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Teaching Inventory Management Simulation Using E-Learning Software: Blackboard, Elluminate *Live!*, and Jing

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Abstract—Introducing the nuances of inventory management systems to undergraduate business students can be a daunting task. Beyond the traditional focus of the selection of order quantity and reorder point lie more murky considerations such as the impact that stockout cost and supplier selection have on these key parameters, including profit. The purpose of this paper is to illustrate how students can cultivate insights of business simulation settings through easy-to-run, downloadable Excel spreadsheet templates from within their Blackboard-driven course website beyond merely grinding out “answers.” This paper shows not only how the simulation templates are employed but also how students can use them to self-correct problems they might encounter during the learning process, how to examine more subtle issues, and how the instructor can use online software to guide students in real time, regardless of the distance that may separate them. Further, while these interactions are taking place, a video software file can be made to memorialize the online learning and can be easily uploaded to the student for their later use should they wish to practice the process. A hypothetical case example of AT&T’s management of the Apple iPhone inventory is used to illustrate the process.

Index Terms—Spreadsheet simulation, inventory management, E-Learning.

INTRODUCTION

In many real-world settings, the depletion pattern of inventories and the lead time necessary to replenish the falling stock do not follow convenient, algebraically-structured models. Instead, these variables often follow unique, random distributions that can only be defined by empirical data collection and their uncertain behavior, illustrated through simulation.

Although there are numerous simulation software products available, the proficiency needed to effectively employ them can involve a relatively steep learning curve [1, 2]. This is particularly true when it comes to a single semester or quarter QBA course offering since it is only one of the several techniques in the total array of skills to be covered [3, 4, 5, 6, 7, 8, 9]. Even though simpler simu-

lation tools such as Excel spreadsheet add-ins Crystal Ball [10] and @RISK [11] are available, neither is cross-platform and both require an additional expense to either the student or university or both.¹ Additionally, both Crystal Ball and @RISK require moderate skills to create the additional features of a discounted inventory system characterized by uncertain demand and stock lead time [12, 13, 14, 15, 16].

PHASE I—EXCEL SPREADSHEET INVENTORY MANAGEMENT SIMULATION TEMPLATE: A QUICK-CHANGE DESIGN

As an alternative to simulation software, a baseline, ready-to-run Excel inventory management template is stored at my Blackboard website that can be downloaded by enrolled students at any time and as often as needed. A version of this spreadsheet is shown in Figure 1.

There are numerous advantages to using self-contained spreadsheets. One of the most important features of this proposed spreadsheet is its ability to be quickly converted into the “next” inventory system to be simulated, e.g., the template that is, say, initially used to analyze the operation of a Pirelli Tire dealership inventory system can be easily “flipped” into a Best Buy analysis of its Canon digital camera inventory in a matter of a few minutes. Additionally, the spreadsheet has a multilevel product discount table to address the possible advantages of larger purchase quantities. A detailed description of the spreadsheet operation is given in Appendix A.

Template Input Parameters

The baseline spreadsheet template uses the following data to generate the best inventory management parameters, Q^* and R^* .²

- Product holding, ordering, and stockout costs (E9:G9)
- Four-tier supplier discount table (J9:K12) the wholesale product costs (L9:L12), and the product retail price, MSRP (M9)

¹ Some quantitative textbooks offer a time-limited version of these software. Of course, if the text is not the preferred one, few teachers will use this software acquisition option.

² The parentheses statements, e.g., (E9:G9), indicate Excel cell array addresses in Figure 1.

