Product Redesign Decisions: Adding Hedonic, Utilitarian or Both Features?

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ABSTRACT

Product redesign, which may help correct design faults, improve quality, and reduce cost, is an important decision when a firm intends to extend product life and revenue streams. We investigate joint decisions of product redesign and marketing when a single firm thinks it is time to redesign. The firm can improve the product appeal by adding hedonic and/or utilitarian features onto the current product. We use an analytical model to derive the optimal solutions for three strategies: hedonic-only, utilitarian-only, and both hedonic-utilitarian. We are able to identify the concavity condition for the objective function and methods to find the optimal solutions when interior optimal does not exist. We find that the optimal decision hinges on five factors: profit margins, design costs, marketing effectiveness, demand expansion of added features, and feature level thresholds. In the analytical form, no dominant strategy can be derived. We utilize numerical examples to highlight the situations where each of hedonic-only, utilitarian-only, and both hedonic-utilitarian strategies can be optimal. In the both-hedonic-and-utilitarian strategy, its optimal levels of hedonic and utilitarian features are higher than those obtained in the hedonic-only and utilitarian-only strategies. The optimal marketing effort for the both-hedonic-and-utilitarian strategy is also highest among three redesign strategies. Although the both hedonic-utilitarian strategy may involve more marketing expenses, adding both hedonic and utilitarian is not always optimal.
SUMMARY

Past research has looked at number of functions integrated into fusion products (Chen, et al. 2010) but has not considered the features themselves in terms of their utilitarian or hedonic value. These two perceptions are important for consumer evaluations. While consumers can distinguish products along the hedonic and utilitarian dimension (Batra and Ahtola, 1990), hedonic attributes tend to explain consumer choices better (Bohm and Pfister, 1996; Dhar and Wertenbroch, 2000; Heath and Soll, 1996; Shafir, Simonson, and Tversky, 1993). The redesign issues of adding features – hedonic and/or utilitarian – have implications not only for design engineering but also for market appeal as well as marketing costs.

These considerations are incorporated in this research to investigate the optimal design and marketing decisions for product redesign. Using two analytical models – base and advanced – we analyze the impact of adding hedonic or utilitarian attributes into an existing product through three strategies - hedonic only, utilitarian only and both hedonic-and-utilitarian feature. Through our analysis, we identify five groups of parameters critical to the optimal redesign strategy: product profit margins, design cost functions, marketing effectiveness, new feature attractiveness, and the minimal acceptable levels of added features. By including both design engineering and marketing issues, our approach is able to provide managerial insights into those conditions that favor an optimal solution.

Keywords: product redesign, hedonic, utilitarian, marketing effort
INTRODUCTION

For companies that target end users, successful new product designs like iPhone, iPad and Netflix are hard to achieve. As a result, companies often rely on product redesign instead of a new design from scratch. The reasons for product redesign include correcting design faults, improving quality, cost reduction, environmental changes, and extending product life and revenue streams (Smith, Smith, and Shen, 2012; Pnueli and Zussman, 1997). For electronic technologies that have made dramatic advances in recent years, improving product design can be more easily achieved by adding new features and functions (Goldenberg, Levav, and Mazursky, 2003; Mukherjee and Hoyer, 2001).

For a variety of reasons, consumers appear to respond favorably to these changes in product design improvements. Feature-richness, in terms of added features, appears to be positively related to consumer perception of product functionality and capability (Thompson, Hamilton, and Rust, 2005). Each added feature enhances the reasons for purchasing a product (Brown and Carpenter, 2000). It is theorized that pre-purchase evaluations focus on abstract attributes or benefits and consumers emphasize product capability more, which is positively related to number of attributes (Thompson et al., 2005). Choices that are publicly visible appear to trigger self-impression management cues and consumers are more likely to favor feature-rich options because they are positively related to the derived ‘social utility’ or ‘other people’s reactions and appreciation of a consumer’s private utility (Thompson and Norton, 2011).

There are some negative consequences to adding features. Product complexity increases and detracts from product usability (The Economist, 2009). Motorola, for instance, took out ‘unused’ features in their new Moto X smartphones (Melendez, 2013). As a result, when consumers use multi-function products or are primed to think about usability, their evaluation of
feature-rich products decline (Thompson et al., 2005). As Goodman and Irmak (2013) argue, consumers tend to underestimate the ‘learning costs at the time of purchase and fail to take usability factors into account’ (p.94).

In addition to adding features, product improvement through redesign has to consider two categories of features, hedonic and utilitarian. Hedonic features address fun, pleasure, and excitement that consumers feel during the experience (e.g., luxury smartphone cover, acceleration of a sports car, 3D movies – Voss, Spangenberg and Grohmann, 2003). Utilitarian features focus primarily on instrumental and functional utility enhancements (Dhar and Wertenbroch, 2000). A product can contain both hedonic and utilitarian features. Apple’s iPhone is a successful example. When iPhone first entered into the smartphone market, it was equipped with utilitarian features to match other smartphones: multitasking, document processing, email, web browsing, etc. However, iPhone’s unique and smooth touch screen interface (larger screen, sleek touch-gliding control interface) brought a whole new hedonic experience to using the smartphone. Furthermore, supported by the open iOS platform, multimedia and numerous applications, the iPhone expanded the possibilities of ‘traditional’ and ‘utilitarian’ smartphones.

Michalek, Feinberg, and Papalambros (2005) point out that isolating engineering design and marketing issues will not typically result in optimal decisions because the two problems are interrelated. In this paper, we explore joint decisions of product redesign and marketing when a single firm thinks it is time to redesign. What features should the redesign add onto the current product? Hedonic? Utilitarian? Or both? Should the firm add a high or low level of hedonic (and/or utilitarian) feature? What is the optimal redesign strategy and how much marketing effort
should a firm invest on the redesigned product? What are the optimal conditions of each redesign strategies?

First we review the literature from the operations research and marketing disciplines and build an analytical model that captures the relationships between design cost, marketing cost, product features, and their impact on profit. The optimal solutions from the analytical model are evaluated. Next, numerical analysis is conducted for different scenarios likely to exist in the market place. The paper ends with a discussion of the results and suggestions for future research.

LITERATURE REVIEW

From a marketing perspective, product redesign has to consider several issues in order to forecast and achieve revenues and profits. The redesign issues of adding features and what type of feature – hedonic and/or utilitarian – have implications for market appeal as well as marketing costs. In general, consumers appear to prefer products with more features to products with fewer features and the specific features do not appear to matter (Goodman and Irmak, 2013; Thompson et al., 2005; Thompson and Norton, 2011). Each added feature enhances the reasons for purchasing a product (Brown and Carpenter, 2000) and these reasons become particularly salient when the consumer focuses on pre-purchase evaluation and in a public setting (Thompson and Norton, 2011). This preference is observed because of ‘social utility’ gained from the positive consumer image associated with ‘having’ such a product. Post-purchase behaviors, however, indicate limited use of the multiple functionalities in a feature rich product (The Economist, 2009).
Research seems to indicate a trend towards hedonic attributes. While consumers are able to distinguish products according to their relative combination of hedonic and utilitarian dimensions (Batra and Ahtola, 1990), consumers tend to choose expensive products based on hedonic reasons but justify their purchases in terms of utilitarian value (Heath and Soll, 1996). Hedonic attributes/reasons dominate when justifications are either not necessary or when it is spontaneous (Bohm and Pfister, 1996; Dhar and Wertenbroch, 2000; Shafir, Simonson, and Tversky, 1993). Pullman and Gross (2004) explored the relationship between different hedonic design elements, customer’s emotional experience and the loyalty in service environment. They found the loyalty behavior of consumer is strongly mediated by eliciting certain basic emotional behavior.

