Chapter 6

Determining the Degree of Parallelisation of Processes in a Tri-process-modelling-tool

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6.1 Introduction

The current situation in product development is increasingly characterised by dynamic and complex tasks. The development of a product is not a linear process, which is continuously guided by well-defined steps to the target. Only few products are newly designed, most are adaptation, modification or variant designs. However, all cases have a common requirement when the processes have to be deposited for the first time in a process management tool: this must be done quickly and without great effort. There are various modelling techniques and languages such as network diagrams (*e.g.* flowchart representation as Business Process Model and Notation (BPMN)), Design Structure Matrix (DSM) and Container Modelling, the advantages and disadvantages and interaction of which are presented in this paper. Furthermore, a possibility is shown to optimise processes with the aid of simultaneous engineering.

For effective product development it is necessary to monitor and control all the processes and activities involved. In order to obtain a common understanding of some of the terms used in this paper, they are predefined as follows:

- A *process* consists of interrelated activities or sub-processes for performing a task. The amount of activities is not limited in its length and duration. The compounds of the activities or sub-processes are not rigid. Thereby a sub-process is the subset of a process and also a set of activities or other sub-processes (Freisleben, 2001; Schabacker, 2001).
- A *project* is a living process (or several connected ones), in which boundary conditions are defined and which is always unique (DIN 69901, 2009).
- A *process element* describes an activity, operation or one or more working steps respectively, and is initiated by one or more events and ends in one or more events. The individual process elements (activities) are closed in content and relate to each other in a logical context. The description is made on the basis of a defined structure, so that they are also suitable for use in computer-aided systems (Freisleben, 2001).

- A *process model* is a procedure model, based on the description and modelling in the form of processes, for efficient treatment of scopes of tasks, which are composed of a variety of interrelated or interactive single activities (Motzel, 2006).

One can distinguish between different types of processes. In Table 6.1 the main differences between processes in production and product development are shown. Insofar as processes in product development are neither predictable nor readily completely reproducible. Additionally, it is difficult to control objectives, durations, resources, and costs of a project in this environment. Thus, these processes are fundamentally different from those of manufacturing, sales, administration, and controlling (Table 6.1) (Vajna *et al.*, 2002).

Table 6.1. Differences of processes in companies (Vajna *et al.*, 2002)

Processes in manufacturing, controlling, administration	**Processes in product development (engineering processes)**
Processes are fix, rigid, to 100 % reproducible, and review able.	Processes are dynamic, creative, chaotic; many loops, and jumps.
Results must be predictable.	Results are not always predictable.
Material, technologies, and tools are physical available in manufacturing and described completely.	Defined objects, concepts, ideas, designs, approaches, trials (and errors) are virtual and often not precise.
Probability for disturbances is low, because objects and environments are described precise.	Probability for disturbances is high because of faulty definitions and change wishes (requirements).
Dynamic reaction ability is not necessary.	Dynamic reaction ability is necessary.
⇒ **Process control**	⇒ **Process navigation** ⇒ **Project navigation**

Figure 6.1 shows the dynamic project navigation with the help of three levels, which are implemented in different modules of the project navigation tool *proNavigator*:

- *Planning level*: The user captures and models processes with the module *proModeller* using predefined process elements. The module *proReviewer* simulates the affiliated processes with specified iteration number and alternative paths and provides information about the expected benefit-return, an estimation of the associated risks and an overview of the potential benefits together with their probability distribution. If necessary, the recorded processes are optimised and improved alternatives are generated.
- *Reference level*: The module *proManager* provides the integrated user interface that coordinates all the activities of the modules of the *proNavigator*.

- *Execution Level*: The simulated processes are carried out as projects in the respective project management software. If disturbances occur, the project will be stopped and a dynamic synchronisation will be performed, *i.e.* the project will be returned as a process to the planning level, simulated again and put back into the project management software. During a project the project participants have access to the belonging process documentation and description in the module *proBrowser*.

