Modeling and teaching inventory management in multiplayer supply chain competition game using Excel and Google Sheets

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Abstract. A modification of the well-known beer distribution game is proposed for teaching supply chain management. The novel feature is utilization of spreadsheets in a multiplayer mode which could help achieve: easy setup and intuitive interface; possibilities of playing locally or via internet in a single or several computers; incorporation of financial parameters for learning inventory control from accounting perspective. An additional option is a simulation of a simple competition between two supply chains. Simulation sessions set minimum requirements towards staff, software, and equipment. Outputs can be immediately made available for demonstration in a classroom by means of graphs and tables. Results of simulations could be particularly suitable for showing bullwhip effects.

Keywords: Simulation games, Engineering education, Supply chain management, Beer distribution game.

1. INTRODUCTION

Applications of simulation games in engineering education have been growing recently with development of information and communication technology which might bring numerous benefits for both academic and business sectors (Deshpande and Huang, 2011). One important area of industrial engineering, supply chain management, has a particularly long tradition of using simulations in education exemplified by beer distribution game (hereinafter referred to as *the game*). The original beer distribution game was first introduced at MIT in the early 1960s and soon became a popular tool not only for explaining but also simulating dynamics of supply chain (Sterman, 1989). Bullwhip effect or increase in variability of orders at upstream stages of supply chain, as one of the main experimental results of the game, was subject of important academic studies (Lee et al., 1997). Many modifications of the original game were proposed to address issues such as difficulty of setup and restrictions on stages and area of application (Simchi-Levi et al. 1999; Anderson and Morrice, 2000; Jacobs, 2000; Holweg and Bicheno, 2002; Sparling, 2002). Despite significant improvements with each subsequent versions, the game implementations are still hindered in many cases by difficulty of setup and implementations, particularly in multiplayer settings. We propose a new version of the game: Supply Chain Competition Game (hereinafter referred to as *the new game*) as a modified version of the beer distribution game for teaching concepts of supply chain management for teachers, students, practitioners. The objective of the new game is simulating supply chain completion with minimum setup efforts. We also show possibility of using the modification of the base version of the new game for online use in Google Sheets. The new game is made freely available for download and unlimited use through the following link in a publicly accessible website: https://sourceforge.net/projects/scmcompetition/

2. DESCRIPTION

The new game models four-stage supply chain (one or two supply chains) consisting of a retailer (R), a wholesaler

(W), a distributor (D) and a factory (F): Figure 1 shows the structure which is common for the new and previous versions of the game. Make-to-stock (MTS) inventory system is used at each stage. Backorders are allowed at a shortage cost. There is a holding (carrying) cost for each unit of inventory and also order setup cost for each order. Additionally, there are fixed costs per period, sales prices and purchasing costs for each player. Lead time is assumed to be two periods and there are 12 periods in total per each game session. Except for the number of periods and some costing parameters, these abovementioned settings are all standard for most of the game versions available.

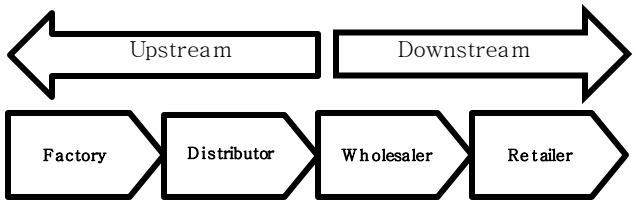

Figure 1: Supply chain structure.

The base version of the new game is made in a format of Office Open XML Spreadsheet (.XLSX) file format which can be opened with common spreadsheet software including ubiquitous MS Excel. This spreadsheet is offered without protection initially; consequently users are capable of administrating relevant protection (for instance, password-protected sheets for players) and modifying important structural parameters of the spreadsheet such as lead time. In the next section, we will describe an online version of the new game using Google Sheets service.

Distinct feature of the game is utilization of spreadsheets with conditional formatting of the cells which allows achieving the following.

- easier setup of multiplayer games and an intuitive interface;
- possibilities of playing locally or over a network via internet or local area network (LAN);
- incorporation of financial parameters for learning inventory control from accounting perspective;
- option to simulate a simple competition between two supply chains;
- minimum requirements towards staff, software, equipment and additional materials.

