DESIGN AND SIMULATION OF PROCESS IMPROVEMENT SCENARIOS

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ABSTRACT

Process improvement involves analysis of different process redesign variants. Evaluation of all these variants might result in a large complicated process model or maintenance of several similar models. The paper proposes a process improvement scenario design and simulation approach aimed at simplifying the analysis of such interrelated models. The approach uses a base process as the evaluation foundation and particular process variants are created on demand according to explore a specific process improvement alternative. The paper describes this scenario design and simulation approach and provides an illustrative example of its application.

INTRODUCTION

Processes describe dynamics of value creation in both production and service industries. They consist of a sequence of activities and are subject of continuous improvement efforts aimed at performance optimization. The process improvement often is based on applying and evaluating multiple process improvement heuristics (Reijers and Mansar, 2005; Zellner, 2011), and simulation is one of frequently used evaluation techniques. However, application of the heuristic rules to changing the process might result in a large number of process improvement scenarios (Orman, 1998). Simulation based evaluation of these scenarios could become a complex exercise both from model running and model management perpectives (Blanning, 1993). This paper focuses on the model management perspectives and proposes an approach for designing and simulating multiple process improvement scenarios. The approach allows storing multiple process evaluation scenarios in a single simulation model without complicating the visual presentation of the process model. That improves model comprehension and maintenance as well as makes easier for domain-experts to get involved in the definition of evaluation scenarios.
The process improvement scenario development is based on the business process variants processing principles (Hallerbach et al., 2010; Kumar and Yao, 2012). Every new scenario is defined as a variant of the base model and specified using a set of rules for transforming the base model. The paper describes the general approach to design and simulation of process improvement scenarios, identifies rules for scenario design, proposes their implementation in process simulation software and reports application of the approach.
The rest of the paper is organized as follows. Section 2 introduces the modelling approach. Section 3 elaborates definition of process improvement scenarios. An application example is provided in Section 4. Section 5 provides concluding remark.

MODELLING APPROACH

The modelling approach is intended for design and simulation of process improvement scenarios. The process consists of interrelated activities performed to manufacture a product or deliver a service. There is a set of process improvement heuristics such as design the process around value-adding activities, work is performed where it makes most sense, reduce checks and reviews and promote process parallelization have been identified (Madison, 2005). Application of these process heuristics results in changes in the process structure, i.e., changes activities constituting the process and sequencing of the activities. The scenario generation approach implies that creating a new scenario does not require direct changing of the existing process simulation model or maintaining of multiple similar simulation models each representing the process structure used in a specific scenario.
The scenario design and simulation process consists of the following activities (Figure 1):

- Develop base model;
- Identify scenarios;
- Create a simulation model version for a particular scenario;
- Simulate scenario;
- Compare simulation results for different scenarios.

A simulation modelling environment is used to develop the base process representing an as-is situation of process design. Domain experts identify process improvement scenarios and a simulation modelling expert specifies representation of these scenarios in using a set of rules. These rules provide a standard way

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of transforming the base model into a process model representing the particular process improvement scenario. The base model itself is not modified during the scenario specification. A version of the base model is created on demand whenever simulation of a particular scenario is requested. The scenario specification is retrieved from the model base and the base model is temporarily modified according to the modification rules. The scenario specific version is simulated for different combinations of the input parameters and other simulation setup data. The simulation results are stored with reference to the scenario and its execution time. Multiple scenarios can be compared at the end of the simulation study.

