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MODELLING INVENTORY CONTROL PROCESS USING COLOURED PETRI NETS

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Abstract
An approach to inventory control, based on Colored Petri Nets, is presented in the paper. Complete approach is illustrated on the example of inventory control in a publishing and printing house Politika a.d. Processes of ordering and stocking are observed and modeled. The AS-IS model is created using hierarchical, stochastic (timed) Colored Petri net. Based on that model, the several TO-BE Petri nets models are created. The first one model includes improvement of ordering strategies for obtaining optimal order quantity and reorder point with safety stock. Microsoft Excel is used for inventory optimization. Other TO-BE models include change of process itself. The core of process is detained, and the activities as annual inventory control, inventory classification and coordination between participants in process are proposed. After the simulations of all models, expected improvement of time performances is confirmed. Applying software package CPN Tools, simulation and performance analysis have been performed.

Keywords*: inventory control, colored Petri nets, optimization*

1. INTRODUCTION

Significance of inventory control is based on value of stock and fact that costs of stock are important part of total production costs. Basic problem of inventory management that is solved is time discordance between order and supply, i.e. discordance between needs and material availability. Modern approaches to inventory management demand use of informational systems and mathematical models [7].

The subject of this research is system for inventory control in the newspaper and publishing company Politika a.d. The company is publisher of the oldest daily in the Balkans and is the biggest printing firm in Serbia. Politika's part of printing services market in Serbia is 60%. Company uses three primary sorts of raw materiel in production. Those are printing paper, printing colors and printing tablets. Two types of printing paper are used; newsprint and sheets of paper. At the beginning of 2004, the company started using completely new printing technology, which required new raw materials [1]. This change caused redesign of inventory control system. For this purpose, we used methods and techniques of industrial logistics.

Current process and system of inventory control is overviewed in details. Having analyzed the current situation, all possibilities of improvement are taken into consideration. At the end of the research, the following system of inventory control is developed, including following:

- Model of material flow of inventory control process represented with colored Petri net with the possibility of its modification and simulation;
- Software for calculation of all necessary parameters for chosen methods of inventory control.

2. INVENTORY PARAMETERS OPTIMIZATION USING MS EXCEL

We created software in MS Excel, which calculates all inventory parameters. We wrote all macros in Visual Basic Editor. Software has the possibility to create complete database for each materiel and to calculate all parameters needed for chosen methods of reordering.

Software can calculate economic order quantity, order point and safety stock for chosen materiel. Calculation of these parameters is completely automatic. As shown in figure 2.1, we created menu bars for each parameter.

When user chooses to calculate economic order quantity, he has to enter code for materiel, acquisition costs and carrying costs, and Excel automatically calculates economic order quantity. Order point is calculated on basis of last years needs for the materiel [1]. Parameters needed for calculation of safety stock are probability coefficient for lack of stock and date of delivery.

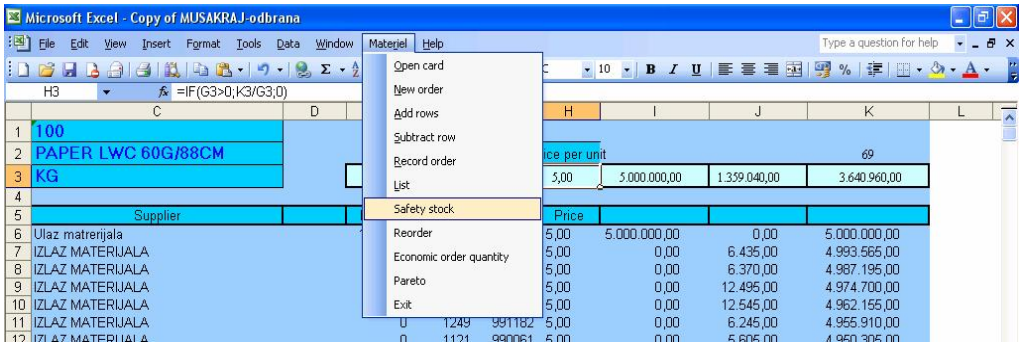

Figure 2.1 Menu bars in MS Excel

When the database is full with all sorts of materiel, Excel can put them in rank order of raw materials for Pareto analysis [3]. For this purpose, we wrote one macro called *Pareto* (figure 2.2).