Technical requirements are as follows.

- MS Excel 2007 (or an open-source alternative such as OpenOffice / LibreOffice) and higher versions.
- One computer is required for a *full information* gaming mode where all players are aware of final customer demand and how much others order.
- For a *limited information* gaming mode (where each player is only aware of orders from the next downstream player) requirements would be higher: at least four (for a single supply chain) or eight (for two supply chains) computers or tablets so that there is one computer for each player; and separately one computer for teacher in the classroom. In case number of players exceeds the number of available computers, assign two or more players to some computers.
- (for a game over network) Internet or LAN connection with administrative rights.
- (optional) software such as “Connectify” or "My WiFi Router" for an easy setup of Wi-Fi enabled network between laptop computers or tablets.
- A projector or a large-screen screen would be desirable for showing final results to all users.

One person in charge of conducting a game session (referred to as *instructor*) and four persons playing the game (referred to as *players*) together represent the minimum staffing requirement. In order to achieve our objective of maximum simplification of setup of the new game, as compared to traditional game versions, we decided to use conditional formatting on decision forms (Figure 2) for sheets of players R1, W1, D1, F1, R2, W2, D2, F2. Cells in the forms are formatted to become visible or invisible for players depending on active period and order so that players can focus on what is the most important at the given moment.

Instructor can control workflow of the game through a respective sheet of control panel (sheets 1 or 2 depending on the number of supply chain) where main parameters and performance of each player are easily accessible (Figure 3). Customer demand (final demand) can be selected for each period in a separate *GenerateOrders* sheet by instructor so the overall demand is either deterministic or stochastic (Figure 4). Automatically updated graphs at each sheet help grasping key indicators of performance for instructor and players at any moment. We believe that all of the abovementioned features is a contribution to advance the game further in direction of ease of use which is important for practical applications in classrooms.

3. HOW TO CONDUCT THE GAME

Step-by-step guide on conducting the game is given in the Table 1 which shows the sequence of instructor’s activities. For record keeping and easier reset, it is better to keep initial starting version of spreadsheet and make a separate copy of the file for each game. Game sessions could be conducted over several days in different demand patterns and information modes and after teaching new inventory control techniques. For instance, players could be taught importance of information sharing among supply chain members after conducting two games in full and

limited information modes and comparing results with the classroom. Teaching newsvendor model concepts using generation of normally distributed demand over several sessions is another example of using the new game for learning by doing.

Table 1: Sequence of activities for instructor

Step	*Description of activity*
1.	Create a separate copy of spreadsheet for each game and save it for record keeping purposes later. Set the main initial parameters (initial inventory, price and costs) at sheets "1" and "2". Enter arbitrarily for each period or generate demand (For network game) set up LAN or internet connection to all computers. Upload and open the spreadsheet to open access in local area network (or Google Spreadsheets in internet).
2.	Restrict access to sheets "1" and "2" to all players (this is enabled in settings of both Excel and Google Spreadsheets).
3.	Set up access of each player to corresponding sheet according to his or her role
4.	Open access to the spreadsheet (or share and show the link in internet) for 4 computers of players in single supply chain game and for 8 computers in two supply chain game, instructor should have one computer for control of entire game and showing results to players.
5.	Explain rules to the classroom as follows. Each player should follow the following steps in each game period: 1) Wait for the *Current Order* from upstream player to be announced. 2) Press "*Save*" 3) *Enter Your Order* (below under the current entry period). 4) Press "*Save*" and announce that you entered your order so that downstream players can check it. Warn players to never change previously entered orders and avoid negative or unrealistic numbers in order not to disrupt the game. Ask to closely pay attention to the most important parameters like service level (SL),inventory costs, profit margin, current inventory and shortage
6.	Conduct the game, monitor observance of rules, especially that players do not modify already changed cell values.
7.	Upon finishing the last period, discuss results with the class (desirably through graphs and using projector), particularly bullwhip effect and possible use of inventory models to improve performance. If this is a 8-players game, emphasize market share competition. Consider some reward for winning players or teams.
8.	Analyze results after completion of class and consider replaying the game in subsequent classes after students learn another inventory control technique (EOQ, linear programming, newsvendor, base-stock) to see how their performance may improve.

