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Use of bus ITS data to improve public transport mode share

Aruna Sivakumar
Director, Urban Systems Lab
Senior Lecturer, Centre for Transport Studies
Imperial College London

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Overview

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- Introduction
  - The concepts, role, and types of Public transport
  - Cases of advanced Public transport system
- Mode choice behaviour
  - Review on Mode choice models
  - Main explanatory variables in public systems
- ITS Functional requirements for data capture
  - Types of ITS data
  - Additional functional requirements for ITS instrumentation (operation system, bus stops, planner app)
  - Additional functional requirements for future extension

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Introduction

Introduction

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- Public Transport
  - Refers to all modes of transportation that are open to the public and provide transportation services
  - Provides rapid transit services to the public
  - Includes civil aviation, railway, highway, water transport and other modes of transportation

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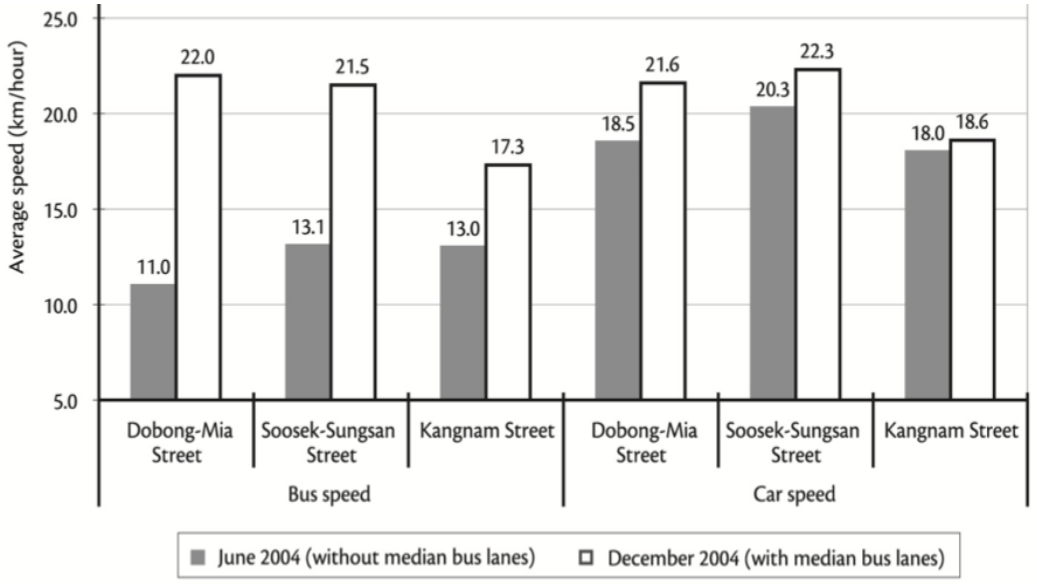
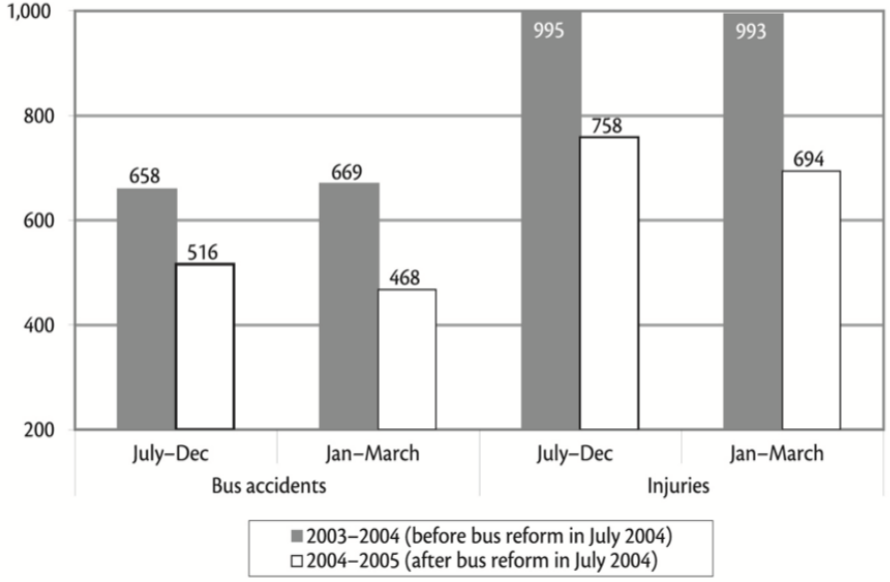
- Case of Public Transport (Seoul)
  - Problems - congestion, air pollution, traffic injuries, and funding shortages
  - Solution - public transport reforms introduced in Seoul in July 2004

