Vehicle Transport System by Sharing, Electrification and Automatization

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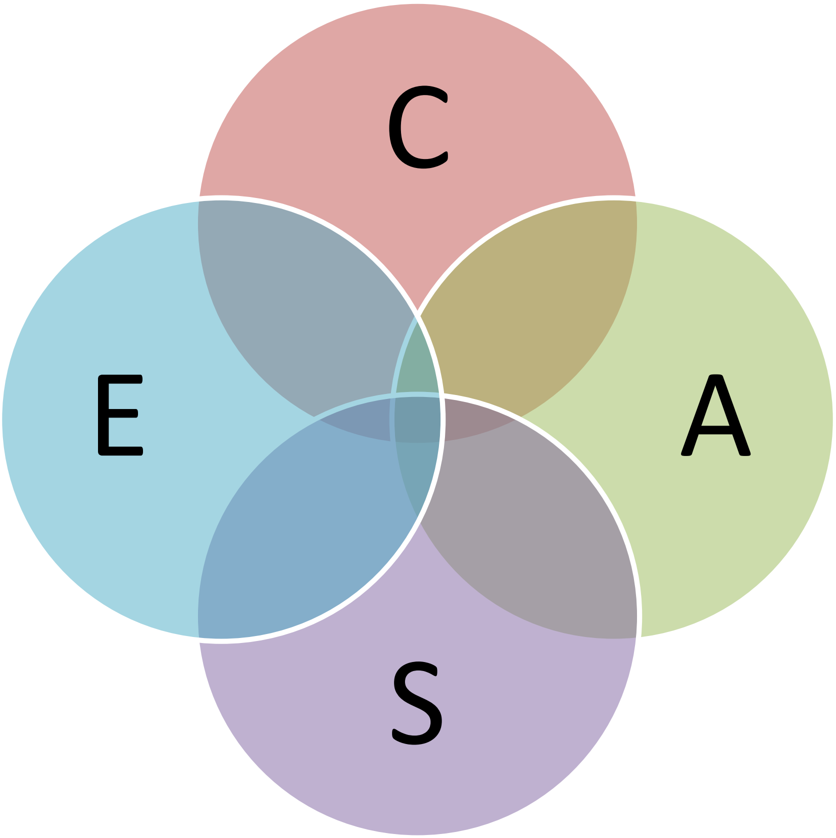
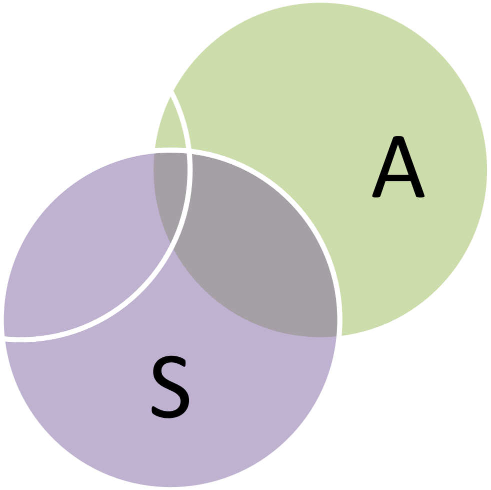
CASE

- **C**onnected
- **A**utonomous
- **S**hared
- **E**lectric

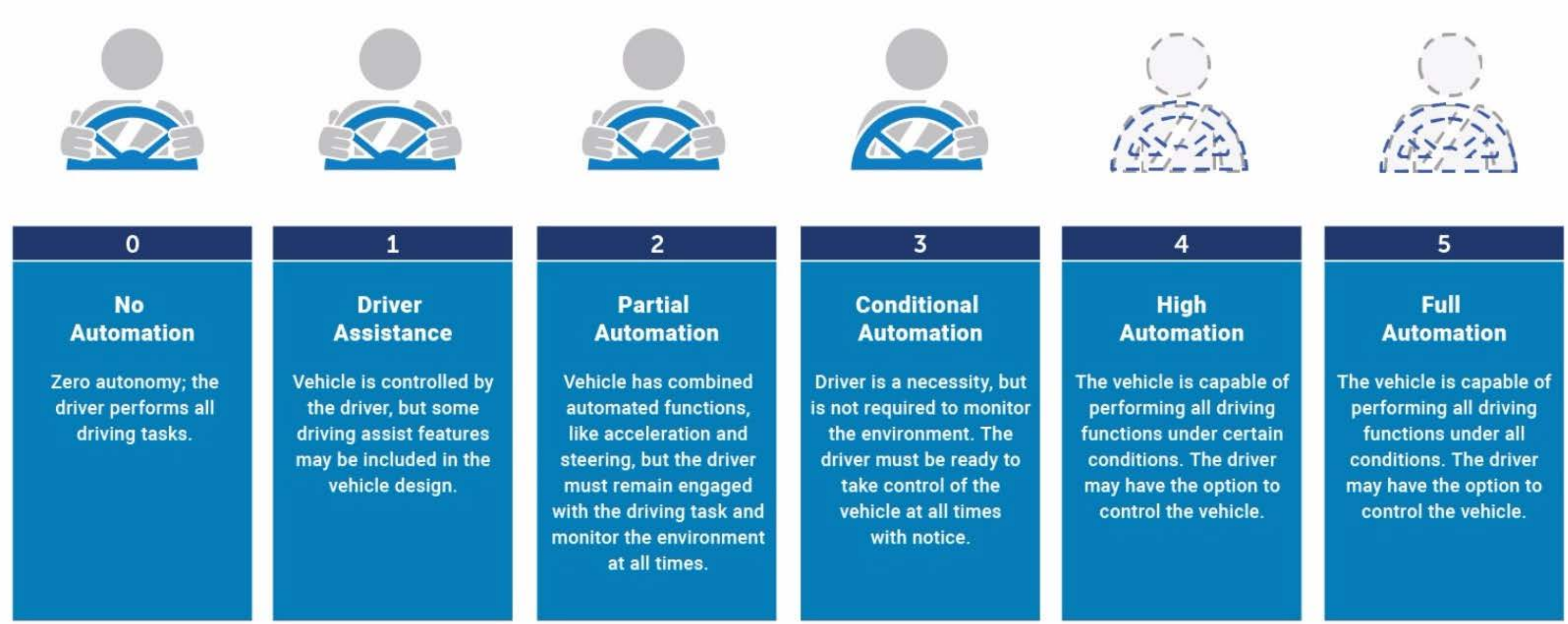


"Connected, Autonomous, Shared, Electric: Each of these has the power to turn our entire industry upside down. But the true revolution is in combining them in a comprehensive, seamless package." by Dr. Dieter Zetsche (Chairman of the Board of Management of Daimler AG)



Shared autonomous vehicles

Automation levels (SAE)



Source: https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety

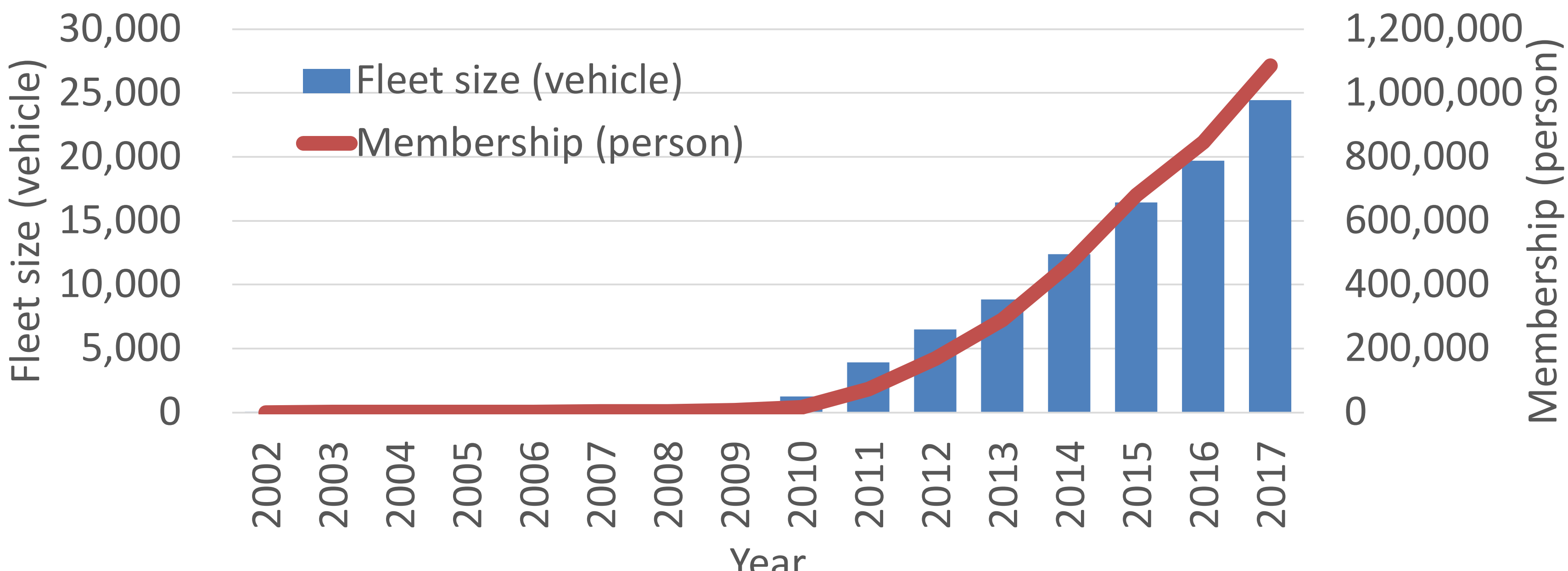
Target year in Japan

Level 3 2020

Level 4 2025

Car sharing

- The fleet is made available for use by members of the car sharing organization
- Merits: Rational mode choice, decrease car dependency, fuel efficient vehicle, save parking space, etc.

