THE BEER GAME,
AN IMPLEMENTATION FOR USE OVER THE WEB

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THE BEER GAME, AN IMPLEMENTATION FOR USE OVER THE WEB[1]

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ALEXANDRE REIS GRAEML

Doctoral Candidate at Fundação Getúlio Vargas (FGV-EAESP) – Brazil

Centro Federal de Educação Tecnológica do Paraná (CEFET-PR) – Brazil

graeml@fulbrightweb.org phone number: 55 41 352-4424 fax: 55 41 675-7685

RONALDO F. MARQUES

Centro Federal de Educação Tecnológica do Paraná (CEFET-PR) – Brazil

rfmarques1979@yahoo.com.br phone number: 55 41 256-1121 fax: 55 41 256-1121

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THE BEER GAME, AN IMPLEMENTATION FOR USE OVER THE WEB

ABSTRACT: The Beer Game was originally introduced by MIT professor Jay Forrester, in the 1960's. Since then, it has been played by business students and executives all over the world, in order to simulate and better understand industry dynamics. It has proved to be an especially powerful tool to show the bull-whip effect, i.e., the magnification of the variability in demand as one moves from the customer towards the producer along the supply chain.

Most implementations of the Beer Game are still very similar to its original proposition, using traditional material. The authors of this paper have developed a web-based version, which they are happy to share with other educators, that provides instructors and students with a lot more flexibility to simulate the supply chain environment.

This paper explains the advantages of the implementation of the Beer Game over the web and discusses ways in which it can be used to teach operations concepts to undergraduate students and business people.

KEY WORDS: beer game, simulation, Forrester (bull-whip) effect, supply-chain.

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EVOLUTION OF ENTERTAINMENT ELECTRONIC GAMES

Electronic games with entertainment purposes started to appear in the mid 1960's, developed by university programmers in their free time. According to Teich (1999), the first entertainment electronic game was created in the MIT (Massachusetts Institute of Technology) and was called Space War. The development of electronic games soon called the attention of a big crowd and a whole new industry was born, which is still growing in our days, fully committed to electronic entertainment.

Those first electronic games cannot be compared in any terms to current computer games. There Sound was not available, while modern games support a quality of sound that is superior to the one achievable using CD technology. Some of the new games have sound tracks specially developed for them and make use of special effects that make the player feel like if s/he were really at the spot where action is taking place. THX, a company created by George Lucas in 1983, has specialized in providing a quality certificate, ensuring that the sound and image quality of a movie, home theater, DVDs, multimedia device or game matches the production director intentions (THX, 2003). Some of the certified games, which follows the strict quality standards imposed by THX are *The Lord of the Rings: the Return of the King* and *Need for Speed Underground*. Many of the recent electronic games have budgets that are comparable to millionaire Hollywood productions. *Shenmue*, for example, costed ca. US$60 million, according to Lui (2000).

Since the beginning of the entertainment electronic games' history, they have had excellent acceptance among male teenagers, eager to test their reflexes, exercising their reasoning or, simply, spending a couple of hours just having fun. A study that was carried out by ESA[2], quoted by Greenspan (2003), however, demonstrates that, today, there are electronic game enthusiasts of all ages and both genders, differently to what happened in the past.

Evolution of simulators for serious applications

Within the industry of the so called video games, a special group of applications has called the attention of other people than those who are just looking for entertainment: the simulators.

Airlines can train their staff on dangerous situations, such as storms or equipment failure, by means of simulators, without any risk to the passengers, the crew or the aircraft, itself. Pilot reactions and crew behavior can be assessed and procedures reviewed without any exposure of material or human life to unnecessary risk. Williams (2004) says that the US marine uses flight simulators to train its new pilots, who have to go through a 27 hour Microsoft® Flight Simulator course in a computer laboratory, prior to actually flying a plane. The same way simulations help training people on their tasks, particularly when they involve risk to people's life and/or the

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[2] *Entertainment Software Association.*

equipment, they also make it possible for new, more effective, solutions to be found, to deal with risky situations.

Another use of simulations is to test the reaction of the equipment to various possible situations.

