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TRAINING FOR TODAY'S SUPPLY CHAINS: AN INTRODUCTION TO THE DISTRIBUTOR GAME

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ABSTRACT

In this paper we present the Distributor Game, which is the first of a series of management games developed for today's supply chain challenges such as globalization, increasing importance of the customer role and mass customization. The learning objective for players of the Distributor Game is centered around globalization and the real-time supply chain. The decision making processes of the distributors in the game are controlled by human players. To confront the human players with a complex and dynamic environment, suppliers and markets are represented by computer-controlled actors. After playing the game for the first time with 32 MBA students, it was evaluated using a detailed questionnaire, the results clearly showed the value of the game. Further research will focus on software services to make game instantiation easier and to enhance the support for development and use of simulation-based supply chain management games.

1 INTRODUCTION

Within supply chains, there was and is a shift from traditional (rigid) supply chains towards flexible supply chains that can even be instantiated on the spot. We briefly introduce a number of developments, which contribute to this shift. Due to the increase in worldwide relations, both quantitatively and qualitatively, globalization is becoming increasingly apparent, especially in supply chains (Archibugi et al. 1999). The emergence of the Internet as the global information infrastructure backbone has accompanied the globalization of markets (Boyson et al. 1999). When operating in global markets, companies experience both threats from foreign competitors and opportunities from foreign customers (Simchi-Levi et al. 2003). The challenges are, for example, dealing with longer transportation times, high inventory levels, complex logistics and the high cost of coordination as companies try to coordinate information, goods and money across the globe (Lee and Whang 2000). Secondly, there is an increasing importance of the customer role. Customers, who become more knowledgeable about products, are demanding a higher quality of products and services and lower prices (Fredendall et al. 2001). In this sense, the concept of a "demand network" might be more appropriate than a "supply chain", since it focuses on demand as the trigger for the processes encapsulated within the supply chain. However, for reasons of readability we use the term supply chain throughout this paper. Modern supply chains must be more responsive to rapidly changing demand, instead of the forecast-driven approach often used in more traditional supply chains (Christopher 2000). Thirdly, we have observed growing attention for mass customization. Mass customization relates to the ability to provide customized products or services in high volumes and at reasonably low costs (Silveira et al. 2001). The reason behind increased attention being given to mass customization is the breakdown of the stable mass market (Hart, 1995). Customers, indeed, are becoming more discriminating and seek products more capable of being individualized to meet their specific tastes and preferences.

Managers often do not have insight into the ripple effects of their decisions on the entire supply chain. Indeed, supply chain managers lack analytic tools to guide their decision processes and/or interventions strategies. At the same time, they are faced with an overwhelming flood of data that crosses their desk daily, weekly and monthly (Boyson et al. 2004). What is lacking, then, are tools to process/analyze the flood of information.

Given these developments, and the need to train students and managers who are able to make supply chain decisions, we recognized a need to develop a new type of supply chain management games and, more importantly, to provide a virtual environment called a "studio" (Keen and Sol 2005). Our studio should support the development and usage of games for different supply chains, multiple problem situations and different scenarios. The games developed using the studio should present recognizable situations for their players. Players should be stress-tested in a way that closely resembles how supply chain managers are tested when managing the complexities of today's supply chains.

We developed the "Distributor Game" as a means for determining the final requirements for the concepts and technologies to be used in our studio. The requirements are presented in more detail in Section 2, and more details about the game are given in Section 3. The objective of the Distributor Game is to address one of the above mentioned developments: globalization. The Distributor Game supports players in becoming familiar with the concepts of globalization and real-time supply chain management by challenging and training their strategic supply chain thinking, critical factor analysis and rapid decision making. The game was played and tested by 32 MBA students who specialized in supply chain management. A questionnaire was used to evaluate the value of the Distributor Game after the players had finished playing. We give the results of this evaluation in Section 4.

2 REQUIREMENTS FOR TODAY'S SUPPLY CHAIN GAMES

A summary of requirements for today's supply chain games is described in this section. A more detailed description of the requirements is presented in Houten and Jacobs (2004).