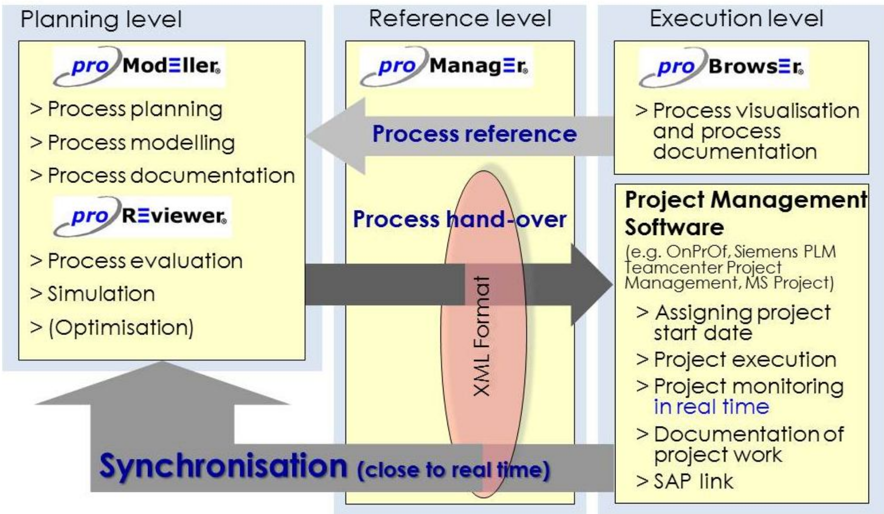

Figure 6.1. Dynamic project navigation

It must be noted that the creation and maintenance of process models require a non-negligible effort. For this reason a sense of proportion is advisable in process modelling instead of a highly detailed approach.

6.2 The Concept of the Tri-process-modelling-tool

While developing the modelling method it has to be kept in mind that the process modelling tool should meet all the requirements, allow different views for modelling and, at the same time, combine the advantages of the modelling method.

The result is a Tri-process-modelling-tool (Figure 6.2), in which a DSM (Design Structure Matrix), a diagram with BPMN symbols (Business Process Modelling and Notation) and a container model are merged into a Tri-Process-Modelling-Tool.

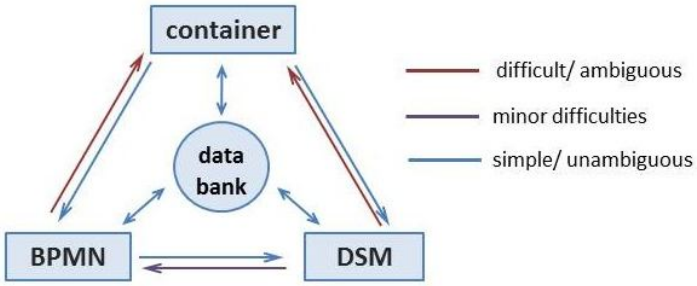

Figure 6.2. Interfaces between the three representations of the process model

The principle of Container Modelling according to the IDEF0 (International DEFinition Language 0) standard (*e.g.* in Marca and McGowan, 1988; Freisleben, 2001; Kim *et al.*, 2001) depicts that the sequential, parallel, iterative or alternative (sub-) processes may form a group, the so-called container. In these containers process activities are added, together with the corresponding process-relevant data and information. The containers can in turn contain other containers or be contained in other, larger, containers (Figure 6.2). Frequently used container constructs can be stored in a sub-process library and reused at any time, at any point in any process model.

From experience it has been found that container modelling on the one hand provides a very well-structured process representation, on the other hand it is difficult to be handled by the user during the process deposition step.

Therefore, the usage of the BPMN 2.0 standard (*e.g.* in Freund and Rücker, 2010; Palluch and Wentzel, 2012) seems beneficial. BPMN provides not only arrow-connected activity elements, but also sub-process icon elements that can be expanded from or reduced to higher level elements.

