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# Inventory Control at Spiegel Grove

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## Abstract

Quantitative models for inventory decision making in a multi-echelon distribution system are very challenging for most undergraduate business or engineering students. To expose students to the challenges of managing multi-echelon inventory levels in an uncertain environment, we have created the Inventory Control at Spiegel Grove classroom exercise, which simulates the inventory management process for a single product in a serial supply chain. Shipments are subject to both transportation quality variability and product quality variability, and students are challenged with adjusting their levels of safety inventory appropriately without carrying an inordinate amount of stock.

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## 1. The Beer Game

The standard classroom activity used to introduce students to the complexity of managing inventory in a multi-echelon distribution network is the Beer Game, which was developed at MIT in the 1960s. By playing the Beer Game, students often organically discover the problem of order-variability amplification through the supply chain that occurs when companies plan their inventory requirements on the basis on the historical orders received from their immediate customers instead of on the actual demand from the end-users. Originally established as a manual board game, the Beer Game has been adapted into a stand-alone, computerized version (See the companion CD-ROM in Simchi-Levi et al., 2003) as well as an internet-enabled<sup>(1)</sup> version. (See Machuca and Barajas (1997) for a discussion and evaluation of a network version of the Beer Game played over the internet.) Coakley et al. (1998) and Jacobs (2000) offer the benefits and drawbacks of implementing computerized version of the game into a classroom compared with the manual board game.

Supply chain management, of which inventory management is a component, is a field of study in higher education that is often enhanced through the use of classroom exercises and games. In fact, Johnson and Pyke (2000) empirically found that the vast majority of supply chain classes utilize at least one classroom game or interactive exercise throughout the course of an academic course or semester. Simulations such as the Beer Game are also used in managerial training sessions that occur outside of academia (Goodwin and Franklin, 1994). Classroom exercises and games are effective in enhancing students' learning experience because they convey course content in a different way from lectures and discussions, create opportunities for students to experience life as a supply chain decision maker, and provide students with appropriate feedback about the effects of their decisions (Lane, 1995). Experimental studies such as Croson and Donohue (2002) have used the Beer Game to identify behavioral tendencies in managerial decision making that can create additional order variability through the distribution channel, which is also known as the "bullwhip effect" in the supply chain vernacular.

<sup>(1)</sup> <http://beergame.mit.edu/>

Johnson and Pyke also note that the Beer Game in its original form is so popular that many instructors do not use it in their classes because many students have likely played it already; this fact further suggests the need for additional supply chain simulation activities. Partially in response to this fear of repetition, many educators and practitioners have created activities that adapt the Beer Game to different industries and more complex decision environments to enable students to develop additional insights. Chen and Samroengraja (2000) discuss the "Stationary Beer Game" where students have knowledge of the underlying demand distribution used to generate customer demand in each round of the game; this information is traditionally not disclosed in the original Beer Game. Sparling (2002) details an extension of the Beer Game that requires students to produce forecasts in order to improve the performance of the supply chain. Lambrecht and Dejonckheere (1999) offer a game that examines the effects of order variability from the bullwhip effect on traditional inventory control policies such as order-up-to and echelon-stock policies. Anderson and Morrice (2000) extend the Beer Game to a service industry, specifically mortgage services. There have also been several industry-specific adaptations of the Beer Game such as Haartveit and Fjeld (2002) [forestry], Holweg and Bicheno (2002) [UK steel], Hofstede et al. (2003) [food production], and Raychaudhuri (in press) [oil].

While the Beer Game has been unquestionably successful in introducing students and managers to the complexity of managing a multi-echelon distribution network for four decades now, the traditional version of the game fails to incorporate much of the uncertainty that inventory managers face when managing stocking levels in their organizations. We have created the classroom exercise, "Inventory Control at Spiegel Grove," in order to provide students with an opportunity to experience the challenges of managing inventory when replenishments are uncertain. The two sources of uncertainty in the exercise, in addition to the Beer-Game uncertainty of inventory availability that is present without information sharing, are shipment quality and delivery performance.

