Simulation Based Case Studies for Management Training in the Fields of Production and Supply Chain Management

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Abstract

It is well known that interactive learning is much more efficient than classical learning with text-books. With the broad propagation of computers, new opportunities for computer-based interactive learning are availble. In particular, simulation based learning allows the student to learn based on experience. In economic and technical environments, where complex systems comprise numerous decision variables, conducting experiments can provide a deeper insights and an intuitive understanding to the student.

In the present paper, a newly developed environment for computer-based interactive learning in the fields of production and supply chain training is described. The different steps from the evaluation of an appropriate electronic platform to the development of eight different case studies for the students are explained. The environment now provides an easily applicable and ready-to-use solution for university teachers and their students.

1. INTRODUCTION

Interactive learning has received increased attention in the recent years. The advances of hardware equipment and software environments as well as the success of the internet have paved the basement for interactive education tools. The benefits of interactive learning are manifold (see [1] - [4]). The following statement, for instance, can be found in [4]: "Visualization plays an increasingly important role in the delivery of educational content. The use of graphical external representations, be they static in the form of picture or animated in the form of simulation, is consistent with the theory of socially shared cognition."

The development of a learning tool for classroom teaching or distant learning in the field of production and supply chain management is explained in this paper. The learning tool is based on well elaborated case studies which are focused on a spedific operational or managerial problem which is to be solved by the student. The training field is a simulation model which simulates the operation of a production unit or a supply chain. In order to solve the case, the student has to retreive information from the simulation, analyse them correctly, and take the appropriate decisions. The effect of the decision can be evaluated by re-running the simulation.

Thus, the learning tool constitutes a training arena which combines several aspects of management and goes far beyond the textbook learning. In fact, the learning tool does not substitute textbooks. In contrast, it gives a learning environment which allows to apply the theroetical knowledge to a practical problem. Therefore, the tool represents a kind of "flight simulator" for production and logistics managers.

The tool is suited for use in higher education classes such as, for instance, MBA- (master of business administration-) courses. It can generally be used in the education at the university level in the fields of economics, business administration, logistics, production management etc.

In the field of production management, the case studies explain aspects of capacity and inventory management as well as production scheduling. Information sharing, cooperation, vendor-managed-inventory and framework contracts represent the topics in the field of supply chain management that are treated by the case studies.

The case studies were developed in the framework of the project “Swiss Virtual Campus” (SVC) [5] in the module OPESS (Operations Management, ERP- and SCM-Systems) [6]. They will first time be used in classroom courses at the École Polytechnique Féderale de Lausanne (EPFL) and at the university of Berne in the winter term 2004 / 2005. It is planned to provide the case studies to other teaching institutions, in particular to the numerous MBA schools.

2. CONCEPT

2.1 Didactical Approach

The general concept of the simulation-based learning tool is to provide the students with an experimental platform that allows them to make management decisisons and to experience their effects in a way that is close to a real world situation. The student works with the tool by solving specific case studies or assignments. In most cases, an operational problem has to be solved, or the effect of a particular action has to be evaluated in a specific context.

It is assumed that the student already has a theoretical background which allows him/her to solve the case. Thus, each case is linked to a textbook chapter which explains the theoretical concepts and strategies. The purpose of the cases is not to *teach* specific knowledge but to *apply* theoretical knowledge to practical situations. On the one hand, the case studies enforce the student to learn the theory. On the other hand, the practical experience gained with the case studies leads to a deeper and more sustainable understanding. In this sense, the simulation-based case studies are a valuable complement to a textbook which significantly improves the learning process.

However, solving an assignment with the simulation-based tool not only requires a correct understanding of the underlying theory of operations management or supply chain management but also includes some important other competence areas which are critical in practice. Examples are:

- **Retrieving information from a complex system:** Where do I find the information which is necessary for applying the theoretical concepts?
- **Disturbed data:** Theoretical concepts often are based on very simplified concepts which, in practice, cannot be observed directly but only in a disturbed manner. How to extract the correct numbers from disturbed data?
- **Practice of data analysis:** For applying many theoretical appoaches, statistical data analysis is required, for example the estimation of means or variances. Students often have practical problems to perform such an analysis in practice. By using the case studies, such basic competences are trained.

