SUPPLY CHAIN DYNAMICS: SIMULATION-BASED TRAINING AND EDUCATION

Yuri Merkuryev[(a)], Jana Bikovska[(b)] , Galina Merkuryeva[(c)]

Riga Technical University
Kalku Street 1
LV-1658 Riga, Latvia

[(a)]merkur@itl.rtu.lv, [(b)]Jana.Bikovska@rtu.lv, [(c)]Galina.Merkurjeva@rtu.lv

ABSTRACT

The paper discusses use of simulation-based business games for training and education in the area of supply chain management. It starts with a state-of-the art review of extant application of simulation games used for training and education in supply chain management, followed by description of a recently developed ECLIPS game. It has been developed within a European project for providing an insight into various aspects of supply chain management, with possibilities to analyze different supply chain structures and control mechanisms. In particular, application of the ECLIPS game to comparison of different supply chain inventory management policies, including non-cyclic and cyclic ones, is provided. For that particular situation, game rules and playing process are explained, as well as sample results obtained by participants are presented and interpreted.

Keywords: simulation-based training and education, simulation business games, supply chain management.

1. INTRODUCTION

Currently simulation-based training and education methods have proved their efficiency in different areas ranging from a military sphere to health care, as they result in greater retention, deeper understanding, higher levels of engagement, and better transfer of knowledge to the job. In particular, simulation-based business games (or shortly "simulation games") are widely used for training managerial, technical, and problem-solving skills, based on the experiential learning principles. Simulation games significantly increase the motivation and interest level of trainees.

In the field of supply chain management, simulation games have been used for over 50 years. Nowadays this sphere is developing rapidly, as new methods and approaches appear for solving actual problems, for example, the one discussed in Merkuryev et al. (2007, 2008). Introducing of new approaches to supply chain management usually causes a necessity for their exhaustive explanation and illustration. For this purpose, new simulation games are often developed. Moreover, the use of modern information and telecommunication technologies also contributes to the development of new games and improving existing ones than could significantly increase the number of potential users, as well as enhances their efficiency.

2. LITERATURE REVIEW

Nowadays many simulation games that focus on supply chain management are available. The most well-known is the Beer Game (Sterman, 1989). It has been developed in the 1960s at the Massachusetts Institute of Technology to demonstrate the bullwhip effect and clarify the advantages of taking an integrated approach to the managing of a supply chain. The Beer Game allows players to simulate the working of a single product distribution supply chain in which each player manages the inventory of a retailer, wholesaler, distributor, or manufacturer. Initially the game was developed as a board game. As an example of its realization, the LOGDIS game developed by Cim_Cil Technology Transfer Center (www.cimcil.be) can be mentioned. Later on a computerized version was developed (Simchi-Levi et al., 1998). The most recent versions are played with computers through the Internet, for example, the one described by (Jacobs, 2000) or another one described by Sparling (2002). These Internet based implementations have the advantage of considerably reducing time required to play the game. Some modifications of the classic Beer Game are proposed by Chen and Samroengraja (2000) - the material and information flows in a production-distribution channel serving a stationary market where the customer demands in different periods are independent and identically distributed. Despite these updates, the Beer Game has a strong focus on the bullwhip effect and its casual factors, i.e., inadequate information sharing across the supply chain, however there are many other aspects that can be considered and illustrated through simulation games.

For example, an Internet based supply chain management game (Zhou L. et. al, 2008) is extended from the Beer Game and provides an Internet supply chain challenge business scenario simulation (ISCS) with a Management Information System built in to support decision making. In other words, ISCS is an on-line multi user information system which links every player together using the Internet technology with capability to test and evaluate comprehensive SCM strategies, e.g., capacity planning and inventory management, production planning, purchasing strategies, supply chain collaboration and integration strategies and others. The game needs a minimum of seven players. There are five types of products considered in the game.

To model a specific supply chain application, the Blood Supply Game (Mustafee and Katasaliaki, 2010) has been developed. It can be used to illustrate supply chain management principles in a special make-to-stock environment with perishable products with limited collection/production. In particular, the game simulates the process of blood collection, production, testing, distribution, hospital stocking, and usage by patients where participant plays a distributor role. It is played by individuals on a PC with Microsoft Excel exploiting VBA environment.

For teaching service-oriented supply chain management principles, the Mortgage Service Game (Anderson and Morrice, 2000) has been developed. It is a computer-based simulation game that can be used to illustrate supply chain management principles in a make-to-order environment as that kind of supply chain typically cannot hold inventory and can only manage backlogs through capacity adjustments. The bullwhip effect is considered in this game. The game can be played in teams or by individual where players manage only one stage of the supply chain.

The Supply Chain Game (Feng and Ma, 2008) has been developed at the Kellogg School of Management at Northwest University by prof. Chopra and prof. Afeche. It is an Internet-based supply network simulator. Here the supply chain structure is not strictly defined; participants are responsible for demand forecasting, inventory control, production planning and scheduling, network design, and logistics; only one product is considered.

SBELP is a supply chain simulator developed at King Fahd University of Petroleum and Minerals (Siddiqui et.al. 2008) that simulates an international supply chain network used to deliver electronic equipment. Here the player acts as a manufacturer who takes decisions that impact the performance of the whole supply chain. In order to investigate the Bullwhip effect three scenarios have to be played: (1) the traditional chain – no information from other echelons is shared, (2) the value of information – all information on flow of material downstream and flow of orders upstream is available, and (3) the true market – customer demand is stochastic.