Furthermore, integration of multiple perspectives contributes methodological richness as well. Aesthetic and usability attributes that constitute experience criteria are obtained from qualitative methodologies while price and other more ‘objective’ attributes are obtained from quantitative methodologies (Srinivasan, Lovejoy, and Beach, 1997). Marketing research often utilize conjoint analysis and multidimensional scaling (MDS) to identify consumer preferences and market segments and recommend best combinations of attributes to be included in product/service design. Verma, Thompson, Moore, and Louviere (2001) point out that one of the major drawbacks of market based design procedure is lack of consideration of operational constraints.

Firms that have a competitive edge in product design can leverage that asset further if the firms also have an understanding of market needs. Michalek et al. (2005) propose an ATC (Analytical Target Cascading) methodology that links the subproblems of marketing and design engineering formally while each discipline remains independent. ATC not merely facilitates
communications between two departments, it also helps marketers confront design or production issues and guide designers to conceptualize how features satisfy customers. In addition, joint marketing and design methodology like ATC reduces time-consuming iterations in product design and renders precious time to market. Gupta and Samuel (2001) provide a systematic approach integrating marketing and product development process.

In an analysis of PDA industry, Bayus, Jain and Rao (1997) report that product introduction times are associated with different marketing strategies and the products incorporate different attribute bundles. In the operational side, the modularity in product design provides synergy and cost savings in production (Morgan, Daniels, and Kouvelis, 2001). The trend of modularity in product design has significant impact on product manufacturability, flexibility in customized design, time to market, multifunction product proliferation, and product differentiation (Chen, Carrillo, Vakharia, and Sin, 2010; Newcomb, Bras and Rosen 1996; Gershenson, Prasad, and Allamneni, 1999).

In this research, we investigate the optimal design and marketing decisions for product redesign. Specifically we examine how adding features – hedonic, utilitarian or both – affect the profit function. Our model and numerical analysis are based on the evidence generated by literature from both the operations and marketing perspectives which suggests the following:

a. A product with more features will be preferred by consumers over a product with fewer features (Brown and Carpenter, 2000; Goodman and Irmak, 2013; Thompson, et al., 2005; Thompson and Norton 2011). This implies marketing efficiency will be higher for a product with more features.

b. A product with an added hedonic feature will be preferred by consumers over a product with an added utilitarian feature (Heath and Soll 1996; Bohm and Pfister 1996; Dhar and
Wertenbroch 2000; Shafir et al. 1993). This implies that marketing efficiency will be higher for a product with an added hedonic feature.

c. Any added feature must exceed a threshold level for it to be recognized by a consumer but exceeding the threshold has a different impact if it is a hedonic rather than a utilitarian attribute (Chitturi, Raghunathan, and Mahajan, 2008). Specifically, exceeding a hedonic expectation evokes delight, not just satisfaction, and is likely to be rewarded more in terms of consumer acceptance.

d. Design costs will increase with the number of features but not with the type of feature (hedonic or utilitarian). The design costs are assumed to increase at an increasing rate along its feature level, which shows the challenge of improving quality and is consistent with previous research (Roemer, Ahmadi, and Wang, 2000).

Supported by these findings, our research investigates the optimal design and marketing decisions for product redesign in terms of hedonic and utilitarian attributes.

ANALYSIS

In this part, we construct two models to capture the product design and marketing problem of our interest. First, we propose a base model that represents the firm’s past and current condition. With given technology that allows the firm to provide a base product with basic functionality, the market demand responds to the company’s marketing effort at a known price level. The firm’s objective is to find the marketing effort that maximizes its profit. Later, in the advanced model, we assume that the firm can redesign its base product into a hedonic and/or utilitarian focused product. We allow the firm to add hedonic/utilitarian feature levels onto the product with basic functionality. We are interested in the conditions that lead the firm to choose hedonic and/or
utilitarian redesign strategy as well as the optimal results of the redesign decision. Note that we do not consider competition from other firms and implicitly assume other conditions are reflected in the price and cost parameters. Also, we assume that the firm will consider launching one product instead of multiple variants of product. Launching multiple variants of product needs better understanding of substitution effects among all variants in the market demand (Chen et al., 2010). We do not consider this in our current model.

**Base Model - Before Redesign**

We assume that there exists a market for the product of our interest and a firm can offer a base product to satisfy the demand. The product’s design has been realized with basic functionality and is fixed. It does not mean the base product does not contain any hedonic or utilitarian feature. Instead, whatever hedonic and/or utilitarian features are included in the current base product, it is a decision the firm made when that product was first designed and the market has accepted it as a basic model.

We assume that the firm’s sales depend on how much effort is allocated to the marketing of the product. Under the current market conditions, the consumers will be willing to buy the product at price $p_B$. We assume that the variable cost is $v$ per unit for the firm given the basic model. Each unit has a profit margin of $p_B - v$, which is denoted as $\delta_B$. Without considering a redesigned product with improved quality, the firm’s decision is to determine how much marketing effort ($m$) to spend. We assume that the cost of marketing effort is $c_B m^2$, which means the marketing effort has a decreasing return. Table 1 contains a variable list used in this paper.

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Insert Table 1 here
To calculate the profit function of this model, we derive it as \( \pi = m(p_B - v) - c_B m^2 \). Given this profit function, we can derive that the optimal solution as below:

\[
\max_m \pi = m(p_B - v) - c_B m^2
\]

\[
\frac{\partial \pi}{\partial m} = (p_B - v) - 2c_B m, \quad \frac{\partial^2 \pi}{\partial m^2} = -2c_B,
\]

In this strategy, the profit function \( \pi \) is strictly concave in the decision variable, \( m \). The optimal marketing effort is \( m^* = \frac{p_B - v}{2c_B} \) can be obtained by solving the equation which sets the first order condition as zero. Since each unit of market effort is equivalent to one unit of demand, the market demand will be \( \frac{p_B - v}{2c_B} \). Substitute \( m^* \) back to the profit function, the total profit at this optimal solution is

\[
\pi_B^* = \left( \frac{p_B - v}{2c_B} \right)^2 = \frac{\delta_B^2}{4c_B}.
\]

**Advanced Model - Hedonic/Utilitarian Redesign Model**

Assume that the firm considers redesigning its product by adding hedonic and/or utilitarian features on top of the base product. We assume that hedonic and utilitarian are two independent features besides the basic functionality. A hedonic feature focuses on experiential, fun, exciting and aesthetic benefits of the product. A utilitarian feature focuses on instrumental and practical benefits that integrate intuitively with the functionality of the product (Noseworthy and Trudel, 2011; Dhar and Wertenbroch, 2000). For example, in the market of high-definition TV sets, a basic LCD TV (e.g., Toshiba 32C120U) can be viewed as a base product, a 3D embedded HDTV (Panasonic VIERA TC-P50ST50) can be viewed as a hedonic-feature added product, and a Wi-Fi built in Internet-Ready HDTV (e.g., Samsung UN55ES6100) as a utilitarian-feature added
product. Note that hedonic and utilitarian features can coexist in one product. For example, LG 55LM6200 HDTV (3D, Wi-Fi and Internet built in) and Apple’s iPhone 5S are products with both hedonic and utilitarian features.