The remainder of the paper is organized as follows. Section 2 provides a brief overview of the inventory exercise including the required materials for conducting it in a classroom setting. The next section discusses the pedagogical goals and objectives we had in creating the activity, and Section 4 provides some strategies

for successfully implementing the exercise. The final two sections offer some classroom experiences and student feedback as well as concluding remarks.

## 2. Activity Overview

The Inventory Control at Spiegel Grove classroom exercise simulates the distribution network for presidential medallions that are sold in the Museum Store at the Rutherford B. Hayes Presidential Center in Fremont, Ohio. The supply chain begins with a supplier, Wheeler Metalworks, that provides blank metal discs to a manufacturer, Tilden Industrial Stamping. The manufacturer stamps the President Hayes design onto the blank discs and then ships the finished medallions to the Museum Store for sale to Hayes Center patrons. Students typically assume the roles of each of these echelons in the supply chain in groups of two to four, depending on the size of the class; additional students act as transportation providers who are responsible for moving shipments of goods between the firms. One additional student is needed to assume the role of the ERP system manager who records the statistics for each round.

Each round of the exercise simulates one day of operations for each of the entities in the supply chain. Since all of the companies are located in Northwest Ohio, the (expected) lead time for all shipments is one day. Each shipment is subject to variable quality and delivery performance, and it is the responsibility of the transportation providers to draw a card for each type of variability and adjust the shipment accordingly if required. For example, the delivery performance card might say that one unit is damaged; the transportation provider would remove one unit from the shipment before delivering it. Quality cards can specify that all of the goods are usable or that one or two units are rejected due to poor quality. The transportation cards can declare that the shipment is delivered on time, that the entire shipment is delayed by one day, that one unit is damaged, or that one or two units are lost. Instructors are free to adjust the cards however they may want to include additional scenarios. A complete description of all of the activities that should occur in each round and their recommended order is provided in the accompanying teaching note.

At the end of each round, each group is required to submit an ERP update form to the central ERP system

manager that summarizes the state of that group's system on that day. These forms include space for students to record their group's closing inventory balance, daily stock-outs, and the number of units damaged and rejected during that round. The ERP system assigns costs to each of these occurrences, with the costs of each increasing as the company is closer to the customer. This follows the principle that inventory-related costs typically increase as goods move through the supply chain toward the customer because value is being added to the product at each stage.

We have included the following files as attachments for instructors' use in implementing the activity:

1. Inventory Control at Spiegel Grove Case Introduction<sup>(2)</sup>
2. Inventory Control at Spiegel Grove Teaching Note<sup>(3)</sup>
3. Inventory Control at Spiegel Grove Group Instructions<sup>(4)</sup>
4. Inventory Control at Spiegel Grove Uncertainty Cards<sup>(5)</sup>
5. Inventory Control at Spiegel Grove ERP Update Forms and Purchase Order Forms<sup>(6)</sup>
6. Inventory Control at Spiegel Grove ERP System Workbook<sup>(7)</sup>

The only additional materials that are needed for the exercise are something to represent the units. We typically use poker chips--an adequate set should be available at any discount retailer such as Target or Wal-Mart for approximately \$15-- but other items such as pennies or bottlecaps could be used as well.

### 3. Pedagogical Goals and Objectives

The main objective we had in creating this exercise was to enable students to develop an appreciation for the challenges of managing inventory under uncertainty. The implications of quality problems and delivery delays are often not considered in traditional inventory

analysis covered at the undergraduate level. The exercise requires students to devise contingency plans in order to ensure the ability to maintain customer service levels even if their supplies do not arrive in accordance with what they had expected. The frustration that students experience when problems occur during the simulation leaves a lasting impact for their professional careers and instills in them the importance of being prepared to deal with unexpected situations that will arise in their firms' supply chain operations.

