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Simulation for change management: an industrial application

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Abstract

This paper describes an application of change management in the context of a growing company: the ABC enterprise. The first step of the proposed methodological framework involves the construction of the As-is process model, adopting the standard BPMN language. The model is based on an accurate analysis of the data concerning the resources and activities of the company being analyzed, in order to perform a computational simulation of its business processes. After examining existing solutions for business challenges and technological opportunities, several scenarios can be proposed that include possible changes to existing processes. By simulating these scenarios, the results can suggest to analysts useful information to evaluate possible restructuring actions in a quantitative way, comparing the values of an appropriate set of indicators before and after the model's restructuring.

Keywords: Business Process Analysis; Change Management; Modeling; Simulation; Scenario Analysis

1. Introduction and Related Work

Industrial organizations are often called upon to reorganize and change their business processes. Change management means adopting strategies, procedures and technologies to deal with changes in external conditions and the business environment. In particular, companies with increasing incomes must decide how to face new opportunities by changing the internal organization to improve their performance [1]. In the context of Business Process Management (BPM) [2,3], simulation plays a key role in defining new processes or restructuring older ones [4].

Several techniques in simulation modeling have been developed. The three major paradigms in this field are: System Dynamics [5], Discrete Event [6] and Agent Based Modeling [7,8]. In particular, computer-based Discrete Event Simulation (DES) is the most used methods for business process analysis, since planning, management and

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decision-making in a company can greatly benefit from a detailed examination of scenarios simulation results. In fact, DES makes it easy to identify inefficiencies, bottlenecks and constraints, as well as to evaluate system performance if some changes to the process would be applied.

This paper refers to the discipline of business process and change management [9], where the goal is to improve, re-engineer and automate business processes. Lean, Six Sigma and Lean Six Sigma are among the most popular quality and process improvement methodology which strives for elimination of defects in the organization processes [10, 11].

Process modeling supports changes at different levels, as human resources, documents, organizations, or applications [2]. Such approach include specific languages, as the standard notation named Business Process Modeling and Notation (BPMN) [12]. Moreover, several tools to improve business processes analysis and implementation, based on both open-source and commercial software, have been developed, e.g.: Signavio [13], Bonita [14], Bizagi [15].

A process model can be very complex, i.e. it depends on numerous parameters (or variables) and therefore its relations between input and output can hardly be understood. Very often, the parameters of the model are subject to sources of uncertainty, including measurement errors, lack of information and poor or partial understanding of the driving forces and mechanisms. This uncertainty imposes a limit on our confidence in the model's response or its results. Furthermore, models may have to cope with the natural intrinsic variability of the system and its external environment, such as the occurrence of stochastic events.

Among the techniques that can be usefully integrated in the analysis of process models are particularly relevant: 1) **sensitivity analysis** [16--15], 2) **scenario analysis** [17--16], and 3) **process simulation** [4]. A scenario analysis consists in formulating hypotheses of change on a number of independent variables and environmental factors and in considering their impact on the result of the analysis. Instead of looking at how a single variable affects the outcome, as in a sensitivity analysis, many different factors that could influence a possible future situation can be considered.

The process simulation is, in our opinion, the most interesting technique. The process model to be simulated must take into account the resources used and the characteristics of the activities that make up the process itself. By specifying the workload to which the system is subjected, the simulator can evaluate the performance of the business process along a number of indicators such as lead time, use of resources and costs. Once built, the process model allows the analysis of many potential new scenarios with a little extra effort (**What-if** analysis) [18—17, 19].

The remainder of this paper is structured as follows. Section 2 presents the methodological framework, which is used in Section 3 to develop and discuss the case study. Some remarks and future works conclude the paper in Section 4.

2. The Methodological framework

This section introduces our methodological framework that includes a **BP** (Business Process) **methodology** and a **BP environment**. The BP methodology is the result of a long research activity carried out at the Department of Computer Science of the University of Turin (see, e.g., [20--18,21--19,22,23]), and consists of three main phases:

1) **Context and Data Analysis** - the *context analysis* step aims: a) to set the overall strategic scenario of the company, and b) to determine the organizational components (units) that will be investigated in relation to the process in question. The *data analysis* step collects, for each unit, the information relevant to the process, i.e. the data manipulated by activities, their structures, their sources, their destinations, and their transformation rules if they are exported to enterprise information systems.
2) **Process Engineering**: the initial purpose of this phase is the determination of the activities that are carried out in the units involved in the process and of the causal relationships existing between them. The process is then reconstructed from external input/output events and objects: this provides the **process diagram** (sometimes referred to as a **process map** or **flowchart**). The process model must therefore be validated with the interested parties involved in the process, using the animation and the simulation of its specifications, obtaining the so-called **As-is model**. This model provides managers and engineers with an accurate organization specification in their current form and allows for detection and understanding of inefficiencies, bottlenecks, constraints and risks.
3) **Scenario analysis and Process Reorganization**: the objective of this phase is to analyze the problems highlighted in the previous phase to determine possible actions to be taken to restructure the As-is model, in order to

build a more efficient and effective version: the **To-be model**. Starting from the baseline scenario (related to the company's current As-is situation), the *What-if analysis* checks different scenarios (at medium and long term) in order to provide indications and guidelines for possible restructuring of the process. The analysis is carried out by modifying the parameters of the model and verifying the validity of these changes by evaluating, through the simulation, the new values of the indicators.

In the **BP methodology**, the process diagram must be integrated with a description of how each activity treats a transaction (for example, an order) that goes through the process, how long it takes and what resources are needed to perform it. Furthermore, it is necessary to specify the way in which the transactions are introduced in the model and the duration of the simulation. The integrated model can then be simulated through the **BP environment**, which is a design and simulation tool based on the iGrafx Process tool [24--20]. In the design step, the latest version of the BPMN language (BPMN2.0.2) is used and the simulation step allows the specification of the basic model (As-is) and different scenarios on which a What-if analysis can be performed.

This framework will be illustrated best during the analysis of the following case study.

3. The case study

Our case study concerns a medium-sized company (that will be called ABC) in northern Italy which produces artistic decorations (stones, rhinestones and studs) used by the most famous names in high fashion for their products. Given that the company's income has doubled in a few years, managers have considered the opportunity to restructure the production process.

According to the Phase 1 of the methodology, after several interviews with manager and operators of the company, we documented the core aspects of the process in a high level functional diagram which is illustrated in Figure 1.

The diagram includes the following organizational units:

- Scheduling: in this unit, **orders** from **clients** are processed in the Management Resource Planning (MRP) system, which checks the stock situation and prepares for each order:
  - a production order,
  - one or more contractor orders. A product may be requested as raw or must undergo further processing (such as painting) that are done by external companies (Contractors),
  - a shipping order that prepares the final shipment to the customer of the requested products.
- Molding: concerns the activities of setting the presses, molding and manual cutting of the pieces.
- Quality: concerns the control activities of products coming from suppliers and contractors.
- Warehouse: concerns the general management of materials, semi-finished and finished products used in the production sector.
- Administration: concerns the management of invoices and other office documents.

In the data analysis step, files and documents have been collected, and ABC units were analysed to determine the **resources** needed for the production process. Resources must be defined in terms of *numbers* and working hours or *schedules*. A schedule defines the time a resource is either available for work or out of service. The approximately 60 workers of ABC are organized on two schedules:

- a *production schedule* **PS**: from 6 am to 10 pm in 2 shifts,
- a *standard schedule* **SS**: from 8.30 am to 5.30 pm.

Five main working roles have been identified:

- *warehouse operators* (4 workers for each shift, PS): they deal with the management of materials and products, and for packaging and shipping packages to clients;
- administrative *employees* (2, SS): they manage invoices and other office documents;
- *cutting operators* (PS): they manually cut the pieces coming out of the molding. At the moment, they are 6, but they vary depending on the workload;
- *quality operators* (2, SS): they control quality and quantity of products and materials;
- *production operators* (3 workers for each shift, PS): they take care of the various machines, in particular their settings.