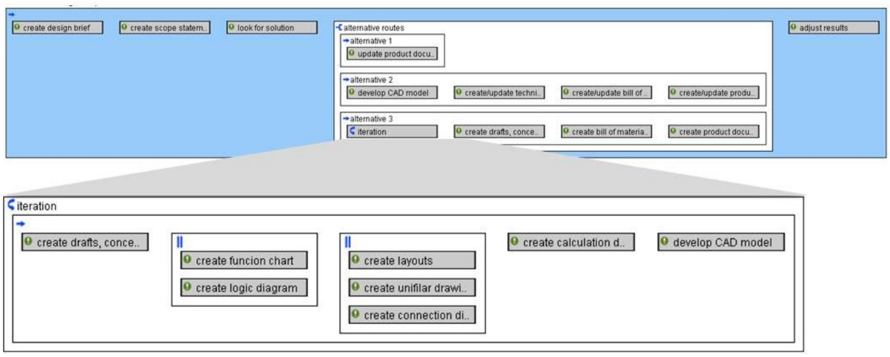

Figure 6.3. Container representation of sample process

The BPMN diagram (Figure 6.4) is a process node network with different gateways, allowing branches in parallel or alternative processes.

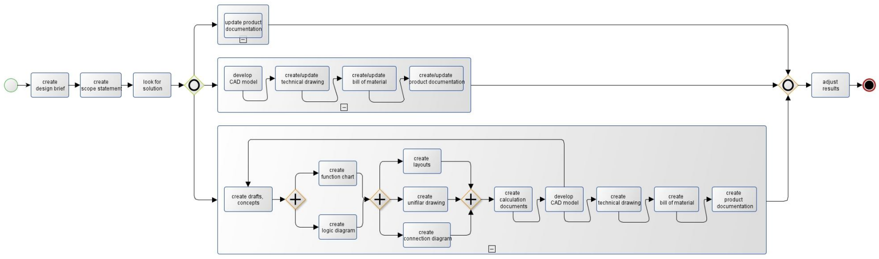

Figure 6.4. Diagram in BPMN representation

The notation uses standardised symbols of the BPMN. This graphic description scheme also allows the representation of stochastic procedures. For modelling the three gateways (data-based exclusive gateway (XOR), inclusive gateway (OR) and parallel gateway (AND) may be utilised, with the help of which the alternatives and parallel elements can be represented. In an exclusive gateway only one alternative can occur, which excludes the other. The gateway can be of a branching or composing type. The inclusive gateway can describe an and-or-situation in which either one, several or even all outgoing paths may be proceeded simultaneously. The combined effect will be reused where the paths converge again. Some actions do not necessarily need the completion of previous actions, but can be done simultaneously with one or more other actions. For this purpose the parallel gateway may be used, which operates both parallelising and synchronising. Parallelisation does not mean that the tasks must necessarily be performed simultaneously.

During the modelling process the number of possible iteration steps and the most likely path of process alternatives are not determined, neither in container modelling nor in BPMN modelling. This occurs at first in a process simulation, when the processing time and the costs of the process are to be determined. If the conclusion of a process simulation is that the process structure should be optimised, it is very difficult to break these structures in container and BPMN representation. Thus an intermediate step is required, which simplifies this breaking.

This is done using the DSM (Rick, 2007; Lindemann *et al.*, 2009), which defines and maps the relations of the single process elements with full precision (Figure 6.5). It treats the cycles and feedbacks clearly and simply. With an extension it is possible to model the alternatives in the process.

	create design brief	create scope statement	look for solution	update product documentation	develop CAD model	create/update technical drawing	create/update bill of material	create/update product documentation	create drafts, concepts	create logic diagram	create function chart	create layouts	create unifilar drawing	create connection diagram	create calculation documents	develop CAD model	create technical drawing	create bill of material	create product documentation	adjust results
create design brief		1																		
create scope statement			1																	
look for solution				1/3	1/3				1/3											
update product documentation																				1/3
develop CAD model						1														
create/update technical drawing							1													
create/update bill of material								1												
create/update product documentation																				1/3
create drafts, concepts										1	1									
create logic diagram												1	1	1						
create function chart												1	1	1						
create layouts															1					
create unifilar drawing															1					
create connection diagram															1					
create calculation documents																1				
develop CAD model									2								1			
create technical drawing																		1		
create bill of material																			1	
create product documentation																				1/3
adjust results																				

