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MODELLING AND SIMULATION OF PROCUREMENT PROCESSES

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Abstract The Authors' research has concentrated on the modelling and parametrization of procurement processes – oder/ delivery processes. The methods employed in the research were: modelling approach towards logistics systems and processes as well iGrafx software. The result of the works is the Authors' own project composed of 10 elements, which allows for conducting a multi-criteria analysis of procurement and transportation processes. This paper describes the simulation of procurement according to economic order quantity method. Business processes today are volatile, complex and with many interdependencies; a tendency to reduce the risk of failure is prevalent. Computer simulation as a tool for analysing and predicting future enables the testing of various solution variants over a short period of time – at no capital investment cost or without taking unnecessary risk. The result of the research has a practical application in both manufacturing and trading companies.

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1. INTRODUCTION

Many scientists believe that thinking about reality and about any problems to be handled is inextricably connected with operating on models. Assuming that the possibilities of cognition are limited, and that modelling is intentional and implies a preference for certain attributes rather than for other, then we indeed think about reality in terms of models.

The problems faced and solved by science often require the involvement of a model. Without having a model, full identification, optimization and innovation processes can't be at their optimum, the only viable method for problem solving is by trial and error, as has been done since the dawn of civilization. Hence, the problem that comes to the fore in science is to find a model for a phenomenon or an object in question (Cempel, 2003, p. 49).

2. MODELS AND MODELLING

A model approach proves very useful for investigating logistics processes in-depth and efficiently. When viewed as the chief idea underlying system approach, today's modelling can be regarded as one of the greatest methodological scientific achievements – in both basic and applied research. Modelling has become the only vehicle for learning effectively about the phenomena occurring in contemporary business environment (Chaberek, 2001, p. 7).

Modelling is a sequence of activities which lead to developing a specific model (Staff, 1966). In practice the concept of modelling has two scopes of meaning: a narrow and a broad one. Modelling in the strict sense of the word is construed as creating and building models, which means representing the reality in an object in line with specific rules. Broadly perceived modelling refers to the entire process of model application (Stachowiak, 1999, p. 54).

There are two types of models: diagnostic models and forecasting models. Diagnostic models represent the situation within the organization "as is" (current situation). Forecasting models represent the situation "to be" (intended situation) (Nowosielski, 2008, p. 64).

When we view modelling as a complex process of model application, it can be divided in four parts (Kurek, 2005, p. 135) :

- task-related (basic) – identifying the model objective,
- project-related (structural) – building the model,
- verification-oriented –validating the model,
- application-oriented – using knowledge gained in the course of model testing for intended purpose.

What is arrived at in modelling is the basic structure of a given object, comprised of basic components - processes. The modelling process should be decomposed in line with the assumed disaggregation level guidelines, into sub-processes, functions, activities or operations. The literature on the issue includes: model objective identification, data collection, model development, model simulations, analysis of simulation results, involvement in making decisions regarding model implementation, consultations during model implementation, model verification (Mańkowski, 2010, pp. 140-141). Process modelling grasps complex interdependencies between particular processes running at various organization levels and the arrangement of those processes into a hierarchy.

3. SYMULATION AND ITS BENEFITS

Process modelling methods involve (Abt & Woźniak, 1993, p. 292), (Dohn, 2006, p. 33): graph theory, queuing theory, reliability theory, simulation techniques. Experiments on real-life phenomena are expensive and time-consuming. This is why simulation approach – namely performing experiments on artificially developed models - is so useful. Simulation means manipulating a model, changing the conditions such as time and space, in order to help understand the interrelations between system components and the behaviour of entire systems - which would be otherwise impossible (Cempel, 2006, p. 27).

Simulation in research is possible because:

- on the one hand the models of phenomena and systems are getting more and more accurate,
- on the other hand, calculating capacities of computers are growing.

