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Deriving vehicle-to-grid business models from consumer preferences

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Abstract

Combining electric cars with utility services seems to be a natural fit and holds the promise to tackle various mobility as well as electricity challenges at the same time. So far no viable business model for vehicle-to-grid technology has emerged, raising the question which characteristics a vehicle-to-grid business model should have. Drawing on an exploratory study amongst 189 Dutch consumers this study seeks to understand consumer preferences in vehicle-to-grid business models using conjoint analysis, factor analysis and cluster analysis. The results suggest that consumers prefer private ownership of an EV and a bidirectional charger instead of community ownership of bidirectional charger, they prefer utility companies instead of car companies as the aggregator and they require home and public charging. The most salient attributes in a V2G business model seem to be functional rather than financial or social. The customer segment with the highest willingness to adopt V2G prefers functional attributes. Based on the findings, the study proposes a business model that incorporates the derived preferences.

Keywords: vehicle-to-grid, business model, consumer preferences

1 Introduction

Vehicle-to-grid (V2G) technology is emerging as a sustainable technology which combines energy with mobility. Combining electric cars with utility services seems to be a natural fit and holds the promise to tackle various mobility as well as electricity challenges at the same time. That is to say, batteries of electric cars (EV) can act as capacitors in the grid and provide regulation services, while using green energy, such as solar power. In theory, when households combine an electric car, solar panels and a smart meter, they could be autonomous from the grid, could become electricity provider and could generate revenues through smart charging and trading of electricity. In practice, this scenario is currently only adopted by a small group of technology enthusiasts.

To that end, the question is how vehicle-to-grid technology can be popularized to an audience beyond technology enthusiasts. So far, V2G has not been commercialized, raising the question for actors in the newly emerging industry which characteristics a V2G business model should have.

Drawing on an online survey amongst 189 Dutch respondents, this study seeks to explore consumer preferences in vehicle-to-grid business models. To that end, the paper sets out to distil the most salient attributes of V2G value propositions, explore likely customer segments, and, explore preferences for a V2G value network. Before moving to the empirical results, we describe the main tenets of V2G business models and the methodology.

2 Vehicle-to-grid business models

Research shows that cars are utilized for transportation only 4% of the time. This makes them available for secondary functions for the remaining 96% of the time. According to several authors, EVs can even be complementary to the electric power grid [1]–[4]. When an EV is connected to a bidirectional charger, it is possible to charge and discharge electricity to the grid. Various studies suggest large potential for V2G as a means to regulate the grid, to provide ancillary services or even as a backup generator in cases of power failures [1], [5], [6] . However, apart from a few pilot projects, no widely available V2G service has emerged so far [7].

Studies on V2G have mainly focused on technical aspects, such as what grid-services V2G technology could provide [1], [2] and the commercial potential it has [5]. Most studies suggest only modest potential [8] and also point to risks such as increased battery wear as a result of V2G [9].

Nonetheless, Lassila et al. [6] suggest that there is commercial value yet, it is not clear how to capture it. There are different types of V2G applications to create economic value for consumers. The applications may roughly be divided into three main categories: Vehicle-to-Home (V2H), Vehicle-to-Building (V2B) and Vehicle-to-Community (V2C). Kempton et al. [7] suggest four different business models, namely using EVs as an appliance, EV charging as a service, EV batteries, and charging as a package service and paying the owner of the EV for grid services. However, since the technology is still in its infancy, it is unclear which business model consumers would prefer.

For EV owners, V2G holds the promise that households could be autonomous from the grid, save electricity costs by charging when the price is low and use electricity from the battery when the price is high, and even generate revenues by selling energy, for instance to neighbours [4]. This study sets out to explore consumer preferences and based on the preferences, derives a possible V2G business model. The business model is conceptualized on three dimensions: the value proposition (product preferences and customer segment), the value network (who is creating the value) and the revenue model (how is the value captured) [10] (see Figure 1).