Just about any field can benefit from simulations, allowing for the test of new products, production processes, scientific thesis and mathematical models.

In operations, for example, simulations have been used in an attempt to compensate for the shortcomings of concurrent engineering. Many companies develop simulation-based-design (SBD) approaches, which simulate the entire life-cycle of a project before physical prototyping takes place. Simulations may involve particular concerns related to detailed design, prototyping, operations, maintenance and disposal of the product. They postpone the need to create a physical prototype or make it completely irrelevant (Graeml and Csillag, 2003).

Goldin, Venneri and Noor (1998) argue that, when engineers are immersed in a virtual design environment, they are able to create or modify their contribution to the overall project, in real time, immediately being able to check the effects of their actions on the whole.

The situations in which one can benefit of simulators are endless, regardless of them being for entertainment or for a serious application. The only limit to the use of simulations seems to be our capacity to think of new opportunities.

Electronic games in the educational environment

Much before the emergence of the electronic games' industry, games and simulations were already used as a support tool in education.

Keeping to business education, it is noteworthy to mention Marie Birshtein's early use of active methods to teach salesmen, training them for managerial positions, in the Engineering and Economics Institute of Leningrad, in the 1920's (Global Business Game, 2003).

Business games developed in a way that they emulate features and characteristics of an organization's routine, so that students can exercise the skills that will be required in the marketplace. Business simulations allow for the observation, in a matter of hours, of facts that would take a long time to happen, such as the behavior of a company along a period of several months, or even years (Rodrigues and Riscarroli, 2001). Achieved results help students understand the consequences of their actions over the time, with an additional advantage of not exposing real organizations to the risk of students' experimentation.

During the 1950's, therefore about a decade before the emergence of the first entertainment electronic games, the *American Management Association* had already started using computer simulations to train executives. The *Top Management Decision Game*, considered the first electronic business game, was introduced in 1956, inspired on a simulation system used by the US Air Force, according to Pessoa and Marques Filho (2001).

The sophistication and richness of details of the entertainment electronic games of today does not easily transfer to the educational games, as a result of the severe differences in development budgets. While entertainment games may cost millions of dollars to produce, as seen before, educational applications, in many cases, are the result of the effort of isolated teachers and students, whose only ambition is to improve the didactics of they own classes. With limited resources and no commercial purpose, they develop “home-made” solutions, but which can still be very useful in their environment. Educational games are, in general, restricted to a small community. Often, only the students of the schools where they are originally developed benefit from the initiative. Prior to the advent of the Internet, it was even more difficult to share educational simulations and games with colleagues from other schools. Fortunately, the new technology allows not only that, but also that people living in different locations participate in the same game or simulation.

Electronic games for the Web

The popularization of the Internet allowed the technology on which it is based to spread to an extent that most local networks today follow its standards. Using the infra-structure made available by the Internet, electronic games, which could only be played in a stand alone situation before, can now accept geographically disperse players.

The growth of the Web has also contributed to the fast development of technologies that allow computer servers to create pages dynamically that can be sent to different users, increasing the possible degree of personalization. Sound, image, animation and broad-band resources made available to the regular user represent an additional push to the development of more elaborate applications. As a result of all those changes in the technological environment, a new kind of electronic games has emerged: games based on the Web. Although this new category still doesn't offer the same level of sophistication of games designed to be played on stand-alone computers (mainly as a result of band restrictions), web based games have the advantage of not requiring all players to be at the same place. By allowing "remote" players to take part in the simulation, Web games are more inclusive and have dramatically increased the potential for sharing, joint development and exchange in the educational environment.

The adaptation of the "Beer Game" for the computer and its use over the Web, which inspired the elaboration of this paper, fits this new category of educational games, based on Web technology.

Supply Chain Management

Supply Chain Management is an area of study that has called a lot of attention during the last few years, as it highlights the need to look for systemic costs/gains in supply chains and not to try to optimize individual operations, in an isolated manner. That can be accomplished by improving the integration and the level of communication among the several participants of a supply chain, including the supplier of raw-materials, all intermediate stages of value aggregation until the delivery of a finished good to the consumer (final customer). The supply chain may involve several layers of suppliers and customers.

