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THE USE OF IT TOOLS FOR THE SIMULATION OF ECONOMIC PROCESSES

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This research paper presents an attempt to assess available IT tools supporting process management, namely Aris, Adonis, iGrafx and IBM BPM. It was indicated that the basic functionality of these tools is similar, but while using the same tools for modeling more complex cases there are substantial differences in the capabilities of description and simulation of economic processes.

Keywords: processes simulation, IT tools for processes modelling, Aris, iGrafx, Adonis, IBM BPM

1. Introduction

Development of IT tools used for modeling of economic processes has been already going on for many years. Especially at the turn of 80s and 90s of the 20th century, a number of applications was created, of which improved versions are used and developed currently. The classics of these tools include:

1) ABC FlowCharter – created at the end of 80s. of the previous century in the Roykore company, which was taken over by Micrografx, which was once again taken over by iGrafx [1, 2] as a part of Corel corporation.
2) MsVisio – you can also model with it processes in the eEPC notations (extended Event-driven Process Chain) and with the downloaded overlay or latest version of MsVisio 2013 you can do it also in the BPMN notation

(Business Process Modeling Notation, now it is referred to as Business Process Model and Notation) [3].

3) ARIS (Architecture of Integrated Information Systems; German: *Architektur Integrierter Informationssyteme*) concept developed by Professor August Wilhelm Scheer from the University of Saarbruecken. ARIS TOOLSET was developed by IDS-Scheer company, which has been taken over by Software AG [4]. Currently, the latest version is Aris 9.0.
4) Adonis of the BOC company [5] – you can model and simulate processes in the BPMN notation as well as on the basis of BPMS notation (Business Process Management Systems) developed by the Institute of Business Informatics in Vienna. The latest version is Adonis 5.0 and free version of Adonis CE 2.0 (Community Edition).
5) IBM BPM (Business Process Manager) - a product created in 2011 as a result of the merger of WebSphere Process Server (WPS) that was developed by IBM since 2005 and purchased in 2010 Lombardi TeamWorks product (subsequently renamed WebSphere Lombardi Edition WLE). It enables the modeling of processes by using the BPMN notation. It also enables the simulation and implementation of modeled processes without additional third-party products [6].

In addition to the tools discussed above a lot of applications for modeling and simulation of business processes can be found on the Internet e.g.:

1) Business Navigator [7].
2) Certus Process Modeler [8].
3) BizAgi [9].
4) Lucidchart – application available as Google Cloud solution which is free of charge for persons having a Gmail account.
5) Simul8 [10].
6) Process simulate [11].
7) Enterprise dynamics [12].
8) ShowFlow Simulation Software [13].

You can find more of such applications, some of which were assessed in the report of Gartner Inc [14].

The purpose of this article is a comparative analysis of four leading applications: Aris, Adonis, IBM BPM and iGrafx in the field of the business processes simulations. Comparative test of simulation capabilities of chosen IT tools is based on sample linear process model, composed of 4 workstations, that process products in series of 10. Results achieved by analysed applications concerns the processing time. A comparison of these results with each other and their processing time observed by team of students performing the experiment shows significant differences. Deviations are caused by both the parameters definitions capabilities and simulation algorithms built in each application.

Analysis presented in the article reveals limitations of simulations performed by each IT tool. Due to the limitations of allowed article volume, the test of simulation capabilities is limited to time parameters that includes waiting time, preparation time, transport time etc. Similarly these problems are reflected in process costs, as resources cost depends on use time (both human resources and assets).
Apart from conclusions on processing time simulation, short characteristic of 4 applications used in test is also presented. It contains:

1) Availability - free trial and test versions, conditions of academic alliance programs.
2) Easy of use of user interface.

These aspects have major impact on the choice of tools for the analysis in this article, therefore, they are included in ending part.

2. Related Works

In the literature many articles on process simulation in IT tools topic can be found. Most of them present simulation capabilities in one chosen application [15, 16, 17]. They are commonly based on the particular case, for example a single workstation [18] or a few of them [19]. However, there not many articles comparing capabilities of more IT tools, like a Visual SimNet and Taylor II applications [20]. The strength of this article is also simulation of very simple process and inspiring analysis of the literature [21, 22].

3. Basic functionality in the area of processes simulation

All four analyzed applications are comparable in terms of basic features in the area of processes simulation. The main parameters controlling the simulation are:

1) Times assigned to activities in the process.
2) Costs assigned to these activities directly or resulting from the use of resources allocated to the implementation of specific activities.
3) Logical gates (operators).
4) The probabilities controlling the course of the process in the situation of forking process paths.