The exercise also emphasizes the importance of cooperation and collaboration between supply chain partners in order to achieve excellent performance. Students see that their ability to satisfy their customers' requirements is dependent on the capabilities and performance of their suppliers as well as the transportation provider. By evaluating supply chains based on their total costs incurred instead of focusing on individual echelon performance, the activity serves as a reminder to students that the goal of effective supply chain management should be achieving channel optimality instead of localized performance measures. The students' instructions intentionally omit any discussion of the ability for different echelons to share information about inventory positions with each other. We always allow this to occur, but we make sure that the students themselves generate the idea that they could (and almost always do) benefit from communicating with each other and sharing information. Students who adopt these strategies exhibit the fact that they have synthesized previous classroom material about the basics of supply chain management and the bullwhip effect and are able to apply it to a practical decision-making environment.

The cost structure embedded in the exercise also reinforces the benefits of utilizing postponement strategies wherever possible within the supply chain. All of the inventory-related costs increase as the products move through the supply chain, which represents the fact that adding value to products also increases the inventory risks. During the course of the exercise, students often organically recognize the benefits of holding larger amounts of inventory at the raw materials stage

<sup>(2)</sup> <http://ite.pubs.informs.org/Vol8No1/DrakeMawhinney/InventoryControlatSpiegelGrove.pdf>

<sup>(3)</sup> <http://ite.pubs.informs.org/Vol8No1/DrakeMawhinney/InventoryControlatSpiegelGroveTeachingNote.pdf>

<sup>(4)</sup> <http://ite.pubs.informs.org/Vol8No1/DrakeMawhinney/InventoryControlatSpiegelGroveGroupInstructions.pdf>

<sup>(5)</sup> <http://ite.pubs.informs.org/Vol8No1/DrakeMawhinney/InventoryControlatSpiegelGroveCards.doc>

<sup>(6)</sup> <http://ite.pubs.informs.org/Vol8No1/DrakeMawhinney/InventoryControlatSpiegelGroveERPUpdateForms.doc>

<sup>(7)</sup> <http://ite.pubs.informs.org/Vol8No1/DrakeMawhinney/InventoryControlatSpiegelGroveERPSystem.xls>

of the supply chain and operating on more of a lean basis further down the channel and closer to the end customer.

## 4. Suggested Use

The Inventory Control at Spiegel Grove exercise is appropriate for any class that covers methods for inventory control. We have used the activity in upper-level undergraduate business courses such as Operations Management and Introduction to Supply Chain Management. It would also be appropriate for industrial engineering and operations research courses on the undergraduate level as well as dedicated courses about inventory control. We could envision using the exercise in a graduate business or engineering course, but such an implementation would likely also require a deeper, more thorough wrap-up session than that which we describe below for undergraduate courses.

The most natural position within the context of a course syllabus to conduct the exercise is within the course module on inventory control. Coverage of inventory control in most basic undergraduate courses is limited to single-location models of deterministic order quantities and reorder points for stochastic demand and/or lead times. Employing this exercise after the traditional single-location models provides a practical example of the issues involved with inventory control in a multi-echelon distribution network. The exercise can be used in lieu of the more complicated multi-echelon models that are often outside the scope of these basic courses. In courses that do address multi-echelon inventory control, the activity would likely provide a powerful motivation of the business conditions that necessitate the complexity of the models that will follow.

Depending on the class size, we try to set up at least two separate, parallel supply chains that complete the exercise in competition with each other. The minimum number of students required to do this is eight, but that would require that each student would perform tasks by himself instead of as part of a small group. The ideal class size for a dual-supply-chain implementation is 15 to 25 students, and we recommend creating additional supply chains for larger classes to make sure that each student has some significant responsibility during the exercise. Assigning course credit (typically extra credit points) to the winning supply

chain induces students to exert a maximum level of effort into playing the game, which increases the cognitive benefit of the activity due to the students' devoted focus.

