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AN ACTIVE LEARNING EXERCISE: SUPPLYING HOOP DREAMS*

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We describe a board game in which students assume the roles of supply chain enterprises and move game pieces (e.g., Legos, Velcro, etc.) that represent the parts of a basketball hoop. They then assemble these parts and form the final product and sell it to the customers. The game is the first of its kind to illustrate the concepts of shortage gaming, synchronization of the flow of parts, demand uncertainty and its impact on location selection, competition and cooperation, and customer service. Students playing this game build skills in both decision making and the execution of operations plans. The game also provides professionals an opportunity to visualize the new role of the operations function, and thus prepares them for the needs of today's supply chain management principles.

1. Introduction

In this paper, we describe a learning tool, a game called "Supplying Hoop Dreams" (SHD). The game can be freely downloaded from the following Web address: http://www.luc.edu/schools/business/academics/kazaz.htm. It is used to prepare students and professionals for the newest trend in supply chain management. The prevailing idea in supply chain management is to focus on a team-based competition in which companies see themselves as part of an integrated supply chain. Traditionally, companies focused on manipulating their costs by constantly negotiating with the suppliers. This technique may have allowed operations departments the immediate benefit of lower acquisition costs, yet the overall supply chain costs remain the same as the supplier commits to lower quality standards, etc. As a result, the cost to the consumer is not decreased.

The latest notion, an integrated approach, requires that enterprises make a conceptual shift with regard to other members of the supply chain. Nicholas (1998) writes that this calls for a change in the culture of an organization from the traditional approach of "negotiating" parties to the new role: "collaborating" with the suppliers. This involves including suppliers in the concurrent engineering and design of the product, in team-based quality improvements, and in an integrated supply chain perspective. Our exercise responds to the classroom need of aiding professionals in understanding what this new role requires.

One of the important contributions of the SHD Game is the illustration of all the factors that contribute to the bullwhip effect, which is defined as the inefficient management of product

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flows and inventory in the supply chain (Lee, Padmanabhan, and Whang 1997b). Concerning other games, such as the Beer Distribution Game (BDG) (see Sterman 1989), Goodwin and Franklin (1994), for example, set the foundation for understanding, but do not provide students with the opportunity to witness *all* of the factors behind this effect. Our exercise, on the other hand, illustrates all of the four primary reasons for the bullwhip effect. According to Lee, Padmanabhan, and Whang (1997b), the four contributing factors are the following:

1. *Information distortion:* As enterprises place orders, the upstream players use it as demand for its products rather than the actual sales occurring at the downstream.

2. *Order batching:* Companies engage in forward buying (i.e., acquiring more than what they need for the next time period) and allocate the fixed costs (e.g., ordering costs) to a higher number of products to obtain lower unit costs through economies of scale. Examples of this include ordering a full-truck load rather than a less-than-truck load to distribute the fixed transportation cost to a higher number of products.

3. *Price fluctuations:* Enterprises offer discounts on their products to push more products out of the inventory. However, this comes at a price: increased uncertainty in customer demand.

4. *Shortage gaming:* When retailers recognize that a distributor does not have sufficient inventory to fill the demand for all retailers, they inflate their order sizes beyond what they need. They take this conservative action, hoping that the distributor will allocate the insufficient supply in proportion to the order sizes.

Extensive discussion on the bullwhip effect can be found in Davis (1993), Lee and Billington (1992), Lee, Padmanabhan, and Whang (1997a, 1997b), and Metters (1997).

In addition to teaching all four reasons for the bullwhip effect, the SHD Game highlights several other issues related to competition among enterprises. For example, in our game there are two suppliers who provide raw materials to the manufacturer and there is a common part that can be purchased from either of these suppliers. Students role-playing these suppliers, decide on the price of the raw materials every week. This enables a "price competition" among enterprises within the supply chain. This setting motivates a postgame discussion over the subject of "competition versus cooperation." Thus, students in SHD actually have the opportunity to observe the impact of competition while recognizing the benefits of cooperation.

1.1. *Comparison of the SHD Game and the Beer Distribution Game*

In the downstream portion of the supply chain there are two retailers who compete for products from the same distributor. The demand for these retailers is not constant as in the Beer Distribution Game, and fluctuates over weeks, introducing *demand uncertainty.* Although the bullwhip effect still appears in this setting, the game motivates another discussion—the implications of the *location selection* of the distributor. We intentionally provide the retailers with negatively correlated demand to discuss the implications of correlated demand patterns on the location selection of the distributor. We use negative correlation here because of the insights it affords the distributor with regard to inventory management.

The setting of multiple retailers enables us to introduce another important issue behind the bullwhip effect—*shortage gaming*. When students role-playing the retailers recognize that the distributor has an insufficient inventory of products to satisfy the demand of each retailer, they inflate their order sizes. The rationale behind this increase in order sizes is that retailers hope the distributor will allocate the available inventory according to the percentage of the total order sizes. Students experience this phenomenon in SHD when the distributor falls short of the supply. When this is the case, students find themselves in an argument over a short supply of Legos (products), and complain about the distributor's allocation policy. This experience motivates a strong postgame discussion on how the limited supply of inventory should be allocated among retailers.