The different case studies or assignments are build around few generic business models like, for instance, a typical production shop floor. Each assignment sheds light on a specific problem area that a manager may be faced with in a real world situation (see Figure 1). This has the advantage of providing the student with a sufficient level of familiarity with the model and still leaves enough space to highlight many different aspects. As will be elaborated in more details later on in this text, two different generic business models were developed, i.e., one representing the workshop floor of a production company and one representing a supply chain.

For both of these configurations, typical problem statements were built in the form of case studies.

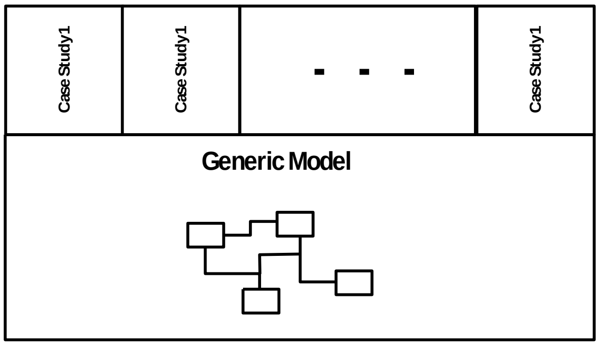

Figure 1: Concept of various case studies on top of a generic business model.

Each case study sheds light on a specific problem area that a manager may be faced with in a real world situation. The student has the possibility to vary problem-specific parameters or to select different system configurations. After these initial settings have been defined, the simulation is executed, which corresponds to letting the company operate over some time period (typically in the order of several months). The student can watch how important performance indicators evolve during the run of the simulation and thus can immediately see the effects of the decisions taken before.

2.2 Technical realization

For implementing the simulation tool, several technical solutions were evaluated. The following requirements were to be met:

- Easy-to-use for both teachers and students, simple and intuitive user-interface
- Cheap (no license costs if possible)
- Ability to quickly adopt or change existing simulation models, and build new ones
- Excellent visualisation and simple data exchange

For cost and time reasons, a commercially available simulation platform had to be chosen a the basis for the learning tool. Several suitable tools were evaluated. The evaluation criteria were, among others, the technical suitability to build the case studies, the platform support, the licence agreements, the costs, and the possibility to use the tool in a distributed environment on a client-server basis (eventually also browser-based via the internet).

Finally, the decision was taken to build the case studies on the basis of the product Extend® by Imagine That Inc. [7]. Various types of licence are offered for Extend. There is a site licence which enables the classroom teacher to use the software in a campus network without the need of installing it on each single computer. Alternatively, there is a free Extend player version which the students and the teacher can install on their local machines and which has sufficient functionality to run the case studies. A developer licence is available if the user wants to modify the models. However, this is not required for the case studies.

Installation guidelines are available for different Windows operating systems that help the user (be it the student or the teacher) installing the simulation tool. A short test case study is provided in order to check if the installation has been successful. Furthermore, a simple introductory assignment has been developed which helps the user getting acquainted with the simulation environment and the style of the case studies. The installation procedure typically requires less than half an hour and is necessary only once.

The installation software, all manuals and guidelines as well as the descriptions of the case studies and the model solutions are packed on a CD which is shipped to the user. The CD can be ordered at the idp [8]. When using Extend for the developed simulation-based case studies, a special license agreement with Imagine That Inc. has been made which allows using of the software at a reduced price.

2.3 Assignments

Each case study consists of

- A description of the case
- An appropriate simulation model with implements the case for use with the Extend® software
- A student assignment specifying the tasks the student has to perform with the model
- A reference solution for the teacher

Each case study refers to a typical teaching unit like, e.g., capacity management or vendor managed inventory. These units are part of the OPESS course (http://virtualcampus.ch/opess) but can be found in most textbooks for operations management and supply chain management. Thus, the assignments can be used with all classical textbooks.

