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ASSESSMENT OF THE PRESS REPLACMENT USING SIMULATION

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ABSTRACT

This paper addresses one case where the simulation was used in order to determine which press machine is best for the production system in a company. This is especially important in small companies. The simulation was specifically selected as a tool because it is very useful to reuse the models for any further experimentation. At first all the conditions of one company were determined, conceptual model was created along with all the assumptions. Historical data were transmitted in the model and after the programming, the model was verified, validated and experimented. The experimentation can be done in the future if required. At the end, a comparison was conducted for the most important elements and how were they affected by the performance of the press machine.
Key words*:simulation, machine replacement, productivity, iThink.*

1. INTRODUCTION

The importance of production planning has always been and always will be one of the key factors in managing one enterprise and eventually gaining profit. Although a lot attention has been invested dealing with this issue globally, we still see a lot of examples of not well planned, and at the end, not well utilized production systems. Production managers may waste more time in managing when and how a tool or a die should be changed, and do not always measure if the machine is already "wasted" or simply not performing by its full potential any more. This type of issues is a huge "hidden" factor when evaluating the performance of the company- mainly its profit. This is especially more emphasized in SME because they are the ones that depend on the limited capacity of the production machines.
For analysing and evaluating the potential of the company, the methodology COMPASS (COmpany's Management Purpose ASSistance) was used [3]. It is foreseen as an open methodology that can utilise various methods and tools in different stages of its implementation. This paper focuses only on the part of the experimentation with the possible improvement, so, not all phases are going to be described.

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2. SIMULATION METHODOLOGY

The simulation has been chosen as a tool for analysing the influence of the selected possible improvements (SFs) because it easy to reuse the created model. The simulation model that is going to be described in here is created under a certain methodology, Figure 1, adopted from [1]. In many literatures there are different methodologies for creating a simulation model, simulation study or simulation project. Please refer to [4], [2], and others for more details. In this section the theory of each step will not be described; instead, all these steps will be mentioned when describing the model. As a basic simulation software the iThink® has been chosen.

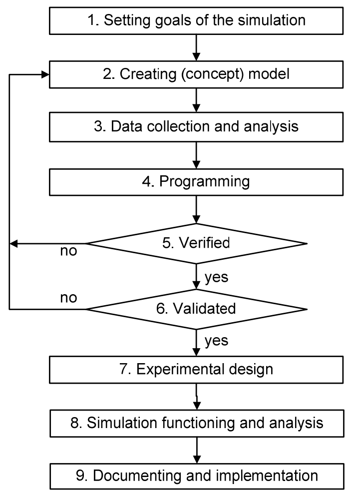

Fig. 1 - Adopted methodology for creating a simulation

3. ANALYSIS OF THE GIVEN CASE

The following information were taken in consideration: the company works in two 8 hour shifts, there are 5 working days in the week, there is one dominant press machine in the production system, the produced scrap is not re-workable, one type of products is produced, the company receives maximum one order per day and they use the first come first serve method when planning the production.

In order to show the genesis of the problem, we will very briefly describe how this problem arose. For the production system that was analysed, an Importance/Performance matrix was created in order to define the critical elements of the system. Since they were recognized, the next step was to define measures for their improvement, called Success Factors (SF) in COMPASS. They can be generated using Ishikawa diagram, relationship diagram, affinity diagram, Pareto analysis etc. After that, a list or a scheme of the possible SFs was created and based on it, a SF or SFs were chosen in order to analyse the improvement they will generate. In this case, the SF new machine has been chosen as the one most influential. So, in the following text the problem is simply on the decision whether to replace the existing press machine with new one depending on certain performance indicators.

