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Experiences in Using XBeerGame Virtual Gaming for Learning Supply Chain Management†

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Abstract. Supply chain management (SCM), due to the large scale and wide scope of the multi-partner supply networks and to the high complexity of the dynamically occuring phenomena, is a difficult topic to teach. Conventional teaching approaches do not allow the students to sufficiently grasp neither the interrelationships between the elements of such a complex system nor the dynamic effects. SCM teaching has therefore a lot to gain from the use of learning-oriented virtual games. The XBeerGame is an immersive simulator enabling students to learn how to master the bullwhip effect through improved decision support, visibility, cooperation and agility. It can be calibrated by the teachers in order to get the students to learn by experience specific characteristics and behaviours of supply chains. The software technology used in the XBeerGame allows it to be used in a decentralized way and in particular with international student teams. The highly developed visual interface of the XBeerGame and the access to the game results favour its use for student tournaments and provide a large choice of pedagogical approaches. The XBeerGame has been used in teaching students at the Bachelor and Master levels as well as in continuous education in both North America and Europe. The pedagogical experience gained and the evaluations of these effective uses have led to several interesting conclusions as well as to further improvement proposals, for the tool itself as well as for the methodologies and pedagogical scenarios. This paper describes the key functionalities and characteristics of the XBeerGame. It then discusses its use in various teaching programs in Canada and in Switzerland. Based on these international hands-on experiences, the use of XBeerGame for SCM teaching is discussed. The tool itself is a point of discussion, but more importantly, the way it is integrated into a pedagogical scenario seems to be the key to an optimal use. It appears in particular that combing a discovery learning approach based on the XBeerGame with a more formal, mathematical description leads to interesting pedagogical results.

Keywords. Supply chain management, learning oriented gaming, bullwhip effect, piloting cockpit, immersive simulation.

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1. Introduction

This paper details our experiences in using the XBeerGame distributed immersive gaming simulator for the purpose of learning the dynamics of supply chain management.

Coined by Oliver and Webber (1982), the expression Supply Chain (SC) generally encompasses the set of organizations and processes involved in supplying a firm's products, from its suppliers' suppliers to its customers' customers. Supply chain management (SCM) has been defined by Simchi-Levi (2000) as a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requirements. Managing a supply chain in a real dynamic setting is a complex task involving many decision makers and analysts from multiple organizations, each supported by specialized supply chain management software technology.

Teaching supply chain management has gained huge popularity in business schools and industrial engineering schools around the world, driven by top strategic recognition of its importance by executives of numerous leading businesses. However, teaching SCM is also quite a challenge.

Courses generally exploit some combination of the following seven means:

- lectures and discussions on concepts and principles;
- lectures and exercises on mathematical models and analytical approaches for tackling the key strategic, tactical and operational decision making;
- case studies based on experiences from industry;
- live discussions with SC managers;
- field projects analyzing a specific SC and attempting to provide insights and solutions to some of their key problems and challenges;
- simulation demonstrations and experiments;
- games, either manual or digital.

Simulations and games have long been recognized as the most powerful means to have the students learn about the dynamics of supply chain management and the impact of the interaction between the distributed actors through the SC. Simulations and games differ widely in their learning intent and efficacy. Simulations serve the important purpose of helping the student learn about the global impact of alternative supply chain designs, supply chain management strategies, supply chain collaborative approaches, or yet of focused decision algorithms and heuristics (e.g. Chen et al., 2000). When simulations are run, students can look at animated interfaces showing the evolution of key performance criteria and of the dynamic status of each actor in the chain. They can contrast the final performance of alternatives under various stochastic scenarios, during a predetermined planning horizon. They are external observers overlooking the virtual worlds operating much faster than real life, and experimenters toying with configurations and parameters, seeking optimized settings.

Games change the student's perspective from an external observer and experimenter to an actual insider actor immerged in the supply chain. Games put the players in a virtual world, where they are given actual decision making responsibilities, aiming for focused performance, and where they can interact with other SC actors enacted by other players or virtual agents. Each student has to behave in the SC, and rely on his knowledge to take real-time decisions affecting the SC performance. Games often put players in combinations of competition and collaboration, having to achieve both individual and team objectives.

By far the best known and mostly used SC learning game is the Beer Game developed by Forrester in the 1960s (Sterman, 1992). The Beer Game requires groups of four players to dynamically manage a simplified SC consisting of a retailer, a wholesaler, a distributor and a factory. It is a manual board game using a table setup as shown in Figure 1. The game is played using a discrete round approach. At each round, each player has to satisfy his demand if possible and has to decide how much to order from his supplier, or how much to produce in the case of the factory manager player). The orders from a client become the demands for his supplier at a subsequent round. There are delays embedded before an order reaches a supplier and a shipment reaches its client. The game master sets the retail demand at each round. The Beer Game is mostly used to teach the bullwhip effect in supply chains. The game master sets the demand level at each round, unknown a priori by any player. This demand

is directly perceived only by the retailer player. At the beginning of the game, the game master generally sets a stable demand level, for example four at each round. Then at some round, he increases the demand level, for example at eight a round, and stabilizes it at that level until the end of the game. At each round, the inventory and orders of each player are logged. The bullwhip effect is such that such a simple variation of demand generally creates major perturbations in the supply chain, increasing with more upstream players. This is exhibited in Figure 2. The trouble with the Beer Game is its limited potential in being used to teach students that the disastrous bullwhip effect can be avoided or at least attenuated through better SCM, and to teach more complex concepts and approaches in SCM. This is where the XBeerGame comes in, which is the focus of this paper.

