BEYOND THE PROFITABLE PRODUCT DEATH SPIRAL: MANAGING PRODUCT MIX IN AN ENVIRONMENT OF CONSTRAINED RESOURCES

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ABSTRACT

Notwithstanding the wide-spread inclusion of product-mix decisions in marketing simulation games, little theoretical work has been done to ensure that the algorithms driving them reflect current knowledge regarding product-mix strategy. Recent work based on relationship marketing theory has sought to address this problem, focusing on the impact of demand correlation within the product mix. This paper extends this line of research, using Goldratt's theory of constraints to address the impact of supply constraints on product-mix interactions. It shows how these factors can be incorporated into a standard simulation objective function.

INTRODUCTION

Product-mix decisions are central to marketing strategy, and are a common feature of marketing simulation games. Nevertheless, they have received relatively little theoretical attention in the literature on simulation design. This is potentially problematic. Traditional simulation designs tend to be governed by marketing and accounting principles that fail to address key interactions among the demand and supply variables associated with various products in a company's product mix (Cannon, Cannon and Schwaiger 2006). By "interactions," we simply mean situations where demand or cost variables cause the decision to carry one product in the mix to influence the decision regarding another. Theory would suggest that these interactions are not only important, but in many cases, critical to profit-optimizing product-mix decisions

Cannon, Cannon and Schwaiger (2006) address this by modeling Rust, Zeithaml, and Lemon's (2000) "Profitable Product Death Spiral" – a phenomenon growing out of *relationship marketing* theory. It posits that consumers are motivated by a desire to purchase portfolios of products, rather than individual product purchases. Cannon, Cannon, and Schwaiger account for product-mix interactions by associating a desired portfolio of products to each segment of the market. Segment sales are based on the marketer's ability to deliver the desired product mix.

Focusing on desired portfolios addresses product-mix interactions from a demand perspective. We would expect to find supply-based interactions as well – conditions that would make certain combinations of products more attractive for a company to produce, based primarily on supply considerations. In fact, this is the case. Over the years, a considerable literature has grown up around the application of Goldratt's (Goldratt and Cox 1992) theory of constraints to product-mix decisions.

This paper will build on Cannon, Cannon, and Schwaiger's (2006) demand-side work with the Profitable Product Death Spiral, adding supply-side considerations from the theory of constraints. It will begin by casting these two approaches into a larger four-part typology. It will then briefly review the literature specifically focusing on the theory of constraints and product-mix decisions. Finally, it will discuss the incorporation of theory-of-constraints considerations into the simulation algorithm that determines the impact of product-mix decisions.

APPROACHES TO MODELING PRODUCT-MIX INTERATIONS

Notwithstanding the relative lack of attention given to the modeling of product-mix interactions, the literature suggests at least four basic theoretical approaches. We can label these according to the principal driver of product-mix decisions: (1) the *competitive interaction* approach, growing out of product positioning theory; (2) the *desired portfolio* approach, growing out of relationship marketing theory; (3) the *volume-oriented resource utilization* approach, growing out the theory of economies of scale; and (4) the *constraint-based resource-utilization* approach, growing out of the theory of constraints.

THE COMPETITIVE INTERACTION APPROACH

One of the most elegant approaches to product-mix interactions is what we might call the *competitive interaction* approach. It grows out of positioning theory, where the attractiveness of a product to a consumer segment depends on the distance of the product (as determined by its attributes) from the segment's ideal product (Johnson 1971). A company's selection of products entails a careful balance of position, where products within the mix are distant enough from each other to minimize cannibalism, but close enough to avoid gaps that might be exploited by competitive entries (Teach 2008).

This has been institutionalized in simulation design through the use of a multi-attribute distance measure that determines unit demand (Teach 1984, 1990). Unit demand is then combined with price and costs to determine the profit contribution by market segment for each product in the portfolio (Gold 2005).

THE DESIRED PORTFOLIO APPROACH

As noted earlier, Cannon, Cannon and Schwaiger (2006) draw on relationship marketing theory to develop a second approach, what we might call the *desired portfolio* approach. Specifically, they use Rust, Zeithaml and Lemon's (2000) concept of the "Profitable Product Death Spiral" to suggest that the *competitive interaction* approach might result in sub-optimal long-term profitability in the presence of demand correlation.

