Shared Autonomous Private Vehicles: potential scenario in Nagoya, Japan

Toshiyuki Yamamoto

Nagoya University







"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)

Automation levels (SAE)



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

Target year in Japan



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.



Weakness of current 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 km²
- 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 1

Current car use (or non-use) Drive frequency Car at garage (hours/day) Z Z z... No license 24 No drive 21 Less than above 1 day/year 18 1 day/half year 15 1 day/2-3 months 12 1 day/month 9 1 day/2-3 weeks 1 day/week 6 2-3 days/week 3 4-5 days/week Not fixed Almost everyday 50 100 0 150 50 100 150 200 250 0 Weekend Weekday

- 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
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• Walk as base alternative

5% significance, ** 1% significance ¹⁴

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		

Supply and demand by time of day

Waiting Time = 1 minute



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)



Increase in traffic demand



Effect of congestion

	A: Constant speed	B: Current speed	C: Reduced speed
Peak (7-9, 17-19)	30 km/h	18.9 km/h	9.5 km/h
Off-peak	30 km/h	24.0 km/h	12.0 km/h



Relationship between supply and



Waiting time: 1 min, limited user Waiting time: 5min, limited users

- Waiting time: 1min, all users
- Waiting time: 5 min, all users

System behavior by scenario

Probability of waiting time over 1 minutes



1 minute of waiting time is satisfied at 95+%

Conclusion

• Autonomous private cars can satisfy travel demand at residential area in Nagoya, Japan

• Considerable amount of revenue can be earned by providing private car for sharing

• Increased car traffic should be well managed