SIMULATION-SUPPORTED SUPPLY CHAIN MANAGEMENT

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1. INTRODUCTION

Simulation is widely used in supply chain management (SCM). In particular, it is employed to support strategic, tactical and operational SCM decisions, to validate new developed supply chain management methods, to demonstrate efficiency of taken decisions, and to support education and training.

In this paper, use of simulation in supply chain management is illustrated by experiences gained within implementation of the ECLIPS ("Extended Collaborative Integrated Life Cycle Supply Chain Planning System") research project of European Commission that ran from 2006 until mid 2009. It addressed the state-of-the-art in supply chain management. Six partners from the industrial, academic and consultancy sectors have teamed up to work together on this project. These were a Belgian consulting company Möbius, a French services company Eurodecision, a Belgian IT service company LoQutus, a Latvian academic partner Riga Technical University, as well as two industrial partners: a German company Huntsman and a Czech company PLIVA-Lachema Diagnostika. The main research subjects of the project were related to the minimisation of inventories during the different phases of the life-cycle of a product (Figure 1).

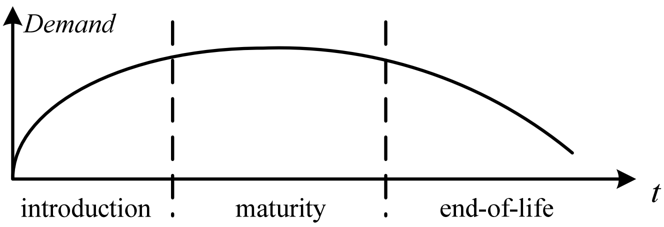

Figure 1: Product Life-Cycle

The aim of the project was to develop methods concerning essential decreasing of total inventories through the supply chain, in particular, with regard to: (1) demand forecasting at the introduction and outtroduction phases of a product life-cycle, (2) implications of using cyclic planning techniques during the maturity phase, (3) automating the detection of life cycle changes.

Simulation has been extensively used in the ECLIPS project, e.g. for simulation-based optimisation of inventory-policy parameters, evaluation of life-cycle changes and validation of the research related to the implications of the use of cyclic planning techniques, as far as training in application of the developed SCM algorithms.

2. MULTI-ECHELON CYCLIC PLANNING

The ECLIPS project has been aimed at essential decreasing of total inventories through the entire supply chain by using appropriate management techniques at each phase of the product life-cycle, starting from the introduction phase, through the maturity phase, and finally to the end-of-life phase. Multi-echelon cyclic planning was used for organizing supply chain operation at the maturity phase (Merkuryev *et.al.* 2007).

For years, researchers and practitioners have primarily investigated a so called single-echelon approach, where one stage or facility in the supply chain is managed (Campbell and Mabert 1991). Recently, increasing attention has been given towards the performance, design, and analysis of the supply chain as a whole. A multi-echelon environment considers multiple processes and multiple stock points.

The underlying idea of *cyclic planning* in a multi-echelon environment is to use cyclic schedules for long term planning at each echelon and synchronisations with one-another. Every process in the supply chain, whether it is a purchasing, production or distribution process, is planned on a repetitive, "cyclic" basis, and the process cycles are synchronised and fit together. Cyclical schedules are preferred for the constant demand lot sizing problems. When demands are dynamic, flexibility in spacing production periods permits non-cyclical schedules to result in a lower total cost. However, the real life performance of a specific planning policy may differ from the theoretical one. More complex policies are less efficient in practice. Practical benefits are typically lower than theoretical ones. Cyclic schedules offer practical benefits in terms of easy planning and control and reduce administrative costs for monitoring planning policy. Cyclic long term benefits (Campbell, 1996; Schmidt *et.al.* 2001) result in reduction of safety stock buffers between echelons, time and cost of material handling; expected order and production lead times and costs, etc.

The focus of the multi-echelon cyclic planning research during the ECLIPS project was the development of techniques for multi-echelon cyclic planning at the tactical level, during the product maturity phase. It was based on an integrated approach that allows both analytical and simulation techniques in order to solve the problem.

3. VALIDATION THROUGH SIMULATION

Simulation was used in the ECLIPS project to support solving of the following tasks: (1) to back up decision making and optimization processes (simulation-based analysis of the optimality gap between planning policies, in order to decide about switching to the cyclic planning and simulation-based optimization of supply chain management parameters during the maturity phase, in order to perform the cyclic planning); (2) to validate developed algorithms; (3) to demonstrate efficiency of the developed approach to potential users; (4) to provide training in use of the developed algorithms.

