# **Demand Forecasting of Autonomous Vehicles**

# **Based on Consumer Preference Analysis**

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### Autonomous Vehicle (AV)

• A vehicle that is capable of sensing its environment and navigating without human input



Illustration by Harry Campbell

Reduction of traffic accidents

by preventing unsafe driving actions

 Enhancement of the transportation efficiency based on efficient traffic flow control than human reaction

#### Environment friendly

such as improving efficiency of fuel consumption



### Definition of AV levels (NHTSA, 2013)

#### > Regulatory change required?





### **The potential of AV**

 AVs will have a significant market potential for sales and their impact promises to be as far-reaching as any modern technological breakthrough



The Self-Driving Vehicle revolution

Source: McKinsey&Company



### Some issue of the diffusion of AV

- Technological uncertainty
  - Unpredictability about timing of Impacts
  - Long co-existence of AV and Non-AV
  - Possible presence of side effect of AV
- Market uncertainty
  - Uncertainty about adoption scale (market sales)
  - The standardization of related industry



Public acceptance and response on AVs

- Consumer preferences for AVs are not explicitly studied yet.
- Legal and Institutional Inadequacy.



### ] The purpose of this study

- Investigating the preference of potential consumers for AVs
  - Conjoint survey with 1,008 Koreans
  - Deriving utility function using a Mixed Logit Model
- Identification of the technical factors that potential consumers consider important when purchasing AVs
  - Relative importance
  - Marginal Willingness To Pay(MWTP) for each technical attribute
- Forecasting the market share of AVs based on some scenarios
  - Managerial and policy implications to increase market share of AV



### □ Recent studies to identify consumer preference of AVs

Author (s) (Year)	Country	Time of data collection	Number of respondents	Methodology	Key attributes
Howard and Dai (2014)	U. S.	2013	107	Survey	Perception of self-driving car, Control, Cost, Equity, Liability, P rivacy, Safety, Amenities, Convenience, Environment, Mobility
Begg (2014)	U. K.	2014	3,500	Survey	Expectations and issues related to the growth of driverless trans portation in London
Kyriakidis et al. (2014)	109 countries	2014	5,000	Online Survey	
Schoettle and Sivak (2014a)	U. K., U. S. and Australia	2014	1,533	Survey	Perceptions about AVs
Schoettle and Sivak (2014b)	U. K., U. S. and Australia	2014	1,596	Survey	Perceptions about AVs
Underwood (2014)		2014	217	Survey	
Piao J. et al. (2016)	France	2016	425	Online survey	Public awareness and understanding about AVs, Attractiveness and concerns of automated bus/taxi/car,
				Telephone interview	Attitudes towards owning or sharing automated car
Bansal P. et al. (2016)	U. <b>S</b> .	2014	358	Online survey	Preference for adoption of AVs, Willingness to pay, Adoption r ates by different pricing, Adoption timing of AVs



# 2. Methodology

### Choice-based conjoint (CBC)

- Gathering stated-preference data through conjoint survey
- Deriving utility function using Mixed Logit model
  - Heterogeneity



• Utility function

$$U_{nj} = V_{nj} + \varepsilon_{nj} = \beta'_n X_j + \varepsilon_{nj}, \forall j$$



# 2. Methodology

### □ Design of Conjoint Card

#### Attribute and its levels of AV

Attribute	Definition	Levels
D 1	Type of roads that autonomous vehicles can run	Highway only
Road condition		Driveway and Highway
condition		Regardless of road types
Time	Available time zones for autonomous vahiolos	Only in daytime
condition	Available time zones for autonomous venicles	Day and Night times
Weather	Dermissible weather for outenemous vahiales	Only in good weathers
condition	Permissible weather for autonomous vehicles	Regardless of weathers
Fuel	Improved fuel economy compared to existing fuel economy by autonomous driving function	10% higehr (13.50 km/L)
		20% higher (14.72km/L)
(Existing average fuel economy of Passenger Car: 12.27km/L)		30% higher(15.95km/L)
<b>.</b> .		Driving assistance level
Autonomous driving level	Classification of autonomous driving level according to driver's participation level during driving	Limited self-driving level
		Full self-driving level
Price of AV option	Amount of extra pay to add autonomous driving capability	4 million KRW*
		7 million KRW*
	(1 USD = 1,150 KRW , FEB 2017)	10 million KRW*



# 2. Methodology

Survey

- 3 alternatives of AV and Non-AV were given in each choice set
- Orthogonal test  $(3x2x2x3x3x3=324 \rightarrow 18)$