Bus Median Lanes



Average Bus and Car Speed Before and After Implementation of Exclusive Median Bus Lanes



Decline in Monthly Bus Accidents and Injuries in Seoul, 2003 to 2005

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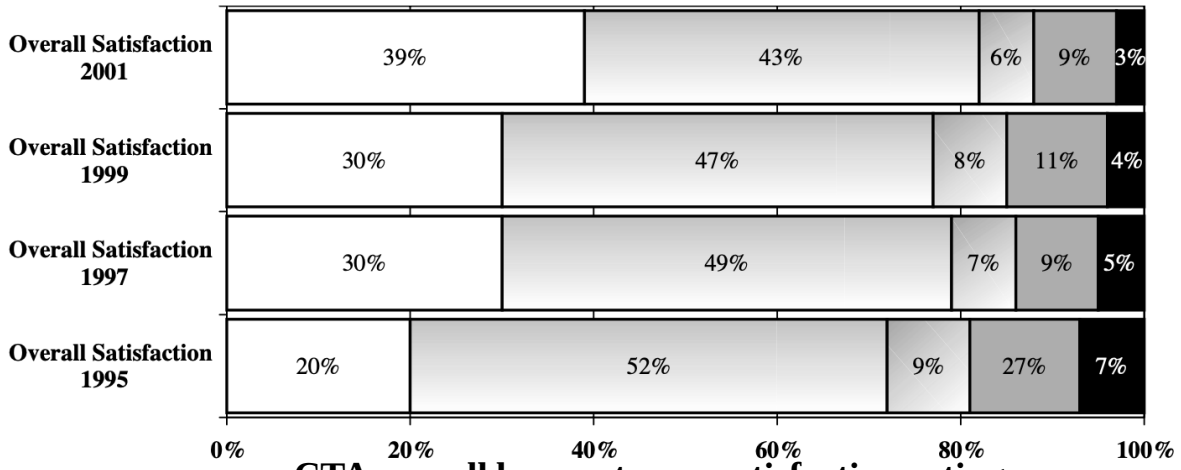
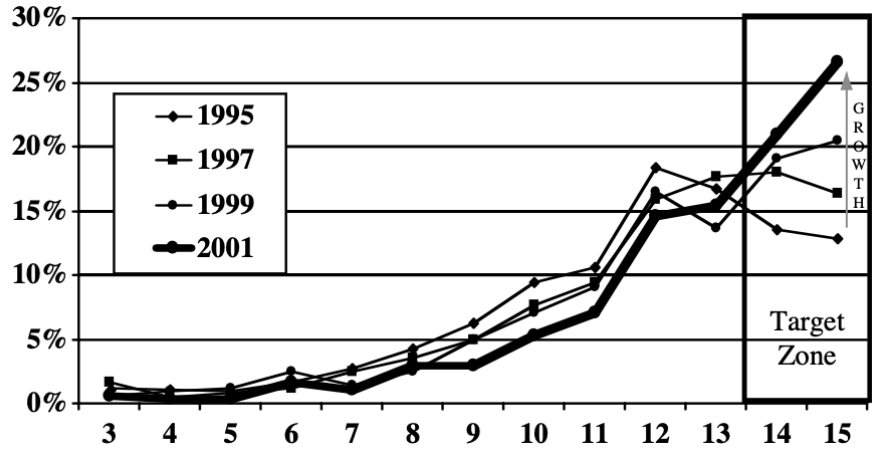
- Case of Public Transport (Chicago)
  - Problems - bus ridership decline
  - Solution - develop customer-focused bus service improvement initiatives
    - new automated fare collection system reduces fare collection costs
    - website provides accurate route, schedule, and service information