3. CASE STUDIES

3.1 Case Studies for the Generic Model "Work Shop Floor"

The generic business model for the work shop floor has the configuration shown in Figure 2. A material processing plant for three different products is investigated. Three different kinds of raw material (A, B, and C) are supplied to a central production planning process of the plant. There are various processing machines, i.e., for lathing, cutting/grinding, painting, galvanizing, assembly, and for late differentiation for each product.

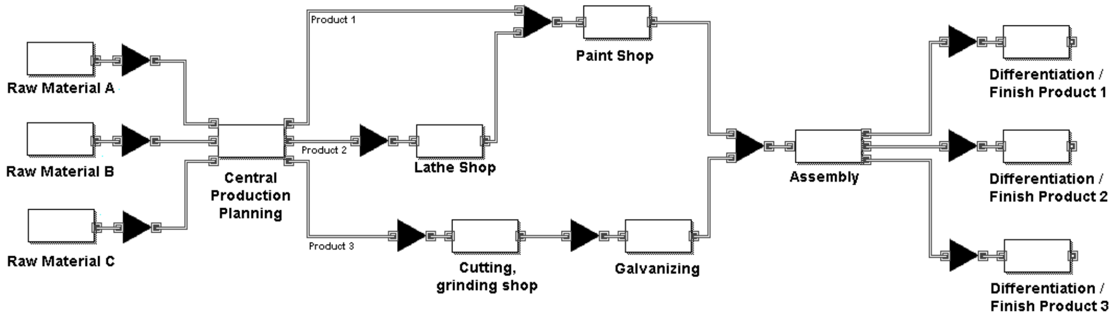

Figure 2: Generic model for the case studies concerning the work shop floor.

Based on this generic business model for the work shop floor, case studies of the following problem areas were developed:

Capacity Management:

In this case study the student gets acquainted with different aspects of capacity related issues in a production environment. The identification and prevention of bottle-necks represents a major topic in this area. The student is instructed how to analytically identify capacity constraints and can then verify these findings by simulation. Furthermore, the student learns the impact of stochastic order arrivals on the delay time from order to delivery of the finished product. It is shown how increasing fluctuations of the order arrivals while keeping the mean order arrival rate constant result in dramatically increased delay times.

Inventory Management:

There are two different case studies in the field of inventory management. The first one is based on the concept of the economic order quantity (EOQ). The theoretically well-established EOQ-concept is used to calculate the total inventory costs, which consist of the inventory holding costs on the one hand an the order costs on the other. The EOQ model provides an analytical derivation of the order quantity that provides the lowest total inventory costs. In the case study, the student can first compute the EOQ analytically given a specific situation and then try out if this quantity also yields optimum values in the simulation. A very important aspect of this assignment is highlighted in the area of stochasticity. The theoretical EOQ-concept is based on the assumption of deterministic order arrivals. In reality, however, this is rarely the case. Therefore, the case study allows the student to introduce stochastic arrivals and to see and explain how the economic order quantity is affected by this.

The second assignment in the area of inventory management sheds light on the trade-off between safety stock and production capacity. The concept of the service level is introduced, which is defined as the fraction of orders that can be delivered to the customers without delay, i.e., out of the inventory for finished goods. If there is a temporarily higher order rate, the inventory may get empty and subsequent customers have to wait until the production facility has refilled the inventory. A higher service level can now be obtained either by having a larger volume on stock, thanks to which the inventory gets empty less often, or by having a higher production capacity, which can refill the inventory faster once it is empty. In this assignment, the student gets familiarized with these ideas and can learn how the service level of a production company is affected by different settings.

Production Scheduling, Priority Rules:

This assignment is focused on the issues that arise when different types of products or jobs are processed by one machine, as it is the case in the given generic model (e.g., the assembly shop or the paint shop). In such a case, the machine needs a decision rule for the order in which the different items are processed. The most frequently applied decision rule is first-com first-served (FCFS), which does not differentiate among different product types. Other decision rules are shortest processing time (SPT), which assigns the highest priority to the item with the shortest processing time (accordingly, there is also a longest processing time first (LPT) scheme). This case study provides an introduction to the issues of priority scheduling. The student learns some theoretic concepts and can verify them using the simulation environment.