The Death Spiral occurs when managers seek to optimize profit by continually pruning low-margin products – i.e. those with inferior competitive positions -- in favor of those with higher contributions. Presumably, this would leave only the most profitable products in the mix, thus increasing the overall company profitability. However, in a relationship marketing environment, where profitability depends on selling bundles – desired portfolios -- of products to the same consumers, product interactions become especially important. Rust cites the example of a textbook that was selling well, accompanied by a readings book that was not. The publisher dropped the readings book, but in the process, it alienated the text-book adopters who had structured their courses around use of the readings book as well. While this was not the majority of adopters, it was a large enough proportion to substantially lower the contribution of the original text book (Rust, Zeithaml, and Lemon 2000, p. 27).

Note that the problem is not really with marketing strategy per se, but with the product-mix decision algorithm that drives it. The *competitive interaction* approach relies on product profitability as its product-mix selection algorithm. Product profitability is measured by unit contribution margin (unit revenue minus unit variable cost). Although seeking to maximize contribution margin is seemingly a logical approach, the unintended consequence is often the Profitable Product Death Spiral, as Rust et al (2000) describe it. That is,

- The company improves profitability by eliminating unprofitable products/services;
- The elimination of unprofitable products reduces the overall value of the product portfolio offered to customers;
- Lower value drives customers away and lowers profits;
- Lower profits increase pressure to make further cuts in an effort to bring profitability back up to targeted levels. Ibid., 26

The problem could be avoided by simply making customers rather than products the unit of measurement when calculating profit (Cannon and Cannon 2008). The Death Spiral effect is created, in part, when demand for products is correlated. That is, a customer prefers products in combination rather than individually (hence product demand for one product decreases as products are removed from the portfolio). Product demand correlation is a function of customer preferences and in fact, may be the major factor that differentiates customer segments. By using customers as the unit of analysis, managers implicitly account for product demand correlation, avoiding the Profitable Product Death Spiral.

THE VOLUME-ORIENTED RESOURCE UTILIZATION APPROACH

Consistent with the aforementioned need for a more customer-oriented approach, Rust, Zeithaml, and Lemon (2000) addressed the product-mix problem from a perspective of relationship marketing theory. This is appropriate for companies whose key investments are customer-related rather than product-related (Cannon and Cannon 2008). For instance, it might be much more appropriate for a retailer. However, the contrast suggests a company that is heavily invested in technology or manufacturing would take a different approach.

The approach would still look at potential interactions among product within the product mix. The interactions would be based on shared costs as opposed to the shared demand that characterized the *desired portfolio* approach. The sharing favors products that have common components and manufacturing processes, thus drawing on the economic theory of economies of scale. Here volume is king, as suggested by the label, the *volume-oriented resource utilization* approach.

The economies of scale express themselves through a lower average unit cost. The actual costs are allocated to individual products, either as indirect costs, or more recently, as activity-based costs (Draman, Lockamy, and Cox 2002). The indirect-costing method seeks to apportion shared costs to the various products through some kind of allocation basis. Activity-based costing uses a two-stage allocation, where overhead and other costs are first traced to specific activities, and then the cost of each activity is allocated to products, based on how each of the products use the activities.

THE CONSTRAINT-BASED RESOURCE UTILIZATION APPROACH

The literature on theory of constraints suggests a different approach for optimizing resource utilization, resulting in a radically different approach to product-mix decisions – what might be called the *constraint-based resource utilization* approach. The theory of constraints grows out of the work of Eliahu Goldratt (Goldratt and Cox 1992), who studied manufacturing processes and found that standard cost-accounting procedures led companies to focus on cost-reduction, even when it actually increased costs and lowered profits.

The contribution of theory of constraints is in its focus on throughput rather than volume (Chakravorty and Verhoeven 1996). By throughput, we mean the amount of contribution margin that is generated by moving products through the system, as opposed to focusing on economies of scale, as is characteristic of *volume-oriented resource utilization* approach. Constraints are anything in the system that limits throughput. In the real world of business, every system is subject to a host of potential constraints – volume limitations from machine capacity or suppliers, availability of trained labor, raw materials, and so forth.

