Choosing the most appropriate simulation method for business process modelling using AHP method

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Abstract: *The appropriateness of certain types of simulation modelling methods for business processes modelling requirements is the goal of this research. Research is based on the example of low series single piece production and assumption that the basic problem is to recognise appropriateness of continuous and discrete simulation methods according to researched case. Acknowledging this assumption, it is deducted that the choice of type of simulation modelling is reduced to choosing between modelling with the system dynamics and modelling with discrete event simulation. For both above mentioned types of simulation modelling there are advanced software tools, which are not taken as a possible choice criteria. Choice criteria are defined in the paper alone, starting from a reasons and goal of creating simulation model to the possibility of simulating different indicators of the simulated business process according to process variables behaviour. Because several criteria are defined during research, final result will be determined using Analytic Hierarchy Process (AHP) method.*

Keywords: business processes modelling, system dynamics simulation, discrete event simulation, Analytic Hierarchy Process (AHP) method

1. Introduction

In times of constant business changes conditioned by turbulent market, companies are confronted with constant striving adjustment to newly emergent conditions. Making decisions and taking necessary preventive actions have become an imperative of competitiveness and the survival on the market. Regarding that company is a complex system, simulation is often used as a means of support in making decisions and reengineering business processes. Simulation enables understanding and organizing business processes, but also reduces risks in planning and bringing decisions. One of the most important business functions of companies is production. Therefore, it is not surprising that the production itself was one of the first areas where simulation is intensively implemented. Simulation in production enables [4]:

- Analysis of complex modern production processes,
- Elimination of production bottlenecks,
- Reasearching the possibilities of incresing production plant/department permeability,
- Reduction in production supply,
- Enhancement of machinery utilization,
- Production parameters optimlization, etc.

The research subject of this paper are two business-productive systems: one deals with screw production and various attachments for barrels and the other with the production of floor central heating distributors. Both systems have one characteristic fact in common – orders are dictated in advance and paid by the buyers. This way of business managing has as an advantage the reduction of the expenses of manipulation and merchandise storage. It also creates the possibility of detail planning a production process. Problems arise in cases when a buyer orders nonstandard dimensions of products because it is not possible to predict how much time and other resources (e.g. raw material) will be required for the production. It follows that all the reasons mentioned above make planning and business processes management more difficult not only in production but in the company as a whole. In order to assist in solving these problems, a high-quality simulation model may serve.

Since there are several methods for creating simulation model, a goal of this research is to identify all the characteristics which a model must have in order to be representative for making decisions, planning and production management. After model characteristics have been identified, alternatives in form of simulation models will be formed, after which the domain experts (functional managers) will evaluate identified characteristics of models. Finally, on the basis of collected data and AHP method, it will be decided which of the methods is the most appropriate for simulation modelling of business processes in low series production.

2. Business Process Modelling

Modelling consists of creating a simplified presentation of a business process, with the purpose to study and understand the business process as best as possible so it could be experimented with [1]. Basic methods of simulation modelling are discrete event simulation and continuous simulation. Conceptual models have an important role in modelling business process since they provide explicit demonstration of modelling business process, thereby facilitating its apprehension. Each of the mentioned methods of simulation modelling has characteristic conceptual models by which they graphically present a modelling business process.

The observed production processes consist of several phases. Each of the phases develops on a particular type of the machine specially designed for that purpose. Production processes which make the subject of this research deal with screw production and the production of floor central heating distributor. Conceptual models that best define both production processes are developed with reference to the mentioned characteristics. The amount of time required for a development of the most of the phases is standardized and familiar in advance. A problem arises when assortment is altered, that is, when the final product should be produced in nonstandard size at the buyer's request. In that case, the time required for drilling phases and thread scribing is extended, thus the drilling machine and CNC lathe machine capacity is also reduced which consequently extends the overall time required for the production process. In observed conceptual models of business production system, the emphasis is placed on the key parts crucial for the production process management and decision making. Naturally, each of these models could be presented in much more detail.

2.1. System dynamics

System dynamics enables continuous simulation of business process with feedback loop. Business system behaviour could be described through interaction of business system entities (components) during a specific period of time.

