Holistic Methodology to Analyze EV Business Models

Ma Jun and Alberto Di Muro

***Abstract*—Climate changes, global population growth, rise of the oil price and sustainability issue are pushing the automotive industry to redefine the concept of mobility. The solution seems to be the battery-powered electric vehicles. Business models related with EV mobility have already been developed but the still unstable EV market will bring out to new possible options and related new business models. This paper aims to illustrate a simple methodology to analyze current EV business models and start to rethink about them in order to develop possible improvements or directly design new solutions. All the systems that act in the electric-based mobility will be considered as a global system, using a holistic approach. The methodology is based on two correlated analysis: the morphological box analysis and the scoring methodology. In the end, the whole method is applied to two different EV business cases and the results will be discussed.**

***Index Terms*—Electric vehicle, business model, morphological box, scoring method.**

I. Introduction

A. Development of Electric Market Concepts

The world is facing right now one of the biggest challenges in the whole human history: climate changes, pollution, global population growth, removable energy and rise of the oil prize are some of the factors pushing the global economy into a new dimension. The automotive industry has been dominated by the internal combustion engine for more than a century. Unfortunately now the situation is changing. Road transportation today is responsible for a significant and growing share of global CO_2 emissions, especially in the fast growing countries. The diesel vehicles and gasoline, major emitters of nitrogen oxides (NO_x), carbon dioxide (CO_2) and micro particles can't be a response to the needs of durable mobility by land transport.

This reason, connected with the rise of the oil prize and the significant increase in the global ecological sense, is pushing governments, OEMs, energy providers and associations to find out a new and innovative mobility system. In this moment the electric cars (EVs) seem to be the definitive solution for a sustainable and "green" mobility concept [1].

They can reduce the dependence from oil, set to zero engines' emissions and can positively answer to the new global environmental preoccupations. All the R&D departments – both of OEMs and battery manufacturers – now are mainly focused to build a technical solution that will emerge as a "standard" with performance and costs that can satisfy the requests from the market. On the other side, OEMs, battery manufacturers, government institutions, energy providers and entrepreneurs are working together to find out business models to introduce in the market the electric vehicles in order to satisfy customers' needs and overcome some problems related with costs and battery duration [2]. The traditional business model used in the automotive cannot be applied: electric mobility is different from combustion engine based one. The product, the features, the usability are different and new for the customers; so it's fundamental to design new business models that can help the transition from oil-based mobility to electric mobility, giving to the customers the same satisfaction level plus more benefits[3], [4].

This paper aims to propose a structured methodology for a strategic and global analysis of new EV business models, especially related with service-oriented ones. The results of this approach are a simple and graphic representation of the business model structure, correlated with a global score useful to compare and evaluate different business models.

Manuscript received Janurary 7, 2013; revised March 9, 2013.

Ma Jun is with the Automotive School of studies at Tongji University (PRC) (e-mail: majun@gmx.net).

Alberto Di Muro is with the Automotive School of studies at Tongji University (PRC) (e-mail:alberto.dimuro1588@gmail.com).

II. Methodology

The method proposed in this paper is an instrument to analyze business models in the field of electric vehicles. The approach used is a holistic and structured method [5]. This methodology is composed by two different techniques for system analysis:

- Morphological box analysis
- Scoring method (AHP approach based)

This approach is more adaptable to service-oriented business models because it takes in account not only the system composed by electric vehicle and battery, but also the infrastructure and the integration with the power grid [6]. However the analysis can be applied also to other business models – for example whole EV selling or whole EV leasing – but some criteria in the procedure have to be ignored and set to zero.

A. Morphological Boxes

The morphological analysis is a technique for exploring all the possible solution to a multi-dimensional, non-quantified problem complex. It breaks down a system, a product or a process into its essential sub-concepts, each concept representing a dimension in a multi-dimensional matrix. Thus, every product is considered as a bundle of attributes. The approach begins by identifying and defining the parameters (or dimensions) of the problem complex to be investigated, and assigning each parameter a range of relevant "values" or conditions [6].