These parameters allows you to perform a simple simulation of the process. However, the question arises whether more advanced capabilities to simulate the process are included in these tools. Such test, designed on the basis of experiments conducted in the classroom with students, will be described and conducted on the selected four applications: Aris, Adonis, iGrafx and IBM BPM.

4. Test structure

The task, which verifies how the analyzed applications deal with the problems of processes simulation under conditions of the variability of the parameters controlling this simulation, is based on a very simple model of the manufacturing process [21. p. 111]. The experiment, carried out with the participation of students, used the model of four manufacturing cells located in series. In each cell, one person manually performed some physical activity, and the second one was supposed to note down the durations of these activities. Each station transferred the effect of their work to the subsequent one. Characterized manufacturing process is shown in Figure 1 where there are consecutive activities, placed in subsequent lanes. In the figure, we can see dialog boxes where the parameters of activities durations and normal distribution, which is applied here, are entered.

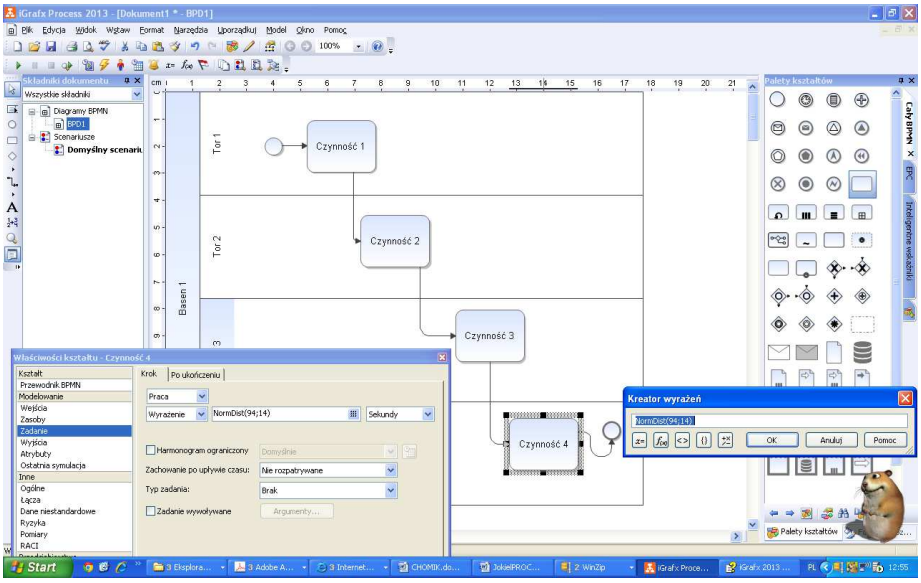

Figure 1. Manufacturing process modeled in BPMN notation in iGrafx 2013

The task was to estimate the production time of a series of 10 finished products in this system. Contrary to all appearances, the estimation of the total time for the passage of 10 process instances is not a simple task. First of all, the outcome is affected by fluctuations in the times of performing actions concerning the subsequent manufactured products by the processing stations. Despite the fact that all stations perform the same range of activities, the duration of this processing is different. Not only between the processing stations, but also within the same working posts as to successive products. The observed fluctuations in performing manual actions at the successive processing stations are presented in Table 1.

Table 1. The results of operations duration measurements for individual processing stations in the examined group of students

Products	The processing time of consecutive products at appropriate stations in minutes			
	Station 1	Station 2	Station 3	Station 4
1	01:58	01:42	01:26	01:27
2	01:38	01:40	01:25	01:31
3	01:49	02:04	01:16	01:42
4	01:27	01:49	01:21	01:37
5	01:42	01:51	01:21	01:43
6	01:23	01:45	01:19	01:25
7	01:32	01:39	01:10	01:43
8	01:30	01:52	01:02	01:50
9	01:22	01:33	01:35	01:42
10	01:48	01:31	01:07	01:35

By subjecting these data to statistical processing, we can calculate the following indicators for these activities (rounded to the nearest second):

1) The arithmetic average is 1 minute 34 seconds.
2) The median is 1 minute 35 seconds.
3) The mode is 1 minute 42 seconds (this result occurs 4 times in the study population).
4) The variance is 1 minute 7 seconds.
5) The standard deviation is 14 seconds.