Some of these requirements are content, i.e. supply chain related, others are related to the way these games are used, for example in a web-enabled setting. When we want to assess the quality of these games, there are three U's that are important: the *usefulness* of the games, for example the value that they add to the goal of training or learning, then there is their *usability*, for example the mesh between users, processes and technology, and finally there is their *usage*, for example their flexibility, their adaptivity and their suitability to the context of the problem environment (Keen and Sol 2005). Furthermore, we consider the different activities and roles, e.g. a developer or a game administrator, involved in these activities while developing and using these games. The activities we consider are: problem formulation, conceptualization, specification, facilitation, technical administration and playing. The latter activity includes debriefing. We summarize the requirements below, based on the three U's.

- **Usefulness** The first requirement we needed to meet is that of providing a credible game context to players. This credibility is expressed in terms of the complexity and dynamics of a game.
- **Usability** To give players the opportunity to really grasp the complexity of a supply chain, we need games that are suitable for distributed, web-enabled use. Furthermore, in games like this, we need a continuous time advance, as opposed to current games, which are often turn-based. In addition, the quality of the user interface, both for entering data and for getting an overview of the state of the distributing organization that is managed, is important. Participants should be able to make decisions on the basis of the information presented to them in the game.
- **Usage** Persistency is an important requirement given possible long playing times of a game and the chances that the connection with the application of a player is unexpectedly lost. Furthermore a persistency service may be used for debriefing purposes, e.g. by showing the state of the actors at a certain moment in the game. Other requirements are related to reliability, robustness, credibility and adaptivity.

A number of games focusing on the same type of decision making processes (complex and dynamic systems), such as Markstrat and the Beer Game have been examined. The list of examined games is based on the enumeration presented by Faria and Wellington (2004). We found that these games usually provide a subset of the above mentioned requirements. They have a 'lock-in' to a certain problem domain or environment and often are turn-based, making them less suitable for training players for today's supply chain management challenges.

3 AN OVERVIEW OF THE DISTRIBUTOR GAME

The Distributor Game needs to support players with becoming familiar with the concepts of globalization and real-time supply chain management. In today's business environments, according to (Boyson et al. 2004), the real-time supply chain is taking on life-and-death importance. The slowdown in demand across many sectors and the longstanding, chronic deflationary pressures on prices and profits have forced companies to overhaul their corporate supply chain strategies. Companies are shifting from reactive to anticipatory logistics. Anticipatory logistics focuses on building supply chain-wide adaptability and robustness in the face of extreme volatility. In the game, players play the role of a distributor. Their main tasks are to buy products from suppliers and to sell them to markets. The products are four different computer systems: laptops, servers, multi-media systems and desktop systems. Players need to manage their inventory carefully, taking into account (dis)advantages of global sourcing and purchasing. An incentive to do so has been incorporated using a 5% depreciation per week of products on stock, which is a realistic figure given the type of products.

To measure players' performances, data is collected for populating balance and equity sheets. These sheets reflect the state of players by taken into account the balance, the value of their inventory, outstanding orders, incoming orders and bills to be paid and payments to be received. These sheets are presented to players on a regular basis, enabling them to see how their strategies perform in comparison to other players' strategies.

To reflect better the pace of the real-time, global supply chain, the simulator we use as part of our architecture (Houten and Jacobs 2004) provides the ability to play the game continuous. While this simulator loops over its eventlist, it takes pre-defined steps in between. The controls, e.g. to slow down or speed up a game, enable us to distort time and help us to emphasize and control the attention and focus of the players (Houten and Jacobs 2004). The simulator is part of the DSOL suite, a set of Java based simulation libraries (Jacobs, Lang and Verbraeck 2002).

