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Variety

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Variety

DESIGN

creation of artifacts in society

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Contents

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Variety

Exhibit FORD shows a portion of the production of the Model T for one day in 1913 at Ford's Highland Park Factory. Henry Ford supposedly said of the Model T, "You can buy it in any color, as long as it's black." In fact, before 1913 the model T was available in red, gray, green, and blue. For the thirteen years following 1913, indeed black was the only color. Then, in the last two years of its product life the model T was available in 11 colors. Ford's design decision relative to paint colors was the response of a producer to economic factors of both supply and demand. In this chapter, I articulate those factors and use them to explore the use of variety in the design and production of artifacts.

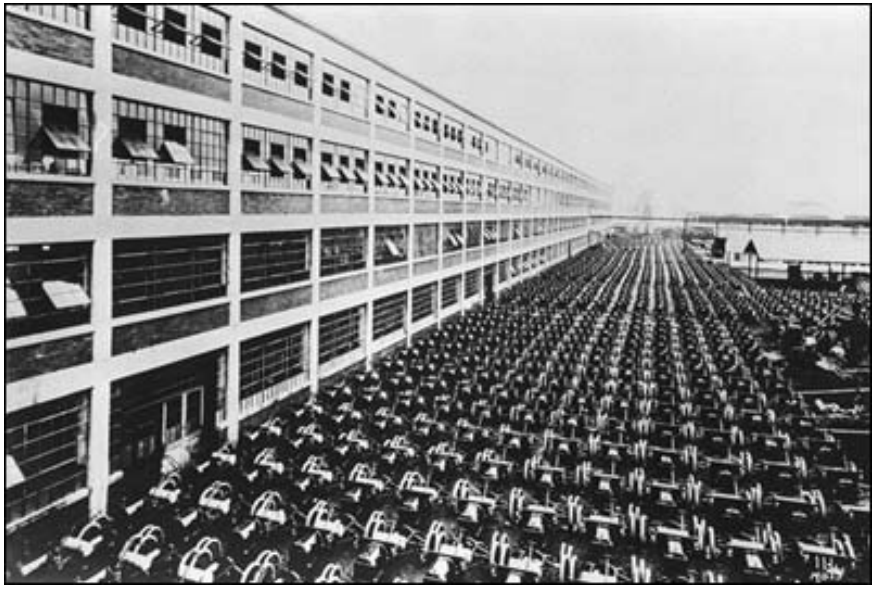

Exhibit FORD. A single day's production of the Model T at the Ford Highland Park factory in August 1913. Source: Henry Ford Museum.

I use *variety* to refer to the assortment of artifacts that differ with respect to one or more attributes. I focus principally on the variety within a product

category available simultaneously from the producers in a marketplace, although variety can also be thought of in terms of the frequency and extent to which a producer changes the artifacts it offers over time. Consider three examples of variety. Exhibit TSHIRT shows several t-shirts (the *category*) that differ in their size (an *attribute*). Exhibit COKE shows several different soft drinks that differ in their formulation. Exhibit CRANK shows several different bicycle cranks that differ in geometry, material properties, and surface finish.

In this chapter, I start by defining three types of variety. I then explain the economic motives for variety and the costs associated with variety. I finish by providing a framework for *designing variety*—determining the type and level of variety for a family of artifacts.

Exhibit TSHIRT. The Hanes Beefy-T shirt is available in several different sizes for a given style, color, and quality level (shown here from S to XXXL). This is an example of *fit* variety.

Exhibit COKE. A dozen of the many variants of Coke. This is an example of *taste* variety.