4. CREATED SIMULATION MODEL FOR CHOOSING THE BEST PRESS MACHINE

The model that was created is actually a synthesis of two models, very similar to each other, Figure 2. The first model represents a picture of the company in case the old press machine stays to operate and the other model represents a situation when the company acquires a new press machine. The main difference between the models was that in the model with the old press machine (from now on referred to the first model) for some of the elements there have been already initial values, which have been cumulated as the machine worked, and in the model with the new press machine (from now on referred to the second model) the same elements had initial value 0, since it has never produced anything.

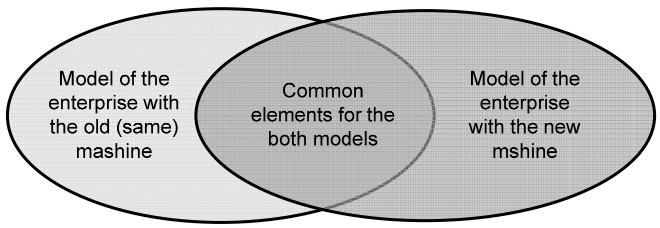

Fig. 2 - Simple scheme of the two models

In the beginning, the first model was created, all of its elements were defined, together with their relationships, it has been tested etc. After the first model was verified and validated, the second model was constructed, with the needed alterations. It was more than obvious that the final model was constructed with numerous iterations, which is characteristic for the simulation process. In Table 1 an overview is given of the activities that were undertaken in every step of the simulation methodology for the given case. A more detailed description can be read in [7].

The initial phase in the concept modelling was the analysis of the current state and defining the elements of the model [4]. From the analysis, a list for all elements was made and it was decided which of the elements to be included or excluded. After that, a detailed table was created with description for the 48 different elements that were included in the simulation study (like Table 2), list of assumptions and a scheme for the logics of the model.

The procedure for data collection and analysis was conducted on four different elements used in the simulation. The idea is to fit the collected historic data for those elements in a specific known format for the simulation software. Two of them (scrap percentage and defects per day) were processed in the Mathcad® software, and two of them (number of parts that need to be manufactured and the time needed to fix a particular defect) in a special software for determining distributions - ExpertFit®. The ExpertFit® software was used to determine the theoretical distributions with a great level of significance for a relatively short period of time and reduced the possibility of errors and doubts in the obtained data. Mathcad® software as much more complex software was used for the required forecasting.

Table 1 - Overview analysis of the activities undertaken in the simulation process according the steps in the adopted methodology

Step in the adopted methodology	Undertaken activities in scope of this model
1. Setting goals of the simulation	To create a simulation model that will help us in making a decision which solution is the most optimal for the company when acquiring a new machine.
2. Creating (concept) model	Describing the included elements and creating a general scheme how the model functions.
3. Data collection and analysis	Acquiring the historical data, their analysis and transformation for the model.
4. Programming	Transforming the ideas of the concept model, the historical data and the distributions using the simulation software iThink.
5. Verification	Creating a parallel simulation in Microsoft Excel in order to compare with the iThink model and determine its accuracy.
6. Validation	Crating a different kind of simulation in Microsoft Excel, which output data are compared with the results that are generated by the model in iThink.
7. Experimental design	Creating few models, different types from the original, where the assumptions are being tested. Additional sensitivity analysis has been conducted as well.
8. Simulation functioning and analysis	Analysing the output data from the simulation and their presentation in various tables, graphs and finally as scenarios.
9. Documenting and implementation	Suggestions from the modeller side and end of the simulation process.

Table 2 - Detailed description of the included elements in the model

Name of the element (formula)	**old machine / new machine / value range**	**Unit**
Order (number of parts) abs(round(NORMAL(282.63158, 98.22408))*MONTECARLO (scrap_percentage)		Parts/ order
▪ This element represents the number of parts that are ordered by the client. It’s the same for the both machines. The number is being generated using the normal distribution with mean of 282.63158 and standard deviation 98.22408. The number is being rounded not to generate decimal values and in absolute values. The value is being multiplied with the MONTECARLO function from the software which determines the tempo of the orders arriving.		
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Generating data in Mathcad®