The RSS-POD Supply Chain Management Game (Chan E.W. et.al, 2009) developed by RAND Health Center for Domestic and International Health Security is a Microsoft Excel-based game that allows players to practice in inventory management. It can be played by individuals or in small groups. Players perform the role of inventory manager at a receipt, storing, and staging (RSS) facility and must allocate inventory among multiple points of dispensing (PODs), with the goal of distributing countermeasures to as many people as possible. The exercise consists of three rounds of playing called modules, in which the player is progressively given more information for managing inventory. These three modules are played through the same time period, so that after all three modules have been completed, performance comparisons can be made across the modules. In the final module, players are provided with a simple mathematical algorithm to make distribution decisions that is a version of a standard periodic-review, "order-up-to" inventory policy. The distribution network consists of one warehouse and ten PODs. Only one product is considered in the game.

The Trading Agent Competition – Supply Chain Management game (TAC/SCM, 2007) has been designed jointly by a team of researchers from the e-Supply Chain Management Lab at Carnegie Mellon University and the Swedish Institute of Computer Science (SICS). Here agents are simulations of small manufacturers, who must compete with each other for both supplies and customers, and manage inventories and production facilities. The game represents of a broad range of supply chain situations. It is challenging in that it requires agents to concurrently compete in multiple markets (markets for different components on the supply side and markets for different products on the customer side) with interdependencies and incomplete information. It allows agents to strategize (e.g. specializing in particular types of products, stocking up components that are in low supply). To succeed, agents will have to demonstrate their ability to react to variations in customer demand and availability of supplies, as well as adapt to the strategies adopted by other competing agents. While the game is well known among researchers, in fact it is not suitable for teaching purposes.

A team of researchers from Delft University and from the Robert H. Smith School of Business at the University of Maryland has developed The Global Supply Chain Game (Corsi et.al., 2006). A specific instance of the game is called "Distributor Game". It focuses on a distribution process in a global real-time supply chain. It replicates the traits of a modern supply chain, which requires multi-tasking in a dynamic 24/7, real-time and event-driven environment in which global supply chain leaders must function that makes it different from other static turn-based games. The supply chain structure simulated within the game is non-linear. The decision-making processes of the distributors are controlled by human players while other echelons can be represented by computer-controlled actors. Four different products are considered in the game.

The comparison of key attributes of the described games is provided in Table 1. It can be concluded that most games have a fixed structure of the simulated supply chain that limits their use for training company personnel within its own supply chain as well as only a few games have focus on inventory control strategies. The recently developed ECLIPS game covers these issues. The detailed description of this game is

Table1: Comparison of Key Attributes of the Reviewed Supply Chain Games

	Beer Game	ISCS	Blood Supply Game	Mortgage Service Game	Supply Chain Game	SBELP: supply chain simulation	RSS-POD Supply Chain Management Game	Trading Agent Competition	Global Supply Chain Game -Distributor Game	ECLIPS
Turn-based (T) or continuous time(C)	T	T	T	T	T	T	T	n/a	C	T
Software assisted	Y*	Y	Y	Y	Y	Y	Y	Y	Y	N
Web-based	Y*	Y	N	N	Y	N	N	Y	Y	N
Players per team	1-4	7	1	1-5	3-5	1	1-5	n/a	2	4
Echelon focus within supply chain: Distributor (D), Factory (F)	All	All	D	D	F	F	D	F	D	All
Demand: pre-planned (P) or random (R)	P	R	R	P	R	P/R	R	R	R	R
Number of products	1	5	1	1	1	1	1	16	4	1
Supply chain structure: fixed (1) or flexible (2)	1	1	1	1	2	1	1	1	1	2
Inventory control strategies: continuous (C), periodic (P) or not considered (No)	No	n/a	No	No	C	No	P	No	No	C, P

*****some versions of the game

presented in the following sections of the paper.

There are also simulation games that cover a much wider range of issues that this article does not intend to cover. For example in (Merkuryeva et al., 2009) the number of simulation games on general logistics management are described, while in (Van der Zee and Slomp, 2009) the use of simulation games for training operations management concepts is discussed.

3. DESCRIPTION OF THE ECLIPS GAME

The ECLIPS simulation game has been developed within a European project "Extended Collaborative Integrated Life Cycle Supply Chain Planning System" (ECLIPS) under the 6th Framework Programme of the European Commission (Merkuryev et al., 2007). It focuses on multi-echelon supply chain networks. A typical managerial problem in a multi-echelon system is to decrease total costs by coordinating orders across the supply chain, while providing a certain service level. The game helps in understanding organization and functioning of a multi-echelon supply chain based on cyclic planning.