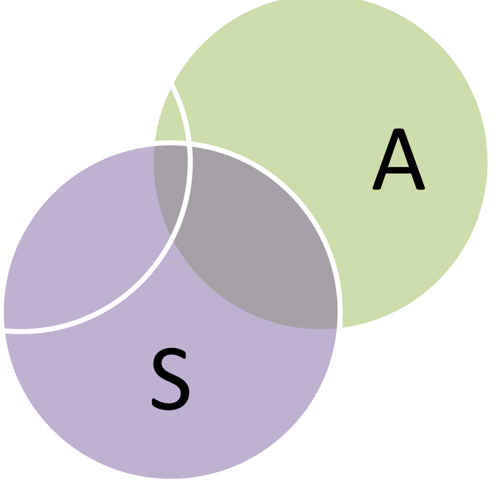


Car sharing in Japan

(Source: Foundation for Promoting Personal Mobility and Ecological Transportation)

Weak point of car sharing

- One-way system is more convenient for users than return-only system
- But, one-way operation causes imbalance of fleet, deteriorating efficiency



Autonomous vehicle can relocate by themselves

Objective

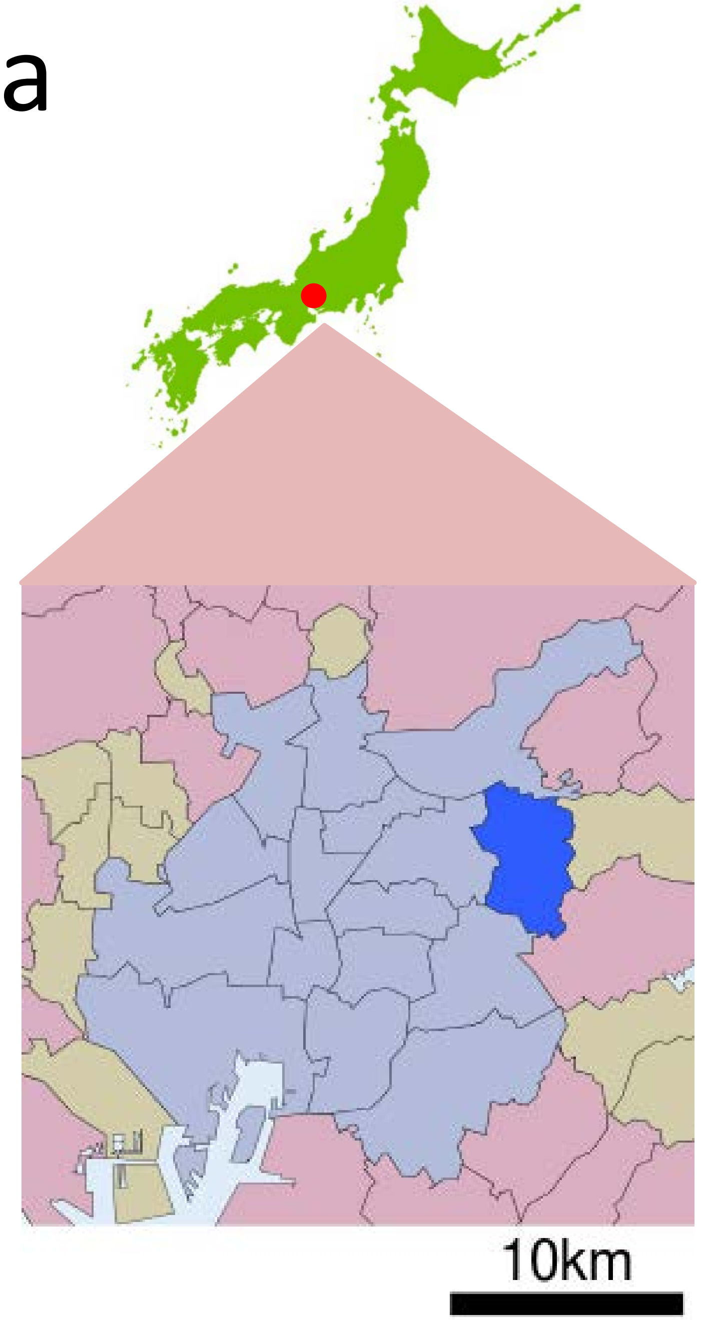
Forecast supply and demand of shared autonomous vehicles

- Probability for sharing private cars
- Potential demand for driverless taxi
- Required fleet size

Study area

Meito Ward, Nagoya, Japan

- Area: 19.45 km^2
- Population: 164,570
- East-end of Nagoya City
- Residential area
- Good access to CBD by subway



Sharing of private autonomous cars

Now

Uber:

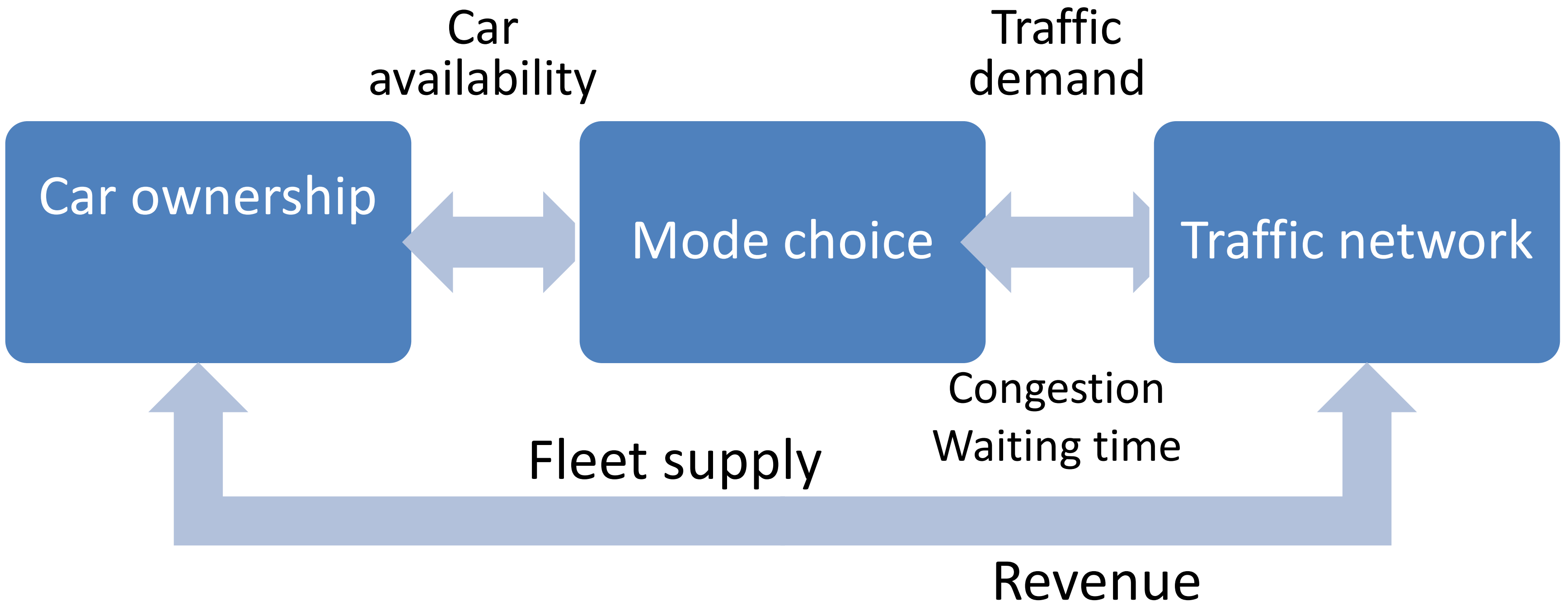
Private car driven by human driver as taxi

Future

Shared private autonomous car:

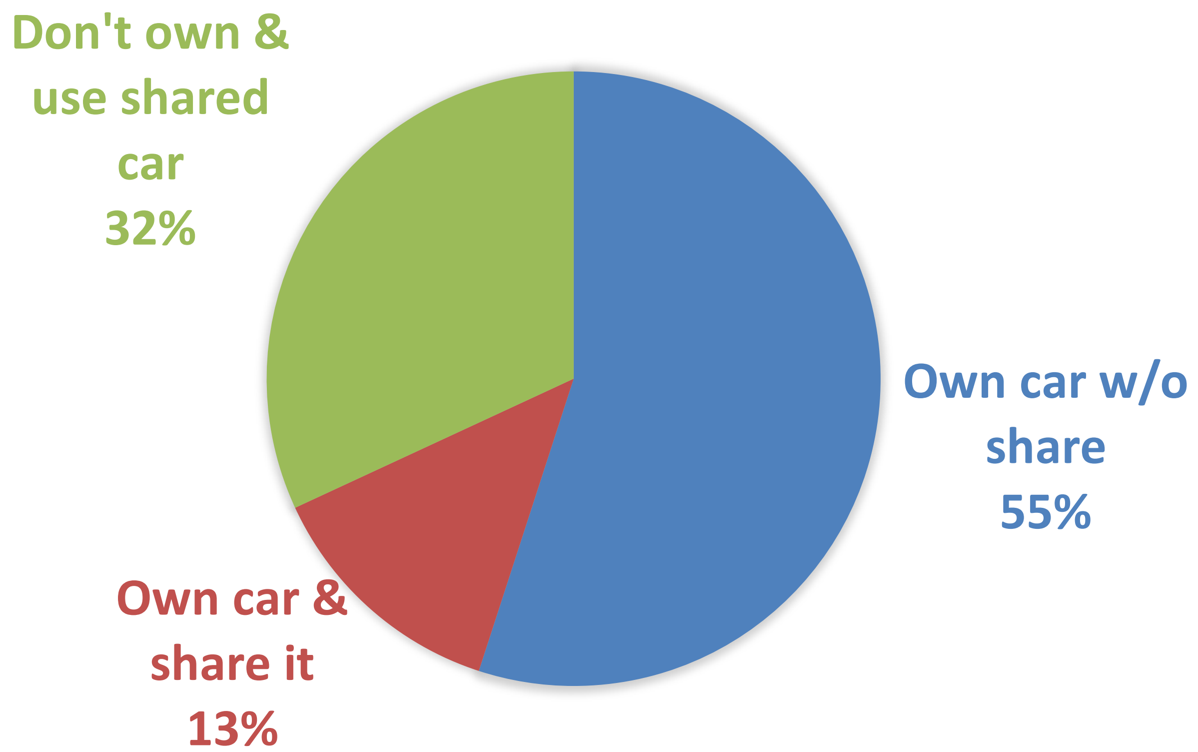
private autonomous car used as taxi at spare time

Framework



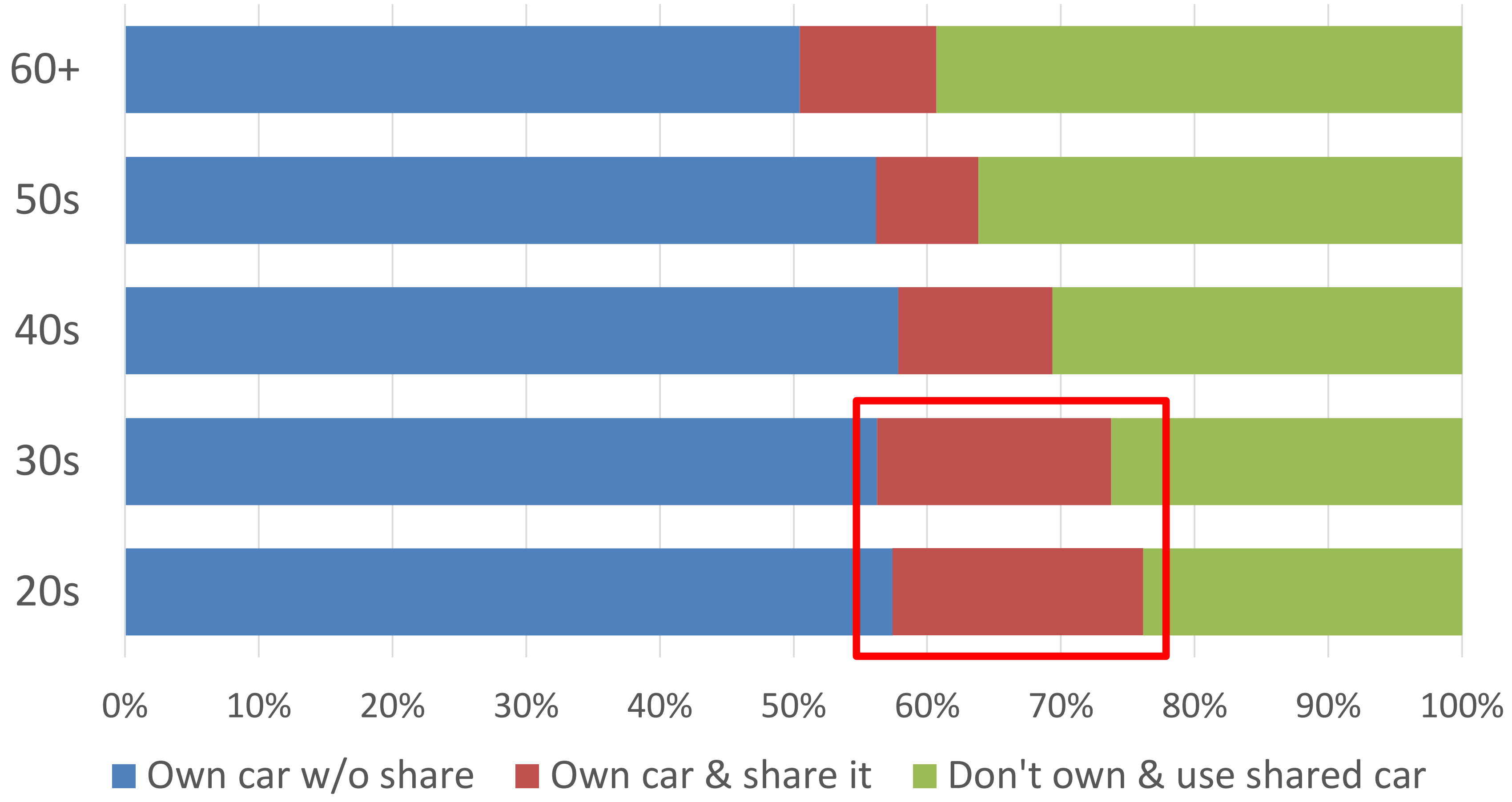
- Interaction is roughly considered
- Equilibrium state is not rigorously calculated