SHD teaches the importance of the *synchronization of parts flow* under the presence of unbalanced lead times. In the upstream of the supply chain, there are two suppliers (see Figure 1) that feed the manufacturer. The first supplier provides the backboard and the rim and has a 2-week lead time, whereas the second supplier is in charge of the net and the rim and has a 3-week lead time. The students assuming the role of the manufacturer in the supply chain are challenged with synchronizing the flow of parts into their facilities. The manufacturer then assembles these three parts and ships the final product to the distributor.

In the upstream portion of the supply chain, it should be noted that both suppliers provide a common raw material (the rim) and set prices every week. Therefore, the game enables students to see the impact of *price fluctuations* while creating a *price competition* among enterprises. Because suppliers do not see each other's price, they feel the pressure to decrease their prices to attract the manufacturer. Although the manufacturer is not allowed to negotiate prices during the game, this setting enables the instructor to motivate a postgame discussion about competition versus cooperation. During the game, students role-playing these suppliers view each other competitively, and continuously decrease their prices. This gives tremendous power to the manufacturer. At the end of the postgame discussion, however, both suppliers agree that, had they been cooperating, they could have made higher profits instead of leaving all the profits to the manufacturer. A detailed discussion over the subject of competition versus cooperation can be found in Fine (1998).

Each team in this exercise has the following objectives: maximize the total supply chain profit while maximizing the order fill rates. The total supply chain profit is determined by total revenue minus the sum of the costs of ordering, holding inventory, and backorders of each enterprise in the chain. The second objective relates to the customer service level, where order fill rates are the basis for performance evaluation.

The network structure of SHD is notably different from that of the BDG, in which there are four enterprises that form the supply chain: a retailer, a wholesaler, a distributor, and a factory. In SHD, however, there are two retailers who are supplied by the distributor; the

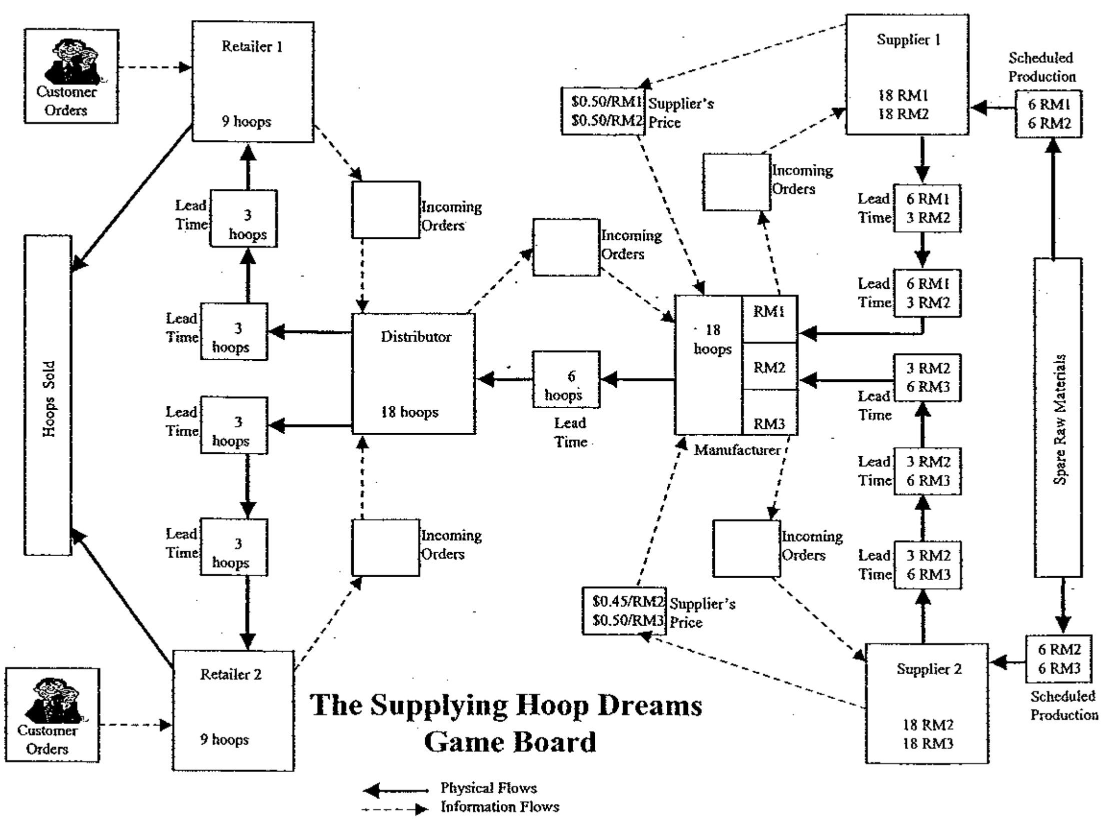

FIGURE 1. The Board of the Supplying Hoop Dreams Game.

distributor orders from the manufacturer and the manufacturer receives raw materials from two different suppliers. In total there are six enterprises each played by at least one student. Whereas the transportation lead time is a constant 2 weeks between enterprises in the Beer Distribution Game, it varies for each player in SHD. For example, the manufacturer has a 2-week lead time with the first supplier and 3-week lead time with the second supplier. Furthermore, there is 1 week of order processing lead time in the Beer Distribution Game; however, in SHD information regarding order quantities is immediately passed on to the upstream players.

