

# Deriving Simulation Models from Business Process Models

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**Abstract.** Simulation of a business process is often used to visualize its behaviour, to identify problems and to improve its performance. It requires the design of a simulation model, a detailed model of the processes, the resources and the variables to be monitored. Here we investigate how the development of such a model can be facilitated by using a language-action model of the business process as a basis.

**Keywords:** Business process model, simulation model, resources

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## 1 Introduction

An important task of business process reengineering is to identify and put into practice alternatives to the current organization that improve the business with regard to key success factors [10]. In the case of a complex process this might be difficult to undertake even if we can avail ourselves of a model of the business process. In such a situation it can be very helpful to see the relevant process in action and to be able to “play with it,” i.e. to carry out a simulation [11].

Modeling becomes even more difficult in an interorganizational setting, where more than one business is concerned, due to the multiplicity of decision making levels involved [4], which makes the use of simulation even more advisable. This has the additional benefit of helping in assessing the impact of suggested changes before we try them out in “real life” where mistakes can be very costly [5]. As a consequence a new area of re-

search called Business Process Simulation (BPS, [15]) has been established.

We encountered a situation that suggested the use of simulation during an interorganizational case study we carried out in spring 2004. It involved two companies, a logistics provider and a retail chain. One of the principal problems we found was related to capacity reservation. The retail chain provides the logistics company with forecasts of future incoming and outgoing deliveries. These are taken as capacity reservations and are used for capacity planning.

A new framework contract between the companies that was about to be negotiated should specify appropriate measures in the case of deviations from the reserved capacities, i.e. for the case that the actual deliveries do not agree with the planned ones for which respective capacities have been reserved. It seemed therefore reasonable to create a simulation model to study the impact

of deviations on transaction costs and delayed deliveries. As we had already developed a language action-oriented business process model, we investigated whether and how this could be of use in creating the simulation model.

The following sections will study this in the following way: First we give an overview of a language-action model of business processes. We then introduce resources into this model and define a specific resource view. Based on this we elaborate on the development of the simulation model (section 3) and give an example for this approach that concerns outbound logistics (section 4). We conclude by summarizing the major issues of this paper and giving directions for future research.

## 2 A Language-Action Model of Business Processes

Language-action approaches have their theoretical foundations in speech-act theory ([1], [18]) and the communicative-action theory [9]. Examples of such approaches are Conversation-for-Action [20], Dynamic Essential Modelling of Organizations (DEMO; [3], [13], [17]), Action Workflow ([12], [14], [2]) and Business Action Theory and SIMM ([7], [8], [6]). According to [3] the world is divided into three areas: *actors* (whom we will also call subjects), the coordination world (C-world, also known as the intersubjective world) and the production world (P-world, also termed objective world).

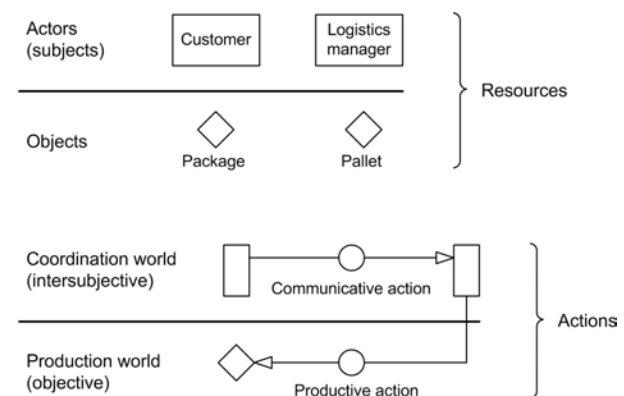
We will call the “inhabitants” of the P-world *objects*. The actors act in both worlds (C and P). Actions in the P-world are called *productive actions*. They are performed by actors on objects. Actions in the C-world are called *communicative actions*. They involve two actors. The basic unit of communication is a speech act ([1], [18]). A conversation is the smallest sequence of actions that has an effect in the social world, such as establishing a commitment. It consists of at least two speech acts:

an utterance and the response (e.g. a request and the promise).