Task 4 is considered in the next section, while tasks 1, 2 and 3 are discussed in (Merkuryeva & Vecherinska 2008; Merkuryeva & Napalkova 2009; Merkuryev *et.al.* 2007).

For validating research results of the ECLIPS project a new multi-echelon inventory simulator was built (Hatem et.al. 2009). It has been tested by simulating three different inventory management policies on a five echelon linear chain (Figure 2): (1) non-cyclic (ROP) policy; (2) cyclic policy without synchronisation (order cycles start at the same time); (3) cyclic policy with synchronisation (order cycles start at different moments depending on lead times).

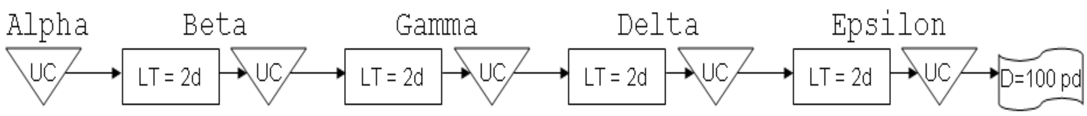

Figure 2: Five Echelon Linear Case

Different policies have been evaluated with the following performance metrics: service level and overall inventory. The following conclusions have been made: (1) the formulas used to calculate the inventory marginally put more inventories in the network if variation of demand increases in the cyclic case compared to the non-cyclic one; (2) synchronising the network when using a cyclic policy yields remarkable benefits.

Then simulation was performed for a real business case. Here more complex supply network structure with 15 nodes, organised in 5 echelons, 26 end products and 14 intermediary products was modelled (Figure 3). Obtained results confirmed conclusions made above.

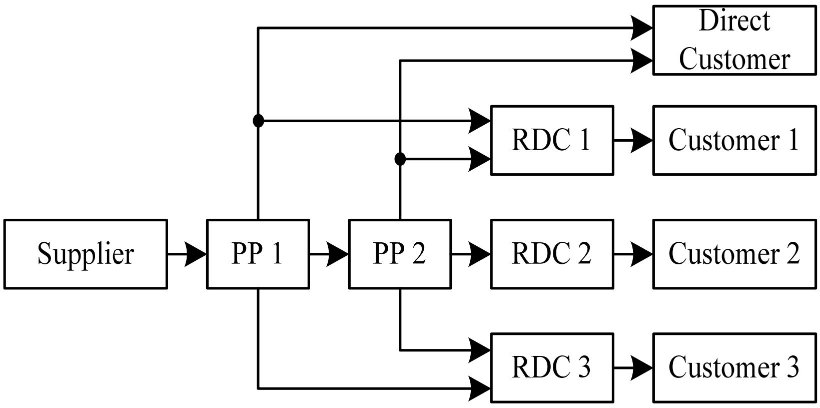

Figure 3: Business Case Network

Practical exploitation of the project results led to the following conclusions:

1. The service has not been threatened by implementation of the multi-echelon cyclic planning concept;
2. The predictability of the planning increased;
3. The planning process was simpler, because only production quantities had to be calculated;
4. Inventory levels dropped noticeably because inventory dropped at intermediary stocks.

4. BUSINESS GAME DEVELOPMENT

While the described simulator has originally been developed for the analysis and validation of inventory policies, it can be modified for other research purposes. One such possible exploitation of the simulator is related to use of simulation for training in application of the discussed approach to supply chain management. For this aim the business game has been developed within the ECLIPS project. Some other potential applications of the simulator are discussed in (Hatem *et.al.* 2009).

The developed ECLIPS game is aimed at providing a tool for practical demonstrating different aspects of supply chain management, i.e., general supply chain mechanisms as well as non-cyclic and cyclic inventory replenishment policies. It helps to evaluate players' efficiency at applying these concepts in practice. In its most summarized form, the ECLIPS game can be described as a set of paper cards placed on the table that are used to model a supply chain where players move inventory, represented by number of tokens, period by period according to inventory replenishment policies which are influenced by demand that occurred at the end of the chain. Players gain insights by going through different scenarios where the supply chain/network and/or the policies are changed. Overall purpose of the game is to decrease the total costs by coordinating orders across the supply chain, while providing a certain service level (usually 95%). In details general rules and mechanics of the game have been described in (Merkuryev *et.al.* 2009).