The correlation factor between the historical data and the data generated with the software is 1, so the data is matched.

$$\mathrm{corr}\left(Y, \overrightarrow{|\mathrm{fit}(X)|}\right) = 1$$

The final output of the Mathcad® calculations was

*Scrap percentage = 5,575 - (5,512*10-3)*time+(9,784*10-6)*time*^{2}

The same procedure is carried out with the "defect per day" element as well, with a slightly lower correlation factor.

$$\mathrm{corr}\left(Y, \overrightarrow{|\mathrm{fit}(X)|}\right) = 0.986$$

The final output of the Mathcad® calculations was

*Defects per day = (5,548+0,215*time+(5,455*10-5)*time*^{2}*)/50*

Generating data in ExpertFit®

This software was used in order to fit the data to a known theoretical distribution. The data for the number of parts that need to be manufactured and the time needed to fix a particular machine defect were processed through this software. For the given cases, the outputs were analysed through graphical and analytical methods, please see Figure 3 and Figure 4.

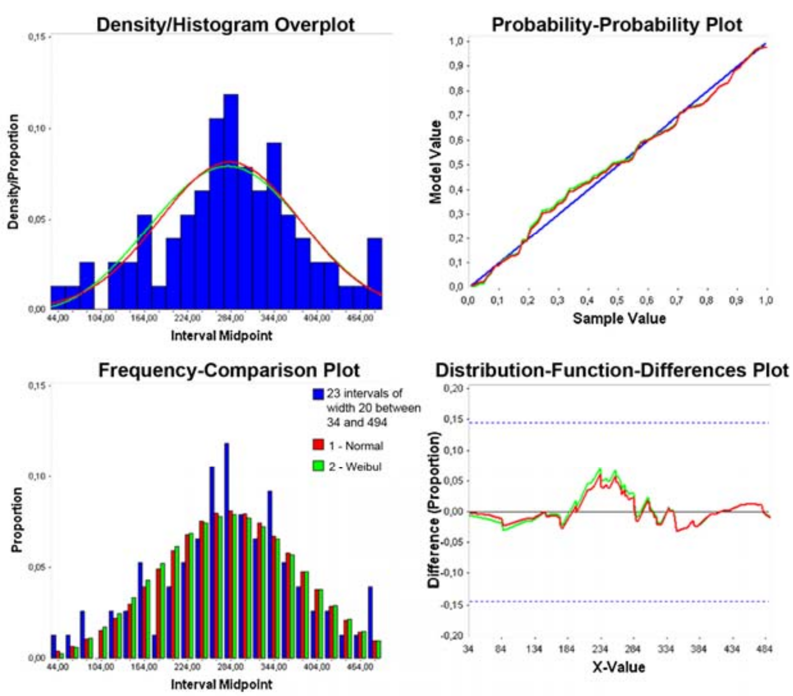

Fig. 3 - Different graphical comparisons of the collected data and the fitted distribution

The goodness-of-fit test was performed using the Kolmogorov-Smirnov test and it resulted in not rejecting the hypothesis that the fitted distribution cannot be taken into consideration as valid for the given data, Figure 4.
For the verification, a simpler version of the model was created in Microsoft Excel. Both models were then tested with the same few examples. At the end, a comparison of the results of both models was made and showing that there were no deviations of the results obtained with the two models.

Kolmogorov-Smirnov Test With Model 1 - Normal

Sample size	76
Normal test statistic	0,06627
Modified test statistic	0,57773

Note: The following critical values are exact.

Sample Size	Critical Values for Level of Significance (alpha)				
	0,150	0,100	0,050	0,025	0,010
76	0,767	0,011	0,886	0,985	1,025
Reject?	No				

Fig. 4 - Analytic goodness-of-fit test

Two tests to check the validity of the model were made. The first was a simple test of correlation and the second was the statistical validity of the model. Given the fact that it was a simulation that simulates a situation what will be in the future, proper validation should be done after 2 years, as it was a time frame which was being simulated. In this part of the simulation study, a correlation test, t-test and test for number of replications was conducted. For the results of the t-test, please see Table 3. The t-value is between the possible range -1,993 ÷ 1,993.