On the third level, the workflow loop (or action workflow, [14]) describes a communicative pattern which consists of two consecutive conversations that aim at reaching an agreement about 1) the execution of an action, and 2) the result of that execution. The first conversation is called *actagenic*, the second *factagenic*. Some authors (e.g. [17]) define the concept of a transaction that includes the agreed-upon action.

### 2.1 Introducing Resources into the Language-Action Model

Resources do usually not play a prominent role in business process models from the language-action perspective. This abstraction is admissible and even useful when our primary concern is the structure of the business process where the communicative actions are in the center of our attention. But as soon as performance plays a role the focus shifts to the productive actions and the resources can no longer be neglected. When we plan to do a simulation we are often interested in measuring performance parameters. Hence resources form a vital part of simulation models.

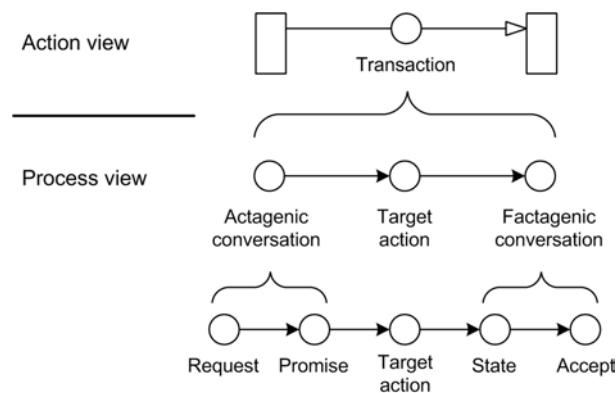


**Figure 1:** Resources and actions

As resources are closely related to actions it makes sense to introduce them into the action model. Figure 1

suggests how this can be done. There are two types of resources: actors and objects. Actors are denoted by rectangles and objects by diamonds. This corresponds to the symbolism introduced in [3]. The actors can perform two types of actions (that are both represented by a circle with an arrow): A communicative action takes place strictly within the coordination world. It involves two actors called *initiator* and *executor* with the arrow pointing towards the latter. A productive action is performed by an actor on an object with the arrow again pointing to the latter.

There are 2 behavioural views: the action view and the process view (see Figure 2). The action view shows how actors interact with each other through transactions. A transaction is a complex communicative action. It consists of three parts which are themselves actions: An actagenic conversation followed by a target action which is in turn followed by a factagenic conversation. The transaction is started by the initiator with the aim of getting a target action done by the executor. The target action is often a productive action but can also be a communicative action. An example of the latter is a boss telling the secretary to order a toner cartridge.



**Figure 2:** Action view and process view

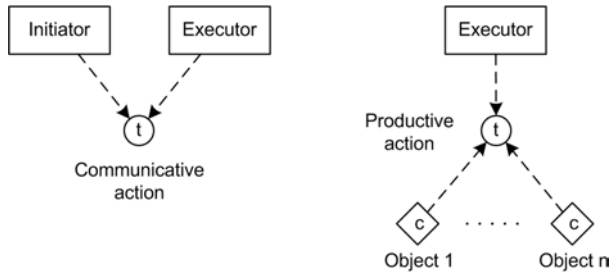
The process view shows the actions on the conversation or speech-act level including the productive actions. The actions are ordered by causal and conditional rela-

tions between them. A causal relation is denoted by a solid arrow, where  $A \rightarrow B$  means that B is a necessary consequence of A, i.e. if A has been done, B **must** also be done. A conditional relation is shown with the help of a dashed arrow from A to B meaning A is a necessary prerequisite of B, i.e. if A has been done, B **can** be done (but B cannot be done in the absence of A).

## 2.2 The Resource View

To perform an action different types of resources are required depending on the type of action. We will assume that each resource is used exclusively by a certain action during the whole execution. This implies that the action requests (and is ultimately granted) the exclusive use of the resource before it starts. Upon completion the resource is released and can subsequently be requested by other actions. We will not consider so-called consumptive resources that “die” in the process.