3.1. Playing process

In the ECLIPS game, the playing process usually consists of playing a number of rounds (or periods). Each round consists of the following steps (which are executed from the end-customer to raw material supplier, echelon by echelon):

1. Tossing the demand die that determines end customer(s) demand;
2. Delivery of the demand by each retailer (if possible);
3. Filling in the "customer demand" and "delivery" columns in the respective transaction form;
4. Echelon by echelon delivery by transport;
5. For each retailer: decision if orders should be send out to the nearest upstream warehouse;
6. Delivery of the demand by respective warehouse (if possible);
7. Echelon by echelon delivery by transport;
8. Decision if orders should be sent out to the nearest upstream warehouse. If an upstream warehouse is absent, production can be triggered;
9. Filling in the "customer demand" and "delivery" columns in the respective transaction form;
10. The raw material and production echelon has an alternating function each period: one period it can be triggered for new production, next period it moves its production one echelon ahead in the chain;
11. Filling in the "customer demand" and "delivery" columns in the respective transaction form.

Ideally, more than three complete cycles have to be played to make conclusions. The required minimum number of periods in a game can be calculated with a following formula: *play_periods* = *echelons* * 3.

The total number of playing rounds is not communicated to the players to avoid endgames. To avoid players guessing the number of periods, the scoring sheets contain entries for more periods than the number that will be played.

If the game is played with more than one player, players are assigned to one or more inventory points. A possible further area of research is to assign different performance targets to the different players.

At the end of the game, summary statistics are calculated based on performance metrics recorded during the game (see Tables 3 and 4).

The following four performance metrics have been identified as being useful:

1. Demand: the sum of the demand at every retailer that is equal to the sum of the dices thrown.
2. Delivered products: the sum of the items delivered by retailers that is equal to the sum of the products that are placed in the trolleys.
3. Orders: how many orders have been issued during that round? An order is issued when a warehouse ships goods (by land, air, sea). Orders can be sent out by wholesalers or retailers.
4. New production: the sum of the newly requested production at raw material and production units.

To analyse and compare different inventory management policies, the following performance metrics have to be calculated at the end of the game:

- *Service level:*

$$SL = \frac{\sum_{t=1}^{n} P_t}{\sum_{t=1}^{n} D_t} * 100, \% \qquad (1)$$

P_t – satisfied end customer demand at period t;
D_t – end customer demand at period t;
n – total number of played periods.

- *Average cost:*

$$AC = \frac{\sum_{t=1}^{n} (TQ_t * C_h + O_t * C_o + NP_t * C_n)}{n} \qquad (2)$$

TQ_t –product items in chain at period t;
C_h – inventory holding per period;
O_t – total number of orders at period t;
C_o – order fixed cost;
NP_t – number of produced units at period t;
C_n – production cost per unit.

- *Average inventory:*

$$AQ = \frac{\sum_{t=1}^{n} (TQ_{t-1} - P_t + NP_t)}{n} \qquad (3)$$

TQ_0 – initial stock of products within the entire supply chain.

As a side remark, it should be noted that, ideally, scoring should not take in account the part of the game where players "discover" the game mechanics. This can be done by scoring only over the number of periods minus the number of supply chain stages in the game.

The second side remark is that assembly games require a different scoring table. Each inventory-point has to be taken into account. Multi-sourcing games do not suffer from this drawback.

3.2. Different game modes to be played

Four ways of playing the game are provided.

1. Supply Chain Discovery: This play mode is suitable as a first introduction into multi-echelon supply chain inventory management. Player objectives are to attain a 95% service level at the lowest cost. Concepts that are suitable for identification are: general mechanisms of supply chains, bullwhip effect, introduction to ordering policies.
2. Ordering policies (ECLIPS mode): This play mode illustrates concepts of the multi-echelon supply chain cyclic planning developed within the ECLIPS project. Different ordering policies are played during the game, namely, non-cyclic, cyclic non-synchronised and cyclic synchronised policies. Concepts that are suitable for identification are: detailed operation of different ordering policies and their best practices.
3. Supply chain design: After playing with an existing supply chain, capacity constraints are introduced, the network is altered. The effects of changing the supply chain network become visible. Concepts that are suitable for identification are: mechanisms of supply chain management and supply chain design.
4. Risk Management: An assembly network is set up. Customer demand is kept as constant. Once the network and playing policies are stabilised, one of the suppliers is removed. Then the demand has to be satisfied by the remaining suppliers. Concepts that are suitable for identification are: supply chain risk management and risk mitigation strategies.

3.3. Symbols used during the game

Different supply chains can be modelled by using placemats with different symbols (as described in Merkuryev et al., 2009).

Only one product is used in the game. Because product large quantities can traverse the supply chain, colour codes are used to designate different quantities (see Table 2).

Table 2: Colour Codes for Different Product Quantities

Products	Explication
	One unit of product
	Five units of product
	Twenty-five units of product

Demand occurs at a "retailer" and is generated by tossing either a:

- octahedron dice with sides 0,1,1,2,2,2,3,13 or
- cube dice with sides 0,1,1,2,2,9 or 0,1,1,2,3,11.

For some games, demand can be constant or variable being read from a table each period.

Fulfilled demand is put in the “trolley” symbol. Unfulfilled demand is lost. No backlogging is allowed during the game. Depending on the game, a penalty for lost sales might be given.

3.4. Networks used during plays

The authors have tested different networks during the development phase. They felt some networks were more appropriate to illustrate some specific problems than others.

Linear supply chain is represented in Fig. 1. It can be used in the ECLIPS mode of the Each warehouse starts with an inventory of 20 products and retailer starts with an inventory of 30 products. Demand is dynamic and stochastic. The chain should be played for at least 30 periods.