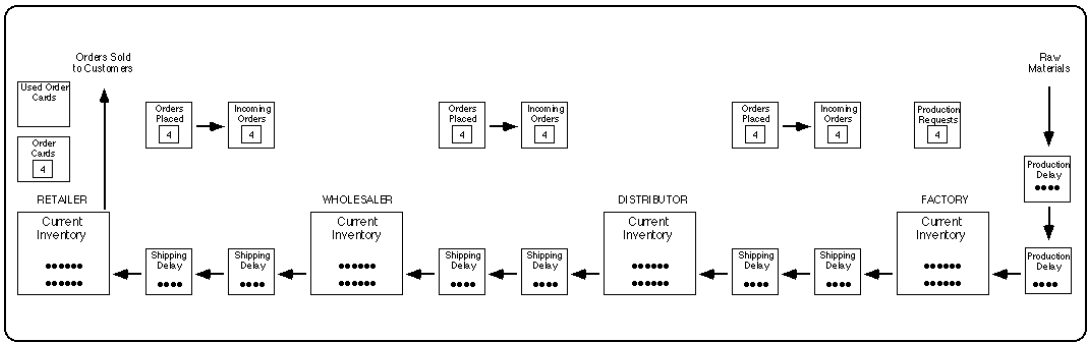


Figure 1: The classical Beer Game table setup

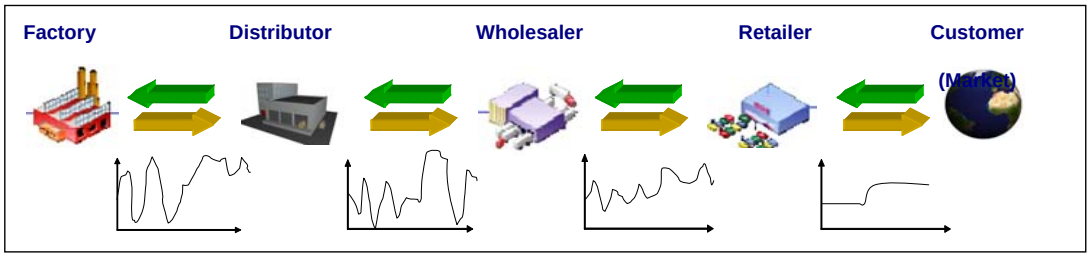


Figure 2: Illustrating the bullwhip effect by depicting orders gotten over time by actors along the supply chain

The remainder of the paper is structured as follows. Section 2 provides a brief literature review on learning oriented gaming. Section 3 introduces the XBeerGame. Section 4 focuses on the means for learning supply chain management skills with XBeerGame. Section 5 describes international field experiences with exploiting XBeerGame for learning supply chain management. Finally section 6 draws conclusions from the research.

2. A brief literature review on learning oriented gaming

Several authors have pointed out the advantages of using educational games. Gee (2003) argues that games provide the learners with an immersive environment, require deep thinking and stimulate complex problem solving. According to Shaffer (2005), educational games allow the learners to develop situated understanding, to explore new identities, to create communities of practice and to support learning by doing. Games also support transfer of knowledge to other contexts (Oblinger, 2004).

Games also have an advantage on simulations, adding to them fun, competition, playfulness, as well as achievement, greed and victory elements (Prensky, 2001).

Although the use of educational games in educational environments seems very promising, there are several issues that have to be considered while developing them. Rieber (2005) has pointed out that learners may focus only on improving their own score, without engaging in reflection. He also observed that some guidance has to be given during the game. Furthermore, Manske and Conati (2005) observed that it is difficult to introduce intervention elements that make students reflect on domain knowledge without interfering with engagement. Reflection indeed is a central element in learning from simulations as it allows transforming experience into knowledge.

3. Introducing XBeerGame

The XBeerGame provides students with an opportunity to experience a simplified yet authentic supply chain management situation. Indeed, the competitive multi-player nature of the game closely models realistic situations. Briefing and debriefing sessions replace traditional lecturing and allow students to reflect on their experience during the game.

As a basic capability, the XBeerGame allows players familiarizing themselves with managing operations in a supply chain, experiencing the bullwhip effect and learning ways of avoiding or attenuating it. Yet it is more generically a great way to experience the impacts and challenges involved in adding more intelligence, visibility, collaboration and agility throughout the supply chain. It thus helps the students become better equipped to master and foster supply chain performance and innovation.

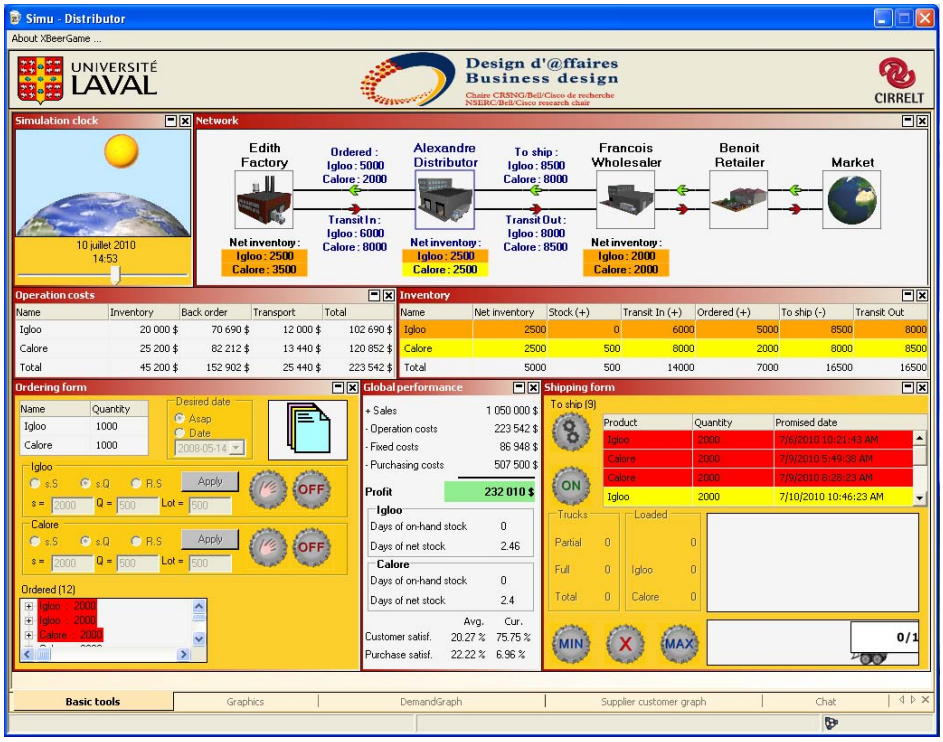


Figure 3: XBeerGame basic cockpit for a player acting as distributor in the supply chain

The XBeerGame has been developed at Université Laval by Professor Benoit Montreuil and his team. Its purpose is to train students and managers in mastering supply chain management through experiencing realistic and challenging simulated scenarios. It is based on the original Beer Game concept, yet with numerous improvements that allow multiple variants not possible in the classic game. For example:

- It works in continuous accelerated time instead of discrete time. This puts a time pressure on players. At any given time during the game, when a player makes no ordering or delivering decision, he is making a tacit decision to postpone such decision making, the clock ticking away through the indecision.
- It supports multiple products, each with teacher defined demand history and future demand. This allows to create various effects such day-within-week and seasonal week-within-year variations. Demand history of players upstream from the retailer can be generated by pre-simulation using virtual agents.
- It allows changing all parameters such as delays, costs, and so on. A key feature is its capability to deal with revenues and profits instead of only the costs. This becomes interesting when clients and the market are allowed to cancel late orders.
- It provides each player with an elaborate yet intuitive and efficient piloting cockpit, with levels of functionality specified by the teacher, ranging from basic transactional information and order forms, to extensive continuously updated tables and graphs on key operating statistics and performance measures.
- It allows the teacher to provide players with capabilities for supply chain visibility and collaboration with partners along the supply chain.