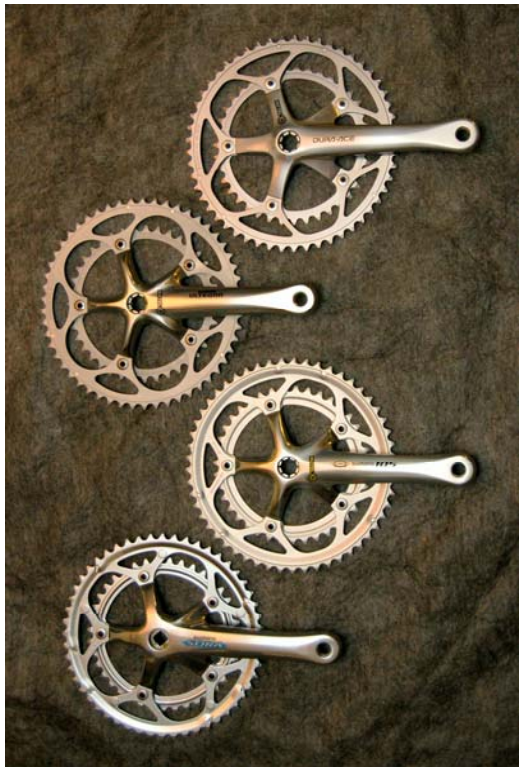

Exhibit CRANKS. Shimano bicycle cranks are available in several different quality levels for a given size and application type. These four artifacts are all 170mm 53/39-tooth cranks sold by Shimano at prices from $60 (bottom) to $350 (top). This is an example of *quality* variety.

Types of Variety

I categorize variety into three types: *fit*, *taste*, *quality*. These categories are defined by the way a user's evaluation of an artifact changes as a function of changes in an attribute. Exhibit TYPES illustrates how a single hypothetical user might value a t-shirt as a function of changes in three different attributes of a shirt. The first attribute is the circumference of the shirt, an element of its size. If the shirt were much too small to wear, it would be useful only as a dust rag. This hypothetical user values the shirt the most if it is 1100mm in circumference, a perfect fit. The user can get by with a shirt a little too small or a little too big, but the value of the shirt falls off steeply as the fit gets too tight or too sloppy. The basic shape of this function characterizes a *fit* attribute. Note that a fit attribute need not refer literally to geometric fit. Rather, fit attributes are those for which the user's preference exhibits a single strong peak for a single value of the attribute, with satisfaction falling off substantially as the artifact diverges from this value. For example, for a software application, a fit attribute might be the operating system with which the application is compatible. For a bicycle crank, a fit attribute might be whether the crank is designed for mountain biking or road biking. Fit attributes are typically easy to measure, characterize, and forecast for the designer and producer, and relatively easy for the user to assess.

The second attribute is the t-shirt's color. For this attribute, the user may have a preference for blues, but also like greens, and the value function may exhibit a lot of peaks and valleys. For this example, color is a taste attribute, an attribute for which the user may have a complex, multimodal response. Preferences for taste attributes are typically much less sharply defined than for fit attributes, and the user may accept as substitutes artifacts with very different values of a taste attribute. I intend *taste* in a broad sense, and not only in the literal sense of flavor. For example, for the bicycle crank, a taste attribute might be the finish on the aluminum surfaces, whether polished or matte.

The third attribute shown is the t-shirt's durability as measured by the number of washing cycles the shirt can withstand before significant degradation. As expected, the user prefers increased durability. The only thing that would prevent a user from preferring the most durable shirt might be the shirt's price. In the crank example, the prices vary by a factor of six as quality increases. Note that for most users, satisfaction increases at a decreasing rate