Microsoft Excel - MUSAKRAJ-odbrana

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	A	B	C	D	E	F	G	H
1								
2					7,900,000.00			
3		No	Code	Materiel sort	Total value [€/y]	Percentage [%]	Percentages summ [%]	Class
4	1	2	10001	BOJA ŽUTA	100,000.00	79.00	79	
5	2	3	10002	BOJA CRVENA	100,000.00	79.00	158	
6	3	4	10003	BOJA PLAVA	100,000.00	79.00	237	
7	4	5	10004	BOJA CRNA	100,000.00	79.00	316	
8	5	1	100	PAPIER LWC 60G/88CM	1,000,000.00	7.90	323.9	
9	6	7	103	PAPIR LWC 60G/95CM	1,000,000.00	7.90	331.8	
10	7	8	120	PAPIR LWC 70G/88CM	1,000,000.00	7.90	339.7	
11	8	9	121	PAPIR LWC 70G/90CM	1,000,000.00	7.90	347.6	
12	9	10	122	PAPIR LWC 70G/95CM	1,000,000.00	7.90	355.5	
13	10	11	235	PAPIR KUNSDRUK 150GR	1,000,000.00	7.90	363.4	
14	11	6	101	PAPIR LWC 60G/90CM	1,500,000.00	5.27	368.6666667	

Figure 2.2 Pareto analysis

All outcome parameters from MS Excel, are income parameters for TO-BE model in CPN.

3. CPN MODEL OF ACQUISITION AND STORAGE PROCESS

Using software CPN Tools [8], we created two Petri nets [5,6], which represent the process of acquisition and storage of raw materials in Politika a.d. First net represent AS-IS process and the second one represent TO-BE process. We simulated AS-IS net and we measured performances like: time, backorders and inventory transaction. Based on results, we suggested modifications and we created TO-BE model. We measured the same performances and compared with results of AS-IS model [4].

3.1 HIERARCHICAL NET STRUCTURE AND DECLARATIONS

The net structure consists of one top level net and nine sub-nets (sub-pages) at four hierarchical levels. At the right side of the figure 3.1.1, is shown the top level Colored Petri Nets (CPN) [2], and at the left side, hierarchical structure of the whole CPN.

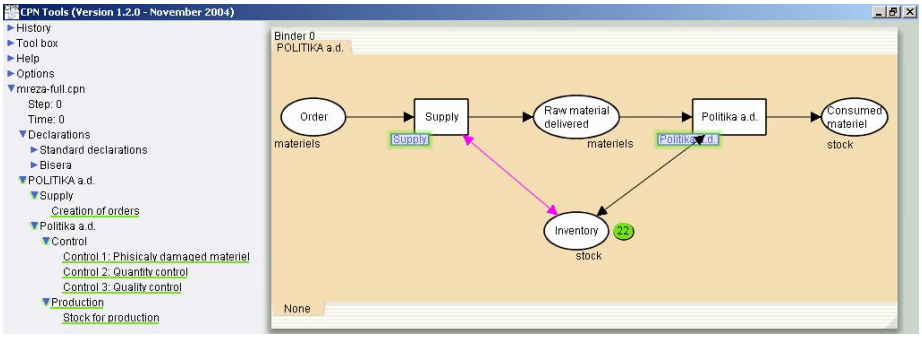

Figure 3.1.1 Top level

The top level CPN presents whole process of acquisition and storage. Process is divided into two processes: the first one is process of acquisition, which is represented by sub-page *Supply*, and the second one is process of storage and production, which is represented by sub-page *Politika a.d.* The arc in different (light color) is added in TO-BE model for modeling the changes which will be explained in following sections.

For description of net, we used following types (colors) presented in table 3.1.1 (simple color sets) and in table 3.1.2 (compound color sets).

SIMPLE COLOR SETS	
sort	Type of materiel (14 types)
quantity	Integer for quantity of materiel
damaged	Information is the materiel physically damaged and photographed or not
quantity1	Information if the quantity of received materiel correspond with invoice of supplier
quality	Information if the materiel is qualitative or not
returned	Information if the materiel is returned from production or not and if it is returned, is the materiel with good quality

Table 3.1.1 Used color sets

COMPOUND COLOR SETS	
need	Information of type and quantity of materiel, timed
stock	Information of type, quantity and quality of materiel
materiel	Information of type and quantity of materiel, timed
approved	Information of type, quantity and damage of materiel
received	Information of type and quantity of materiel, and if it is returned from production

Table 3.1.2 Compound color sets

We also used predefined functions (uniform and normal distribution) for modeling different proportions in process and we defined function rest for modeling fulfillment order activity.