In system dynamics models, entities and events are being aggregated into levels and flows in order to simulate behaviour of business process with feedback loop [12]. Material accumulates in the levels while flows of material and information between levels are determined by transition speed which are influenced not only by levels, but also by auxiliary variables. Levels where delay occurs belong to a specific type of levels. These are exponential delays of finite or infinite queue (it could refer to a delay of material or delay of information) .

Processes which are modelled by system dynamics are observed from the point of different resources (people, money, etc.) which transit from one state to another.

There are two types of conceptual models in system dynamics: causal loop diagrams and flow charts.

2.1.1. Causal loops

Causal loops diagrams demonstrate cause-effect relationships between the elements of business process [8]. An arrow indicates a course of the relationship and symbol + or – next to the arrow represents that relationship as qualitatively positive or negative. Positive relatioship is the one where increase in causes results in increase in effects (and by reducing causes, effects are also reduced), while in negative relationships cause and effect function in reverse direction and vice versa, cause reduction brings about effect increase. Two (or more) relationships that connect cause and effect, that is, two or more concatenated arrows in a direction of cause-effect-cause create retroactive loop so they are replaced in a diagram by one circular arrow which is marked in the middle by + or - .

Positive feedback loop is the one where loop elements function retroactively on themselves in the same direction which results in constant increase or constant decrease of the elements value.

Loop elements in negative feedback loop cause a direction change due to their own effect which is why the system goes towards equlibrium (stationary) state regardless if that occurs gradually or by fluctuating around that feedback loop. If all cause-effect relationships within one feedback loop are positive, it follows that the whole loop will be positive as well. If there are negative relationships within a loop, then the type of the loop depends upon the overall number of these negative relationships which may be even or odd-numbered: the loop with an even number of negative relatioships is a positive loop, and odd-numberesd loop is a negative feedback loop. This is due to the fact that negative relationships mutually cancel one another (because negative relationship alters direction of changes in the loop) so that each pair of negative relationships in loop results in positive relationship (redirects direction of changes to positive).

One of the advantages of the causal loop diagrams is the possibility to display control management system that presents the consequences which may occur if certain causes are manifested. It also shows corrective measures for the prevention and alleviation of these consequences. Conceptual model in the form of a causal loop diagram which displays only critical parts of the production system could be seen on the Figure 1.

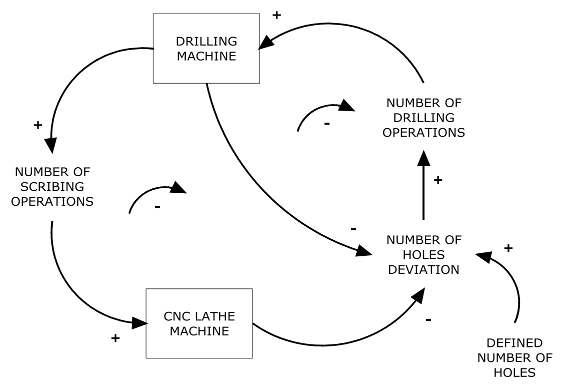

Figure 1. Causal loop diagram of production process

2.1.2. Flow charts

Flow charts explain in detail the connection between the levels, the flows and the delays in the business process, thus presenting a more accurate business process model [4]. Rectangles are used to represent levels in which accumulation of material takes place during certain amount of time. (the input flows increase the accumulation, and the outgoing flows decrease it). The flows of the material are symbolized by the valve that can let through more or less material in the unit of time: the intensity of the valve's permeability is regulated by the information flows. Double (solid) arrows mark the flow of the materials, while the single arrows mark the flow of the information. The circle is used to present the auxiliary variables (special type of auxiliary variables are constant variables), and the disfigured shape is used as a symbol for flow sources and gulfs. The exponential delays are represented with rectangles as are the levels (this type of level is connected to delay schedule and the time constant of delay). Flow diagram of production process could be seen on Figure 2.