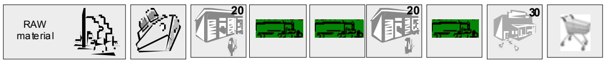

Figure 1: Three-echelon Supply Chain

In the Discovery mode the distribution network presented in Fig. 2 can be used. It consists of two subsequent distribution steps (see Fig. 2). The black lines in figure indicate the possible ways to supply products to three end-customers (labelled from one to three). The initial stock of products is placed on the respective card; it is indicated in the figure below with numbers. Demand is dynamic and stochastic. The network should be played for at least 30 periods.

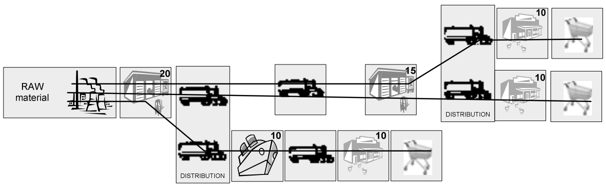

Figure 2: Three-echelon Distribution Network

Small assembly chain consists of one assembly step which is intertwined with long transports and only one customer (see Fig. 3).

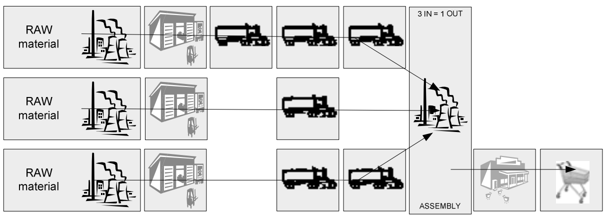

Figure 3: Small Assembly Chain

Large assembly chain consists of three subsequent assembly steps which are intertwined with long transports and only one customer (see Fig. 4). If a risk management game is played, the assembly step in the 2nd echelon could be replaced with a multi-sourcing.

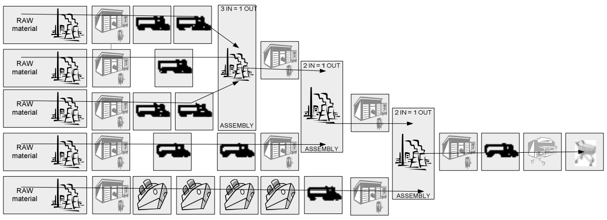

Figure 4: Large Assembly Chain

4. GAME TESTING RESULTS

At Riga Technical University (RTU) Department of Modelling and Simulation, the ECLIPS game is played since 2008. This chapter describes an example of typical results of the game obtained by master level students within the course ‘Supply Chain Management’.

The following educational scheme and agenda of the day were proposed for playing the game at RTU:

1. Introducing the game –general rules (20’);
2. Playing the Discovery mode as an introduction into multi-echelon supply chain management (40’);
3. Analysing the results of the Discovery mode (10’);
4. Playing the ECLIPS mode as getting insight into the following replenishment policies and their best practices (40’):
   a. Non-cyclic, or continuous review policy (ROP);
   b. Cyclic, or periodic review policy (POR):
      - Cyclic non-synchronised,
      - Cyclic synchronised;
5. Analysing the results of the ECLIPS mode (10’);
6. Making general conclusions (10’).

4.1. General guidelines

The following are general guidelines of playing the game at RTU:

1. Supply chain networks are physically simulated in the game.
2. For each game mode, a specific multi-echelon supply chain network is designed, i.e. a distribution network with 3 echelons and 5 nodes (see Fig. 2) for the Discovery mode, and a three-echelon 3 nodes linear chain (see Fig.1) for the ECLIPS mode. Each element of the supply chain is represented by a card. The meanings of cards are explained in (Merkuryev et.al, 2009).
3. Possible roles of players are defined as:
   i. Retailer (R),
   ii. Distribution Centre (DC),
   iii. Factory Warehouse (FW).
4. Players’ objective is defined as follows: to attain a 95% service level at the lowest cost.
5. The following costs are considered:
   i. inventory holding cost - 1 EUR per period per unit,

ii. fixed order cost - 10 EUR per order,
iii. production cost that is equal to 3 EUR per unit.
6. Customer demand is dynamic and stochastic.
7. Only one product is used in the game.
8. Production can be triggered every 2 weeks in the Discovery mode, and it is instantaneous in the ECLIPS mode, so the manufacturer can produce when needed.
9. Information about the end customer demand, inventories at each stock point and placed orders in the network is visible for all players.
10. The number of periods in the game play is defined by 15 periods for the Discovery mode and by so called "long run", i.e. 100 periods, for the ECLIPS mode. Here, 1 period corresponds to 1 week of a real life.

4.2. Gameplay

The recommended number of players for each supply chain network is defined by 3 in each team. Several teams supported by game moderators could play simultaneously.

Each player is assigned to a particular inventory point(s); e.g., in the Discovery mode:

- Player 1: R1, R2, R3 (retailers Nr. 1, 2, 3);
- Player 2: DC (distribution centre);
- Player 3: FW (production site with an inventory point).

Cards are placed on the table for a specific supply chain network layout defined in section 3.4.

Special forms developed for each player role, i.e. R, DC and FW in the network (see Tables 3 and 4) were used by players in order to fix all transactions made during the game sessions.