The XBeerGame is built on the BusinessWebGame platform, also developed at Université Laval by Professor Montreuil and his team. This platform allows multiple players to each play a role in a supply chain. This permits for example to have sixty students in a class concurrently playing the game, corresponding to fifteen teams of four players, each team assigned to a supply chain. Each supply chain operates in a parallel world, facing the same market demand as all the other supply chains, thus allowing teams to compete for best performance under the same fair conditions. Players can be located in the same room or distributed all over the world, connecting to a game through the web.

Each player has access to a piloting cockpit such as depicted in Figure 3. The cockpit is designed as a collection of panes, each with specific functionalities and information continuously updated.

- The upper left *Clock* pane indicates the current date and time. It operates in continuous accelerated time, with the clock speed defined by the game master. He can set it for example at a fast rate of a month per twelve minutes or at much lower rates such as a month per hour or a week per day, depending on the teacher's learning objectives.
- The upper right *Network* pane identifies the position of the player in the supply chain and the identities and roles of his colleagues in the SC. For the two most critical products, it also shows the current net inventory, the quantity of products having been ordered from the supplier, the quantity actually in transit from the supplier, the quantity of products requiring to be shipped given current standing orders from clients, and the quantity of products currently in transit toward clients.
- The mid left *Operating Costs* pane provides, for each product and overall, the cumulative costs related to inventory, backorder and transport, as well as the total costs.
- The mid right *Inventory* pane provides the current inventory status for each product and overall: net inventory, stock on hand, products in transit from supplier, products ordered from supplier, products to ship to client, and products transiting to client.
- The lower left *Ordering* pane allows each player to order products from their supplier, either manually by specifying the ordered quantity and required delivery time, or through automated reordering policies. For example, the player can set an ordering lot size and a reorder point for a given product, dynamically modifying them, and overriding them as desired. The pane also provides a log of standing supply orders.
- The lower central *Global Performance* pane is an executive dashboard depicting current cumulative revenues, costs and profit, days of stock and service levels.
- The lower right *Shipping* pane registers all standing client orders and allows the player to load delivery trucks and ship them to the client, either interactively or through automated ways.

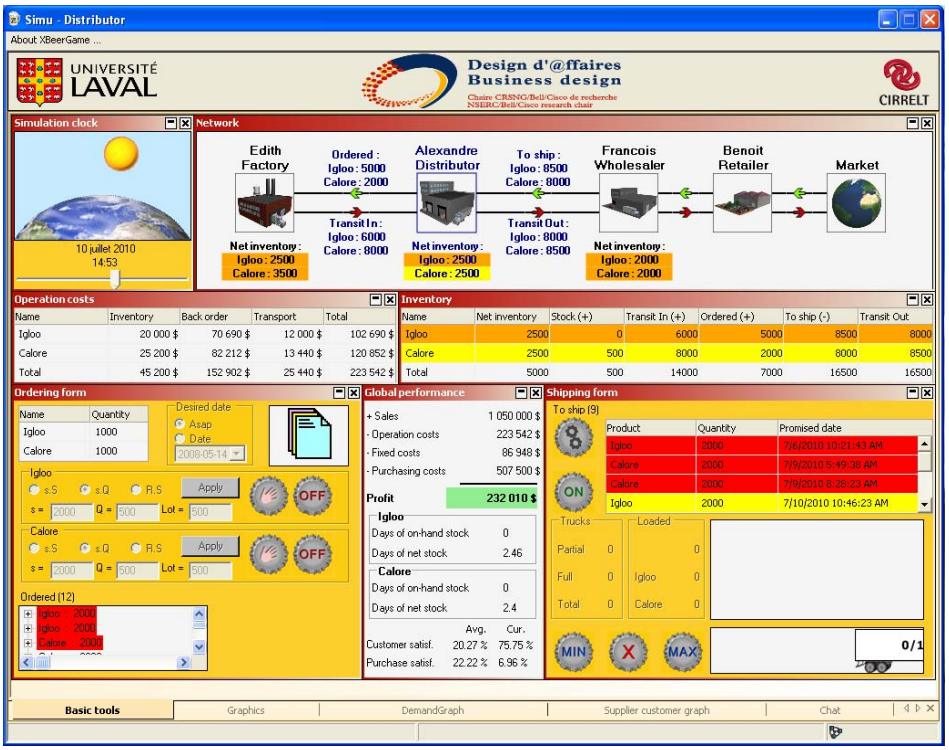


Figure 3: XBeerGame basic cockpit for a player acting as distributor in the supply chain

The cockpit also exploits colour signals to warn players of critical situations. For example, in the *Inventory* pane, a red underlining states that the current net inventory is not sufficient to cover the current standing client orders.

All cockpit pane functionalities can be enabled or disabled by the teacher depending on his learning objectives. Similarly, other panes and screens can be made available to the players. Figure 4 shows four examples of screens.

- The upper left screen provides the demand history for a selected player, up to a past specified by the teacher. He may want the players to go blind relative to past years, as done in the classical Beer Game, or, as an alternative example, rather provide the players with three years of past demand.
- The upper right screen provides a combination of dynamic demand, inventory and operational cost graphs.
- The lower left screen offers visibility on demand and inventory history for both the direct client and supplier partners in the SC.
- The lower right screen permits the player to chat with his direct client and supplier. The teacher may also forbid such chatting or, at the other extreme, allow it directly among all players in the SC.