3.2 Case Studies for the Generic Model “Supply Chain Management”

Figure 3 shows the generic model of the supply chain used for the case studies. The consumer shown on the right hand side of the figure buys products from the retailer. The retailer keeps a specific number of products in its inventory and reorders them from the manufacturer according to its order policy. The manufacturer, keeps a stock of finished goods and a stock of raw material, which is ordered from the raw material supplier.

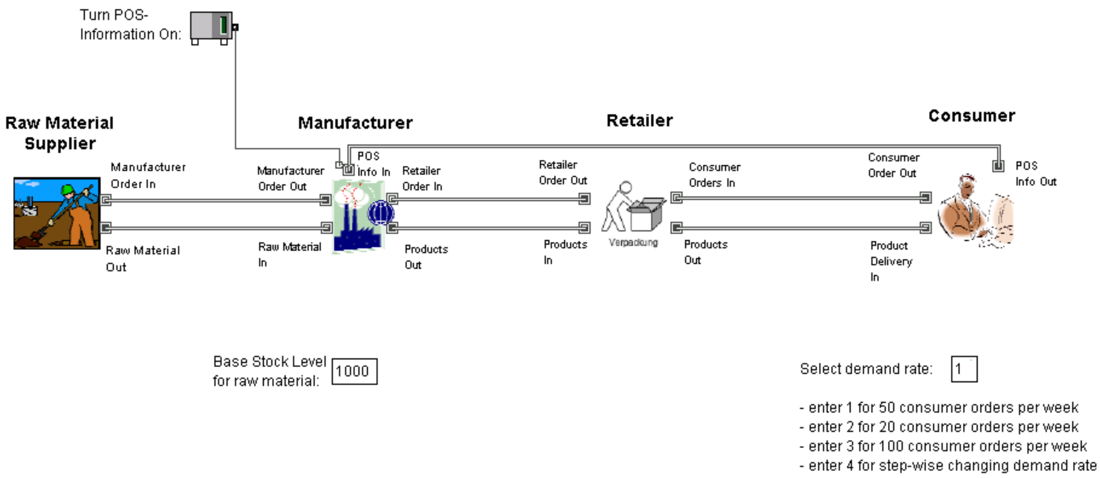

Figure 3: Generic model for the case studies concerning supply chain management.

The generic model shown in Figure 3 represents a very simple supply chain but can be used in a didactic way to show various issues that arise in real supply chains.

The case studies described below are built on top of this generic model. The first one, the information sharing case study, is explained in more details as an illustrative example.

Information Sharing:

In this case study the student can experience the benefit of information sharing in a supply chain. In traditional supply chains, information is often shared in an insufficient way. If, for instance, the retailer's sales volume unexpectedly changes because the consumer behaviour has changed, the manufacturer does not get aware of this new situation before the retailer places his orders more frequently or with a higher volume. Depending on the order cycles, there may elapse quite a long time between the change of the consumer behaviour and the point of time when the manufacturer sees the impact of this change. If the sales volume suddenly grows, for instance, the manufacturer may be caught unexpectedly and run in a stock out situation, which may have negative impacts such as loss of reputation, loss of customers or penalty payments for violated service level agreements.

The concept of information sharing can alleviate this kind of problems in a very effective way. An information channel is introduced between the point of sales and the manufacturer, which keeps the latter one continuously and immediately informed about the sales volume. As soon as the sales volume changes, the manufacturer can now adjust its production rate or its stock level in order to be prepared early enough.

The case study allows the student to choose different scenarios of customer behaviour and to see the impact on the availability of stock with or without information sharing. The student can, for instance, choose the heavily fluctuating demand rate shown in Figure 4. The entire period of the simulation consists of 200 week, which can be considered as approximately 4 years (with 2 weeks of production stop for holiday and maintenance per year). The figure shows that in week 30, the customer demand rate jumps from 50 items per week to 170 items per week and falls back to 70 items per week in week 60. There is another phase of quite dramatically increased demand between weeks 100 and 130. It can be anticipated that these two phases of higher demand put the manufacturer under heavy stress.