Day	Beg Inv, Q _i	D	End Inv, Q _i	Ave Inv, Q _{ave}	SO units	Place order?	Lead time, L	Days to receive order	Total Inv costs	Total Product Costs	Revenue	Total daily profit	
1	400	23	377	388.5	0	NO	*	*	1,943	3,725	3,220	-448	
2	377	59	318	347.5	0	NO	*	*	1,738	4,425	8,260	2,098	
3	318	86	232	275	0	NO	*	*	1,375	6,450	12,040	4,215	
4	232	77	155	193.5	0	YES	3	3	1,268	5,775	10,780	3,738	
5	155	50	105	130	0	NO	*	2	630	3,750	7,000	2,600	
6	105	77	28	66.5	0	NO	*	1	333	5,775	10,780	4,673	
7	28	59	399	398.5	0	NO	*	0	1,993	4,425	8,260	1,843	
8	399	41	328	348.5	0	NO	*	*	1,743	3,075	5,740	923	
9	328	41	287	307.5	0	NO	*	*	1,538	3,075	5,740	1,128	
10	287	86	201	244	0	NO	*	*	1,220	6,450	12,040	4,370	
11	201	41	160	180.5	0	YES	5	5	1,203	3,075	5,740	1,463	
12	160	86	74	117	0	NO	*	4	585	6,450	12,040	5,005	
13	74	59	35	44.5	0	NO	*	3	223	4,425	8,260	3,613	
14	35	50	0	7.5	35	NO	*	2	1,788	1,125	2,100	-813	
15	0	86	0	0	86	NO	*	1	4,300	0	0	-4,300	
16	400	14	386	393	0	NO	*	0	1,965	3,050	3,960	-1,055	
17	386	59	327	356.5	0	NO	*	*	1,783	4,425	8,260	2,053	
18	327	32	295	311	0	NO	*	*	1,555	2,400	4,480	525	
19	295	59	236	265.5	0	NO	*	*	1,328	4,425	8,260	2,508	
20	236	59	177	206.5	0	YES	3	3	1,333	4,425	8,260	2,503	
21	177	32	145	161	0	NO	*	2	805	2,400	4,480	1,275	
22	145	41	104	124.5	0	NO	*	1	623	3,075	5,740	2,043	
23	104	32	472	488	0	NO	*	0	2,440	2,400	4,480	-360	
24	472	50	422	447	0	NO	*	*	2,235	3,750	7,000	1,015	
25	422	50	372	397	0	NO	*	*	1,985	3,750	7,000	1,265	
26	372	86	286	329	0	NO	*	*	1,645	6,450	12,040	3,945	
27	286	41	245	265.5	0	NO	*	*	1,328	3,075	5,740	1,338	
28	245	68	177	211	0	YES	1	1	1,355	5,200	9,520	3,065	
29	177	59	518	547.5	0	NO	*	0	2,738	4,425	8,260	1,098	
30	518	77	441	479.5	0	NO	*	*	2,398	5,775	10,780	2,608	
1680										121		Mean daily inventory profits =	1,798
												Service Level =	0.928
												% of "Loss" days =	16.667

Figure 1. Excel 30-Day Baseline Inventory Simulation Template (Q=400, R=200)

- A specific combination of order quantity, Q (G11) and reorder point, R (G12)
- Data sets for the samples of random variables product demand, D, and supplier lead time, L are organized into probability distributions that are used to randomly generate values of D and L during the 30-day simulation.³

Template Output/Performance Parameters

The simulation is initiated by using the calculate command: F9 for Windows or ⌘ = for Macintosh. The 30-day business cycle is then automatically replicated 200 times for 25 specific Q-R combinations.⁴

1. The five (5) Q-values selected are “edge” values of the discount table: the lower limit values for the four price breaks given in cells J9:J12 plus the largest value of the fourth break, K12.
2. In turn, each Q-value is paired with five (5) reorder point values, R, equal to 10, 30, 50, 70, and 90 percent of the Q value, e.g., the template values of Q=200, 300, 400, 500, and 600 are each examined with corresponding R values of .10Q, .30Q, .50Q, .70Q, and .90Q.⁵

These baseline parameters are quickly “changed-out” or “flipped” with the result that the baseline inventory system is painlessly transformed into a completely fresh product simulation. It usually takes students less than two 90-minute class sessions to effectively manipulate the baseline model template. In two more sessions, they have

³ The probability distributions are used to construct a VLOOKUP table that imitates the behavior of the empirical data collected for demand and lead time.

⁴ Later, the influence of replications on the level of confidence and the tolerable error of the simulation are reviewed.