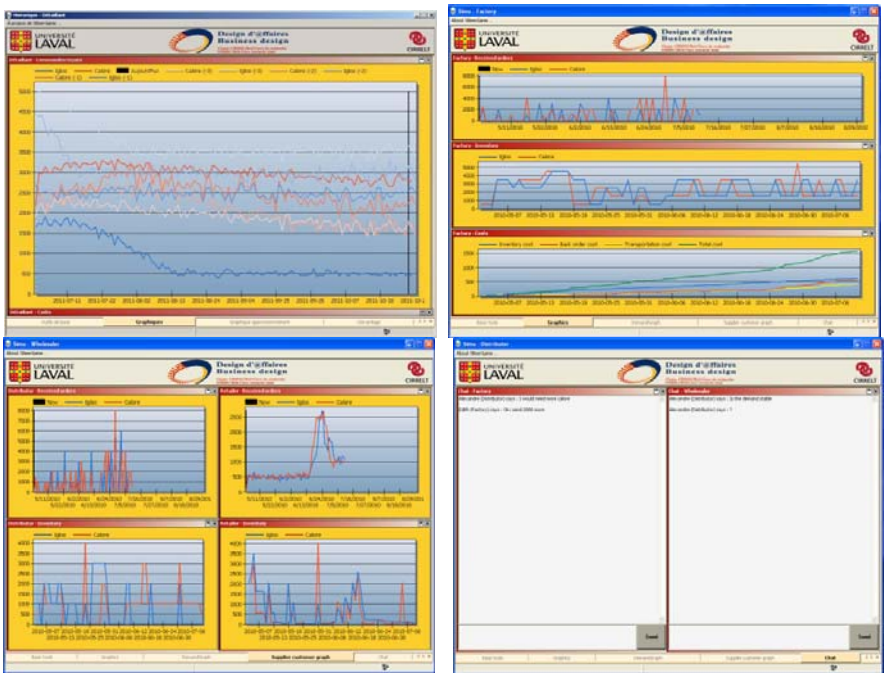


Figure 4: Others interfaces of the XBeerGame (advanded rounds)

4. Learning supply chain management skills with XBeerGame

A variety of experiences can be run using the XBeerGame. There are six main differentiators: (1) SC consciousness and structure, (2) decision support, (3) SC visibility and collaboration, (4) market demand patterns, (5) geographical SC deployment and (6) agility level.

The supply chain consciousness and structure variants include:

- The players are not told they are part of a supply chain. Provided their role, they just know that they are to receive orders which they will try to satisfy on time, and that they need to replenish their stock through ordering from a supplier who is not always reliable. Each player aims to optimize his individual performance.
- The players know that they are part of a supply chain and that other players are their client or their supplier, yet they aim at optimizing their own performance. They act as independent businesses, each with its own profit-and-loss statement.
- The players know they are part of an internally integrated supply chain, each facility belonging to the same business. They know that other players are their client or their supplier, and their partner within their business.

The decision support variants include:

- Players are limited to minimal transactional cockpit functionality, with no operating statistics, no performance measures, no graphs, no coloured signals. Indeed the players know their financial and service performances only at the end of the game. They have to individually create and launch each supply order and delivery shipment.
- Players are provided with various levels of piloting information, such as operating statistics, performance measures, dynamic graphs, pre-simulation historical information, and warning signals. They have to individually create and launch each supply order and delivery shipment.
- Players are provided with various levels of piloting information and they have access to automated ordering and shipping decision making agents. Thus they can decide to simply oversee the transactional flow, setting decision parameters, and intervening with rush orders and shipments as deemed necessary.

The supply chain visibility and collaboration variants include:

- No visibility or collaboration among players among the supply chain.
- Collaboration is allowed only prior to starting the experience, through a team meeting to discuss joint strategy.
- The dispersed players are allowed to view the demand, inventory and/or cost performance graphs of their direct client and/or supplier.
- The dispersed players are allowed direct client and/or supplier visibility and are also enabled to communicate with them through digital chatting.
- The dispersed players are allowed pan supply chain visibility and communication with all supply chain players.
- The dispersed players are allowed full visibility and open communication, both digital and phone based.
- The players are physically seated side by side and allowed full visibility and unrestricted communication, both digital and oral.

The demand pattern variants are generated by setting the number of products and by fixing their demand distribution through time. Variants for each product differ in terms of:

- Basic demand volume level;
- Growth-steadiness-decline patterns;
- Daily and seasonal effects;
- Presence of special holidays and events affecting demand;
- Inherent stochastic variability.

Geographical supply chain deployment variants can be set by fixing the delivery times and costs between facilities, as well as their stochastic variability.

- Basic variants locate the facilities in the same large region, so that delivery times are counted in single-digit days.
- Global economy variants locate some facilities far form the others, for example playing with an Asian brewing factory serving a North American market.

Agility variants can similarly be set up by adjusting:

- The internal lead time for ordering and preparing orders at each facility;
- The internal lead time for producing lots in the factory.

The overall set of variants allows a wide spectrum of learning opportunities, so that the XBeerGame can be used in a one-shot sensitization session or exploited repeatedly in courses, each time focusing on a specific set of learning objectives.

5. Experience with exploiting XBeerGame for learning supply chain management

Since January 2005, the XBeerGame has been used widely in multiple universities including Université Laval (Canada), EPFL (Switzerland), UQAM (Canada) and Fraunhofer Institute of Technology (Germany). It has also been used as a teaching tool for practitioners, as illustrated in Figure 5.

Hereafter are reported two representative activities to illustrate actual usage and the associated learning.

Figure 5: Practitioners pictured live in a XBeerGame tournament at Université Laval

5.1 MBA-Games tournament at Université Laval

A XBeerGame tournament was held at Université Laval during the 2005 MBA-Games. It included thirteen teams of four players. Each Canadian university offering an MBA program and attending the MBA Games was represented by a team in this tournament.

The tournament was conceived as a series of three rounds. Each round lasted 45 minutes, simulating a 4-month period in accelerated continuous time. The first round was played with basically the same rules as the classic Beer Game, but using a slightly more complex demand patterns and two products rather than one. After the first round, the 10 best teams based on total supply chain costs were invited to the second round. The second round was played with another demand pattern and an added degree of visibility for the players, allowing them to monitor their individual status and performance through demand, inventory and cost graphs. The five best teams were then invited to the final round.