The game layout is represented in Figure 4. Here a four echelon supply chain is considered. The initial stock of products, represented by tokens, is placed on the respective card. It is important to note that stock of raw material is unlimited as well as there is no capacity constraint for stock points and transport. The possibility of backlogging is not considered in the game. End customer demand has a stochastic nature and is generated by tossing dices.

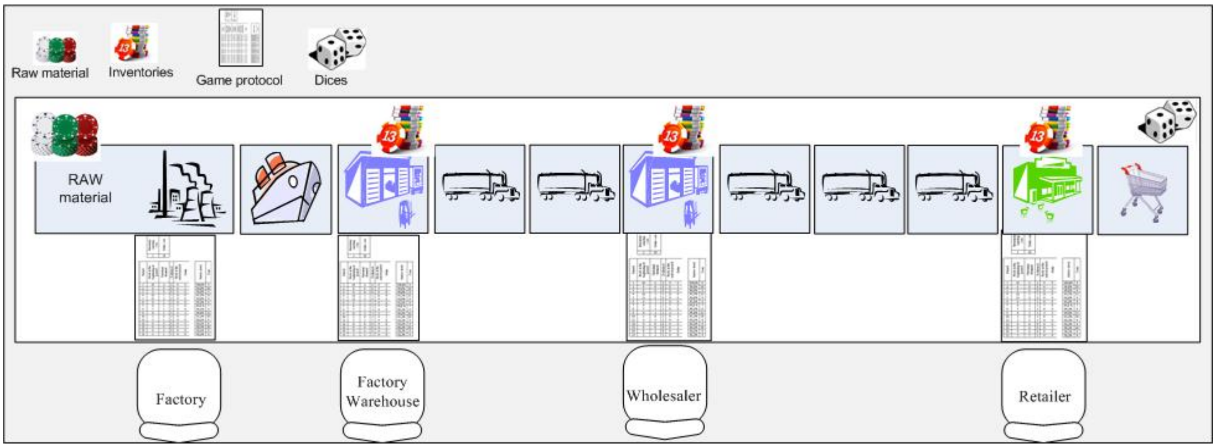

Figure 4: Layout of a Four Echelon Supply Chain on the Table

Company (supply chain) is represented by four players assigned to different supply chain echelons, respectively retailer, wholesaler, factory warehouse, and factory (see Figure 5). During the gameplay, participants have to fix all performed actions (generation of end customer demand, supply, ordering, new production, etc.) in special protocols for further calculations of the following performance metrics: (1) service level, (2) average cost for the entire supply chain, (3) average inventory for the entire supply chain. It is recommended to play not less than 20 periods of the game for each scenario.

Figure 5: Participants playing the game

Three different scenarios are played, where:

- inventory management policy is not indicated and decisions are made based on players' own experience;
- non-cyclic inventory management policy (ROP) is applied;
- cyclic inventory management policy (POR) with synchronisation is applied.

To apply the policies some parameters have to be calculated. For the cyclic policy, the most important parameters are cycle length and order-up level, and for non cyclic policy these are the reorder point and the order lot size. The detailed discussion of those parameters could be found, for instance, in (Axsäter 2000, Simchi-Levi *et.al.* 2003, Chopra and Meindl 2010).

At the end of the game the scenarios are evaluated by comparing performance metrics indicated above. Thus the most efficient inventory management policy is selected as well as its hard and soft benefits are discussed.

When playing the game, a variety of supply chain networks can be modelled, for instance, to simulate the current supply chain environment of the participants playing it. This feature distinguishes the ECLIPS game from other supply chain games.

5. CONCLUSIONS

In the ECLIPS project, simulation proved to be a key factor in development and validation of advanced supply chain management methods. In particular, it was valuable for the theoretical validation of multi-echelon cyclic planning concepts that convinced the project industrial partners for testing multi-echelon cyclic planning in their business environment. Development of a simulation business game for training in application of different approaches to supply chain management is another example of exploiting simulation in the ECLIPS project. Synergy of simulation and gaming efficiently demonstrates advantages of the developed approach to potential users as well as provides training in use of different inventory management algorithms. While currently the game is manually implemented, a computerised version is considered as the next step in development of the game.

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