The added hedonic or utilitarian attribute needs to be integrated with the basic product. The design costs for integrating hedonic and utilitarian features are $d_h h^2$ and $d_u u^2$, respectively. Decision variables $h$ and $u$ are constrained within $[0, \bar{h}]$ and $[0, \bar{u}]$, respectively, where $\bar{h}$ and $\bar{u}$ represents the highest levels of hedonic and utilitarian features under current technology development. The design costs are assumed to increase at an increasing rate along its feature level, which shows the challenge of improving quality and is consistent with previous research (Roemer et al., 2000). The unit variable costs associated with hedonic and utilitarian features are $v_h$ and $v_u$, respectively. To simplify the problem, we assume that $v_h$ is invariable of $h$ and $v_u$ is invariable of $u$.

As the firm adds hedonic and utilitarian features on the base product, its pricing power often increases as consumer preference is more favorable for feature-rich products (Thompson et al., 2005; Thompson and Norton, 2011). A 3D- or Internet-embedded HDTV is often sold at a higher price. We assume product price $p_{HU}$ for the product that adds both hedonic and utilitarian features. It implicitly reflects the pricing power given the added features and market conditions; hence, it is not a decision variable. However, the unit profit margin (price minus all variable costs) of a redesigned product can be either higher or lower than that of the original product. The profit margin is $\delta_{HU} = (p - v - v_h - v_u)$ in this case.

We assume that both hedonic and utilitarian features will increase demand for the product and the increased marketing efficiency is proportional to the add-on features. We assume that the different effectiveness of hedonic and utilitarian attributes is reflected in the market expansion
coefficients $k_h$ and $k_u$, respectively. Noseworthy and Trudel (2011) found that consumers appreciate a hedonic feature only if the functionality of the product meets their expectations. Chitturi et al. (2008) propose that exceeding a utilitarian expectation merely evokes satisfaction while exceeding a hedonic expectation evokes delight. Due to this, we assume a threshold hedonic level, $h_0$, and a threshold utilitarian level, $u_0$. Hence, the utilitarian and hedonic features will increase the demand by $mk_h(h - h_0)$ and $mk_u(u - u_0)$, respectively. If the added features fail to reach this threshold, then it will negatively impact on demand. In the real world, the values of $k_h$ and $k_u$ are correlated to the added hedonic and utilitarian feature and the product price.

In this redesign model, the firm has three decisions to make. First, the firm determines whether they should add hedonic ($h$) and utilitarian ($u$) features. To simplify the model, we assume these two features are independent from each other and are independent from the basic product too. Second, as the redesigned product is new to the market, the firm needs to decide its level of marketing effort. The market size is positively related to its marketing effort ($m$). Note that we assume $1 > k_h h + k_u u$, to avoid a trivial (and unlikely) situation that the whole demand will vanish when the firm adds just very low levels of hedonic and utilitarian features. However, because the redesigned product is different from the base product, the effectiveness of marketing effort is different too. We assume that the marketing cost coefficient is $c_R$ in the redesigned product and the total marketing investment is $c_R m^2$. As a result, the objective function of the redesign model is

$$\pi = m[1 + k_h (h - h_0) + k_u (u - u_0)]\delta_{HU} - d_h h^2 - d_u u^2 - c_R m^2.$$  

To fully investigate the company’s actions, we consider three strategies: (1) both hedonic and utilitarian features, (2) hedonic feature only, and (3) utilitarian feature only.
Both hedonic and utilitarian features

When the firm decides to add both hedonic and utilitarian features, the objective function is

$$\max_{m, h, u} \pi = m[1 + k_h(h - h_0) + k_u(u - u_0)]\delta_{hu} - d_hh^2 - d_uu^2 - c_Rm^2.$$

The first term represents the profit margin from the market demand. The second, third, and fourth terms are the hedonic design cost, utilitarian design cost, and marketing cost, respectively. We then take the derivatives of the objective function as follows.

$$\frac{\partial \pi}{\partial m} = \delta_{hu}[k_h(h - h_0) + k_u(u - u_0) + 1] - 2c_Rm, \quad \frac{\partial \pi}{\partial h} = k_hm\delta_{hu} - 2d_hh,$n
$$\frac{\partial \pi}{\partial u} = k_um\delta_{hu} - 2d_uu, \quad \frac{\partial^2 \pi}{\partial m^2} = -2c_R, \quad \frac{\partial^2 \pi}{\partial h^2} = -2d_h, \quad \frac{\partial^2 \pi}{\partial u^2} = -2d_u,$$

$$\frac{\partial^2 \pi}{\partial h \partial m} = k_h\delta_{hu}, \quad \frac{\partial^2 \pi}{\partial u \partial m} = k_u\delta_{hu}, \quad \frac{\partial^2 \pi}{\partial u \partial h} = 0.$$

$$H_3 = -8c_Rd_hd_u + 2(d_hk_h^2 + d_uk_u^2)\delta_{hu}^2.$$

The objective function will be strictly concave in $m$, $h$, and $u$ if and only if

$$-\frac{H_3}{2} = 4c_Rd_hd_u - (d_hk_h^2 + d_uk_u^2)\delta_{hu}^2 > 0.$$

When $4c_Rd_hd_u - (d_hk_h^2 + d_uk_u^2)\delta_{hu}^2 > 0$, the optimal solution will be

$$\left(h^*, u^*, m^*\right) = \left(\frac{d_hk_h(1 - h_0k_h - u_0k_u)\delta_{hu}^2}{(-H_3/2)}, \frac{d_uk_u(1 - h_0k_h - u_0k_u)\delta_{hu}^2}{(-H_3/2)}, \frac{2d_hd_u(1 - h_0k_h - u_0k_u)\delta_{hu}^2}{(-H_3/2)}\right).$$

If $h^* < h$ and $u^* < u$, in this case, the market demand will be

$$m^*(k_h(h^* - h_0) + k_u(u^* - u_0) + 1),$$

which is equivalent to

$$\frac{8c_Rd_h^2d_u^2(1 - h_0k_h - u_0k_u)^2\delta_{hu}^2}{(-H_3/2)^2},$$

and the profit will be

$$\pi_{hu}^* = \frac{d_hd_u(1 - h_0k_h - u_0k_u)^2\delta_{hu}^2}{(-H_3/2)^2}.$$
From the analysis above, we can find the optimal solution and the profit no matter whether the added features are bounded by the maximum upper bounds. We leave the discussion in the section titled as “Optimal Redesign and Concavity Conditions” that there may be two possible conditions where the optimal solution above will not be applicable. In the next parts we examine the firm’s other strategies -- to add only hedonic or utilitarian feature because the pricing powers and the structure of the objective function is different.

