BUSINESS SIMULATION GAME FOR TEACHING MULTI-ECHELON SUPPLY CHAIN MANAGEMENT

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ABSTRACT
The objective of this paper is to present a new educational tool developed in the form of a business game for helping to understand concepts developed in the ECLIPS project, supported by the European Commission. The game provides an insight into different aspects of supply chain management, i.e. general supply chain mechanisms, as well as non-cyclic and cyclic inventory replenishment policies. This allows for people that have no deep notion in this area to better understand the project concepts and evaluate their efficiency in practice. Demonstrating concepts in a playful way is considered as more powerful and effective than purely explaining the underlying theory. The paper describes the rules of the game, playing process and provides results of the game test sessions.

Keywords: multi-echelon supply chain, supply chain management, simulation business game, education.

1. INTRODUCTION

Introducing of a new approach to supply chain management usually causes a necessity for its exhaustive explanation and illustration. For this purpose a new business game was developed that aims at providing an *educational tool* for helping in understanding concepts developed within the ECLIPS (Extended Collaborative Integrated Life Cycle Supply Chain Planning System) project. It specially targets creating awareness among supply chain key persons, managers of small and medium size enterprises (SME), students and decision makers that have a supply chain management background. The ECLIPS project objectives and developed approaches are discussed in Merkuryev et al. (2007, 2008).

The game focuses on multi-echelon supply chain networks. According to Chopra and Meindl (2007), a multi-echelon system can be defined as s series of two or more different facilities, where any change in the policy parameters in one facility affects the other facilities. A typical multi-echelon system (see Fig.1) is one involving factory (1st echelon), central warehouse (2nd echelon), regional depot (3rd echelon) and retail outlets (4th echelon). There may be more than one facility at each echelon. 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.

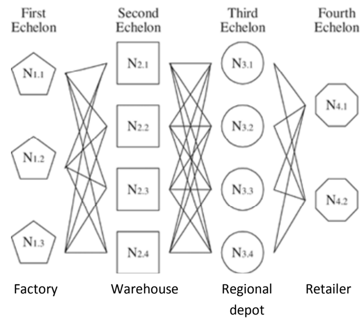


Figure 1: Multi-echelon Supply Chain Network

The game helps to understand how a multi-echelon supply chain based on cyclic planning is organised and functioning.

This game would not have been developed without the inspiration and experience drawn from other business games played and analysed by the authors. Some sources of inspiration include:

- MIT: beer game (Simchi-Levi et al., 2003);
- MÖBIUS: S&OP Game (Möbius);
- Involvation: Supply Chain Game (Iinvolvation);
- EHSAL: ECOMAN business game (EHSAL).
- Gent University: ORSIAM Int. (Muller(-Malek), 1999);

2. DESCRIPTION OF THE GAME

The general process and playing rules by which the game is played is outlined in this sub-chapter. The different variations on the game, together with their educational benefits are explained, as well as a short overview of the props used during the game and examples of possible networks are given here.

2.1. Playing process

The playing usually consists of playing a number of rounds (or periods) in the game. 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 dice(s) 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 & 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.

2.1.1. Number of rounds to play

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.

2.1.2. Playing with more than one player

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.

2.1.3. Performance metrics and scoring

At the end of the game, summary statistics are calculated based on performance metrics recorded during the game (see Tab. 2 and 3).

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 warehouses or retailers.
4. New production: the sum of the newly requested production at raw material & production units.

Calculation of the summary statistics is done by:

1. summing the four columns described above at the bottom of the sheets;
2. calculating the "inventory in the supply chain" at the end of the game by subtracting "start inventory" by "the sum of delivered" and adding "the sum of new production";
3. estimating the "Service Level" at the end of the game is by dividing "delivered" by "demand";
4. calculating the "total cost of the play" by summing up following components:
   i. "inventory in the supply chain" * "inventory carrying cost";
   ii. "sum of orders" * "order cost";
   iii. "sum of New Production" * "New Production cost";
   iv. Eventually: negative penalty for "sum of demand – sum of delivered" * "lost sales cost".

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.