3.1 The Supply Chain

To support the concept of globalization, the world has been divided into three regions: the U.S., Europe and Asia. In the U.S. region 6 distributors were present when we played the game, the other two regions each had 5 distributors. Furthermore a number of suppliers and markets were present in each region. The number of distributors was based on the number of students that played the game during the first test, but it is a flexible number that can easily be changed. There were 32 students who were placed in 16 teams. It is possible to buy products globally, so there is global competition, both for the distributors buying from global suppliers, and for the global markets buying from the global distributor student teams.

An overview of the European region is presented in Figure 1. In total there were 36 suppliers, 16 distributors and 18 markets present in the game, providing as such a complex and recognizable situation for the players. The suppliers and markets were all computer-controlled. Computational algorithms were used for all their decisions. Again, other settings are possible, for instance allocating the roles of suppliers and markets to human players, but as they only either buy or sell, the game would be less interesting to play for these players when compared to the game play for the distributors, who have a buying *and* a selling role.

3.2 The Scenario

The scenario we played focused on a demand surge for laptops and a diminishing demand for desktops in the Asian region. The suppliers in the Asian region were modeled in such a way that they could not meet the increased demand of the distributors. Hence, a shift in demand from Asian distributors to suppliers in the U.S. region was expected. We used news messages to inform the players in advance that the above situation might occur. If players anticipated to this situation, they could get an advantage over the other players in the game. The scenario was implemented as a predefined list of events, designed to make sure the demands of the markets would increase over time.

3.3 Managing a Distributor

Players had to manage a variety of decision making processes to keep their distributors in an economically healthy state. First, each team of players had to develop a strategy of what to buy, when to buy and where to buy. The business messages a player has to deal with concern requests for quotes, quotes, orders, order confirmations, shipments, bills and payments. For the Distributor Game, we chose a situation where a player had to deal with all the messages, except the shipments and payments. These were handled by computational algorithms that supported the human players. The level of decision making for the game was clearly on an operational level. However, for other games we could choose a situation where players only focus on setting *policies* for more advanced "agents" that handle the business messages on their behalf. Furthermore we are able to make games in which we really split the decision making processes between the players of a team. For example one player who focuses on inventory, with another who focuses on sales. As such, a variety of games for teaching today's supply chain management issues is supported by our architecture.

3.4 Using the Distributor Game

The Distributor Game was tested with 32 MBA students at the R.H. Smith School of Business of the University of Maryland, U.S.A.. After a one hour introduction, and a practice round of one hour to get acquainted with the supply chain and with the user interface of the game, the game was played for 2.5 hours. The students had access to a web-portal that contained the instructions, context and background information for the game. The web-server for this portal was based in Delft, The Netherlands. In Figure 2 we present an overview of the technical setting of the Distributor Game.

The players used a graphical user interface, developed in Java, to control the distributors. The graphical user interface could be downloaded from the web-portal and started using Java Webstart. This enabled the players to always use the latest available graphical user interface, without installing new software. Furthermore, the installation process is straightforward, and the only software that needs to be installed is Java, which is rarely a problem. No specific game software has to be installed on the classroom computers. The architecture of the Distributor Game allows multiple game administrators to login at the same time from different computers. Each of them may focus on a different part of the game. During the test, one of the game administrators