The exercise is designed to accommodate a typical 80-minute class session, but it would also fit into a shorter 50-minute class period. It takes approximately 30 to 40 minutes to run ten rounds (days) of the exercise depending on how quickly the students catch onto the flow of the tasks they are to complete in each round. If class time is either constrained or plentiful, students could play fewer or more rounds at the instructor's discretion. (Playing more rounds than, say, 15 can start to become tedious for the students, though.) The first 15 to 20 minutes of the class is typically devoted to setting up the exercise and giving students a chance to read the case document that describes the supply chain scenario simulated in the activity as well as the group instructions prepared for their particular group. We then explain the flow of the exercise by slowly taking the students step-by-step through the execution of the first round's tasks. The remainder of the class session after the ten rounds are complete is reserved for a wrap-up discussion of what students observed during the course of the activity as well as the follow-up points provided in the attached teaching notes. Instructors should be sure to take note of any interesting behavior or phenomena that occur during the exercise for possible inclusion in the wrap-up discussion.

As we discussed in Section 3 above, students will often ask if they are allowed to talk with the other members of their supply chains or engage in some other collaborative activity that is not explicitly authorized nor banned in the activity instructions. We are encouraged when this happens because it shows that these students are able to recognize the benefits of implementing strategies we have discussed in class into a practical decision environment. As long as their suggested action is appropriate for the business scenario presented in the exercise, we allow it. At the same time, it could be instructive to restrict students' collaborative ability to emphasize the inefficiencies that can occur when companies are not able to collaborate with the other members of their supply chains.

## 5. Classroom Results

This exercise often includes a very steep learning curve for the students. They are able to understand the tasks that they are charged to complete each round, but it usually takes them a few rounds to acquire that full understanding. We as moderators pay special attention to the first few rounds and provide in-depth guidance to lead them through their tasks. The activity quickly reaches the point, however, where the students no longer need such focused guidance. In contrast to manual implementations of the Beer Game, most students understand the flow of this exercise much faster than they do in the Beer Game. (In our experiences with the latter activity, there is inevitably that one student who never does catch onto his tasks no matter how many rounds are played.)

We have used the Inventory Control at Spiegel Grove exercise and its predecessors in undergraduate business courses for several years. Student response to the activity has been overwhelmingly positive, and it is clear that the competitive nature of the exercise generates enthusiasm for inventory control, a topic that students typically find very dry and mechanical. Of course, some of this enthusiasm is undoubtedly a result of the introduction of an experiential game into the classroom to replace typical lecture and quantitative problem-solving sessions, but students also confirm that the exercise helps to solidify the topics discussed in class in their minds ("This exercise was fun, and it helped me understand inventory management a lot more. It was nice to have a break from note taking."). Most students tell us that the exercise seemed complex at the beginning, but that they caught on quickly as the rounds of the simulation progressed ("At first the game was really hard to understand/follow. However, after about the third round I really began to understand."). The fact that the students quickly attained a grasp of their responsibilities shows that they understood how goods flow through the supply chain and the role of inventory control. They also showed an understanding of important inventory concepts ("It definitely improved my understanding of how stock-outs and things like that happen."; "It's easier and cheaper for me [the raw material supplier] to keep high levels of inventory that for you [the manufacturer and the retailer] to do it.").

## 6. Concluding Remarks

Most business disciplines that fall under the scope of Supply Chain Management require that students actually experience them to develop a full understanding and appreciation for their complexities. The Inventory Control at Spiegel Grove exercise enables students to experience the challenges inherent in managing finished-goods inventory levels in a multi-echelon distribution system in an uncertain environment. By simplifying the decision scenario to include a serial supply chain for a single product, the exercise isolates the impacts of transportation and product quality uncertainty on managerial efforts to operate with a minimum level of safety inventory. Thus, this activity expands upon the concepts illustrated through the use of the popular Beer Game and provides students with an opportunity to experience additional real-world factors that complicate the inventory management process.

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