Journal of Cleaner Production 70 (2014) 132–144

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Assortment planning of automotive products with considerations for economic and environmental impacts of technology selection

Ali Taghavi, Ratna Babu Chinnam*

Department of Industrial and Systems Engineering, Wayne State University, 4815 Fourth Street, Detroit, MI 48202, USA

ARTICLE INFO

Article history:
Received 26 April 2013
Received in revised form
3 February 2014
Accepted 4 February 2014
Available online 12 March 2014

Keywords:
Assortment planning
Configurable products
Product substitution
Technology selection
Sustainability
CAFE requirements

ABSTRACT

A manufacturer's assortment is the set of products that the company offers to its customers. Assortment planning considerably affects both the sales revenue and product offering costs for the company and it had experienced growing attention across different industries over recent decades. In this study, we propose a modeling framework that seeks to identify the optimal assortment for a manufacturer of configurable products (in particular, automobiles). Our model accounts for environmental considerations (Corporate Average Fuel Economy requirements, tailpipe emissions, and greenhouse gas emissions related to the production of the fuel used to power the vehicle) during assortment planning. We formulate the economic and environmental requirements in the model through a mixed-integer programming framework and present a hypothetical product case study motivated by an American automaker that involves 120 potential configurations employing different engine technologies (gasoline, diesel, and hybrid technologies). Notwithstanding consideration for consumer perceptions and acceptance, the results of this research work show that diesel technologies are a better choice to satisfy average fuel economy requirements compared to hybrid and conventional powertrains with current technology maturity.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

A manufacturer's assortment is the set of products that the company builds and offers to its customers. Kök et al. (2008) describe the goal of assortment planning as finding an assortment that maximizes company's profit subject to various constraints such as limited budget to purchase products and limited shelf space to display products. For configurable products such as automobiles, which are a combination of required and/or optional components (Rodriguez and Aydin, 2011), each model comes in a number of configurations; the set of configurations and the associated logic for a configurable product is sometimes termed *product definition*. *Assortment planning* requires a tradeoff between sales revenue and product offering costs for the company (MacDuffie et al., 1996). The automotive product offerings and configurations have steadily grown in the U.S. until recent years. For example, the number of car models available in the U.S. market increased from 30 models in 1955 to 142 models in 1989 (Womack et al., 1990). Including nameplates, body styles, and special performance editions, the industry is offering 394 new models in the U.S. market in 2013 (Baumann, 2013). However, growing awareness for the costs associated with increasing manufacturing complexity and plant productivity issues under large product configuration assortments is compelling major volume-driven automotive original equipment manufacturers (OEMs) to consider controlling their configuration variety to decrease their operational costs while maintaining their sales and market shares. For example, Ford Motor Company reduced the ordering complexity (i.e., number of orderable configurations) of the 2009 F-150 truck by more than 90%. As for cars, it planned for the 2010 Ford Focus to have just 150 "major" (or "core entity") combinations, a drop of 95% from the 2008 model (Wilson, 2008). OEM data from Pil and Holweg (2004) for a popular vehicle segment in Europe even suggests that there is little correlation between the total number of configurations offered by a brand model and the total sales experienced. While there are a number of factors that influence sales besides product variety (e.g., product quality, value, brand image), overall it appears that automakers are not necessarily driving their strategic decisions regarding product configuration variety based on objective and holistic decision support models.

Besides economic objectives to maximize profit, there are also other factors affecting the final assortment of an OEM.

* Corresponding author. Tel.: +1 313 577 4846.
E-mail addresses: taghavi@wayne.edu (A. Taghavi), ratna.chinnam@wayne.edu, r_chinnam@wayne.edu (R.B. Chinnam).

http://dx.doi.org/10.1016/j.jclepro.2014.02.004
0959-6526/© 2014 Elsevier Ltd. All rights reserved.

Environmental considerations are important driving forces that impact the automotive industry due to increasingly strict governmental regulations and social expectations (Geffen and Rothenberg, 2000; Koplin et al., 2007). In the U.S., the main federal regulations on vehicle fuel economy have been expressed through Corporate Average Fuel Economy (CAFE) standards by the National Highway Traffic Safety Administration (NHTSA) and the Environmental Protection Agency (EPA). CAFE is the sales-weighted fleet average fuel economy of an OEM, expressed in miles per U.S. gallon (3.785 L) of vehicles for sale in the U.S., for any given model year. The CAFE requirements were relatively static from 1990 to 2010, with a requirement of 27.5 miles per U.S. gallon (mpg) for passenger cars. Starting in 2011, the CAFE standards are newly expressed as mathematical functions depending on vehicle "footprint", a measure of vehicle size determined by multiplying the vehicle's wheelbase by its average track width. Going forward, the CAFE requirements are tightening: 2016 target fuel economy is 35.5 mpg for car and light trucks and will further increase to 54.5 mpg by model year 2025. The current penalty for failing to meet the standards is $5.50 per tenth of a mpg for each tenth under the target value times the total volume of vehicles manufactured. In addition, a Gas Guzzler Tax is also levied on individual passenger car models (but not trucks, vans, minivans, or SUVs) that get less than 22.5 mpg. Instead of CAFE requirements, some countries including European states have imposed taxation policy on gasoline and diesel prices (Sterner, 2007; Ekins, 1999). This policy has been considered one of the best ways to fiscally control the amount of energy consumption and emissions from the transportation sector (Steenberghen and Lopez, 2008). This policy often involves significantly increasing fuel price (van Vliet et al., 2010) and motivates customer's evolution toward more fuel-efficient vehicles. This dynamic will be implicitly considered in our model through the impact of vehicle price on primary demand fractions for distinct configurations. Another important measure for OEMs in deciding the product configuration assortment is the emissions footprint from vehicle manufacturing as well as product use and disposal/recycling.

