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SIMULATION OF AUTO DESIGN PERFORMANCE IN THE MARKET TO MEET FUEL EFFICIENCY STANDARDS

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ABSTRACT

This research effort demonstrates an analysis and simulation methodology a manufacturer could employ to determine the recommended vehicle architecture that maximizes profit, while complying with government corporate average fuel economy (CAFE) standards. We scope our target system to a Jeep multi-purpose vehicle (MPV) segment by Fiat Chrysler, which is a crucial part of the manufacturer's product portfolio. We utilize multi-criteria decision analysis (MCDA) using the criteria of cost, acceptance, effectiveness, fuel type, and electrical factor to rank many possible fuel efficient technology configurations. Employing discrete event simulation, a select group of configurations are analyzed for profitability based upon market acceptance and economic performance. The discrete event simulation studies the expected profit distribution with variability in market acceptance and cost categories of production, research and development, warranty, and recall. This variability is treated as a risk and coupled with profit level and technology effectiveness lead to a final recommendation.

1 INTRODUCTION

In the latest round of regulations, the government recently mandated CAFE standards for vehicles to be built from 2017 to 2025 that nearly doubled the previous standards in an effort to make cars more efficient and to reduce greenhouse gas emissions. This has caused auto manufacturers for the North American market to seek configurations of different technologies for its vehicles and to development a strategy to move them along a technology roadmap to meet these constraints. The challenge for the auto manufacturer becomes maintaining profitability while achieving the CAFE and CO_2 emissions targets. There is a wide range of alternatives and technologies available to auto manufacturers to achieve these requirements, including adoption of improved engines (such as diesel, hybrid or electric) and transmissions, reducing the vehicle weight with advanced materials and parts, improving vehicle aerodynamics, and installation of other efficient accessories. Each of these options have costs, projected effectiveness ratings at achieving the CAFE standards, and impacts on the vehicles' market acceptance. Furthermore, the manufacturer is also balancing the complexity of the new technologies with the risk associated with technology return-on-investment and the possibility of safety recalls or warranty claims due to the roll-out of insufficiently tested technologies. This is a complicated problem set, but one that can be analyzed using modeling and discrete event simulation.

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2 METHODOLOGY

Through our MCDA, we reduced the search space of over 560 government pre-determined technology packages to 7 worth analyzing based upon the criteria of technology cost, market penetration, effectiveness at achieving CAFE standards, minimizing CO2 credit, and electrical conversion. MCDA provided us with the necessary subset of technology packages that not only satisfied the manufacturer's criteria, but also were effective at satisfying the CAFE government standards for fuel economy and emissions. We developed a discrete event simulation of the economic performance of each vehicle configuration. Our subsequent discrete event Monte Carlo simulation allowed us to analyze the economic performance of each technology package and specifically determine how variability in production costs, market acceptance, research and development costs, warranty costs, and recall costs impacted the expected profit distribution. The SIGMA simulation performs repeated stochastic calculation of the following equation:

$$\text{Profit} = \sum_{t=\text{month 1}}^{\text{month 108}} \text{NPV}[Revenue(x_t) - PC(x_t) - WC(x_t) - RC(x_t) - RD(x_t)]$$

Where $x_t \in \mathbb{R}^n$ are the decision variables of the n vehicle configurations for 108 months (January 2017 to December 2025), $Revenue$ is the monthly income from sales of cars in North America, RD is the monthly research and development cost used to acquire technological advancements, PC is monthly production cost for the vehicle, RC is the monthly recall (safety) costs, and WC is the monthly reliability cost in the form of warranty reimbursements or repairs.

3 EXPERIMENTATION AND RESULTS

The main experiment compared the economic impact of each of the 7 technology packages at the discount rates of 6% and 12%. Both experimental factors, technology package and discount rate, showed statistical significance for the model outputs of Profit NPV, and reported packages P9, P353, P317, P577, and P40 in order of decreasing positive profit. However, in order to ultimately recommend to Fiat Chrysler the technology package to incorporate in their Jeep mid-size SUV model, we performed additional analysis on the risk associated with the package, as well as the effectiveness of the package on achieving government CAFE standards. The confluence of all three factors led us to conclude that package P40 was the best choice. It consisted of a diesel engine, double clutch transmission with hydraulic fluid, 10% weight reduction, and resulting in 58.5% fuel efficiency increase and CO2 reduction effectiveness rating.

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