Figure 6.5. Extended DSM

In the DSM all alternatives are listed. These are represented as a fractional number. At three alternatives the value 1/3 may be possible. This value is not related to the likelihood of the alternatives. The active alternatives are treated later like the parallel elements.

The transition between the three representations is associative. It is possible to enter the process data in any representations, which is then converted to other representations. Each of the three representations has its advantages and disadvantages. It is not possible to create all process information in all the representations equally well. Therefore, the Tri-process-modelling-tool is used. So it is possible to treat all information in the currently best representation and to estimate and optimise the time and resource requirements of the process.

6.3 Process Optimisation of Product Development Projects

With graphical representation, such as BPMN, the process structure is modelled intuitively by using arrow connections. However, the sub-process structures are difficult to survey in this representation mode, especially for parallel structures. This drawback is countered by container modelling (a container includes a serial, parallel, iterative or alternative process structure), which provides a clear visibility with respect to process results present when leaving the container. However, this modelling technique has the weakness that, for iterative or alternative procedures, additional containers must be defined in order to know whether serial, parallel, iterative or alternative process structures are included. The representation of iterative processes in BPMN may be very confusing and ambiguous, because especially for nested, iterative processes the beginning of an iterative sub-process can hardly be seen. This disadvantage in turn is countered by DSM, as with DSM the relations between the elements are unambiguously specified and a clear process structure can be obtained. It is not expected that the elements are immediately written in the correct order (from the perspective of time, resources and costs). With DSM, the reorganisation of the process elements for compliance of time, resources and cost targets is possible.

After modelling a process, the following optimisations of the process may be initiated (Figure 6.6) (Schabacker and Vajna, 2003):

- *Qualification Balancing*: In the first step qualified personnel is assigned to the process elements based on the profile of necessary qualifications resulting from the individual process elements. In the second step, existing methods, approaches and tools are replaced by the most appropriate version with the BAPM method (Schabacker, 2001; Schabacker, 2002; Schabacker and Wohlbold, 2002; Schabacker, 2010).
- *Simultaneous Engineering*: The output data of process elements are compared to the input data of follow-up process elements with the aid of the degree of fulfilment (see Section 6.4). If the conditions of the degree of fulfilment are met, matching process elements are linked together, so that several different process elements can be (partially) processed in parallel. Additionally, waiting and idle periods of the individual process elements are minimised in this step. A control variable here is the provision of the minimum information necessary for the parallel or follow-up process element to begin (Vajna *et al.*, 2005a).
- *Concurrent Engineering*: A process element is distributed to several parallel processing commissioners, whereas a clear definition of skills and (chronological and physical) interfaces between these has to be made in advance to maintain the consistency of the process element (Vajna *et al.*, 2005a).

- *Time Concentration*: In the sense of a maximal shortened project processing duration, the entire process topology of the project is restructured (reconfiguration) with the aid of evolutionary methods (similar to the optimisation of products, such as in Vajna *et al*., 2005b; Vajna *et al*., 2011). Results may include, for instance, modified processing sequences and further parallelisation of the process elements.