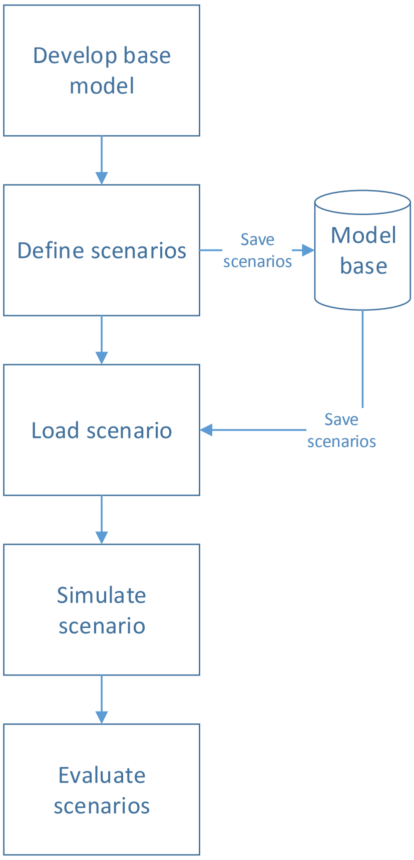

Figure 1: Process flowchart of the scenario design and simulation approach

SCENARIO DESIGN

Each scenario defines one process improvement alternative to be evaluated by means of simulation. A scenario by itself can be evaluated under various conditions by varying values of the input factors. The scenario is defined by a domain expert and the process improvement alternatives are expressed in the form of standard operations to be performed on the base simulation model to obtain the process structure characterizing the current scenario.

The scenario is defined using a specification template containing the following items:

1. Scenario name;
2. Scenario description;
3. Base process reference;
4. Process redesign alternatives;
5. Process constraints.

The base process reference specifies which base process is being modified. The process redesign alternatives describe structural changes to be made in the process design. Three types of process redesign alternatives are considered:

1. Add – a new activity is added to the process design;
2. Modify – an existing activity is changed in the process design;
3. Delete – an existing activity is removed from the process design.

Every activity in the process can be characterized by multitude of parameters. Some of the parameters might require special treatment and possibilities as their automated specification are limited. The attributes, which can be easily modified during the scenario definition are duration; batch size, schedule and resources. These are typical attributes for process activities used in simulation. Duration specifies the activity execution duration, batch size defines a number of items processed simultaneously; schedule defines operating hours for the activity (e.g., two shifts every working day); and resources specify the number of resource units available. Values of the attributes can be indicated as constants or expressions as well as using typical probability distributions. The attributes are specified for newly added activities and updated for the activities being modified.

Table 1: Types of process design constraints

Type of constraints	Description
Requirement	If the *i*th activity is included in the process design, then the *j*th activity also should be included.
Dependency	It the *i*th activity is omitted form the process design, then the *j*th activity also should be omitted.
Parallel	Activities *i*th and *j*th run in parallel.
Prohibition	If *i*th activity is included in the process design, then *j*th activity should be omitted, or both are omitted.
Direct input	There should be a direct connector from the *i*th activity to the *j*th activity.
Indirect input	There should be a path from activity *i* to activity *j*.

To define relationships among the activities, the process constraints also should be included in the scenario definition. Table 1 defines types of process design constraints. These types are derived on the basis of process design constraints defined by Becker and Klinger (2012).

Figure 2 shows a sample base process, the process improvement scenario and the process variant obtained according to the scenario specification. The process is modelled using BPMN (Chinosi and Trombetta, 2012). The base model consists just of a single activity. The scenario specification implies that two new activities are added. The parallel constraints imply that the new activities are added as a parallel flow to activity A.

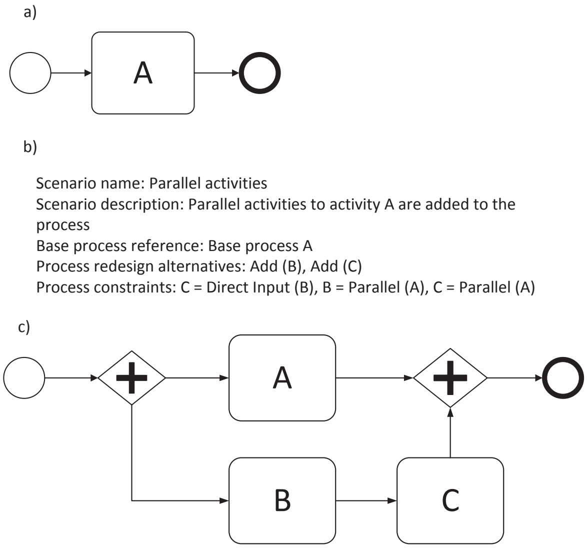

Figure 2: The base process modification example: a) base process; b) specification of the scenario; and c) a base process variant after applying the scenario specification rules