**Hedonic feature only**

When the firm chooses to only add a hedonic feature, the objective function becomes

\[
\max_{h,m} \pi = m[1 + k_h(h - h_0)](p_H - v - v_h) - d_h h^2 - c_R m^2.
\]

Let profit margin \( \delta_H \) to be \( p_H - v - v_h \), then we can take derivatives of the objective function.

\[
\frac{\partial \pi}{\partial m} = \delta_H [k_h(h - h_0) + 1] - 2c_R h,
\]

\[
\frac{\partial^2 \pi}{\partial m^2} = -2c_R,
\]

\[
\frac{\partial \pi}{\partial h} = k_h \delta_H - 2d_h h,
\]

\[
\frac{\partial^2 \pi}{\partial h \partial m} = k_h \delta_H.
\]

\[
[H_2] = 4c_R d_h - k_h^2 \delta_H^2
\]

The objective function will be strictly concave in \( m \) and \( h \) if and only if \( 4c_R d_h - k_h^2 \delta_H^2 > 0 \).

When \( 4c_R d_h - k_h^2 \delta_H^2 > 0 \), the optimal solution will be

\[
(h^*, m^*) = \left( \frac{k_h(1 - k_h h_0) \delta_H^2}{4c_R d_h - k_h^2 \delta_H^2}, \frac{2d_h (1 - k_h h_0) \delta_H}{4c_R d_h - k_h^2 \delta_H^2} \right).
\]

Under this condition the market demand will be

\[
m^* [k_h(h^* - h_0) + 1],
\]

which is equivalent to \( \frac{8c_R d_h (1 - k_h h_0)^2 \delta_H}{[4c_R d_h - k_h^2 \delta_H^2]^2} \), and the profit will be

\[
\pi^*_H = \frac{d_h (1 - k_h h_0)^2 \delta_H^2}{4c_R d_h - k_h^2 \delta_H^2}.
\]
If \( 4c_Rd_h - k^2_H \delta^2_H > 0 \) holds, but the optimal hedonic level exceeds its upper bound, then the re-optimization process will be similar to that in the previous section to obtain the optimal solution. Again, we omit further discussion when \( 4c_Rd_h - k^2_H \delta^2_H \leq 0 \) because optimal unbounded solution is unlikely to occur in the real world.

**Utilitarian feature only**

When the firm chooses to only add a utilitarian feature, the objective function becomes

\[
\max_{u, m} \pi = m[1 + k_u(u - u_0)](p - v - v_u) - d_u u^2 - c_R m^2 , \text{ where we substitute } p_U - v - v_u \text{ with } \delta_U .
\]

Since the utilitarian feature has a similar structure in the objective function as the hedonic feature in our model, we skip the algebra and show the results of all three redesign strategies in Table 2. Note that the objective function in this strategy will be strictly concave in \( m \) and \( u \) if and only if

\[
4c_Rd_u - k^2_u \delta^2_U > 0.
\]

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Insert Table 2 here

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**Optimal Redesign and Concavity Conditions**

In this part we discuss the firm’s optimal redesign strategy for two situations. First, we provide detailed optimal solution and conduct sensitivity analysis when the strict concavity of the objective function holds and the optimal solution does not exceed the upper bounds. Second, we provide the process to find the optimal solution when the strict concavity of the objective function is violated or the optimal solution exceeds the upper bounds.
**Strict concavity condition holds and no boundary solution**

Table 2 above summarizes and compares the optimal solutions for four strategies – three redesign and the base -- through some algebraic operations when the objective functions are strictly concave and the optimal solution does not exceed the upper bounds. The algebraic operations help understand the sensitivity analysis later on.

From Table 2, we find that the optimal redesign strategy for the firm depends on several groups of variables: profit margins ($\delta$), design costs factors ($d$), marketing effectiveness ($c$), demand expansion of added features ($k$), and feature level thresholds that the aggregate demand starts to appreciate the added features ($h_0$ and $u_0$). We conduct sensitivity analysis of these parameters on the optimal solution when the strict concavity conditions hold for all redesigned strategies and summarize the results in Table 3.

The sensitivity analysis (Table 3) indicates a higher profit margin is associated with higher optimal market demand and higher level of hedonic and/or utilitarian features. As a result, a firm will generate a larger unit demand and a higher total profit when the redesigned product has a higher unit profit margin. The marketing and design cost parameters ($d$ and $c$) have the opposite effects. When the marketing cost parameter is higher, it negatively impacts on the optimal marketing efforts as well as the optimal level of hedonic and utilitarian features that should be added. Similarly, when the design cost parameter of hedonic (utilitarian) feature is higher, it not only negatively impacts on the optimal hedonic (utilitarian) level but also on the optimal utilitarian (hedonic) level and the marketing effort. Not surprisingly, if the consumers have higher threshold for added hedonic ($h_0$) or utilitarian ($u_0$) feature, then the optimal
marketing effort, optimal hedonic and utilitarian levels will be smaller, which leads a smaller demand and profit. Based on the analytical result, the influence of the demand expansion parameters \((k)\) is uncertain and can go either way due to its complicated interaction with other parameters.

\[\text{Strict concavity condition is violated or the optimal solution is on boundary}\]

When the strict concavity of the objective function is violated or the optimal solution exceeds the upper bounds, the optimal solutions provided in Table 2 would not apply. Under these circumstances, we have to use different approaches.

First, when the strictly concavity condition holds but at least one of the optimal solutions exceeds its upper bounds, we need to re-optimize a modified problem objective function. Let us use one example to explain the approach. Assume \(4c_Rd^*_u d^*_a - (d^*_a k_h^2 + d_h^a k_u^2)\delta_{HU}^2 > 0\) holds but \(h^*>\overline{h}\), we then substitute the decision variable \(h\) in the objective function with \(\overline{h}\), and find the optimal solution with a modified objective function:

\[
\max \pi = m[1 + k_u(\overline{h} - h_0) + k_u(u - u_0)](p_{HU} - v - v_h - v_u) - d_h\bar{h}^2 - d_u u^2 - c_R m^2
\]

In the modified problem, there are only two decision variables -- \(u\) and \(m\). The decision maker will obtain \((u^*, m^*) = \left( \frac{k_u(1 + k_u(\overline{h} - h_0) - u_0 k_u)\delta_{HU}^2 / d_u}{4c_R - (k_u^2 / d_u)\delta_{HU}^2}, \frac{2(1 + k_u(\overline{h} - h_0) - u_0 k_u)\delta_{HU}^2}{4c_R - (k_u^2 / d_u)\delta_{HU}^2} \right) \) given that the strictly concavity condition hold (i.e., the concavity condition in the original problem \(4c_R d^*_u d^*_a - (d^*_a k_h^2 + d_h^a k_u^2)\delta_{HU}^2 > 0\) implies \(4c_R d^*_a - k_u^2 \delta_{HU}^2 > 0\), which is the concavity condition in the revised problem). Note that the newly obtained \(u^*\) is larger than that old \(u^*\) in the original
problem. If $u^* < \bar{u}$ in this case, then the revised optimal solution for the HU strategy will be $(\bar{h}, u^*, m^*)$. If $u^* > \bar{u}$, then we substitute the decision variable $u$ in the objective function with $\bar{u}$, and find the optimal solution with a modified objective function

$$\max_{m} \pi = m[1 + k_h(\bar{h} - h_0) + k_u(\bar{u} - u_0)](p_{HU} - v - v_{h} - v_{u}) - d_h\bar{h}^2 - d_u\bar{u}^2 - c_R m^2$$

This modified problem is strictly concave in $m$; hence, the optimal market demand in this problem will be $m^* = \frac{\delta_{HU} [1 + k_h(\bar{h} - h_0) + k_u(\bar{u} - u_0)]}{2c_R}$. This approach also applies to the hedonic-only or utilitarian-only problem when the strict concavity condition holds but the optimal feature level exceeds the upper bound.