CTA overall bus customer satisfaction ratings



Customer Loyalty Score

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Mode choice behaviour

Review on Mode choice models

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- **Category 1**: **Using Meta-analysis**
  - **Data:** Stated Preference (SP) and Revealed Preference (RP) data;
  - **Description**: pooling together the results from different empirical studies and developing a quantitative model that produces generalisable insights into mode choice behaviour, and more specifically the underlying values of time;
  - **Comments:** Especially in contexts where location specific mode choice data is not available ;
  - **Examples:** Wardman (2001); Paulley et al. (2006); Hensher (2008a) (2008b); Fearnley et al. (2018).

Table 3
Summary of internal cross-modal transit elasticities assembled from the research literature & practice review.

Demand for	With respect to	Change in Policy Variable																			
		Fare				VT/journey time				Wait time headway				Access/egress/transfer time				No. of interchanges			
		N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max
Light rail	Bus	5	**0.21**	0.11	0.28	1	**0.15**	0.15	0.15	1	**0.06**	0.06	0.06	1	**0.03**	0.03	0.03	1	**0.23**	0.23	0.23
	Rail	1	**0.01**	0.01	0.01	1	**0.01**	0.01	0.01	1	**0.01**	0.01	0.01	1	**0.06**	0.06	0.06	1	**0.01**	0.01	0.01
Bus	Light rail	3	**0.16**	0.10	0.25	1	**0.15**	0.15	0.15	1	**0.05**	0.05	0.05	2	**0.38**	0.38	0.38	1	**0.17**	0.17	0.17
	Rail	31	**0.28**	0.02	1.31	23	**0.48**	0.03	1.09	9	**0.22**	0.03	1.00	5	**0.15**	0.03	0.34	1	**0.03**	0.03	0.03
	Metro	1	**0.16**	0.16	0.16																
Rail	Light rail	1	**0.02**	0.02	0.02	1	**0.06**	0.06	0.06	1	**0.01**	0.01	0.01	2	**0.11**	0.11	0.11	1	**0.06**	0.06	0.06
	Bus	32	**0.15**	0.01	0.49	26	**0.26**	0.02	0.91	12	**0.08**	0.03	0.18	3	**0.13**	0.04	0.25	1	**0.24**	0.24	0.24
Metro	Bus	1	**0.21**	0.21	0.21																
	Rail	1	**0.10**	0.10	0.10																

Source: Fearnley, N., at al (2018) Competition and substitution between public transport modes, *Research in Transportation Economics*.

Review on Mode choice models

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- **Category 2: Criteria information**
  - **Data:** RP data;
  - **Description**: investigating the impacts of quality attributes of public transport on travellers' choice of mode;
  - **Comments:** Quality attributes of PT explored in these models include reliability, frequency, price, comfort, safety and others. Many of these studies do not involve any choice modelling, but rather use qualitative analysis methods. ;
  - **Examples:** Khan (2007), Redman et al. (2013), Jain et al. (2014), Chowdhury and Ceder (2016)

Number of studies of public transport (PT) improvement strategies targeting different quality attributes.

Improvement strategy	Targeted quality attribute						
	Reliability	Frequency	Price	Speed	Access	Comfort	Convenience
Bus rapid transit (BRT)	15	13		16	1	15	8
Priority bus lanes		2		2			
Extended service		6			5		
Rail lines replacing bus	9			10			
Underground improvements	3			3			
Integrated public transport systems (quality bus partnership)	7	2	7	8	7	9	9
Price mechanism (discounts, free tickets, integrated ticketing)			14		1		5
Improved information							2
Reduced distance between PT nodes					2	2	

Source: Redman, at al (2013). Quality attributes of public transport that attract car users: A research review. on Transp. Policy

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- **Category 3**: **Using attitudinal data**
  - **Data:** individual information;
  - **Description**: consider the latent and unobservable attitudes of travellers towards public transport;
  - **Comments:** Models in this category are Aim primarily at understanding the impact of individual perceptions an attitudes. This approach is particularly important when modelling the impacts of quality attributes of public transport, which are known to influence travellers' attitudes;
  - **Examples:** Matas (2004), Poku-Boansi & Adarkwa (2013).