Intention for autonomous vehicle ownership & shared use (N=803)

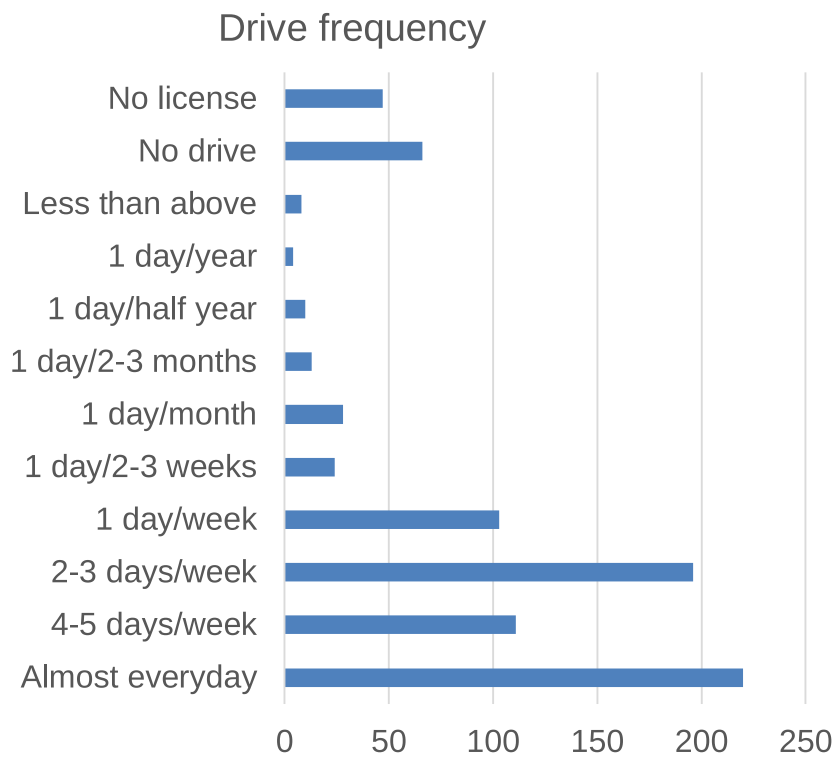


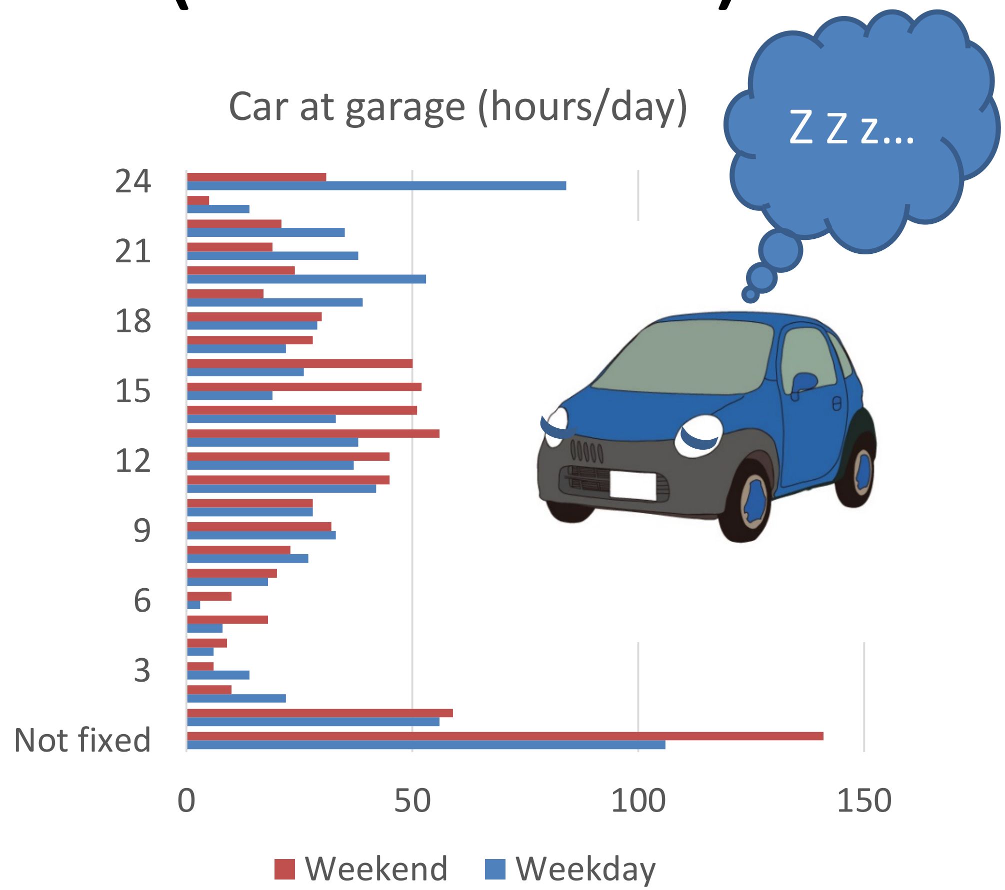
- 70,000 Private cars in the area
  -> 9100 potential shared cars
  -> Driverless taxis system can be organized by them

Age difference in intention



Current car use (or non-use)