Several universities in Executive MBA, MBA, and advanced undergraduate courses, as well as seminars and certificate programs for professionals, use SHD. Student comments on the game are overwhelmingly positive. Among the many benefits, they appreciate the opportunity to build decision-making skills through active participation based on real-world practice. Professors who implement the game have provided similar feedback as well. They use the exercise as a tool to motivate the pitfalls of supply chain management and to teach how these operations can be managed effectively. A Chief Information Officer (CIO) in an Executive MBAclass had played the Beer Distribution Game before and, although the Beer Distribution Game taught the value of sharing demand information, he liked the fact that the Supplying Hoop Dreams Game gave a clear example of "shortage gaming."

The paper is organized in the following manner: Section 2 describes how SHD is played. Section 3 contains the details of the lessons learned from the exercise. Section 4 provides potential variations that can be used to implement the game. Conclusions are presented in Section 5.

2. The Dynamics of the Game

In this section, we explain how SHD is played. As can be seen in Figure 1, there are six positions in the supply chain: two retailers, one distributor, one manufacturer, and two suppliers. Each of these positions can be played with preferably one (or at most two) player(s). Students are asked to form teams of six. The objective of each team is to maximize the total supply chain profit (the total of revenue minus the sum of ordering, inventory holding, backordering, purchasing, and transportation costs of all six enterprises) while maximizing their fill rates as a measure of their service quality.

The materials used in SHD include a game board (a large print of Figure 1), Legos (Velcro pieces or pipe cleaners may be substituted) with three different colors for each team, a position worksheet (see Table 1) for each player, and blank order sheets. Each color of Legos (or Velcro) represents a different raw material. When three different colors are attached at the manufacturer, the final product is produced. To eliminate repetitive setups, it is recommended that instructors laminate game boards and blank order cards. Students are asked to use nonpermanent overhead pens so that the order cards can be used again in the future. Furthermore, empty inventory and order graphs are provided for each position if the game is not played in a computer lab.

The inventory in each position is initialized as follows: 9 hoops for each retailer, 18 hoops at the distributor and 18 hoops (or 18 of each raw material) at the manufacturer. There is also an initial inventory in the pipeline: 3 hoops in each "Lead Time" square between retailers and the distributor, and 6 hoops in the "Lead Time" square between the distributor and the manufacturer. In between the manufacturer and Supplier 1, there are 6 units of Raw Material 1 and 3 units of Raw Material 2 in each "Lead Time" square. Similarly, there are 3 units of Raw Material 2 and 6 units of Raw Material 3 in each "Lead Time" square between the manufacturer and Supplier 2.

The sequence of the game requires each player to follow a four-step cycle once in every game-week. This involves receiving incoming inventory, filling orders by shipping hoops (or raw materials in the case of suppliers), recording the status of inventory and backlog, and

TABLE 1

Example Position Worksheets

Retailer 1

Week	Quantity Received	Customer Demand	Quantity Delivered	Inventory	Backlog	Order Size	Weekly Revenue	Weekly Cost	Weekly Profit	Weekly Fill Rate
1										
2										

Retailer 2

Week	Quantity Received	Customer Demand	Quantity Delivered	Inventory	Backlog	Order Size	Weekly Revenue	Weekly Cost	Weekly Profit	Weekly Fill Rate
1										
2										

Distributor

Week	Quantity Received	Incoming Order R1	Quantity Delivered to R1	Incoming Order R2	Quantity Delivered to R2	Inventory	Backlog	Backlog (R1)	Backlog (R2)	Order Quantity	Weekly Revenue	Weekly Cost	Weekly Profit	Weekly Fill Rate (R1)	Weekly Fill Rate (R2)
1															
2															

Manufacturer

Week	Quantity Received S1/RM1	Quantity Received S1/RM2	Quantity Received S2/RM2	Quantity Received S2/RM3	Incoming Order	Quantity Sent to Distributor	Inventory Hoops	Backlog Hoops	Extra Inventory RM1	Extra Inventory RM2	Extra Inventory RM3	Sup. 1 Ordered RM1	Sup. 1 Price RM2	Sup. 1 Ordered RM2	Sup. 2 Price RM2	Sup. 2 Ordered RM2	Sup. 2 Ordered RM3	Weekly Revenue	Weekly Cost	Weekly Profit	Weekly Fill Rate
1																					
2																					

Supplier 1

Week	Quantity Received RM1	Quantity Received RM2	Incoming Order (RM1)	Quantity Shipped (RM1)	Incoming Order (RM2)	Quantity Shipped (RM2)	Inventory (RM1)	Backlog (RM1)	Inventory (RM2)	Backlog (RM2)	Production Scheduled (RM1)	Production Scheduled (RM2)	Asked Price for Next Week (RM2)	Weekly Revenue	Weekly Cost	Weekly Profit	Weekly Fill Rate (RM1)	Weekly Fill Rate (RM2)
1																		
2																		