⁵ As an example, an order quantity of Q=200 units will be automatically replicated with R combinations of 20, 60, 100, 140, and 180 units.

gained a level of comfort with changing the baseline spreadsheet values to accommodate a different product and to generate new inventory system parameters. They can see the baseline template mean daily profit of about \$2,200 per day for a Q-R combination of 500 and 175 units (Figure 2) transformed into the AT&T iPhone spreadsheet that produces a daily profit of approximately \$22,700 for a Q-R combination of 3,000 and 1,500 units, respectively (Figure 3).⁶ The 200 “flip” replications of all 25 Q-R combinations are completed in less than 2 minutes.

By reducing the need for number grinding, using overly simplified algebraic inventory models, or employing dedicated simulation software of any kind, the student is now able to shift attention to more non-traditional inventory management considerations discussed next.

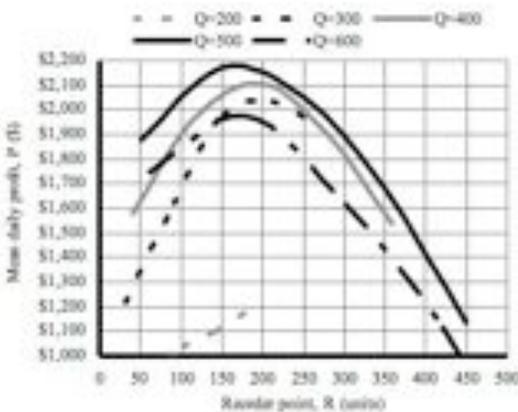


Figure 2. Baseline Excel Simulation Template Mean Daily Profit (stockout cost=\$150/unit).

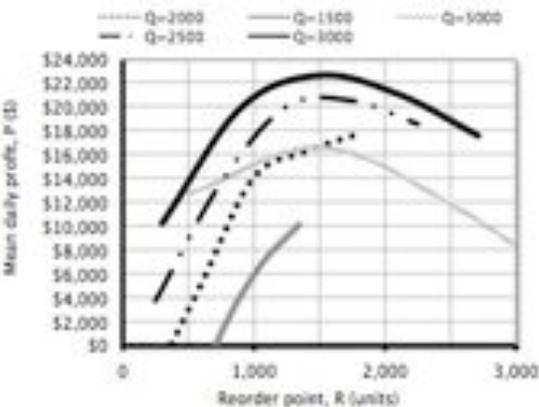


Figure 3. AT&T-iPhone Inventory Simulation for Mean Daily Profit (stockout cost=\$400/unit)

⁶ The selection of the three output performance factors of service level, mean daily profit, and percent of “loss” days is arbitrary. The spreadsheet can be easily modified to look at other criteria such as number of monthly orders placed, percent of time profit exceeds or falls below a specified amount, etc.

PHASE II—EXPLORING BEYOND THE BASICS OF INVENTORY MANAGEMENT: CONNECTING REAL WORLD IMPACT

The employment of our simple, Blackboard-posted, Excel spreadsheet template provides students with a quick and easy way to manipulate numerous inventory system elements and to quickly see how these changes alter system performance. The traditional, fundamental issues such as, “How many units should we order and how far do we let our supply fall before placing a new order?” are easily determined and allow more sophisticated topics to be covered. Here are a few examples of these issues and student responses:

Q1. “Lost sales resulting from inventory shortage is a significant concern of inventory management [17]. What if management is unable to agree on assigning a value to stockout cost? Help them determine what influence, if any, this highly subjective parameter has in determining the inventory system parameters, i.e., order quantity, Q^* and reorder point, R^* . Also, is there a significant impact on the mean daily profit, P ?”

Response: As stockout cost increases from \$0 to \$1,000, the average daily inventory profit drops from about \$27,300 to \$20,200, respectively (Figure 4). This makes sense because higher shortage penalties will never help profits. Over this same range of stockout cost, the best order quantity remains constant at 3,000 units while reorder point increases from 900 to 2,100 units (Figure 5). This makes sense also because higher reorder points will generally make it less likely to experience stockouts.⁷ This impact becomes increasingly pronounced as stockout cost increases.