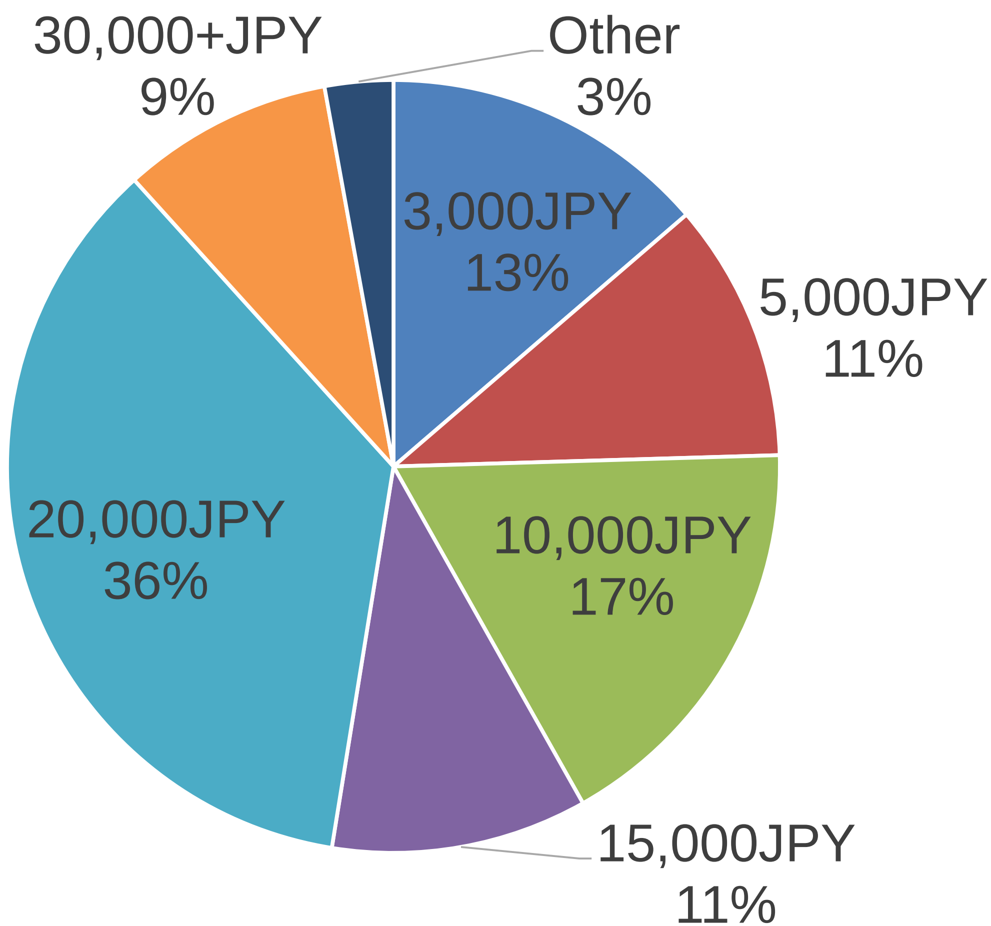




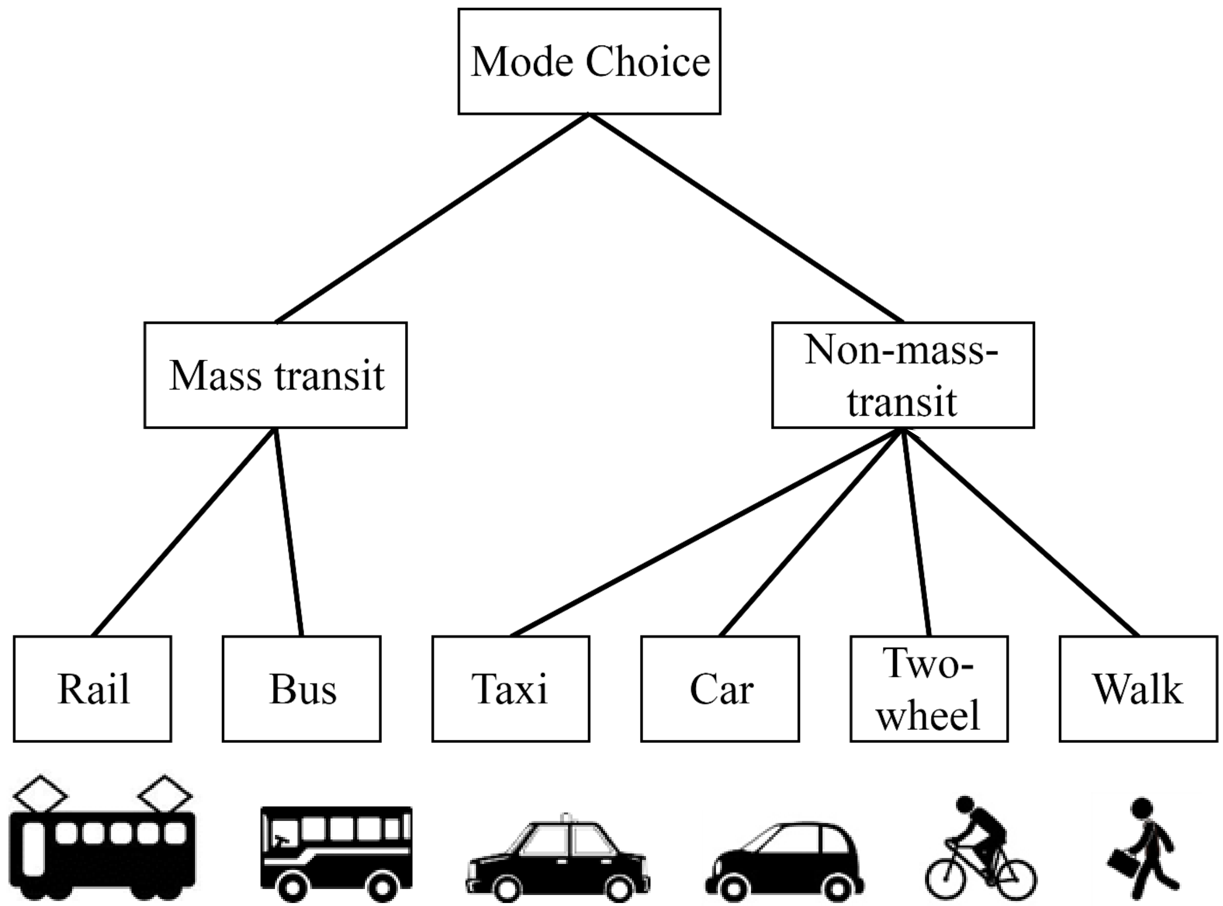
- 14 & 13 hrs. at garage on weekday and weekend on average
- 10 & 14% of households don’t use car on weekday and weekend

Expected monthly income by sharing

- Assumed to provide your private car for 5 hrs. each day



Nested logit model of intra-zonal travel mode choice



By Chukyo person trip survey data in 2011

Estimation results (N=4542)

Generic variable	Coef.
Travel cost [100JPY]	-0.126**
Travel time [hour]	-0.998**
Waiting time [hour]	-2.211**

- Adjusted rho-square = 0.158
- Value of time = 792 JPY/hr
- Inclusive value = 0.245** (for NMT)
  =1.0 (fixed for MT)

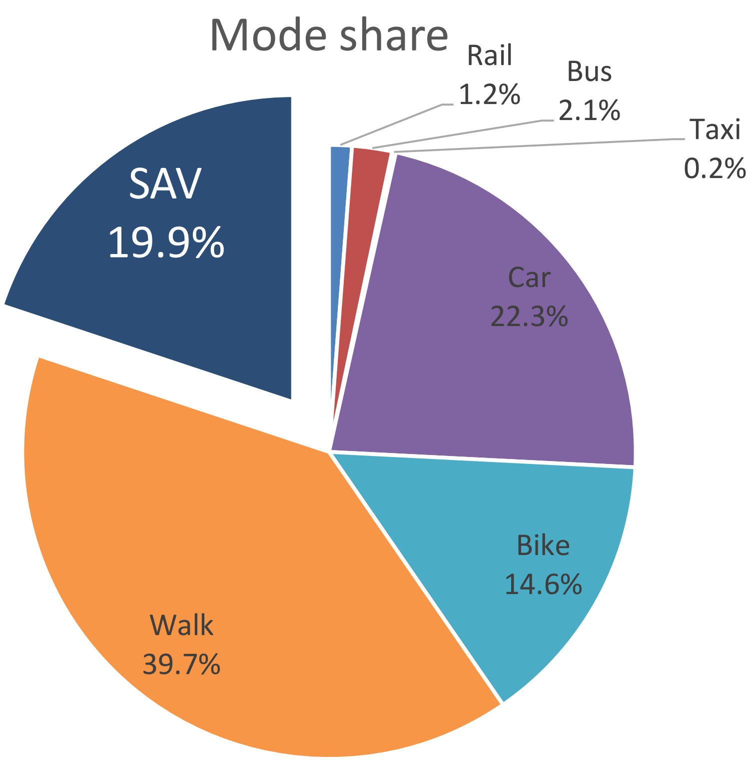
Alternative specific variable	Rail	Bus	Taxi	Car	2wheel
Male	0.106	-0.328	0.253	0.071*	-0.059*
Child (<16)	-2.241**			-0.348*	-0.785**
Student				-0.350*	0.335**
Old (65+)	0.197	2.419**	0.805**		
Unemployed	-0.605*	0.224	-0.163	-0.129**	-0.161**
Commute	1.007**	1.711**		-0.141**	
Constant	-2.199	-3.907	-0.71	0.273	-0.099

- Walk as base alternative

* 5% significance, ** 1% significance

Potential demand scenarios

- Cost is assumed as 55 JPY/km (slightly less than private car)
- Waiting time is assumed as 1 minute
- Those who own car w/o share will not use other share cars

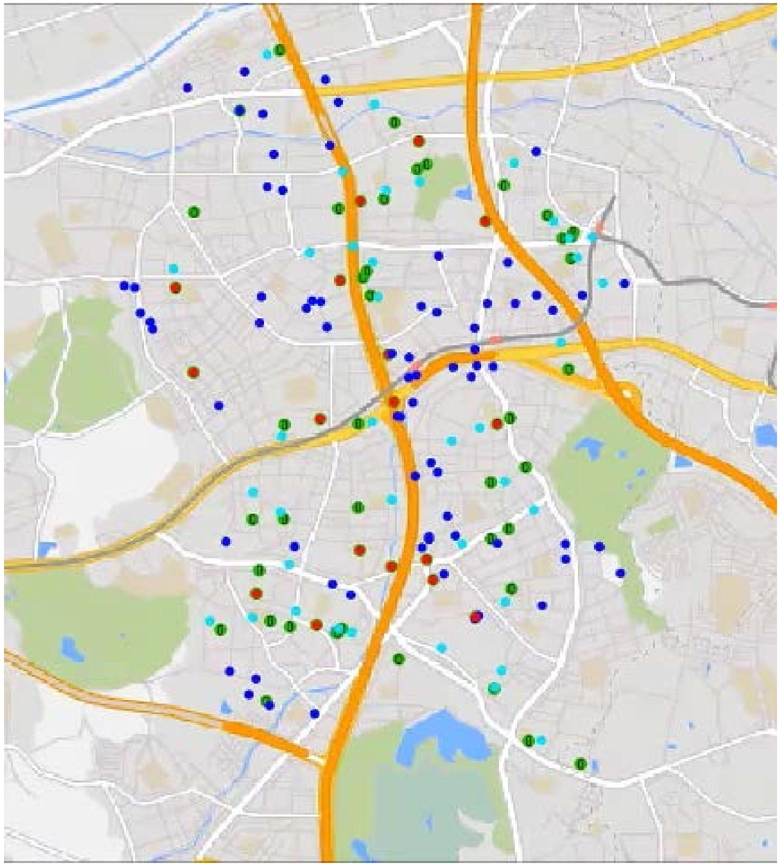


Trip demand by scenario

	Those who own car w/o share	
Waiting time	won’t use	will use
1 minute	**22455 trips**	43307 trips
5 minutes	18107 trips	34005 trips

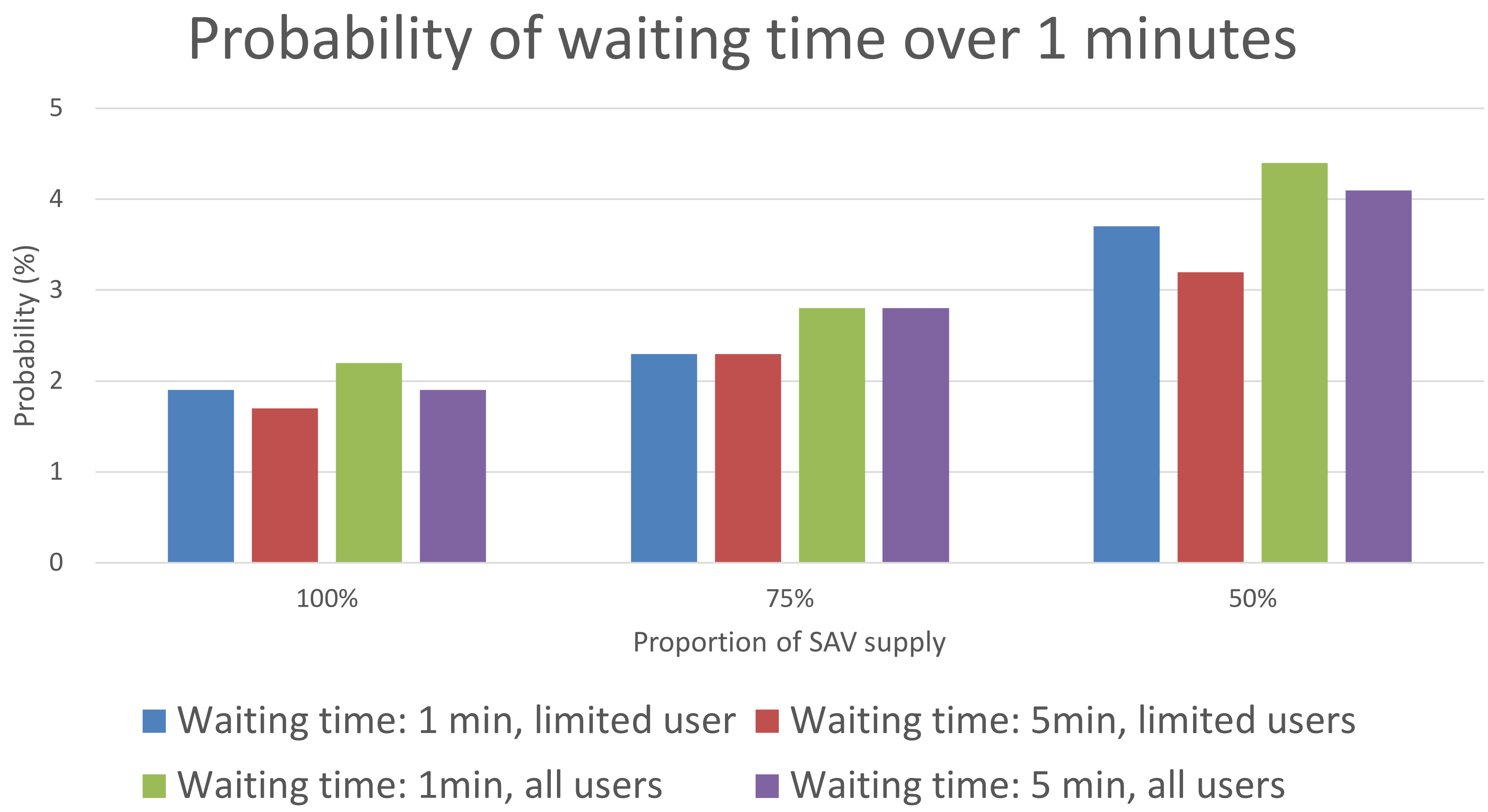
Agent-based simulation

- Trip demand:
  - Generated based on actual OD pattern
- Vehicle agent:
  - Distributed based on population distribution
- Vehicle speed:
  - 18.9 km/h (peak hour)
  - 24 km/h (off-peak)