Supplier 2

Week	Quantity Received RM2	Quantity Received RM3	Incoming Order (RM2)	Quantity Shipped (RM2)	Incoming Order (RM3)	Quantity Shipped (RM3)	Inventory (RM2)	Backlog (RM2)	Inventory (RM3)	Backlog (RM3)	Production Scheduled (RM2)	Production Scheduled (RM3)	Asked Price for Next Week (RM2)	Weekly Revenue	Weekly Cost	Weekly Profit	Weekly Fill Rate (RM2)	Weekly Fill Rate (RM3)
1																		
2																		

placing new orders. In the case of the suppliers, they also submit the price of the raw materials for the next week to the manufacturer. At the beginning, the game is initialized with prices from Supplier 1 as \$0.50 for each raw material 1 and 2, and as \$0.45 for each raw material 2 and 3 from Supplier 2. It is recommended that the two retailers start the game. When the retailers finish their four-step cycle, the distributor starts his/her four-step cycle. Next, the manufacturer starts playing when the distributor completes his/her cycle. Finally, the two suppliers play their turn. On completion of the cycle by the suppliers, the game repeats the same procedure for the next game-week. This sequential play should be followed until students become familiar with the four-step cycle. Each player can then play simultaneously every week without waiting for the previous enterprise to complete his/her four-step cycle. The details of the four-step cycles for each position can be found in the description of the game.

It takes approximately 1.5 hours to complete 20 to 25 weeks. This should be sufficient to experience all possible outcomes of the game, and there is no need to complete all 52 weeks. However, informing the students that the game will end in 52 weeks will eliminate end-game effects (e.g., cases such as students not ordering to decrease their final inventory, etc.). The instructor should announce the termination of the game at the end of 1.5 hours (or earlier if all teams reach week 25).

The instructors provide the retailers with random demand. The demand is nonstationary because there is a change in the process at the end of the sixth week. During the rest of the game, it follows a stationary process. Next, the procedure that can be used to generate random demand with negative correlation is explained.

2.1. *The Procedure for Generating Random Demand with Negative Correlation*

The demand for each retailer is first generated using a discrete distribution, then a dispersion term is added (or subtracted) to create negative correlation. In the first 6 weeks, a discrete distribution for the values of (2, 3, 4) is used with the probabilities (0.3, 0.4, 0.3), whereas in the rest of the game a discrete distribution for the values of (5, 6, 7) is used with probabilities (0.2, 0.6, 0.2). The mean for these distributions, μ, is 3 and 6, respectively. Denoting the random variables generated by these processes as d_1 and d_2 for each retailer, we then check whether d_1 is greater or less than the mean. If d_1 is less than μ, then a dispersion term of $u \times 2$ is further subtracted from d_1, where u is generated using a uniform distribution between 0 and 1. The maximum dispersion is limited to 2 units and this is equal to the difference between the highest and lowest values for the discrete random variables. When d_1 is less than μ, d_2 is increased by a complementary dispersion term $(1 - u) \times 2$. However, if d_1 is greater than μ, then a dispersion term of $u \times 2$ is further added to d_1, and d_2 is decreased by $(1 - u) \times 2$. Finally, these values are rounded to the closest integer to provide integral values for the demand. It should be noted that these dispersion terms guarantee that the demand for each retailer follows negative correlation. D_1 and D_2, the demand of each retailer, can then be expressed as follows:

$$D_1 = \begin{cases} d_1 - u \times 2 & \text{if } d_1 < \mu \\ d_1 + u \times 2 & \text{if } d_1 \geq \mu \end{cases}$$

$$D_2 = \begin{cases} d_2 + (1 - u) \times 2 & \text{if } d_1 < \mu \\ d_2 - (1 - u) \times 2 & \text{if } d_1 \geq \mu \end{cases}$$

It should be noted that the means of D_1 and D_2 are still equal to μ. This process usually generates demand for retailers with 15 to 40% of negative correlation.

The implication of the negatively correlated demand on the location selection of the distributor is presented in Section 3.

3. Lessons of the Game

In this section, we present the lessons that SHD highlights. The game is designed to provide hands-on experience with the many challenges that one faces in managing the supply chain. It responds to the need students have to engage in the execution of inventory planning. Alternatives to improving the management decisions are provided for each of these problems. Students see the dangers of suboptimization on the total supply chain profits at the end of the game. They appreciate the value of team play and, in the end, find that organizations of supply chains should carry an integrated enterprise perspective rather than the traditional functional perspective.

We begin this section with a discussion on demand uncertainty and its implications on the location selection of the distributor. This is followed by an explanation of shortage gaming and the bullwhip effect. Then, the importance of the synchronization of parts flow in the upstream portion of the supply chain is described by using the unbalanced lead times of the suppliers. Later, we show the inventory, backlogging, and financial performance implications of price competition between two suppliers. Finally, we present an explanation of order-fill rate and its use as a means of performance evaluation.

The downstream portion of the supply chain, as presented in Figure 1, contains two retailers who are provided with a random demand every week. These two retailers do not communicate with each other, and thus do not know the demand of the other player. Furthermore, the demand is negatively correlated between the two retailers as described in Section 2.1. The impact of demand uncertainty combined with the distributor's location on inventory levels is explained later.