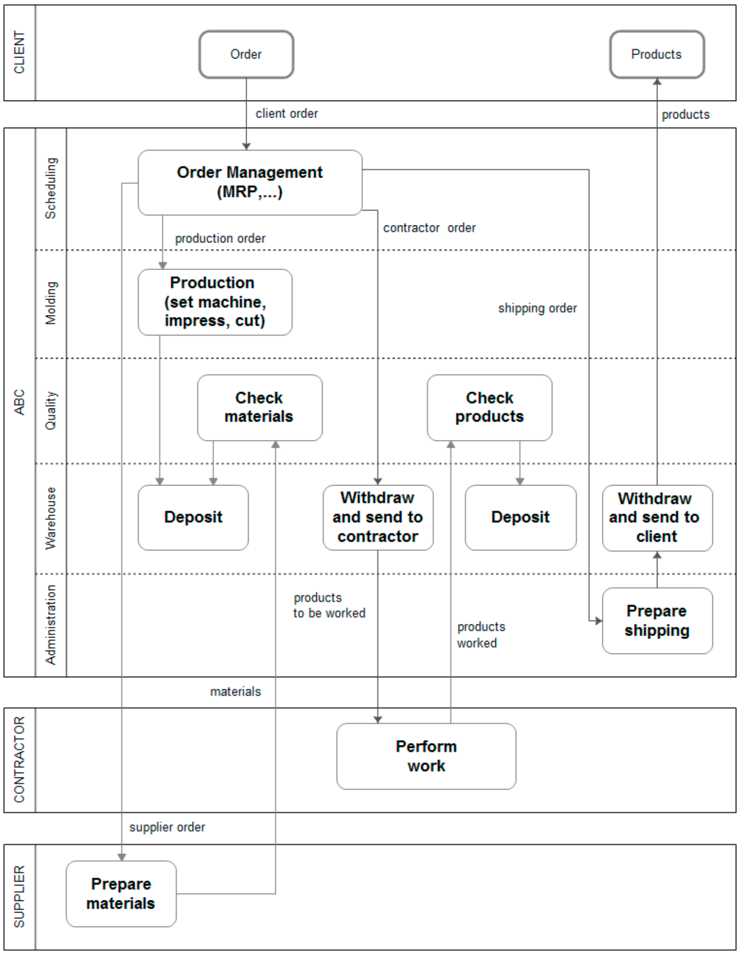

Fig. 1. High level diagram of the ABC company.

The company's main machines are **presses** for molding parts. They work with the production schedule PS and can be of three types:

1) Medium Tonnage (MT) – 11 presses,
2) Low Tonnage (LT) – 8 presses,
3) Plastic-Clad Silica (PCS) – 3 presses.

Interviewing the operators and analyzing the tasks that they perform, the **activities** of the process have been identified. Table 1 shows the activities obtained with their duration and the resources necessary for their execution.

Table 1. Activities of the production process.

Activities	Resources	Duration (min)
Set machine (MT-LT-PCS)	production operator, press	Variable
Impress (MT-LT-PCS)	press	Variable
Manual cutting products	cutting operator	Variable
Deposit raw product	warehouse worker	From 2 to 60
Check purchased materials	quality operator	Variable
Deposit material	warehouse worker	From 2 to 60
Check products	quality operator	Variable
Deposit products	warehouse worker	From 2 to 120
Prepare shipping to contractors	warehouse worker	From 5 to 40
Withdraw from warehouse	warehouse worker	From 2 to 120
Prepare shipping to client	warehouse worker	From 5 to 40
Withdraw product from warehouse	warehouse worker	From 2 to 120
Prepare invoice	employee	From 3 to 20
Send shipping	warehouse worker	From 5 to 20

It should be noted that, for activities with variable duration, the actual estimated duration in the simulation step is determined according to the workload (e.g., the number of pieces to be produced or to be shipped).
According to Phase 2 of the methodology, activities, events and decisional points of the ABC production unit, and the causal relationships existing between them were analyzed. The production process was then rebuilt, obtaining the diagram shown in Figure 2 (expressed with the BPMN language).