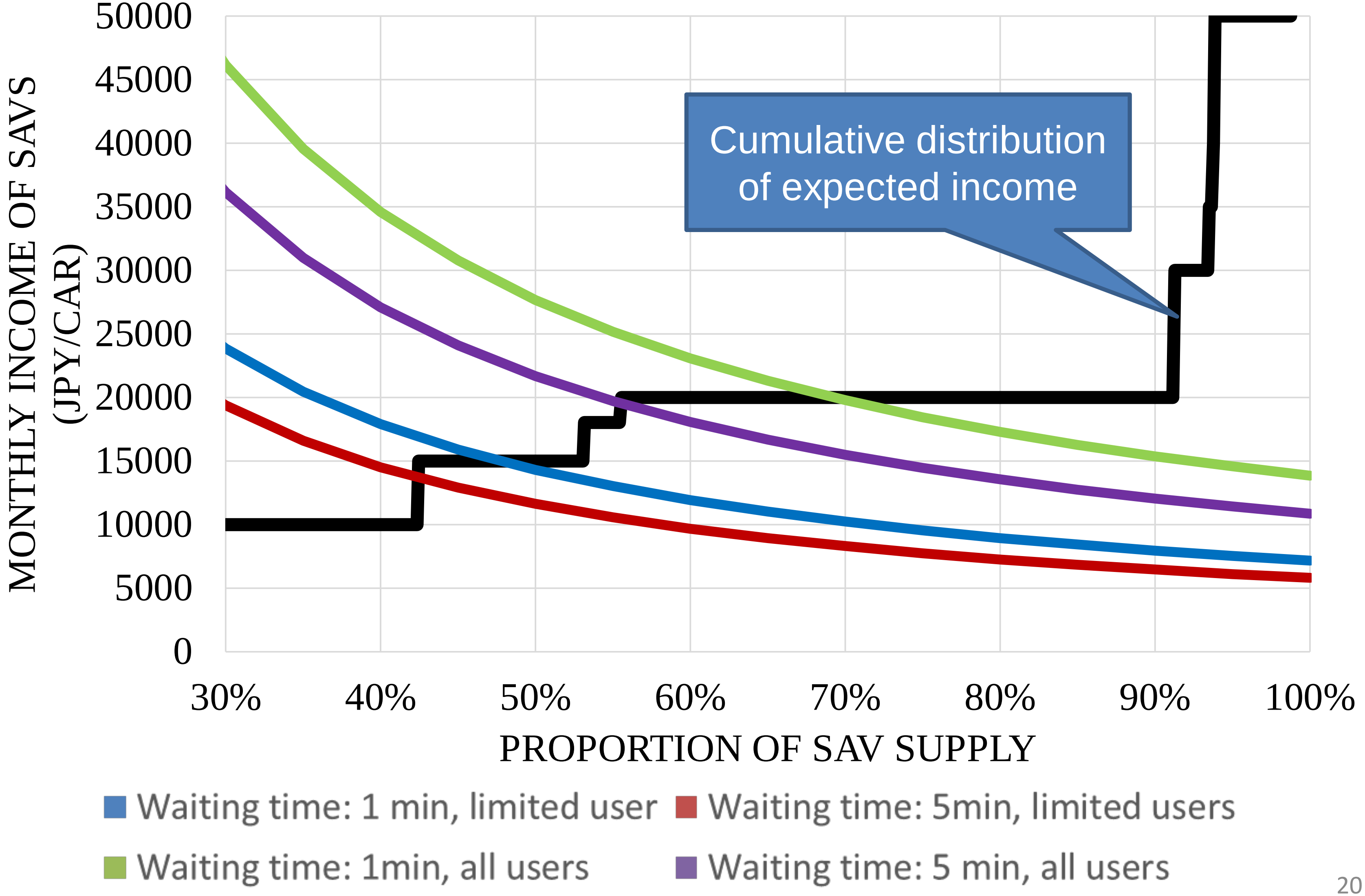
Empty taxi
En route to customer
Occupied taxi
Waiting customer

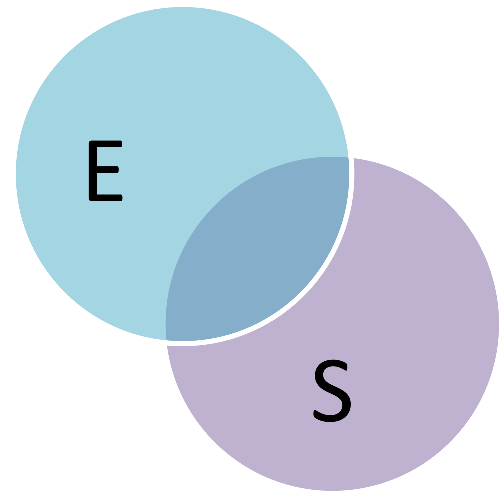
System behavior by scenario



1 minute of waiting time is satisfied at 95+%

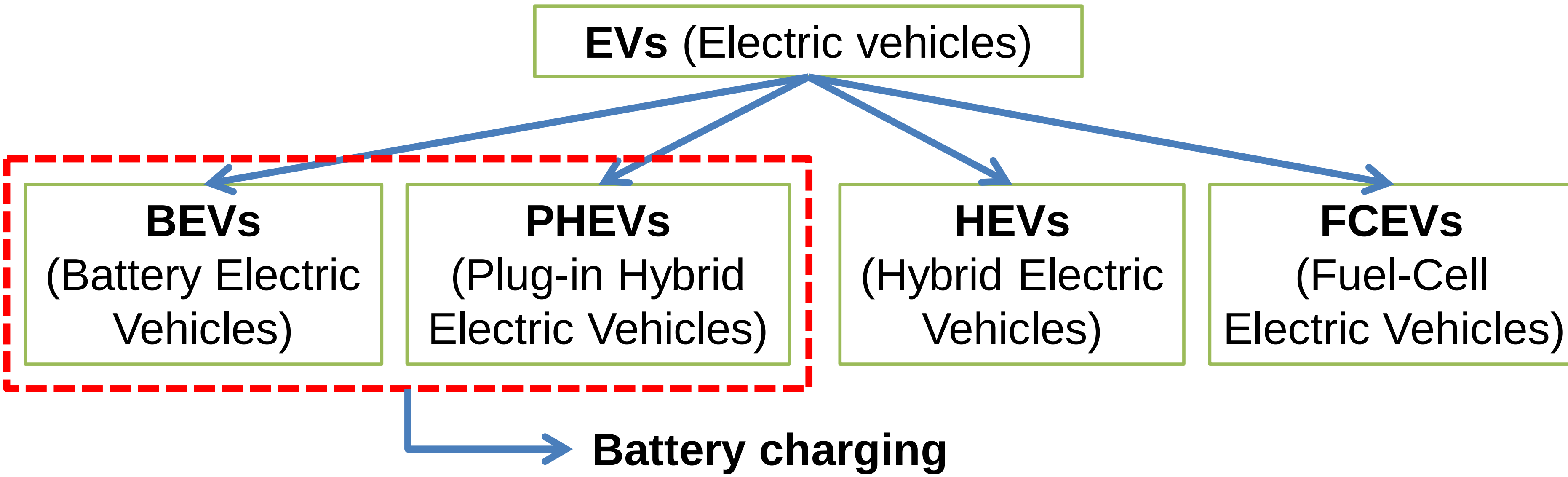
Relationship between supply and income





Electrification of university car fleet: A case of Nagoya University

Electric vehicles



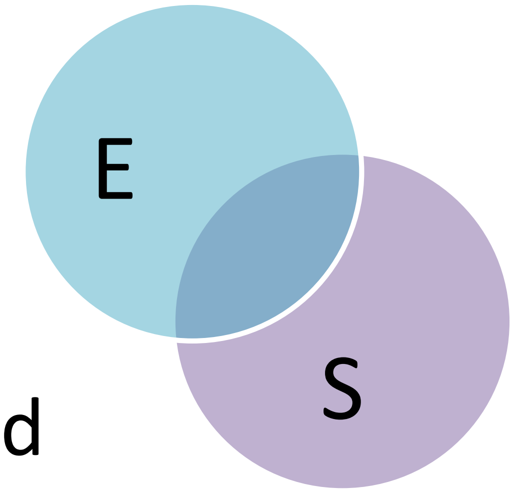
Charging Level	Type*	Power supply	Charging time (24kWh battery)	Typical use	Standard
Level 1	Normal	120V AC	16 hours	Home	SAE J1772
Level 2	Normal	240V AC	8 hours	Home or public places	SAE J1772
Level 3	Fast	480V DC	30 minutes	Public places	CHAdeMO/CCS/ Tesla

*Normal charging aka slow charging
Fast charging aka quick or rapid charging

Anxiety about electric vehicle

- Shorter drive distance than gasoline vehicle

Mostly short distance trips are served by car sharing

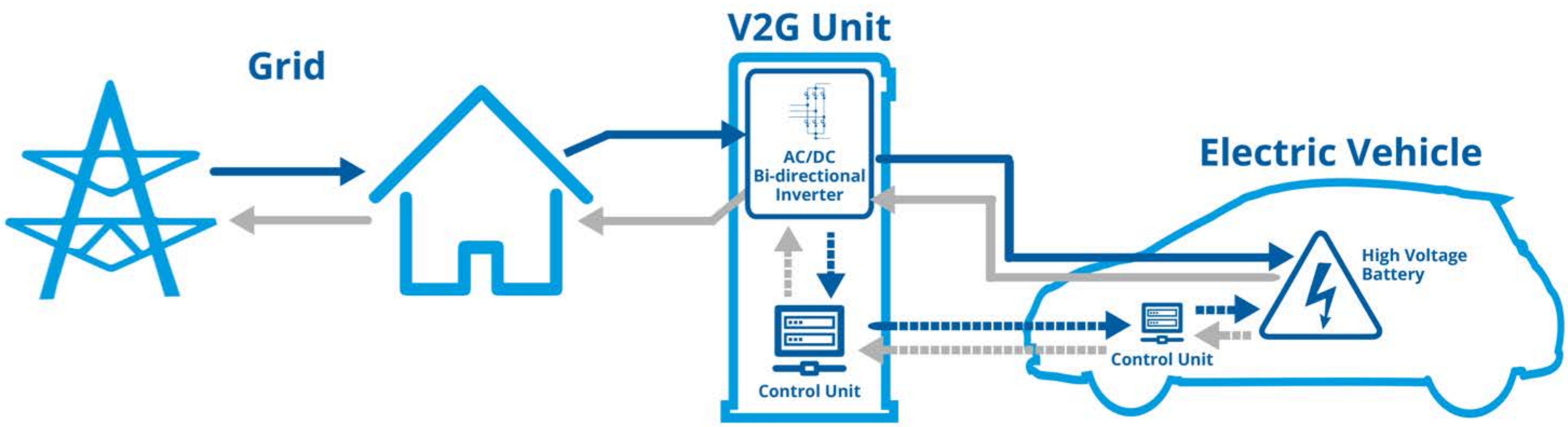


- Increase in electricity demand

V2G can contribute peak cut of demand

Vehicle to grid (V2G)