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

2.2. 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: Different ordering policies are played during the game and they are non-cyclic, cyclic non-synchronised and cyclic synchronised. Concepts that are suitable for identification are:

detailed workings of different ordering policies and their best practices.

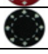
3. Supply chain design: After playing with an existing supply chain, capacity constraints are introduced, the network is altered. The effects of changing the supply chain network become visible. Concepts that are suitable for identification are: mechanics of supply chain management and supply chain design.
4. Risk Management: Some 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.

2.3. Symbols used during the game

Different supply chains can be modelled by using placemats with different symbols. They are described in the Appendix.

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 Tab.1).

Table 1: 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.

2.4. 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.

2.4.1. Linear Supply Chain

Linear supply chain is represented in Fig.2. It can be used in the Discovery mode of the game. 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.

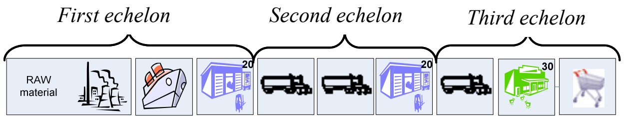


Figure 2: Three-echelon Supply Chain

2.4.2. Distribution Chain (Paint Production Network)

Paint production network can be used in the ECLIPS mode. It consists of two subsequent distribution steps (see Fig.3). 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.

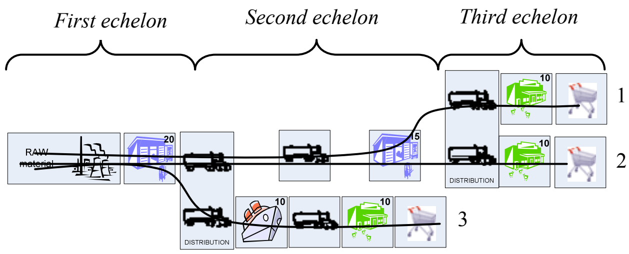


Figure 3: Three-echelon Distribution Network

2.4.3. Small Assembly Chain

Small assembly chain consists of one assembly step which is intertwined with long transports and only one customer (see Fig.4).

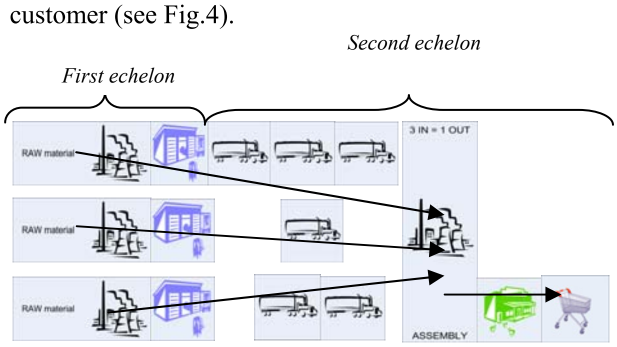


Figure 4: Small Assembly Chain

2.4.4. Large Assembly Chain

Large assembly chain consists of three subsequent assembly steps which are intertwined with long transports and only one customer (see Fig.5). If a risk management game is played, the assembly step in the 2nd echelon could be replaced with a multi-sourcing.

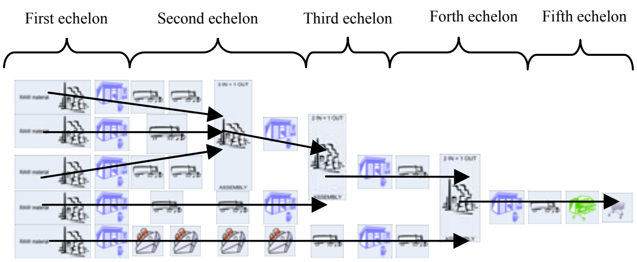


Figure 5: Large Assembly Chain

3. GAME TESTING RESULTS

The business game tests were performed by MÖBIUS and Riga Technical University (RTU) in January - February, 2008. This chapter describes the results of the game first plays and demonstrates what has been learned by the game players.

In the business game tests at MÖBIUS 8 players from the company participated and 5 concept tests were performed. At RTU the game tests were held within the course 'Supply Chain Management', where participated 18 Master students and 3 members from the department staff.

The following educational scheme and agenda of the day were proposed for the game plays 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 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').