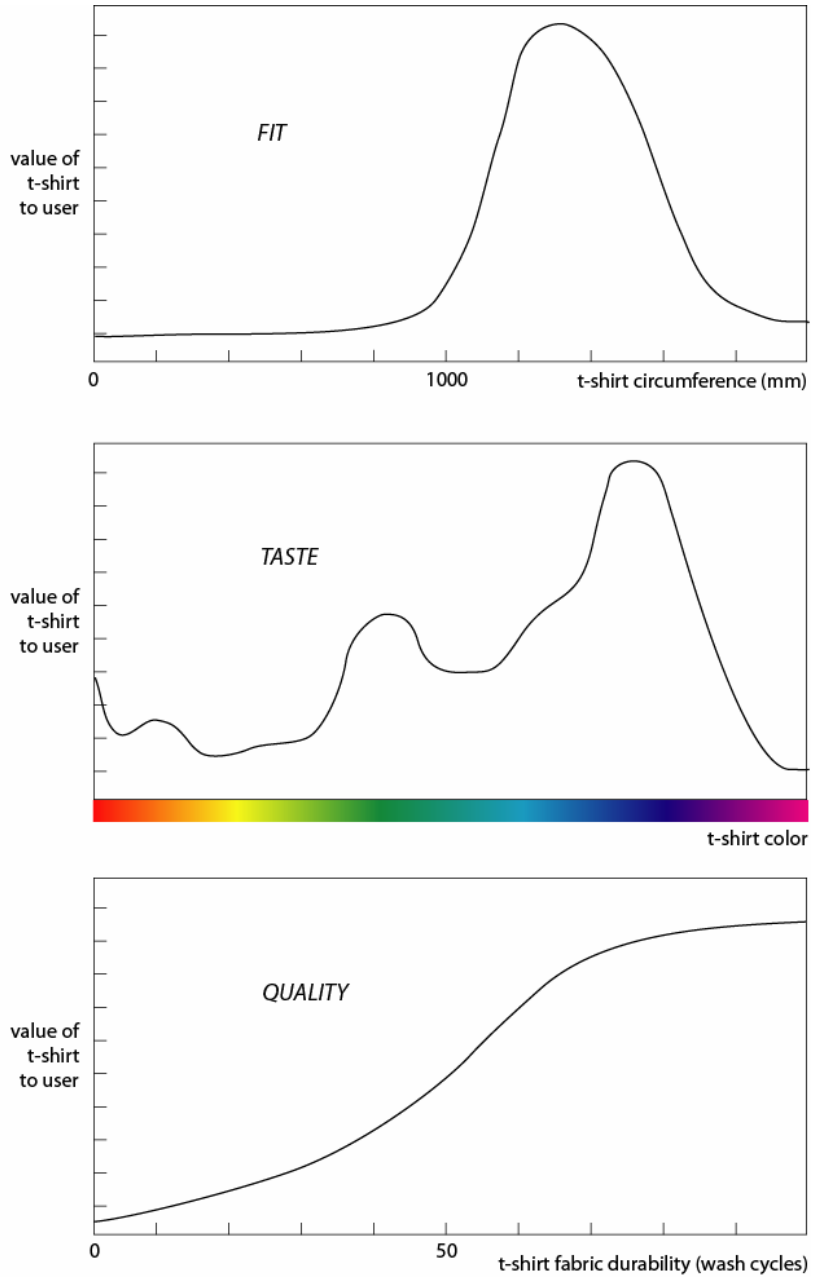

Exhibit TYPES. Illustration of how a hypothetical user's evaluation of a t-shirt might change as a function of changes in fit, taste, and quality attributes.

as quality approaches a high level. Indeed, one must be a sophisticated cyclist to even detect which crank is considered the highest quality, and I actually doubt most cyclists could *feel* any kind of difference in the performance of these cranks.

For completeness and to avoid confusion, note that economists typically divide variety into two categories: *horizontal* and *vertical*. Horizontal variety is essentially what I call taste and fit variety; and vertical variety is quality variety. The terms horizontal and vertical variety are not very descriptive and so I prefer to use fit, taste, and quality, which I find both more memorable and more useful conceptually[1].

Motives for Variety

Variety is the result of decisions made by the producers of artifacts. Producers respond to seven basic economic motives for variety:

Heterogeneous user preferences

Each individual user of an artifact exhibits different preferences for attributes of that artifact. In a commercial setting, a user is willing to pay the highest price for an artifact whose attributes are at that user's *ideal point*. In the limit, to maximize user satisfaction, a producer would offer an artifact at the ideal point of each potential user. Hotelling (1929) is a beautiful paper that provided the seminal conceptual framework for thinking about consumer preferences and variety.

Variation in user experience

Some but not all users seek variety in their experiences over time (Kahn 1995), preferring different breakfast cereals on different days or different hotels on subsequent visits to a city. In a setting in which users seek variety for the intrinsic value of its diversity, producers will offer variety.