Being critical to the success of business, supply chain management should not be neglected by any organization, as poor management may have severe consequences to its competitiveness, as well as that of its business partners. Therefore, business schools concern themselves with preparing their students for the challenges that the real world will impose on them with respect to managing their companies' roles within value chains.

The Beer Game and its Web version

The Beer Game was originally introduced by MIT professor Jay Forrester, in the 1960's. Since then, it has been played by business students and executives all over the world, in order to simulate and better understand industry dynamics. It has proved to be an especially powerful tool to show the bull-whip effect, i.e., the magnification of the variability in demand as one moves from the customer towards the producer along the supply chain (Senge, 1998, p. 69).

Most implementations of the Beer Game are still very similar to its original proposition, using traditional material. The authors of this paper have made little adaptations to the game and developed a web-based version, which provides instructors and students with a lot more flexibility to simulate the supply chain environment.

The “Beer Game” attempts to demonstrate the so called “Forrester effect”, also known as “bull-whip effect”. Such an effect consists on the amplification of the variation in the demanded volumes of a specific good along the supply chain, causing an increase in the costs of keeping inventory or not fulfilling an order. The effect becomes clear when, after having played the game, one analyses the level of inventory kept by each player in the supply chain, as well as the volumes ordered to their immediate suppliers.

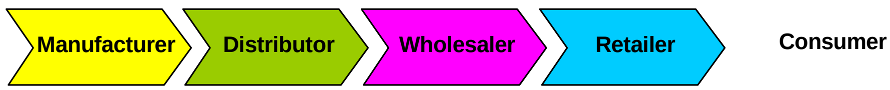
The “Forrester effect” is caused by the difficulty organizations have to fulfill their customers’ orders in a diligent manner, as well as for the deficient information flow along the supply chain. In some cases, companies choose to keep high levels of safety stock, to ensure customers will not have to wait for the good. As the definition of inventory levels to be kept is performed by the participants of a supply chain individually, in an attempt to minimize their own internal operation costs, no processes are usually developed in order to minimize the systemic costs of the whole supply chain.

In the “Beer Game”, each player represents a “link” in the beer business supply chain. There is no limit to the number of teams that can play the game. Teams comprise of four players: a retailer, a wholesaler, a distributor and a manufacturer (brewer). Although the game can be played by as little as four people, comprising just one team, larger groups allow for competition among teams, which adds to the fun of the simulation.

The members of a team (retailer, wholesaler, distributor and manufacturer) only interact by means of the orders they place to the next upstream link in the supply chain and the confirmations they receive for their orders. No other form of communication is acceptable.

Each team exclusively produces, distributes and commercializes only one brand of beer. No participant should belong to two different teams at once, in this game (although, in the real world companies often sell their goods to competitors, therefore belonging to more than one supply chain, at once).

Figure 1 – Participants in the supply chain, in the Beer Game



To start each turn of the game, which corresponds to a new week, the system, performing the role of the consumer, places an order to the retailer of each beer brand in the game. The retailer will fulfill the order, depending on the availability of the product in stock and will place his/her own order to the wholesaler. The same will happen to the wholesaler and the distributor, who will supply their respective customers with the amount of beer they ordered, if possible, and place orders to their own suppliers. The manufacturer replenishes the distributor's stock, according to the order that is placed and subject to the availability of the product in stock and then decides on the production schedule for the week, i.e. how much beer to produce.

The decision on the volumeto buy – for the retailer, the wholesaler and the distributor – and the decision on how much to produce – for the manufacturer – is influenced by the costs of each participants' own operation. They all incurs in the cost of keeping inventory or in the cost of not fulfilling the customer's orders. Figures 2 to 4 show the screens through which players place their orders and receive confirmations from their suppliers.