In this final round, each team member had visibility on the demand and inventory of its supplier and its client, and was allowed to chat with them. The winners were judged on total cost for the team, which included inventory, order, backorder and transport costs. In third round, five teams remained in competition: Université Laval, McGill, McMaster, Toronto and York. Due to technical software difficulties, the team from Université Laval could not complete the round, demonstrating the huge importance of software and hardware robustness in such gaming contests.

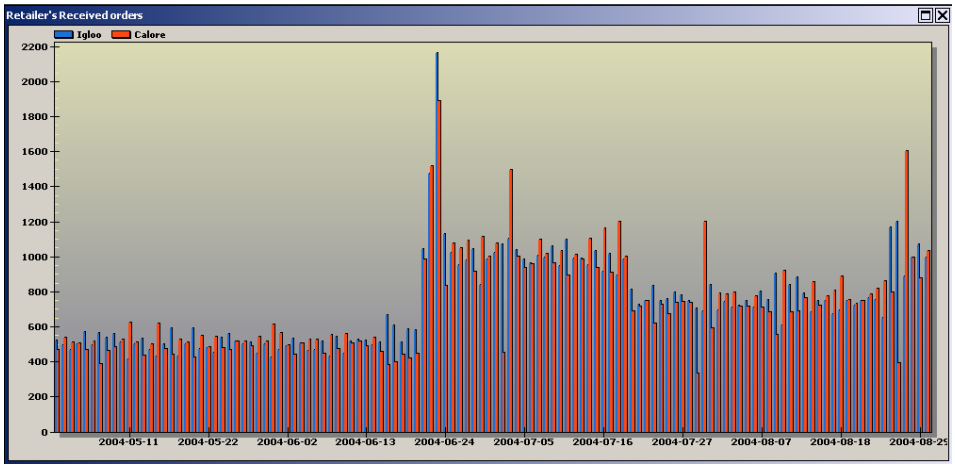


Figure 6: Market demand for the first round of the 2005 MBA-Games XBeerGame tournament

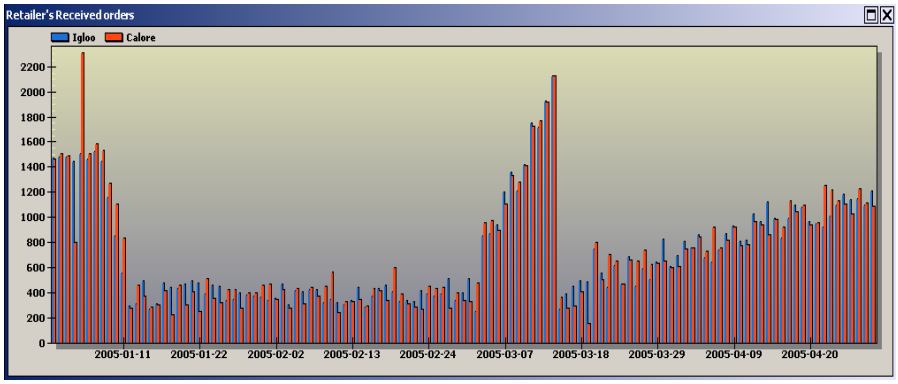


Figure 7: Market demand for the third round of the 2005 MBA-Games XBeerGame tournament

Figures 6 and 7 contrast the market demand patterns imposed on the supply chains in rounds 1 and 3. The overall demands are on the same order of magnitude. However they structurally differ significantly, requiring very distinct behaviours from the players.

Figure 8 and 9 contrast the total cost generated by each team from round 1 to 3. In round 1, they range from roughly 1,5 M$ to more than 5 M$, depicting the huge impact of SCM on the overall financial performance of the supply chain. In round 3, the winning team from McGill University generated an overall supply chain cost of 1,1 M$ with the four teams scoring below 1,6 M$, all having clearly profited from the added decision support, supply chain visibility and collaboration.

The combination of Figures 9, 10 and 11 allow to clearly see the difference between best teams and eliminated teams from round 2. All players from the bests teams have managed to keep low costs, indeed below 0.9M$, where the players from eliminated teams were not as good individually and collectively.