Table 3: Transaction Form for R and DC

Inventory Carrying Cost	Order Cost
1	10

Period	Stock at the begining of period	Customer Demand	Delivered	Stock at the end of period	Order
1					
2					
3					
4					
...					
...					
14					
15					

To generate the end-customer demand, a cube dice with sides 0-1-1-2-2-9 was used (see Fig. 5).

Figure 5: A Die for the Game

If the respective network contains more than one end customer, a dice is tossed several times to simulate demand for each end customer.

Table 4: Transaction Form for FW

Inventory Carrying Cost	Order Cost	Production Cost
1	10	3

Period	Stock at the begining of period	Customer Demand	Delivered	Stock at the end of period	New production
1					
2					
3					
4					
...					
...					
14					
15					

At the end of each game mode, the following tasks are performed:

1. Making cost calculation, i.e. total costs for each echelon and for the whole company (for this purpose special Excel templates of transaction forms are provided).
2. Drawing graphics based on processing data in Excel transaction forms to analyse:
   a. company service level;
   b. company inventory level;
   c. company total costs;
   d. demand variation through the network (only for the Discovery mode);
3. Explaining a decision strategy (only for the Discovery mode).

4.3. Results of the game

In the Discovery mode, 15 playing rounds were performed. As defined in the general guidelines, players' objective is defined as follows: minimising the company total costs while attaining a service level of 95%.

Let us note that lead times in the network are set at 1 period between retailer 1, retailer 2 and distribution centre as well as between distribution centre and factory warehouse, and at 3 periods between retailer 3 and factory warehouse (see Fig. 2). Initial inventories are set at 10 pieces for retailers, 15 pieces for distribution centre and 20 pieces for factory warehouse as well as 10 pieces are in transit between factory warehouse and retailer 3.

An example of the completed transaction form by DC player is presented in Table 5 below. All data recorded by the game players in the transaction forms are summarised in the Excel template sheet "Summary results" and used to calculate "Debriefing" results presented in Table 6 below. These results include company performance metrics such as total costs, service level, new production, etc.

In the debriefing session, the analysis of the company service level, inventory level, total costs and demand variation (see Fig. 6, 7, 8 and 9) leads to the following main conclusions.

Table 5: Example of Completed Transaction Form

Inventory Carying Cost	Order Cost
1	10

Period	Stock at the begining of period	Customer Demand	Delivered	Stock at the end of period	Order
1	10	2	2	8	0
2	8	9	8	0	1
3	0	0	0	0	0
4	12	1	1	11	0
5	11	2	2	9	0
6	9	1	1	8	0
7	8	1	1	7	0
8	7	1	1	6	0
9	6	1	1	5	1
10	5	9	5	0	1
11	5	1	1	4	0
12	9	0	0	9	0
13	9	9	9	0	1
14	0	2	0	0	0
15	5	1	1	4	0

As it follows from Fig. 6, the game objective was not fully met. After period T9, the service level dropped below 95%.

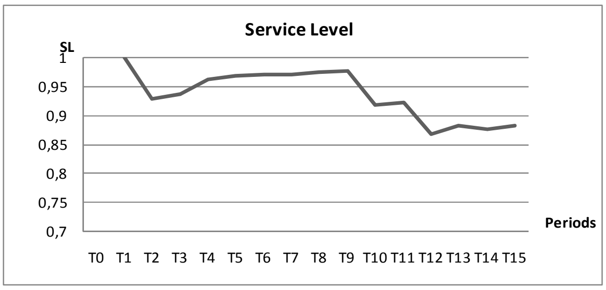

Figure 6: Company Service Level

Inventory initially raised, then dropped below starting levels (see Fig. 7). This could be explained by a company decision to decrease a safety stock level in order to minimise the company total costs. Due to this reason, as follows from Fig. 8, costs were reduced after period T6. However, since the decisions were made intuitively, it caused the decrease of the service level already after two periods (see Fig. 6). This is due to the lead time of 2 periods between stock points. This result could have been partially expected, because the time to travel completely through the network is 8 periods and players did not have enough time to overpass arisen problem. Moreover, as follows from Fig. 9 the demand variation increases in the network upstream echelons.

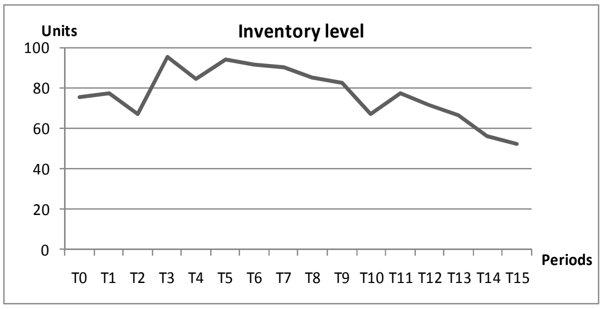

Figure 7: Company Inventory Level

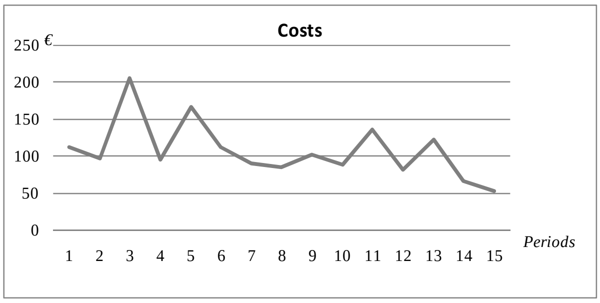

Figure 8: Company Costs

As a result, the company's strategy was not successful and it is necessary to introduce some inventory management techniques that could help to calculate a safety stock level that ensures service level of 95% and avoid the bullwhip effect.