### Sample alternative set in the survey questionnaire

AV Attribute	Туре А	Туре В	Туре С	Type D
Road condition	Driveway and Highway	Highway only	Highway only	
Time condition	Only in daytime	Only in daytime	Only in daytime	
Weather condition	Only in good weather	Only in good weather	Regardless of the weather	
Fuel efficiency	20% higher	10% higher	10% higher	Non-AV
Autonomous driving level	Driving assistant	Full self-driving	Limited self- driving	
Price of AV option (KRW)	4,000,000	10,000,000	4,000,000	
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### Survey

- January 2017 to February 2017, Gallup Korea
- 1,008 consumer from 19 to 69 years old in South Korea

		Respondents	Percentage
Say	Male	513	50.90%
Sex	Female	495	49.10%
	21-29	187	18.60%
	30-39	209	20.70%
Age	40-49	237	23.50%
	50-59	229	22.70%
	60-69	146	14.50%
Education Level	High school graduate or lower	505	50.10%
	College graduate or higher	503	49.90%
	Use	667	66.20%
	Do not use	341	33.80%
	Total	1008	100%

#### Descriptive statistics of survey respondents



### **Model specification**

Utility

 $U_{nj} = \beta_1 \cdot BASE_j + \beta_2 \cdot ROAD2_j + \beta_3 \cdot ROAD3_j + \beta_4 \cdot TIME_j + \beta_5 \cdot WEATHER_j + \beta_6 \cdot FUEL_j + \beta_7 \cdot AUTO2_j + \beta_8 \cdot AUTO3_j + \beta_9 \cdot \Pr{ice_j} + \varepsilon_{nj},$ 





### **Estimated results**

Attribute	Mean	Standard deviation
BASE	27.6659***	21.0930***
ROAD2	6.33848***	9.22410***
ROAD3	1.26718	15.8475***
TIME	4.45526***	7.53623***
WEATHER	6.93330***	8.00866***
FUEL	0.22677***	0.82219***
AUTO2	4.56001**	10.2557***
AUTO3	0.32257	10.5197**
Price	-0.05022***	0.04615***

### Parameter estimates of utility function



### **Relative Importance (RI)**

- Part-worth
  - Estimate associated with each level of each factor used to define the product or service
- Relative Importance
  - A measure of how much an attribute affects a consumer's choice

$$RI_{k} = \frac{part \ worth_{nk}}{\sum_{k} part \ worth_{nk}} \times 100$$





### Marginal Willingness to Pay (MWTP)

• The amount of money consumers are willing to pay for a 1-unit change in attribute k







### □ Market simulations

• Choice probability of alternative j

$$P_{nj} = \frac{e^{\beta_{n}' x_{j}}}{\sum_{k=1}^{J} e^{\beta_{n}' x_{k}}}$$

### Market scenarios for forecasting

Attribute	Non-AV 1 <sup>st</sup> generation AV		2 <sup>nd</sup> generation AV	Full-AV
Road		Highway only	Driveway and Highway	Whole road
Time		Daytime only	Daytime only	Day and Night
Weather		Only in good weather	Only in good weather	Regardless of the weather
Fuel		0	10% higher	30% higher
Auto		Driving assistant	Limited self-driving	Full self-driving
Price		\$5,652.17	\$8,260.87	\$11,739.13
Scenario 1	0	0		
Scenario 2	0	0	0	
Scenario 3	0		0	0
Scenario 4	0			0



### Market simulations



Market share by scenario analysis



### **Market simulation by the price of AV option**

- Market share can be increased to 80% or more when the price is \$ 9,500
- This result show that Korean Market share can be changed drastically



#### Market share when the price of AV is changed



# 4. Conclusion and recommendations

#### We forecast demand for the future AV market

- Conjoint Analysis to investigate the preference of potential consumers for AVs
- Mixed logit model to derive utility
- Market simulation for some scenarios

### MWTP for 'BASE' was very high (\$ 5,500) and RI also high (29.03%)

- Consumers are giving high value to AV
- However, entrepreneurs can not expect a high market share if they set a strategy based on this price
- Companies will have to cut prices much lower than consumers' MWTP

#### 'ROAD3'&'AUTO3' have a significant variance, but the mean is not statistically significant

That is, consumer preference for high level of technological attribute is heterogeneous.



# 4. Conclusion and recommendations

### ] Limitation

- The scope of our research objective in this study was limited
- Further consumer preference analysis of Connected Autonomous Vehicle (CAV) will be necessary in order to forecast future market of AV
- CAV is predicted to have a greater network effect on the automobile industry as time goes by.



# Thank you!

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