Sole source to customer

There are costs in time, effort, and money to procure goods and services from multiple suppliers, and so from the standpoint of convenience a consumer prefers to purchase from a single supplier. Of course, the producer reaps benefits from being the sole source as well, including diminished price competition and higher volume of sales. These pressures may lead a producer to offer additional variety, some of which may not be profitable when viewed in isolation, in order to reduce the number of suppliers a customer deals with.

[1] A pet peeve of mine is the adoption of arbitrary labels for concepts when more descriptive terms could be used. For most people, labels like *horizontal*/*vertica variety* or *left-brain/right-brain* require rote memorization and cognitive effort every time they are used.

Price discrimination

Different customers exhibit different levels of willingness to pay for quality attributes. Assuming that the profit margins as a percent of price do not diminish with higher prices, a producer would prefer that a high willingness-to-pay consumer buys a higher quality, higher price product than a lower willingness-to-pay consumer. This phenomenon leads producers to offer different quality levels of artifacts, often with fairly slight differences in their attributes, but at significantly different prices.

Niche saturation

Existing producers have an incentive to inhibit rivals from entering their markets. An existing products in a niche deters entry by a second firm. As a result, incumbent firms may offer products in small niches, even when the marginal benefit of doing so is not positive, in order to prevent a new entrant from gaining a toehold. Schmalensee (1978) provides a comprehensive discussion of the literature and a theoretical treatment of this phenomenon.

Avoiding price competition

Have you ever tried to find the best price on a new mattress? For a consumer, it's an exercise in frustration. The same producer will offer similar but not identical models through different retailers. At Acme Mattresses, one finds the SoftSleep Excel 2150 and at Beta Mattresses one finds the SoftSleep Delux B150. These mattresses may differ in terms of quilting pattern, number of ties on the springs, and which specific foam is used. However, discerning which is actually preferred is essentially impossible. This use of variety inhibits the consumer's efforts to directly compare prices, allowing Acme and Beta to avoid direct price competition and therefore charge higher prices.

Channel shelf space

Shopping can be a cognitively challenging task. When faced with a shelf of toothpaste options, few consumers will carefully evaluate each alternative comparing features and benefits. In fact, there is a certain element of randomness to the purchase decision, and so almost anything on the shelf will garner some sales. In fact, holding all other factors constant, sales volume is remarkably proportional to the shelf space allocated to the product. Imagine a shelf in which there are two brands of toothpaste, say Colgate and Crest. Given the shelf-space phenomenon, the producer that adds a second variant, say Minty Crest, will have two thirds of the shelf and all other things equal will garner two thirds of the sales. This action will of course lead to an "arms race" of variety. In fact, Crest toothpaste can be purchased today in about 100 different formulations (even counting them all exactly is tricky) and this figure does not include variety in packaging and size.

Exhibit TOOTHPASTE. The toothpaste aisle. (Source: http://thetonyashow.blogspot.com/2005/09/back-to-school-shopping.html, accessed March 13, 2006.)

Costs of Variety

The economic motives for variety would quickly push producers to offer infinite variety if there were no costs associated with variety. Indeed there are two basic types of costs: *reduced scale* and *consumer search costs*.

Reduced Scale

Variety erodes scale for producers, and given the ubiquity of economies of scale, will therefore increase production costs. Holding total production quantity constant, if a producer substitutes two similar variants of a product for a single product, total costs will rise. Consider the specific example of the Xootr Mg scooter (a product I designed with my brother Nathan and Jeff Salazar, an industrial designer at Lunar Design). Exhibit SCOOTER shows the product, whose central structural element or *deck* is a die-cast magnesium part. When we contemplated developing the Mg scooter, we considered offering two versions of the product, one with a wide deck and one with a narrow deck. The different decks represent fit and taste variety and different customers prefer different shapes and sizes.