3.2 SUB-PAGE SUPPLY

The following figure presents CPN model of acquisition. AS-IS process starts with order for acquisition, which is based on historical data of production needs. This is modeled with dark nodes and arcs at page *Supply* and its sub-page *Creation of orders* in figure 3.2.1. Light parts of nets represent improvement of model.

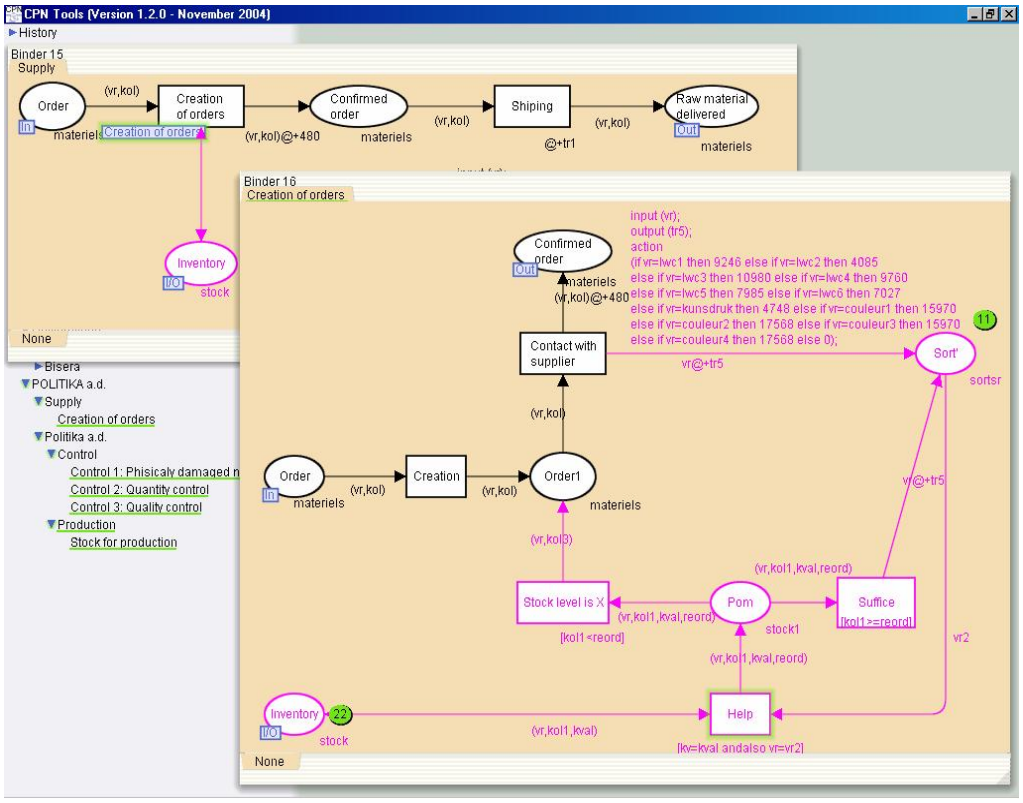

Figure 3.2.1 Sub-pages Supply and Creation of orders

The idea of TO-BE model was that the supply orders should be created based on results obtained from software created in MS Excel. Added part of net includes order point and safety stock, which are necessary for determination of moment of reorder and order quantity. This is modeled with transition *Stock level is X* at sub-page *Creation of orders.*

3.3 SUB-PAGE POLITIKA A.D.

Two main processes, which were analyzed within the company, are reception and controls of the received materiel; and consummation and returning of materiel by the production. Those processes are modeled by means of substitution transitions (Figure 3.3.1): *Control* and *Production*. Both sub-pages will be explained in following sections.

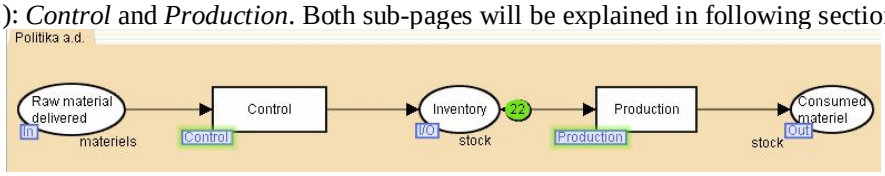

Figure 3.3.1 Sub-page Politika a.d.

3.3.1 SUB-PAGE CONTROL

CPN net presented in the figure 3.3.1.1 shows three controls of received materiel that are performed in the company. Each control is modeled by one substitution transition.

