilot	2018 Q1	<ul style="list-style-type: none"> • 10 establishments
	Integrated shipment and driver survey	2018	<ul style="list-style-type: none"> • TBD
SG	Establishment survey pilot	2017	<ul style="list-style-type: none"> • 106 establishments
	Heavy Vehicle Survey	2017.01 – 2018.08	<ul style="list-style-type: none"> • ~5000 HVs planned for 1 mth each • To date: 3400 tracked, 1591 recruited (pre-survey), 792 drivers verified 5 days each
	Integrated Commodity Flow Survey	2018.02 – 2018.08	<ul style="list-style-type: none"> • 2300 establishments island-wide, 600 driver surveys, 50 shipment tracking

SimMobility, an agent-based simulation

- **Laboratory** for urban passenger/freight mobility
- **Agent-based** integrated/modular platform (freight-related: shippers, carriers, receivers, drivers)
- **Multiple** spatial-temporal **scales**
- **Dynamic** plan/action-transaction behavioral models
- **Multimodal** networks
- **Open-source**



Disclaimer: departure from original direction

- Proposed to analyze tour typology and topology using factor and cluster analysis for both SG and US datasets.
- Research team realized more research should be done regarding the tour identification and labeling methods before moving to the next step.
- Thus, this presentation will be focused on this particular research challenge.

Sample characteristics - Singapore

Vehicle type

Prime Mover	18%
Tipper/Dump Truck	39%
Platform Truck	2%
Crane	1%
Lorry Wooden	20%
Garbage/Sanitary Wagon	6%
Low Loader	0%
Van	4%
Tanker	3%
Lorry Metal	3%
Refrigerated Vehicle	1%
Unknown	1%

Industry served

Construction	65%
Utilities and Waste	5%
Other services	2%
Manufacturing	9%
Transportation and Storage	8%
Retail – Non F&B	5%
Wholesale	0%
Retail – F&B	1%
Agriculture	0%
Unknown	4%

Sample characteristics - Boston

Vehicle type

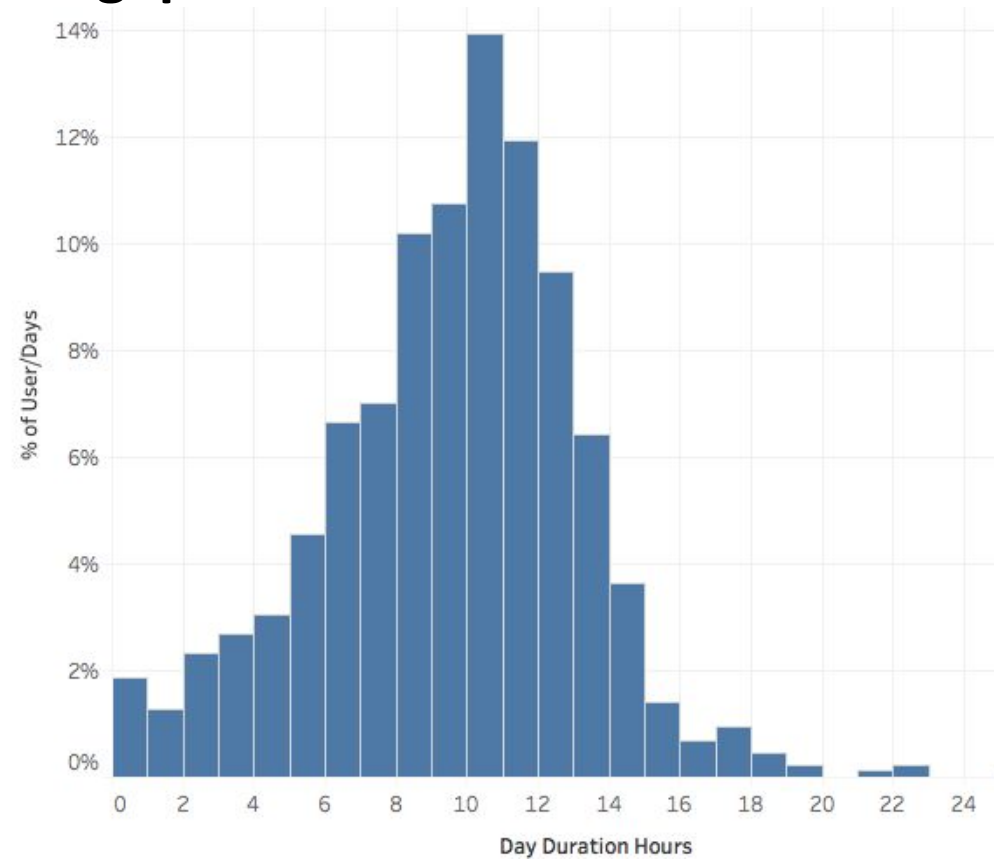
Single unit (>2-Axle)	22%
Single unit (2-Axle)	26%
Single unit (open top)	4%
Detachable Trailer - Auto Carrier	11%
Detachable Trailer - Flat Bed	11%
Detachable Trailer - Low Boy	4%
Detachable Trailer - Tractor Trailer (Single)	15%
Other - Cement mixer	4%
Other - Fuel/Gas Tank	4%