Table 3: Summary of Correlation of Independent Variables used in Estimating the Demand Model

	Annual number of passenger kilometres	Fares	Income of household	Population	Trip duration	Access to transport	Employment status	Vehicle kilometres operated
Annual number of passenger kilometres	1	-.186 (**)	-0.031	.757(**)	-.183(**)	.104(*)	-0.02	0.094
Fares		1	0.089	-0.013	.482(**)	-.726(**)	-0.031	-.449(**)
Income of household			1	-0.026	0.095	-0.087	-0.055	-0.033
Population				1	-0.026	-0.007	0.051	-0.046
Trip duration					1	-.288(**)	-0.013	-.499(**)
Access to transport						1	.118(*)	.281(**)
Employment status							1	.136(**)
Vehicle kilometres operated								1

*** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed). N = 400*

Source: Poku-Boansi, M. & Adarkwa, K. (2013) The determinants of demand for public transport services in Kumasi, Ghana, *Journal of Science and Technology (Ghana).*

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- **Category 4: Using data from supply side**
  - **Data:** objective data (timetable etc);
  - **Description**: passengers' choice behaviours are assumed to be affected by supply side factors such as vehicle capacity and seat availability;
  - **Comments:** Factors from the supply side could affect passengers' choice behaviour, and this is mostly investigated in the context of transit assignment modelling.
  - **Examples:** Cepeda et al. (2006), Fu et al. (2012), Nuzzolo et al. (2012).