Second, if the strict concavity condition is violated, the objective function becomes unbounded along at least one decision variable. This situation arises in a joint combination when (i) the design or marketing cost parameters are relatively small, (ii) adding features cause a substantial increase in the profit margin, and (iii) adding hedonic and/or utilitarian features attracts a large extra demand (e.g., large $k_h$ or $k_u$). This situation implies that the firm can always increase the level of hedonic or utilitarian feature (or both) and it becomes more profitable. Eventually at least one of the upper bounds, $\bar{h}$ or $\bar{u}$, will constrains the objective function. In the real world, this situation is very unlikely to occur. If it does, the way to find the optimal solution is guaranteed through a full range search of the entire feasible region, which is $[0, \bar{h}] \times [0, \bar{u}]$.

From the discussion above, we can find the optimal solutions for Hedonic-only, Utilitarian-only and both Hedonic-Utilitarian strategies, respectively. To find the optimal strategy, the firm just needs to compare the three strategies together and find the global optimal solution that has the maximal profit. Since the objective functions of three strategies are
independent from one another, there is no rule of thumb that can identify the optimal redesign strategy. In the next section, we use numerical examples to demonstrate the dynamics of our product redesign problem.

**Numerical Analysis**

We propose a before-redesign strategy as follows: \( p = 40 \), \( v = 20 \), and \( c_a = 2.5 \). According to the analytical results, we can derive the optimal market demand to be \( 4 \left( \frac{40 - 20}{2 \times 2.5} \right) \) units and the profit will be \( 4 \left( \frac{40 - 20}{2 \times 2.5} \right)^2 \) or \( 4 \left( \frac{40 - 20}{2 \times 2.5} \right)^2 \). Under this before-redesign strategy, the unit profit margin is \( 40-20=20 \) and the total marketing cost is \( 2.5 \times 4^2 = 40 \). When a firm considers redesigning a product, it implies that the current profit has been harvested. Hence the analysis above is a realized event.

Now the firm plans to add hedonic and/or utilitarian onto the base product to generate more profit. We set the baseline case (Case [0]) with the following parameter values: (1) \( \delta_{HU} = \delta_H = \delta_U = 20 \), (2) \( c_R = 3 \), (3) \( h_0 = u_0 = 1 \), (4) \( d_h = 3 \), \( d_u = 2.5 \) (5) \( k_h = k_u = 0.15 \) and (6) \( \bar{h} = \bar{u} = 10 \).

- Part (1) shows that all redesigned products have the same profit margin as the base product. We assume that a redesigned product has a new product positioning in the market, which takes more effort to persuade the same number of buyers;
- in part (2), the marketing cost coefficient \( c_R \) is assumed to be higher than that for the base product. Though each unit of marketing effort costs more, the marketing efforts and the realized demand is not at one to one ratio. In the redesign model, the realized demand can be \( m[1 + k_h(h-h_0)] \), \( m[1 + k_u(u-u_0)] \), and \( m[1 + k_h(h-h_0) + k_u(u-u_0)] \) for hedonic-only (subscripted with H), utilitarian-only (subscripted with U), and both hedonic-
utilitarian (subscripted with HU) redesign strategy. As long as the added hedonic or utilitarian feature exceeds consumer’s expectation (with thresholds of $h_0$ and $u_0$), each unit of marketing effort will generate more than 1 unit of demand.

- We assume that the thresholds of hedonic and utilitarian features are both 1 in part (3).
- In part (4), to avoid symmetric results, we made the hedonic feature to be slightly more expensive to design than the utilitarian feature. Later, we change the design cost parameters to see its impacts.
- In part (5), for the baseline case, we assume that both hedonic and utilitarian has the same demand expansion effect. We test this assumption in our numerical examples by changing parameter values in $k_h$ and $k_u$.
- Finally, we assume that, under current technology, the maximal values of hedonic and utilitarian are the same as 10, which is shown in part (6).

The results of the three strategies (H, U or HU) are presented in Table 4. Note that the baseline case we select here is sensitive to parameter value changes in order to show the dynamics and the complexity of this problem. Hence, the magnitudes of the results we conduct below should not be taken nominally.

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Insert Table 4 here

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In Table 5, we conduct several runs (with three cases in each run) of sensitivity analysis. In each run, we compare the optimal solutions from three cases, which differ only in one parameter while other parameters remain the same. The case shown in the middle column in Table 5 is always the baseline case. In the first run, we change the marketing cost coefficient ($c_R$
from a low of 2 (Case 1) to a high of 4 (Case 2). Figure 1 shows the dominance regions of three strategies of the baseline case in a feasible area of $[0,\tilde{h}] \times [0,\tilde{u}]$ while the marketing effort for three strategies are optimized based on the corresponding hedonic and/or utilitarian levels. It shows that the optimal solution is located at the black dot in Strategy HU region, which is medium gray in color. The double star in the superscript indicates that the black dot ($h^* = 2.59, u^* = 3.11$ with implicit $m^* = 5.19$) is the global optimum in this case. The dashed lines in Strategies H’s and U’s dominant region represent their correspondent local optimums, of which $h^* = 1.89$ with implicit $m^* = 3.78$ is the maximum for Strategy H and $u^* = 2.43$ with implicit $m^* = 4.05$ is the maximum for Strategy U. The dominance regions of strategies H and U are represented in dark gray and light gray. The white region in the top right corner suggests that the firm will not make a profit in product redesign at the corresponding hedonic and utilitarian levels no matter how much marketing effort they invest.

---

Insert Table 5 and Figure 1 here

---

Figure 2 shows the dynamics when we change the value of $c_R$. As the marketing cost becomes cheaper ($c_R = 2$), it benefits all strategies with the most positive influence on Strategy HU. We can see the dominant region of Strategy HU expands significantly in Case 2.1 of Figure 2. However, when $c_R = 4$, which means it is more difficult or more expensive to market the redesigned product to consumers, Strategy HU also has the greatest disadvantage from increasing marketing cost (Case 2.2). Under this circumstance, the utilitarian-only redesign becomes the optimal strategy for the firm. In Case 2.2 of Figure 2, redesign with both hedonic and utilitarian features (Strategy HU) is never better than hedonic-only or utilitarian-only
strategy. The white area in the top right corner indicates none of the three strategies can make a profit to integrate a high level of hedonic and/or utilitarian features when the marketing cost of the redesigned product is expensive. Obviously, the white area of “no redesign” strategy expands as the marketing cost increases.

