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A Collaborative Decisional System to Support a Business Model for the Development of Charging Infrastructure

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Abstract. The obstacles to the E-Mobility (EM)'s development are widely discussed both in scientific and in industrial fields. Approaches to overcome these obstacles are still not consolidate. At the same time, it is not so clear, what Business Models (BM) are more sustainable for the owners of Charging Infrastructure (CI). With the aim to support the development of charging network (CN), the authors propose a new BM based on intelligent, collaborative and digital services for all actors of the value chain. The implementation of this BM starts with the development of a decisional structure (DS) and the sharing of data and information among all operators that are involved into the charging process. The main elements of the model are explained and the first results of implementation are given. Future development are discussed to enrich the research and to supply at industrial field a useful tool to face decisions in the real context of CNs.

Keywords: Collaborative Business Models. Service Systems ICT oriented. Optimization. Decision Support System

1 Introduction

The de-carbonisation of the transport sector is a priority goal of the whole European Commission (EC), that has been proved through several efforts, such as the Kyoto Protocol, the European plan on climate change (2009, 20-20-20 goals) and its related white papers. With respect to the targets imposed by the EC on the reduction of CO₂ emissions, especially in the transport sector, the development of electric vehicles represents an important key driver towards achieving the prefixed objectives. Despite the fact that the benefits related to the diffusion of EM in both urban and/or extra-urban contexts are well known, with reference to their environmental, social and economic impacts, the development of such a market still presents significant impediments, widely discussed in the scientific literature. In particular, the main obstacles are related to the long battery charging time, scepticism among potential

end-users [3], high costs of electric cars with respect to traditional combustion engine vehicles [22] and, as here studied, the lack of a widespread, accessible and homogeneous recharge infrastructure. The objective of this work is to create a digital and collaborative system to support the decisional processes for the development of new BM for charging services at national and international level.

Adopting the point of view of [13], this article does not claim to deliver detailed solutions for all the decisions on different business levels. Rather, it aims to create a structured approach, which can be used as decision support when developing of BM for the owners of charging stations. Today the decision to invest into this sector is limited by a too high degree of uncertainty with respect to demand of users, the payback time and the profitability linked with the CI. For this reason, the authors here propose a structured BM based on an engineering approach able to reduce this degree of uncertainty and to support the development of intelligent and collaborative CNs. The assumptions made in this work could support the creation of a new BM based on digital services for CIs. This kind of offering, nowadays represents an innovation for the global market and could help the investors to create a “Blue Ocean” in the field of e-stations. The remainder of the paper is so structured: Section 2 explores the most recent scientific contributions on EM field from point of view of developed BM and implemented DS. Section 3 explains in detail the proposed BM based on three levels of DS. Finally, conclusions and future works suggested.

2 Literature Review

Hybrid Electric Vehicle (HEV) and full Electric Vehicle (EV) have been developed rapidly in the last years in order to counteract the CO₂ emissions and the liveability of crowded and polluted urban areas. The great part of efforts made into industrial and scientific field to support this development are linked to technological aspects of sector, first of all on battery durations. Unfortunately, these efforts have been not sufficient to overcome all obstacles to the development of the EM. Only recently, researchers and managers are developing the fundamental elements aimed at supporting the EM sector's progression. Among them the lack of a homogenous CI represents the main problem still un-solved in some European countries. But why there aren't enough investors for this market? For the authors of this work the reasons are to be found in: (i) degree of uncertainty on real demand of charging during the next five years, (ii) lack of new BM for the investors; (iii) lack of decision support systems to manage the CN. Strategies aimed to contrast the aforementioned points, will result in more profitable BM for EM.

The two following paragraphs reassume the collected scientific contributions in this field. In particular, the cited works highlight the steps made forward and the questions still open from both industrial and scientific point of view. Among them, particular emphasis is given to gaps, above mentioned, for the development of CIs.