- Batteries in EV could be used to let electricity flow from the car to the electric grid
- Provide power to help balance loads by "valley filling" and "peak-shaving"



Source: http://www.cenex.co.uk/vehicle-to-grid/

Objective

- To evaluate the reduction of CO_2 emission by replacing university car fleet with EV
- To quantify electricity supply with V2G for campus use

Method

- Fitting the Daily Travel Distance (DTD) data with different distribution functions
- Based on the distribution function, determining the vehicles that can be replaced by EV
- Calculating electricity supply with V2G considering usage and charging pattern

Data

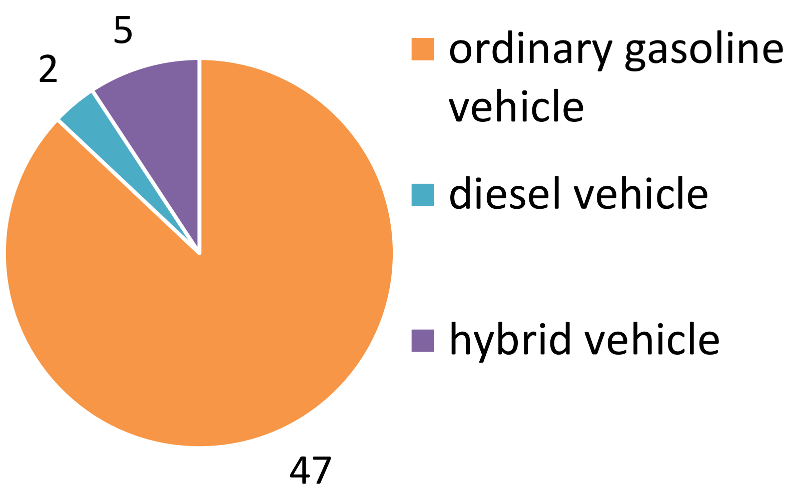
Nagoya University's fleet system

- Observations: Oct. 2014 to Sept. 2015 with 54 vehicles
- Item: department, vehicle ID, vehicle type, time of check-out and check-in, etc.

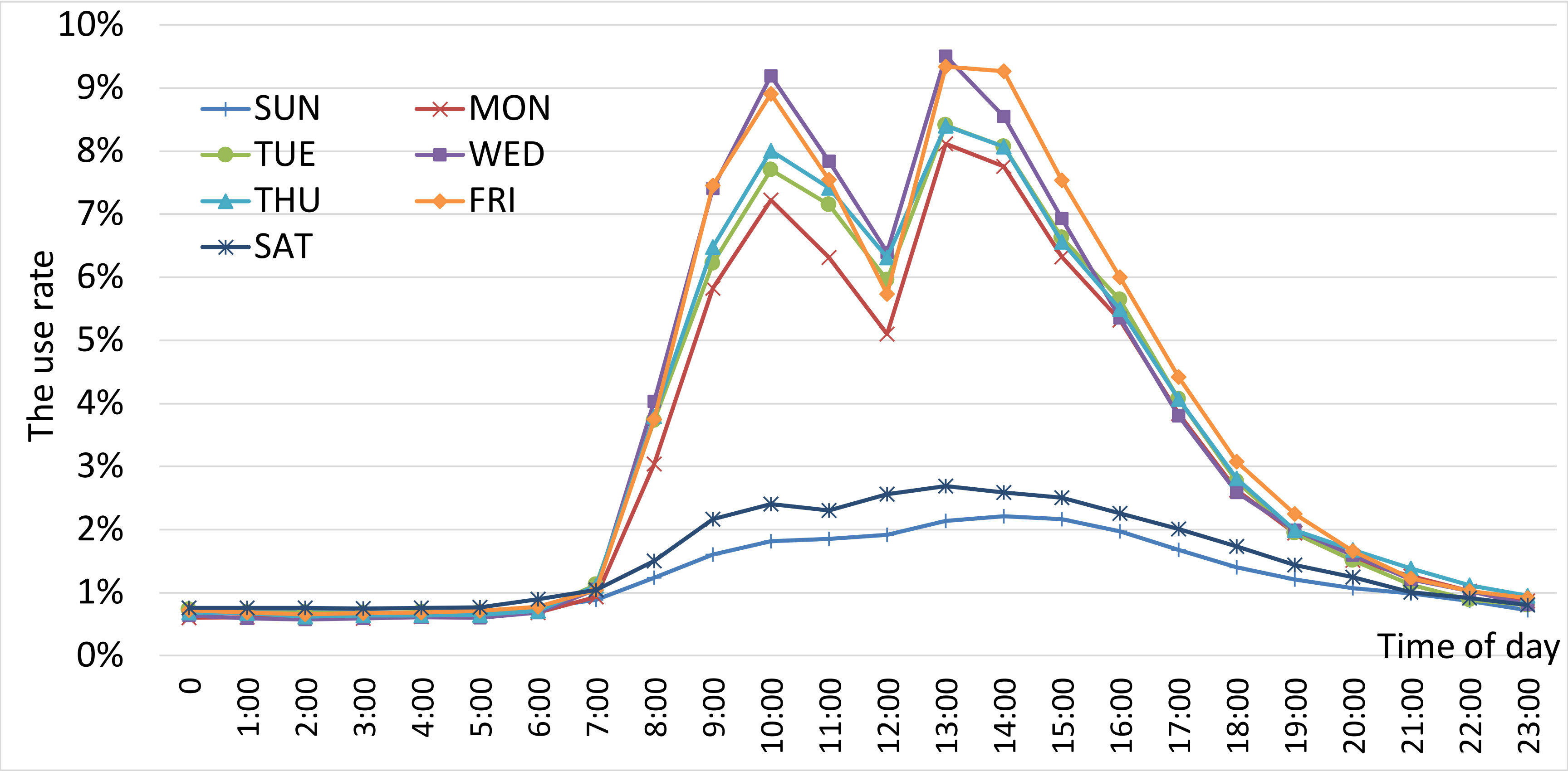
Number of vehicles by Faculty

Graduate School of Env. Studies	12
School of Agricultural Science	10
Research Institutes	10
Secretariat	8
Faculty of Science	5
Faculty on Liberal Arts	3
School of Engineering	2
School of Informatics and Science	2
Museum	1
Physical Education Center	1