To illustrate the *constraint-based* approach, consider a simple example of a company that makes two products. Both sell for $100 and are made in the same factory with the same production inputs (material and labor). Product A uses three units of material, costing $10 per unit, and one unit of labor, costing $20 per unit. Product B uses one unit of material and three units of labor.

All else being equal, the company would produce both. Both have a positive profit contribution, ($100 – 3*$10 – 1*$20 =) $50 and ($100 – 1*$10 – 3*$20 =) $30 per unit respectively. The company would shift production to Product A, because it provides a higher contribution margin. By contrast, suppose there is a constraint in available materials. The company would shift production to Product B, because it can make three times as many units given the same amount of materials. For instance, suppose the company has access to 3,000 units of material. It can produce 1,000 units of Product A, yielding a profit contribution of ($50*$1,000=) $50,000, or it can produce 3,000 units of Product B, yielding a contribution of ($30*3,000=) $90,000.

The point is that the nature of the constraint determines the product mix. While actual product-mix problems are usually much more complicated, the example illustrates the basic principle underlying the *constraint-based resource-utilization* approach to modeling product-mix interactions. Perhaps most striking, the example illustrates that, when resources are constrained, product managers may arrive at product-mix decisions that yield sub-optimal profit if they do not use the *constraint-based resource-utilization* approach.

A BRIEF SUMMARY OF THE LITERATURE

We have already suggested that the literature can be roughly divided into four basic approaches to developing product-mix simulation algorithms: (1) the *competitive interaction* approach, (2) the *desired portfolio* approach, (3) the *volume-oriented resource utilization* approach, and (4) the *constraint-based resource-utilization* approach. The first three approaches have already been addressed in the literature on simulating and gaming.

While the fourth (*constraint-based*) approach has not been addressed in the simulation and gaming literature, the literature does contain a number of studies discussing how the principles of the theory of constraints might be incorporated into a simulated business environment (Chakravorty and Verheven 1996; Mukherjee and Wheatley 1999; Jordan 2006; Taylor, Jackson, Jackson, and Seanard 2007). These provide useful background, but do not address the specific problem of product-mix interactions.

Looking beyond the literature on simulation and gaming, we find a number of studies addressing product-mix decisions. For instance, searching the ProQuest data base for “product mix” AND “theory of constraints,” we found 19 studies. With the exceptions of three expositional studies on the merits of theory of constraints for making product-mix decisions (Hilmola 2001), how to improve it (Koksal 2004), and a case study for teaching the *constraint-based* approach (Brewer, Campbell and McClure 2000), the studies were split evenly between papers addressing the use of mathematical programming to implement optimal theory-of-constraint solutions and studies comparing *constraint-based* (theory of constraints) *resource utilization* approaches with *volume-based resource utilization* approaches to product-mix formulation.

The mathematical programming papers address a simulation game player’s perspective – how to develop an optimal product mix, given types of resource constraints. A review of these papers could be useful in the debriefing process of the game, but it is beyond the scope of this paper.

The papers comparing *constraint-* versus *volume-based* approaches are useful in providing a rationale for this paper. Two of them found that throughput accounting appeared to be superior to conventional allocation approaches (Patterson 1992; Draman, Lockamy and Cox 2002). The others suggest various improvements in the *constraint-based* approach, either through some form of integration with activity-based accounting (Kee and Schmidt 2000; Lea and Fredendall 2002; Sheu, Chen and Kovar 2003; Yahya-Zadeh 2008), or through a new approach altogether (Tsai, Lai, Tseng and Chou 2008). Spoede, Henke and Umble (1994) suggest that activity-based accounting should be used to generate the data for a *constraint-based* approach.

Overall, the weight of evidence appears to support the basic arguments underlying the *constraint-based resource utilization* approach sufficiently, at least, to justify addressing it in a simulation game environment. This failing, the introduction of constraints into a simulation game environment parallels what one would encounter in the real world, regardless of how students choose to address them.

SIMULATING A CONSTRAINT-BASED PRODUCT MIX

Cannon and Schwaiger (2005) suggest that game development would be more efficient if it built upon a standard platform whenever possible, thus avoiding unnecessary duplication and economizing on common learning. They recommend Gold’s (2005) system-dynamic model as such a platform, what they refer to as the “Gold standard.” We will take this approach, casting our product-mix model as a modification of Gold's standard algorithm.