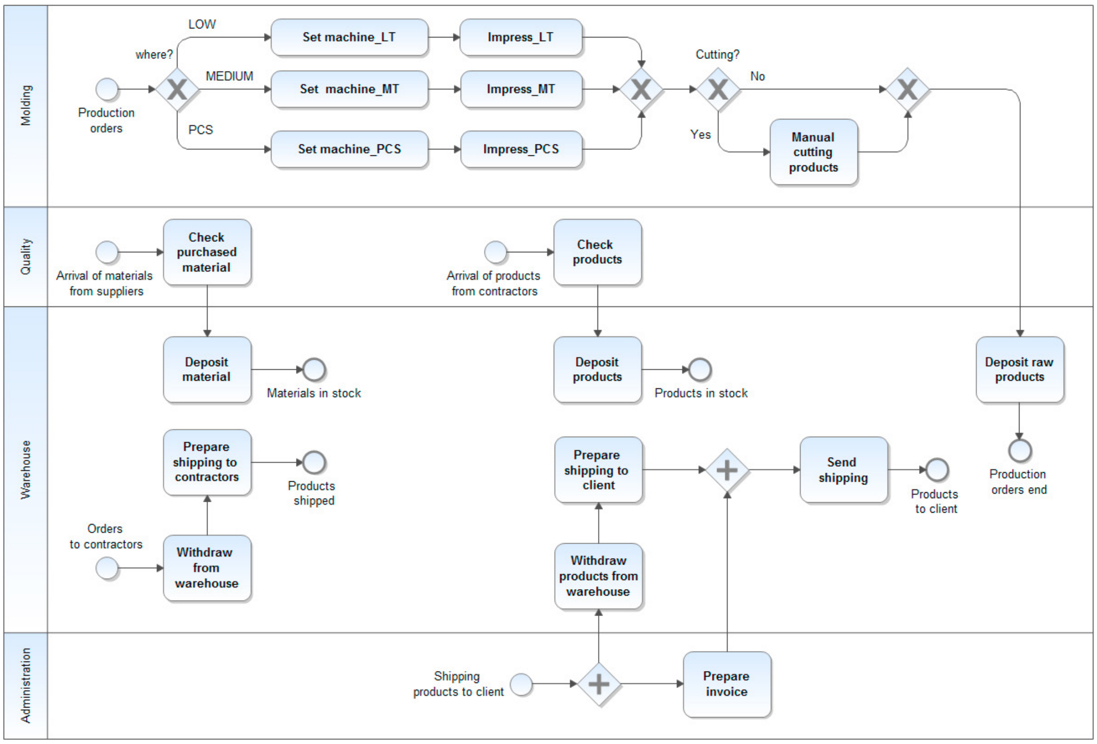

Fig. 2. As-is diagram of the ABC production process..

Once the process diagram has been integrated with resource and activity data, the BP environment allows to simulate this As-is model of the ABC production process, against a given workload. In our case, from the ABC information management system we extracted the data related to six months of work in 2017, in the form of files corresponding to the different **start events** in the diagram in Figure 2. For example, the file corresponding to the *Production Orders* event describes the production orders for raw pieces to be produced which, day after day, arrived at the *Molding unit* during the period considered.

The simulation allows to verify that the As-is model represents the system in a reasonable way. This **validation step** is performed by comparing the results provided by the simulation for a set of **critical indicators** with the values of the same indicators detectable in the real world.

Table 2 shows the simulation results for the activities of the ABC process.

Table 2. Simulation results (hours).

Activities	Average cycle	Average work	Average wait
Set machine-MT	111,48	2,63	108,86
Set machine-LT	84,10	3,03	81,07
Set machine-PCS	147,40	2,37	145,03
Impress-MT	37,34	17,21	20,13
Impress-LT	8,35	3,70	4,65
Impress-PCS	19,49	9,23	10,26
Manual cutting products	18,87	3,01	15,86
Deposit raw product	1,36	0,52	0,84
Check purchased materials	40,27	0,48	39,80
Deposit material	0,45	0,12	0,34
Check products	8,16	1,86	6,03
Deposit products	0,45	0,37	0,08
Withdraw from warehouse	1,89	0,19	1,70
Prepare shipping to contractors	0,37	0,37	0,00
Prepare invoice	1,51	00,19	1,32
Withdraw products from warehouse	6,82	0,08	6,74
Prepare shipping to client	0,32	0,21	0,11
Send shipping	12,85	0,21	12,64

Simulation results were presented to managers and operators of ABC, who judged reasonable these simulated times, based on their experience and an assessment with real data (controlled over a short period of work). The comparison between simulated and actual times concludes the validation step for the As-is model which is then ready for the analysis of possible different scenarios.

A **scenario** is a description of a possible future situation. It is not intended to be a complete specification of the future, but rather the description of the basic elements of a “possible” future in order to draw analysts' attention to the key factors that can help to effectively improve the process.

Scenario analysis allows you to process various scenarios in order to offer different possible results compared to a baseline scenario. In our approach the specification of the scenarios to be analyzed is very simple if they can be defined as changes to be made to the As-is model parameters. As seen above, the scenarios will be compared based on three indicators: Average cycle, Average work, and Average wait time for each activity.

According to the ABC managers, two different types of scenarios have been considered for our case study, which will then be compared with the baseline scenario provided by the As-is model (Base Scenario - BS).