Cases 3.1 and 3.2 and Figure 3 reflect the results of changing design cost of the hedonic feature. In the baseline Case 1, the hedonic feature has a slightly higher design cost than the utilitarian feature. When the hedonic feature has the same design cost as the utilitarian feature, the firm should increase the levels of hedonic and utilitarian features while decreasing the marketing efforts (compared to Case 1) and Strategy HU is still the optimal (Case 3.1). If the hedonic feature is even more expensive to design, then Strategy HU becomes suboptimal to Strategy U. In the mid 90’s, WebTV (later called MSNTV) was introduced as a device that connected TV to the Internet. As a hedonic product integrating entertainment and Internet, WebTV failed due to expensive product development cost and immature technology in the 90’s that was unable to realize significant killer-app features to attract enough subscribers.

In the baseline case, we set the hedonic feature as more expensive than the utilitarian feature to design, but the demand expanding capability to be the same for both features (i.e. $k_h = k_u = 0.15$). In Case 4.1 of Figure 4, we further decrease the demand expansion coefficient of
the hedonic feature. It turns out that the Strategy HU becomes worse off and the optimal strategy is Strategy U as hedonic feature is less attractive. If the hedonic feature is desirable and attracts consumers, then Strategy HU is more dominant as shown in Case 4.2 of Figure 4. This strategy is exemplified in the case of cell phones that add the camera feature, if the camera feature is viewed as hedonic. Since a camera phone can replace a single-function digital camera, we see almost all cell phones equipped with camera function in the market. If the hedonic feature is more expensive to design, but the demand reaction is more favorable to the hedonic feature than to the utilitarian feature (like \( k_h = 0.2 \)), then it turns out Strategy H is better than Strategy U and Strategy HU is the optimal strategy. Similar impact of changing value of \( k_u \) can be found in Cases 5.1 and 5.2 of Figure 5.

Cases 6.1 and 6.2 discuss the impact of minimal threshold of consumers for the utilitarian feature. When the threshold is higher (e.g. \( u_0 = 1.5 \) in Case 6.2), it negatively impacts Strategies U and HU. Videotelephony, which provides video and audio communications simultaneously, has been proposed since 1950’s. After 1990’s, the video quality on video-telephone has improved; however, immobility of landline phones significantly decreases its usability and the landline videophone is still not commonly accepted by consumers. Cases 7.1 and 7.2 are related to the profit margin of the redesigned product. If adding hedonic and/or utilitarian feature leads to the same lower profit margin than the original base product and the strategy to add both hedonic-utilitarian has the lowest profit margin, then Strategy HU is worse than the other two strategies. Strategy U is the optimal since adding utilitarian feature has a relatively lower design cost (i.e., case 7.2). However, if adding hedonic and utilitarian feature is associated with the
same higher profit margin than the original base product but the strategy to add both hedonic-utilitarian has the highest profit margin, then Strategy HU outperforms the other two strategies. We see this phenomenon now prevailing in many electronic products (such as smartphones or blue-ray DVD players) that have increased their hedonic as well as utilitarian features.

Comparing the optimal solutions from three strategies in Table 5 lead to following managerial conclusions. First, among the three strategies, a higher marketing effort always generates a higher demand; however, a strategy with the highest marketing effort is not always the global optimal strategy (examples are cases 2.2, 3.2, 4.1, 5.1, 6.2, and 7.2). Second, the optimal marketing effort in the HU strategy will be higher than those in the H and the U strategies, especially when the marketing cost coefficient is cheaper (case 2.1) or when the added hedonic or utilitarian feature can attract more demand (Cases 4.2 and 5.2). This is reasonable because the firm has to address the hedonic as well as the utilitarian feature in the marketing campaign when a new product has both features. Third, in most cases (except case 7.2), the optimal hedonic/utilitarian level in the HU strategy is higher than that in the H/U strategy. We find this condition will most likely hold as long as the profit margin of adding both features is not worse than just adding hedonic or utilitarian feature.

CONCLUSION AND FUTURE RESEARCH

In this paper, we provide a stylized analytical model to reflect the optimal product redesign (hedonic and or/utilitarian) and marketing decisions. Our model captures a firm’s decision to add various levels of utilitarian and/or hedonic features and adjust its marketing effort. At the same time, our model also reflects the changes resulting from product redesign: different product
prices and variable costs, different design costs for hedonic and utilitarian features, different market responses to changes in both features, and the impact on marketing effectiveness. Our analytical results identify the optimal solution and its corresponding conditions when the profit function is strictly concave and the approach to finding the optimal solution when strict concavity is violated.

The numerical analysis demonstrates the impact of parameter changes of any one variable on the optimal redesign strategy (note that we do not exemplify all possible conditions). Through our analysis, we identify five groups of parameters critical to the optimal redesign strategy: product profit margins, design cost functions, marketing effectiveness, new feature attractiveness, and the minimal acceptable levels of added features.

Several managerial insights follow from our analytical and numerical results. First, both-hedonic-and-hedonic strategy has a higher optimal marketing effort than that in the hedonic-only or in the utilitarian-only strategies. Second, in most cases, both-hedonic-and-hedonic strategy also has higher levels of utilitarian and hedonic feature compared to those optimal levels obtained in hedonic-only and utilitarian-only strategies, respectively. Finally, though both-hedonic-and-hedonic strategy tends to have higher optimal added hedonic/utilitarian levels and marketing effort, adding both hedonic and utilitarian is not always optimal. Since the objective functions of three strategies are independent from each other, the firm should find the optimal solutions from all three strategies and select the best.

Product evolution in the real world seems to parallel some of the cases. As we noted above, many electronic products such as smartphones or blue-ray DVD players have been adding hedonic as well as utilitarian features and the market response seems to be favorable. This is consistent with research that shows in general, feature rich products are preferred over feature
poor products and the specific features do not appear to matter (Goodman and Irmak, 2013; Thompson et al., 2005; Thompson and Norton 2011). This preference is observed because of ‘social utility’ gained from the positive consumer image associated with ‘having’ such a product. This suggests that it is likely to be easier (and therefore less costly) to persuade consumers with a feature-rich over a feature-poor product.

The decision to add hedonic or utilitarian feature is also significant. Sometimes it can significantly shift the categorization of products (in iPhone’s instance, from utilitarian to hedonic), and the firm needs to invest in marketing efforts to support the new categorization. The first generation of iPhone has a video commercial that emphasizes the connectedness of iPhone in 30 seconds: from thinking of seafood from viewing Pirates of the Caribbean movie, to searching restaurants nearby, and to making a phone call to the restaurant directly from the iPhone. But not all product redesigns are equally successful; a marketing campaign alone cannot reverse a redesigned product that falls short of consumer’s expectation. Microsoft spent $500 million for marketing Windows Vista in order to replace Windows XP platform (Ratcliffe, 2007). Though Vista addressed utilitarian features like integrated security, parental control and other functions like searching and wireless networking, Vista use led to a slowdown of user’s experiences with tedious processes. PC World rated Windows Vista as the top technology disappointment in 2007 (Tynan, 2007).