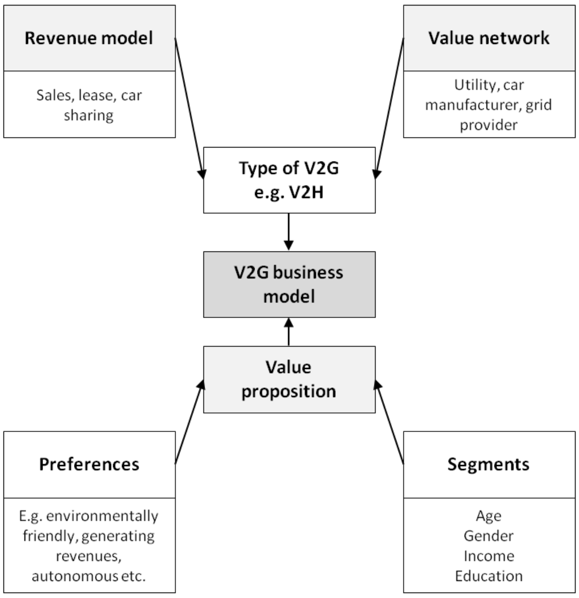

Figure 1: Operational framework

3 Method

The results of this paper are part of a larger study on V2G business models. In order to measure consumer preferences for V2G business models, the extant consumer research literature on EVs was scanned for attributes that have been used to analyze EV consumer preferences. These were complemented with factors that deemed relevant regarding V2G technology.

Table 1 provides an overview of attributes and illustrates the selected items for the survey. Some attributes have not been considered in the survey, namely fuel cost/efficiency because these were already covered in operating costs, policy incentives since these are not available at

Table 1: Overview of performance attributes used in EV consumer research

Attributes/ studies	**Ahn, Jeong, & Kim [11]**	**Caulfield, Farell, & McMahon [12]**	**Chorus, Koetse, & Hoen. [13]**	**Daziano & Chiew [14]**	**Eggers & Eggers [15]**	**Hackbarth & Madlener ([16]**	**Hidrue, Parsons, Kempton, & Gardner [17]**	**Kudoh & Motose [18]**	**Lee, Wang, & Lee [19]**	**Miao, Xu, Zhang, & Jiang [20]**	**Potoglou & Kanaroglou [21]**	**Number of times mentioned**	**Included in survey**
Initial purchase price		X	X	X	X	X	X	X	X	X	X	10	Yes
Sufficient range			X	X	X	X	X	X	X	X		8	Yes
Charging time (fast and slow)			X	X	X	X	X		X	X		7	Yes
Public charging network			X	X	X	X				X	X	6	Yes
Environmentally friendly		X		X	X	X	X				X	6	Yes
Reliable performance		X		X			X		X	X	X	6	Yes
Operating/maintenance cost	X		X	X	X					X	X	6	Yes
Safe usage		X							X	X		3	Yes
Maintenance network					X							1	Yes
Comfort					X							1	Yes
Fuel cost/efficiency	X	X			X	X	X	X		X	X	8	No
Policy incentives		X	X	X	X	X				X	X	7	No
Design/style		X	X						X	X		4	No
Size/internal space		X						X	X	X		4	No
Motor sound					X							1	No
Easy to use													Added
General trend													Added
Source of income													Added
Freedom of mobility													Added
Confidence in technology													Added
Image													Added

the moment, and last design, size, and motor sound because they were not regarded as important with respect to V2G technology. Instead, we added some relevant V2G specific attributes, namely V2G as a source of income, confidence in technology and easiness to use. Also, we added social aspects, namely general trend, image, and freedom of mobility.

In order to explore consumer preferences, an online survey was designed. Before dissemination, a pilot among 20 participants was conducted. In this pilot, issues regarding the survey or unexpected biases were corrected. The survey then was spread to a Dutch population in Dutch language to prevent bias. The sample was recruited by various means, e.g. social network sites, Rotary clubs, universities and work places. Out of 350 respondents, 189 fully answered the survey.

Table 2 summarises the sample characteristics. Male participants outnumber female participants, but given the sample size female respondents are still sufficiently represented. The minimum age of participants was set at 18 years. The first age group from 18 to 24 is overrepresented. This can be explained with a selection bias on online platforms towards younger participants. The age groups until 64 are well represented. The group of 65 and older is less represented which we also attribute to the online platform selection bias. The sample is considerably higher educated than the average in the Netherlands which is also somewhat reflected in the average income and the possession of EVs.

Table 2: Characteristics of the sample

	Survey (%)	National (%)
Gender		
Male	65.4	49.5
Female	37.6	50.5
Age		
18-24	41.8	8.7
25-34	15.3	12.6
35-44	6.9	13.6
45-54	18.5	14.6
55-64	14.3	12.8
65 or older	3.2	16.7
Education		
Secondary education	8.5	10.5
Interm. Voc. Edu.	5.3	29.8
Bachelors degree	55.0	18.5
Masters degree	25.9	9.8
Professional Degree	5.3	NA
Income		
Less than 30.000	47.1	46.7
30.000 – 39.999	5.8	11.2
40.000 – 49.999	5.3	7.2
50.000 – 100.000	21.6	9.1
More than 100.000	20.1	1.5
Possess EV		
Yes	3.7	0.3
No	96.3	99.7

N=189
National data from Statistics Netherlands [22]–[26]

4 Results

This study adopts a three-step-approach to derive a business model from consumer preferences. First, the preferred value network and revenue model is examined by means of a conjoint analysis. Next, the preferred value proposition characteristics are explored using a factor analysis. Last, the respective customer segment is analyzed in a cluster analysis.