According to the literature [7]-[9] about this topic, it is possible to design three different morphological boxes, each for one of the three main drivers identified:

- Vehicle & Battery (Table I)

DOI: 10.7763/IJIMT.2013.V4.402

- Infrastructure system (Table II)
- System services that connect the electric vehicle with the electric grid (Table III)

TABLE I: VEHICLE & BATTERY SYSTEM MORPHOLOGICAL BOX (BETTER PLACE)

Vehicle & Battery						
Parameters		Alternatives				
Property	Vehicle	Customer	Energy provider	Indipendent provider	Battery producer	Vehicle manufacturer
	Battery	Customer	Energy provider	Indipendent provider	Battery producer	Vehicle manufacturer
Type of billing	Vehicle	Pay for equipment		Fixed rate	Pay for use	
	Battery	Pay for equipment		Fixed rate	Pay for use	
After-sales service provider	Vehicle	Customer	Energy provider	Indipendent provider	Battery producer	Vehicle manufacturer
	Battery	Customer	Energy provider	Indipendent provider	Battery producer	Vehicle manufacturer
Esclusiveness of use	Vehicle	One customer		More than one customer		
	Battery	One customer		More than one customer		

TABLE II: INFRASTRUCTURE SYSTEM MORPHOLOGICAL BOX (BETTER PLACE)

Infrastructure system				
Parameters	Alternatives			
Type of power supply	Wired	Wireless		Battery exchange
Accessibility	Private	Semi-public		Public
Power connection	1-phase	3-phase	high V AC	high V DC
Connection type	Undirectional		Bidirectional	
Info flow	None	Undirectional		Bidirectional
Info processing	Day-ahead	Intra-day		Real time
Operator of power supply	Private	Energy provider	Indipendent provider	State
Billing type	No fee	Fixed rate		Pay per use
Metereing	No meterring	At charging station		In vehicle

TABLE III: INFRASTRUCTURE SYSTEM MORPHOLOGICAL BOX (BETTER PLACE)

System Services					
Parameters	Alternatives				
Type of service system	No service	Load shifting		Back-feeding	
Number of partecipants	One partecipant		More than one partecipant		
Control	Uncontrolled	Indirect		Direct	
Level of grid integration	Local	Balancing group	Control zone	Nation	
Provider	Private	Semi-public	Energy provider	Indipendent provider	Public
Type of power input	Public grid	Local generation		Renewable energy	
Billing	No fee	Fixed rate		Pay per use	

B. Scoring Method

The scoring method is a technique to obtain with a mathematical procedure the “global score” of the business model analyzed. The “global score” can be considered as an index that defines how much one parameter’s alternative of the business model could combine with other parameters in an optimal way. In a general view, this “global score” highlights how much a business model is innovative and able to offer benefits to the customers. Using this approach it is also possible to understand the rank of priority of the different alternatives, and the relative influences between them.

The mathematical theory used for the scoring method is quite similar to the one used for the Analytic Hierarchy Approach (AHP). The equation (1) represents the summation of all the parameter`s score (from 1 to n), each multiplied by the score of the selected alternative.

$$GS = \sum_{i=1}^{n}(p_i * a_{i\,s}) \quad (1)$$

where:
GS = Global Score
p_i= parameter (from 1 to n)
$a_{i\,s}$ = alternative selected from the business model analysis (from 1 to n)

In case of multiple alternative selections for one parameter – that could happen especially in the Infrastructure System where different typologies of power supply can be used at the same time – the equation needs to be modified in order to consider this hypothesis. So the multiple alternative selection equation (2) results as:

$$GS = \sum_{i=1}^{n}\left(p_i * (\sum_{j=1}^{m} a_{js})\right) \quad (2)$$

where:
GS = Global Score
p_i= parameter (from 1 to n)
$a_{j\,s}$ = multiple alternatives selected from the business model analysis (from 1 to m)

The approach for the pairwise comparison between the parameters (1st level) is based on the same theory used in the AHP methodology. Once the hierarchy has been constructed starting from the elements showed in the morphological analysis, the experts start a series of pairwise comparisons, based on Saaty`s scale [10], between the parameters in order to define the relative influence / importance with the global system. Saaty in [10] clearly proofs that the best way to assign a prioritization between the parameters p_i starting from the pairwise matrix is to solve an eigenvalue problem $A\overline{w} = \lambda\overline{w}$. In fact, evaluating the principal eigenvector normalized of the matrix, it is possible to understand the ranking between all the elements analyzed. The eigenvalue problem can be solved using dedicated software or specific algorithms – for example the Power Iteration Algorithm.