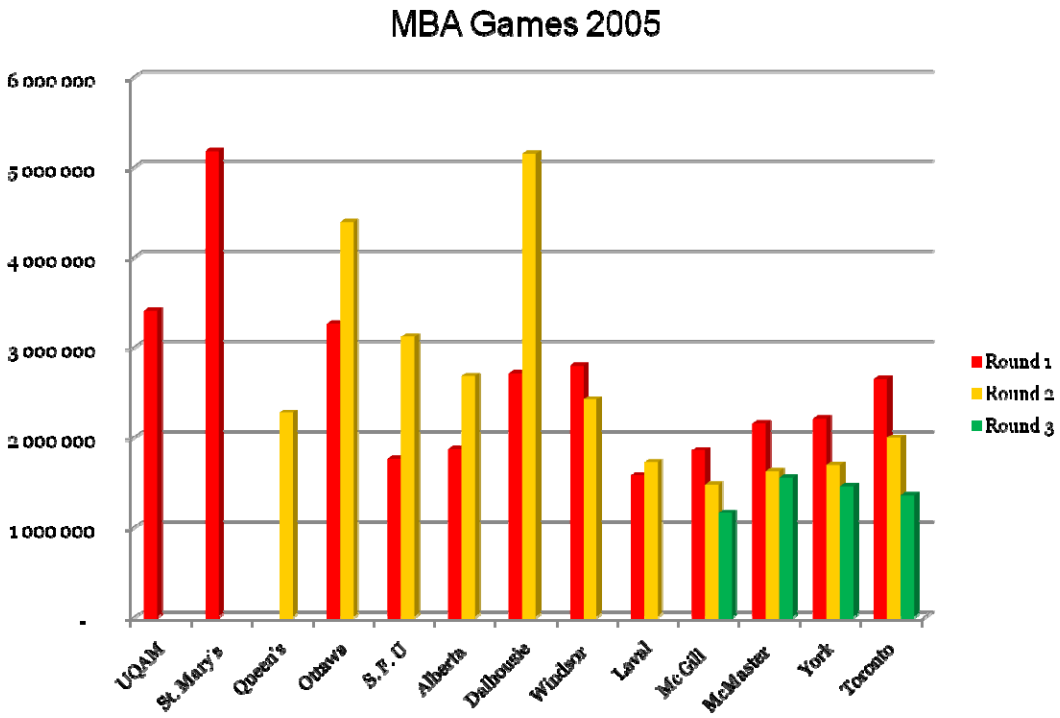
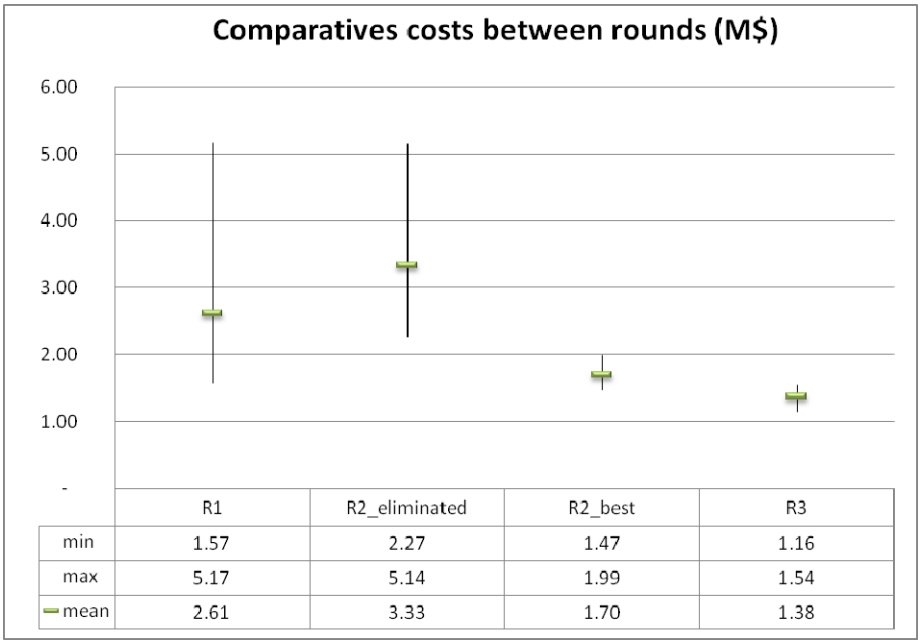


Figure 8: Team results for all 3 rounds of the 2005 MBA-Games XBeerGame tournament



	R1	R2_eliminated	R2_best	R3
min	1.57	2.27	1.47	1.16
max	5.17	5.14	1.99	1.54
mean	2.61	3.33	1.70	1.38

Figure 9: Comparative team results for the 2005 MBA-Games XBeerGame tournament

In Figures 10 and 11, it is also interesting to note that the distribution of the various costs varies from player to player in a team and between same role players in distinct teams. Similarly the relative cost performance varies from player to player in a team and between same role players in distinct teams.

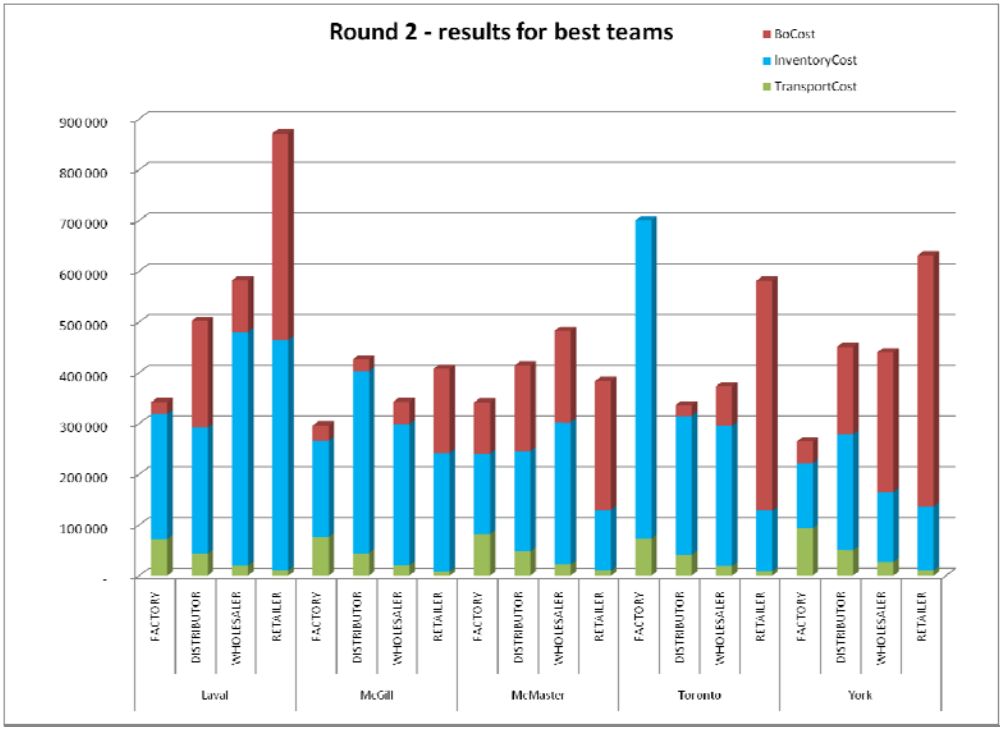


Figure 10: Cost performance of each player in the five best teams for round 2 of 2005 MBA Games tournament