2.1. Business Model for e-Mobility Market

The uncertainty, regarding the development of EM sector, creates obstacles about the decision of how to enter and how to manage a profitable business for this market. Car manufacturers, batteries producers, utilities, charging services providers, oil and gas companies, public authorities at national and international level, are among the potential players involved in the process of developing the culture of EM that ultimately pertains to car drivers. Some previous research on the perspective of car manufactures [10] and charging service providers [11] show that different approaches can be implemented for managing a business linked to EM. For this reason, the role of BM is a key element in exploring the business possibilities stemming from the EM field. In general, the relevance of BM as public information in annual reports published by corporations is a topic of emergent interest [12].

In a context where a continuous evolving technology allows for a lower cost of information to find customer solutions, innovative companies need to think about their role in capturing value in providing new products or services, satisfying customers need and if possible with benefits for the society at large. For this reason, a BM and a Decision Support Tool (DSS) may provide support for business pioneers in this field. “A business model articulates the logic and provides data and other evidence that demonstrates how a business creates and delivers value to customers. It also outlines the architecture of revenues, costs, and profits associated with the business enterprise delivering that value [23]. From this definition, we can draw different elements. The starting point is the product or service with specific technological features to deliver to customers. The second element is the benefits to the customers, and if possible to the society at large, stemming from using the product/service. The third element is the market where to sell the product/service. The 4th element is the possible revenues configuration in connections with the costs structure of a business entity, and as a consequence the design of a mechanism able to capture value. In a definition, “a business model defines how the enterprise creates and delivers value to customers, and then converts payments received to profits [23].

The lack of a generally accepted theoretical background for BMs in economic theory drives researchers toward methodology based on case studies often involving a multidisciplinary approach. Contributions devoted to EM and BMs come from different areas: economics, business administration, accounting, engineering, environmental sciences. The effort is made for defining the main components and operating procedures for this business area. For example, [5] analyses the opportunity to implement a specific BM related to the question of “range anxiety” and battery pack charging in Denmark.

Authors in [1] attempts to generate BM innovations in the field of EM, using the idea of systematically combining five dimensions of the values concept (often a key concept in any BM). This approach is expression of a need to explore new patterns in an innovative business field. [1] underlines that BM patterns such as disintermediation, product-to-service, and leasing have been already implemented in the automotive industry. Some of them, for example car sharing (product-to-service BM) may get additional boost in the context of EM. In designing BMs in the field of EM, it seems there is space for different players, such as car manufactures and service

providers. In this context of uncertainty, there is a need for simulation “in order to identify the most suitable model from the perspective of the actors involved in the automotive network. This often represents an academic exercise. Certainly, the simulation cannot be carried out without making assumptions about the BMs of the other players, the development of the market for EM, and the dynamics of technology development. In addition, as in the near future we will have a situation, in which conventional, hybrid and electric cars are co-existing, it is very important to think of transition scenarios that consider these patterns of technologies.” [1].

The need to use simulation with the DSS tool stems from the idea that the typical BM described by some authors [2],[25],[14] largely used for combustion engine vehicles, cannot be transferred to EM concepts because of technological restrictions. For this reason, an effort is required to explore BMs for EM, trying to understand which of the classic BM components are needed and what factors must be integrated.

BMs in the EM field are also influenced by regulation at national and international level regarding the distribution grid, the standardization of CIs, the localization and the quantity of charging points / stations. Therefore, new mobility concepts and BMs should be integrated in the regulatory framework and public policy for transforming the technological advantages of electric vehicles (EV) into value added for the customers [13]. A key point in solving this problem is the way (and where) energy is delivered to EV drivers, since this decision may create space for new agents. Authors in [19] discuss the role played by the “EV supplier-aggregator” considered a competitive business as other trading activities in the market, selling electricity to EV owner. What kind of charging technology and where to locate charging points are relevant elements in designing a BM in the EM field?