Regarding the evaluation of the series of alternatives for each parameter, it has to be done by the same experts that worked on the parameters' evaluation. The goal for the evaluation is the "importance" of each alternative in relation with the main parameter. The experts can provide a global "importance" evaluation for each alternative using a 5-level scoring scale. The key factors that have to be taken in account by the experts for the "importance" evaluation are:

- Technological factors
- Innovation
- Business implementation
- Possible customer satisfaction and benefits

III. Application of the Methodology

In this Section the complete methodology exposed in the previous one will be applied to two different business models: Better Place and "whole EV selling" model. The inputs for the morphological analysis are provided by the evaluation of the two case studies and by the analysis of the value proposition and proposed commercial offer to the customers.

A. Better Place Case Study

Unlike traditional business models, in the Better Place case [11] study the ownership of the batteries is separated by the ownership of the vehicle. In fact the owner of the car is the customer and the owner of the battery pack is the company, which is responsible also for the purchase from the battery producer and the provision. This service is charged to the customers in the form of a rate for kilometer. This means that the vehicle is used only by its owner, while the battery pack, due to the swapping feature, is used by several customers. In this way it is possible to turn the high investments for the batteries and to share the costs between several customers, overcoming then one of the biggest obstacles for the adoption of EV mobility in this moment. Regarding the infrastructure system [12], Better Place is very flexible. Alongside the convention charging way with wired connections – in private, semi-public and public places – the concept of battery switch stations is implemented in the Better Place offer and this one is probably the most innovative idea regarding this business model. The battery switch station is in fact the Better Place answer to one the biggest and actual problem of EV mobility: the electric car's limited driving range. Otherwise this solution is relative more expensive and complex – especially from the technical side – compared with other common solutions provided by other companies (PHEV, rapid charging). The communication type can be provided in unidirectional and bidirectional way – of course the bidirectional one is more suitable for the implementation of system services [13]. However the communication type and the power connection are subjected to the network type, technical and legal imitations in force of the specific country where the business model is applied. The idea of Better Place to provide grid management and in-car communication system determines the need of back-feeding, bidirectional communication regarding information flow and especially a complex system of real-time communication between vehicle and Better Place central stations. Invoicing system services is done via rate paid per kilometer and the metering is realized at the charging station during recharging phase, due to technical limitation. The Better Place business model is still relative unclear concerning system services [14]. Different prequalification requirements in reserve energy market and communication protocols for controlling electric cars on the grid – which are in development but still not defined as a common standard – are the most important issues regarding this point. The situation about the type of energy input is quite complicated because it involves different factors: economic factors (private and public investments in renewable energy), technical ones and also political ones, especially regarding the country policy about the development of future energy.

After some experts' interviews, the data have been collected and analyzed according to the scoring methodology illustrated before. The ranking/prioritization between the parameters of each system is showed in the tables below (Table IV).

TABLE IV: PRIORITIZATION SCORES FOR THE PARAMETERS

Vehicle

Property	Type of billing	After-sales service provider	Exclusiveness of use
0,1675	0,2978	0,4694	0,0653

Battery

Property	Type of billing	After-sales service provider	Exclusiveness of use
0,1353	0,4105	0,4052	0,0491

Infrastructure system

Type of power supply	Accessibility	Power connection	Connection type	Info flow	Info processing	Operator of power supply	Billing type	Metering
0,2301	0,188	0,1125	0,0824	0,0516	0,0703	0,0539	0,1788	0,0322