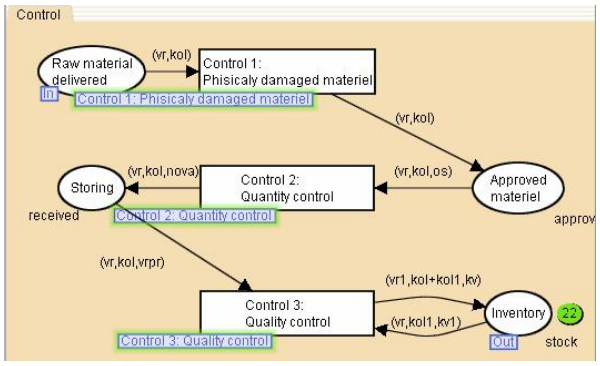

Figure 3.3.1.1 Sub-page Control

By CPN shown in the figure 3.3.1.2, the first control activity is modeled. In this sub-process, received materiel is checked for eventually damages during the transport.

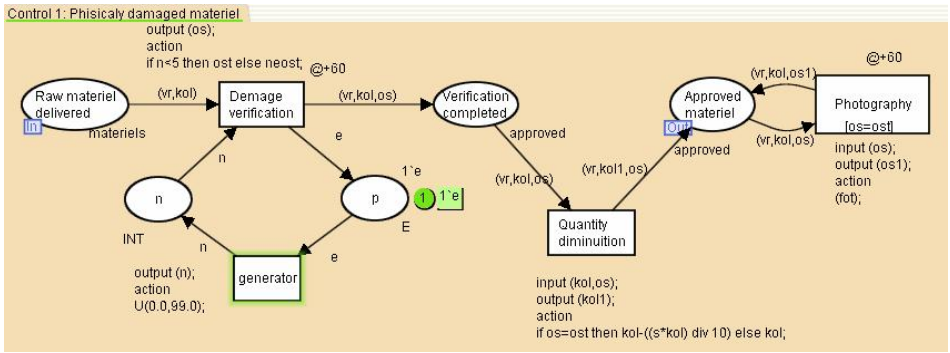

Figure 3.3.1.2 Sub-page Physically damaged materiel

We needed precise information about the quantity of materiel in stock, which can be taken into production. When the materiel is damaged, we added one transition (*Quantity diminution*), which lessen quantity of received materiel. This activity is very important from the aspect of the company.

Control than continue with quantity verification of reel quantity and the quantity which is written on the invoice of supplier (figure 3.3.1.3). This part of the process is significant from the point of its duration.

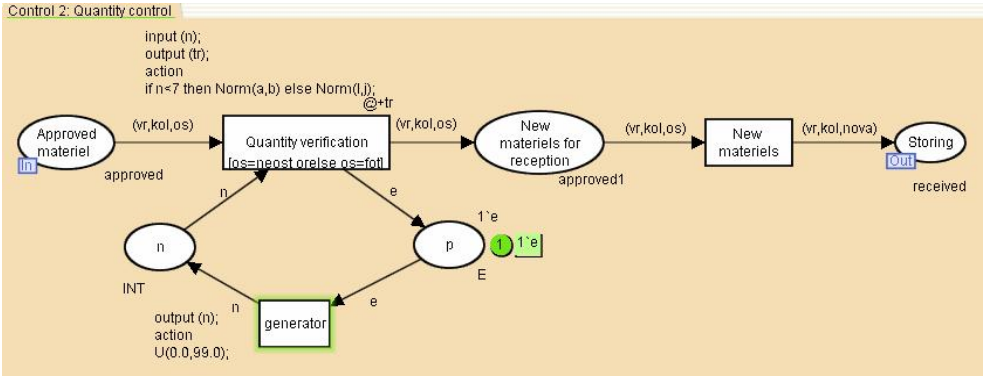

Figure 3.3.1.3 Sub-page Quantity control

Department of quality control in Politika a.d. performs control of quality parameters (transition *Quality control* in figure 3.3.1.4) and assigns the attest for production. This control is done only for printing papers.