Q2. “Can you suggest why factions of management might disagree on the “pricing” of stockout cost? What are a few scenarios that could support a high or low stockout cost pricings?”

Response: If AT&T management views the iPhone as a disruptive technology—a product that is distinctly innovative and currently dominates the marketplace—then low stockout costs are defensible. Why? Because if the buyer wants the product, AT&T is the only “show in town”, i.e., only they sell it. On the other hand, if AT&T feels that even though the iPhone is a strong product, the market place of other PDA-type cell phones is so competitive that a buyer would likely purchase another product—such as a Blackberry from Verizon—the loss would include not only the price of the cell phone sale but would also consist of the revenues lost from the typical two-year user contract and word-of-mouth ill-will. This

⁷ Regardless of order quantity size.

loss could amount to well over a \$1,000 stockout cost. For sake of argument, let's say that management believes the competition places the stockout cost somewhere closer to the \$400 price of the product. If we use this assumption, Figure 5 supports the selection of a reorder point of approximately 1,650 units to compliment the 3,000-unit order quantity.

Q3. "Suppose that AT&T is concerned about Apple's history of product delivery problems [18]. AT&T then asks Apple if a faster delivery alternative is available. In response, Apple offers AT&T a faster lead time but increases the order cost for each iPhone unit from \$4.00 to \$10.00. Is the higher premium justified?"

Response: In order to see if the more costly, shorter lead-time is justified, we need to rerun the simulation using the shorter lead-time distribution and, additionally, increase the order cost to \$10. In fact, if we don't want to assume that management will agree on a specific stockout cost, then the entire range of stockout cost values between \$0 to \$1,000 per shortage unit will need to be reassessed as well. These findings reveal that unless a very low stockout cost of no more than \$50-60 is agreed upon, the faster, more expensive delivery option will deliver consistently higher daily profits (Figure 6).

PHASE III—MEMORIALIZING THE LEARNING WITH ELLUMINATE *LIVE!* AND JING

Synchronous E-Learning

Traditional office hours are used to supplement the class meetings. Additionally, internet-hosted, or synchronous learning tutorials that includes live, online support via a virtual meeting room, are also arranged for those students not able to attend the regular office sessions. Elluminate *Live!* is a web-hosted environment that helps the teacher to create a real-time, interactive, virtual office space with both audio and visual conferencing, a shared whiteboard

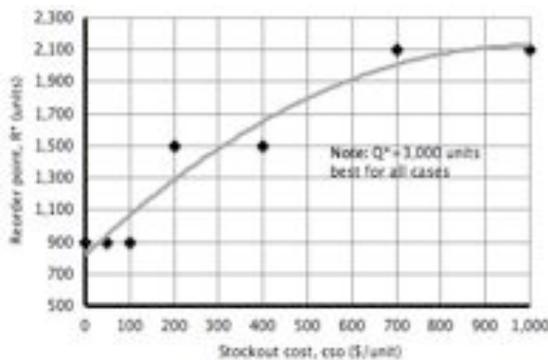


Figure 5. Influence of Stockout Cost on Reorder Point, for AT&T iPhone Inventory

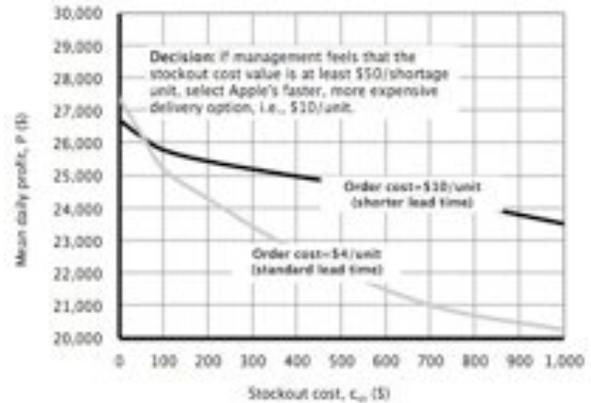


Figure 6. Comparing Standard Versus Premium Apple Delivery Options for AT&T iPhone

to conduct "work," and the ability to share applications [19]. Regardless of where students are geographically located, type of computer operating system used, or internet connection, the instructor can interact with one, two, or dozens of students in the Elluminate *Live!* virtual office called a vRoom. A typical session is set up like this:

1. After the instructor (moderator) signs into the Elluminate *Live!* website, a java script is downloaded onto his/her desktop. Opening the script starts the Elluminate *Live!* session that creates a virtual meeting room, complete with audio and visual access controlled by the moderator. This step takes about 90 seconds.
2. The moderator then posts the Elluminate *Live!* link at the Blackboard course website and either group emails all course-enrolled students or selectively invites a particular group of students if it is a special session. Participating students will simply click the link, a java script immediately downloads onto his/her desktop, and the session begins.
3. Each student has an inexpensive microphone and a headset to contribute and listen to other members in the session. Elluminate *Live!* also walks the student through an audio check to insure that microphone and headset settings are acceptable.

Visual access to a "white board" or the host's desktop is the key to the session: it becomes the "live" demonstration of any features that students may have been experiencing problems. The moderator chooses which tools to use to visually support the subject of the conversation. This could include a white board presentation using drawing or graphing tools, a PowerPoint presentation, a Wall Street Journal article downloaded from the WSJ website to review together, or an Excel spreadsheet demonstration on building and formatting scatter diagrams

The students sees, in real time, how the teacher manipulates a particular task and can ask questions regarding any unclear steps (Figure 7).⁸

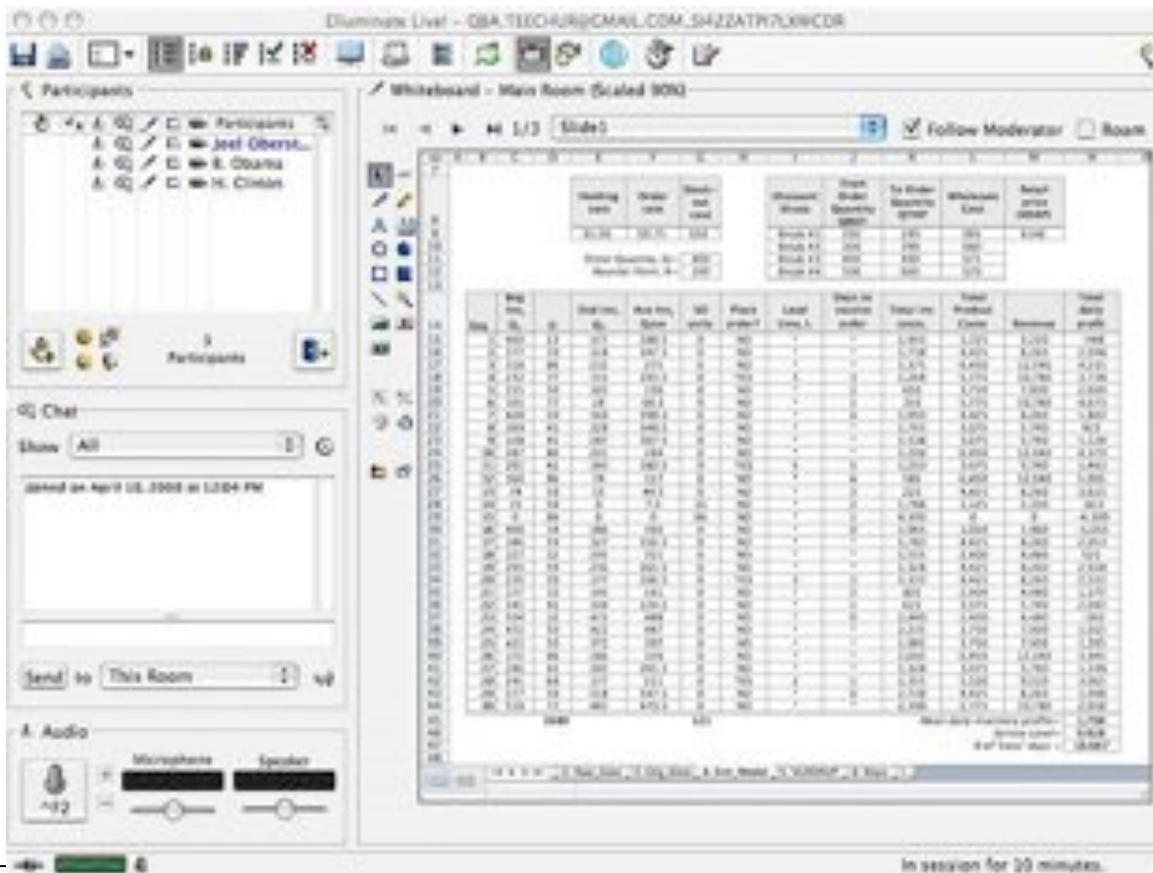
Asynchronous E-Learning

In order to further accommodate students who may not be able to attend a vRoom session, or even for those that would like to be able to review the tutorial content “anytime, anywhere,” step-by-step, video clips of the more challenging operations are made and saved in a file that is stored at the Blackboard course website, e.g., charting skills, developing the random variable probability distributions, recording the replications, defining the confidence interval of the simulation, etc. The asynchronous software product used to record the video is briefly discussed next.

Jing is an audio and video screen capture tool that can be used to transparently record either the entire tutorial session or portions of the session [20]. The recording is saved so that it can then be shared with the student by either emailing the URL of the saved recording or posting

it to the Blackboard website (or both). A screenshot of one these videos—in this case, the live Excel 30-day simulation template—is shown in Figure 8.