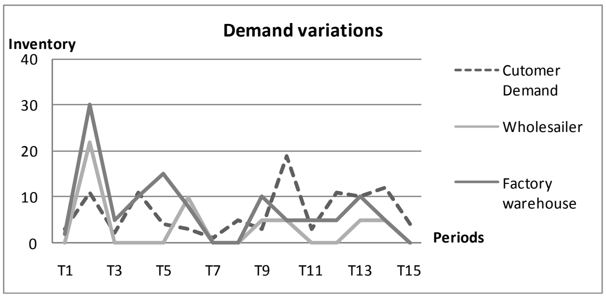

Figure 9: Demand Variations

The results of the Discovery mode were discussed in debriefing and acknowledged the material to be learned in the next game session.

The ECLIPS mode of the game practically demonstrates the theoretical aspects of using different reordering policies. A non-cyclic (reorder point driven referred to as ROP) policy is compared with a cyclic policy (referred to as POR).

Table 6: Results of the Discovery Mode

	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	Sum	Average	FR
WIP	75	77	67	95	84	94	91	90	85	82	67	77	71	66	56	52		76,9	
SL		100,0%	92,9%	93,8%	96,3%	96,8%	97,1%	97,1%	97,5%	97,7%	91,9%	92,3%	86,8%	88,4%	87,8%	88,2%			88,2%
Cost pp		112	97	205	94	166	111	90	85	102	87	136	81	121	66	52		107,0	
Cutomer Demand		3	11	2	11	4	3	1	5	3	19	3	11	10	12	4	102	6,8	
Delivered		3	10	2	11	4	3	1	5	3	15	3	6	10	10	4	90	6,0	
Orders		2	3	2	1	3	2	0	0	2	2	2	1	4	1	0	25	1,7	
New Production		5	0	30	0	14	0	0	0	0	0	13	0	5	0	0	67	4,5	

Hard and soft benefits of using the latter have been indicated. The hard benefit is an inventory reduction that can be witnessed during the game (see Fig. 10). As the most evident soft benefit, easy decision implementation and control can be mentioned.

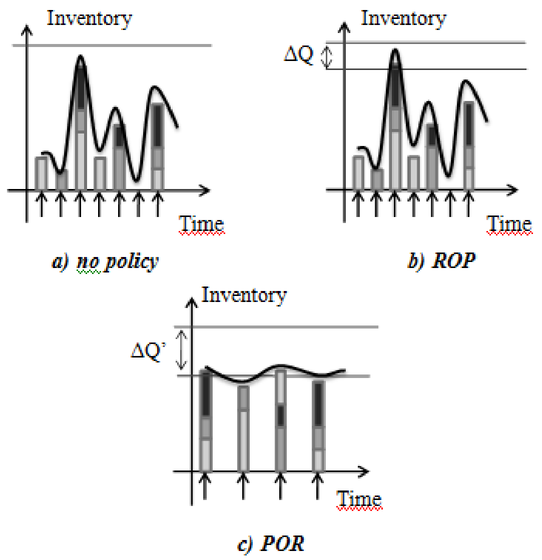

Figure 10: Inventory Reduction Potential

For testing purposes, a "long run" of 110 periods was performed for each of the three replenishment policies:

- non-cyclic,
- cyclic non-synchronised and
- cyclic synchronised.

For regular plays, only 30 playing rounds have to be performed. As defined in the general guidelines, players follow the objective defined in the Discovery mode.

Let us note that lead times in the network are set at 1 period between retailer and distribution centre, 2 periods between other stock points and 1 period between raw material and production and the nearest downstream warehouse (see Fig. 1). Initial inventories are set at 30 pieces for retailer and 20 pieces for distribution centre and factory warehouse. The following policies are played in the game:

- non-cyclic policy with lot size 7 and reorder point equal to 8, 14 and 22 for retailer, distributor and factory warehouse, respectively;
- cyclic non-synchronised policy with cycles of 3 days and order-up levels of 21, 25, 25 for retailer, distributor and factory warehouse, respectively, that order at the same time;
- cyclic synchronised with cycles of 3 days and order-up levels of 21, 25, 25 for retailer, distributor and factory warehouse, respectively, that order when the previous stage has been supplied.

All calculations are made according to respective formulas described in (Simchi-Levi et al., 2003).

While testing, all results from transaction forms completed by players were aggregated and processed by the game moderator in the Excel template sheet "Summary results" and used to calculate and analysed "Debriefing" results presented in Table 6 and Fig. 11, 12, 13 and 14. These results include company performance indicators such as average inventory level and average costs, etc. For regular playing, players calculated the company performance indicators and draw graphics by their own.

The customer demand simulated in the game is shown in Fig. 11. As follows from Fig. 12, all replenishment policies allow keeping service level up to 95%.