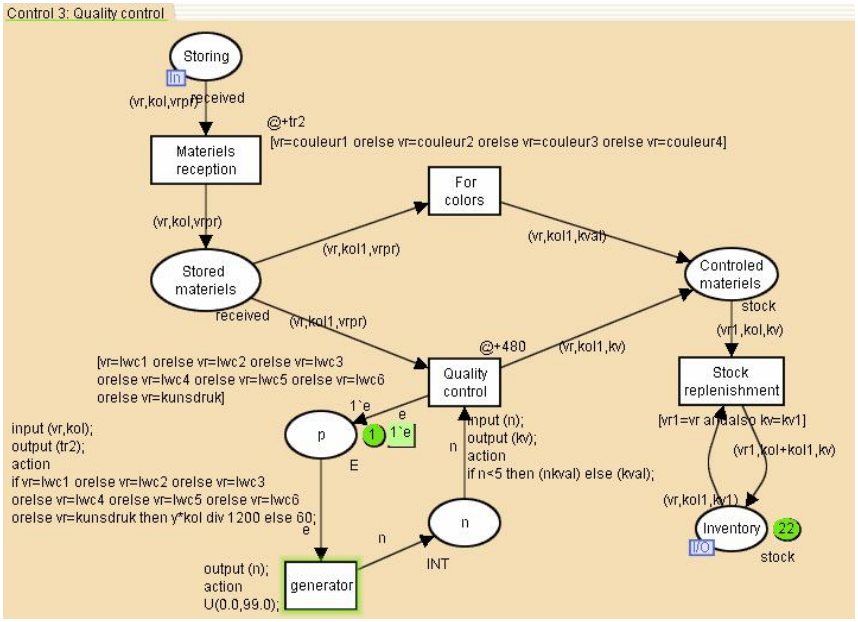

Figure 3.3.1.4 Sub-page Quality control

Inventory is replenished with positive attested materiel.

3.3.2 SUB-PAGE PRODUCTION

In the figure 3.3.2.1, we presented CPN for production orders and for production itself. If the production order is larger than quantity in stock, backorders information can

be seen at the place *Need for materiel*. At this place, initial markings of needs are historical data. We did not model creation of production needs for materiel. We observed production only from the aspect of consumed and returned materiel.

In the AS-IS model, returned materiel from the production has been put on stock for all materiel. This resulted in informational problems, i.e. we could not differentiate new materiel from returned materiel.

One part of materiel which production returns is damaged and put on stock with one new given attribute. At this way, that materiel does not have the attest to goes again in production.

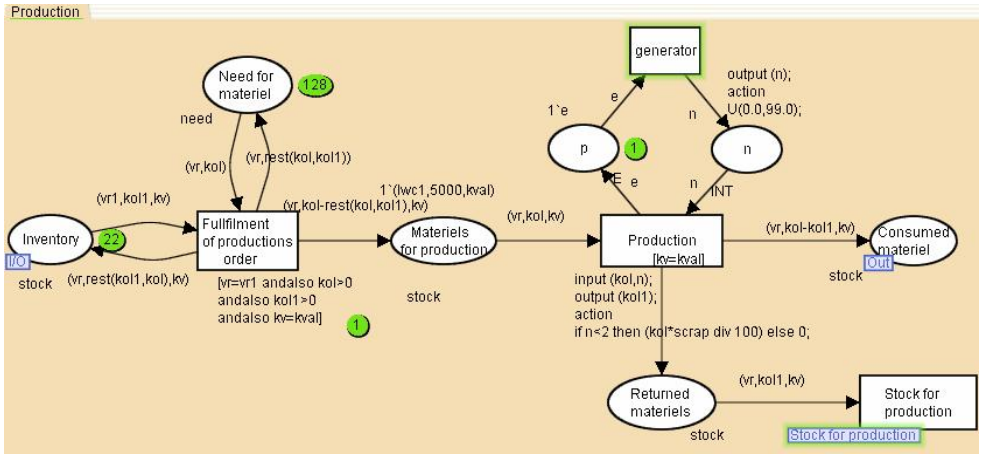

Figure 3.3.2.1 Sub-page Production

Our proposition in TO-BE model was adding new stock for production (see figure 3.3.2.2) for the returned materiel. This is shown in light color. Now, we can, in our database, follow up this materiel.