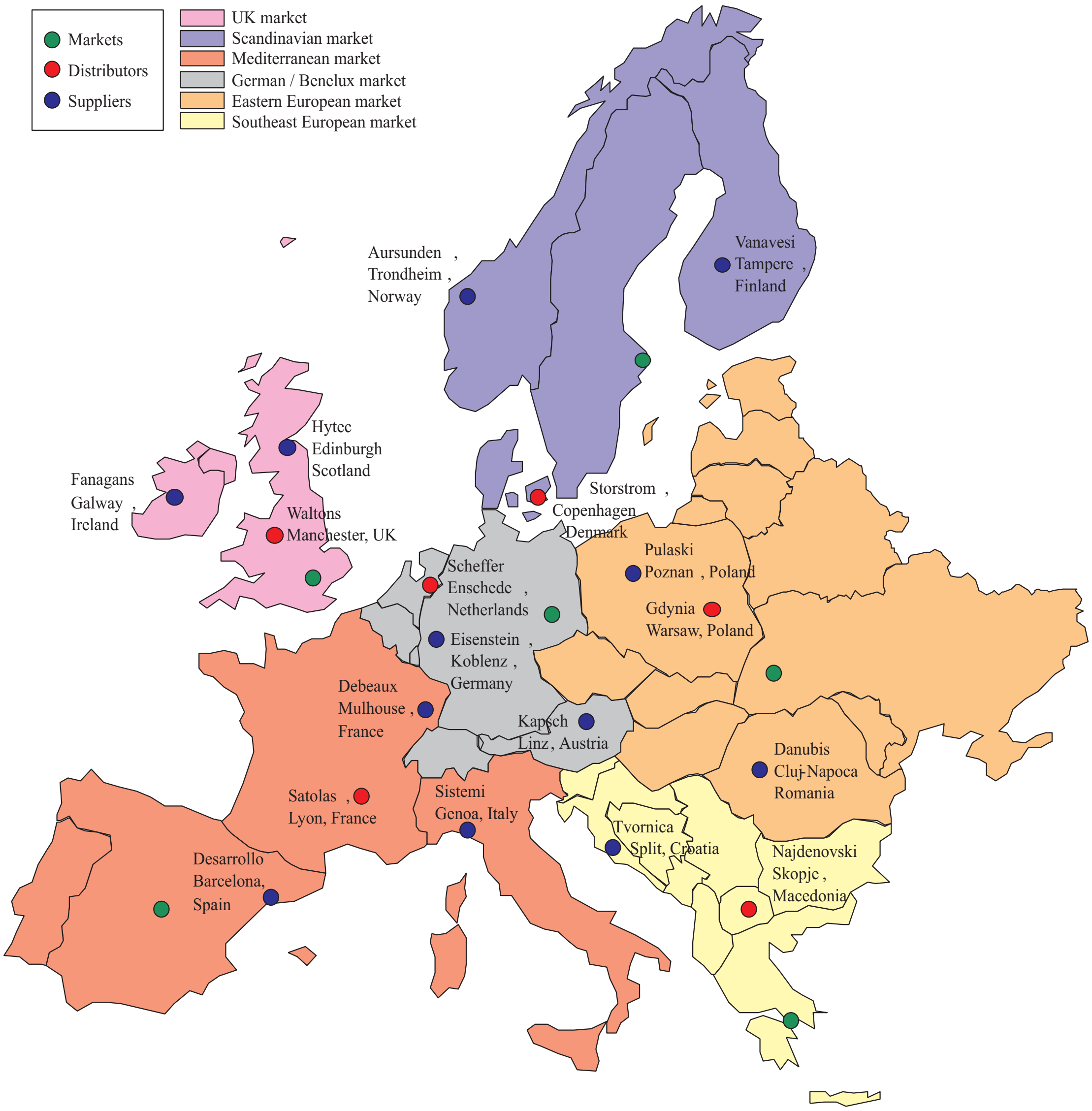

Figure 1: Companies in the European Region of the Distributor Game

presented, using a beamer, an animated overview of all the messages between the actors in the game. The other game administrator hosted the whole game on his computer. Providing an animated overview of the flow of messages helped players better to understand the complexity and dynamics of the scenario. Players were able to see their own and other players' messages being transmitted between actors on the screen. Furthermore, as game administrators, we were able to select a business message on the animation screen, using a mouse, and then reveal its contents. Using the same technique, we were also able to select an actor and if necessary change one or more of its attribute values, such as its balance or inventory levels. For future versions of the Distributor Game, or other games based on this architecture, we can choose to use a central server for hosting, thus making the game globally accessible. An animation to give insight into the transactions between players could be provided through a Java applet.