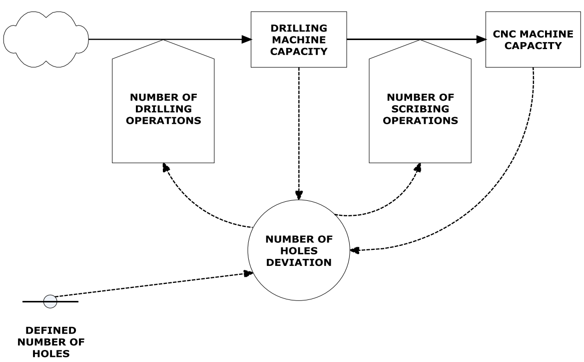

Figure 2. Flow diagram of production process

2.2. Discrete event simulation

Discrete event simulation is used for detail description of business process structure and its' elements [14]. Business process behavior is described as a sequence of various events and activities, that is, in a discontinuous manner.

The event is a change in a system state that occurs in an instant. The event can occur as a result of entity entrance or entity exit from the system, or as a result of change in entity's attribute value which is a consequence of the beginning or the end of entity interaction (e.g. the beginning of processing of a semi-finished product).

Activity is an entity interaction with the duration of some time, and during the proceeding of the activity the state of the entity does not change.

Conceptual models, characteristic for the simulation of discrete events are activity cycle diagrams and Petri nets.

2.2.1. Activity Cycle Diagrams

Activity cycle diagrams (ACD) are a graphical method used for describing basic elements of a business process and presentation of their interaction during operation of a certain realistic business process [5]. Although activities and delay lines are at the core of ACD's diagram observation, they also display entities.

Entities are business process objects that have a specific identity during the time they spend in the simulation model. Activities represent a certain interaction between entities. Delay line is an entity state during which it (the entity) is not included in any activity. Cycle is composed of all the activities which include the entity, and is presented as a closed circular cycle in which there is a constant exchange of lines of delay and lines of activity. Figure 3 displays activity cycle diagram of an observed production process.

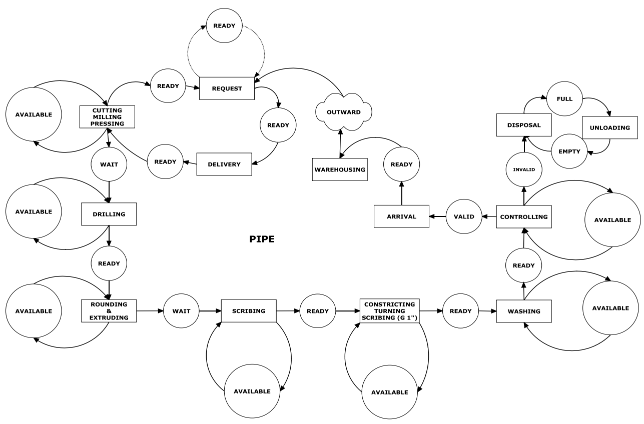

Figure 3. Activity cycle diagram of production process

2.2.2. Petri nets

Petri nets are used as means for modeling dynamic systems with the purpose to analyze their behavior in different circumstances [7]. Therefore, Petri nets represent a graphic conceptual model which can be used for observation of main and alternative events within a certain business process, as well as the sequence and the conditions necessary for their development. For a certain event to arise, specific preconditions have to be fulfilled. If the preconditions do not get fulfilled, the main or the alternative event arises, which is followed by a corresponding system state. The basic elements that form a Petri net are places, transitions, arcs and marks.

Place is the name of the state of system elements, and is presented by a circle or by an ellipse. Next to the place sign it is possible to mark down a specific capacity. The transition is presented by a solid line or by a narrow rectangle, and it represents an event that makes crossing from one place to another possible. The arc (in the shape of an arrow) connects the place with the transition and vice versa. The mark is presented by a small, solid circle, and it represents resources at disposal for crossing to the next place.

Special type of Petri nets are colored Petri nets which can be used to present combinations of submodels of the business process, that is, the hierarchy of relations in the business process [9]. Figure 4 displays a Petri net of production process.