The model treatment of the process execution at the average gives 13 x 94 seconds = 20.37 min. However, this value rather cannot be expected

The whole process of manufacturing a series of 10 products through the above described manufacturing process handled by the students was 23 minutes and 43 seconds (not considering the quality level goods manufactured at that time, i.e. without adding the time needed for correction of errors made in processed products by the work stations to this result).

The described process will now be simulated using four analyzed IT applications. First of all, we should determine the duration of each activity. As can be seen from the actual data, it varies between the values of: 1: 02 and 2: 04.

The advantage of positive deviations (observations of times exceeding the average) does not significantly differ from the sum of negative deviations (observations operation times shorter than the average). It amounts to 12 seconds (below the standard error). In this situation, it is usually assumed that for the estimated time of operations execution, one can adopt symmetric probability distribution. But the usual practice is that the normal distribution is adopted because of the convenience of use resulting from, for example, well-prepared and easily accessible tables of this distribution [23]. Unfortunately, such minor rounding or smoothing of small differences can have a significant impact in the

case of processes simulated in series, especially large series. This is a typical situation, in which the butterfly effect may occur [24].
It is also worth noting that, although small, yet the regularity is observed also in this case, consisting in that the probability of completing the operation X_i within a time shorter than the average $\overline{X}$ is smaller than the probability of completing this operation over a period longer than the average, which is denoted by the formula [22, p. 375]:

$$P(X_i < \overline{X}) < P(X_i > \overline{X}) \quad (1)$$

This is proven by the aforementioned predominance of positive deviations from the sum of negative deviations by 12 seconds.

5. Test results and tools assessment

Thus, the following data were adopted for the needs of simulation:
1) The duration of operations has been assumed at the level of the arithmetic mean, in particular owing to the fact that its value deviated from the determined median only a little within the surveyed population (1 minute 34 seconds).
2) Normal distribution was used for the probability estimation of deviations for the average value.
3) The value of the standard error was adopted at the level of 14 seconds.

These data were introduced as parameters of tasks in process models created in the analyzed applications. It is shown in Table 2.

Table 2. Results of simulation in the studied IT tools (normal distribution)

No.	Application	The applied notation	The result of the passage of one process instance	Simulation result of a series of 10 pieces in minutes.	Range of results achieved by 10 series of 10 products in minutes.
1	Aris Simulation 6.0	eEPC	6:03	21:40	21:40
2	Adonis 4.0	BPMS	6:16	No result	No result
3	iGrafx 2013	BPMN	6:10	22:14	from 20: 57 (simulation No. 10) to 23: 40 (simulation No. 7)
4	IBM BPM	BPMN	6:53	22:35	from 21: 19 (simulation No. 1) to 23: 14 (simulation No. 4)

Aris simulations were conducted in Aris 6.0 and Aris 7.1 due to the access to these versions of licenses. The current version of Aris 9.0 is not available free of charge. Unfortunately, it was not possible to carry out 10 series of 10 products in a single course of the simulation. Therefore, 10 subsequent simulations of the same model were conducted one by one, but the results achieved in each of these 10 simulations were the same 21:40.

In the case of Adonis, in the standard version, it is not possible to assign probability distributions to the attributes of a task. One of them is the execution time. It can be expected that in column 4 of the above table, the result of 13 x 94 sec should appear, namely 20 min and 37 sec. However, the results generated by Adonis 4.0 are 1: 02: 40 – one hour two minutes and 40 sec. This means that application did not take into account the possibility of parallel processing of successive products by work stations. At first, only 10 products were processed at the Processing Station 1 for 15 minutes and 40 sec and then the same thing happened at three subsequent stations. It is possible to modify Adonis, so as to handle more sophisticated simulations, but the BOC company does this at the individual request of a customer, for an additional fee.

iGrafx 2013 has a very friendly and intuitive user interface and a wide range of simulation capabilities.

In the IBM BPM program, 10 simulations with identical parameters have been carried out. The average execution time of 10 process instances was 22 minutes and 35 sec (the scope from 21 minutes 19 sec to 23 minutes 14 sec). Within the additional parameters of applications available in this tool, it has been established that each station is assigned one unique person, and the time interval, at which a new process instance is executed, was set to a constant value of 1 minute. This resulted in visible in the simulation results quickly increasing waiting time for the process instance at the first station and variable waiting times for subsequent stations, resulting from the variable (dependent on the normal distribution) execution time at the preceding stations.