3.1. *The Location of the Distributor and its Impact on Inventory Levels*

Using the random nature of retailers' demand, the game stimulates a strong discussion regarding the alternatives for distributor's location. Inventory management principles are used to show the impact of these location choices. It should be noted that the game involves periodic review; therefore, order-up-to policies should be followed. We initiate the conversation by asking those students who played the role of the factory about their preferences with regard to the location of the distributor. We then repeat the same question to those who role-played the retailers. Students almost always prefer the distributor to be closer to their own site. In the end, students find themselves arguing on where the distributor should be located.

The nature of the demand pattern provides students with both insightful and practical solutions for the location decision by using inventory levels. We first present students the demand that occurred at each retailer. An example of a demand pattern used in one of the games is shown in Figure 2. Students recognize that, because of negative correlation, demand at each retailer shows opposite dispersion from the mean. More important, students learn that the total demand shows a variance that is smaller than the sum of each retailer's variance.

$$var\,[D_1 + D_2] = var\,[D_1] + var\,[D_2] + 2\,cov\,[D_1, D_2]$$

Because of the negative correlation, the covariance term, $cov\,[D_1, D_2]$ is negative, so:

$$var\,[D_1 + D_2] \leq var\,[D_1] + var\,[D_2]$$

When demand information is shared among enterprises of the supply chain, students see that this property can decrease the required safety stock level of the distributor. They understand that the further the distributor is located from the retailers (the higher the lead time), the higher the safety-stock commitment at the distributor and retailers. We discuss how moving the distributor closer to the retailers results in savings through the reduction in safety stocks and total inventory levels.

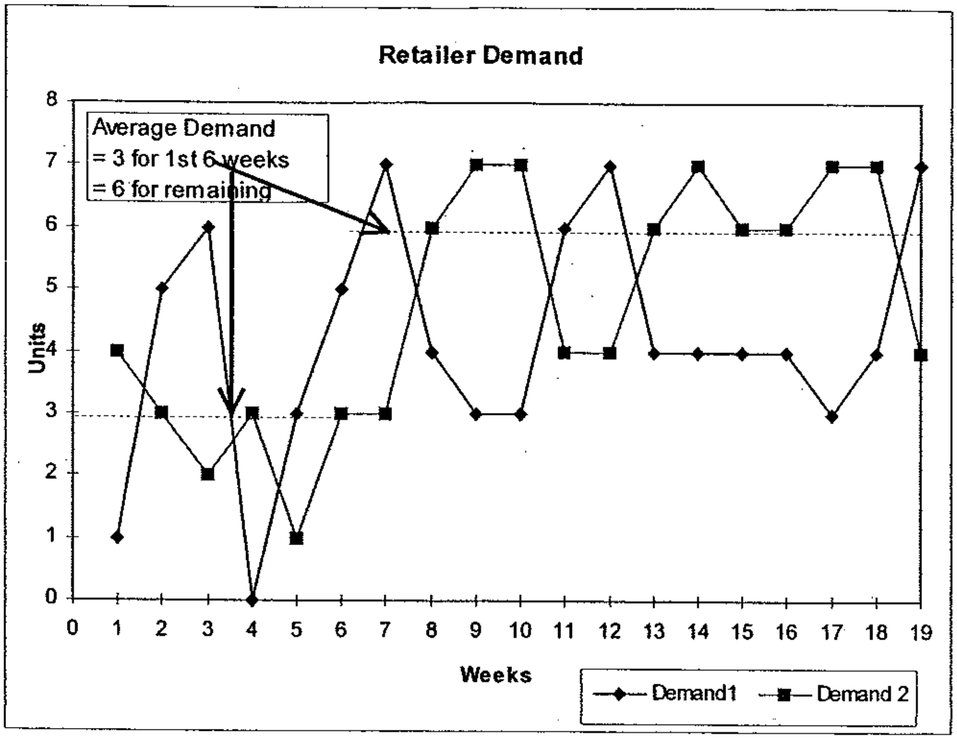

FIGURE 2. Example Graph for Retailer Demand.

The implications of the distributor's location combined with sharing demand information on inventory levels are a result of the "risk pooling effect." [A detailed discussion of inventory policies in supply chain management can be found in Silver, Pyke, and Peterson (1998, Chapter 12).] We discuss with students the case when the distributor can be located next to the retailers with no lead time in between. In this case, the distributor can deliver products instantly to the retailers in the quantity ordered while receiving an almost constant flow of products from the manufacturer. Although the distributor's safety stock increases because of increased lead time, retailers' safety stock decreases because of the immediate deliveries made from the distributor (zero lead time). The decrease in retailers' safety stock justifies the increase in that of the distributor because of negatively correlated demand. In the current setup of the game, however, the distributor is 2 weeks away from the retailers. Consequently, the amount shipped to each retailer is received in 2 weeks and usually is not equal to that week's demand because of the demand fluctuations. Students realize that such a structure causes excess inventory or backorders (when insufficient safety stock is carried at the retailers). On the other hand, they usually show a reaction to the effect of location proximity between retailers and distributor, in particular to no lead time. We then provide examples of such practices, such as Wal-Mart and Sam's Club in the same shopping mall area in the Midwest, and Jewel and Osco retail stores located next door or across the street from each other. We also describe how their warehouse (similar to the function of the distributor in SHD) is situated behind these retail stores. Students appreciate the fact that the distributor is now more flexible to alter the allocation of its inventory between these retailers.