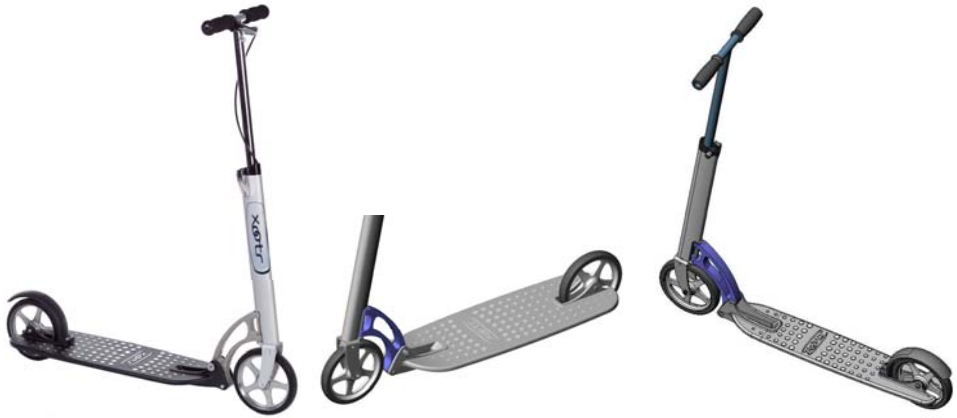

Exhibit SCOOTER. The Xootr Mg scooter with a die-cast magnesium deck (left) along with computer models of designs contemplated for the deck. The two shapes appeal to different users for reasons of style, comfort, and kicking efficiency.

The die-cast deck is produced by a very large press that brings together two halves of a *die* (or *mold*) into which molten magnesium is injected. When the part has cooled and the magnesium solidified, the die is opened and the part is ejected. The process is magnificent in that once the machine is set up, a

precise and nearly finished part can be produced once per minute indefinitely, with a batch of about 500 requiring only a single shift of production.

Exhibit PRODUCTION. Production of the Mg deck requires a die (or mold) as shown in the upper two panels. The raw castings as they come from the die are shown in the lower two panels. The lower right panel shows a production batch of about 500 pieces.

If the part were produced in two versions, then most costs would increase, including the costs of designing and testing the two versions, the costs of the dies to make two different parts, and the costs of supporting the production and sale of two variants of the product. If we assume that the two decks use approximately the same amount of magnesium, then the unit production costs will also increase when the product is made in two versions, because the machine has to be set up and adjusted for two different batches of parts instead of for just one batch. Exhibit COSTS summarizes the cost comparison.

Exhibit COSTS. Comparison of costs for 25,000 scooter decks over five years in one versus two variants. Approximate costs in US$.

	Costs of 25,000 decks of one shape	Costs of 12,500 decks in each of two shapes
Design and testing costs	12,000	16,000
Tooling costs (e.g., dies and fixtures)	40,000	70,000
Material costs and processing costs	675,000 (27.00 per deck)	725,000 (29.00 per deck)
Purchasing, logistics, and inventory costs	6,000	10,000
Marketing communications (e.g., photography, brochures, website)	4,000	5,000
Total Costs	**737,000**	**826,000**

The costs for the scooter are indiosyncratic to this setting and to this production process. However, virtually all producers of artifacts face economies of scale in their production and delivery processes. Holding all else equal, when variety is increased, the volume per variant is decreased and therefore the total costs of production increase.

Consumer Search Cost

The second cost of increased variety is increased cognitive load on the consumer. When a dinner menu only has one item on it, choosing what to eat is easy. As the number of options increases, the likelihood increases that one of the choices will be pleasant, but the consumer must also invest more and more cognitive effort in identifying relevant alternatives and in making a selection. I call this consumer effort *search cost*. At some point, the increase in search cost may exceed the increase in value derived from additional variety. As variety reaches very high levels the selection problem may become so painful that the consumer may actually prefer forgoing the product altogether to avoid the agony of the selection process.

As producers develop an increasing ability to offer variety, due to enhanced process flexibility, there is a temptation to offer more variety than can be usefully absorbed by the consumer. With my colleagues Christian Terwiesch and Taylor Randall, I have explored methods for easing the cognitive burden of choosing from among many alternatives using decision support technologies (Randall, Terwiesch, and Ulrich 2006). These methods may serve to diminish the relationship between variety and search cost for consumers.