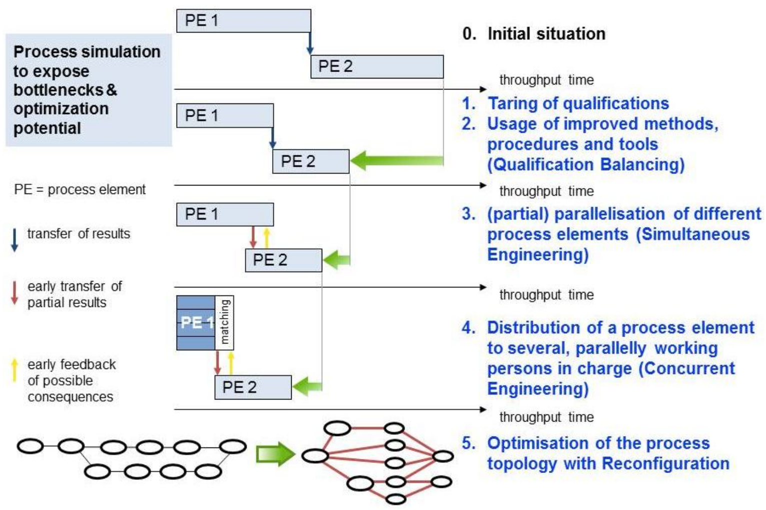

Figure 6.6. Stages of process optimisation (Schabacker and Vajna, 2003)

For the optimisation stages 'simultaneous engineering' and 'concurrent engineering' it has to be determined what percentage of a process element needs to be completed in order to start the next process elements. This can be done reasonably with the use of the documents to be created, such as CAD models, technical drawings, product documentation (Schabacker *et al.*, 2002). The degree of fulfilment needed for parallelising process elements is thus measured by the partial completion of documents. Therefore, document types will be defined (Figure 6.7).

Depending on the process and the company, the extent of overlapping of process elements and thus the degree of fulfilment for parallelising process elements may vary. For simultaneous elements a lower limit for the time advance must be introduced, with which the earlier element completes before the later element (called minimum time advance), to ensure that the later element, which depends on the information of the earlier element, has enough time to run. Surveys can determine the percentage.

		product planning						product development													
		request for proposal	tender	quotation calculation	customer order	market study		design brief	scope statement	drafts, concepts	logic diagram	function chart	unifilar drawing	connection diagram	calculation documents	layouts	CAD model	technical drawing	bill of material	documentation	patent application
product planning	request for proposal			100		100		100													
	tender			100		100		100													
	quotation calculation					50-100		100													
	customer order					75-100		100													
	market study							100									80-100				
product development	design brief									70-100		100					50-100				
	scope statement									80-100	70-100	100					100				
	drafts, concepts										50-100	100			100		80-100				
	logic diagram											80-100					80-100				
	function chart																80-100				
	unifilar drawing																80-100				
	connection diagram																30-100				
	calculation documents																50-100				
	layouts																50-100				
	CAD model																	30-100	75-100		
	technical drawing																			25-100	80
	bill of material																			50-100	100
	documentation																				70-100
	patent application																				

Figure 6.7. Document types with possible degrees of fulfilment in percentages

If multiple documents are created in a single process element and a premature beginning of a document within a process element is possible, it is useful to divide the process element into sub-process elements (concurrent engineering), where each sub-process element contains exactly one document and therefore multiple commissioners can work on different documents and sub-process elements in parallel.

The lower limit of the degree of fulfilment provides the highest parallelisation, along with the highest risk. In this case, it may happen that the element needs to be divided into several parts, to ensure that the minimum termination condition is satisfied. If partial elements are undesirable, the degree of parallelisation is obtained by a comparison of the weighted difference between the degree of fulfilment and element length (100%) with the weighted difference between the minimum termination and the length of the next element. The smaller of these two differences is the degree of parallelisation of two elements. The degree of parallelisation of the overall process is the sum of the individual parallelisations. Standardisation is already taking place through the individual weightings, the sum of which is always exactly one.

Sample: In a process element, the three documents: a CAD model, the technical drawing and the product documentation are created. Of course, a CAD model doesn't need to be 100% completed in order to derive the technical drawing or begin with the product documentation. Perhaps the product documentation can be performed in parallel with the technical drawing. Furthermore, the project manager will be able to select the best possible qualification profile for all three documents separately. Instead of assigning a design engineer to work on all three documents, the project manager can leave the technical drawing to a draftsman, which under certain circumstances may lead to lower process costs, due to the lower hourly rate (Figure 6.8 and Equation 6.1).

