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EXPLORING ELECTRIC VEHICLE MARKET DYNAMICS WITH AGENT-BASED MODELLING: THE IMPACT OF DESIGN STRATEGIES AND CONSUMER CHARACTERISTICS

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ABSTRACT

In this paper, we present an agent-based simulation framework to assess the effect of battery electric vehicle optimal design methodologies employed by original equipment manufacturers, on their market share and customer uptake. First, we create demographically accurate customer agents representing their characteristics based on recent real-world data, whereby we implement a choice model enabling each agent to make purchases according to their preferences. Second, we develop company agents who design and manufacture their vehicles according to the different optimal design methodologies: vehicle-tailored and concurrent design. Finally, we compare the evolution of the market over multiple years to obtain final profitability of the different strategies and final consumer vehicle adoption, with respect to base scenarios. Our results show that leveraging concurrent design increases the attractiveness of electric vehicles for customers, leading to increases in sales compared to the traditional vehicle-tailored approach.

1 INTRODUCTION

Recent advancements in powertrain design methodologies have enabled complex system-level optimization strategies, expanding design spaces. The integration of product family design strategies, such as modularity and standardization, with optimal powertrain design allows for trade-offs between energy efficiency and production costs. Unlike traditional vehicle-specific designs, concurrent design optimization uses modular components across a vehicle family, reducing production costs through economies of scale. However, the market impact of these strategies remains unclear.

This study aims to evaluate whether lower acquisition prices, at the expense of reduced energy efficiency, align with customer preferences. Previous research on Tesla BEVs demonstrated significant reductions in Total Cost of Ownership (TCO) through concurrent powertrain design, though it did not consider customer interactions. J. Kusar's work supports the cost and time benefits of concurrent design, while other studies have applied product family strategies to vehicle bodies and chassis with similar conclusions (Kušar, Rihar, Duhovnik, and Starbek 2014) (Fellini, Kokkolaras, Michelena, Papalambros, Saitou, and Perez-Duarte 2002).

Agent-based modeling, which simulates complex systems of autonomous entities, provides insights into how individual decisions lead to collective outcomes (Schieritz and Milling 2008). This method has been used to explore the interaction between customer markets and vehicle portfolios, highlighting factors beyond cost, such as driving range, energy efficiency, size, age, customization, and performance. Emotional responses and personal attitudes towards electric vehicles also play a significant role in purchase decisions, often overlooked in strategic company decisions. In this paper, we develop an agent-based model that captures the complex interactions between vehicle manufacturers and customer choices, analyzing the impact of different design methodologies on customer preferences and company revenues in a competitive market.

2 METHODOLOGY

We develop a model where customers, companies, and factories interact in a shared market environment (Figure 1). **Customers** are segmented by characteristics (age, income, gender, location) and preferences (type, price, range, energy consumption, speed). Based on available vehicle offerings, they make purchase decisions according to their requirements (Purchase Policy). **Companies** use distinct design optimization procedures, informed by market research and sales data, to determine production volumes and vehicle types (Design Policy). We consider three vehicle types (city-car, sedan, cross-over) and two production policies (*Tailored* and *Concurrent*, following (Clemente, Salazar, and Hofman 2024)). **Factories** produce specific components (engine, chassis, etc.) and receive design orders from companies. Production volume and design type influence manufacturing times and costs.

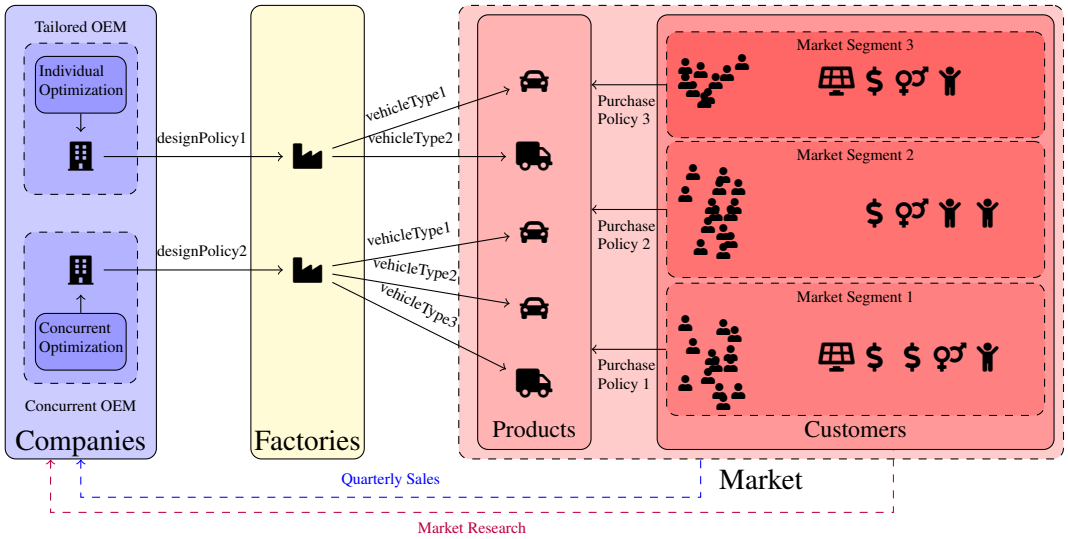

Figure 1: Diagram of model components.

3 PRELIMINARY RESULTS

We analyze the electric vehicle market in the Netherlands, comparing a company using concurrent design optimization with one using vehicle-tailored design optimization. Our results show that the concurrent-design company achieves 105% more sales and 28% additional final capitalization due to reduced costs and production times. Introducing two more companies (one per design strategy) drastically shifts market shares, leading to the bankruptcy of one tailored-design company. Higher disposable income, potentially from subsidies, increases electric vehicle adoption by 13.92%, with a preference for longer-range models. In conclusion, our agent-based simulation framework combines customer and company behaviors to assess the impact of different electric vehicle design methodologies. Future work will explore additional market scenarios and refine the model to account for dynamic changes in customer behavior and market conditions.

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