4 EVALUATING THE DISTRIBUTOR GAME

One of the main reasons for evaluating the Distributor Game was to see whether it would indeed meet our goal to support training and learning for managing today's supply chains. The evaluation of business games can be divided into two categories: internal and external evaluation (Angelides and Paul 1999). Internal evaluation focuses on the assessment whether the desired behavior of the developed business game has actually taken place. This assessment can either be formative or summative and is carried out by the developer (Angelides and Paul 1999). For the Distributor Game, the internal evaluation has been executed in a formative way, i.e. during the process of development. Analysis of the

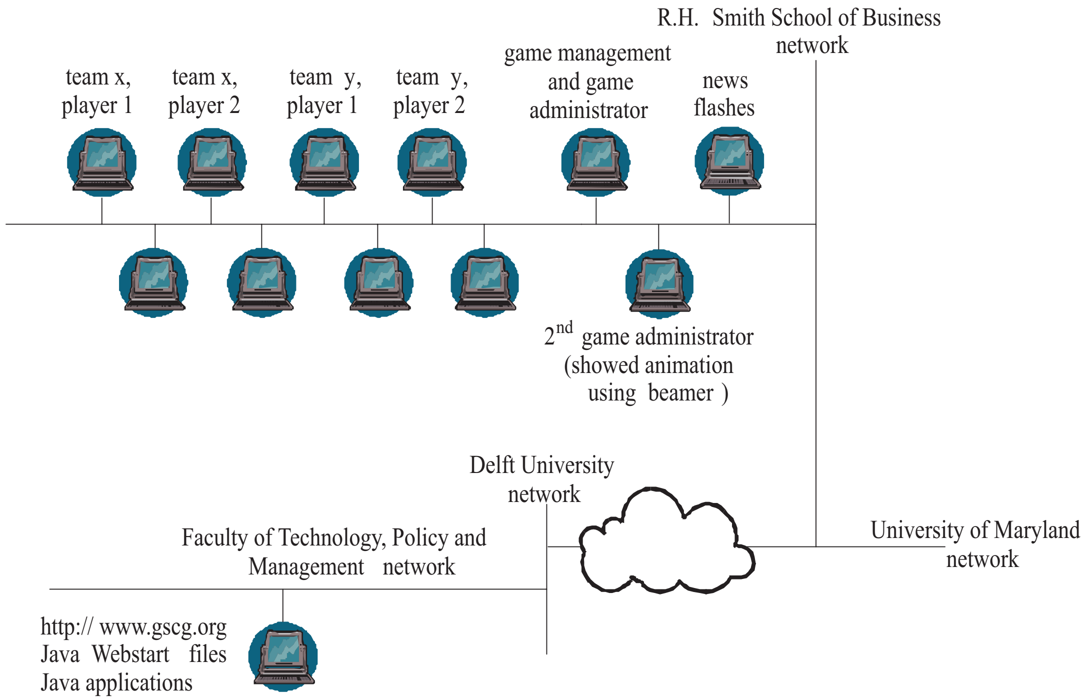

Figure 2: Technical Architecture of the "Distributor Game"

business logic of the supply chain library, as well as analysis of the specified behavior was performed in an iterative way. Furthermore, several test runs, both with and without human players, have been executed in order to test the scenario and specification of the actors in a dynamic way. A last test run was executed with a number of domain experts of the R.H. Smith School of Business, and it was positively evaluated.

The purpose of external evaluation is to assess the impact of the simulation on the players and observers (e.g. teachers). We used a questionnaire to evaluate the quality of the graphical user interface, of the web-portal and of the game. The basis for the questionnaire was technology acceptance model (TAM) introduced by Davis (1989). TAM is used to measure why people accept or reject information technology, in this case the graphical user interface of the game. For the questions we used a 5-point Likert scale ranging from "strongly disagree" to "strongly agree", plus an exit option. For the quantitative analysis of the questionnaire, we followed the series of steps presented by Creswell (1994):

- report information about the number of players who did and who did not return the questionnaire
- discuss the method by which response bias will be determined
- identify the tools for statistical analysis and a statistical computer program for testing the major questions from the questionnaire