The process is similar to using TIVO to record television programs for viewing at a later date. The student now has unlimited access to the “tutorial” and can practice the skills as often as desired. A particularly valuable feature of this process is that even students who are not highly interactive, who prefer to sit back during these sessions, can watch and reexamine specific tutorials created including those that they did not attend in any setting they wish. All of these tutorials are saved in a tutorial library and are downloadable throughout the course (Figure 9).



⁸ Any participant may interact with the Elluminate vRoom White Board with Excel Simulation Template on Host Desktop.

are “raising their hand” in the session—a necessary courtesy so all questions and answers can be heard and understood without being trampled over.

⁹ Refer to 30-day Excel spreadsheet in Figure 1.



Figure 8. Jing Inventory Tutorial of 30-Day Inventory Operation

SUMMARY

The standard collection of methodologies offered in an undergraduate quantitative business analysis course makes the time open to cover any single topic tightly compressed. Arguably, inventory simulation is one of the more challenging skills and begs the need to find creative ways to effectively teach this subject in the very limited time available. In order to accomplish this task, e-learning software products Blackboard, Elluminate *Live!* and Jing are woven into the course fabric to create extended, interactive online classroom learning opportunities called vRooms. In turn, students have the choice whether to be either an interactive member of the vRoom session or to be a “viewer.” Regardless of whether they are active participants, the sessions are recorded in short videos that illustrate the computer procedures used, including every mouse click, screen, pull-down menus—everything! The videos are saved, stored at the courses Blackboard website and can be downloaded, reviewed, and practiced by the student at any time. Together, the collaboration of teaching method and software are integrated to make the learning process less intimidating for the student and, of no minor importance, fun for the teacher. Possibly of even greater importance, the process diffuses the more laborious traditional computational component of the topic and instead allows for greater exploration of more sophisticated issues than is typically covered during more common exposures to inventory management.



Figure 9. Jing Inventory Simulation Video Library

Finally, even though this paper focuses on undergraduate university students, the e-learning process described is equally applicable to a professional, workplace setting. At the end of the day, there little difference between a student who needs to demonstrate an understanding of course materials and a corporate employee who is expected to apply new skills gained from an in-house training workshop to his/her occupation. Far more important than any difference between audiences are the e-learning methods used in both the delivery and continued accessibility of the study materials.