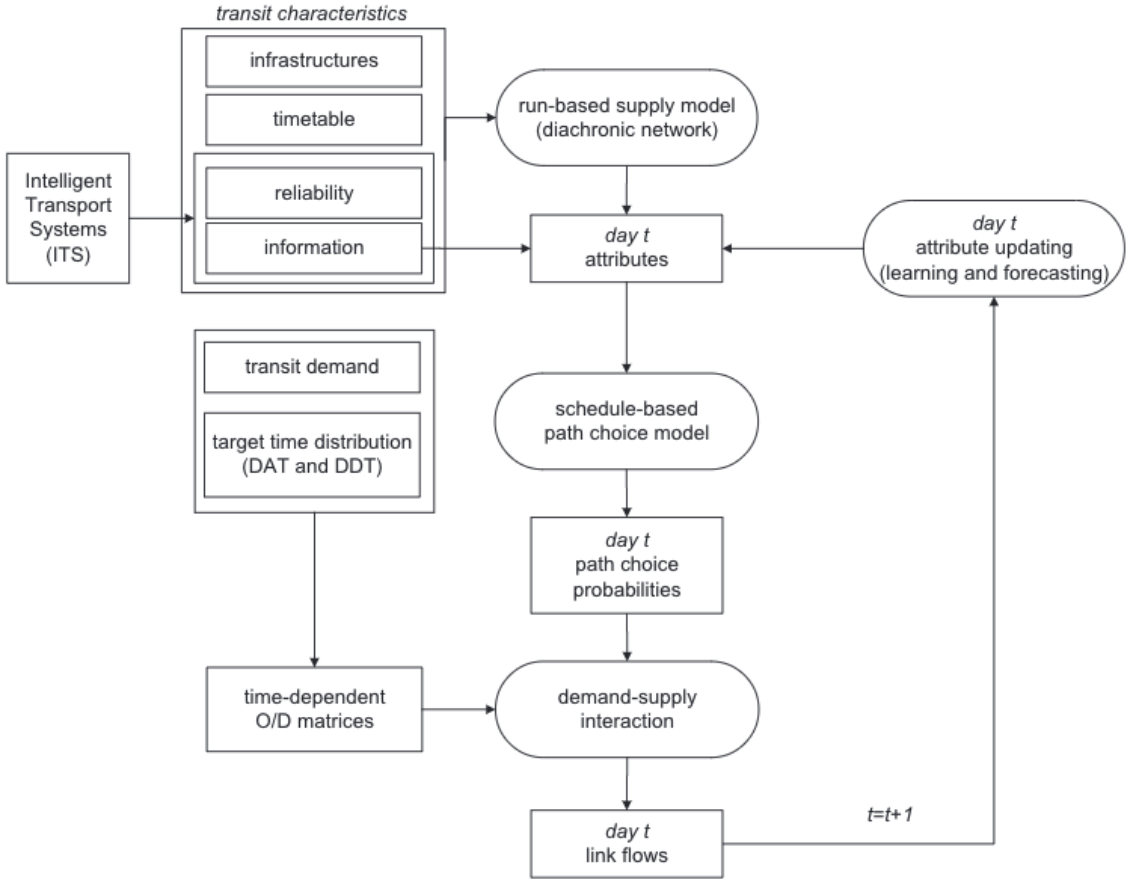

Fig. 1. The proposed schedule-based assignment model: general scheme.

Source: Nuzzolo at al(2012) A schedule-based assignment model with explicit capacity constraints for congested transit networks, *Transportation Research Part C*.

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- **Category 5: Using passive data**
  - **Data**: Passive data (mobile phone trace and social media data);
  - **Description**: Passive data refers to the data not collected through active solicitation and is often generated for purposes that are not originally intended but can potentially be used for practical transport planning applications;
  - **Comments:** This class of models attempts to model and analyse mode choice behaviour using, for e.g. active reviews;
  - **Examples:** Mondschein (2015); Chen et al. (2016); Lee et al. (2016)

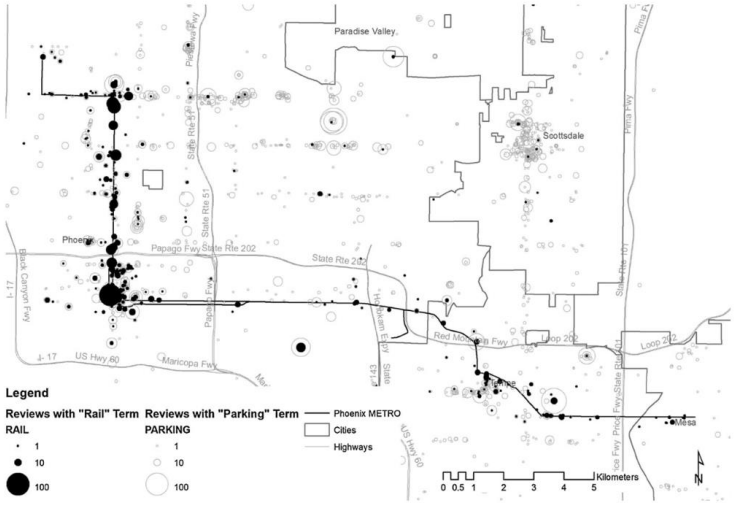

Fig. 1 Distribution of "Rail" and "Parking" terms around Phoenix

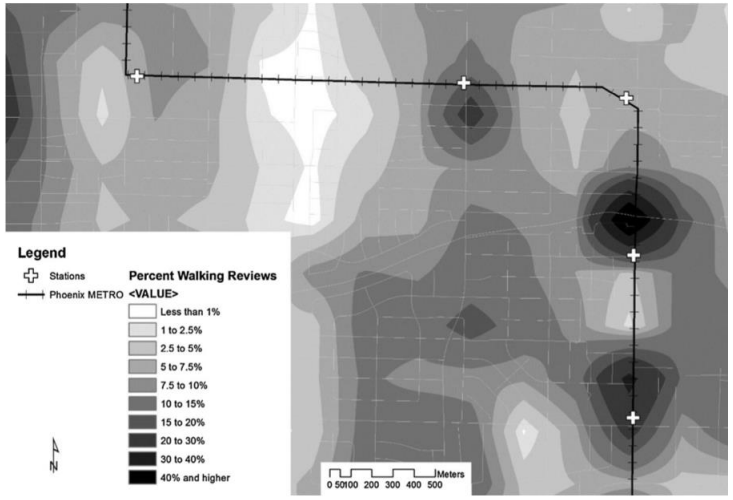

Fig. 3 Relative number of walking-term reviews, as a percentage of all transportation-content reviews