Societal Perspective

Consider the amusing discussion by *Fast Company* magazine of the differences in four of Coca-Cola's offerings (Exhibit CRAZY). *Coke Zero* is a diet cola with no calories and is sold alongside *Diet Coke* another diet cola with no calories. The company calls Coke Zero "a new kind of beverage that features real cola taste and nothing else." How critical is it that consumers are now able to enjoy Coke Zero in addition to Diet Coke? Even if the Coca Cola Company is economically rational in its offering a dozen formulations of a diet cola, this action somehow seems wasteful and wrong from a societal perspective.

A moral judgment about variety might include some of the following arguments. Intelligent and creative professionals should be able to find better things to do with their lives than identifying and exploiting micro segments of the carbonated beverage market. As a society we should spend fewer resources on designing, producing, and marketing dozens of different variants of diet colas and more resources on educating children and improving human health. Yvon Chouinard (2005), the founder of Patagonia, writes "when I die and go to hell, the devil is going to make me the marketing director for a cola company. I'll be in charge of trying to sell a product that no one needs, is identical to its competition, and can't be sold on its merits." Ultimately, moral judgments rest on moral principles and a particular set of principles may give rise to a particular argument about the moral value of variety. Personally, I'm amused by variety, sometimes confused by it, but do not find variety as morally offensive as, say, the design, production, and purchase of automobiles that weigh 3 tons and achieve 12 miles per gallon (5 km per liter) of fuel economy.

This chapter has mostly taken the perspective of a single producer responding to various forces to increase or decrease variety. One could also analyze variety from the perspective of the entire product category. There is some empirical evidence that over the lifecycle of a product category, variety increases substantially with the entry of new firms and then peaks and declines as the more economically fit firms drive out unprofitable rivals (Balasubramaniam et al. 2006). This dynamic suggests that from a societal perspective there may be more variety than strictly necessary to address the heterogeneous needs of consumers.

[LAB TEST]

THE MARKETING GODS MUST BE CRAZY

By Paul Lukas

For a long time, the reason to drink Diet Coke was "Just for the Taste of It." Things are a lot more complex these days as Coke marketers parse demographic segments and create drinks for each niche. There's now a new Diet Coke sweetened with Splenda and Coca-Cola Zero, which, as its name implies, has zero calories—as opposed to the regular and Splenda versions of Diet Coke, both of which have, um, zero calories. And then there's still Coke's original no-cal cola, Tab. All of which leads to some very creative marketing-speak.

	Product	Core demographic	Brand message, as found on Coke.com	Brand message from Katie Bayne, a senior VP, Coca-Cola Brands	Actual brand message, as translated by FAST COMPANY	Flavor profile, according to Scott Williamson, Coca-Cola spokesman	Flavor profile, according to admittedly unscientific FAST COMPANY taste test
DIET COKE	Launched in 1982; sweetened with aspartame **0 calories**	Very broad footprint, with marketing efforts focused on those in their late twenties to early thirties, skewing slightly female	"Diet Coke is your style, it's your sass, it's doing what makes you happy. . . . So flirt, laugh, dance, prance, giggle, wiggle—do what feels good."	"The adult cola taste that uplifts with style—it's a very stylish brand. It's upscale. It's sophistication, but an invitational sophistication."	"Tastes just as good while watching *Sex and the City* reruns as it did while watching the original episodes on HBO."	"According to lore—I've never heard this internally disputed or confirmed—it resembles what used to be New Coke."	Sweet nectar of the gods
DIET COKE w/ Splenda	Launched in May 2005; sweetened with Splenda [sucralose] and acesulfame potassium **0 calories**	30- to 40-year-olds, skewing slightly female	"For those who love the sweet and intense taste of Splenda Brand Sweetener, now there's one more way to enjoy Diet Coke!"	"An adult cola taste, it uplifts with style, and it's sweetened with Splenda, which is a sweetener people say they want. It's that simple."	"Hey, we'll sweeten it with denatured monkey sweat if that's what the carbophobe crowd wants."	"It's meant to mimic Diet Coke. But with Splenda, you will taste a difference, and the Splenda lover loves this new flavor note."	Clean and crisp but a bit short on depth. There's no there there.
COCA-COLA ZERO	Launched June 2005; sweetened with aspartame and acesulfame potassium **0 calories**	18- to 34-year-olds, skewing slightly male	"A new kind of beverage that features real Coca-Cola taste and nothing else. Nothing that could potentially get in the way of your chill."	"It's really the pause that lets them recenter in this fast-paced, time-warped world, and keep going. That's the 'just chill' part of the positioning."	"We're still trying to figure out what those crazy gen-X and gen-Y kids are into, but one thing we're sure of: They don't like the word 'diet.' "	"It's formulated to match regular Coca-Cola."	Sure enough, it really does taste remarkably like Coke.
TAB	Launched in 1963; sweetened with saccharin and aspartame **0 calories**	Urban-sophisticate baby boomers with a sense of ironic kitsch	"Tab has achieved a retro pop-culture status and has the reputation of being somewhat hard to find."	"It's continuing to meet the needs of the small but unbelievably passionate group of people who continue to love Tab, but it isn't actively marketed."	"We can't believe anyone's still buying this stuff."	"It has a strong cola flavor, with that distinctive saccharin sweetness."	Singularly metallic and synthetic in a "You can tell it's a diet drink because it totally makes you lose your appetite" sort of way.