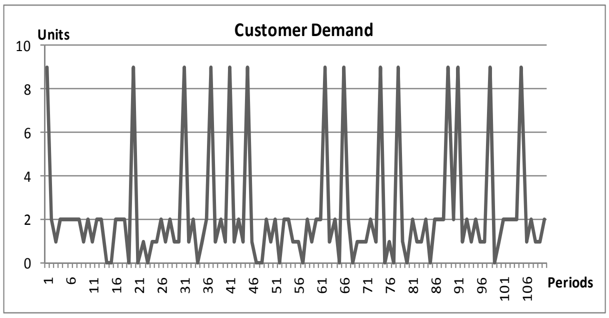

Figure 11: Customer Demand

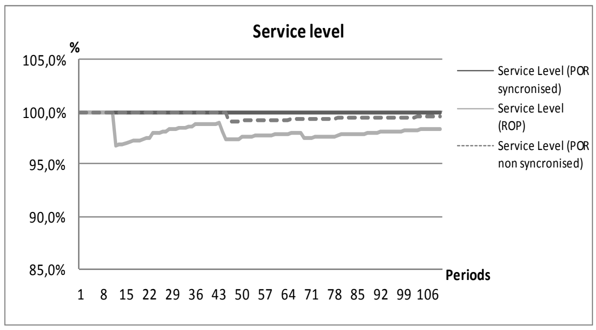

Figure 12: Service Level

However, by comparing average costs (see Table 7), one can conclude that implementation of the cyclic policy reduced the company average costs and average inventory level, in comparison with the non-cyclic policy (see Fig. 13 and 14). Moreover, implementing the synchronised cyclic policy can improve the results even more.

Table 7: Results of Different Replenishment Strategies

	ROP	POR non-synchronised	POR synchronised
Service Level	99%	98%	100%
Average Costs	86,47	85,41	81,03
Average Inventory	71,15	68,74	64,46

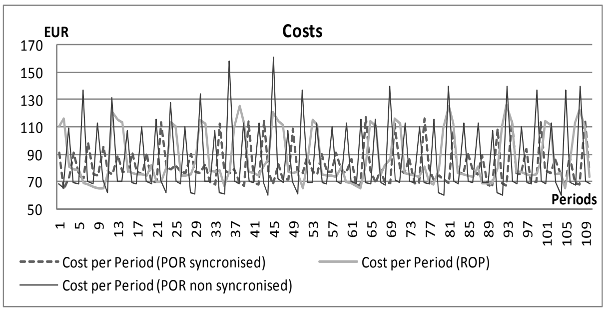

Figure 13: Total Costs

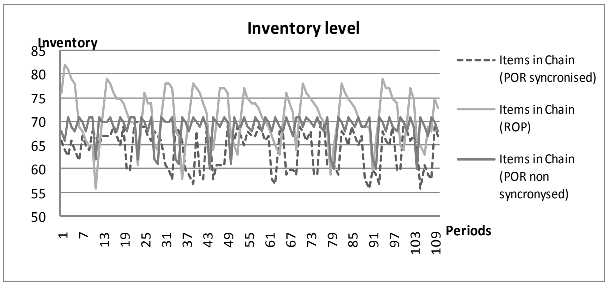

Figure 14: Inventory Level

Finally, it could be concluded that through playing the game participants learn about typical problems that arise in supply chain inventory management and what benefits the company could gain by implementing the cyclic replenishment policies.

5. CONCLUSIONS

The performed review of supply chain simulation-based business games allows indicating the main development trends of such training and educational tools. In particular, modern simulation games are tended to cover a wide range of supply chain management issues, instead of concentrating on a single phenomenon.

The discussed experiences approve the statement that demonstration of different events and decisions in supply chain through simulation games is a powerful and effective way to teach them.

The described ECLIPS game demonstrates ability to support understanding general concepts of supply chain management. In particular, the game was used to introduce ordering policies aimed to improve supply chain performance, proving their efficiency and demonstrating implementation benefits. The game creates awareness of modern inventory management policies in supply chains of different structures, demonstrating efficiency of collaboration between supply chain partners.

The development of a computer-aided supporting tool for the ECLIPS game is currently in progress. It is aimed at providing special templates for testing different supply chain networks and supporting processing of game results.

ACKNOWLEDGEMENT

The present research was partly supported by the European Regional Development Fund within the project No. 2DP/2.1.1.2.0/10/APIA/VIAA/003.

REFERENCES

Anderson Jr., E.G., Morrice, D.J., 2000. Simulation game for teaching service-oriented supply chain management: does information sharing help managers with service capacity decisions? *Production and Operations Management,* 9 (1), 40-45.

Chan, E.W., Fan C.E., Lewis, M.W., King, K., Dreyer, P., Nelson, C., 2009. *The RSS-POD Supply Chain Management Game: an Exercise for Improving the Inventory Management and Distribution of Medical Countermeasures.* Available from: http://www.rand.org/content/dam/rand/pubs/working_papers/2009/RAND_WR661.pdf [accessed 06 June 2011].

Chen, F., Samroengraja, R., 2000. The Stationary Beer Game. *Production and Operations Management,* 9 (1), 19-30.

Chopra, S., Meindl, P., 2007. *Supply Chain Management: Strategy, Planning, and Operation.* New Jersey, Prentice Hall.

Collins, J., Arunachalam R., Sadeh, N., Eriksson, J., Finn,e N., Janson, S., 2006. The supply chain management game for the 2007 trading agent competition. Available from: http://www.sics.se/tac/tac07scmspec.pdf [accessed 06 June 2011].