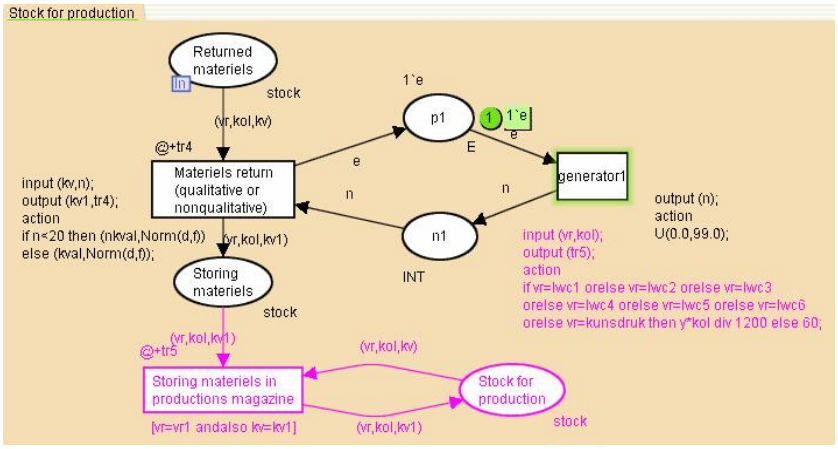

Figure 3.3.2.2 Sub-page Stock for Production

4. SIMULATION RESULTS

We have simulated AS-IS and TO-BE models using CPN Tools. After the simulation, CPN Tools creates report, which can be opened with MS Excel. This report is hard to analyze, and for this reason, we wrote macro in Visual Basic Editor. This macro sorts all results in one, easy to analyze, table. We had chosen three parameters that were important for our work. Those are time, backorders and inventory transaction.

Figure 4.1 shows inventory transaction difference between AS-IS and TO-BE model results. This is result for one sort of printing paper. We showed that in AS-IS model, there is lack of stock, and for TO-BE model, stock is moving around safety stock for this materiel.

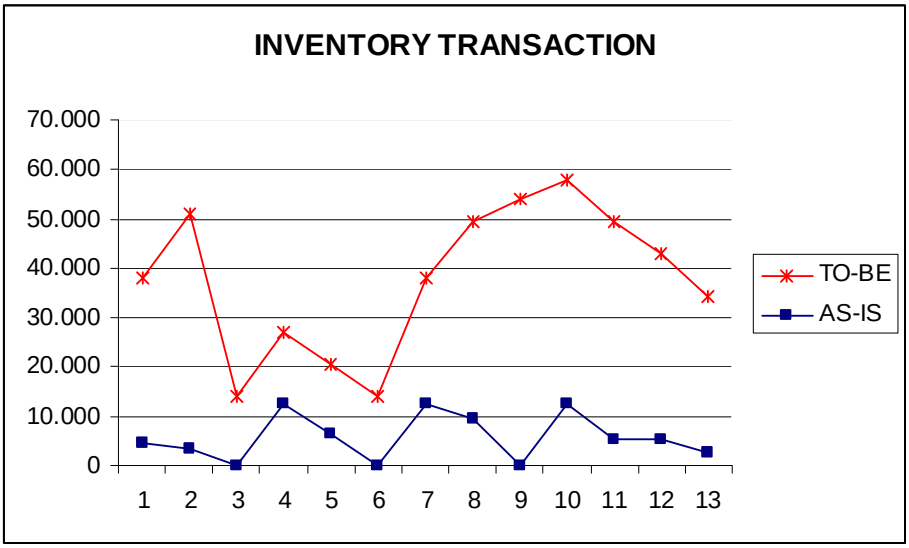

Figure 4.1 Inventory transaction

Simulation also showed that there are 15% less backorders in TO-BE model than in AS-IS model. These results show improvement of process itself.

5. CONCLUSIONS AND FUTURE RESEARCH

In this paper, we showed how inventory control process can be modeled and analyzed using CPN. Once when the AS-IS process is overviewed and presented in CPN, it is easy to change and add parameters, which are important to follow. We followed three parameters: time, backorders and inventory transaction. Based on simulation results in AS-IS model, we created TO-BE model. We compared simulation results from each model. In this way, we could validate the new model of inventory control, and make new changes in TO-BE model. We proposed changes to the company.

In addition to this, we linked up two completely different software. We chose methods of inventory control for each raw materiel and wrote macros in MS Excel, which calculate necessary parameters for these methods. We can calculate safety stock, economic order quantity and order point. These outcome parameters from MS Excel are

income parameters for CPN. On basis of these parameters, creation of orders and their quantity is completely automatic in CPN. This had as a result, completely new inventory management, which can be applied in the company and give better results than the AS-IS model of inventory control. Simulation results from both models show this improvement.

Some parts of the process (like production) are not analyzed in details. In the future research, we can overview all parts of process in the company in details, and model it with CPN. One of our ideas is to model whole process of supply, production and storing of finished products in the company.

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