In the future, several redesign issues need to be addressed. One issue is regarding the market size of full/fewer featured products. For example, IBM, Sony, BellSouth and Motorola targeted the narrower professional PDA market while Apple, Sharp, Tandy, Casio and Amstrad targeted the larger, more diffused market (Bayus, Jain and Rao, 1997). What market segments should a firm target? How many features should be included in a product for the target segment?
Motorola, for instance, took out ‘unused’ features in their new Moto X smartphones (Melendez, 2013). At the same time, they added hedonic attributes by allowing personalization of phones with color palettes, patterns, and engravings. This should allow Motorola to charge a higher price than if this feature was not available. Future models have to consider a more elaborate cost structure of different advertising and distribution strategies and their impact on profit calculations.

Profit calculations are more realistically based over a product’s life cycle. When the product (base or redesign) relies on repeat purchases to generate revenue, then it is important to consider the design implications of a stream of revenue generated over a period of time. Once touch screen has been integrated into smartphones, each new successive generation of Apple iPhone and Samsung Galaxy has become a showdown of new features between the various brands in a battle to retain old users and gain new consumers. Galaxy II Note, for instance, has been successful in attracting consumers who prefer a large screen. Most recently, Apple with its iPhone 5C is experiencing sluggish sales compared to the richer iPhone 5S (Carew, 2013).

Finally, this paper did not consider competition. Whether it is intra-company competition, as in the case of iPhone 5S vs. iPhone 5C or inter-company competition, as in the case of iPhone vs. Motorola or Samsung, competitive actions are important determinants of a firm’s redesign. In the future our model has to incorporate the effect of competition in product redesign decisions.
REFERENCES:


Melendez, E. D. 2013. Moto X Defies Conventional Wisdom About U.S. Production. *Huffington Post TECH*. (September 23) Available at: 


### Table 3.1 List of Variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p_i$</td>
<td>Unit price for strategy $i$, $i = B, H, U, or HU$ for no add-on (base product), hedonic-only, utilitarian-only and both hedonic and utilitarian strategies</td>
</tr>
<tr>
<td>$v$</td>
<td>Unit variable cost for the basic functionality</td>
</tr>
<tr>
<td>$v_u$</td>
<td>Unit variable cost for utilitarian feature</td>
</tr>
<tr>
<td>$v_h$</td>
<td>Unit variable cost for hedonic feature</td>
</tr>
<tr>
<td>$c_B$</td>
<td>Marketing cost coefficient for the before redesigned product</td>
</tr>
<tr>
<td>$c_R$</td>
<td>Marketing cost coefficient for the redesigned product</td>
</tr>
<tr>
<td>$\pi$</td>
<td>Profit function</td>
</tr>
<tr>
<td>$m$</td>
<td>Marketing effort, a decision variable, assume that each marketing effort generates a unit of consumer demand.</td>
</tr>
<tr>
<td>$u$</td>
<td>Utilitarian feature level, a decision variable</td>
</tr>
<tr>
<td>$h$</td>
<td>Hedonic feature level, a decision variable</td>
</tr>
<tr>
<td>$d_u$</td>
<td>Design cost coefficient for utilitarian feature</td>
</tr>
<tr>
<td>$d_h$</td>
<td>Design cost coefficient for hedonic feature</td>
</tr>
<tr>
<td>$k_u$</td>
<td>Market expansion coefficient for utilitarian feature</td>
</tr>
<tr>
<td>$k_h$</td>
<td>Market expansion coefficient for hedonic feature</td>
</tr>
<tr>
<td>$\delta_i$</td>
<td>Profit margin for strategy $i$, $i = B, H, U, or HU$</td>
</tr>
<tr>
<td>$h_0$</td>
<td>Hedonic level threshold beyond that the demand starts to expand</td>
</tr>
<tr>
<td>$u_0$</td>
<td>Utilitarian level threshold beyond that the demand starts to expand</td>
</tr>
</tbody>
</table>
Table 2. Optimal Solution Comparison for Four Strategies

<table>
<thead>
<tr>
<th>Strategy</th>
<th>No Add-on</th>
<th>Hedonic &amp; Utilitarian</th>
<th>Hedonic Only</th>
<th>Utilitarian Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal Marketing Effort</td>
<td>( \frac{p_n - v}{2c_n} = \frac{\delta_h}{2c_n} )</td>
<td>( \frac{2(1 - h_k u_k - u_k k_0)\delta_{HU}}{4c_n - (k_u^2 / d_u + k_h^2 / d_h)\delta_{HU}^2} )</td>
<td>( \frac{2(1 - k_n h_0)\delta_{HU}}{4c_n - k_h^2 \delta_{HU}^2 / d_h} )</td>
<td>( \frac{2(1 - k_n u_0)\delta_{HU}}{4c_n - k_u^2 \delta_{HU}^2 / d_u} )</td>
</tr>
<tr>
<td>Optimal Hedonic Level</td>
<td>N/A</td>
<td>( \frac{k_n (1 - h_n k_n - u_n k_n)\delta_{HU}^2 / d_n}{4c_n - (k_n^2 / d_n + k_p^2 / d_p)\delta_{HU}^2} )</td>
<td>( \frac{k_n (1 - k_n h_0)\delta_{HU}^2 / d_n}{4c_n - k_h^2 \delta_{HU}^2 / d_h} )</td>
<td>N/A</td>
</tr>
<tr>
<td>Optimal Utilitarian Level</td>
<td>N/A</td>
<td>( \frac{k_n (1 - h_n k_n - u_n k_n)\delta_{HU}^2 / d_n}{4c_n - (k_n^2 / d_n + k_p^2 / d_p)\delta_{HU}^2} )</td>
<td>N/A</td>
<td>( \frac{k_n (1 - k_n u_0)\delta_{HU}^2 / d_u}{4c_n - k_u^2 \delta_{HU}^2 / d_u} )</td>
</tr>
<tr>
<td>Market Demand</td>
<td>( \frac{p_n - v}{2c_n} = \frac{\delta_h}{2c_n} )</td>
<td>( \frac{8c_n (1 - h_n k_n - u_n k_n)\delta_{HU}}{4c_n - (k_n^2 / d_n + k_p^2 / d_p)\delta_{HU}^2} )</td>
<td>( \frac{8c_n (1 - k_n h_0)\delta_{HU}}{4c_n - k_h^2 \delta_{HU}^2 / d_h} )</td>
<td>( \frac{8c_n (1 - k_n u_0)\delta_{HU}}{4c_n - k_u^2 \delta_{HU}^2 / d_u} )</td>
</tr>
<tr>
<td>Total Profit at the Optimal Solution</td>
<td>( \frac{(p_n - v)^2}{4c_n} = \frac{\delta_h^2}{4c_n} )</td>
<td>( \frac{(1 - h_n k_n - u_n k_n)\delta_{HU}}{4c_n - (k_n^2 / d_n + k_p^2 / d_p)\delta_{HU}^2} )</td>
<td>( \frac{(1 - k_n h_0)\delta_{HU}}{4c_n - k_h^2 \delta_{HU}^2 / d_h} )</td>
<td>( \frac{(1 - k_n u_0)\delta_{HU}}{4c_n - k_u^2 \delta_{HU}^2 / d_u} )</td>
</tr>
</tbody>
</table>

a.: The solutions above do not include the case that the optimal solution exceeds the allowable upper bounds.