One of the advantages of Gold's algorithm is that it separates demand and cost functions, thus enabling the designer of a marketing simulation to easily incorporate both demand- and supply-driven product interactions into the algorithm that determines the payout of various marketing-mix combinations. Cannon, Cannon, and Schwaiger (2006) discussed demand-oriented approaches. Addressing what we have referred to as the *desired portfolio* approach, they expressed the attractiveness of various product-mix portfolios through Gold's measure of product-market fit (D_j, or the distance between a company's product offering and the ideal for segment *j*). They use the same basic algorithmic approach that drives the *competitive interaction* approach and forms the basis for Gold's D_j (Teach 1984, 1990, 2008).

A simulation would typically model one approach or the other, seeking to school game participants in either *product positioning* or *relationship marketing* theory, but not both simultaneously. However, there is no reason it could not do both. The two approaches could be integrated by simply weighting the desirability of each product in a segment's preferred portfolio by the relative strength of its position, as determined by the *competitive interaction* approach.

We find even greater compatibility in modeling supply-side product-mix interactions. Gold's discussion of cost is based on the assumption that production will be internal to the simulated firms (as opposed to outsourced), and that costs will be a non-linear function of amount of labor, materials, and capital equipment investment. The non-linearity of cost factors provides a mechanism for incorporating economies of scale into the cost function. In order to implement the *volume-oriented resource utilization* approach, the simulation designer need only give participants the option of sharing resources across products in order to increase economies of scale.

In concept, the *constraint-based resource utilization* approach can be implemented in the simulation by simply introducing constraints into the cost equation, either by limiting the availability of materials or labor, or by converting them to step functions through the introduction of expensive outside suppliers, the utilization of less efficient machinery, or some other plausible scenario. This would be totally compatible with the *volume-oriented resource utilization* approach.

In practice, the art of designing an effective simulation is to make it as simple as possible, while still capturing the essence of the phenomenon being modeled. Our suggestion to the simulation designer, then, would be to focus on one approach or the other, depending on the objectives of the simulation. The obvious exception would be an advanced simulation game, where participants are well versed in the theoretical bases for product-mix interactions, and the objective is to experience how they work together in a complex environment.

Our purpose here is to discuss a simple method for modeling the impact of resource constraints on product-mix interactions – for implementing the *constraint-based resource utilization* approach. In order to make our discussion more concrete, we will work backwards from a sample scenario that would illustrate the kind of constraint-based problem we might want participants to confront.

Imagine a simple case where three market segments provide demand for three products. For simplicity, assume that there is no product demand correlation (demand for one product does *not* decrease if other products are not offered). The contribution margin per unit (price less unit variable cost) associated with each product is described in the first row of Exhibit 1. For simplicity, we can assume that product prices do not vary across segments, and that the products are outsourced and purchased for an established unit cost. Both of these can be handled through Gold's (2005) standard algorithm.

A product manager using the *competitive interaction* approach would add products to its portfolio in order of product profitability (in terms of contribution margin per unit). It is evident that the most profitable product is A, followed by B and C respectively.

The rows under "Segment Information" present the quantities demanded by each segment of each of the three products. Column 5 provides the customer investment required to serve each customer segment. This investment represents fixed advertising/promotion expenses specific to and required for serving each segment. For example, a fast-food restaurant may invest fixed advertising expense targeting the "children" segment by associating a "kid's meal" with the latest children's film. Column 4 reports the total contribution margin provided by each segment. Column 6 reports the net profit provided by each

Exhibit 1:
Desired Product Portfolios with Profit Contribution by Product and Segment

	Product A	Product B	Product C	Segment Contribution	Cost to Serve	Net Profit	Input X Required	Input Y Required
Unit Contribution:	$100	$45	$30					
Segment Information:								
Segment 1	1,000	2,300	2,750	$286,000	$256,000	$30,000	13,650	9,350
Segment 2	300	0	1,000	$60,000	$40,000	$20,000	2,200	1,600
Segment 3	0	200	1,000	$39,000	$50,000	($11,000)	1,600	1,400
Resource Requirements:								
Input X per product	4	3	1					
Input Y	2	2	1					
Production Constraints:		Capacity of Input X = 15,000				Capacity of Input Y = 15,000		