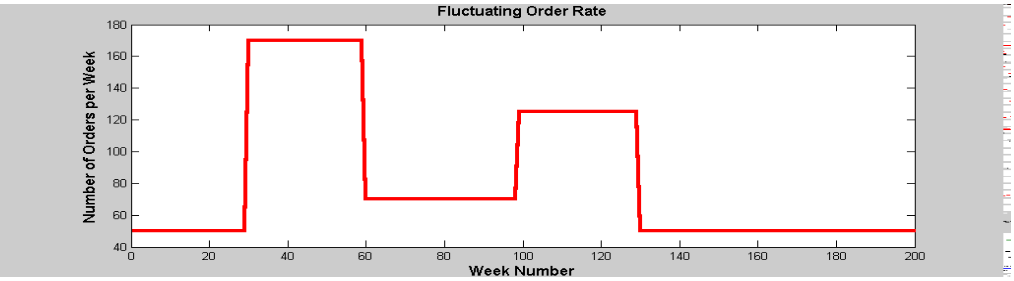

Figure 4: Fluctuating customer demand rate (number of orders per week over the duration of 200 weeks).

The student can now run simulations and observe the fluctuations over time of the different inventory levels. As an example, shows the manufacturer's inventory level for the case without information sharing. It can clearly be seen that in weeks 30 and 100, when the demand rate grows, the manufacturer's inventory declines during a transient phase and then, when the manufacturer has adjusted its production rate, stabilizes at a lower level. A similar effect occurs in weeks 60 and 130, when the demand rate drops. It can also be seen that the manufacturer needs a considerable safety stock in order to prevent a stock-out situation.

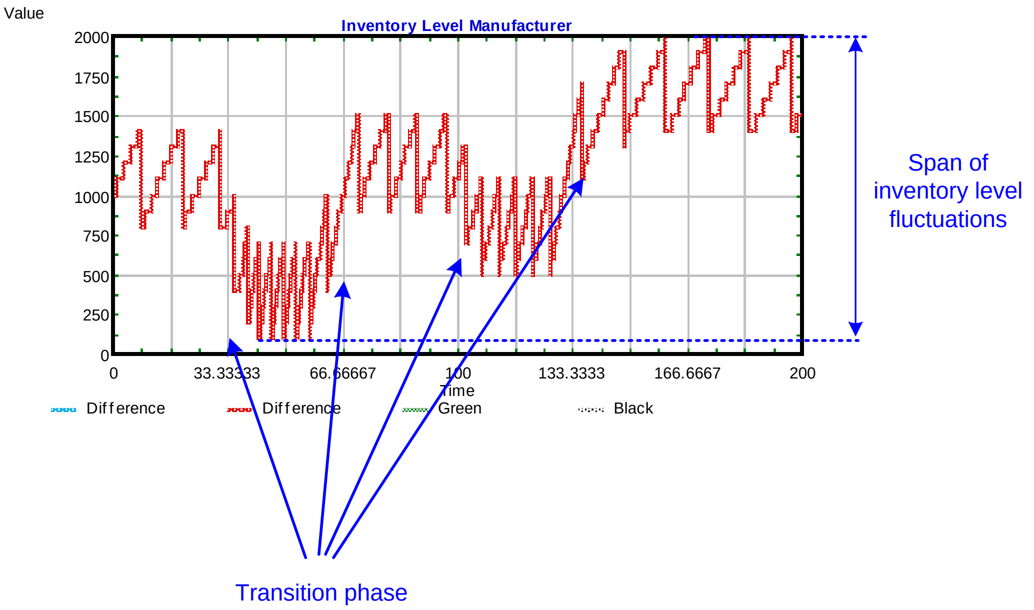

Figure 5: Fluctuations of manufacturer inventory (no information sharing).