The scenario definition is used to automatically modify the base model and to generate process improvement alternative to be evaluated using simulation. The modeller is not required to create a new model or populagte the existing model with conditional and temporarily inactive elements. She requests the scenario of interest and the modelling environment sets-up the scenario for simulation.

The scenario design and simulation approach is implemented on the basis of iGrafx process simulation tool. The scenario definition is stored in a spreadsheet and iGrafx API is used to make changes in the simulation model according to the scenario definition. A simple user interface for adding, deleting or modifying activities is provided. If scenario definition requires more complex modification of the base mode, then these are implemented using the standard iGrafx process modelling features.

APPLICATION EXAMPLE

The Sharffen Berger Chocolate maker case study (Snow, Wheelwright and Wagonfeld 2007) is used to illustrate the scenario generation and simulation approach. Scharffen Berger is a high-end premium chocolate manufacturer, wholesaler and retailer located in Berkeley, California (Scharffen Berger, 2014). Demand has always exceeded capacity and it could be tripled over the next five years. The company is looking for ways to increase capacity while ensuring the quality of their products.

The production process consists of seven main steps (Figure 3). It covers end-to-end chocolate production from processing of raw cacao beans to packaging of the finished product. Every step is performed in batches on dedicated equipment with finite capacity. The equipment is highly specialized and unique. Human operators are involved in every step though labour intensity varies significantly with the highest labour content in packaging. Major attention is devoted to quality, and quality inspection is performed throughout the process often using artisan methods. Additional details concerning the case can be found in the original case description.

The base process is simulated for different demand levels (Table 2). Its performance is measured by throughput characterizing the ability to satisfy the demand, and production cycle time characterizing queuing in the production system. The results show that the current process is not able to cope with increasing demand (the flow time increases exponentially because the push-type process becomes non-stationary for the high demand level).

Table 2: The base process simulation results

Demand level, kg/years	Throughput, kg/years	Flow time, days
330,000	321,880	6.6
500,000	480,560	12.0
750,000	480,560	70.5

Bottlenecks in the process are identified and the process improvement alternatives are proposed accordingly (Table 3). The specification column only specifies structural changes in the process by applying process redesign rules and design constraints.

Figures 3: The base manufacturing process

Table 3: Process improvement scenarios

Scenario	Description	Specification
S1	The conching activity is replaced by a combination of ball milling and short conching	Delete (Conching) Add (Short Conching) Add (Ball Milling) Modify (Short Conching, Duration:=3-4 hours, Schedule:=7 days 24 hours, Batch size:= 1400 kg, Resources:=1) Modify (Ball Milling, Duration:= 1 hours, Schedule:=7 days 24 hours, Batch size:= 1400 kg, Resources:=1) Short Conching = Direct Input (Ball Milling) Ball Milling = Direct Input (Tempering) Melangeur = Direct Input (Short Conching)
S2	Additional melangeur equipment is installed	All changes made in S1 Modify (Melangeur, Resources:=2)
S3	The roaster is operated 7 days, 16 hours	All changes made in S2 Modify (Roaster, Schedule:= 7 days, 16 hours)
S4	The roaster and tempering machine are operated 7 days, 24 hours	All changes made in S3 Modify (Roaster, Schedule:= 7 days, 24 hours) Modify (Tempering, Schedule:= 7 days, 24 hours)

The conching activity is the most severe bottleneck in the process because of its long duration (bottleneck identification results are not shown). The conching activity can be replaced by two shorter activities of ball milling and fast conching (scenario S1). The specification defines that Conching should be removed from the scenario and Ball Milling and Short Conching should be added to the scenario (in the base process, conching duration is 40-60 hours). Scenarios S2 to S4 do not require structural changes of the process but modify the schedule and resources properties of the selected activities.