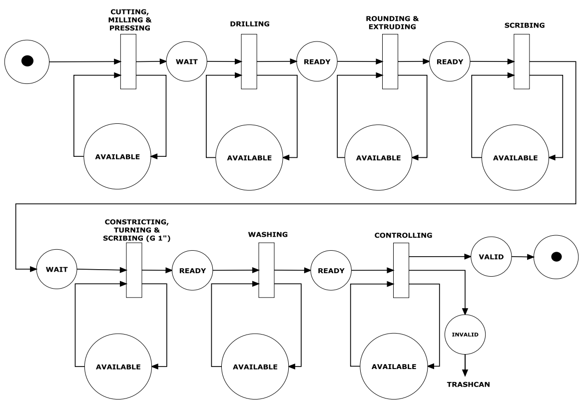

Figure 4. Petri net of production process

3. Evaluation Criteria for Simulation Methods

When making strategic decisions and managing the production, it is of great importance that the functional manager is able to construct a quality simulation model. Before the model is constructed using one of the tools for simulation modelling, it is necessary to make a quality conceptual model that will show a detail presentation of a realistic business process. Many authors have focused their research on selecting the appropriate tool for simulation modelling (e.g. [3, 6, 10 and 11]). Considering that a conceptual model is the basis for the construction of a simulation model, we have stressed the importance of selecting the most appropriate conceptual model in the low-series production. In order to select the most suitable model for functional manager's line of work, some of the requirements of different levels of importance that a model is obliged to possess have been identified [2]:

- Correctness, the model needs to be syntactically and semantically correct,
- Relevance, the model should not contain irrelevant details,
- Economic efficiency, the model should serve a particular purpose that outweighs the cost of modelling,
- Clarity, the model should be (intuitively) understandable by the reader,
- Comparability, the models should be based on the same modelling conventions within and between models,
- Systematic design, the model should have well-defined interfaces to other types of models such as organizational charts and data models.

Beside the mentioned characteristics the following are also recommended:

- Formalization, the model needs to be sufficiently formalized in order to be presented in a form of a mathematical formula, that is, a program code
- Model simplicity, the model needs to be simple enough to be understood by a functional manager, and that the key, work related elements, can be extracted from it
- Hierarchical structure, with how much detail the model is able to present a realistic system
- Computer support, for the manufacturing of a conceptual model there needs to be a suitable software tool that will facilitate the modelling and decrease the time of its' realization
- The quality of display, model should possess the option to display dependent, independent and meta variables and their interaction
- Quality statistics, the possibility of defining arbitrary process parameters, their monitoring and measuring

After developing conceptual models and identifying evaluation criteria, AHP method needs to be implemented.

4. AHP analysis and results

Analytic Hierarchy Process (AHP) is a powerful and flexible method used for making decisions that help determine the priorities, and leads to making optimal decisions in cases where aspects of quantity and quality are being taken into consideration [13]. Reducing complex decision making to a comparison between alternative pairs, and synthesizing the obtained results, AHP not only helps to make decisions, but leads to the rational decision.

This research included two domain experts, that is, managers from two manufacturing companies. Their role in the companies is to plan production, to manage the control and licensing of products, to reconstruct manufacturing processes etc. The research has been conducted through an open interview. During the interview each of the managers first assessed the determined evaluation criteria and then the developed conceptual models. This assessment was based on previously determined criteria. Result analysis was performed by Expert Choice 2000.

After implementing the AHP evaluation criteria analysis, the first (Figure 5.) and the second (Figure 6.) domain expert concluded that a conceptual model must possess the option of presenting all the variables in the system, their interrelations (0.293 and 0.158), quality statistics (0.145 and 0.136), and that it needs to be comprehensible (0.092 and 0.140). On the other hand its' (in)ability to translate into program code, that is, a mathematical equation is not of significant importance (0.013 and 0.021).