4. SIMULATION OVER NETWORK

The original MIT game was multiplayer in nature. Including more players can bring many benefits for learning. For multiplayer versions setting a network is a complicated but necessary task. Conducting the beer distribution game in a network has never been an easy task and several versions of the game were proposed to this end (see authors mentioned in Introduction section). The new game further makes an effort to make setup of a network-based game as easy as possible in classrooms. It also provides an option of conducting a multiplayer game in full information mode using a single computer offline. After fulfilling technical requirements for a network described in Table 1, instructor has to actually share Excel spreadsheet via LAN, by enabling *Share Workbook* option (on the *Review* tab, in the *Changes* group). In the same download webpage, there is a simplified version of the new game which could be uploaded to Google Drive and then used directly in Internet using Google Sheets service. This is a reduced version of the base (Excel) version with only one supply chain of four players and limited costing parameters. This simplification was made to avoid frequent crashes when opening the spreadsheet online. Setting online user rights would be needed for a Google Sheet. To summarize, multiplayer game offers the greatest potential of effective use of the game. Still, implementing the new game over network requires careful preparation and still remains complicated in the new game. One issue still remaining with implementation of the multiplayer game is the constant need for instructors and players to update / save respective sheets after each action. Nevertheless we hope that our approach is likely to be easier and quicker to implement for many users than with available alternatives.

5. CONCLUSION AND FURTHER WORK

We develop a new version of beer distribution game for teaching concepts of supply chain management for teachers, students, practitioners. The novel feature is utilization of spreadsheets in a multiplayer mode for easy setup and intuitive interface. There is an option of simulating a simple competition between two supply chains. The new game can be played locally and via a network. Our future work would focus on experimentally testing the new game in a classroom environment and preparing surveys of users for empirical support of effectiveness of the new approach and further improvements. Another aspect is working on implementation of easier workflow for the multiplayer game over a network in a manner that there is less need for the constant updating and saving of respective sheets after each action.

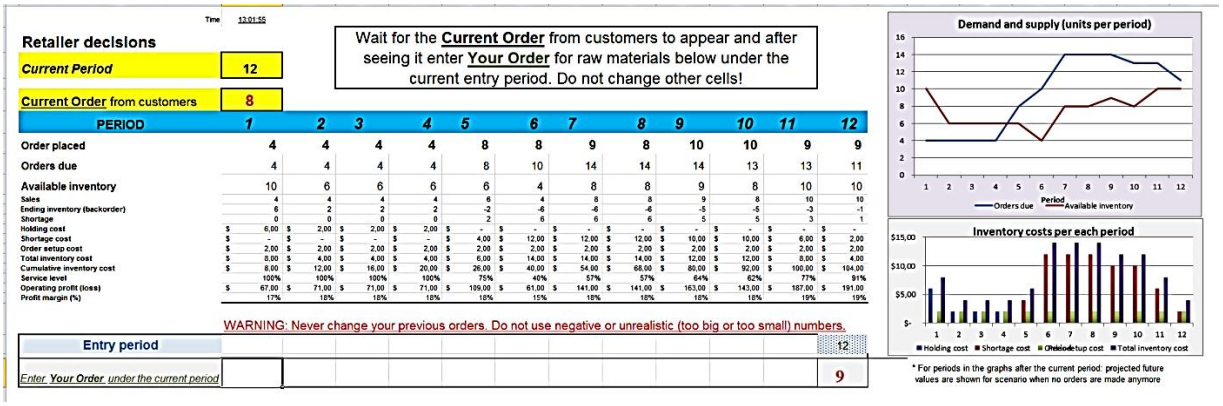

Figure 2: Decision form for each player and output tables and graphs (wholesaler sheet)