System Services

Type of service system	Number of participants	Control	Level of grid integration	Provider	Type of power input	Billing
0,3468	0,0547	0,1312	0,1241	0,0756	0,1739	0,0937

In the Vehicle & Battery systems, the two most important parameters are the *Type of billing* and the *After-sales service provider*. In the EV mobility business, the billing, especially the one related with the battery, is fundamental because it represents the biggest investment share for the customers. Furthermore the after-sales services are becoming every day more important and essential for the customers – the automotive industry is not more only product-oriented but is evolving to a more complex system where the services have the same relevance of the product itself. Customers are always more careful about after-sell services offer regarding normal ICE vehicles, and it will be amplified for the electric vehicles. On the other side, the *Exclusiveness of use* has a low importance, and it is in line with new automotive trend, as battery swapping or car sharing.

Regarding the Infrastructure system, the *Type of power supply* and the *Accessibility* are predominant. In fact they are the two factors closer to the current problem that slows the adoption of EV mobility: the limited driving range. Also the *Billing type* has an important impact because the energy source, together with the correlated infrastructure services, has to have a competitive price for the customers and has to justify economically the switching from oil to electricity. The others parameters have less importance because they are more related with the infrastructure technical implementation and so they impact mainly on the technological side, not on customers and marketing offer.

In the System Services, parameters with the highest rank are the *Type of system service* and the *Type of power input*. The first one is relevant because it mainly define the typology of possible services offered by the vehicle-grid integration (from a technical point of view) and the level of service delivered to the customers. The second one is mostly relevant not only for the technical side – how to generate the electricity for the EV – but also for the image impact on the customers and the social responsibility of the company. Of course, a company that promotes an EV business model where the electricity is entirely provided by renewable energies has a great impact on the customer and can improve its image on the market.

Appling the (2) to the Better Place case study, it is possible to evaluate the global score of the whole system. The results are highlighted in the table (Table V) – the scores related to all the alternatives, after the experts evaluations, are not reported in this paper due to the huge amount of data.

TABLE V: VEHICLE & BATTERY SYSTEM MORPHOLOGICAL BOX (WHOLE EV SELLING MODEL)

Vehicle & Battery							
Parameters		Alternatives					
Property	Vehicle	Customer	Energy provider	Indipendent provider	Battery producer	Vehicle manufacturer
	Battery	Customer	Energy provider	Indipendent provider	Battery producer	Vehicle manufacturer
Type of billing	Vehicle	Pay for equipment		Fixed rate	Pay for use	
	Battery	Pay for equipment		Fixed rate	Pay for use	
After-sales service provider	Vehicle	Customer	Energy provider	Indipendent provider	Battery producer	Vehicle manufacturer
	Battery	Customer	Energy provider	Indipendent provider	Battery producer	Vehicle manufacturer
Esclusiveness of use	Vehicle	One customer		More than one customer		
	Battery	One customer		More than one customer		

B. Whole EV Selling Model Case Study

The whole EV selling business model is a "product-oriented" model and it is the classic business model used for selling combustion engines vehicles. The only difference from the ICE application, is that for the EV business the battery can be sold together with the vehicle or can be acquired by the customers in other ways, for example with leasing contract from a leasing company or a battery provider. In this paper will be considered the simplest solution, where the electric vehicle, together with the battery, is sold by the EV Manufacturer to the customers, with the auto dealer as intermediary.

In this case study, will be considered only the Vehicle & Battery System; the other two systems are not include in the analysis because they are covered in the whole EV selling business model – however the customers could sign specific contracts with other providers for the energy delivery and related services. So the analysis in this case is simpler and the morphological box associated to this business is showed below (Table VI).

In the whole EV selling business model, the owner of the vehicle and the battery is the customer; it means that he is the only one with the exclusiveness of use. The payment for the entire equipment is done at the beginning when the whole vehicle is bought. The after sales service provider is the car manufacturer; it provides after sales services for both vehicle and battery.