Exhibit CRAZY. An analysis of four variants of diet cola offered by Coca Cola.

An economic evaluation of variety could in theory address the question of whether or not variety maximizes social welfare (Lancaster 1975). While variety pursued for the economic motives of addressing heterogeneous user needs is hard to oppose, one could object to variety pursued by the producer to garner additional shelf space or to avoid direct price competition in the sales channel. As with many economic concepts, one must be careful about relying on intuition. It is possible that such actions provide incentives for producers to provide artifacts that better meet user needs. I do not know enough economics, nor have I devoted enough attention to this question to offer a compelling argument one way or the other. Instead I leave for others the question of the extent to which variety offered by producers is a good thing for society.

Designing Variety

In this book, I address the design of many types of artifacts, including buildings, graphics, services, software, and physical goods. I consider settings ranging from an individual designing for his or her own use to an institution creating products for a large market of consumers. The problem of designing variants of artifacts is most prominent in the institutional setting where a team of product designers creates a family of products for a market of many customers. In this section, I assume this context and lay out a framework for making an optimal choice of the level of variety of a product. This framework is simple and static, but forms a foil against which I can articulate a set of more subtle complications and issues that face the firm.

Optimal variety

The notion of optimizing variety has its roots in economics and operations research. Ramdas (2003) provides a comprehensive review of the literature related to decisions faced by producers in managing product variety.

I can illustrate the basic idea behind the optimization of variety with additional detail on the scooter example. I provided the cost analysis in Exhibit COST for two scenarios, one deck and two decks. Conceptually, I can extend this cost analysis to many decks by considering how the various costs of producing the scooter would change as variety is increased. There are two problems with this extension. First, as variety increases, one would be less likely to use a production process like die casting, with high fixed costs per variant. Each new die for each new variant would add about $30,000 in up-

front investment. If the scooter company were to offer 10 different scooters using this production technology, then the required investment would be $300,000 a sum that I can assure you the company would not spend. Instead, the firm would adopt a different production process technology, in this case computer-controlled machining (*CNC machining*) which requires investment of only about $1000 per variant, but incurs unit costs of materials, labor, and processing of about $40 per scooter deck. Process *flexibility* refers to the ability to produce additional variants of an artifact while incurring relatively lower fixed costs per variant—CNC machining is more flexible than die casting. The optimization of variety relies not only on the choice of a level of variety, but on the simultaneous choice of a production technology.

The second problem with the static cost analysis is that the production volume would not remain the same as variety is increased. Indeed, if the demand for scooters did not increase with increased variety, then there would be no motive for having more than one variant. The quantity produced is, however, a determinant of cost. This mutual dependency of variety, production process technology, costs, prices, and demand make the optimization problem tricky even when these factors can be readily modeled with mathematical expressions. One of the first such efforts was undertaken by deGroote (1994) who simultaneously considers costs, demand, production technology, and variety. Even so, he is able to do so only for a stylized model, which would be somewhat difficult to apply in practice.