2.2. Location Problems Modelling and Algorithms

Despite the problem of location of stations for charging is widely discussed in the scientific literature, there is a gap of useful tools for this specific aim and where present, often they are too complex to become efficient solutions in a business context. Traditionally, discrete location problems deal with the decision about which site(s) select for opening or establishing facilities able to serve commodities to satisfying a given demand, with the goal to minimize fixed installation and variable (transportation) costs. Discrete location problems are usually modelled using graphs and integer programming. Even simplest classes of discrete location problems such as the un-capacitated facility location problem (UFLP) are proven to have exponential complexity (UFLP is NP-Complete), although several efficient solution procedures can be found in literature [15]. Facility location problems are applied to a wide range of disciplines such as location of plants, telecommunication networks, rescue facilities [21], and so on. Recently, a growing trend can be observed where facility location problems are applied to the optimization of green logistics and sustainable mobility. [7] surveys the peculiarities of network design for plug-in hybrid electric vehicles (PHEV). According to the authors, the most important characterizing features of PHEV to be considered in network design are: the driving patterns, the charging characteristics, the number of vehicles on the network. A critical factor is the stochastic behaviour of the system. [24] proposes an integer formulation for location

of recharging stations to serve electric scooters, considering constraints related to the charging time. [25] uses a simulation and optimization based technique to define optimal location of charging stations for private owned electric vehicles. The work in [9] compares different location models and considers institutional requirements for charging stations network design in an application case of Beijing, China. In [27] the location problem for charging station is expanded to consider the capacity of each station with the aim to design the number of recharging station in each facility. The surveyed literature shows a growing coverage of location problems considering more and more the particularities of electric mobility as an integration of the classical facility problem. In most of the surveyed works, the problem instances are not too big and standard commercial solvers adopting branch and bound based algorithm is used.

3 The Collaborative and Digital Decisional System to Support a New Business Model for the Development of Charging Infrastructure

The proposed collaborative and digital DS for supporting the creation of a new BM for the development of CNs, is able to support the owners, managers and operators on three decisional level: strategic, tactical and operative. The authors propose to face the uncertainty of persons that invest into infrastructure of charging into three different layers corresponding with three different decision makers or three different roles into the value chain. At the same time, the flow of the business is divided into five steps, at each one a digital service has to be implemented and a collaborative procedure has to be developed for the sharing of information and data. The business idea is based on the offer of a set of digital services able to support the decision making process, under explained, at different levels. The framework is sketched in Figure 1 and detailed in the following.

Strategic level. The decision maker at this level is usually the owner or the manager of fleet of areas for position of stations, vehicles or of commercial distribution chain, or of fuel stations. Typically, he can decide how many, which and where to open charging stations. These decisions fall back into the classification of strategic decisions as they involve an amount of resources and time that cannot be changed in easy way and in fast manner. The proposed BM offers for this kind of actors a decision support system including 3 phases corresponding to actions to develop:

Phase 1: Collection of data and information about the geographic area object of analysis. For example, thanks to this action the decision maker collects data as traffic information, proximity of Point of Interests (PoIs), proximity of parking, proximity of other charging stations, behaviours of potential users, et others;

Phase 2: During this phase, a feasibility analysis is performed. At this point of decisional process, the decision maker makes a selection of potential sites for the installation of charging station. This action is important to discard unrealizable projects and to focus the efforts towards objectives more achievable.

Phase 3: On basis of acquired data, this action puts in place an optimization process to select the best network's configuration with the location of charging points. In the

proposed DS, this decision is taken thanks to mathematical models known in Operation Research and their relative implementation.