TABLE VI: GLOBAL SCORE OF BETTER PLACE MODEL

Better Place case study				
Vehicle	Battery	Infrastructure	System services	
0,3495	0,3484	0,6445	0,4998	1,8422
				Total Global Score

The scoring method uses the same scores for the prioritization of the parameters but, since the selected alternatives for the Vehicle & Battery System are not the same, the score of the alternatives will be different. So it will be used the (1). The results are highlighted in the table (Table VII).

TABLE VII: GLOBAL SCORE OF THE WHOLE EV SELLING MODEL

Whole EV selling model case study				
Vehicle	Battery	Infrastructure	System services	
0,3495	0,2506	0	0	0,6002
				Total Global Score

C. Comparison between the Results

The comparison between the results shows that the Better Place business model is more economically/technically efficient than the whole EV selling model and it is able to provide greater benefits to the customers. This result is quite predictable because, during this first stage of adoption of EV mobility, the offer of a complete service package of services by an independent provider – not only the vehicle and battery – is more convenient for the customers and should be more suitable to the current EV market status. Furthermore the fact that Better Place manages the whole system (vehicle & battery, energy delivery and grid integration services) should lead to an efficient/globally integrated system and this will deliver to the customers an important benefit. On the other side, the whole EV selling models forces the customers to a greater economical investments and to find other possible providers for the related services – energy delivery and integration services. So, if Better Place will maintain its offer and develop it properly, the Better Place appeal on the customer will be higher and successful. Analyzing the scores associated to Vehicle & Battery Systems, the one related with the vehicle is the same in both business models but Better Place has a higher score in the Battery System due to its different offer, especially related with the battery swapping feature. In fact this solution leads to a different *Type of billing* where the customers can pay in relation with the real use of the battery and so they don`t need to purchase the battery. As well the multiple *Exclusiveness of use* generates the chance to split the initial batteries investment of Better Place around different customers, with high benefits for everyone. These are the main reasons for the higher score of the Better Place business model compared with the whole EV selling model.

IV. CONCLUSION

This article develops a methodology to analyze business models in the field of electric mobility. The methodology is based on morphological boxes and scoring method. Using this instrument, it is possible to analyze different business models related with electric vehicle using a holistic approach, taking in consideration not only the vehicle and battery system but also the energy delivery and the integration between all the factors. The result is a visual representation of the main features of the specific EV business model, correlated with a global score that represents the global evaluation, based on technical indexes and possible benefits for customers. The methodology has been applied to two different case studies: the Better Place business model (service-oriented) and the whole EV selling model (product-oriented). The result shows that the Better Place model is more suitable for the current EV market status and is able to provide greater benefits to customers due to its offer of a services package able to integrate all the components of the EV mobility concept. In fact the service-oriented business model seems to be more suitable for the EV mobility than the traditional product-oriented model: the customers can interface with only one independent provider and buy in one step all the equipment and services needed for the electric-based mobility.

This approach is first step for a strategic business model evaluation and it has to be used only to define a preliminary overview, without wasting too much time or money. It should be used to understand which ones are the most critical parameters that could affect the business model, which ones are the possible strengths and the weaknesses and where it is possible to increase the business effectiveness. Of course this methodology has to been followed by a deep and detailed business analysis of the most relevant parameters individuated. Starting from the results obtained, is possible to rethink about the structure of the business model and try to find out some new possible solutions to improve the current offer.

REFERENCES

[1] F. Nemry, G. Leduc, and A. Mun˜oz, "Plug-in hybrid and battery-electric vehicles: state of the research and development and comparative analysis of energy and cost efficiency,*"* European Commission, Joint Research Centre, Luxembourg, 2009

[2] E. D. Tate, M. O. Harpster, and P. J. Savagian, *"The electrification of the auto- mobile: From conventional hybrid, to plug-in hybrids, to extended-range electric vehicles*," presented at the 2008 SAE World Congress, Detroit, Michigan, April 14–17, General Motors Corporation, 2008.

[3] A. Afuah, *Business Models: A Strategic Management Approach*, 1st ed, Boston: McGraw- Hill/Irwin, 2004.