Table 3 - Data from the t-test

Components	Real system	Simulation model
Mean	18,52631579	18,63157895
Variance	28,79658606	29,21194879
Number of data	38	38
Degrees of freedom	74	
α	0,05	
t=	-0,022522154	

The generated model in the software is presented in Figure 5.

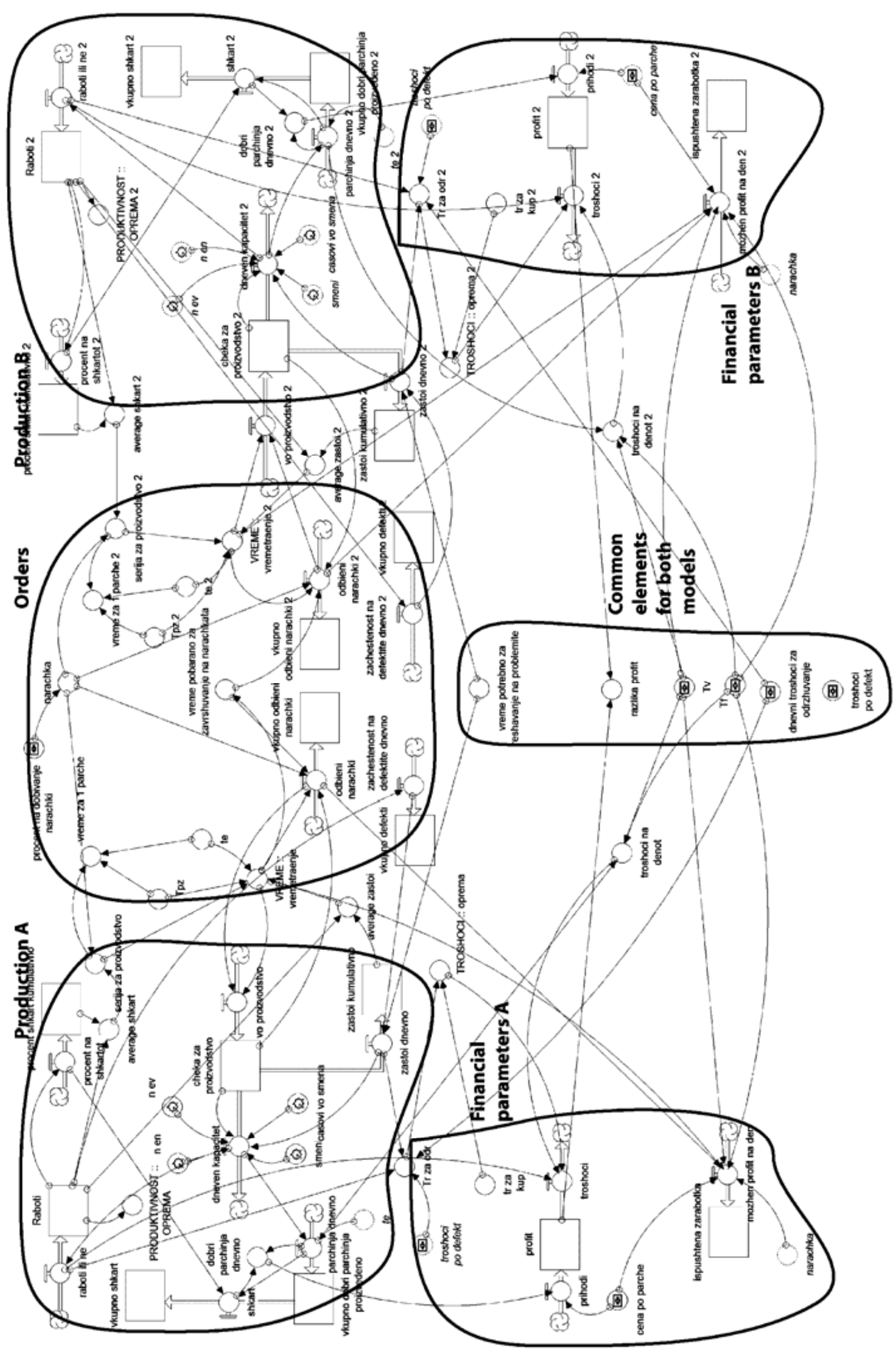

Fig. 5 - Final overview of the simulation model

The sensitivity analysis was a way of experimenting with the model, but also a way to test it [5]. In the simulation there were some elements that were taken from historical data or assumptions. Using this analysis the values (parameters) were changing of certain element(s) and it was tested how the model reacts to it [6]. In this section there will be only one analysis mentioned - for the element "Number of shifts", we analysed the data if the values of the particular element changes in 1, 2 or 3 (shifts per day). As expected, the test showed significant changes in the values when the number of shifts increased, Figure 6.

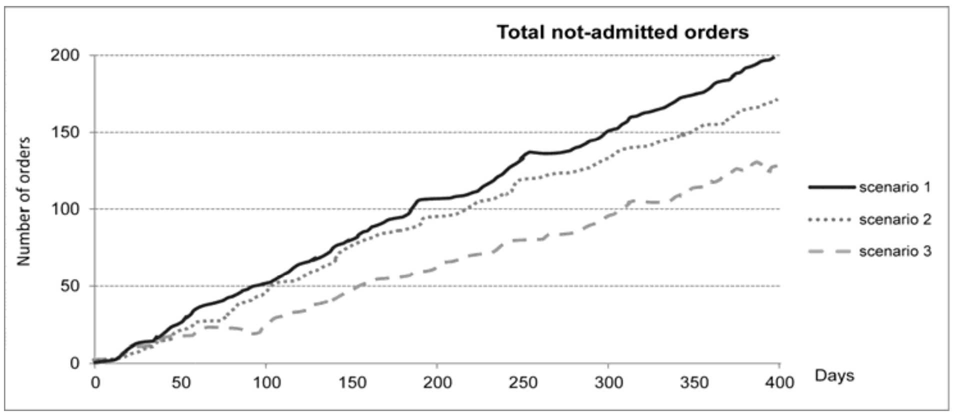

Fig. 6: Output results of the sensitivity analysis

As it can be seen, Table 4, the new machine generates more profit compared to the old one, mostly because of the time for production of one part was shorter and it has fewer defects i.e. it has less stoppages in production. Therefore, the new machine can produce far more pieces per day and thus more profit per day (an assumption was that there was a continuous demand for the product).

In determining the duration of the series a big difference between the two models (5,24 vs. 3,40 days) can also be seen, where the advantage of not having so much stoppages during the day is obvious. The missed out profit (this refers to the revenue that the company is missing out when it cannot fulfil an order) in the model with the old machine was greater (but with not a big difference as expected) mostly because of the fact that it has rejected several orders from the model with the new machine (52 versus 46). Daily costs and equipment-costs were higher for new machine because there was more working time (productivity- equipment is 95% compared to the old machine - 85,75%).

The advantage of the simulation and modelling is when a successful model is created, it can be used for different analysis. In this case, we made another analysis as described before with another machine and compared it as in Table 4. Three different elements were analysed, according to COMPASS. These are:

- TIME-duration (the cycle time of the production),
- PRODUCTIVITY-equipment (the utilisation of the appropriate machine) and
- COST-equipment (the summed costs for the appropriate machine, fixed and variable).

The performance of the TIME-duration when it comes to new machine has increased, appropriate to the performance of the machine. In the case of the old machine it has even a slight decrease in value, which was somehow expected- there was an increased percentage of scrap and stoppages which affected this critical element.