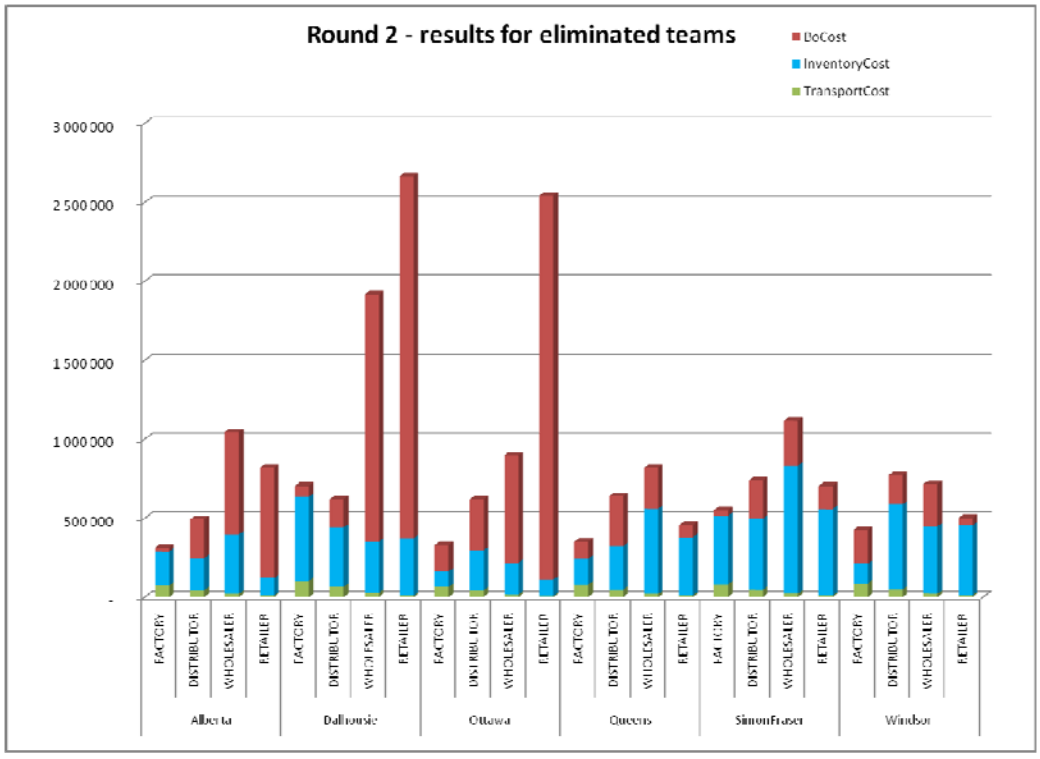


Figure 11: Cost performance of each player in the five eliminated teams for round 2 of 2005 MBA Games tournament

Figures 12 and 13 contrasts the bullwhip effect measure (Chen et al. 2000) of each player of each team, respectively in rounds one and three. In round one, a factory player climbed the bullwhip effect to the ceiling, with a score of nearly 200, while all other players ranged below 45. Université Laval's team players averaged on the order of 10, with all other teams averaging above 20. In the final third round, the worst bullwhip effect of a player was below 12. All players of all teams, except for factories, scored less than 5. This reflects the huge power of better SCM to attenuate the bullwhip effect, and simultaneously the power of XBeerGame to support this significant learning.