3.1. General guidelines

The following are general guidelines of the game plays 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.3) for the Discovery mode, and a three-echelon 3 nodes linear chain (see Fig.2) for the ECLIPS mode. Each element of the supply chain is represented by a card. The meanings of cards are explained in the Appendix.
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 that is equal to 1 EUR per period per unit,
   ii. fixed order cost that is equal to 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.

3.2. 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 2.4.

Special forms developed for each player role, i.e. R, DC and FW in the network (see Tables 2, 3) were used by players in order to fix all transactions made during the game sessions.

Table 2: 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	Service Level	Costs
1							
2							
3							
4							
...							
...							
14							
15							

Table 3: 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	Service Level	Costs
1							
2							
3							
4							
...							
...							
14							
15							

To generate end-customer demand, a cube dice with sides 0-1-1-2-2-9 was used (see Fig.6). If respective network contains more than one end customer, a dice is tossed several times to simulate demand for each end customer.

Figure 6: A Dice for the Game

At the end of each game mode, the following tasks are performed by the game moderator (in the Discovery mode) or by participants (in the ECLIPS mode):

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 the following 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).

3.3. Results of the game

3.3.1. Discovery mode

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's 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.3). 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.

Table 4: 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	Service Level	Costs
1	10	2	2	8	0	100,0%	8
2	8	9	8	0	1	90,9%	10
3	0	0	0	0	0	90,9%	0
4	12	1	1	11	0	91,7%	11
5	11	2	2	9	0	92,9%	9
6	9	1	1	8	0	93,3%	8
7	8	1	1	7	0	93,8%	7
8	7	1	1	6	0	94,1%	6
9	6	1	1	5	1	94,4%	15
10	5	9	5	0	1	81,5%	10
11	5	1	1	4	0	82,1%	4
12	9	0	0	9	0	82,1%	9
13	9	9	9	0	1	86,5%	10
14	0	2	0	0	0	82,1%	0
15	5	1	1	4	0	82,5%	4

Example of completed transaction form by DC player is presented in Tab.4. All data recorded by the game players in transaction forms are summarised in the Excel template sheet "Summary results" and used by the game moderator to calculate "Debriefing" results presented in Tab.5. 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. 7, 8, 9, and 10) leads to the following main conclusions.

As it follows from Fig.7, the game objective was not fully met. After the period T9 the service level dropped below 95%.

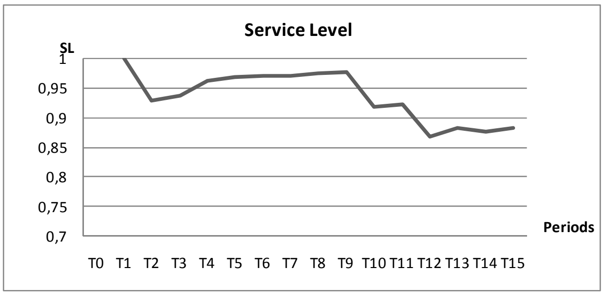


Figure 7: Company Service Level

Table 5: 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	

Inventory initially raised then dropped below starting levels (see Fig.8). 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.9, costs were reduced after period T6.

Figure 8: Company Inventory Level

However, since the decisions were made intuitively, it caused the decrease of the service level already after two periods (see Fig.7). 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 trough the network is 8 periods and players did not have enough time to overpass arisen problem. Moreover, as follows from Fig.10 the demand variation increases in the network upstream echelons.

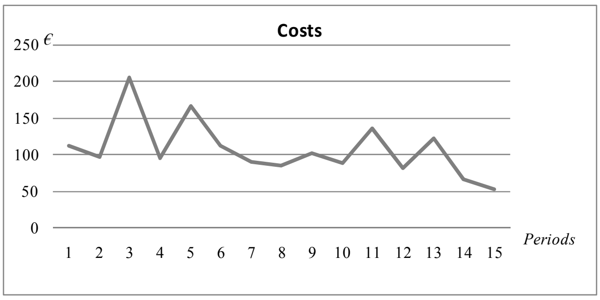


Figure 9: Company Costs

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 so called bullwhip effect problem.