A communicative action takes place strictly in the intersubjective world and therefore requires as resources only its participants, i.e. the initiator and the executor (see Figure 3, on the left). In the resource view the use of a resource is shown by a dashed arrow (conditional relation) from the resource to the action. To facilitate the creation of the simulation model the modeler can already in the resource view specify key performance characteristics of the action such as its execution time (deterministic number or probabilistic distribution), the costs associated with it or variables for performance measurement. If it seems more appropriate they can also be added to the simulation model later. Please observe that the basic information for generating the resource view concerning communicative actions is already contained in most conventional language-action models of business processes so that no extra effort is required.



**Figure 3:** Resource view

Concerning the productive actions the situation is depicted in Figure 3, on the right. The executor is the only actor that is involved. The other resources are objects that are used in the action such as machines, tools etc. They might also include staff that does not perform in an actor role. The information about required objects is not always present in language-action models of business processes. This implies that some extra effort is required here. We found in our case study that this extra effort is by far outweighed by the savings in setting up the simulation model faster so we consider that this effort is well justified.

### 3 Designing the Simulation Model

Even the information that is present in the extended language-action model (i.e. the one including the resource view) is not sufficient to generate a complete simulation model automatically but it can contribute significantly. When we tried to design the simulation model described in the next section, we found the task very difficult (not being simulation experts) and even after investing several hours we did not succeed in arriving at a satisfactory model. We tried to make use of the existing language-action model of the business process but that did not help us as much as we had expected.

When we investigated the reasons for this we found that we knew too little about the relations between the processes (that is what actions are called in many simulation languages) and the resources. That gave us the idea to create a resource view for the language-action

model. With the help of that we were able to set up the skeleton of the simulation model in a very short time (this part of the job could actually be done automatically by a computer but in the absence of appropriate software we did it by hand). With this skeleton as a guideline we found it much easier to “fill in the gaps,” i.e. to specify the variables and monitors for performance measurement.

In the remainder of this section we give a detailed description of how to create the skeleton of the simulation model. We do so with the help of a commonly available simulation language called SimPy (Simulation in Python, [19]) which is based on the programming language Python [16]. SimPy is available under the GNU Lesser General Public License, Python under the Python Copyright which is GPL-compatible. We only make use of standard features of discrete-event simulation so that this approach should also work with most other simulation languages, systems and tools.

For each action  $a_i$  a simulation process has to be defined. This is done as follows (triple quotation marks enclose comments, variables in italics are to be replaced by the corresponding resources from the resource view; see Figure 3):

```
class a_i(Process)
    """ Define simulation variables """
    """ Define __init__(self) """
    def Run(self):
        """ Set simulation variables and monitors """
        yield request, self, Initiator """ only in case
            of communicative action """
        yield request, self, Executor
        yield request, self, Object 1 """ only in case
            of productive action """
        """ ... """
        yield request, self, Object n """ only in case
            of productive action """
```

```

yield hold, self, t "" duration of action a_i
""
yield release, self, Initiator "" only in case
of communicative action ""
yield release, self, Executor
yield release, self, Object 1 "" only in case
of productive action ""
"" ... ""
yield release, self, Object n "" only in case
of productive action ""
"" Set simulation variables and monitors ""
a_i_finished.signal()

```

In the main body of the program we add the following lines for each actor  $A_i$  and object  $O_i$ :

**A<sub>i</sub> = Resource (1)**

**O<sub>i</sub> = Resource (capacity) ""** where capacity = number of objects of type O<sub>i</sub> ""

Also in the main body of the program we add an activate command for each action. This command depends on the precedence order, more specifically on the incoming causal and/or conditional relations in the process view. Actions  $a_i$  without antecedents are activated as follows:

**activate (a<sub>i</sub>, a<sub>i</sub>.Run(), delay = 0.0)**

Actions  $a_i$  with at least one causal antecedent are activated with the commands:

```

yield waitenv, self, a_j_finished "" for each
antecedent a_j ""

```

**activate (a<sub>i</sub>, a<sub>i</sub>.Run(), delay = 0.0)**

Actions  $a_i$  that only have conditional antecedents are activated as follows:

```

yield waitenv, self, a_j_finished "" for each ante-
cedent a_j ""