Exhibit 2: Evaluating the System Constraint

	Quantities Demanded		
	Product A	Product B	Product C
Segment 1	1,000	2,300	2,750
Segment 2	300	0	1,000
Segment 3	0	200	1,000
TOTAL	1,300	2,500	4,750
Input X:	1,300*4 + 2,500*3 + 4,750*1 = 17,450 (capacity = 15,000)		
Input Y:	1,300*2 + 2,500*2 + 4,750*1 = 12,350 (capacity = 15,000)		

Exhibit 3: Evaluating the System Constraint after Dropping Segment 3

	Quantities Demanded		
	Product A	Product B	Product C
Segment 1	1,000	2,300	2,750
Segment 2	300	0	1,000
TOTAL	1,300	2,300	3,750
Input X:	1,300*4 + 2,300*3 + 3,750*1 = 15,850 (capacity = 15,000)		
Input Y:	1,300*2 + 2,300*2 + 3,750*1 = 10,950 (capacity = 15,000)		

Exhibit 4:
Desired Product Portfolios with Profit Contribution by Product and Segment

	Product A	Product B	Product C
Contribution Margin per Unit	$100	$45	$30
Input X required per product	4	3	1
Contribution Margin per unit of Input X	$25	$15	$30

segment. The last two columns summarize the total inputs X and Y required to service each segment.

Following the logic of the *desired portfolio* approach, game participants would identify the segments they wished to target, and address them by including products within the company's mix that would meet the needs of each target's desired portfolio. In our example, a product manager using the *desired portfolio* approach would choose to serve segments 1 and 2, but not segment 3 (which yields a negative profit).

Finally, the bottom rows of the exhibit report the quantities of Inputs X and Y that are required to produce a unit of each product and the input constraints the firm faces as well as the total supply of Inputs X and Y available to the firm. A product manager using the *constraint-based resource utilization* approach would follow a two-step process. First, the manager would determine the system constraint. In this example, we can calculate that the amount of resources X and Y required to service the demand for all products in Exhibit 2.

We conclude that Input X is a potential system constraint because it requires 17,450 units of Input X to satisfy all demand. However, remember that Segment 3 would not be served given that is unprofitable ($11,000 loss). Dropping the segment, we get a new constraint, as shown in Exhibit 3. We can see that Input X is still the system constraint regardless of whether we initially apply a *competitive interaction* or *desired portfolio* approach.

The second step to the *constraint-based resource utilization* approach is to calculate contribution margin per unit of constrained resource. Exhibit 4 shows the contribution margin per unit in row 1, Input X requirements per product in row 2 and contribution margin per unit of input X in row 3. Product C provides the most contribution margin per unit of Input X, followed by Products A and B, respectively. This suggests that the product manager should produce enough Product C to satisfy demand, followed by product A and B until the constrained input X is exhausted.

To put the *constraint-based resource utilization* approach to designing product-mix interactions into perspective, let's consider what managers would do if they were to focus on either profit contribution by product or by segment. Looking first at product contribution, their priority would be on Products A, then B, then C, given their profit contributions of $100, $45, and $30 per unit, respectively. This means that the production plan would include 1,300 units of Product A (consuming 5,200 of Input X) → $130,000 contribution margin. It would include 2,500 units of Product B (consuming 7,500 of input X) → $112,500 contribution margin. Finally, the remaining Input X (15,000 – 5,200 – 7,500 = 2,300) would be used to produce 2,300 units of Product C (consuming 2,300 of Input X) → $69,000 contribution margin. The total profit contribution would be ($130,000 + $112,500 + $69,000 =) $311,500. Subtracting the cost of serving each segment, the net profit would be ($311,500 – $256,000 – $40,000 – $50,000 =) a loss of $34,500.

If managers focused on profit contribution per segment, their priority would be Segment 1, with a contribution of $30,000, and then Segment 2, with a contribution of $20,000. They would not address Segment 3, with a contribution of negative $11,000. Segment 1 demand consumes 13,650 of Input X, leaving 1,350 of input X to satisfy Segment 2 demand.