Until recently knowledge was acquired in an experiment-theory cycle. It means that an experiment revealed basic facts, based on which a model could be developed. The refinement, extrapolation and interpolation of the model implied further questions, serving as a basis for a subsequent experiment and for iterative cognition of reality. Such a dyadic approach to exploring the reality is more and more often expanded to a triad: experiment – theory – simulation (Cempel, 2003, p. 38).

In the study of complex systems (complexity in terms of details and dynamics), the capacity for manipulating time and space makes simulation the only tool which allows for capturing and learning about cause-and-effect interdependencies spread over time and interacting through feedback. System simulation is a common practice in almost every field of science and technology (Cempel, 2003, p. 61).

Developing the right model of multi-variant material flow simulation in supply processes is iterative, it starts from the lowest degree of complexity, goes into more details, until a complex target model is arrived at (Jacyna, 2009, p. 36). The algorithmisation of calculations related to the flow of materials is not always geared towards finding an optimum solution. Management practices which meet the relevant requirements can also be considered a satisfactory solution.

4. PROCESSES AND THEIR ATTRIBUTES

Process orientation makes an organization focused on the processes running within it. The Authors of this paper provide the following definition: a process is a sequence of related activities, which lead to the transformation of input into output (Manganelli & Klein, 1998, p. 28). Each process can be described by means of several attributes: process name, process objective and structure, input and output, supplier and customer, process owner, attributes and metrics (Nowosielski, 2008, p. 49).

The process capacity for delivering specific goods and services in compliance with customer requirements can be measured with the use of certain basic process attributes (parameters) (Kasiewicz, 2002, p. 159). They are, among others (Nowosielski, 2008, p. 51):

- duration– average time needed to complete a given process, comprising all the operations,
- timeliness – on-time completion of the process, in compliance with the deadline (as agreed),
- quality – the level of customer satisfaction with the process output,
- cost – all the expenses related to performing the activities integrated into the process.

Attributes serve as a basis for defining process performance metrics. Process evaluation on the one hand testifies to what we already know about how it progresses, and on the other hand – may reveal any potential deficiencies in its running (Grajewski, 2003, p. 143). The following performance metrics can be identified at the operating level of process measurement (Grajewski, 2007, pp. 80-81): (1) feed metrics – with input information and resources, transformed in the course of the process, (2) resource metrics – with the data on the consumption of resources in the course of the process, (3) output metrics – with output information and resources.

Logistics processes (the functions of logistics) include: customer order processing, inventory and material flow management, transport, warehousing, packaging management, logistics management (Fertsch, 2006, p. 29).

Procurement processes addressed in this paper are directly linked with inventory and material flow management, and indirectly – with other logistics functions. In this paper procurement is viewed from a narrow, activity-centred perspective – acquiring raw materials, materials and semi-manufactured products required for manufacturing at production plants or finished goods at trading companies (Kowalska, 2005, p. 9).

5. LOGISTICS SYSTEM MODEL

The company's logistics system is a highly complex structure. At the functional level logistics cooperates with many other systems within the company. Its level of complexity is determined by links, information flow, decision loops and feedback. This paper describes procurement process model and simulation. The degree of detail of the logistics system model varies; it is higher in the components related to sourcing and lower in accompanying components. The model diagram is presented in Figure 1.

