Socio-economic Characteristics, Current Technology Use and Willingness-to-pay for Connected Vehicles: A Structural Equation Modeling Approach

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INTRODUCTION

- Connected vehicles (CVs), capable of wireless communication with other CVs and infrastructure, will soon be on the nation's roads.
- Safety improvement is considered the most significant benefit of CVs. Once they are fully adopted, approximately 81% of crashes involving unimpaired drivers would be avoided.
- Additional benefits like a decrease in negative externalities such as congestion and vehicle emissions are also expected as a result of the estimated crash reduction.
- Of interest among CV supporters is the design of effective strategies facilitating a faster adoption of the new technology.
- Several various market penetration estimations for coming years.
- Similarities and dissimilarities with some other new technologies like anti-lock brake systems , airbag, and so on.
- The authors have suggested that the estimated CV penetration rates may be overly optimistic. Diffusion of CVs could take longer because of the different nature of CV technologies from conventional vehicles.
- The benefits of driving a car with innovations such as seatbelts, airbags, and anti-lock brake systems could be enjoyed by the driver regardless of other drivers' use.
- However, CV owners may not feel the full benefits until a significant number of vehicles can communicate with each other and share real-time information.

OBJECTIVES

- Understanding drivers' perceptions of and preferences for CV technologies
- Identifying characteristics of potential early adopters
- What CV features do people prefer and how much are they willing to pay? (Answered in past studies by authors)
- **Which population groups are the first targets for diffusion of CVs?** (New critical question)

LITERATURE REVIEW

- Diffusion is defined as "the process by which an innovation is communicated through certain channels over time among members of a social system."
- Personal characteristics (or socio-economic traits) of individuals are often considered as predictors of new product adoption. Gender plays a role, too.
- Safety and environmental benefits of CVs may be attractive attributes to women, while additional cost would be a concern.
- Consumer behavior research found that consumers' knowledge of a certain product category influences their purchasing decision.
- The characteristics of innovativeness and early adopters are associated with socio-economic and personal characteristics, individual perceptions on certain features/issues (e.g., safety, environment), and the use of product/technology.

METHODOLOGY

Adaptive Choice-based Conjoint Survey and Analysis

↓

Structural Equation Model
Exploratory Factor Analysis

↓

Re-specification step of SEM
Final Model

Adaptive Choice-based Conjoint (ACBC)

- ACBC analysis is a new and the most advanced conjoint analysis technique that examines how people make decisions by simulating their purchasing behaviors.
- This method is appropriate for estimating preferences and willingness-to-pay for new products or products not yet on the market.
- The survey was developed using ***Sawtooth Software***'s SSI Web software, commercial software specializing in conjoint analysis and market simulation.
- Survey components:
  - *Build-Your-Own (BYO) Task*
  - *Screener Task*
  - *Choice Tournament Task*

Structural Equation Model (SEM)

- SEM is a useful tool to test theories and hypotheses.
- It is a data reduction technique widely used to identify a small number of common characteristics (i.e., factors) "*underlying a relatively large set of variables.*"
- It is particularly useful when no predefined relationships/theories on the subject are available.
- This task was carried out using *IBM SPSS (Statistical Package for the Social Sciences) 22*.
- Steps:
  - *Measurement model*
  - *Confirmatory factor analysis*
  - *The structural model*

Connected Vehicle Technology Choice Attributes

Attributes	Levels	CV Technologies
Collision Package	1	None
	2	Front Collision Warning
	3	Side Collision Warning
	4	Front & Side Collision Warning
	5	All-Around Collision Warning
Driver Assistance Package	1	None
	2	Lane Departure System
	3	Intersection & Left-Turn Assist
	4	Lane Departure System; Intersection & Left-Turn Assist
Enhanced Safety Package	1	None
	2	Do-Not-Pass Warning
	3	Pedestrian & Cyclist Alert
	4	Do-Not-Pass Warning; Pedestrian & Cyclist Alert
Roadway Information Package	1	None
	2	Road Condition Notification
	3	Slow/Stop/Wrong-Way Vehicle Advisor
	4	Road Condition Notification; Slow/Stop Wrong-Way Vehicle Advisor
Travel Assistance Package	1	None
	2	Real Time Travel Planning & Route Optimization
	3	Parking Spot Locator
	4	Real Time Travel Planning & Route Optimization; Parking Spot Locator

DATA

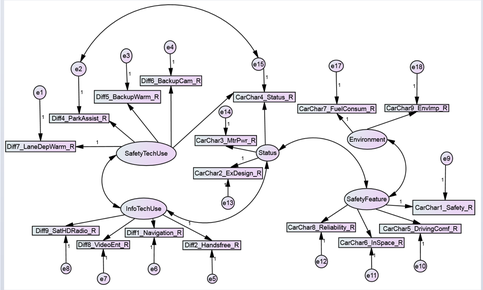
- Pilot study on small group (~ 50 people)
- Survey posted online from *September 26, 2013*, to *April 16, 2014*
- Total participants: 1,432
- Participants with complete surveys: 611 (42.7%)
- Useable surveys after data cleaning: **529** (36.9%)