```

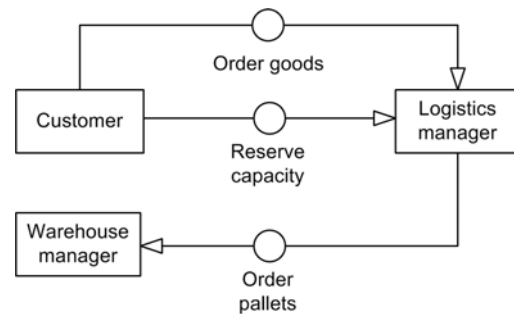
**if condition:**

**activate (a<sub>i</sub>, a<sub>i</sub>.Run(), delay = 0.0)**

To complete the simulation model we have to define and set the simulation variables and monitors as mentioned in the comments. In addition to that the collected data has to be output in a suitable format and an appropriate number of simulation runs has to be carried out.

#### 4 Example: Outbound Logistics

In the course of our case study we developed simulation models for the inbound and outbound logistics performed by the logistics provider. The example we give is part of the outbound logistics. The corresponding action view is shown in Figure 4. The customer (i.e. the retail chain) reserves the capacity for handling a certain number of packing units with two months notice. The reserved capacity pertains to one week. This means that the reservation made in week 15 constitutes a forecast of the number of packing units to be handled in week 23.



**Figure 4:** Outbound logistics (action view)

The logistics manager uses the capacity figures to schedule the staffing of the warehouse. Two months later the customer sends an order containing the actual packing units to be delivered to the shops during the current week. The number of them can (and often does) disagree with the amount for which capacity was re-

served. In extreme cases the actual number was three times higher than the forecast putting the logistics provider under enormous pressure. But even in general the forecasts were not sufficiently reliable. The order is then forwarded to the warehouse manager who will instruct his staff to build the pallets, one for each shop, according to the order. If the number of packing units exceeds the forecast the warehouse manager has to mandate overtime or to call in extra staff. If these measures are not sufficient deliveries can be delayed.

When decomposing the transactions into the speech acts and productive actions we get the process view as shown in Figure 5. The business process starts with a request for a certain capacity which is used to schedule the warehouse staff accordingly. After that the availability of the capacity is confirmed. Due to the framework contract we can omit the speech acts “promise” and “accept” in this and later transactions. The next step in the process is the order that is sent by the customer. Observe that this action is not caused by the confirmation of the capacity because the customer might decide not to make use of the capacity and not send an order. Hence there is no causal relation. But on the other hand, the order cannot be sent without prior reservation of capacity which makes the relation conditional (dashed arrow).

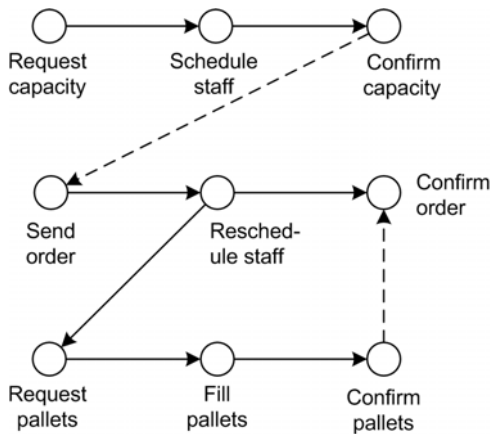


Figure 5: Outbound logistics (process view)

The information in the order is used to reschedule the staff depending on the actual package load. This might involve that the outbound staff is required to do extra hours or that inbound staff is reassigned. After that the “building” of the pallets is requested, the pallets are filled, each with the goods destined for that particular shop, and the completion of the pallets is confirmed. This finally allows us to also confirm the completion of the whole order.

The resource view shows the actors and objects that are involved in each action. We assume that an actor who is engaged in an action cannot perform another action at the same time. Most of the information contained in Figure 6 can be derived from the action and process views (Figure 4 and Figure 5, respectively) in the following way: For each action in the process view find the corresponding transaction in the action view and from there the actors involved (initiator and executor). These are the resources of the respective communicative action. If the action is productive we drop the initiator and record only the executor as a resource.