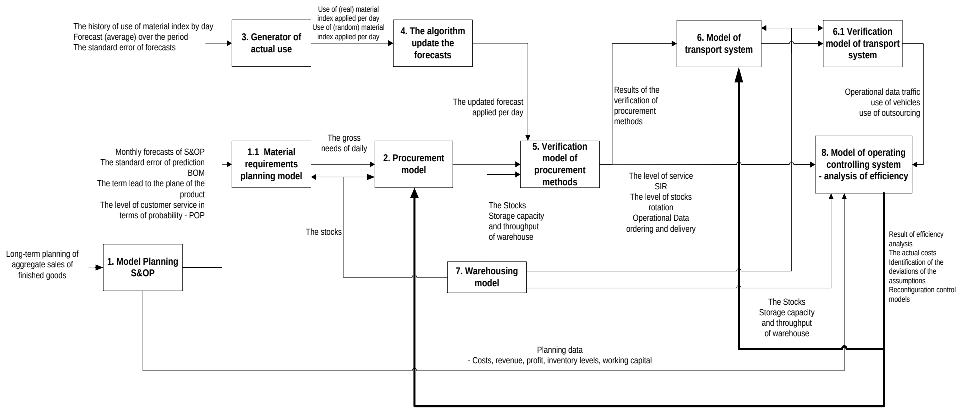

Fig. 1 Logistics system model in an enterprise (Śliwczyński & Koliński 2012, p. 301)

This model is composed of 10 main elements. A short description of each element is provided below, as divided into groups. Input data elements:

- S&OP model – long-term planning, delivering monthly sales forecasts for finished products, estimating prediction error rates, safety stock levels, monthly demand schedules, product structures;
- Material requirements planning model – a tool calculating and capturing finished goods requirements on a monthly basis into projected daily demand for component parts, based on product structure and defined time advance;
- Real consumption generator – allows for downloading the data on real consumption, for example from IT system reports, or for generating consumption automatically based on the selected schedule and its parameters;
- Forecast updating algorithms – a tool for updating consumption forecasts based on the current consumption;
- Warhousing model – a model representing goods issued from and received in the warehouse.

Sourcing elements:

- Sourcing model – the most vital element in the model, allows for determining order quantity and order date based on planned consumption, available stock level and order lead time; in presented solution order quantity can be determined in line with three traditional methods: lot for lot, fixed order quantity and economic order quantity;

- Ordering method verification model – a tool for a preliminary verification of each ordering method, sets the degree to which material requirement is satisfied (in terms of quantity).

Support elements:

- Transport system model – represents basic issues related to transport, such as: creating palletized unit loads, placing palletized unit loads on vehicles, physical transit, unloading vehicles;
- Transport system verification model – a tool for checking if the selected transport solutions meet the requirements set in input parameters in the sourcing model;
- Operational controlling model – a comprehensive model for evaluating the efficiency of a logistics system with particular emphasis on the efficiency of procurement and transport processes.

The elements presented above combine into the structure of a logistics system model. The processes performed within their framework have been described in more detail in the chapter to follow.

6. PROCUREMENT PROCESS SIMULATION

The process of material process requirement changes S&OP parameters and captures them on a daily basis. Quarter analysis requires all the calculations to be made in 3 variants. With identified simulation day the algorithm is able to, based on assumed schedules, match the required levels of safety stocks and to calculate projected requirements for a given day and for stock replenishment cycle.
The process matches this data against the current stock level and, thus, the net requirement is arrived at. If it is greater than 0, then the process communicates with the process which sets order quantity. Otherwise the procurement process is ended on a given day. Material requirements planning model is demonstrated in Figure 2.

When an order must be placed, its quantity is calculated based on one of the three models (description provided in the previous chapter). The process has been illustrated with the economic order quantity method. Economic order quantity (EOQ) is calculated based on consumption forecast and cost data - with the use of Wilson formula. Demand is analysed during the replenishment cycle to make sure that it will be met. If demand is greater than ECQ, then its multiple is requested. Other process elements are used for calculating inventory in transit. Figure 3 presents ordering model consistent with economic order quantity method.