Source: Mondschein, A. (2015) Five-star transportation: using online activity reviews to examine mode choice to non-work destinations, *Transportation*,

Main explanatory variables in public systems

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The factors that influence mode choice can be summarised as given below.

- Bus system related factors: Walking time, waiting time, bus route configuration, travel time, travel cost, vehicle capacity, seat availability
- Neighbourhood related factors: Walkability, land-use, design
- Socio-economic factors: Gender, age, number of children in the household, income level, car/bike ownership, possession of a driving licence, education, occupation, attitude towards public transport

Main explanatory variables in public systems

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Summary of information needed for mode choice models

Variables in mode choice models (ideal)	What AFCs can offer	What Bus ITS can offer	What Journey Planner app can offer	Future Extensions
Gender	Gender in user profile		Gender in user profile	
Age	Age in user profile		Age in user profile	
Level of income	Optional level of income in user profile		Optional level of income in user profile	
Car ownership	Optional in user profile		Optional in user profile	
Travel cost	Yes		Yes	
Travel time		Yes	Yes, using user tracking feature	
Comfort				Using additional instrumentation (gyroscope and accelerometer) on-bus Smiley feedback instruments at bus stops
Seat availability	Yes, with enhancements			
Service intervals		Yes	Yes	Yes, with additional instrumentation at bus stops
Waiting environment				With the addition of smiley feedback instruments at bus stops
Vehicle characteristics				Yes, with additional on-bus instrumentation (noise, vibration sensors)
Ease of transfers/ interchanges			Yes	
Information provision			Yes	
Walkability				

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ITS Functional requirements for data capture

Functional requirements for data capture

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Types of ITS data

The scope of the ITS system used for data capture covers the following aspects.

- Data collected from the bus (on-bus ITS)
- Data collected from bus stops
- Data collected from journey planning and passenger information apps and websites
- Data collected by actively eliciting passenger responses using additional hardware

Functional requirements for data capture

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Additional functional requirements for bus ITS

- Buses shall be instrumented with additional detectors that shall do the following.
  - Vehicle characteristics
    - Measure ambient noise levels
    - Measure ambient temperature
    - Measure vibrations
  - Ride comfort
    - Acceleration
    - Jerk
    - future extension

Functional requirements for data capture

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Additional functional requirements for bus ITS

- Buses shall be instrumented with additional detectors that shall do the following.
  - Data capture
    - The system shall capture vehicle characteristics data at one-minute granularity and send timestamped data to the backend server
    - The system shall capture ride comfort data at one-second granularity and send timestamped data to the backend server
  - Data analysis
    - The backend system shall store the collected data
    - The backend shall have functionality to provide access to the stored data using a messaging platform that supports MQTT protocol allowing external analyses engines to access and process the data

Functional requirements for data capture

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Additional functional requirements for bus-stop instrumentation

- Bus stops shall be equipped with passenger counters
  - The sensors shall measure the number of people at the bus stop every second
  - Data capture
    - The sensors/system shall send timestamped information to the backend server whenever the detected people count changes
    - The backend system shall make the data available to external software modules over a messaging bus that supports MQTT protocol
  - Data analysis
    - The backend server shall have an algorithm to estimate bus frequency by analysing the captured passenger count data

Functional requirements for data capture

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Functional requirements for future extensions

- Additional on-bus instrumentation
  - On-bus ITS system shall include the following sensors: gyroscope, accelerometer, noise sensors, vibration sensor and a thermometer
  - Noise and vibration sensors and the thermometer shall collect data from the passenger environment
- Additional instrumentation at select bus stops and waiting areas
  - People sensor
  - Feedback smiley instrument