Figure 2 – Table used by retailer to place orders and receive confirmations

History

Week	Initial inventory	Customer order	Actual delivery	Non-fulfilled orders	Final inventory	Order to supplier	Acknowledged delivery by supplier	Cost of non-fulfilled orders	Cost of keeping inventory	Total cost for the week
-							5			
-				0	15	5	5			
1	20	5	5	0	15	5	5	0	15	15
2	20	5	5	0	15	10	10	0	15	15
3	20	5	5	0	15	0	0	0	15	15
4	25	5	5	0	20	0	0	0	20	20
5	20	10	10	0	10	20	15	0	10	10
6	10	10	10	0	0	10	4	0	0	0
7	15	10	10	0	5	15	5	0	5	5
8	9	10	9	1	0	0 Order	Not yet available	2	0	2

Aggregate total cost: **82**

Figure 3 –Table used by wholesaler and distributor to place orders and receive confirmations[3]

History												
Week	Initial inventory	Customer order	Late orders	Expected delivery	Actual delivery	Current week's non-fulfillment	Final inventory	Order to supplier	Acknowledged order by supplier	Cost of non-fulfilled orders	Cost of keeping inventory	Total cost for the week
-									5			
-						0	15	5	5			
1	20	5	0	5	5	0	15	5	5	0	15	15
2	20	0	0	0	0	0	20	0	0	0	20	20
3	25	0	0	0	0	0	25	0	0	0	25	25
4	25	4	0	4	4	0	21	0	0	0	21	21
5	21	5	0	5	5	0	16	0	0	0	16	16
6	16	20	0	20	16	4	0	10	10	8	0	8
7	0	30	4	34	0	34	0	40	25	68	0	68
8	10	15	34	49	10	39	0	10 Order	Not yet available	78	0	78

Aggregate total cost: **251**

Figure 4 – Table used by manufacturer to plan its production schedule

History											
Week	Initial inventory	Customer order	Late orders	Expected delivery	Actual delivery	Current week's non-fulfillment	Final inventory	Production schedule	Cost of non-fulfilled orders	Cost of keeping inventory	Total cost for the week
-								5			
-						0	15	5			
1	20	5	0	5	5	0	15	10	0	15	15
2	20	0	0	0	0	0	20	5	0	20	20
3	30	0	0	0	0	0	30	0	0	30	30
4	35	0	0	0	0	0	35	0	0	35	35
5	35	0	0	0	0	0	35	0	0	35	35
6	35	10	0	10	10	0	25	0	0	25	25
7	25	40	0	40	25	15	0	50	30	0	30
8	0	10	15	25	0	25	0	20 Produce	50	0	50

Aggregate total cost: **240**

3 Tables for the wholesaler and the distributor are identical.

Tables are very similar for all players, regardless of their role in the supply chain. The differences are as follow:

(1) The retailer does not accumulate “late orders”, which could be sent to the consumer at a later stage. The consumer is very time sensitive, i.e., s/he either gets his/her beer when s/he wishes or the retailer looses that sale opportunity. As a result of that, columns “expected delivery” and “current week’s non-fulfillment” do not exist for the retailer.

(2) The manufacturer’s table does not have column "Order to supplier". It has “Production schedule”, instead.

(3) For the sake of simplification, the manufacturer does not buy any raw-materials, i.e., it does not have to place orders to suppliers. Therefore, there is no column “acknowledged order by supplier”, for the manufacturer.

Calculations that are carried out by the system

For each turn of the game (week), the system automatically calculates the following fields, which can be seen on Figures 2 to 4:

- “Initial inventory” – it is the sum of “final inventory” for the previous week with the “acknowledged delivery by supplier” (or the “production schedule”, for the manufacturer) from two weeks before. That is so, because inventory replenishment is not instantaneous. There is a *lead time* of two weeks, required for order processing, sorting, transportation and other delays in fulfilling an order.

- "Customer order" – when the participant places an order in the system, it is replicated to the supplier's screen, after a few seconds (or by pressing <F5> to refresh the browser's screen), appearing in the supplier's "customer order" column.

- "Late orders" – this column brings a transcription of the value contained in column "current week's non-fulfillment" for the previous week.

- "Expected delivery" – this column contains the sum of "customer order" and "late orders".