The results obtained by the three tools (Aris, iGrafx, IBM BPM) differ from one another. The shortest simulation time for the production of a series of 10 products was reached by iGrafx with the time of 20 minutes and 57 sec per series. Also, with the use of this software the longest simulation time, which is 23 minutes and 40 seconds, was reached. This means that iGrafx generates the greatest deviations of simulated values. The reasons for these differences can be explained by calculating algorithms and the number of decimal places used for the calculation in different tools. However, the difference (though not radical) is visible between the results generated by machines and the time achieved by the team of students. Maximum production time of a series of 10 products generated in iGrafx only came closer to the time achieved by the students actually performing this simulation, i.e. to 23 minutes and 43 sec. One may draw conclusion that in the case

of people, greater deviations of activities completion should be expected than in the case of idealized simulation model.

In this situation, a simulation with the use of asymmetric probability distribution was carried out, the modified triangular distribution was used to reproduce the situation in accordance with the formula 2, which describes this phenomenon. Figure 2 shows an example of such asymmetric distribution.

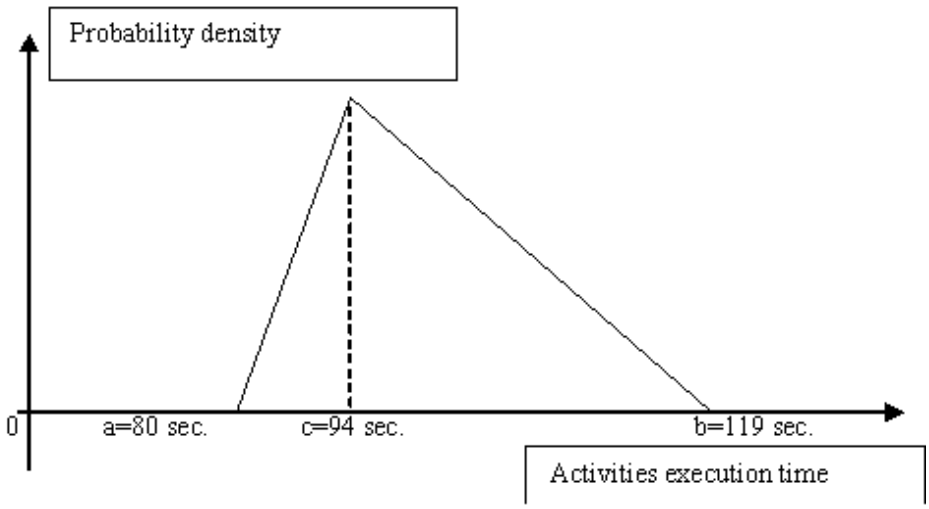

Figure 2. Triangular distribution attributing higher probability to longer execution times of activities

Only two applications, Aris and iGrafx, support the triangular distribution. The IBM BPM does not provide for the use of asymmetric probability distributions.
When using a triangular distribution with the following parameters:

1) a – minimum processing time by any processing station within the simulation of the production of a series of 10 products = 80 sec. (1 min 20 sec.).
2) b – maximum processing time for any station within the simulation of the production of a series of 10 products = 119 sec. (1 min 59 sec), which is longer than any of the simulations presented above.
3) c = 94 seconds (1 min. 34 sec) – the average mean was adopted here instead of the usual modal value.

results were obtained, which are shown in Table 3.

Table 3. Results of simulation in the studied IT tools (triangular distribution)

No.	Application	The result of the passage of one process instance	Simulation result of a series of 10 pieces in minutes	Range of results achieved by 10 series of 10 products in minutes
	1	2	3	4
1	Aris Simulation 6.0	6:15	22:06	22:06
2	iGrafx 2013	6:20	21:56	from 21: 22 (simulation No. 1) to 22: 52 (simulation No. 9)

The use of the triangular distribution also did not result in significant differences in the simulation results. Further, even the longest times achieved in this simulation (22 minutes 52 sec) do not come up to the time achieved by the team of students (23 minutes 43 sec). Interestingly, this maximum time is shorter even than maximum simulation time with the use of normal distribution with the following parameters (E=1 min 34 sec; sigma = 14 sec) that was 23 minutes 40 sec. This observation is worth further analysis, but at the present moment it can be only commented on with underestimation of the protein factor, as expressed by some engineers, i.e. the human factor in the form of performers of these activities.