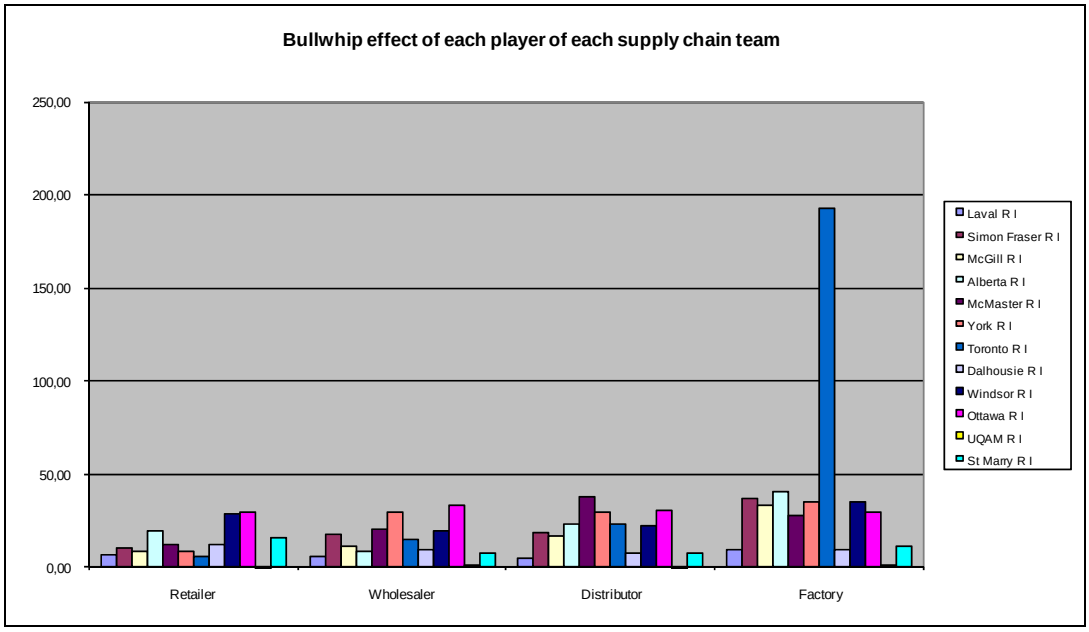


Figure 12: Bullwhip effect measure for round 1 of 2005 MBA Games tournament

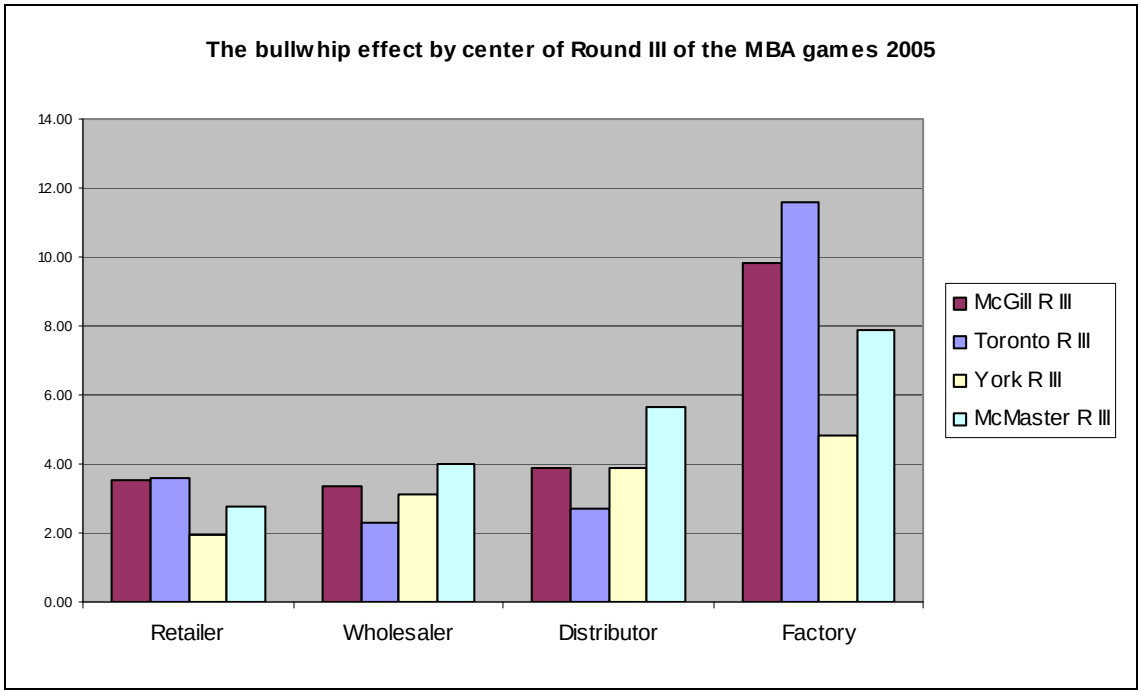


Figure 13: Bullwhip effect measure for round 3 of 2005 MBA Games tournament

The feedback received from the players showed that they loved the game, having lived an exciting learning experience. They claimed that the XBeerGame has elevated the bar in the field and that it should in the future be played systematically in their respective universities.

An interesting functionality of the BusinessWebGame platform supporting the XBeerGame is its capability of remotely projecting game master views of the various supply chain teams in a tournament, as exhibited in Figure 14. This allows yet another level of potential learning, with groups of students watching an ongoing team or overall tournament in action, comparing and contrasting the relative performance and behaviours of the various teams and of the distinct players in a team.

Figure 14: Monitoring teams remotely during a tournament from a laboratory in Université Laval

5.2 Embedding XBeerGame in the core of a supply chain course at EPFL

Since the academic year 2006-2007, the XBeerGame has been used at EPFL in Lausanne, Switzerland, for a Masters course on Supply Chain Management. This course is composed of three parts:

1. Discovery of the basic Supply Chain principles by using the XBeerGame in the form of guided game sessions and contests.
2. Formal presentation of a complex mathematical model of supply chain characteristic behaviour inspired by the work of Daganzo (2003).
3. Critical analysis by the students of several real world cases

The first part of the course program is mainly organized around XBeerGame competitions. For example, in a specific year, forty students participated in the game in the class, divided into 10 groups of four students. Each student in a group plays the role of one of the XBeerGame actors. The beer market deals with two types of beers. The level of difficulties and running time can be parameterized for example by setting strong variations in the market demand. The optimization conditions are announced at the beginning of each round such as: i) local optimization for the purpose of maximizing personal profit within a supply chain; ii) global optimization in order to maximize the sum of the profits within each supply chain.

In most cases, the first round is dedicated to getting used to the game environment. Without giving too many details, instructors guide students to learn by themselves how to react in a certain situation. That is to say, the pedagogical scheme is based on discovery learning.

The experience gained demonstrates clearly that the use of a dedicated tool such as XBeerGame for teaching supply chain management helps improving the learning effects. The following benefits are particularly observed:

- Student motivation – Using a realistic game motivates student's participation and increases learning effects.
- Learning efficiency – XBeerGame is not a general game environment but a specific environment tailored to help understand different issues concerning supply chain management.
- Learning method – According to the observations, the method of discovery learning is suitable for assimilating the main principles of supply chain behaviour. The typical non-linear behaviour is particularly well understood through the discovery of unexpected strong effects and sensitivity.

The experience highlights also some improvement potential related with the game-based learning approach.

- Need to make it easier and faster for teachers to customise the game scenario and context to the learner's level and teaching objectives. We have used the same tool both for university students and for experienced enterprise practitioners in the context of continuing education. Although in both cases, interest and participation rates were high, learners would have clearly benefited from a more tailored context.
- Need to reflect more realistically the complexity of real supply chains serving real markets. Here are two examples of potential improvements. The current four-serial-player supply chain is quite simple: more complex chains should be allowed. The current market is not competitive, each supply chain operating in its parallel world. It would be preferable to allow competition between supply chains depending on the teacher's learning objectives.

These insights have lead to launch a currently ongoing project on improving the technical and functional aspects of the XBeerGame and the BusinessWebGame platform.

6. Conclusion

While long recognized as a necessity in the training of airline pilots, virtual games based on immersive simulators are just starting to be recognized widely as an important tool in the training of managers, planners and engineers. Supply chain management, through a triad of large scale, wide scope and high complexity, is a targeted candidate for exploiting virtual gaming. The Beer Game has already been digitized a large number of times. The most well known is M.I.T.'s on line version. The XBeerGame is among the latest entries, and definitely among the most elaborate, powerful and convivial. Yet such technologies are just in infant phase as compared with what is expected to develop as the field gets more mature and integrates smoothly with the widely commercial gaming technologies enabling such widespread successes as SimCity, the Sims, Roller Coaster Tycoon and Second Life.

Technologically there is still a long roadmap ahead. Yet at least as important are the needs for much more research on the functionalities required from a learning oriented SCM gaming platform, on how to exploit such platforms so as to best enable experiential learning, and on how to adapt the learning mechanisms, the courses and the education programs to better exploit virtual gaming.

Université Laval and EPFL are teaming to continue exploring this important emerging research area. The motivation is that in the emerging global knowledge society, the minds of people are to be among the key differentiators between businesses. Shaping these minds, helping them grasp how to tackle the challenges of driving supply chains in a global, digital, coopetitive and turbulent economy, is a quest worth investing.

The XBeerGame and the underlying BusinessWebGame platform are keystones in the joint research. Conceiving, developing and testing versions with higher levels of functionality are core activities under way. Also active are experiential investigations on how to conceive and implement the exploitation of such SCM virtual gaming in various learning contexts, and how to evaluate the acquisition of the mandatory learning outcomes resulting from the various specific game sessions.

Being motivated from the encouraging results and feedback from students, in 2009 the use of XBeerGame is planned to be introduced in the context of a new international executive master program on global supply chain management, offered jointly by École Polytechnique Fédérale de Lausanne in Switzerland, Université Laval in Québec, Canada, and École des Ponts et Chaussées in Paris, France. This will involve XBeerGame competitions between student teams split between Europe and North America, thus developing a strong sense of international cooperation and confronting the students to practical difficulties related to separated locations.

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