Since we used a five-point Likert scale for measurement, we were not able to use statistics like a 95% confidence interval or a standard deviation. The reason is that the Likert scale is not an interval scale, because the distances between the values of the scale are not equal. We only know that, assuming a question is asked positively, "strongly agree" will be better than "agree", however, we do not know how much better. All answers were translated into equidistant numerical values, where 1 means "strongly disagree", and 5 means "strongly agree", but the distances between the values are not treated as equidistant. The statistical tests we applied therefore are the mode and the *geometric* mean. The latter is a "summary" statistic useful when the measurement scale is not linear. It is calculated as follows: $G = (x_1 * x_2 * ... * x_n)^{1/n}$.

The results of the set of questions related to the applicability of the Distributor Game for supply chain management and the usefulness of computer-controlled actors are presented in this section. Based on the results for question 1, as illustrated in Table 1, we conclude that the game supported the players in better understanding the basic concepts in supply chain management. Comments from players pointed to the recognizability of the game for showing the complexity of the market, showing insight into matching supply and demand and the usefulness of the richness of information.

We can conclude from the results presented in Table 2 that the scenario had a positive effect on the players' opinion with regards to its usefulness. However, during the debriefing some more insight into the scenario was given, which may have biased the players' opinion.

Table 1: Did the Distributor Game Support Understanding the Illustrated Basic Supply Chain Management Concepts?

Question 1	n	mode	G
The game helped me better understand the illustrated basic concepts in supply chain management.	32	agree	4.14

Table 2: Did the Scenario Support Understanding the Illustrated Basic Supply Chain Management Concepts?

Question 2	n	mode	G
The scenario has supported me in understanding the illustrated basic concepts in supply chain management.	30	agree	4.09

Based on the results presented in Table 3 we conclude that the players enjoyed playing the game. Comments showed that they thought the game was fun, though perhaps a little bit overwhelming according to some players.

Table 3: Did the Players Like Playing the Distributor Game?

Question 3	n	mode	G
Overall, I liked playing the game.	32	agree	4.31

Overall, we conclude, based on the results presented in Table 4, that the players found the game useful for helping them understand the illustrated basic concepts in supply chain management. One player commented that the game offered examples of how situations change in a global context, that the game showed the richness of information one would expect and that the game showed the importance of balancing ones inventory and ordering strategy.

Table 4: Overall, Did the Players Find the Distributor Game Useful for Understanding Supply Chain Management?

Question 4	n	mode	G
Overall, I found playing the game useful for understanding the illustrated basic concepts in supply chain management.	30	agree	4.23

Though the decision algorithms used for the computer-controlled actors in the game were fairly simple, they did gave the majority of the players the feeling that their behavior was lifelike as the results presented in Table 5 show. One of the respondents indicated that the randomness of the inter-arrival times of requests for quotes and the variance in requested amounts were great.

When the players compared playing the game to working experiences they had as a manager in supply chain management, they thought that the computer-controlled actors showed comparable behavior, see Table 6. However, given the number of responses for this question (18, other players had no working experience in the field of supply chain management) and the fact that the score of the remaining players is close to neutral, we need to be careful with drawing conclusions based on the results for this question.

Table 5: Did the Computer-controlled Actors Show Lifelike Behavior?

Question 5	n	mode	G
The computer-controlled actors showed lifelike behavior.	27	agree	3.93

The questionnaire had more than 30 additional questions, which provided us with detailed insight into the quality of the user interface and the alignment between the game and the real-time supply chain course of which this game was a part. The user interface was judged positively, and the players provided us with some detailed comments on possible improvements that will be implemented in the next version of the Distributor Game.

Table 6: Were the Inputs from the Computer-controlled Actors Comparable to Real-life Inputs?

Question 6	n	mode	G
The inputs I received from the computer-controlled actors were comparable to inputs I have as a working manager.	18	neutral & agree	3.33

5 CONCLUSIONS

A description of the Distributor Game, which is the first of a series of games for today's challenges in supply chain management is given in this paper. The Distributor Game is based on an architecture suitable for providing games for many different problem contexts and scenarios, in a distributed, web-enabled setting.