Table 4 - Comparison of several elements in the simulation, between the two models

Elements	Old machine	New machine
Profit	54 684,7 m.v.	**146 137 m.v.**
Income	397 720 m.v.	**638 960 m.v.**
Good parts	29,07 per day	**42,04 per day**
Scrap	676	**213**
Missed out profit	170 597 m.v.	**153 176 m.v.**
Costs	343 125 m.v.	**492 943,34 m.v.**
Costs for maintenance	15 350,29 m.v.	**10 268,304 m.v.**
Daily costs	305 475 m.v.	**444 675 m.v.**
Not admitted orders	52	**46**
Stoppages	33 % per day	**12 % per day**
Time-duration	5,24 days	**3,50 days**
Productivity-equipment	85,75 %	**95 %**
Costs-equipment	43 350,3 m.v.	**50 268,31 m.v.**
m.v. – monetary value		

In the case of the PRODUCTIVITY-equipment, the second new machine has better results than the first. Maybe that was strange at the beginning, but first, it is a very small difference (97.25% versus 95%), and second, the new machine 2 has less refused orders from the first (41 versus 46). This leads to the fact that the new machine 2 has been used more, but that does not mean that profits increased. As a note, the second machine needs more time for producing a piece (22 minutes versus 18), so it will take more time to produce the same size of batch than the first machine.

The COSTS–equipment was left to be analysed. In this case, although with unexpected start, but very interesting results regarding the improvement of the indicator were received. Namely, it was expected that the new machine 1 will have some kind of improvement over the initial value and in terms of the old machine, but that didn't happen because most of the values of the indicator come from paying the cost of the investment for the machine. Another part relates to the costs identified for the cost of regular maintenance of the machine and the cost of eliminating the defects in the machine. The first is quite larger in the new, expensive machine, and the second is greater among the old machine.

As the very last phase of COMPASS demands, another analysis was performed - the creation of possible scenarios. They include all analyzed critical elements, given the improvements and the cost for a given scenario. From the analysis made after the simulation of the three models, the limit values for improvement were defined and further a prism was created. The limit values (in this case 10%) were taken according the level of improvement the management wants for the specific subKE. Each performance was backed-up with the cost of implementing one scenario. Based on this, the final decision has to be made.

5. CONCLUSION

It is important to apply methodologies, like COMPASS, and methods, like simulation, to assure that the production capacities are well utilised.
In this article the focus is on utilization of simulation as a tool for coping with the replacement problem of press machines. The created model encompassed most of the influential factors of this complex problem.
This model, as an output provided three possible scenarios by which the management (based on the adopted strategy) can make the decisions. Possible types of strategies are the following three:

- Choose the scenario with best cost/benefits ratio – optimal
- Choose the best scenario - that gives major improvements, but often requires major investments and
- Choose the scenario that the company can financially stand (it can be the weakest of all possible).

This model can be seen also as a tool for continuously experimenting with the production process in order to gain maximum profit all the time. This is a basis of the continues improvement of the company.

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ABSTRACT

Ovaj rad bavi se izborom optimalne prese u odnosu na sistem proizvodnje u preduzeću putem simulacija. Ova problematika naročito je važna u malim preduzećima. Simulacija je odabrana kao sredstvo optimizacije zato što omogućava razmatranje većeg broja modela i njihovu modifikaciju tokom eksperimenata. U prvom koraku su određeni svi uslovi jedne kompanije, a nakon toga kreiran je konceptualni model zajedno sa svim pretpostavkama. Prethodni podaci su preneti u model i nakon programiranja model je verifikovan, potvrđen i eksperimentalno proveren. Eksperimentisanje može da se nastavi u budućnosti ako je potrebno. Na kraju, sprovedena je komparacija i analiza uticaj performansi prese na najvažnije elemenate.

Ključne reči: simulacija, zamena mašine , produktivnost, iThink .