Obviously, relocating the distributor closer to the retailers is not the only solution that improves the system performance. However, this discussion over the location also motivates the study of other solutions such as vendor-managed inventory, channel alignment, etc.

3.2. *Shortage Gaming*

The game also illustrates the concept of shortage gaming. The network structure of the supply chain with two retailers and one distributor feeding them creates a clear scenario for this phenomenon. During the game, when the distributor receives orders from retailers exceeding its total inventory of hoops, the distributor has to make a decision as to how to allocate the insufficient supply between the two retailers. In general, students playing the role of the distributor follow an allocation policy based on the percentage of order sizes received from each retailer. When retailers recognize that the distributor does not have a sufficient supply to satisfy both retailers simultaneously, they increase their order sizes tremendously to a quantity much higher than they actually need. They respond this way to influence the distributor and thus receive a higher share of the insufficient supply. In certain instances, aggressive students increase their order sizes by more than 10 times what they would order normally. We also discuss with the students how such behavior can be observed in actual practice. As stated in Lee, Padmanabhan, and Whang (1997b), Motorola experienced an increase in orders it received for its cellular phones before Christmas in 1994 because of an anticipation of shortages. Similarly, IBM experienced an unexpected increase in orders for its Aptiva PCs before Christmas of 1994. In both instances, the orders from retailers were cancelled after the Christmas holiday.

At this point in the discussion, students can learn about alternative solutions. One of the solutions recommended in Lee, Padmanabhan, and Whang (1997b) is that distributors allocate the insufficient supply according to historical sales information. General Motors practiced this solution in the past with its allocation of cars to dealers.

3.3. *Information Distortion*

The information distortion in the supply chain causes students to manage their inventories inefficiently. A common behavior is that when students are not provided with the same quantity they ordered from the upstream players, they inflate their order sizes. Upstream players, however, recognize this as a sign of an increase in demand, and thus, increase their order sizes. As a result, students experience a shortage of inventories, and incur unnecessary backorder costs. This behavior continues for 8 to 10 weeks followed by a glut of inventory in the supply chain. At this time, they incur unnecessary inventory holding costs. This is

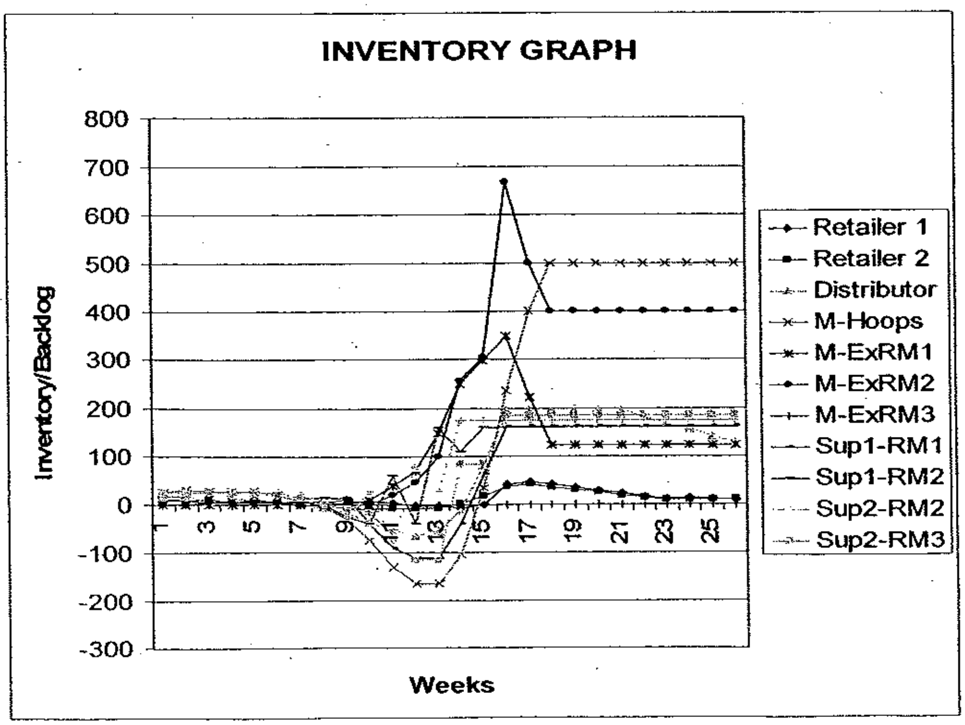

FIGURE 3. Example Graph of Inventory Levels.