Value network and revenue model preferences

First, we conducted a conjoint analysis to analyze consumer preferences with regard to the value network. Conjoint analysis is a tool to study multi attribute decision-making and has been applied widely to measure consumer preferences regarding attributes [27].

The analysis was conducted in two stages. In the first 'trade-off' stage, respondents were asked to select the most (score 10) and the least preferred attribute (score 0), and subsequently rank the remaining attributes on a scale from 1 to 9 (see Table 6, column LOP). This was done for three dimensions, namely preferred ownership, preferred charging spot and preferred aggregator, and is reflected in the average level of preference (LOP). In the second 'ranking' stage, the respondents were asked to rank the importance of the dimensions overall by allocating in total 100 points over the three dimensions (see column UCS). The highest number of points would reflect the most important dimension and the lowest number of points would reflect the least important dimension and is calculated in the utility constant sum. The result of multiplying LOP and UCS is the weighted score of level of preference (WLP).

The most important dimension to the sample was the charging location (45.12), least important was the type of aggregator (18.78). The most important attribute for the sample was to charge at home (4.27) and to have a public charging network (2.84). This is also reflected in the fact that the preferred ownership and revenue model is to own an EV and discharge at home (2.75). Least interesting for the sample were community EVs (1.06). Although the dimension preferred aggregator was least important, a closer look reveals interesting insights. Surprisingly, the energy supplier was ranked as the most preferred aggregator (7.54) as compared to the car manufacturer (5.48). This is interesting for utility companies since this could be a new source of revenues. Car manufacturers were even lower ranked than the distribution network operator (5.5). This is interesting because the car is an important part of the V2G business model.

Table 3: Results conjoint analysis

Features	Utility constant sum (UCS)	Average level of preference (LOP)	Weighted level of preference (WLP) LOP x UCS
Preferred ownership and revenue model	36.1		
Private EV, revenues through bidirectional charger at home		7.37	2.75
Company EV, revenues through bidirectional charger at home & work		6.57	2.37
Private EV, revenues through bidirectional charger shared in a community		2.88	1.06
EV car sharing, no revenues, but reduced costs		3.75	1.31
Preferred location to charge	45.12		
At home		9.23	4.27
At work		6.11	1.51
In the neighbourhood		3.93	1.83
On public places.		3.46	2.84
Preferred aggregator	18.78		
Energy supplier		7.54	1.48
Distribution network operator		5.5	1.1
Your mobile telecom provider		3.65	0.66
Battery manufacturer		5.06	0.98
Car manufacturer		5.48	1.11
A company that is also connected to my employer		3.4	0.65

Value proposition preferences

Next, respondents were asked for their preferences with regard to V2G, for instance “I would use V2G if it is safe.” The full list of items is displayed in the appendix. The dimension that is most important to respondents is sufficient range with a mean score of 4.04 on a five-point scale. There were only two attributes that received a mean score below the ‘neutral’ point, namely ‘Charging time’ and ‘Image’. Table 4 summarizes the means and standard deviations of the 16 attributes.

Table 4 also shows the results of a rotated varimax factor analysis of the sample [28], which identified three factors with an eigenvalue greater than 1.00 explaining a total of 63.9% of the sample. The factors were theoretically labeled to qualitatively describe the attributes that they include. The attributes that load on the first factor have in common that they describe largely functional aspects of a V2G business model. Attributes that load on the second factor suggest to be related to financial aspects and the last factors to be related to social elements. These characteristics were then applied as the names of the factors, namely functional, financial and social.

Table 4 also indicates that the items comprising the functional attributes scored highest, resulting in a factor mean of 3.93 and standard deviation of 0.77. The second factor combining four items representing the financial attributes produced a mean of 3.49 and a standard deviation of 0.88. This shows that the view on the importance indicates a wider dispersion on the desirability of these features. The scale representing the social attributes received the lowest score at 2.76 (SD .89). However, the low ratings of ‘Image’ account for most of this difference. The environmental aspect on the contrary was highly appreciated (3.62).