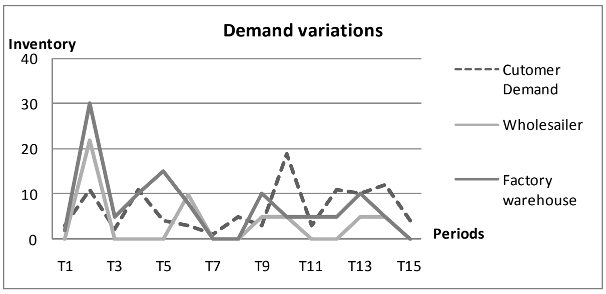


Figure 10: Demand Variations

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

3.3.2. ECLIPS mode

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). The ECLIPS research has indicated hard and soft benefits of using the latter.

The hard benefit is an inventory reduction that can be witnessed during the game (see Fig. 11). As the most evident soft benefit, easy decision implementation and control can be mentioned.

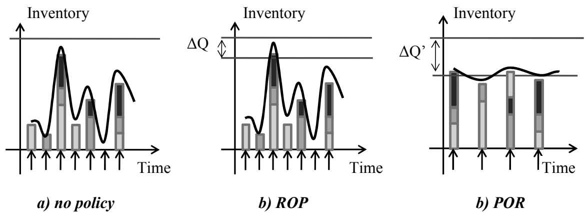


Figure 11: Inventory reduction potential

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

- non-cyclic,
- cyclic non-synchronised,
- 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's 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 & production and nearest downstream warehouse (see Fig.2). 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 Tab.6 and Fig. 12, 13, 14, and 15. 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.

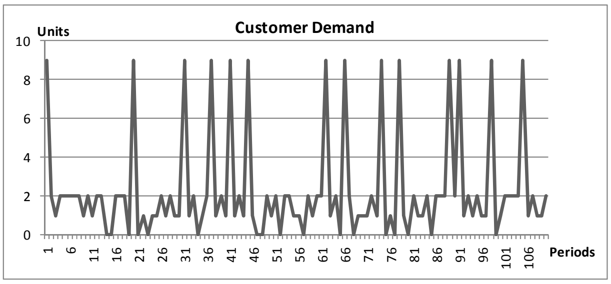


Figure 12: Customer Demand

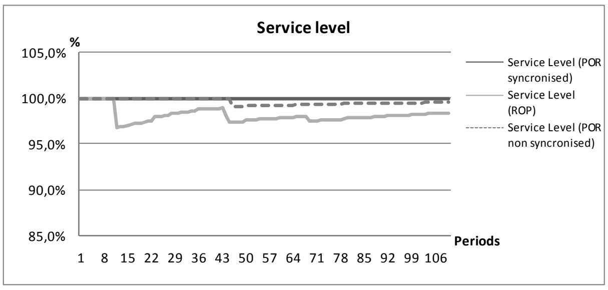


Figure 13: Service Level

Customer demand is shown in Fig.12. As follows from Fig.13, all replenishment policies allow keeping service level up to 95%.

Table 6: Results of Different Replenishment Strategies

	Non-cyclic	Cyclic non-synchronised	Cyclic synchronised
Average Costs	86,47	85,41	81,03
Average Inventory	71,15	68,74	64,46

However, by comparing average costs (see Tab.6), we can conclude that implementation of cyclic policy reduced the company average costs and average inventory level, in comparison with non-cyclic policy (see Fig. 14 and 15). Moreover, implementing synchronised cyclic policy can improve the results even more.