Fig. 2 Material requirements planning process. Source: own study – *iGrafx® Process* 2011

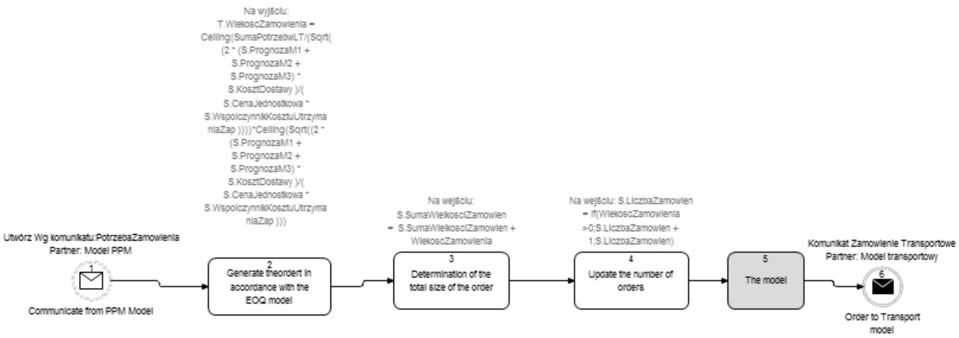

Fig. 3 EOQ ordering process – EOQ. Source: own study - *iGrafx® Process* 2011

Each method of determining economic order quantity provides for various customer service levels. In the solution put forward in this paper the level of customer service is evaluated using quantitative execution degree (SIR – Stopień Ilościowej Realizacji) metrics. It is calculated using aggregate demand for a material index and executed delivery quantity. Figure 4 represents a model for evaluating the degree to which requirements are met.

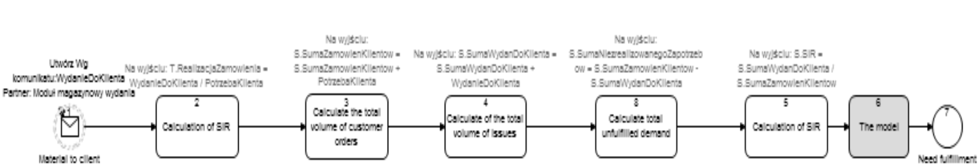

Fig. 4 A model for evaluating the degree to which requirements are met. Source: own study - *iGrafx® Process* 2011

The developed simulation model allows for analysing requirements, orders, and supplies over the period of three months. It has been assumed in the solution that procurement analysis will be focused on quantity-centred analyses, such as: average inventory level, quantitative execution degree (SIR), number of orders, aggregate unmet demand, aggregate delivery quantity. Presented quantitative analyses can be easily translated into cost analyses. This task is performed in the controlling model. Figure 5 demonstrates the results of procurement simulation in ECQ scenario.

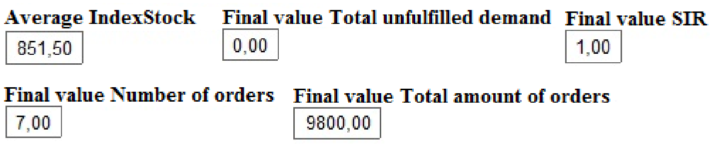

Fig. 5 Non-standard simulation results in EOQ scenario. Source: own study - *iGrafx® Process* 2011

The opportunity for creating non-standard simulation results in iGrafx environment allows for a multi-aspect study of process variants.

7. CONCLUSION

Logistics process modelling and simulation in a company is a complex issue. Some of the system elements must be simplified. Such a measure is necessary if the modelling process is to generate profits. Hence the model objective should be identified at the beginning of the work. This solution has been developed for the purpose of analysing procurement and transportation processes. The Authors' principal point of interest and the main focus of this paper is to give a description of a part of the model involved in procurement processes.

Another major conclusion derived from the research related to process modelling and simulation is that process operation in real world is different from the operation shown in a simulation model. A person dealing with the modelling and designing a simulation experiment must select the right tools offered by the simulation environment to make as accurate and real process representation as possible.

The solution that has been developed is universal in nature. A set of input parameters allows for representing a number of situations faced in reality. Proper demand scheduling allows for developing models which involve inventory maintenance (MTS) and exclude inventory (MTO). The model gives therefore grounds for further work. It allows for testing various process variants and for solving scientific problems in the area of question.

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BIOGRAPHICAL NOTES

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