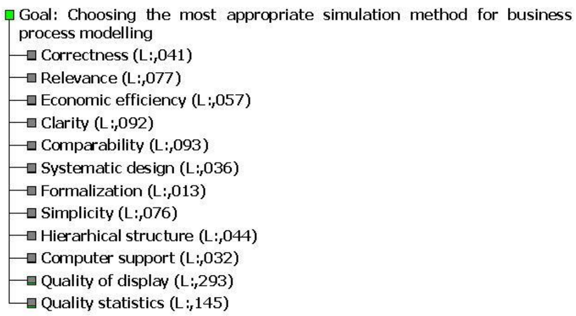

Figure 5. Evaluation criteria priorities of the first domain expert

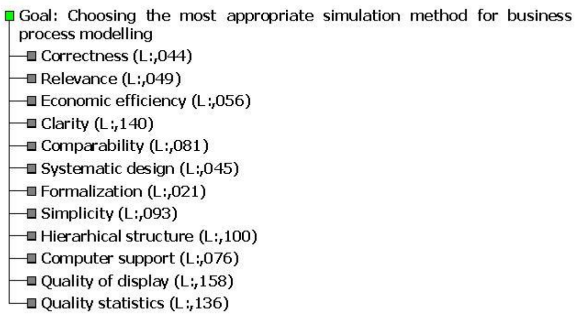

Figure 6.Evaluation criteria priorities of the second domain expert

After analysing the assessed alternatives it was established that the first domain expert (Figure 7.) prefers the activity cycle diagram (0.354) because of its' comprehensibility, quality of display and the ability to provide a detail presentation of a realistic system.The listed characteristics are of great importance when managers wish to have a complete insight into a manufacturing process. Casual loops diagram is, according to our first expert, the second most preferred conceptual model (0.330). The characteristics that placed this model so high on the scale of desirability are the focus put on important details, the ability to display quality statistics and its' simplicity. The main quality of this model is the ability to make decisions in time of crisis and the development of preventive measures. Casual loops diagram is followed by Petri nets (0.197). The opinion of the first expert is that Petri nets could most successfully be integrated with models already existing in company. In the end we have the Flow charts (0.120) that, according to the first expert, in spite of their ability to display only important ili crucial details do not fulfill other criteria, which makes them least suitable for modeling of a manufacturing system of this type.

The second (Figure 8.) and the first expert, according to the AHP analysis, agree that the activity cycle diagram is the most appropriate diagram for modeling a low series production process (0.281). Activity cycle diagram is followed by Petri nets (0.261). After Petri nets come the Flow charts (0.245). In the opinion of the second expert the display of important details and the high quality of display are its' main characteristics. According to the second expert the last place goes to causal loops (0.213).

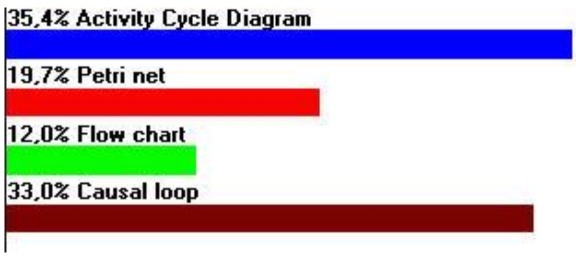

Figure 7. Comparison of the alternatives according to the evaluation criteria of the first domain expert

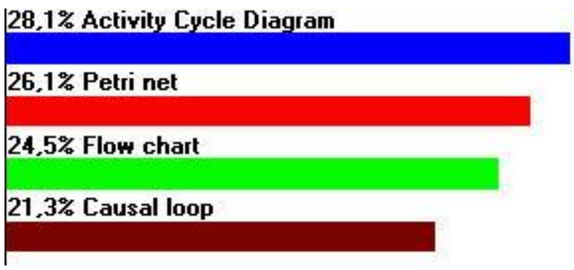

Figure 8. Comparison of the alternatives according to the evaluation criteria of the second domain expert

5. Conclusion

This article contains the preliminary analysis of conceptual models of basic simulation methods using the AHP method. The analysis has shown that the most suitable model for the manufacturing processes of this type of low series production is a conceptual model presented by an activity cycle diagram. Because the activity cycle diagram can be used to present the desirable level of detail of the observed complex system, it also enables the presentation of interrelations between all the basic elements of the manufacturing process in a comprehensible manner. This makes the conceptual model the one that satisfies the most important criteria which are, according to experts, obligatory for a model in order for it to provide a credible presentation of a realistic system, thus making high quality business process managing possible.

The future research will be focused on more detail analysis of the developed conceptual models, the development and the assessment of models from the aspect of continuous-discrete simulation, and verification of obtained results through the development of simulated computer programs.

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