Demographic Characteristics		Count	Percent
Gender	Male	271	51.2%
	Female	258	48.8%
Age	Younger than 30	113	21.4%
	30-39	114	21.6%
	40-49	121	22.9%
	50-59	113	21.4%
	60 and older	68	12.9%
Race/ethnicity	White (Non-Hispanic)	345	65.6%
	Hispanic	27	5.1%
	Black/African-American	91	17.3%
	Asian	31	5.9%
	American Indian/Alaska Native	9	1.7%
	Native Hawaiian/other Pacific Islander	3	.6%
	Other	20	3.8%
Education	Associate degree and lower	202	38.5%
	Bachelor's degree	167	31.9%
	Master's degree	102	19.5%
	Doctoral or postdoctoral degree	53	10.1%
Household annual income	Less than 50K	186	36.1%
	50K-100K	167	32.4%
	More than 100K	162	31.5%
Current vehicle type	Sedan or coupe	230	44.4%
	SUV	109	21.0%
	Truck	37	7.1%
	Minivan	28	5.4%
	Luxury vehicle	17	3.3%
	Station wagon	25	4.8%
	Convertible	9	1.7%
	Van	4	.8%
	Crossover	23	4.4%
	Sports car	11	2.1%
	Other	24	4.6%
	Not sure	1	.2%

ANALYSIS

Identified Factors after Varimax Rotation

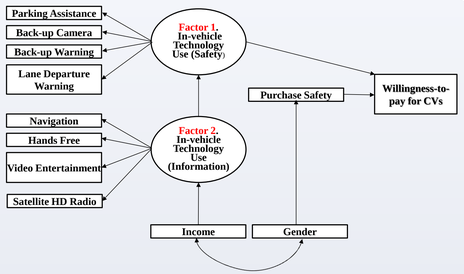
	Factor				
	1	2	3	4	5
Diff4_ParkAssist_R Parking Assist	.751	.104	-.066	.177	.085
Diff5_BackupWarm_R Back Up Warning	.746	.225	.080	.042	-.040
Diff7_LaneDepWarm_R Lane Departure	.636	.138	.085	.144	.032
Diff6_BackupCam_R Back Up Camera	.598	.381	.055	.023	.032
Diff9_SatHDRadio_R Satellite/HD radio	.137	.658	.031	.180	.007
Diff2_Handsfree_R Hands-free	.186	.619	.126	.058	-.019
Diff1_Navigation_R Navigation	.306	.564	.042	.151	-.052
Diff8_VideoEnt_R Video Entertainment	.355	.402	-.018	.309	.052
CarChar5_DrivingComf_R Driving comfort	.058	.118	.703	.256	.007
CarChar6_InSpace_R Interior space	.028	.100	.620	.277	.096
CarChar8_Reliability_R Reliability	-.034	.007	.456	-.026	.180
CarChar1_Safety_R Safety	.114	.003	.429	.065	.326
CarChar4_Status_R Status	.180	.046	.049	.653	.058
CarChar3_MtrPwr_R Motor power	.008	.199	.237	.504	-.017
CarChar2_ExDesign_R Exterior	.070	.153	.153	.495	-.063
CarChar9_EnvImp_R Environ impact	.038	-.024	.169	.068	.758
CarChar7_FuelConsum_R Fuel consumption	-.052	-.071	.258	-.030	.570
Diff3_HEFuel_R HV/EV	.323	.117	-.051	-.128	.357



Graphical Representation of the Specified Confirmatory Factor Analysis Result from IBM SPSS AMOS 22

The Model Fit Indices – Confirmatory Factor Analysis

Fit Measures	Measurement Values
Chi-Square Test Statistic	X^2 (113, N 500) = 295.357, ***p < .001***
Normed fit index (NFI)	.867
Goodness-of-fit index (GFI)	.934
Comparative fit index	.913
Root mean square error of approximation	0.057



The Specified Model and Its Standardized Coefficients

The Model Fit Indices

Fit Measures	Measurement Values
Chi-Square Test Statistic	X^2 (52, N 500) = 144.166, ***p < .001***
Normed fit index (NFI)	.895
Goodness-of-fit index (GFI)	.952
Comparative fit index	.929
Root mean square error of approximation	0.06

CONCLUSIONS

- The SEM model has excellent goodness-of-fit results, and warrants further discussion of the details.
- Both a confirmatory factor analysis and structural equations found two statistically significant fitted models, identifying the characteristics of early adopters.
- The first structure model suggests that **high-income individuals** using recent **in-vehicle safety, information**, and **entertainment** technologies should be targeted at the earliest stage of CV deployment.
- The second structure model implies that drivers, especially **females**, who highly value **vehicle safety** are willing to pay more for CVs.
- ANOVA showed a significant influence of safety features to willingness-to-pay, the association between gender and WTP was not significant. This is because ANOVA only shows a partial relationship assuming all other factors are constant. In SEM, variables' roles in relation to other direct and indirect measures are revealed.
- These findings provide broader policy directions to facilitate faster diffusion of CVs.

FUTURE WORKS

- To conduct a disaggregate level analysis to identify relationships between winning bundles of CV technologies from the survey and participants' demographics mixed with the content analysis based on comments from the **three open-ended questions**.
- To conduct market segmentation simulation on various diffusion scenarios. The simulation will predict the time to be taken for a (near) full deployment of CV technologies.

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