Vehicle Type



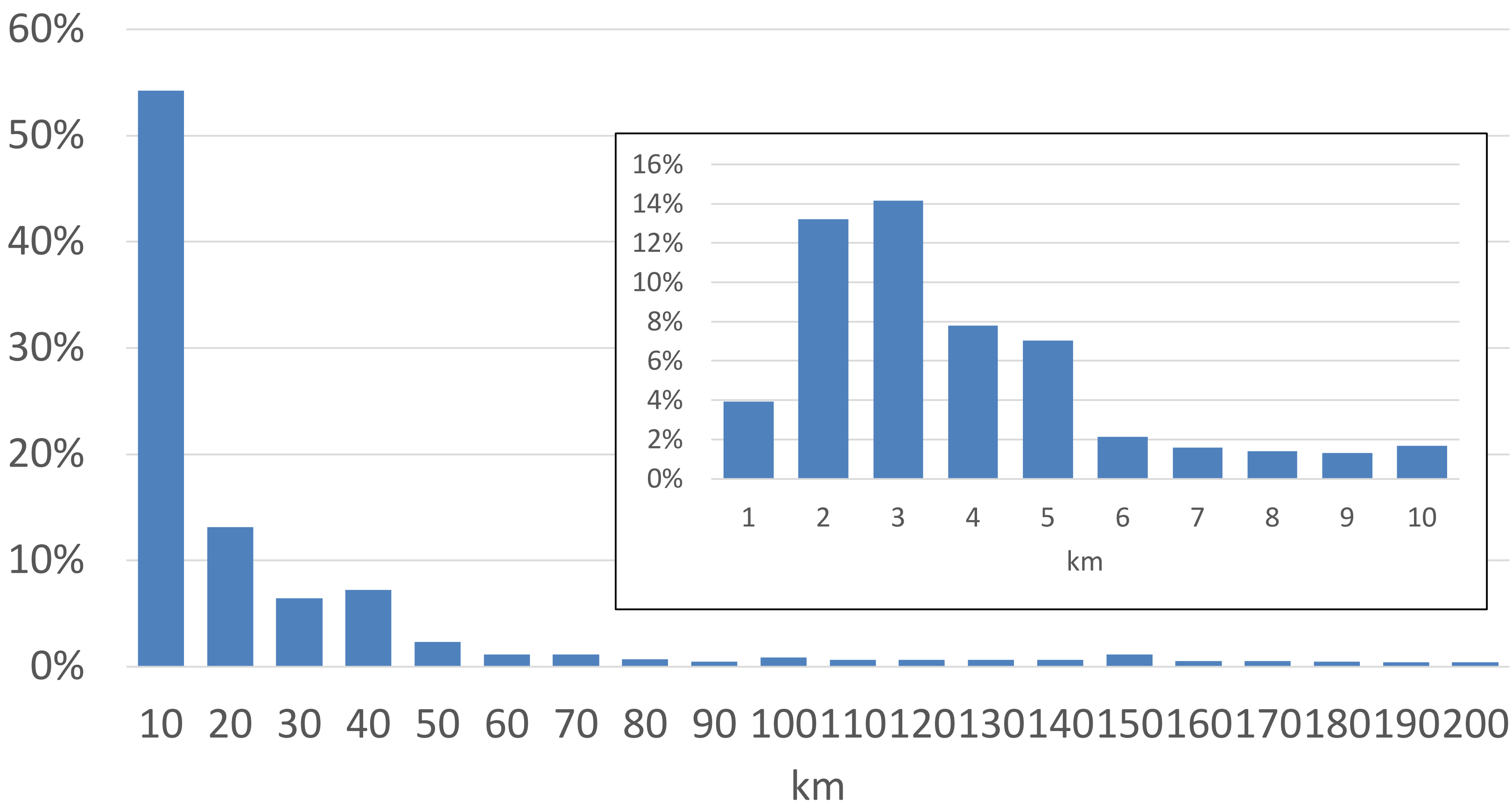
Vehicle use rate by time of day



Two peaks (10:00 and 13:00) and significant drop at 12:00

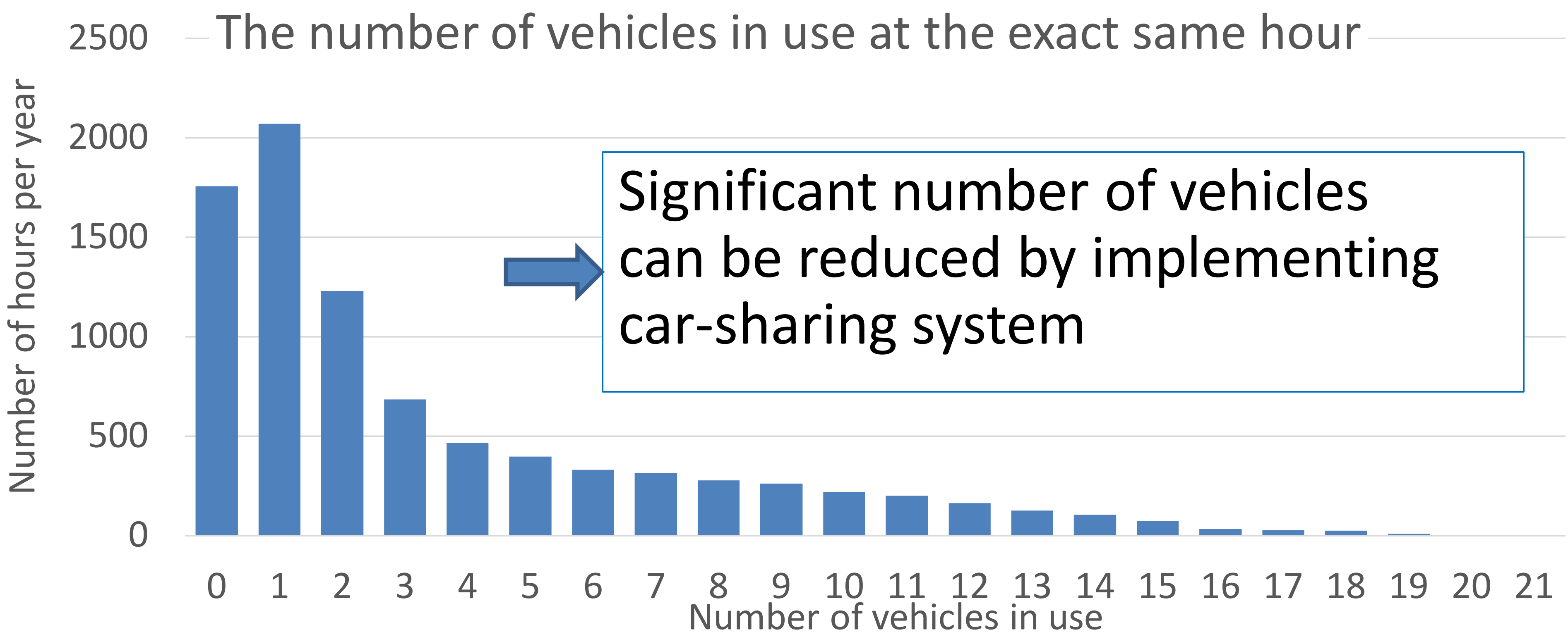
Consistent with people's daily work schedule

Trip distance per check-out



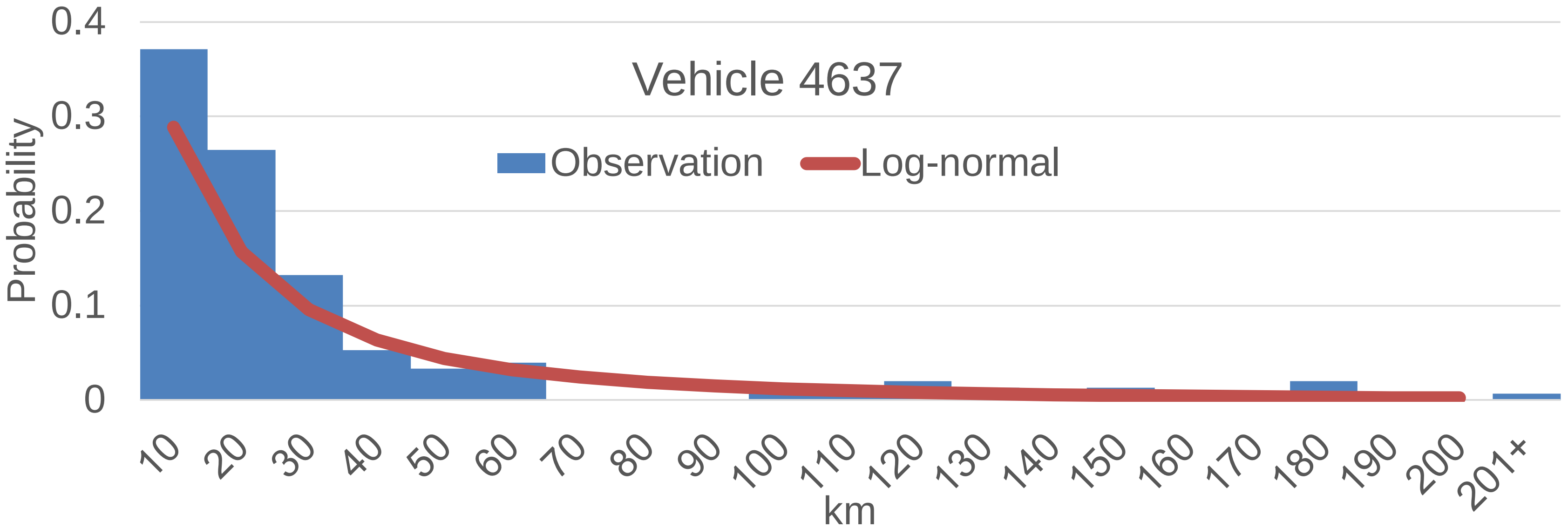
- Mostly, vehicles are used for short distance trips

The number of vehicles used at the same time

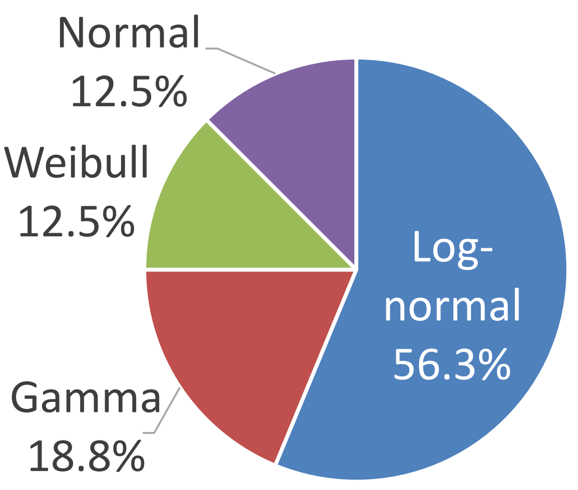


- At maximum, **21 vehicles (out of 48)** are used at the exact same hour, and it **happened only once** in a year.

Distribution of daily travel distance



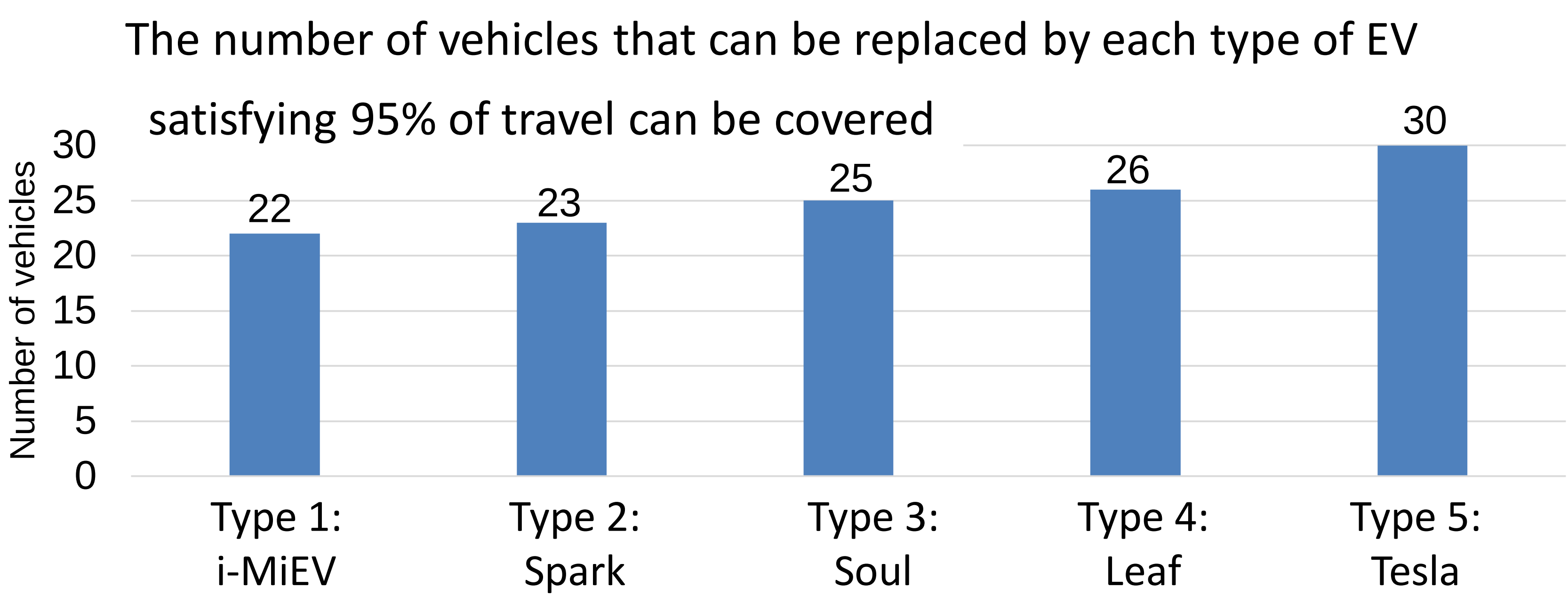
- Best fitted distribution is chosen for each vehicle although 20 vehicles didn’t fit any at 95% confidence level



Replace by EV

5 EV Scenarios

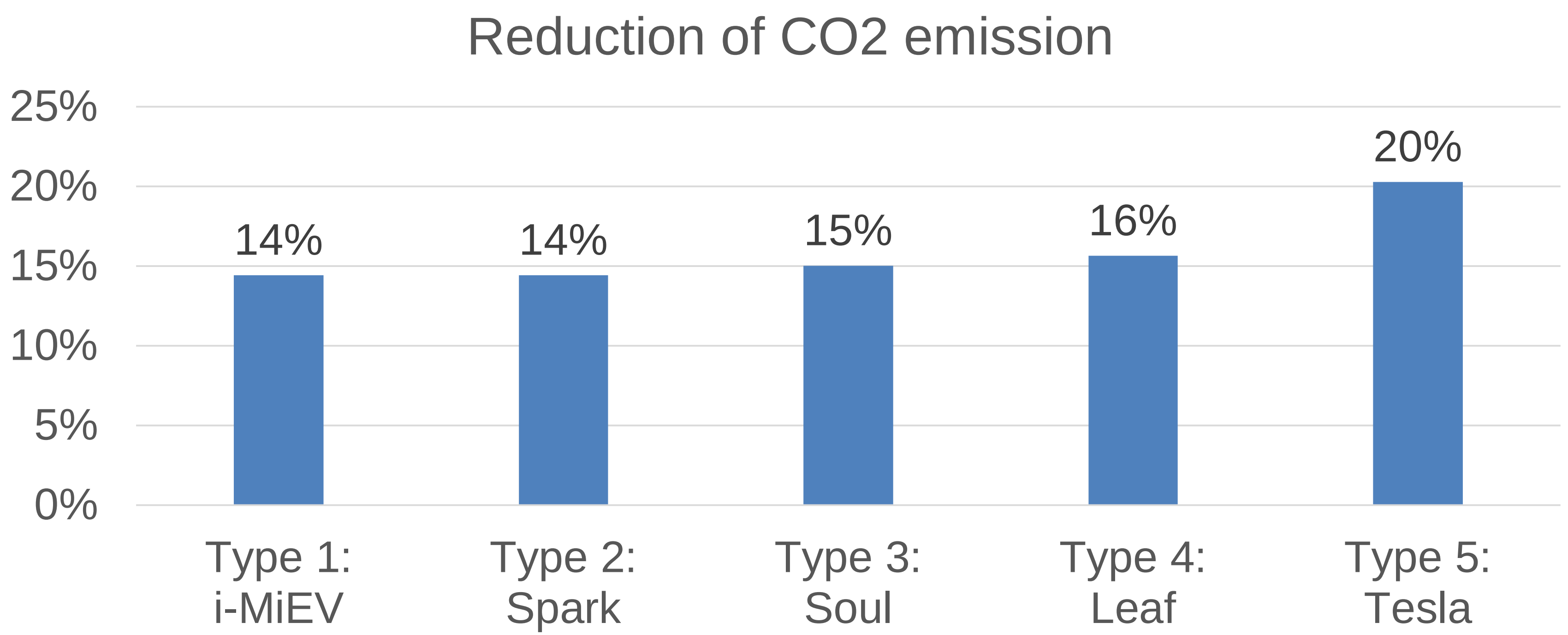
- Type 1: Mitsubishi i-MiEV (**100km, 16kWh**)
- Type 2: Chevrolet Spark EV (**130km, 21kWh**)
- Type 3: Kia Soul EV (**150km, 27kWh**)
- Type 4: Nissan Leaf (**170km, 30kWh**)
- Type 5: Tesla Model 3 (**320km, 60kWh**)



