

Application of Coloured Petri-Nets for the Business Process Modelling in Construction Companies

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ABSTRACT: Business processes represent a series of added value activities which lead flow-oriented with one or more measurable inputs to a defined, measurable output. The modelling of business process is very complex because of the large number of modelling purposes, modelling subjects and modelling methods and it therefore requires a systematic preparation. The modelling of business processes by means of CPN represents an excellent opportunity to carry out both qualitative and quantitative evaluation of the business processes in construction companies.

1 INTRODUCTION

Business processes represent a series of added value activities which lead flow-oriented with one or more measurable inputs to a defined, measurable output. In the financial field of the construction company, areas which can be mentioned include for example audit, procurement and payroll accounting. In the technical field there are, for example, design, construction site controlling or supplement processing.

2 THE SPECIAL SITUATION OF THE BUILDING INDUSTRY AND SPECIAL FEATURES OF THE BUSINESS PROCESSES IN CONSTRUCTION COMPANIES

The building industry can be distinguished basically from the industries with permanent sites by the uniqueness of the building projects. The delivery of the service occurs almost exclusively as a local production on the premises of the building owner. As a result of influences such as ground conditions, traffic conditions or weather, identical buildings types can result in completely different building projects with costs differing from each other greatly under the circumstances. On the one hand the costs of transportation and communication being two of the most important parts of the business process costs, increase as the distance of the construction site to the corresponding administration and the suppliers increases. On the other hand, due to increasing project complexity, particularly concerning technical problems between the project participants, there arises the requirement for improved communication.

Building projects distinguish decisive from industrial production processes. The production can include anything from a detached house right up to a complex multi-story building or from the construction of a tunnel right up to a bridge project. This variety has differing results. Thus the personnel and device intensity differ by the entire projects quite considerably. The business processes are influenced in a project-specific way by varying contract and organizational structures.

The construction companies themselves can be distinguished from many viewpoints. For example, only a small number of large-scale enterprises compete with a very large number of companies with only a few employees. Hardware and software equipment varies greatly. Therefore the business processes can be accurately compared in different construction companies only with great difficulty. This hinders the training of open, universal and transparent business processes. There must be a high degree of flexibility of business processes in the building industry in order that it is able to adapt itself to the customer preferences. As a result of that the number of procedures can be reduced.

As a conclusion it must be shown that the business processes are on the one hand heavily dependent on the projects to be dealt with, but also on the enterprise itself, that means, its flow organisation, structure and size. The long and nonuniform process chains and the specific problems and orders within individual subprocesses in the construction company place a high demand for experienced and qualified specialists.

An automation of processes that leads to improvements in procedures in the industrial enter-



prises, due to the same or at least similar business processes which can be considered as an optimization potential of the business processes, can be implemented only with great difficulty in construction companies. This often leads to a manual processing of the processes and complicates the application of IT-tools.

The error rate can also increase with the ascending extent of the documentation to be adapted to the individual employees, which reduces the quality of the business processes. Furthermore only insufficient project information is often available to the project participants as a result of poor communi-

cation. Further deficiencies frequently result from that in the processing.

A data exchange between the project participants applies in this case to all specialist fields (figure 1). At the heart of building projects are a great number of persons and companies, who have a variety of different tasks to fulfill and to exchange and use data. Below is a list of data that is continuously exchanged:

- Drawings and technical data;
- Contract documents;
- Tenders as well as
- Caveats, protocols and hindrance advertisements.

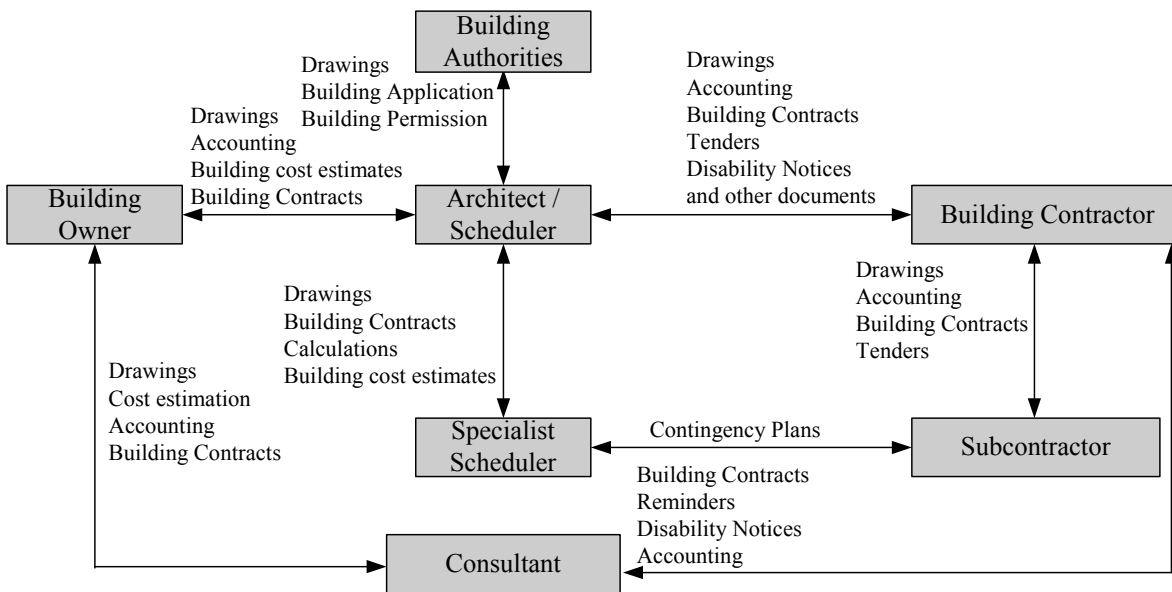


Figure 1: Data exchange during a building project (rough structure, exemplary in extracts representation)

An exchange of information is also necessary within a construction company, conditional through spatially separate buildings, such as the headquarters, the responsible departments and the construction site offices.