In this paper, while limiting our discussion to the automotive industry, we aim to develop configurable product assortment planning models that take environmental considerations into concern while explicitly accounting for both demand and supply issues. In the past decades, there has been considerable work dedicated to demand aspects of assortment planning (see Kök et al., 2008, for a literature review). However, very little research has been done that integrally considers demand and supply/manufacturing aspects in planning product assortments. This paper proposes an objective decision support modeling framework for configuration assortment planning for individual automotive products by exploiting exogenous demand models. Moreover, and to the best of our knowledge, this is the first work on product assortment planning that takes environmental issues into consideration. The rest of the paper is organized as follows: Section 2 reviews the relevant literature; Section 3 discusses the problem setting in more detail and the main assumptions behind our model. Methodology and problem formulation are discussed in Section 4. Section 5 reports the results from a number of experiments. Finally, we conclude and identify directions for further research in Section 6.

2. Literature review

van Ryzin and Mahajan (1999) were the first to study assortment planning and inventory decisions by using a multinomial logit (MNL) model of consumer choice. They assume that each product variant carried in the assortment has an identical unit cost and is offered at an identical price. Later, Mahajan and van Ryzin (2001) study the same problem with substitution under stock-outs. Smith and Agrawal (2000) study assortment planning problem with the exogenous demand model by solving an inventory optimization problem that selects both items to stock and the stock levels for each item in the assortment. Kök and Fisher (2007) solve an assortment planning problem with exogenous demand. They formulate their problem in the context of a supermarket chain and offer a procedure for estimating the parameters of substitution behavior and demand for the stores' products. They also propose a heuristic to solve the assortment planning and inventory problem with one-level stock-out-based substitution in the presence of shelf-space constraints. Honhon et al. (2009) propose an algorithm to determine the optimal assortment and inventory levels under stock-out-based substitution for a single-period problem assuming that each customer type has a specific preference ordering amongst products and chooses the product with the highest rank according to his type (if any), which is available at the time of purchase. None of these models accounts for environmental considerations, and their treatment of manufacturing/supply complexity is limited. In many industries (including auto-industry), there is an increasing awareness toward addressing environmental issues in their products as well as the processes (see Transportation Research Board-National Research Council, 1997; Sutherland et al., 2004). Goldberg (1998) studies the effects of CAFE standards on automobile prices and sales and the expected environmental effects of CAFE standards. He claims that policies oriented toward shifting the mixture of the new car fleet to more fuel-efficient vehicles are promising, and CAFE provides incentives for OEMs to develop more fuel-efficient vehicles. Maclean and Lave (2000) study the environmental implications of alternative-fueled automobiles with respect to air quality and greenhouse gas trade-offs. They analyze different fuel-powertrain options and estimate fuel efficiency, energy use, pollutant discharge, and greenhouse gas emissions for internal combustion engine automobiles and show that compressed natural gas (CNG) vehicles are giving the best exhaust emission performance while direct injected diesels had the worst. On the other hand, greenhouse gases can be reduced with direct injected diesels and direct injected CNG compared to a conventional fueled automobile. Michalek et al. (2004) study the impact of fuel efficiency and emission policy on optimal vehicle design decisions in an oligopoly market. They evaluate several policy scenarios for the small car market, including CAFE standards, carbon dioxide (CO_2) emissions taxes, and diesel technology quotas. The results show that imposing CO_2 taxes on producers for expected life-cycle emissions results in diminishing returns on fuel efficiency improvement as the taxes increase, while CAFE standards lead to higher average fuel efficiency per regulatory dollar. Although their model decides on design parameters (such as engine size), prices, and production volumes, it is different from our approach on assortment planning by considering no substitution effects. Recently, Hoen et al. (2010) study the effect of carbon emission regulations on transport mode selection in supply chains. Although they study a different sector, their results suggest that introducing a constraint on emissions is a more powerful tool for policymakers in reducing emissions compared to introducing an emission cost for freight transport via a direct emission tax or a market mechanism. In this paper, similar to results of Hoen et al. (2010), we too conduct experiments constraining the average emissions allowed by the OEM during product use rather than introducing an emissions cost.

3. Assumptions

Suppose that for the product under consideration, $N = \{1, \ldots, I\}$ denotes the set of potential configurations that can be made available by the OEM. Assortment planning involves selecting a

Download English Version:

https://daneshyari.com/en/article/8106538

Download Persian Version:

https://daneshyari.com/article/8106538

Daneshyari.com