- "Actual delivery – it represents the minimum value between "expected delivery" and "initial inventory" for the week. It means that, if there is enough inventory to fulfill the "expected delivery" (which includes late orders from previous weeks), it will be done. Otherwise, the whole amount in stock will be sent to the customer and there will still be late orders to be fulfilled in the future, which will be recorded in column "current week's non-fulfillment". Of course, this does not apply to the retailer, who can only sell what is available for immediate delivery to the consumer.

- "Current week's non-fulfillment" – it corresponds to the "expected delivery" minus the "actual delivery".

- “Final inventory” – it corresponds to the “initial inventory” minus the “actual delivery”.

- “Order to supplier” (or “production schedule”, for the manufacturer) – it is a data input field, in which the player makes a move for every turn of the game. The move consists on deciding on the volume of goods to order from the supplier, based on the participant’s game strategy and taking into account the “cost of non-fulfilled orders” and the “cost of keeping inventory”.

- “Acknowledged delivery by supplier” – it is the value that is calculated and sent automatically by the system after checking the supplier’s capacity to fulfill an order (existence of enough beer in stock).

- “Cost of non-fulfilled orders” – it is a value that is calculated by the system as a result of the participant’s inability to fulfill the customer’s order (in the real world, it would relate to the customer’s unsatisfaction, loss of *market-share* or, simply, loss of the opportunity to perform a sale, for the retailer[4]).

- “Cost of keeping inventory” – it is a value that is calculated by the system, related to the amount of stock that is kept by the participant from one week to the next.

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[4] In the Beer Game, wholesaler, distributor and manufacturer do not loose the opportunity to perform a sale, as they record the order for future fulfillment.

- "Total cost for the week" – it is the sum of "cost of non-fulfilled orders" and "cost of keeping inventory" for the week. It should be noted that these two costs are mutually exclusive, i.e., if one incurs in one of them, it will not incur in the other. In an attempt to optimize their local operation, participants will try to keep their "total cost for the week" as low as possible.

After every turn of the game, and after the game is over, an aggregate total cost for the operation is automatically calculated. During the game, that value can be seen below the last row of the table (see any of Figures 2 to 4). After the game is over, the total costs incurred by the four participants of a team are presented in a report, along with the total cost for the supply chain (sum of the results for each of the individual participants). This report can be seen in Figure 5, below. The supply chain that has the lowest systemic costs will benefit from a competitive edge in the market, as lower costs allow for lower prices or higher profits (or both).

Figure 5 – Operation costs for each of the participants and total cost for the team (supply chain)[5]

Information on the Skol team				
	Retailer	Wholesaler	Distributor	Brewery
Player's Name	Thais	Renan	Michele	Helton
Cost of Keeping Inventory*	165	555	1895	5595
Cost of Non-fulfilled Orders*	20	210	470	330
Total Cost for the Participant*	185	765	2365	5925
Total Cost for the Team* : 9240				

[5] Results for one of the teams in a simulation carried out with CEFET students, in Curitiba, Brazil, in February, 2004.

Educational purposes of the game

The aim of the game is to demonstrate the huge systemic costs incurred by organizations belonging to a supply chain, when the participants try to minimize their own individual operation costs, by developing inventory management strategies that are not shared with partners. That makes it really difficult for any of the "links" in the chain (particularly those further away from the consumer, along the supply chain) to understand the actual demand for the product at the consumer level. In most simulations, unnecessary expenditure with excessive stocks or lack of products to deliver to the customer becomes clear. If the instructor asks the participants about the consumers' behavior, after the game is over, the only ones who usually show an understanding of the consumers market are the retailers. There is a good chance that participants that played the manufacturer's role have no idea, what-so-ever, of the consumers' behavior and think it was really erratic. They usually find it amazing that the consumers demand was stable and well behaved during most of the game[6].

The "Forrester effect" is usually easily noticeable. Figure 5 shows that, in the case of our illustrative simulation, the retailer had a total cost of 185, the wholesaler's cost was 765 and the

[6] In the simulation that was used to ilustrate his paper, involving CEFET's students, the game was set in a way that consumers demand was 5 cases of beer during weeks 1 to 5 and 10 cases of beer for all other turns, from week 6 up to week 28, when the game was terminated.

distributor and manufacturer had costs of 2365 and 5925, respectively. The bull-whip effect (little changes in the consumers' behavior pattern cause great variability along the supply chain) becomes even more noticeable when one plots the data obtained during the game, as shown in Figures 6 and 7, below. Total costs of the participants upstream (closer to the manufacturer) are usually higher than for those downstream (closer to the consumer).

