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Description automatically generated**Dissertation submitted in fulfillment of the requirements for the award of the degree of Doctor of Business Economics (Doctor in de toegepaste economische wetenschappen)

**INTRODUCTION OF V2G-ENABLED GRID BALANCING SERVICES INTO EV CHARGING BUSINESS ECOSYSTEM.**

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**ABSTRACT.**

The modern world faces a transformative shift towards sustainability and electrification. The electrification of transport is a significant part of this paradigm shift. The transition from internal combustion engine (ICE) to electric vehicles (EVs) promises significant benefits, such as a reduction in air pollution and a decrease in dependence on fossil fuels. However, the ambitious targets for the major transition to EVs in the coming years, encouraged by European guidelines, national action plans, and private investments, are resulting in the increasing EV charging demand.

In order to maintain the electric grid stability, the electricity consumption and injection in the grid should match at every moment of time. The simultaneous charging of a large number of EV batteries puts significant pressure on the grid by increasing the peak energy and power demands. Currently, in order to maintain the balance inside the grid, the grid operators employ the services, of so-called, Balancing Service Providers (BSPs). The BSPs are mainly large centralized entities injecting or consuming power and energy in the grid in case of necessity. The balancing energy and power provided by these BSPs is predominantly generated by means of fossil fuels, due to the high volatility of renewable energy production and challenges related to energy storage.

However, the rising popularity of EVs can also become a solution to this problem by employing vehicle-to-grid (V2G) technology. The V2G technology allows for bi-directional power transfer between the EV battery and the electricity grid, giving the opportunity to adjust the timing, power level, and direction of energy flow. This functionality allows the entities owning and operating V2G charging networks to become decentralized BSPs, employing the growing EV fleet for balancing the grid in both directions: for consuming and storing energy excesses, and for providing balancing energy and power back to the grid in case of necessity. Therefore, the application of V2G technology in grid balancing can become key to maintaining the environmental benefits brought by the switch to EVs and increasing the share of renewables in the energy mix.

The aim of this research is to provide guidelines for a financially viable integration of V2G-enabled grid-balancing services into the existing EV charging business ecosystem, eventually designing a new complimentary V2G-enabled grid-balancing business ecosystem. For this purpose, the current research offers a novel qualitative business modeling approach, comprising a business model transformation mechanism triggered by the introduction of a new technology. The developed approach has allowed to define the EV charging ecosystem, the business models of its participants and to zoom in on the changes caused by the introduction of V2G technology. To enable utilization in practical use cases, the qualitative approach is also complemented by the development of a quantitative business modeling framework for the calculation of costs, revenues, and derived Earnings Before Interest and Taxes (EBIT) of the core participants of the EV charging business ecosystem.

To understand the broader context of the introduction of V2G into the defined business ecosystem, the current study identifies the barriers hindering the adoption of V2G technology by its potential stakeholders (e.g., suppliers, distribution channels, direct customers, governmental agencies, etc.). The business ecosystem, formed by the interactions of these stakeholders, represents a dynamic system of cause-effect relationships. Therefore, the barriers to the adoption of V2G technology are taking part in the same business ecosystem and are interrelated as well. After the identification of the barriers, the current study analyzes their potential risk level and the interdependencies between them. This allows to understand the relative importance of the barriers which can guide involved stakeholders toward the necessary efforts for the adoption of V2G technology. The performed analysis allows to conclude that the most prominent barriers to V2G adoption represent the business-related challenges.

After the definition of the EV charging business ecosystem, investigation of the revenues and costs of its core participants, and the identification of barriers to V2G adoption, the current study researches the profitability effects of the introduction of V2G-enabled grid balancing services. Based on real-life EV charging data, and a set of grounded assumptions, it explores the potential profitability of V2G-enabled Frequency Containment Reserve (FCR) and automatic Frequency Restoration Reserve (aFRR) services.

All the above-mentioned research findings eventually allow to map the V2G-enabled grid-balancing business ecosystem and build a dynamic model of its internal cause-effect relationships. The defined model uncovers and clarifies the intrinsic mechanisms crucial for the stakeholders’ business models optimization, the definition of a suitable regulatory framework (e.g., technical and communication standards, taxation schemes, grid balancing market entry requirements, etc.), and the facilitation of EV users’ acceptance.