1) Improve molding schedule (S1): in this scenario, all molding presses are allowed to work with a continuous program, so even at night and on weekends. Such a scenario may be necessary to deal with some very heavy orders that do not require a particular urgency.
2) Full time schedules (S2): in this scenario, all the operators (warehouse, cutting, production and quality) and the presses work with a continuous schedule, i.e. for 24 hours a day and five days a week. Clearly, this scenario concerns a situation in which there is a strong increase in the demand for products to be satisfied as soon as possible.

3.1 Improve molding schedule (S1)

By performing the simulation of the new scenario S1 with the same workload as the base scenario, we obtain the results shown in Table 3.

Table 3. Simulation results S1 (hours).

Activities	Average cycle		Average work		Average wait	
	BS	S1	BS	S1	BS	S1
Set machine-MT	111,48	24,12	2,63	2,68	108,86	21,45
Set machine-LT	84,10	20,99	3,03	3,03	81,07	17,96
Set machine-PCS	147,40	34,98	2,37	2,39	145,03	32,59
Impress-MT	37,34	23,87	17,21	23,85	20,13	0,02
Impress-LT	8,35	3,77	3,70	3,77	4,65	<0,01
Impress-PCS	19,49	9,32	9,23	9,32	10,26	<0,01
Manual cutting products	18,87	25,51	3,01	3,26	15,86	22,25
Deposit raw product	1,36	9,42	0,52	0,52	0,84	8,90

As we can see in Table 3, times are drastically reduced with regard to average cycle times and waiting times in production. This means that production orders have been completely satisfied, while in the base scenario compared to 1642 production orders about one hundred have not yet been satisfied at the end of the simulation. The greater number of orders to be cut and deposited justifies the increase in average times for cutting and deposit activities.

3.2 Full time schedules (S2)

As in the previous case, the simulation of the new S2 scenario provided the results shown in Table 4.

Table 4. Simulation results S2 (hours).

Activities	Average cycle		Average work		Average wait	
	BS	S2	BS	S2	BS	S2
Set machine-MT	111,48	37,61	2,63	2,68	108,86	34,94
Set machine-LT	84,10	26,59	3,03	3,03	81,07	23,56
Set machine-PCS	147,40	48,24	2,37	2,39	145,03	45,86
Impress-MT	37,34	28,91	17,21	21,13	20,13	7,78
Impress-LT	8,35	5,22	3,70	3,69	4,65	1,52
Impress-PCS	19,49	12,40	9,23	9,32	10,26	3,08
Manual cutting products	18,87	4,82	3,01	3,53	15,86	1,29
Deposit raw product	1,36	1,02	0,52	0,52	0,84	0,50
Check purchased materials	40,27	3,36	0,48	0,48	39,80	2,88
Deposit material	0,45	0,29	0,12	0,12	0,34	0,17
Check products	8,16	2,75	1,86	1,86	6,03	0,88
Deposit products	0,45	0,38	0,37	0,37	0,08	<0,01

Also in this case conclusions similar to those seen for the previous case can be deduced.

4. Conclusion and future work

The methodological structure presented in this paper includes a methodology for modelling, validation and analysis of business processes, and an extended process environment that allows the simulation of the current process (As-is) and several possible evolutionary scenarios, providing analysts useful suggestions to decide the most appropriate restructuring actions to improve the efficiency of the process itself. The possibilities offered by the framework have been illustrated through a complex case study, which has allowed us to draw some conclusions:

1. The framework allows obtaining quantifiable feedback on the possible evolutionary scenarios of the analyzed process, with minimum effort and time. Managers can quickly test various projects without the risks, costs and timing associated with the effective implementation of the restructuring projects in the real world.

2. What-if analysis allows you to quickly perform sensitivity tests to identify and prioritize areas for improvement. For example, if the simulation shows that 70% of the cycle time is spent in department A, 10% in department B and 20% in department C, and the goal is to achieve an improvement of 20%, optimizing the process only in department B can not provide the desired result.

3. The simulation BP environment is also an excellent communication tool. The presentation of quantifiable information on the performance of existing processes and the performance of the proposed processes can be used in much the same way as a spreadsheet to present, convince and simplify the decision-making process and the implementation of process modifications.

In the near future, different scenarios will be treated to assist the company in its reorganization activities. Furthermore, we intend to study the extension of the methodology to take into consideration the analysis of risks connected to production activities.

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