Fortunately, the practical extent of variety in most settings is quite finite, and so one can consider discrete scenarios of say 1, 2, 5, 10 variants of the product and estimate what production process would be used, what revenues would likely be generated, and what would be the overall costs of delivering the particular level of variety. Then, one can compare total profits under the different scenarios and make an informed decision about the level of variety to offer. One such analysis is Exhibit PROFIT, which for the scooter is the result of analysis, and judgment based on experience.

We should not get too carried away with our optimization however, as the reality of design practice is that we have many more degrees of freedom in addressing this problem than simply what level of variety to offer, and the rules of the game are changing constantly. In the balance of this section, I consider several interesting complications that make designing variety an intellectual challenge.

Exhibit PROFIT. Revenues, costs, and profits for four different variety scenarios for scooter example. Illustrative values in US$.

Deck Variety	**1**	**2**	**5**	**10**
Total quantity sold	25,000	31,000	34,000	35,000
Ave price	150.00	165.00	170.00	172.00
Total revenues	3,750,000	5,115,000	5,780,000	6,020,000
Process technology	Die casting	Die casting	Die casting (2) + CNC (3)	Die casting (2) + CNC (8)
Fixed costs	52,000	86,000	89,000	94,000
Support costs	12,000	14,000	20,000	28,000
Ave unit variable cost	90.00	92.00	101.00	107.00
Total variable costs	2,250,000	2,852,000	3,434,000	3,745,000
Total costs	2,314,000	2,952,000	3,543,000	3,867,000
Profit contribution	**1,436,000**	**2,163,000**	**2,237,000**	**2,153,000**

Variety is best measured in terms of attributes as well as end items

In this chapter I have mostly used variety to refer to the number of *end items* or *stock keeping units* (*SKUs*) offered by a producer. However, this measure of variety can be deceptive. A toothpaste manufacturer offering nine different toothpaste end items comprised of the same formulation in the same tube, but placed in nine cartons printed in different languages, is behaving quite differently from a manufacturer offering nine end items comprised of a gel and two paste formulations, each available in a pump and two sizes of tubes. Superficially each offers nine variants, and yet the modes of competition, the design requirements, and the systems of production and distribution are likely to be very different for the two producers. For this reason, an analysis of variety is most useful when considered both in terms of the number of end items as well as in terms of the variety offered with respect to each of the important individual attributes of the product.

The architecture of the artifact dictates what can be varied

In Chapter Four, I treat the architecture of artifacts in detail. The key idea is that a physical decomposition of an artifact into chunks may or may not correspond to a functional decomposition of the artifact, and the nature of the mapping from structure to function is dictated by the architecture. Variety refers by definition to differences in the attributes of the product, which can only be created by differences in structure. The architecture of the product constrains the ways in which the product can be changed and therefore constrains the variety that can be achieved by the producer. A static optimization of variety may fail to account for dramatic changes to cost structure that could result from a fundamental change to the product architecture.

Variety is an element of competitive strategy

Taylor Randall and I (2001) studied the choices firms made in the bicycle industry with respect to product variety, production process technology, and supply-chain strategy. We discovered that successful firms had made harmonious decisions across three different sets of decisions: the attributes over which variety would be offered, the production process technologies used to produce the bicycles, and the configuration of the supply chain for producing and distributing the goods. There is typically no single dominant strategy for competitive superiority. Rather, different firms may adopt different equally coherent sets of choices which provide differentiation in the market in a relatively efficient fashion.

Concluding Remarks

Variety has indeed increased in most categories in current society. This is partly the result of increasingly global markets in which firms serve highly heterogeneous consumers. It is also the result of increased production process flexibility and the associated loosening of the bonds of scale economies. In this world, design is less and less focused on the creation of a single perfect artifact and increasingly a puzzle requiring creative problem solving and analytical judgment about product architecture, production process technology, supply chain structure, and market strategy.

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