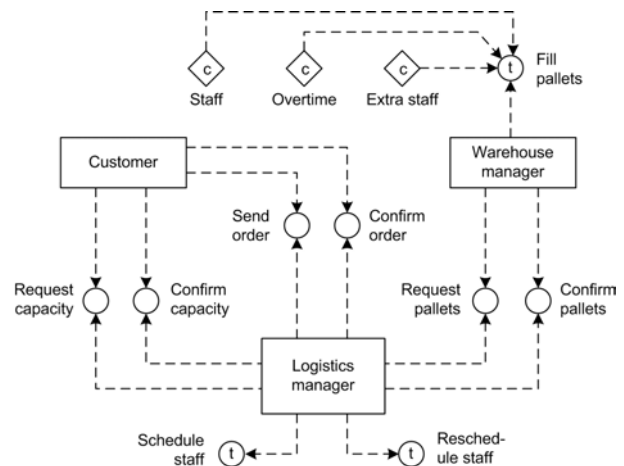


Figure 6: Outbound logistics (resource view)

In the example of Figure 6 this procedure yields an almost complete diagram with only three resources missing. These concern the action “Fill pallets” that requires additional resources: the scheduled staff, extra

staff that might be called in and overtime of the scheduled staff. The use of these resources is associated with certain costs (“c” in Figure 6). The time (t) for filling the pallets depends on the actual number of packing units to be handled, the number of available staff (incl. extra staff), the overtime and the time required for handling a unit. The latter is assumed to be normally distributed with given  $\mu$  and  $\sigma$ . Packing units that cannot be handled during the week in question have to be treated in the following week which leads to delays and further overtime. The time for (re)scheduling is also normally distributed with given  $\mu$  and  $\sigma$ . All other actions are assumed to require a negligible time.

The work described so far was part of the initial business analysis where we also identified problems and goals. One of the most pressing problems (from the point of view of the logistics provider) was related to the discrepancies between planned and actual capacities so we suggested to do a simulation of the relevant parts of the overall process to determine how these deviations affect transaction costs and delays in delivery. As men-

tioned earlier we found it difficult to develop the simulation model with the sole help of the models developed so far. We therefore decided to introduce a new view of the business process to get a clearer picture of the use of resources by the actions in the process. As a result we got the resource view that is shown in Figure 6. It contains information that can be derived directly from the other views but also some information that is new.

Table 1 shows the simulation results for 5 successive weeks (out of 52). The complete results suggest a new pricing model where the unit price is raised by 0.10 € if the reserved capacity is exceeded by more than 20 %, and by 0.02 € for each percentage point the actual value falls short of the forecast. In certain individual cases the transaction costs can differ considerably from this pricing model due to the non-linear nature of the overall process, but on the whole it compensates the logistics provider fairly well for the increased transaction costs and it is definitely superior to the original model which assumed a constant unit price.

**Table 1:** Simulation results

Capacity	Actual units	Scheduled staff	Extra staff	Over-time	Handled units	Excess units	Total costs	Costs per unit
3121	2775	6	0	-18,00	2775	0	3.600,00€	1,30€
2459	3777	5	0	50,00	3125	652	4.000,00€	1,28€
3423	3226	7	0	-21,92	3226	0	4.200,00€	1,30€
2142	3554	4	0	40,00	2500	1054	3.200,00€	1,28€
3769	4988	8	1	39,04	4988	0	6.180,80€	1,24€

## 5 Conclusion

Simulation can be helpful in visualizing a complex business process or in assessing the impact of changes to a process on performance characteristics. But setting up a

simulation model is a difficult task even for experienced modelers. We started from the assumption that both the language-action model and the simulation model are

essentially business process models and that therefore the former should be helpful in developing the latter.

But the two types of models focus on different aspects of the process: the former on coordination and the latter on performance. The concept that holds the two together is that of a resource. It exists implicitly also in language-action models but it has to be made explicit when defining the simulation model. By introducing an explicit notion of resource and the corresponding resource view into the language-action perspective we facilitate the elicitation of resource dependencies and thereby support the design of a simulation model.

Future work in this field should investigate how the results from the simulation can be used to improve the business process. This would close the loop of modeling the process, verifying it (simulation), remodeling it, and so on.

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