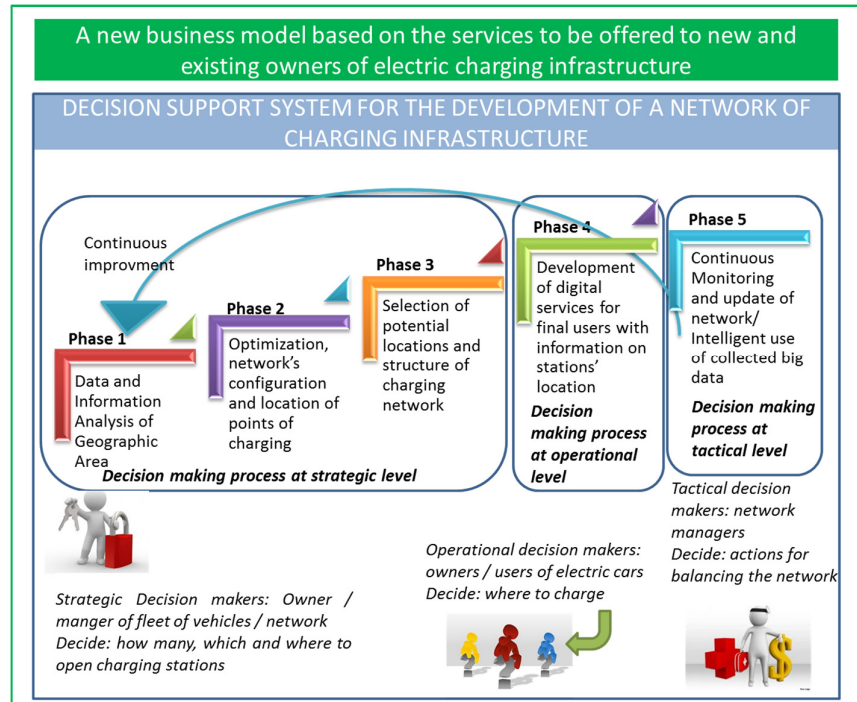


Fig. 1. Proposed structure for new BM based on decisional process system

Operational Level. The decision makers at this level are the operators, the owners or drivers of electric cars that, on basis of digital supplied services, they decide where going to charge their electric vehicle. These decisions fall back into the classification of operational decisions as they involve an amount of limited economic resources and limited time. The decision can be changed abruptly without involving great amount of resources and time. At this level one activity or phase has to be developed:

Phase 4: In this phase the proposed BM foresees the development of digital services for final users thank to information on location of charging stations. This kind of services includes the possibility to book charging, direct the car to the nearest station, receive the invoice of recharges and others. This process can be monitored and checked at the same time by the owner of the network such as by the final user, thanks to sharing of data-base for single client.

Tactical Level. The decision makers at this level are the directors of the network that on basis of users' behaviours can adopt actions for balancing the network applying for example strategies of marketing or pricing. These decisions fall back into the classification of tactical decisions as they involve an amount of resources that can be changed in a medium term horizon. For this level one phase has to be implemented:

Phase 5: The last phase of proposed structure is relative to monitoring and update of CN. Moreover, an intelligent use of collected big data is desirable to enrich the availability of data relative to e-mobility sector. Thanks to elaboration of these data the managers, the directors and the operators can adopt decision more efficient than to a continue set of updated data. The framework underline the importance for the BM, of the use of hyper-connected data along all the decisional phases for all the decision makers which have to coordinate in order to execute the process. The study presented in this paper presents the preliminary steps for the creation of this DS for development of a new BM able to support the increase of CI at national and international level. In particular, the following paragraph describe implementation details both with respect to BM and to respect to the phase 1 and 2 of DS.

3.1 Elements for Designing a New Business Model

The literature put in evidence as many authors agree that the elements on which BMs for EM are based are: vehicles, their autonomy and batteries [6]; CI [4],[13]; System integration of EV into the energy system [4],[8]. The market of digital services for the managing of charging process is not yet sufficiently developed, especially regarding the CIs. For them, key elements are the accessibility to the charging stations, the type of connection and the communications links [13]. Efficient combinations of these variables can be numerous. The charging stations can be public, private or semi-public, and can have different recharging speed. Moreover, the type of connection can be unidirectional, which can only deliver power in one direction, or bidirectional, which transmit electricity in both directions. Infrastructure maturity and connected services increase the efficiency and operation of the model, so we can consider also the power connection, the information flow, the type of operator and the type of billing. Others services that have to be developed are related to drive the car to the nearest station on basis of traffic information and charge information. To do it, the shortest path algorithm that characterizes many navigators has to consider not only the distance of the route but also the need charge to reach the destination. Moreover, the users should have the possibility to booking the charge and to have real-time information on the status of station. Thanks to this kind of managing of the charging process, monitored and checked by a shared database, will be possible in few time to create also ad hoc services for specific kind of clients. From this consideration, the owners of CN could implement a different pricing policy for users and a set of marketing strategies able to increase the demand of charging in shortly time. Shifting the focus, from the technological problems to management and commercial ones, it will allow to move the efforts toward projects today more needed such as: (i) the development of communication plans; (ii) dissemination of information on incentives for the use of EV; (iii) the implementation of services that enable the accessibility to charging points; (iv) the definition of pricing policy cheaper respect to traditional fuel; (v) the introduction of strategies for the storage/production of energy with renewable sources, and of procedures for an intelligent use of energy on the line (smart grid technologies); (vi) the production of a continue flow of information for the managers and the clients/users. The combination of these smart and digital solutions could be