LIST OF SYMBOLS

Q	Order quantity of product (units)
R	Reorder point (units)
Q*	Best order quantity (units)
R*	Best reorder point (units)
Q ₁	Beginning inventory (units)
Q ₂	Ending inventory (units)
Q _{ave}	Average inventory (units)
SO	Number of stockout/shortage units
D	Daily demand (units)
L	Order lead time (days)
c _h	Per unit holding cost (\$/unit/day)
C _h	Total holding cost (\$)
c _o	Per unit order cost (\$/unit/order)
C _o	Total order cost (\$)
c _{so}	Per unit stockout cost (\$/unit)
C _{so}	Total stockout cost (\$)
C _t	Total inventory costs (\$)
c _w	Wholesale product cost (\$/unit)
C _w	Total product cost (\$)
MSRP	Manufacturer suggested retail price (\$/unit)

R_s Daily revenue (\$)
 P Total daily profit (\$)

8. Total daily profit $P = R_s - (C_h + C_{so} + C_o + C_w)$, e.g., for day 1, $P = 3,220 - (1,943 + 0 + 0 + 1,725) = -\448 .

APPENDIX A. EXPLANATION OF EXCEL INVENTORY MANAGEMENT TEMPLATE EVENTS⁹

1. The beginning inventory, Q_1 , is reduced by the demand for that day, D , if there is sufficient stock, ending the day at Q_2 . If there is insufficient stock to cover the daily demand, a shortage of SO units will be experienced of $SO = D - Q_1$. For day 1, $Q_1 = Q = 400$ units, $Q_2 = Q_1 - D = 400 - 23 = 377$ units. (The reorder point used for this simulation is $R = 200$ units.)
2. The average inventory level, $Q_{ave} = (Q_1 + Q_2) / 2 = (400 + 377) / 2 = 388.5$ units, is used to determine the holding cost component for that day, i.e., $C_h = c_h \times Q_{ave} = (5)(388.5) = \$1,942.50$ or \$1,943; if there is a shortage for the day, there would also be a stockout cost calculated, $C_{so} = c_{so} \times SO = 50 \times SO$, e.g., the first shortage of 35 units occurs during day 14, resulting in $C_{so} = c_{so} \times SO = (50)(35) = \$1,750$. The additional holding costs occurring during day 14 are $Q_{ave} \times 5 = (15 + 0) / 2 \times 5 = \37.50 . No product was ordered, so the total inventory costs for day 14 is $\$1,750 + \$37.50 = \$1,787.50$ or \$1,788.
3. A new order of Q units will be placed if the ending inventory at the end of the day does not exceed the reorder point, R , i.e., if $Q_2 \leq R$, an ordering cost of $C_o = c_o \times Q$. The first reorder launched occurs at the end of day 4 when the stock level drops below 200 units for the first time. The order cost component charged for this day is $C_o = (.75)(400) = \$300$. Since the holding cost for this day is $(5)(193.5) = \$967.50$, the total inventory costs for day 4 is \$1,267.50.
4. If/when a new order is launched, the lead time, L , will be randomly generated and the days to receive the new order will count down over L days. On four (4) occasions during this 30-day period—days 4, 11, 20 and 28—the inventory level dips below 200 units and new orders are placed. These are the only days that will have an order cost component (and the only times during which stockout costs can accrue).
5. The total inventory costs are calculated for each day, i.e., $C_h + C_{so} + C_o = Q_{ave} \times c_h + c_{sob} \times SO + Q \times c_o$.
6. Total wholesale product costs, C_w , are calculated using the demand satisfied during the day, i.e., $c_w \times \{D, Q_1\}_{min}$, e.g., for day 1, 23 units are sold and $C_w = c_w \times \{D, Q_1\}_{min} = (75)(23) = \$1,725$, where $c_w = \$75$ per unit based on the third price break tier.
7. Daily revenue, R_s , is calculated for total units sold based on retail sales price, MSRP, i.e., $MSRP \times \{D, Q_1\}_{min}$, e.g., for day 1, the same 23 units sold will generate revenues of $R_s = (23)(140) = \$3,220$.

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