Corsi, T.M., Boyson, S., Verbraeck, A., van Houten, S.P., Han C., Macdonald J.R., 2006. *Transpotration Journal,* 45 (3), 61-73.

Feng, K., Ma, G., 2008. Learning Supply Chain management with Fun: An Online Simulation Game Approach. *California Journal of Operations Management,* 6 (1), 41-48.

Jacobs, R., 2000. Playing the Beer Distribution Game over the Internet. *Production and Operations Management,* 9 (1), 31-39.

Merkuryev, Y., Hatem, J., Merkuryeva, G., Bikovska, J. and Desmet, B., 2009. Business simulation game for teaching multi-echelon supply chain management. *Int. J. Simulation and Process Modelling,* 5(4), 289-299.

Merkuryev, Y., Merkuryeva, G., Desmet, B., Jacquet-Lagreze, E., 2007. Integrating Analytical and Simulation Techniques in Multi-Echelon Cyclic Planning. *Proceedings of First Asia International Conference on Modelling and Simulation,* pp. 460-464. March 27-30, Phuket (Thailand).

Merkuryev, Y., Merkuryeva, G., Hatem, J., Desmet, B., 2008. Supply Chain Simulation in the ECLIPS Project. *Proceedings of Second Asia International Conference on Modelling and Simulation,* pp. 684-690. May 13-15, Kuala Lumpur (Malaysia).

Merkuryeva, G., Merkuryev, Y., Pecherska, J., Peruhova, J., 2009. Active Learning Logistics Management through Business Gaming. *Proceedings of the 4th International Conference on Interdisciplinarrity in Education,* pp. 181-186. May 21-22, Vilnius (Lithuania). Available from:

http://demosthenes.ece.ntua.gr/PDF/ICIE2009/ICIE2009-181-186.pdf [accessed 06 June 2011].
Mustafee, N., Katsaliaki, K., 2010. The Blood Supply Game. *Proceedings of the 2010 Winter Simulation Conference,* pp. 327-338. December 5-8 Baltimore (USA).
Siddiqui, A., Khan, M., Akhtar, S., 2008. Supply chain simulator: a scenario-based educational tool to enhance student learning. *Computers and Education*, 51, pp. 252-261.
Simchi-Levi, D., Kaminski, P., Simchi-Levi, E, 2003. *Designing & Managing the Supply Chain*. New York, McGraw-Hill.
Sparling, D., 2002. Simulations and Supply Chains: Strategies for Teaching Supply Chain Management. *Supply chain Management: An International Journal,* 7 (5), 334-342.
Sterman, J.D., 1989. Modeling managerial behavior: Misperceptions of feedback in a dynamic decision making experiment. *Management Science,* 33 (3) 321-339.
Van der Zee D-J, Slomp, J., 2009 Simulation as a tool for gaming and training in operations management – a case study. *Journal of Simulation,* 3 (1), 17-28.
Zhou, L., Xie Y., Wild, N., Hunt, C., 2008. Learning and Practicing Supply Chain Management Strategies from a Business Simulation Game: a Comprehensive Supply Chain Simulation. *Proceedings of the 2008 Winter Simulation Conference,* pp. 2534-2542. December 7-10, Miami (Florida, USA).

AUTHORS BIOGRAPHIES

YURI MERKURYEV is Professor and Head of the Department of Modelling and Simulation at Riga Technical University in Riga, Latvia. His professional interests include methodology of discrete-event simulation, supply chain simulation and management, as well as education in the areas of simulation and logistics management. Prof. Merkuryev is a corresponding member of the Latvian Academy of Sciences, President of Latvian Simulation Society, Board Member of the Federation of European Simulation Societies (EUROSIM), SCS Senior Member and Director of the Latvian Center of the McLeod Institute of Simulation Sciences, and Chartered IT Professional Fellow of the British Computer Society. He authors about 300 scientific publications, including 6 books, and is a co-editor (with Galina Merkuryeva, Miquel Angel Piera and Antoni Guasch) of a recently published by Springer-Verlag book “Simulation-Based Case Studies in Logistics: Education and Applied Research”. He is editorial board member of several journals, including “Simulation: Transactions of the Society for Modeling and Simulation International,” and “International Journal of Simulation and Process Modelling”. Prof. Merkuryev regularly participates in organising international conferences in the area of modelling and simulation. In particular, he has served as General Chair of the International Conference "European Conference on Modelling and Simulation", ECMS'2005. He is permanently involved into organising of the HMS (The International Conference on Harbour, Maritime & Multimodal Logistics Modelling and Simulation) series of conferences within the annual International Mediterranean and Latin American Modelling Multiconference, I3M. Prof. Merkuryev is General Co-Chair of the I3M 2012 multiconference to be held in Vienna, Austria in September, 2012.

GALINA MERKURYEVA is Professor at the Department of Modelling and Simulation at Riga Technical University, Latvia. Her research interests and experiences are in the fields of discrete-event simulation, simulation metamodelling and optimisation, decision support systems, supply chain simulation and management, and simulation-based training. She is an editor of The Baltic Journal on Sustainability, Technological and Economic Development of Economy.

JANA BIKOVSKA is a researcher and teaching assistant at the Department of Modelling and Simulation, Riga Technical University, Latvia. Her professional interests are in the field of supply chain management, business simulation games, scenario approach in complex systems with application to simulation games.