6. Conclusion

Finally, it is worth presenting a summary comparison of the discussed applications in terms of economic processes simulation, which is shown in Table 4.

Table 4. Synthetic comparison of the described IT applications

Application	Advanced simulations	Availability for the test	User interface
Aris	Broad possibilities in licensed versions	Aris Express - only to paint process maps	There are difficulties in defining and positioning of objects parameters
Adonis	Limited simulation in the standard version	Adonis CE 2.0 -the possibility to simulate the modeled processes	Unintuitive arrangement of menu components (animation, assigning contractors in dialog screens)
iGrafx	Broad possibilities	Full trial functionality for 30 days	Easy and intuitive operation
IBM BPM	Vast possibilities, however, some limitations are present (the use of asymmetric probability distributions	There is a temporary access to the test system though irregular (such possibilities should be tracked on the website)	Intuitive handling but its mastering takes more time than in the case of iGrafx

For the purposes of more sophisticated simulations, we recommend iGrafx, Aris and IBM BPM; as these programs have extensive simulation capabilities. In the case of IBM BPM; it should only be remembered that there is no possibility to characterize the parameters by means of asymmetric probability distributions. In the case of Adonis the main problem is the need to define the parameters "rigidly", i.e. the duration and the costs assigned to activities may be defined as one value.

Conclusions from performed test includes results comparison between the several applications, as well as the juxtaposition of simulation results with experiment performed by students. Time values in 10 products simulation series in presented manufacturing process were shorter than values achieved by the human team. It can be easily explained by the unexpected occurrence of performer deconcentration, wariness caused by monotony, fluctuations of media read times by workstations, etc. factors during the simulation performed by the students team. These phenomenon were hard to reflect in process models for simulations, so the IT tools have not taken it into account. Therefore it shows the problem of including in process simulations phenomenon with undefined probability of occurrence.

The second observation is the diversity of the same process (with the same time parameters values) in different applications. It may be caused by different calculation accuracy (number of decimal places) in algorithms.

However, the surprising observation comes from results of simulation using triangular distribution which takes into account a greater probability of achieving longer execution times. iGrafx applications

shows smaller execution time of 10 products series in a process in both, the simulation of one 10 products series and the longest time of series in 10 series of 10 products simulation. These simulations results are surprising due to intuitive feeling, that longer execution times should occur when using triangular distribution. However it is statistical regularity, about greater probability of observing longer execution times. To identify significant statistical difference there should be much more than 10 series.

In all applications, it is possible to create a process map in the BPMN notation. In some of them it is also possible to create them in the eEPC notation (Aris, iGrafx 2013). In terms of availability iGrafx 2013 should be distinguished for the possibility to test the full versions of the software for 30 days. On the contrary, tools such as Adonis and Aris Express are always available in the community version. The functionality of Adonis Community Edition 2.0 definitely exceeds the functionality of Aris Express, because it is possible to perform both the simulation along with animation and the analysis of process paths, use and resource loads. IBM BPM is available temporarily and irregularly only for the prepared training activities. Then, it is possible to log in on the website [25] and use the tool in the test mode.

By contrast, iGrafx should be distinguished above all in terms of the ease of use, i.e. intuitive user interface. Familiarity with similar applications causes that the user is able to master the program in a very short time. IBM BPM has more difficult and less intuitive interface. Aris supports a lot of simulation parameters, but by mastering this application is difficult, more difficult than, for example. iGrafx. In the case of Adonis is surprising location of certain functions, eg. the animation of process simulation is on the menu in the area of modelling, not in simulation.

However, depending on user requirements, sometimes a greater emphasis can be placed on quick and easy processes modeling, application usage time, or possibility to carry out rough process analyses rather than on the possibility to make sophisticated simulations. Tools presented in this paper can be variously assessed in terms of these purposes. Therefore, this paper may contribute to more accurate selection of a given application supporting process management tailored to individual needs of the user.

Another aspect that is worth mentioning is the ability to implement the processes in organizations. In this respect, the most interesting solution is the IBM BPM, which is a motor itself, where the modeled processes are the backbone of the workflow. Thus, users work directly on the previously modeled in this environment process-related models without the need for other systems/applications. Other programs operate on different principles. The models, which are created in them, can be transferred to another environment, which usually is the ERP system (*Enterprise Resource Planning*), namely SAP, Oracle, BAAN, etc. The XML language is most commonly used for this purpose, into which process models from these tools are translated, and then they are transferred from XML to ERP.

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