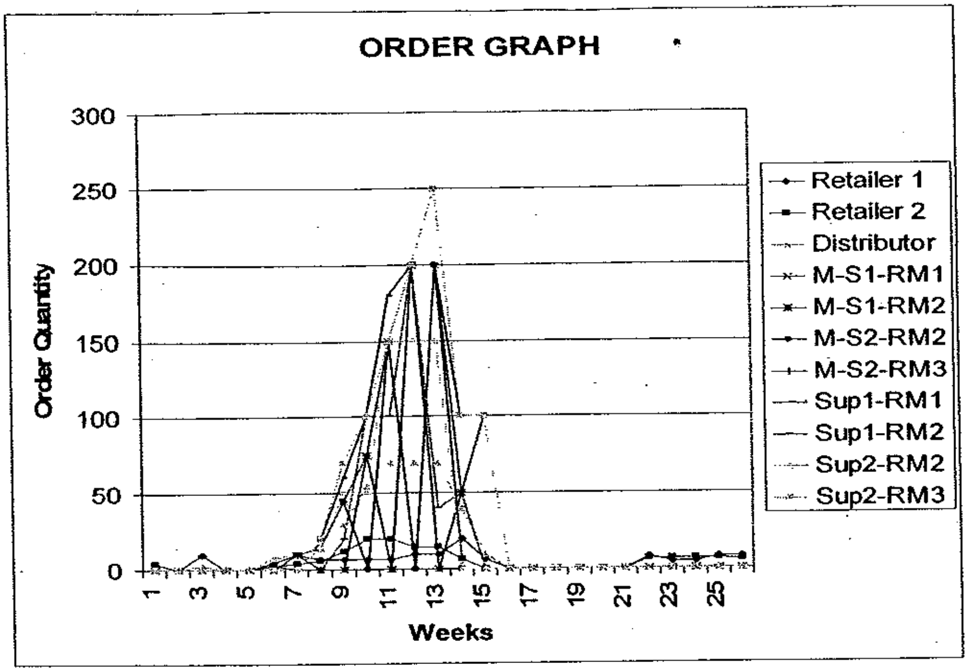

FIGURE 4. Example Graph of Order Sizes.

caused by the distortion of information in the supply chain. An example of inventory and order graphs from classroom experimentation is provided in Figures 3 and 4, respectively.

This discussion helps students understand the value of sharing demand information with upstream players. Although some students who play the role of the retailers show some resistance to such an idea at first, later they unanimously agree that communicating about demand would reduce the bullwhip effect. They learn that information sharing would benefit all as the upstream players recognize the changes earlier and respond more quickly to the downstream players.

3.4. *Synchronization of Flow of Parts into the Manufacturer*

SHD teaches the importance of the synchronization of parts flow. Given that the two suppliers have unbalanced lead times, the manufacturer needs to synchronize the inflow of raw materials. In the game, the first supplier has a 2-week lead time, and the second supplier has a three-week lead time. In most experiments, students playing the role of the manufacturer experience backorders for hoops while having inventory of (at least) one raw material. When this is the case, the manufacturer incurs both backorder and inventory holding costs simultaneously. This is usually sufficient for them to appreciate the importance of synchronization.

We then discuss how synchronization can be accomplished. We motivate the discussion as follows: suppose that a quantity of q is ordered from the 3-week lead time supplier. In the following week, the same order quantity, q, should be placed with the 2-week lead time supplier so that an equal number of parts arrive at the factory at the same time. Although the solution for the synchronization of parts flow is relatively simple, it takes many rounds of play before most of the students recognize this solution.

3.5. *Competition versus Cooperation*

SHD creates an environment where the two suppliers compete via prices to win the order of the manufacturer for the common raw material. At the beginning of the game, the manufacturer usually prefers Supplier 2 for this raw material (the rim) because of its lower price. Later in the game, when the manufacturer falls in backlog, the role-player starts ordering from Supplier 1 because of its shorter lead time. Students see the trade-off between the cost (purchasing price) and the lead times through this experience. Although Supplier 2 is the winner of the orders at the beginning because of its lower price, Supplier 1 starts decreasing its price as well, and initiates a price war. As a result, the manufacturer switches the orders from Suppler 2 to Supplier 1, and increases its order size beyond actual need. This is an example of what is known as "forward buying." At the beginning, suppliers cannot provide them with the quantity requested and fall into backlog. Furthermore, suppliers take the increased order size as a signal for increased demand. They plan their production and inventory with these numbers ending up with high levels of unwanted inventory. On the supplier end, it creates more fluctuations in demand and thus results in higher levels of unwanted inventory and backlog, and safety stock. From the manufacturer's perspective suppliers cannot provide them with the material on time in the quantity they want. These all negatively impact the performance of the chain.

3.6. *Customer Service*

SHD also emphasizes the issue of customer service. The position worksheets provided for each player in Figure 4 have a column for the weekly fill rate. Before the start of the game, fill rate is defined:

$$\text{Fill rate} = (\text{amount delivered/amount necessary to be shipped}) \times 100\%$$

The term "amount necessary to be shipped" is equal to the sum of backorders from the previous week and the demand of the current week. The distributor is specifically asked to keep track of the performance of the fill rate, separately for each retailer.

As a result of the bullwhip effect, students usually find their fill rates unsatisfying at the end of the game. This instills an appreciation for better management of customer service. More importantly, after the postgame discussion, students uniformly respond that demand information must be shared with other members of the supply chain. Furthermore, they recognize that sharing information will lead to better planning of inventory, improving fill rates, and increased customer satisfaction.