Figure 6 – Orders placed by participants of the Skol team, during the CEFET simulation

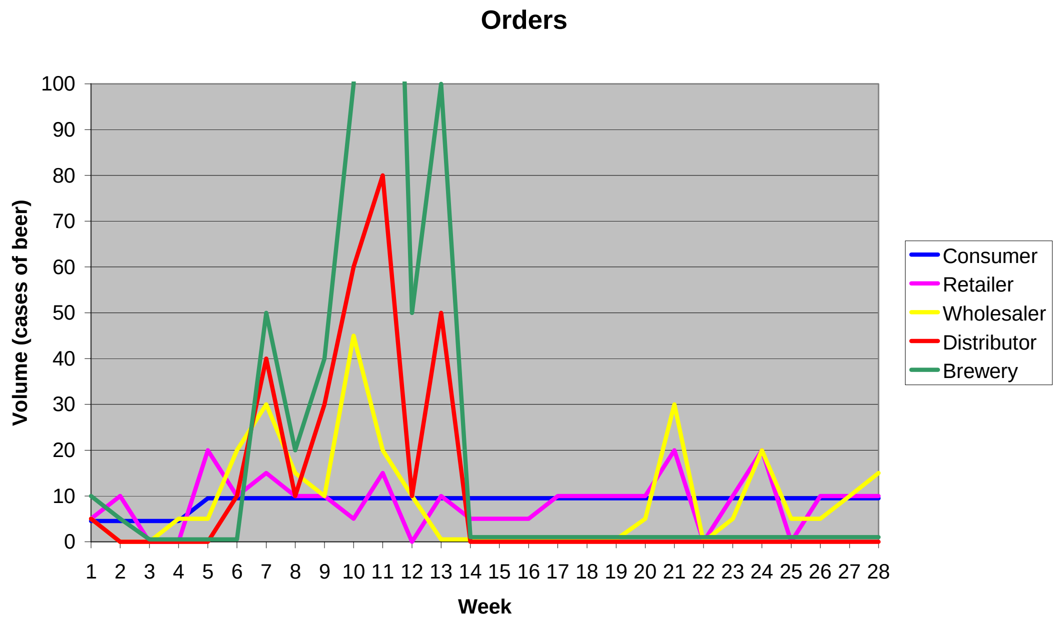

Figure 6, above, shows the fast de-stabilizing effect of the increase in the consumers' demand on week 6. In spite of the consumers' demand afterwards remaining at the level of 10 cases of beer per week until the end of the game, the demand of the intermediaries (middlemen) never stabilized again.

Figure 7 – Inventory kept by participants of the Skol team, during the CEFET simulation