Scenarios are developed as extensions of the previous scenarios, i.e., S2 inherits the process changes made in S1 and includes some additional modifications.

Simulation is performed for scenarios S1 to S4 for the demand level 750,000 kg/year (Table 4). It can be observed that scenario S1 is still not able to cope with the demand increase (though it should be noted that in another experiment for demand level of 500,000 kg/year, S1 allows reducing the flow time to 5.7 days, thus suggesting lesser queuing and improvement over the base scenario). Similarly, scenarios S2 and S3 are not sufficient to cope with the demand increase. Only scenario S4 provides an acceptable performance.

Table 4: Scenario simulation results, if demand is 750,000 kg/year

Scenario	Throughput, kg/year	Flow time (days)
S1	480,560	70.5
S2	500,560	65.3
S3	708,500	14.5
S4	741,360	5.4

The evaluation result is acceptance of scenario S4 as the best process redesign alternative shown in Figure 4. The process variant includes the new activities of ball milling and short conching. The attributes of several

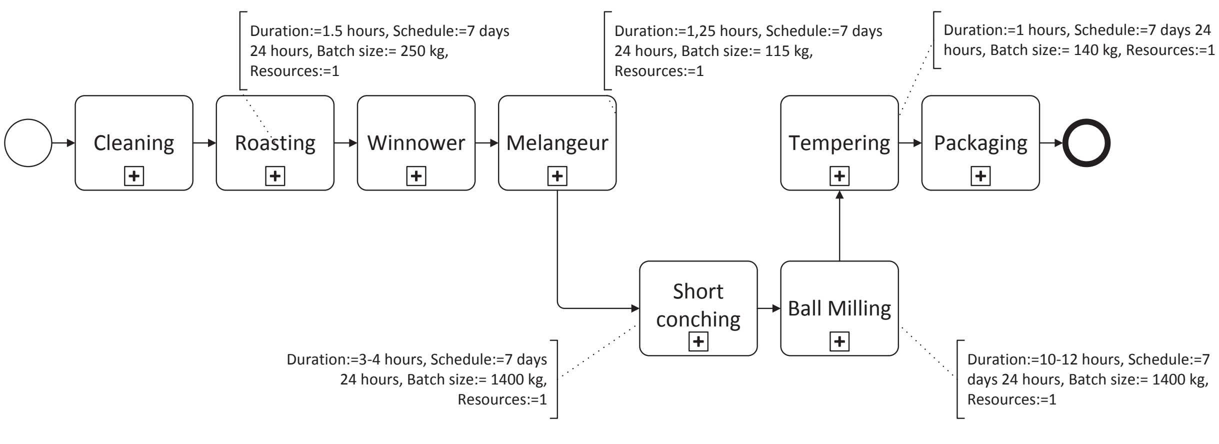

Figure 4: The process variant developed for scenario S4 with activity execution attributes

activities are also modified to change scheduling and resource availability (not all are shown).

All process variants for scenarios S1 to S4 were created without permanently changing the base model. Every process variants contained only elements relevant to the particular scenario. That allows avoiding creation of multiple similar simulation models and making the process models too complicated, if one would have attempted representing all scenarios in a single model.

CONCLUSION

The approach for simplifying evolution of multiple process improvement strategies has been elaborated. It uses the process variant management techniques to create an on-demand process evaluation variant according to the scenario specification.

The scenario specification allows changing the process design, though more advanced changes still should be made by editing the model and other model management techniques should be used for these purposes. Several typical process attributes are identified in the paper, which can be treated automatically. Additional attributes would require manual editing of the model.

The paper describes the overall approach and an initial application example. In order to generalize the approach, process modification rules and constraints should be formalized and integrated with process modelling standards and BPSim (WfMC, 2012) in particular. That would allow to develop common scenario design tools.

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