3.7. *Total Profit*

At the end of the game, students are asked to find the profit of the position they played. They first sum the costs of inventory holding, ordering, transportation, purchasing, and backordering. They then subtract this sum from the revenue they generated from sales. A good exercise is to ask students to calculate their average weekly profit of the entire supply chain. Students notice that the results vary quite drastically, and several teams post losses rather than profits. It also gives an estimate for gains from streamlining operations in the supply chain. Here, students recognize that individual performance is not as important as the overall profitability of the supply chain. This is particularly important for the professionals who play this game as it motivates the necessary changes in corporate culture. Firms such as Ford are currently trying to change the culture of their purchasing people to recognize the importance of an integrated enterprise perspective. Assessing the total profit of the supply chain, rather than that of the manufacturer, allows players to witness this impact.

4. Potential Variations and Future Revisions

This section suggests several variations of the game. The first one deals with forecasting. Students can be asked to forecast demand for the upcoming weeks and use it in their plans. Another variation includes extending the price competition to the downstream of the supply chain. However, to implement such a variation at the retailers, we need to introduce a new demand pattern that is varying by different price levels. This can be accomplished in a computerized version. Another variation can be the addition of direct transportation from the manufacturer to the retailers, with a shorter lead time at an extra cost. Such a revision would provide a springboard to understanding the impact of transportation costs on safety-stock levels and their corresponding costs. Furthermore, an addition of random exchange rates for one of the suppliers would increase the value of the game as it illustrates the issues in a global supply chain. Such an addition would enable students to see how macroeconomic factors influence the ordering/purchasing decisions and what can be done to mitigate the risks. The downside of this alternative is that it would complicate the calculations of the manufacturer and slow down the pace of the game.

Another option is to use computers to play the game rather than a game board. Although we have developed Excel spreadsheets to play SHD, we find that such an implementation does not allow students to visualize the physical dynamics of the entire supply chain. In the computer version students focus so much on their spreadsheet that they lose sight of the "big picture." The physical play of the game facilitates interaction, and students respond quickly to changes in the environment.

We are currently developing an Internet version of SHD that will illustrate a holistic view of the events and animate the flow of parts and products on the computer screen. The Internet version of the game will have several benefits: the ability to test the performance of different ordering policies, and the ability to play the game with students on different campuses, thus providing experience in managing a "global" supply chain, etc. However, this version is likely to preclude the physical interaction benefit just mentioned.

5. Conclusions

SHD has proven to be a teaching tool that is as useful as it is fun. Students enjoy the ability to visualize the supply chain, particularly the cases where they can observe the concepts learned in the classroom. These include demand uncertainty, location selection, the bullwhip effect, shortage gaming, the impact of competition and collaboration, and customer service levels.

We have received extremely positive results in all institutions in which the game is used. One Loyola MBA student wrote: "I found this (SHD) a lot of fun and useful. Active participation allowed us to see each step and the effects of each action. Very good!" Participants find the exercise to be a good simulation of real-world practices, and appreciate it as it builds skills for decision making and the execution of operations plans. Comments from written evaluations include:

"Fun, hands on learning!"

"Helped to visualize the difficulties of lead times in an unpredictable environment; showed the effects of carrying and not having significant inventory."

"Excellent hands-on tool!"

"Great—Do more with it. Most people do not understand these concepts in Supply Chain."

"Good activity to prove the point of supply chain problems."

"Excellent! It truly helps you understand the 'bullwhip effect' and the challenge of running a business with your goal of maximizing profit."

SHD can also be a useful research platform for studying managerial/purchasing behavior, an opportunity we are currently also considering.[1]

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References

DAVIS, T. (1993), "Effective Supply Chain Management," *Sloan Management Review*, Summer, 35–46.

FINE, C. (1998), *Clock Speed*, Perseus Books, Reading, MA, USA.

GOODWIN, J. AND S. FRANKLIN (1994), "The Beer Distribution Game: Using Simulation to Teach Systems Thinking," *Journal of Management Development*, 13, 8, 7–15.

LEE, H. AND C. BILLINGTON (1992), "Managing Supply Chain Inventory: Pitfalls and Opportunities," *Sloan Management Review*, Spring, 65–73.

———, V. PADMANABHAN, AND S. WHANG (1997a), "Information Distortion in a Supply Chain: The Bullwhip Effect," *Management Science*, 43, 4, 546–558.

———, ———, AND ——— (1997b), "The Bullwhip Effect in Supply Chains," *Sloan Management Review*, Spring, 93–102.

METTERS, R. (1997), "Quantifying the Bullwhip Effect in Supply Chains," *Journal of Operations Management*, 15, 89–100.

NICHOLAS, J. (1998), *Competitive Manufacturing Management*, Irwin McGraw-Hill, Burr Ridge, IL, USA.

SILVER, E. A., D. F. PYKE, AND R. PETERSON (1998), *Inventory Management and Production Planning and Scheduling*, John Wiley & Sons, New York.

STERMAN, J. D. (1989), "Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision-Making Experiment," *Management Science*, 35, 3, 321–339.

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