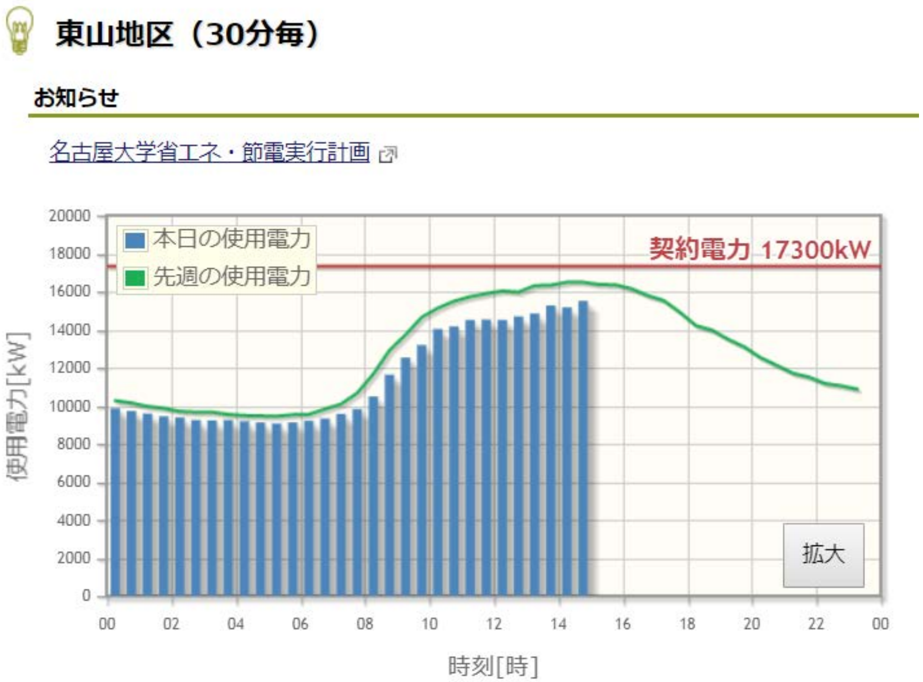
CO2 reduction

Emission factor	
Gasoline	Electricity
2.3 kg/L	0.39 kg/kWh

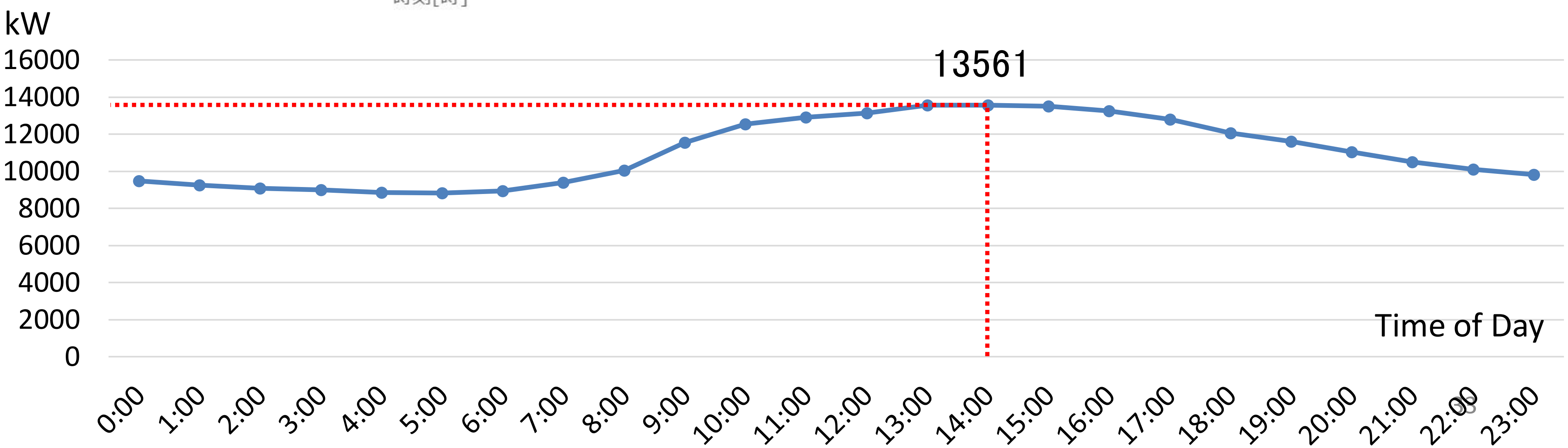
$$\begin{cases} CO_2 \text{ from } electricity = \dfrac{DTD}{Driving\ range} \times C \times 0.39 \\ CO_2 \text{ from } gasoline = DTD/JC08 \times 2.3 \end{cases}$$



Vehicle to grid



- University provides real time data of electricity use
- Collected data from Jun 20th 2017 to Jul 9th 2017, and used the average as reference
- According to NU announcement, even 0.3% reduction at peak could be helpful for contract



Charge/discharge speed

Estimated Electric Vehicle Charge Times

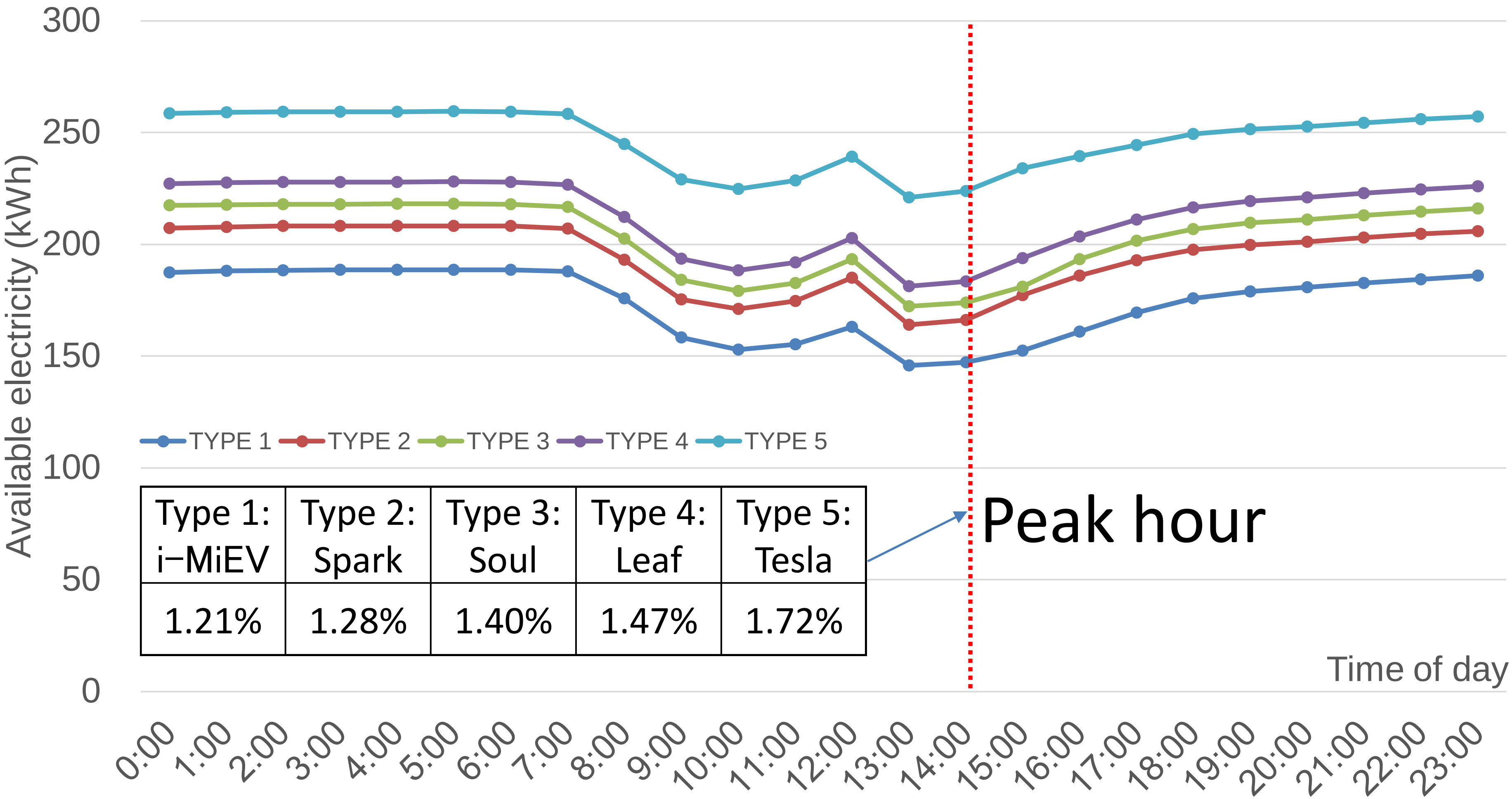
Vehicle	Battery Size	Level 2 LCS-30 5.8kW	Level 2 LCS-30 7.7kW	Level 2 LCS-30 9.6kW	Level 2 LCS-30 11.5kW
Mitsubishi i-MiEV	16kWh	5	5	5	5
Chevrolet Spark EV	21kWh	7	7	7	7
Kia Soul EV	27kWh	4.5	4	4	4
Nissan Leaf	30kWh	5	4.5	4.5	4.5
Tesla Model 3	60kWh	10.5	8	6.5	5

Source: https://www.clippercreek.com/charging-times-chart/

$$Speed \begin{cases} the\ speed\ of\ {\color{red}charging} \\ the\ speed\ of\ {\color{red}discharging} \Rightarrow 10kW\ \ per\ hour \end{cases}$$

- Available electricity from EV is calculated according to charge/discharge speed considering vehicle usage pattern

Average available electricity by V2G



Type 1: i−MiEV	Type 2: Spark	Type 3: Soul	Type 4: Leaf	Type 5: Tesla
1.21%	1.28%	1.40%	1.47%	1.72%

Final remark: Image of Car

Now

- Status symbol
- Independence
- Pollution emitter

Future

- Mobility tool
- Fleet (cars)
- Part of energy management