The simulation environment now allows the student to activate an information channel for the information sharing between the point of sales and the manufacturer. The resulting fluctuations of the manufacturer's inventory level are shown in Figure 6. Comparing this graph to Figure 5 shows that the overall fluctuations of the manufacturer inventory level are considerably smaller when the POS-information is distributed to the manufacturer. Furthermore, comparing Figure 6 and Figure 5 makes clear that the smaller fluctuations of its inventory level allow the manufacturer to keep a smaller level of stock. Therefore, it becomes evident that the supply chain can considerably save inventory costs when the information about the end consumer demand is shared among the partners.

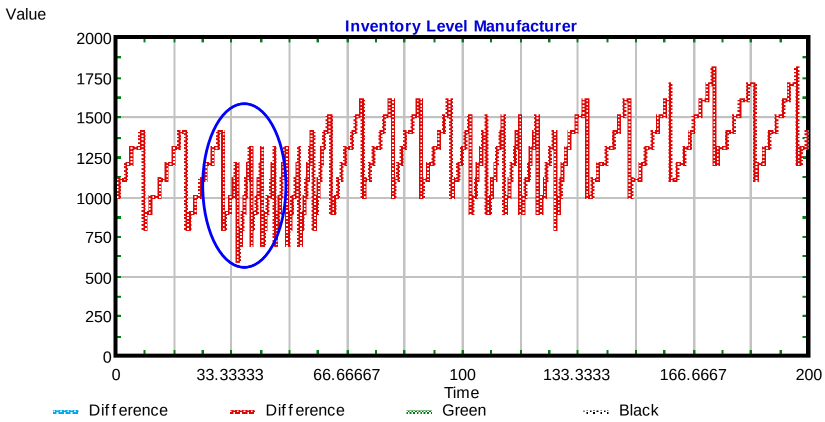

Figure 6: Fluctuations of manufacturer inventory (information sharing activated).

Vendor Managed Inventory (VMI):

In a traditional business process without VMI, the manufacturer ships items to the retailer based on orders: the retailer maintains its own inventory policy and decides when to place an order.

If VMI is introduced, the manufacturer controls the re-supply of the retailer's inventory. To do so, it has to continuously monitor the level of the retailer's inventory. This monitoring is typically based on modern communications infrastructure. VMI is often applied in the retailer market for food (e.g., supermarkets), where the manufacturer is responsible for monitoring and re-filling the shelves in the shop.

In the case study the student can experience how the total inventory management costs of the different partners of the supply chain (with a focus on the manufacturer and the retailer) are affected when VMI is introduced. In particular, it is shown how the entire supply chain can benefit from VMI because the manufacturer can optimally align the production and the retailer's inventory management.

Cooperation in the Supply Chain:

This case study sheds light on the fact that the entire supply chain can benefit if the individual members of it cooperate. In the case study, cooperation means that the supplier and the manufacturer optimize the production capacity and the inventory levels jointly. The student learns that the retailer can reduce its inventory level if the manufacturer increases its production capacity and vice-versa. Using the simulation tool, the student can experience this trade-off and determine optimum settings for the inventory level and the production capacity. The case study creates the awareness that all partners can benefit from cooperation in a supply chain.

Framework Contracts:

The high variations of the retailer's order volume challenge the manufacturer in the sense that it needs an appropriate production capacity and stock level in order to cope with the peak demand from the retailer. Framework contracts can be used to level out the fluctuations of the retailer's order volume. By signing the contract, the retailer commits itself to place order volumes that stay within a specified bandwidth (defined by a maximum and a minimum order quantity). In return, the retailer gets a price reduction from the manufacturer. The student can experiment with different levels of constraints to the order volume in this assignment. This way, the awareness is created that the both manufacturer and retailer may benefit from a framework contract if it is properly designed.

4. CONCLUSIONS

A self-contained package of simulation platform and case studies have been developed for the simulation based management training in the fields of production and supply chain management With this tool, students can apply their theoretical knowledge to practical problems in near real-life situation. This enables them to make practical experiences by applying the learned theoretical concepts, to get a deeper understanding of the issues, and additionally to develop important practical competences which include data retrieval, data analysis and handling of stocahsticity.. The case studies will first be used by the EPFL and the university of Berne and will be offered to other educational institutes at the university level in the near future.

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