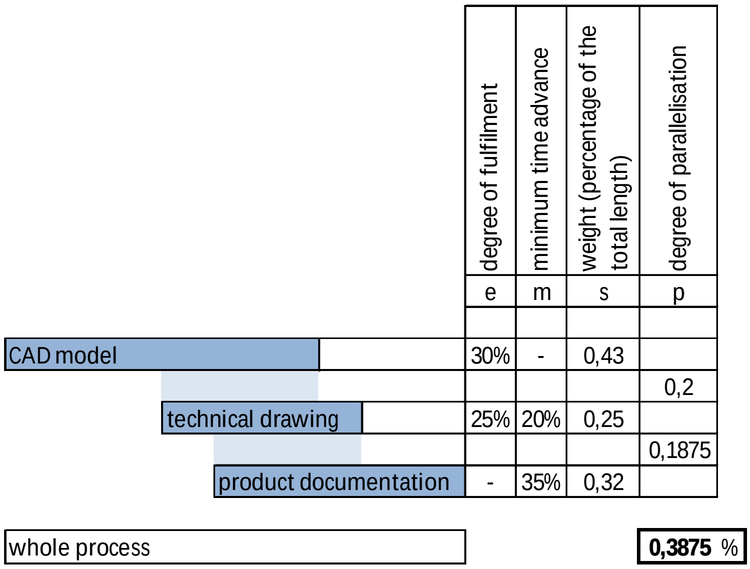

Figure 6.8. Sample data for the calculation of the degree of parallelisation

$$p_{process} = \sum_{i=1}^{n} \min \left[s_i (1 - e_i); s_{i+1} (1 - m_{i+1}) \right] \tag{6.1}$$

6.4 Simultaneous Modelling in a Tri-process-modelling-tool

The time overlap of normally sequential workflows thus provides a bonus time and/or a shortened processing time, respectively. Once there has been sufficient information gathered in a workflow, the next workflow is started in parallel. This sometimes leads to more work, because it cannot always be operated with the final level of information, but the basis for work may change at any time.

For sequential process elements a time overlap is possible. A process element can be initiated before the previous item has been completed. The processing of the element can start with a certain amount of information delivered by the predecessor. The further data are supplied continuously. The predecessor must be ended earlier than the current element, so that all information can be adopted.

In the diagram representation the arrows that do not begin at the end of the element but at a certain point (with given percentage) indicate that at this degree of fulfilment overlapping is possible (Figure 6.9). These arrows lead to the beginning of the next element. Additional arrows from the end of a predecessor to a point in the current element indicate where no further proceeding is possible without the final data.

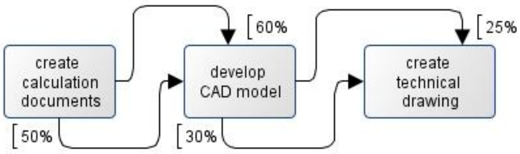

Figure 6.9. Representation of a simultaneous case

6.5 Summary and Outlook

With the modelling methods discussed above the Tri-process-modelling-tool combines the following benefits for a project manager:

- a flowchart representation for process planning, which is combined with BPMN;
- a container modelling tool is useful for checking the consistency of a process and;
- a DSM for time, cost, and risk forecasts especially for iterative and alternative processes.

Companies applying the optimisation approaches discussed above will be able to perform better and more efficient product development projects. The above mentioned assessment and optimisation approaches allow shortening the product development cycle times, therefore reducing the cost of product development and improving the utilisation of project participants in on-going product development projects.

The higher the degree of fulfilment to parallelise processes is, the smaller is the expected value for the total duration of the process. At the same time the risk that this expectation is exceeded grows, *i.e.* the distribution deforms toward larger total process duration.

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