Industry served

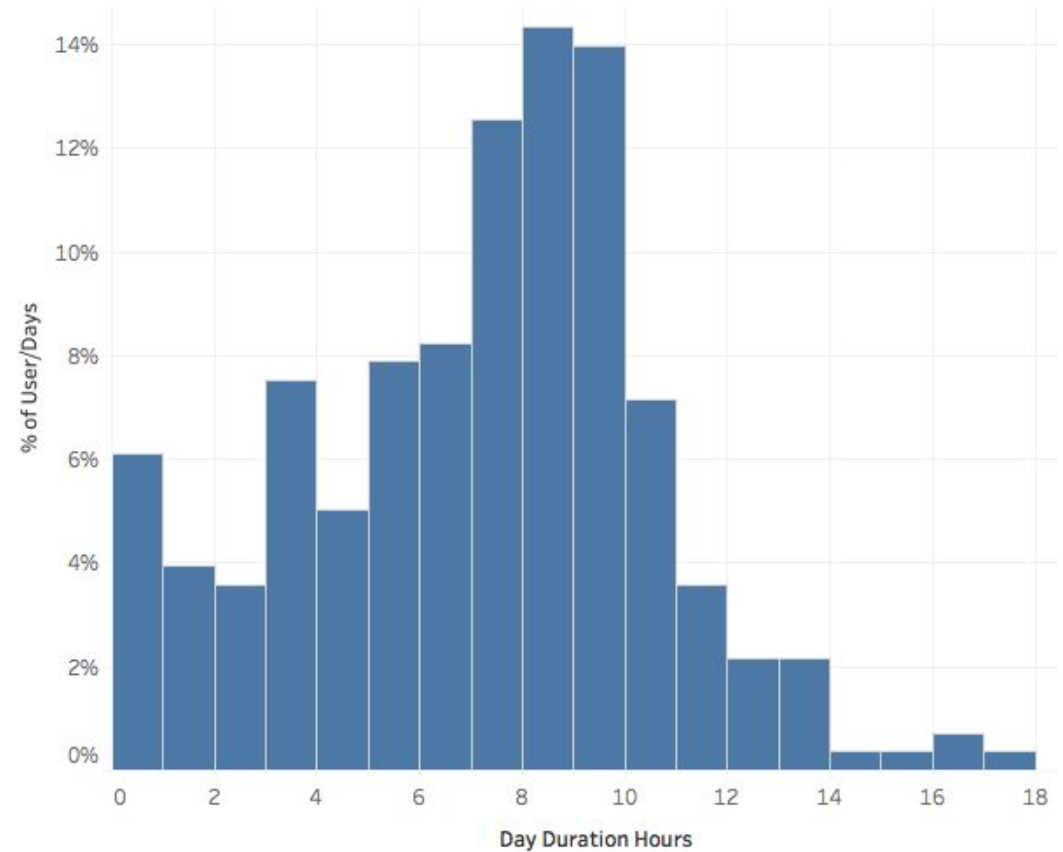
Agriculture	3%
Construction	18%
Manufacturing	8%
Other	21%
Retail – F&B	24%
Retail– Non F&B	11%
Utilities	3%
Wholesale	13%

Work day duration (includes breaks < 4 hours)

Singapore

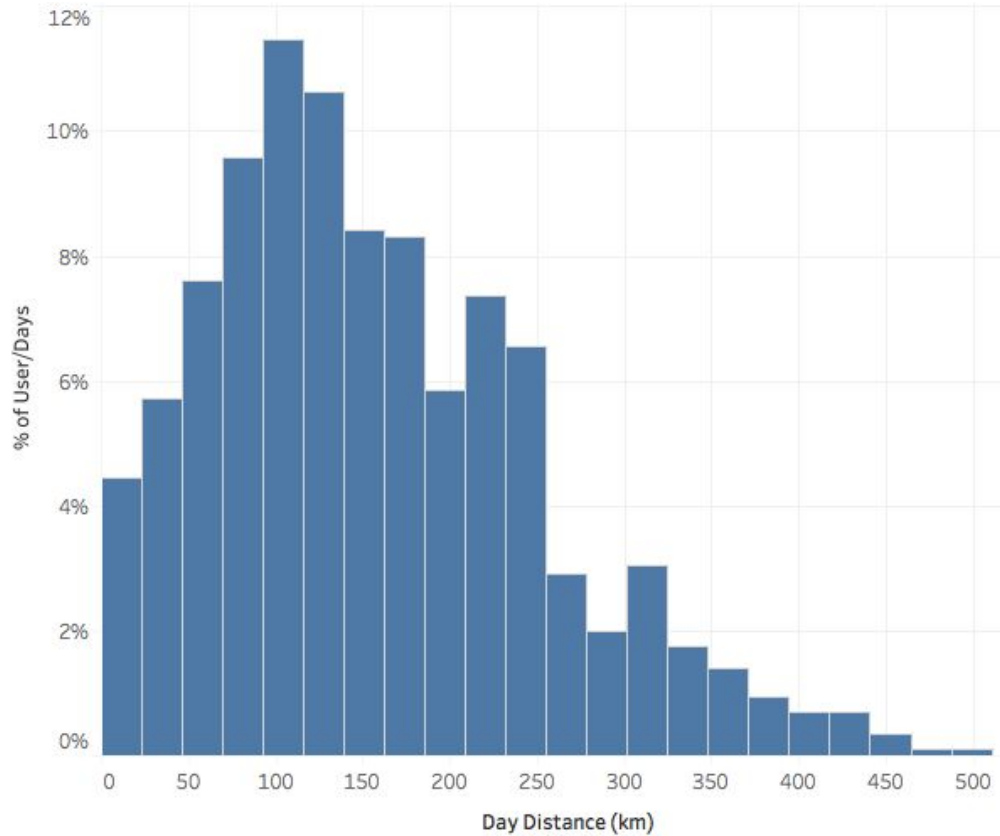


Boston



Day distance

Singapore



Boston