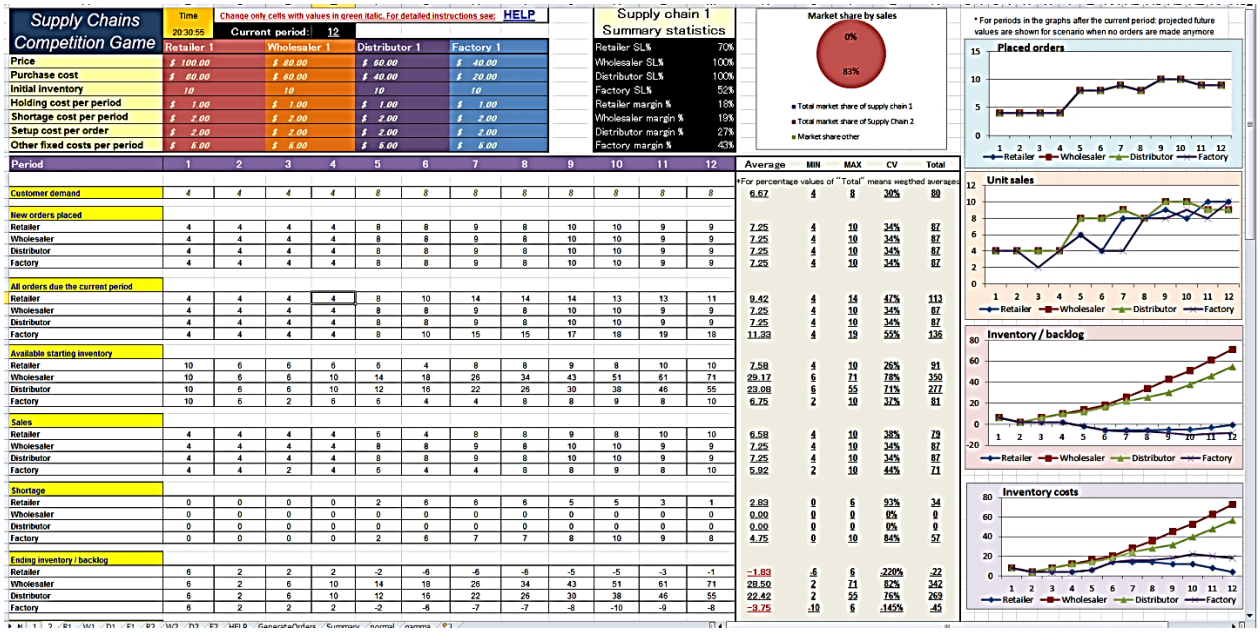

Figure 3: Control panel of instructor where cost parameters can be set

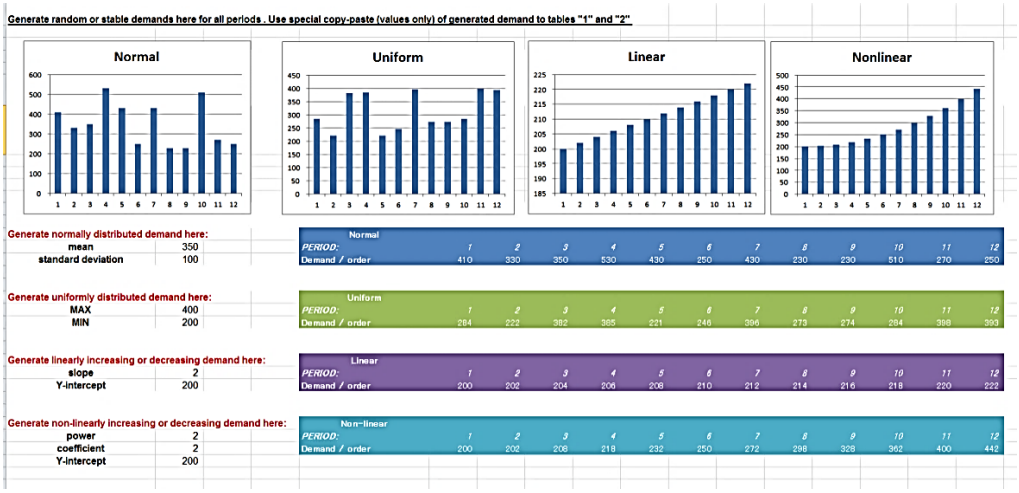

Figure 4: Generation of deterministic or stochastic customer demand

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