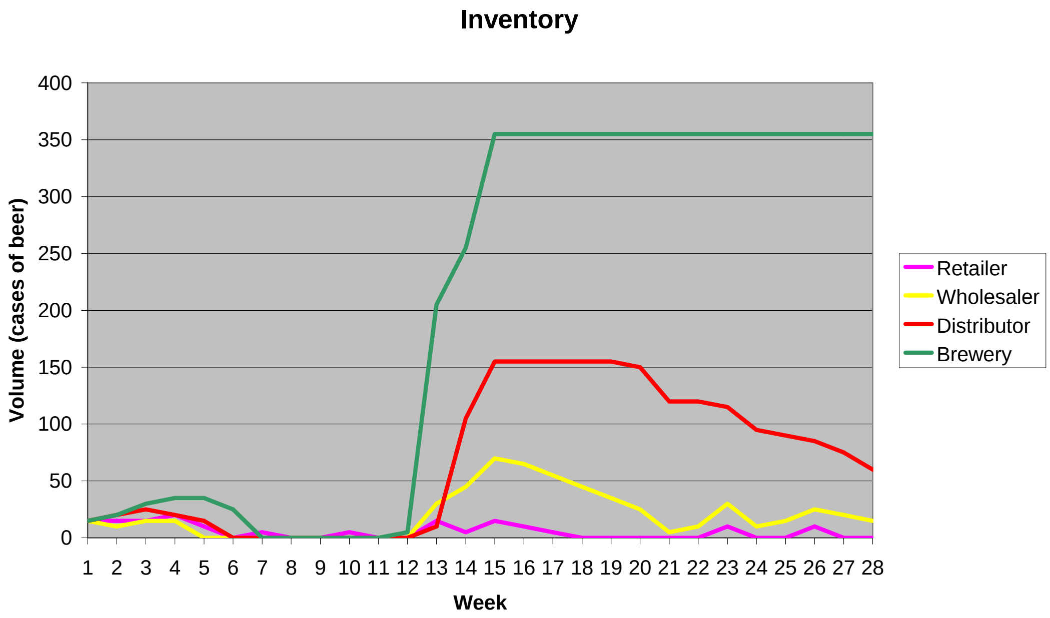

Figure 7 shows the distributor and the manufacturer absolutely over-stocked after weeks 13 and 14. Considering that the customers demand remained at the level of 10 units/week, the distributor has inventory to supply the market for more than 15 weeks, without having to place any new order to the manufacturer. The manufacturer, in its turn, has stock for 35 weeks, without the need of further production. That is the reason for no orders from the distributor to the manufacturer and no production by the manufacturer from week 14 until the end of the game on week 28 (see Figure 7).

Time and space restrictions

Although the technology allows the game to be played from anywhere, which means players do not have to share the same physical environment, restrictions were set with respect to the possibility of playing at any time. As the game was originally intended to be played in a computer lab, during class time, the authors restricted the amount of time each player has to perform his/her move, each time a decision is required, to 2 minutes. Therefore, the members of a team (participants in the same supply chain) have to participate in the game in a synchronous way. There is no need for synchronization among different teams, which may even comprise students from different classes to be taught at a latter time or "remote" players.

Conclusion

Technology advances, represented by enterprise integration systems and by shared computer networks (among which the Internet, itself), provide the necessary technical conditions for the integration of processes to go beyond department boundaries and even company boundaries. That allows the information on customers' needs to be shared by partners and flow upstream, along the supply chain. It also allows for the information on capacity restrictions and stock availability to flow downstream[7]. Better information quality becomes an important tool to obtain a competitive edge, because it contributes to better decision making.

Information systems become essential to the organizations' strategy when they are used to improve the information flow along the supply chain, reducing the feeling of weakness with respect to the ability of responding to customers' demand (felt by the players of the Beer Game). More information may represent less need of inventory, as safety stock is kept in order to prevent from the uncertainty of the markets. Reducing the level of uncertainty, by means of improved information flow, one can significantly reduce safety stocks, contributing to lower costs and to a more responsive supply chain scheme.

The integration of companies with their customers and suppliers would, at least in thesis, allow customers to directly interact with their suppliers' production systems, triggering the production of items they need, when they need them. Following the same reasoning, customers would be able to cancel, or change the production schedule, for items they are not interested in, anymore, or when priorities change. Such level of interference in the partner's systems and production

[7] The terms *upstream* and *downstream* are usually used to refer to the portions of a river closer to its spring and to its mouth, respectively. By analogy, the "links" of the supply chain to the suppliers' side are referred to as being upstream, and those to the consumers' side are refered as being downstream.

organization will only be accepted by suppliers that are really trustful on their customers, besides having strong common interests, which justify abdicating of part of one's own autonomy, in order to increase the agility of the supply chain as a whole.

It is romantic to think that this kind of cooperative behavior will prevail in the majority of business relationships, even when it clearly allows for systemic optimization. However, that is the direction towards which organizations are going, when they believe that the benefits of the integration are higher than the risks involved in sharing information and control with their partners.

The Beer Game, by imposing severe restrictions to the information flow along the supply chain, provide a strong example of why companies should do the opposite and improve the quality and intensity of the communication with their partners. Potential risks of doing so, as well as the extent to which that integration is possible or advisable, would have to be discussed elsewhere.

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