[4] K. Chojnacki, *Relationship Marketing: Gaining Competitive Advantage through Customer Satisfaction and Customer Retention*, 1st ed, Springer, Berlin, 2000, pp. 49–59

[5] F. C. Lerch and D. Dallinger, "New business models for electric cars-A holistic approach," *Elsevier Energy Policy*, vol. 39, pp. 3391-3403, 2011

[6] F. Zwicky and A.G. Wilson, *New Methods of Thought and Procedure: Contributions to the Symposium of Methodologies*, 1st ed, Berlin: Springer, 1967.

[7] M. Delucchi, "An analysis of the retail and lifecycle cost of battery-powered electric vehicles," *Transport and Environment, Transportation Research Part D*, pp. 371–404, 2001.

[8] G. Lay, M. Schroeter, and S. Biege, "Service-based business concepts: A typology for business-to-business markets," *European Management Journal*, vol. 27, no. 6, pp. 422–455, 2009.

[9] T. G. San Roman, I. Momber, M. R. Abbad, and A. S. Miralles, "Regulatory frame work and business models for charging plug-in electric vehicles: charging infrastructure, agents and commercial relationships," *Elsevier Energy Policy*, vol. 39, pp. 6360-6375, 2011.

[10] T. L. Saaty, " How to make a decision: The Analytic Hierarchy Process," *European Journal of Operation Research*, vol. 48, pp. 9-26, 1990.

[11] Emerging Electric Vehicle Business Models. (2012). Working Document of the NPC Future Transportation Fuels Study. [Online]. Available: http://npc.org/FTF_Topic_papers/18-Emerging_Electric_Vehicle_Business_Models.pdf

[12] C. Zhang, Q. Huang, J. Tian, L. Chen, Y. Cao, and R. Zhang, "Smart Grid facing the new challenge: the management of electric vehicle charging loads," *Elsevier Energy Procedia*, vol. 12, pp. 98-103, 2011.

[13] C. Guille and G. Gross, "A conceptual framework for the vehicle-to-grid (V2G) implementation," *Elsevier Energy Policy*, vol. 37, pp. 4379–4390, 2009.

[14] W. Kempton, J. Tomic, S. Letendre, A. Brooks, and T. E. Lipman, "Vehicle-to-grid power: battery, hybrid, and fuel cell vehicles as resources for distributed electric power in California," Working paper, Institute of Transportation Studies, UCDavis, California, 2001.

Ma Jun was born in 1970 and graduated from Darmstadt University in automotive electronics and owns 15-year working experience in automotive industry, including 5-year experience as an Engineer and 4-year experience in the field of marketing and after-sales. He has worked for Continental TEVES, and Audi AG in technology development, marketing and management. By the end of 2003, invited by Dr. Wan Gang, Dean of School of Automotive Studies at that time, currently the Minister of MOST and Vice Chairman of CPPCC, and also his colleague in Audi AG, he has come back to China to begin his career as a professor in Tongji University. Currently he is Associate Professor, Chief Professor of Automotive Marketing faculty and Vice Dean of School of Automotive Studies at Tongji University. His main field of studies and research are: macro & micro environment study, customer study and product study. He also conducts, together with his students, strategic researches, mainly regarding brand positioning, competitor analysis, target group analysis, CRM, business development and company development strategies.

Alberto Di Muro was born in Torino, Italy, in 1988. He received his Bachelor Degree in Automotive Engineering at Polytechnic of Torino, Italy, in 2010. Now he is joining a Double Master Degree Program in Automotive Engineering at Polytechnic of Torino, Italy, and Tongji University, PRC. He will get his double Master Degree in Automotive Engineering in March 2013. The program mentioned is the result of cooperation between the Italian Minister and the Chinese Government for the international promotion of young talents. During the last year in China, he worked in the Automotive Marketing and Management Institute at Tongji University on different marketing studies and concept developments for famous foreigners OEMs. His primary business was the development of products and concepts designed for the Chinese market and able to satisfy Chinese customers` needs. He also conducted specific market studies, mainly focused on the Chinese automotive market.

.