Table 3. Sensitivity Analysis for Redesign Strategies

| \( m^* \) | \( m_n \uparrow, m_v \uparrow, m_w \uparrow \) | \( m_n \downarrow, m_v \downarrow, m_w \downarrow \) | \( m_n \downarrow, m_v \downarrow, m_w \downarrow \) | \( m_n \downarrow, m_v \downarrow, m_w \downarrow \) |
| \( h_0^* \) | \( h_n \uparrow, h_v \uparrow \) | \( h_n \downarrow, h_v \downarrow \) | \( h_n \downarrow, h_v \downarrow \) | \( h_n \downarrow, h_v \downarrow \) |
| \( u_0^* \) | \( u_n \uparrow, u_w \uparrow \) | \( u_n \downarrow, u_w \downarrow \) | \( u_n \downarrow, u_w \downarrow \) | \( u_n \downarrow, u_w \downarrow \) |
| \( D_n^* \) | \( D_n \uparrow, D_v \uparrow \) | \( D_n \downarrow, D_v \downarrow \) | \( D_n \downarrow, D_v \downarrow \) | \( D_n \downarrow, D_v \downarrow \) |
| \( \pi_n^* \) | \( \pi_n \uparrow, \pi_v \uparrow \) | \( \pi_n \downarrow, \pi_v \downarrow \) | \( \pi_n \downarrow, \pi_v \downarrow \) | \( \pi_n \downarrow, \pi_v \downarrow \) |

a. The optimal demand is denoted by \( D \). Hedonic-only, utilitarian-only and both add-ons are denoted in the subscript by \( H, U \) and \( HU \).

Table 4. Results of three strategies in the baseline case (Case 1).

<table>
<thead>
<tr>
<th>Strategy</th>
<th>( \pi^* )</th>
<th>( h^* )</th>
<th>( u^* )</th>
<th>( m^* )</th>
<th>( D^* )</th>
</tr>
</thead>
<tbody>
<tr>
<td>HU</td>
<td>36.29</td>
<td>2.59</td>
<td>3.11</td>
<td>5.19</td>
<td>8.07</td>
</tr>
<tr>
<td>H</td>
<td>32.11</td>
<td>1.89</td>
<td>3.78</td>
<td>4.28</td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>34.40</td>
<td>2.43</td>
<td>4.05</td>
<td>4.92</td>
<td></td>
</tr>
</tbody>
</table>
Table 5. Optimal Strategy Comparison with Parameter Values Change.

<table>
<thead>
<tr>
<th>Strategy</th>
<th>$\pi^*$</th>
<th>$h^*$</th>
<th>$u^*$</th>
<th>$m^*$</th>
<th>$D^*$</th>
<th>Results</th>
<th>$\pi^*$</th>
<th>$h^*$</th>
<th>$u^*$</th>
<th>$m^*$</th>
<th>$D^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>HU</td>
<td>33.63</td>
<td>2.06</td>
<td>2.88</td>
<td>4.80</td>
<td>6.91</td>
<td>See Table 4</td>
<td>30.65</td>
<td>1.54</td>
<td>3.61</td>
<td>3.90</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>34.40</td>
<td>2.43</td>
<td>4.05</td>
<td>4.92</td>
<td>2.74</td>
<td>3.01</td>
<td>34.40</td>
<td>2.43</td>
<td>4.05</td>
<td>4.92</td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>40.74</td>
<td>2.64</td>
<td>4.40</td>
<td>5.48</td>
<td>2.74</td>
<td>3.01</td>
<td>40.74</td>
<td>2.64</td>
<td>4.40</td>
<td>5.48</td>
<td></td>
</tr>
<tr>
<td>$u_0 = 0.5$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$u_0 = 1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HU</td>
<td>59.08</td>
<td>4.22</td>
<td>5.06</td>
<td>7.67</td>
<td>16.05</td>
<td>See Table 4</td>
<td>23.86</td>
<td>1.70</td>
<td>2.05</td>
<td>3.78</td>
<td>4.77</td>
</tr>
<tr>
<td>H</td>
<td>36.65</td>
<td>2.16</td>
<td>4.11</td>
<td>4.83</td>
<td>3.81</td>
<td></td>
<td>28.07</td>
<td>1.65</td>
<td>3.48</td>
<td>3.81</td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>39.67</td>
<td>2.80</td>
<td>4.45</td>
<td>5.65</td>
<td>3.81</td>
<td></td>
<td>29.80</td>
<td>2.10</td>
<td>3.69</td>
<td>4.30</td>
<td></td>
</tr>
</tbody>
</table>

a. $\delta_{\text{hu}} = \delta_{\text{h}} = \delta_{\text{u}} = 20$, $c_r = 3$, $d_h = 3$, $d_u = 2.5$, $k_n = k_u = 0.15$, $h_0 = u_0 = 1$, $h = \bar{u} = 10$ when the parameters are not specified.
b. The optimal strategy is shown in bold.
c. The case number is shown in brackets.
FIGURES

Figure 1. Optimal solutions for HU, H, and U strategies for the baseline case, Case 1.

Figure 2. Dominance regions of Strategies HU, H, and U when $c_R = 2$ (Case 2.1) and $c_R = 4$ (Case 2.2).
**Figure 3.** Dominance regions of Strategies HU, H, and U when $d_h = 2.5$ (Case 3.1) and $d_h = 3.5$ (Case 3.2).

**Figure 4.** Dominance regions of Strategies HU, H, and U when $k_h = 0.1$ (Case 4.1) and $k_h = 0.2$ (Case 4.2).
Figure 5. Dominance regions of Strategies HU, H, and U when $k_u = 0.1$ (Case 5.1) and $k_u = 0.2$ (Case 5.2).

Figure 6. Dominance regions of Strategies HU, H, and U when $u_0 = 0.5$ (Case 6.1) and $u_0 = 1.5$ (Case 6.2).
Figure 7. Dominance regions of Strategies HU, H, and U when $\delta_{HU} = 22, \delta_{H} = 21, \delta_{U} = 21$ (Case 7.1) and $\delta_{HU} = 18, \delta_{H} = 19, \delta_{U} = 19$ (Case 7.2).
Our responsibility is to provide strong academic programs that instill excellence, confidence and strong leadership skills in our graduates. Our aim is to (1) promote critical and independent thinking, (2) foster personal responsibility and (3) develop students whose performance and commitment mark them as leaders contributing to the business community and society. The College will serve as a center for business scholarship, creative research and outreach activities to the citizens and institutions of the State of Rhode Island as well as the regional, national and international communities.

Mission

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The University of Rhode Island started to offer undergraduate business administration courses in 1923. In 1962, the MBA program was introduced and the PhD program began in the mid 1980s. The College of Business Administration is accredited by The AACSB International - The Association to Advance Collegiate Schools of Business in 1969. The College of Business enrolls over 1400 undergraduate students and more than 300 graduate students.

The creation of this working paper series has been funded by an endowment established by William A. Orme, URI College of Business Administration, Class of 1949 and former head of the General Electric Foundation. This working paper series is intended to permit faculty members to obtain feedback on research activities before the research is submitted to academic and professional journals and professional associations for presentations. An award is presented annually for the most outstanding paper submitted.