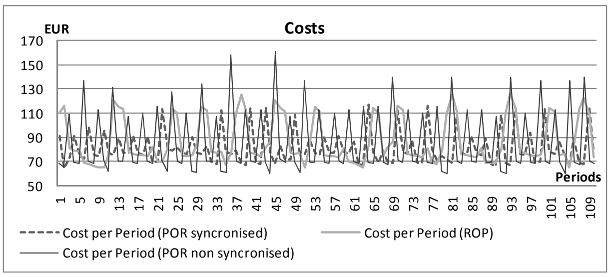


Figure 14: Total Costs

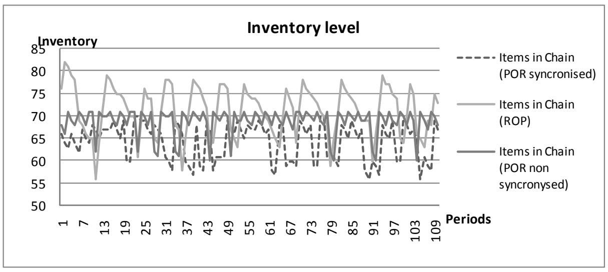


Figure 15: Inventory Level

Finally, we could conclude that trough playing the game participants could learn about the problems that arise in supply chain inventory management and what benefits the company could gain by implementing the cyclic replenishment policies.

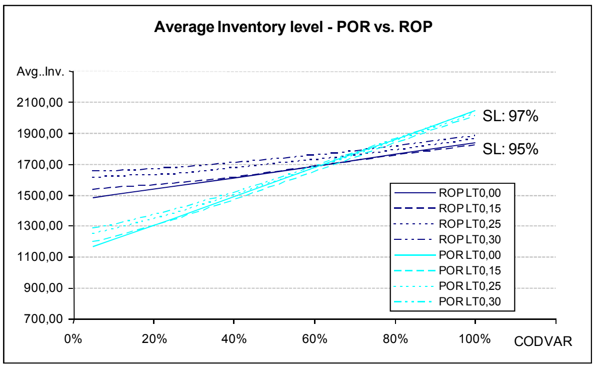


Figure 16: Industry case

Within the ECLIPS project a real industry case was investigated. The first results obtained from simulation indicate that the theory developed during the project can be proved (see Fig. 16). A real life implementation is scheduled at the end of the ECLIPS project. This implementation will be done for an even more complex case then those used in the simulations (= a "complex" generic network with 3 product branches in it resulting in 42 end products and 33 intermediary products).

4. CONCLUSIONS

A business game for bringing over the ECLIPS concepts of Multi-Echelon Cyclic Planning (MECP) has been developed. Performed tests demonstrated ability of the game to help in understanding general mechanisms of supply chain management concepts, has been developed within the ECLIPS project. In particular, the game was used in order to introduce ordering policies aimed to improve supply chain performance, proving their efficiency and demonstrating benefits of their implementation. Performed experiments allowes practically demonstrate to the game participants the theoretical aspects of investigated theory.

This business game can be used, for instance, at: large companies (early during a MECP deployment track); small and Medium companies (to propagate knowledge and concepts, and during a MECP deployment track); educational institutions and seminars (to bring over the ECLIPS concepts).

The discussed experiences approve the statement that demonstration of different events and decisions in supply chain in a playful way is a powerful and effective way to bring them over to a public. It is a worthy alternative to classic ex-cathedra explaining of the considered theory.

ACKNOWLEDGEMENT
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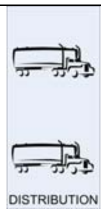
APPENDIX. SELECTION OF SYMBOLS USED IN THE GAME

Card	Explication
	**Raw Material & Production** Production takes two periods to complete. • During the first period raw materials are ordered and processing starts. • During the second period the produce becomes available and can be moved to the next placemat (probably a warehouse). The difference between this symbol and the "production unit" is that this symbol is the first echelon of the network, whereas the "production unit" is placed in the middle of the network.
	**Production Unit** A product can be transformed at a production unit. Production is pushed to the next placemat on the next period.
	**Warehouse** Products can be stored at a warehouse. They only move if an order is received from either a production unit or a retailer.
	**Transport by ship** Takes 1 period to complete. Unlimited capacity.
	**Transport by truck** Takes 1 period to complete. Unlimited capacity, unless otherwise indicated.
	**Retailer** Depicts a place where end-customers go shopping. A retailer (or a shop) is always succeeded by a shopping trolley.
	**Trolley** End customer demand is placed in the shopping trolley. If the retailer has not enough inventories, only the fulfilled demand is put in the trolley.
	**Distribution** These placemats indicate a distribution step. The examples on the left indicate two and three way distribution. Products are placed on the truck that goes to a specific sub-chain of the network. Once goods are put on a specific truck, they cannot be moved to another sub-network anymore.

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