The Distributor Game presented in this paper demonstrates the various possibilities for building and playing this type of games with human and computer-controlled actors. Furthermore it demonstrates the value of presenting complex and recognizable models of supply chains to players in an interactive way.

Several topics remain for further research and implementation. First, the usage of computer-controlled actors for these type of games requires further attention, especially the modeling of their behavior. Research into the algorithms used for operational decision making remains a challenge. An agent-based approach for modeling their behavior seems promising. Secondly, the architecture we used does not yet provide the ability to model any type of game we would like to create. An example could be closed-loop supply chains, where returns and spare parts play an important role (Guide et al. 2003). Further research will focus on the services required for such an architecture. One might think of visually modeling a supply chain and the behavior of computer-controlled actors. Furthermore we have found that the design of a scenario, and its control during a game, poses a big challenge, which should be supported by appropriate services.

REFERENCES

Angelides, M. and R. Paul. 1999. A methodology for specific, total enterprise, role-playing, intelligent gaming simulation environment development. *Decision Support Systems*, 25:89-–108.

Archibugi, D., J. Howells, J. Michie. 1999. *Innovation policy in a global economy*. Cambridge: Cambridge University Press.

Boyson, S., T. Corsi, M. Dresner, and L. Harrington. 1999. *Logistics and the Extended Enterprise*. New York: John Wiley & Sons, Inc.

Boyson, S., L. Harrington, and T. Corsi. 2004. *In real time. Managing the new supply chain*. Praeger Publishers.

Christopher, M. 2000. The agile supply chain, competing in volatile markets. *Industrial Marketing Management*, 29(1):37–44.

Creswell, J. 1994. *Research Design Qualitative & Quantitative Approaches*. Thousand Oaks: SAGE Publications.

Davis, F. 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3):319—340.

Faria, A. J., and W. J. Wellington. 2004. A survey of simulation game users, former-users and never-users. *Simulation & Gaming*, 35(2):178–207.

Fredendall, L., J. Hill, and E. Hill. 2001. *Basics of supply chain management*. New York: St. Lucie Press.

Guide Jr., V. D. R., T. P. Harrison, and L. N. Van Wassenhove. 2003. The challenge of closed-loop supply chains. *Interfaces*, 33(6):3–6.

Hart, C. 1995. Mass customization: conceptual underpinnings, opportunities and limits. *International Journal of Service Industry Management*, 6(2):36–45.

Houten, S. P. A. van, and P. H. M. Jacobs. 2004. An architecture for distributed simulation games. In *Proceedings of the 2004 Winter Simulation Conference*, ed. R. G. Ingalls, M. D. Rossetti, J. S. Smith, and B. A. Peters, 2081–2086. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers. Available online via <http://www.informs-cs.org/wsc04papers/279.pdf> [accessed March 04, 2005].

Jacobs, P. H. M., N. A. Lang, and A. Verbraeck. 2002. D-SOL; A distributed Java based discrete event simulation architecture. In *Proceedings of the 2004 Winter Simulation Conference*, ed. E. Yücesan, C.H. Chen, J. L. Snowdon, and J. M. Charnes, 793–800. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers. Available online via <http://www.informs-cs.org/wsc02papers/102.pdf> [accessed March 06, 2005].

Keen, P. W. G., and H. G. and Sol. 2005. *Rehearsing the future.* To appear.

Lee, H. and S. Whang. 2000. Information sharing in a supply chain. *International Journal of Technology Management*, 20(3/4):373–387.

Silveira, G. D., D. Borenstein, and F. Fogliatto. 2001. Mass customization: Literature review and research directions. *International Journal of Production Economics*, 72(1):1–13.

Simchi-Levi, D., P. Kaminsky, and E. Simchi-Levi. 2003. *Designing & Managing the Supply Chain*. 2nd ed. New York: McGraw-Hill.

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