Exhibit 5:

Objective Function:

Maximize Contribution Margin = $100\ A_1 + 100\ A_2 + 100\ A_3$
$+ 45\ B_1 + 45\ B_2 + 45\ B_3$
$+ 30\ C_1 + 30\ C_2 + 30\ C_3$
$-256000\ Z_1 - 40000\ Z_2 - 50000\ Z_3$

Subject to:

Demand Constraints

$A_1 - 1000\ Z_1 <= 0$
$A_2 - 300\ Z_2 <= 0$
$A_3 - 0\ Z_3 <= 0$
$B_1 - 2300\ Z_1 <= 0$
$B_2 - 0\ Z_2 <= 0$
$B_3 - 200\ Z_3 <= 0$
$C_1 - 2750\ Z_1 <= 0$
$C_2 - 1000\ Z_2 <= 0$
$C_3 - 1000\ Z_3 <= 0$

X supply constraint: $4\ A_1 + 4\ A_2 + 4\ A_3 + 3\ B_1 + 3\ B_2 + 3\ B_3 + 1\ C_1 + 1\ C_2 + 1\ C_3 <= 15{,}000$
Y supply constraint: $2\ A_1 + 2\ A_2 + 2\ A_3 + 2\ B_1 + 2\ B_2 + 2\ B_3 + 1\ C_1 + 1\ C_2 + 1\ C_3 <= 15{,}000$

Where

$A_m >= 0$ for all m
$B_m >= 0$ for all m
$C_m >= 0$ for all m
$Z_m = 0$ or 1 for all m

Producing 1000 units of Product C and 87 units of Product A for Segment 2, the segment now generates a contribution of (1000 units x $30/unit + 87 units x $100/unit =) $38,700. Subtracting the cost of service for the segment ($40,000), the result is a $1,300 loss from segment 2. The product manager would choose to only serve segment 1 demand resulting in a net profit of $30,000.

Contrast these with a throughput accounting approach. Recall that the product manager would choose to produce product C, then product A, followed by product B. Again, managers would not choose to serve Segment 3, because the potential contribution ($39,000) will never be high enough to cover the cost of service ($50,000). The manager would produce 3,750 units of Product C (consuming 3,750 of input X) → $112,500 contribution margin; 1,300 units of Product A (consuming 5,200 of input X) → $130,000 contribution margin; and 2,016 units of Product B (consuming 6,048 of input X) → $90,720 contribution margin. Total contribution margin ($112,500 + $130,000 + $90,720 =) $333,220. Net profit would be ($333,220 – $256,000 – $40,000 =) $37,220 by serving both segments 1 and 2.

The analysis becomes more complicated, but the concept remains substantively the same if labor and capital investments are considered production inputs. Labor can be constrained by labor market availability, skill development, etc., while capital investment can be constrained by capital budgets, capital accessibility, and the like. Similarly, if we allow product prices to vary across segments then contribution margin per constrained input for a given product also varies across segment. The product then becomes defined by both its production inputs and segment-defined price. Once again, the analysis becomes more complicated, but the concept remains substantively the same.

There are, of course, many ways participants might approach the constraint-based product-mix problem. Presumably, these would be covered in lecture/discussion and/or written materials accompanying the game. They would be covered again in the debriefing process.

Mixed integer linear programming is one tool that players might employ to find the profit-maximizing product mix. Mixed integer linear programs are supported by various software solutions e.g., Excel Solver, LINDO Callable Library, and What's Best, and described in prior literature (Manne 1960a, Manne 1960b, Manne 1960c, Gomory 1963, Gomory 1965). The example lends itself to such a solution.

Let A_m, B_m and C_m represent the quantities of products A, B and C to be produced for each segment m. Following the example, m can take the value of 1, 2 or 3 referencing segments 1, 2 and 3. Let Z_m be a segment integer variable equal to 1 if a segment is targeted (i.e. any amount of demand for a segment is served) and 0 if the segment is not targeted. The Mixed Integer Linear Program set up would be as follows:

The objective function maximizes the contribution of each product per segment while subtracting the customer investment required when entering a segment. The demand constraints ensure that the program does not produce more products than segment demand can support. The X and Y supply constraints ensure that the program does not consume more production inputs than are available to the firm. The final program constraints disallow negative production and define the segment integer variables.