Customer segments

Last, the objective of this study was to explore whether clear customer segments could be identified. We therefore undertook a cluster analysis [29], using the abovementioned three factors. The inspection of dendrograms, based on hierarchical cluster analysis suggested a three cluster solution. Two step clustering was then applied. Before the analysis, sixteen outliers were excluded. These had either missing values or were negative on all factor dimensions and in a first analysis represented a cluster by itself which could be labelled as Anti-V2G, however this cluster was not regarded as relevant to identify preferences. The exclusion of outliers resulted in a sample size of 173.

Table 4: Preferred characteristics of V2G business models and factors

Factors/Attributes	**Mean**	**Std. Deviation**	**Factor 1**	**Factor 2**	**Factor 3**
Eigenvalue			6.3	2.1	1.8
Variance explained			39.4%	13.2%	11.3%
Functional	**3.93**	**.770**			
Ease of use	3.80	.736	.791	.149	.220
Sufficient range	4.04	.849	.686	.142	-.075
Public charging network	3.99	.872	.728	.159	-.001
Confidence in technology	3.97	.775	.867	.118	.062
Comfortable ride and dis/charging	3.85	.716	.801	.337	.108
Safe usage	3.89	.723	.802	.263	.163
Reliable usage	3.95	.686	.826	.161	.066
Availability of charging points	3.83	.812	.788	.157	.114
Freedom of mobility	4.04	.804	.777	.014	.051
Financial	**3.49**	**.880**			
Purchasing price	3.88	.723	.600	.419	.076
Source of income	3.88	.886	.261	.816	.031
Operating costs	3.72	.950	.233	.859	.027
Charging time	2.48	.943	.042	.382	.345
Social	**2.76**	**.890**			
Image	2.09	.826	-.060	.076	.859
Environmentally friendly technology	3.62	.873	.464	.258	.428
Trend	2.56	.982	.165	-.030	.807

Note: The 16 descriptions are presented in full in the Appendix. Factors loadings are based on varimax rotation.
Mean from 1 to 5, 5 being most important, 1 being least important.

The cluster analysis resulted in three clusters, the size of the smallest cluster was 44 (25.4%) and the size of the largest cluster was 90(40.5%). The ratio of the size between the largest and smallest cluster was 1.59. All factors influenced the cluster formation equally.

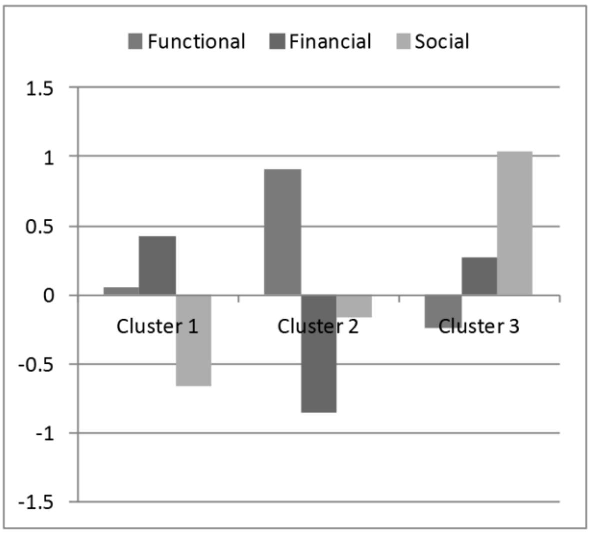

Figure 2: Clusters

Cluster 2 is most positive towards the adoption of V2G with a median of 4.00 for Willingness to use. This is concomitantly the smallest in size of the three clusters, accounting for 25.4% of respondents. Both, cluster 1 and 3, are more neutral towards V2G with medians each of 3.01 for willingness to adopt. For cluster 1, the most important factor is the financial aspect whereas the social factor is not important. This cluster is the largest, is male dominated, almost 50% of the respondents have less than 30.000 Euro income and they are least educated. Cluster 2 is the smallest one with 44 respondents but has the highest willingness to use. Their most important factor are the functional aspects, the financial aspect is of least importance. It has to be noted that the explanatory value is limited, as apart from age, none of the relationships were significant; however, they provide a good starting point for further validation.