the turning point for the crossing of obstacles to changing from traditional car to electric car. Thanks to the proposed DS structure will be possible to create a data base and a set of collaborative procedure to create and to manage the CN in intelligent and digital way. As consequence, the manager could propose a set of commercial offers for each users and check the profitable of each action made, improving continuously its business implementation. In the following paragraph the phase 1 and 2 of DS are explained in details and discussed.

3.2 Proposed Optimization Tool for the Positioning of Charging Stations

Traditionally, location problems are used to decide where and which plants to open in order to satisfy a given demand localized into a geographical area. The decision maker, on the basis of a preliminary analysis, selects a set of potential sites to activate. In the same way, the owner or manager of the CN collects data and information on geographical area where he has interest to put in place a set of CIs (**Phase 1**). During the **Phase 2**, the information on demands of charging, traffic information, presence of competitors, are elaborated and inserted as input into the mathematical model such as proposed by [20] and [17]. The optimization model has been designed and implemented considering: (i) The as-is scenario coming from mapping the location of existing charging stations; (ii) Charging demands; (iii) Electricity network loads or the possibility to power the charging station from renewable energy sources; (iv) Availability of areas in order to mark them as potential sites for charging-stations. A first release of the described decisional tool for the charging-stations positioning has been successfully implemented for the city of Viterbo, a small town of 65,000 citizens localized in the centre of Italy. The demand of electric charging has been estimated on the busiest streets of the city, estimating a number of EV equal to 1% of vehicles on the road. The potential locations have been selected on the basis of market's needs, with an estimation of 20 available potential location sites, such as: (i) Parking of shopping centres; (ii) Parking of schools, universities, courts, town hall etc.; (iii) Parking for mobility interchange (rail, metro, bus); (iv) Fuel stations located on the routes to entry at the city. On the basis of the estimated demand and of the potential sites where to install a charging station, the tool returns the best solution in terms of number of stations and their locations. In the implemented test, 11 has been the exact number of infrastructures needed to satisfy the demand of charging. The problem has been modelled and solved at its optimality by using the Cplex[®] solver, considering several variants of the model depending for example from budget, from number of stations, or from maximum distance between each customer respect to the charging station. For brevity of discussion complete test results are omitted; a set of 20 tests have been carried out for each type of proposed model, while the solver returned in a few seconds the optimal solution to the problem.

4 Conclusion

Currently, the offer of ICT services for e-mobility is lower of its demand and collaborative and integrated solutions are lacking. The authors believe that moving

the attention from technological point of view toward managerial one, may help the e-mobility market to explode in the short term. For helping in this aim, they propose in this work a new BM based on a three level DS for the development of CIs and their relative integrated digital services. The paper focused in particular on detailing the first two steps of the framework. The authors are actually working on the other phases proposing intelligent approaches for the problem solving procedures for each actors of the value chain. As last step, when the data base will be built and the collaborative procedure defined, the authors could build the BM based on structured DS and on available information coming from data warehouse. In future works, the authors want to put in evidence the great potentiality offered by the proposed model, enriching it of new algorithms and new models able to increase the ability to create / incentive charging demand and to manage in a profitable way the charging process.

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