SUMMARY AND CONCLUSIONS

At the most general level, the purpose of this paper has been to demonstrate the importance of considering alternative theories when modeling the consequences of product-mix decisions in business simulations. The traditional approach would simply add products to the simulation, each with its own demand and cost functions, leading to a corresponding profit function. If the purpose of the product-mix decisions is to address product-mix strategy, rather than simply adding complexity to the game by giving players more products to manage, a game would typically introduce some kind of constraint, such as a limit in the number of brands that may be launched, or some kind of budget constraint. This would force them to make some kind of strategic choice among products.

As an alternative, Teach (1984, 1990, 2008) offers what we have characterized as the *competitive interaction* approach. It draws on positioning theory to introduce issues of competitive encroachment and cannibalism into the product-mix decision. While this represents a major step forward in simulation design, it fails to address the growing movement toward relationship marketing, where marketers seek to lower transaction costs by providing loyal customers with shopping convenience, offering them their desired portfolios of products.

Cannon, Cannon, and Schwaiger (2006) built on Teach's positioning approach by modeling Rust, Zeithaml, and Lemon's (2000) Profitable Product Death Spiral concept. The Death Spiral drives to the weakness in the *competitive interaction* approach, explaining how the interactions in product demand distort traditional measures of a product's true profit contribution. The response – what we have referred to as the *desired portfolio* approach -- grows out of consumers' desire to purchase assortments rather than individual products. This, too, represents a significant step forward in simulation design, addressing the shift from product-centric to customer-centric marketing (Rust, Zeithaml, and Lemon 2000). However, it also signals a change in the unit of analysis that a company would use for managerial accounting, from products to customers (Cannon and Cannon 2008).

Shifting accounting focus from products to customers is strategically vital in a simulation that seeks to reward relationship marketing. However, it does not obviate the need to look at supply- as well as demand-related factors in product-mix decisions. Both the *volume-oriented* and *constraint-based resource utilization* approaches address supply-side considerations. Presumably, any supply-side considerations built into a simulation game would lend themselves to a complementary strategic response. That is, any customer-driven marketing-mix decisions would consider costs as well as customer needs. We have addressed this by defining strategic alternatives in terms of preferred product-mixes – a demand-side consideration. The strategic decision, however, is based on the most efficient utilization of constrained resources – a supply-side consideration.

In theory, relationship marketers will tend to avoid supply-side constraints by outsourcing to companies that have both robust supply capabilities and large economies of scale. If supply breaks down, particularly due to changing technology or some other factor that cannot be quickly addressed from within the company, they have more flexibility in breaking the constraint by switching to new suppliers. This suggests several alternative ways to handle constraint-based considerations in a marketing simulation:

First, the simulation can focus on long-term constraints. For instance, a simulated automobile company might take a *desired portfolio* approach to its markets, using the value of long-term customer equity to establish the relative value of the segments. U.S. government CAFE standards present average fuel-economy requirements that constitute a long-term constraint on the mix of cars the company is able to produce. This would have a dramatic impact on the company's product-mix strategy.

Second, the simulation can focus on the tension created by intermediate constraints whose resolution might lead a company away from its long-term strategy. For instance, falling demand for non-fuel-efficient vehicles might create a price inversion, where smaller, fuel-efficient vehicles actually become more expensive than their larger, gas-guzzling cousins. This could create a situation where supply-side realities argued for pursuing segments that favored larger vehicles, even though this is not consistent with the company's long-term strategic direction. If the objective of the simulation is to reward long-term strategic consistency, the simulation would need to incorporate customer-equity metrics that would help astute participants quantify the present value of long-term future profits. The game would then have to have to span a long-enough time horizon for forward-thinking students to see actual profits vindicate their approach.

Finally, the simulation can simply ignore the strategic issue. The approach we have suggested can be fit to an intermediate time frame, where the constraints are credible and binding. For instance, again using the automotive example, the game can specify constraints on volume of various models available with no further discussion. This would allow students to work out a constraint-based product-mix decision, which in itself is a worthy educational experience.

As a final comment, we should note the depth of the scratch in the hard surface of our ignorance. We have yet to explore the full range of product-mix models and how they might be incorporated into simulation games. This is not to mention explorations of how and to what extent they foster participant learning. In this sense¸ our paper is a call to arms, a research agenda whose topic is particularly relevant in a market where product-mix is becoming an increasingly important part of marketing success.

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