Table 5: Cluster characteristics

	Cluster 1 Financial	Cluster 2 Functional	Cluster 3 Social
#	70	44	59
%	40%	25%	34%
Willingness V2G			
Average	3.21	3.55	3.42
Median	3.01	4.00	3.01
Factors			
Functional	0.05	0.91	-0.24
Financial	0.42	-0.86	0.27
Social	-0.67	-0.17	1.04
Demographics			
Age group			
until 24	42.9%	43.2%	35.6%
until 44	24.3%	18.2%	22.0%
over 45	32.9%	38.6%	42.4%
Gender			
Male	65.7%	61.4%	55.9%
Female	34.3%	38.6%	44.1%
Income			
Less than 30.000	48.6%	45.5%	40.7%
30.000 – 49.999	12.9%	9.1%	13.6%
More than 50.000	38.6%	45.5%	45.8%
Education			
Vocational training	47.1%	56.8%	49.2%
Higher education	52.9%	43.2%	50.8%

Deriving a business model from consumer preferences

Building on the operational model in Figure 1 and the results of the three analyses, a business model for this sample could be designed as follows. First, the conjoint analysis revealed that the sample would prefer owning a car and to charge at home. Thus, revenues would be generated by selling EVs, electricity and a home (dis)charger. Also, the conjoint analysis showed that customers would prefer the utility company to be the aggregator, i.e. the company that would

sell the product. Next, a factor analysis revealed that functional aspects, such as range, comfort, ease of use, are most salient in a potential V2G business model. Financial and social attributes are of less importance. Consequently, functional attributes should be emphasized. Last, a cluster analysis segmented the sample into three customer segments with different preferences. The cluster that was most likely to adopt the V2G business model was the male dominated functional cluster which was most attracted to the functional aspects of V2G. Table 6 summarizes the business model characteristics.

Table 6: Derived V2G business model

Value proposition	**Value network**	**Revenue model & cost model**
Based on factor analysis	*Based on conjoint analysis*	*Based on conjoint analysis*
- Sample prefers functional attributes, e.g. ease of use, range; financial and social aspect less important - Functional customer cluster in the sample has the highest willingness to adopt	- Utility company is the preferred provider/aggregator - Provide public charging network	- Sample prefers to own an EV, bidirectional charger and charge at home - Revenues through sales of EVs, bidirectional charger, electricity, grid regulation

5 Conclusion

This study set out to explore V2G business models derived from consumer preferences. Based on an exploratory study of a Dutch sample in an online survey, the results suggest a V2G business model with the following characteristics: an emphasis on functional attributes, targeted at the functional customer cluster, provided by the utility company which should also provide a public charging network, used by private owners of EVs with bidirectional chargers at home (see Table 6).

It is surprising that utility companies are the preferred aggregator for V2G business models, which points to new revenue sources for that industry. Also, it seems that the potential customer is not attracted by the revenue potential but rather by functional aspects.

Due to the sample size the results of this study need to be treated with caution. However, the three-step-approach to derive a business model from consumer preferences could be further developed and potentially used in other industries or studies.

Acknowledgments

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Appendix

V2G attributes and questions in Dutch in the survey

Attribute	Question in Dutch
Initial purchase price	Ik zou V2G gebruiken als de aankoopprijs naar tevredenheid is.
Sufficient range	Ik zou V2G gebruiken als er geen beperkingen zijn in de afstand die ik kan rijden.
Charging time (fast and slow)	Ik zou V2G gebruiken, ongeacht dat ik rekening moet houden met het indelen van mijn tijdschema.
Public charging network	Ik zou V2G gebruiken als de beschikbaarheid van publieke (ont)laadplaatsen hoog is, omdat ik dan op meer plekken kan (ont)laden.
Environmentally friendly	Ik zou V2G gebruiken als het een milieuvriendelijke innovatie is.
Reliable performance	Ik zou V2G gebruiken als het betrouwbaar is en fatsoenlijk werkt.
Operating/maintenance cost	Ik zou V2G gebruiken als ik er 7.500 euro mee bespaar in 5 jaar vergeleken met auto's aangedreven door fossiele brandstof.
Safe usage	Ik zou V2G gebruiken als het veilig is om te gebruiken.
Maintenance network	Ik zou V2G gebruiken als (ont)laadplaatsen toegankelijk zijn als ik ze nodig heb.
Comfort	Ik zou V2G gebruiken als het comfortabel rijdt en (ont)laadt (ontladen is energie terugleveren).
Easy to use	Ik zou V2G gebruiken als het makkelijk te gebruiken is.
General trend	Ik zou V2G gebruiken als het trendy is.
Source of income	Ik zou V2G gebruiken als ik er per jaar 2.500 euro mee zou verdienen.
Freedom of mobility	Ik zou V2G gebruiken als ik nog steeds flexibel ben om te gaan en staan waar ik wil.
Confidence in technology	Ik zou V2G gebruiken als ik vertrouwen heb dat het laden en ontladen werkt.
Image	Ik zou V2G gebruiken als mijn vrienden denken dat ik hierdoor milieu bewust ben.

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