Since the place of the service delivery – the construction site – and the main office of the enterprise will in most cases not be the same, a communicative data exchange is indispensable for a common information base and for the avoidance of redundant data. Therefore the means of communication and the technology used play an important role in the construction company. A wide range of dispersion of process costs and the connected running times can result from this given situation.

In addition there is a high demand on the flow of information and communication, as a result of the large number of personnel that participate in the building project.

Furthermore, business processes in the construction company show a series of special features which are very different to the processes of manufacture in the fixed base industry.

In order to be able to assess the quality of the highly complex and dynamic business processes in a construction company it is necessary to model and to evaluate these through simulations.

3 MODELLING OF BUSINESS PROCESSES

The modelling of business process is very complex because of the large number of modelling purposes, modelling subjects and modelling methods and it therefore requires a systematic preparation. In this case the selection of the modelling language has special importance.

In the center of the business process modelling poses the question what, for which and how the process can be modelled.

Over a period of time many methods for the business process modelling were developed based on the available software technology.

The business process models represent a simplified illustration of the real activities in the enterprises. They are used, above all, as a basis for the process analysis, for documentation purposes, for



taking decisions for the optimization of the business processes, for the planning of the resources and also in the enterprises depending on the modelling method for the computer-aided simulation of business processes. This is particularly dependent on

high viewpoints the business processes are modelled. The methods for the modelling of business processes can be distinguished from each other, as can be shown in chart 1.

Methods	Function viewpoint	Data viewpoint	Object viewpoint	Process viewpoint
Data Flow Diagram (DFD)	X			
Structur Analysis (SA)	X			
Structur Analysis and Design Technique (SADT)	X	X		
Data Dictionary (DD)		X		
Jackson Diagram (JD)		X		
Entity Relationship Model (ERM)		X		
Vorgangskettendiagramm (VKD)				X
Wertschöpfungskettendiagramm (WSK)				X
Funktionszuordnungdiagramm (FZD)	X	X		X
Semantic Object Model (SOM)			X	
Object Behavior Analysis (OBA)			X	
Classes Diagram (CD)			X	
Integrierte Unternehmensmodellierung (IUM)			X	
Objekt-Oriented Software Engineering (OOSE)			X	
Objekt-Oriented System analysis (OOSA)			X	
Object-oriented Modelling and Design (OMT)			X	
Vierdimensionale Prozessdarstellung (VPD)				X
Prozesskettenmodell (PKM)				X
Ereignisgesteuerte Prozesskette (EPK)	X	X		X
erweiterte Ereignisgesteuerte Prozesskette (eEPK)	X	X	X	X
Architektur integrierter Informationssysteme (ARIS)	X	X	X	X
Petri Nets (PN)	X	X	X	X

Chart 1: Modelling methods of business processes

The modelling according to the functional viewpoint covers the description of the activity, the flow of information or the work flow of a business process, which consists of several connected tasks. It transforms input data into output data.

The visualization of the data view includes both paper based documents and electronic documents of the business process under consideration.

By modelling according to the object viewpoint which is characterized also as a structure-oriented and/or organization-oriented modelling, the information and/or utilization systems in an integrated model formation must be described.

The above mentioned approaches for the modelling of business processes which are necessary in order to carry out a process analysis and to suggest improvements of the work flow, do not form any basis for the integrated description of the process viewpoint in enterprises. For this purpose many approaches were developed in the last few years, within which activities and work flow, data structures, states and structural units and dynamic properties of business processes are integrated.

In chart 2 the most important methods for the modelling of business processes for certain viewpoints are compared. The aim is to find out a suitable method upon which the business processes can be modelled and evaluated in building enterprises

taking into account the observation of the most important requirements of the business process management.

	Modelling Methods					
	DFD	SADT	SOM	ARIS	EPK	PN
Data flow	+	+	o	+	+	+
Data structur	-	+	+	+	-	o
Parallelism	+	+	+	+	+	+
Hierarchy	+	+	+	+	o	+
Learnability	o	o	o	o	+	+
Prospects	-	o	-	o	-	+
Clearness	+	+	o	o	o	o
Flexibility	o	o	o	-	-	+
Structur variance	+	o	o	o	o	+
Time modelling	-	-	-	o	o	+

Chart 2: Comparison of the modelling methods of the business processes ((-) not possible, (o) hardly possible and (+) possible)

By means of the comparison which can be carried out and the important requirements of the modelling of business processes, the Petri Nets (PN), due to their exceptional advantages and their specific characteristics, present a very suitable method for the modelling and description of business processes.

It can be proved, that Coloured Petri Nets (CPN) with its programming language SML, is most suitable as a tool for the modelling and evaluation of business processes because all states and cases can be represented and can be modelled with CPN.



4 EXAMPLE OF A PROCESS MODELLING BY MEANS OF CPN

The process modelling is clarified by the examples of the “audit” and “Supplements processing” in construction companies.

The audit is divided, depending on the company size, for example, into the following subprocesses, as is represented in figure 2:

- invoice receipt;
- price checking of the invoices;
- factual check;
- possible treatment of supplements, which is divided into the negotiation stage, processing and confirmation of supplements;
- arithmetic check;
- allocation and posting;
- payment releasing.

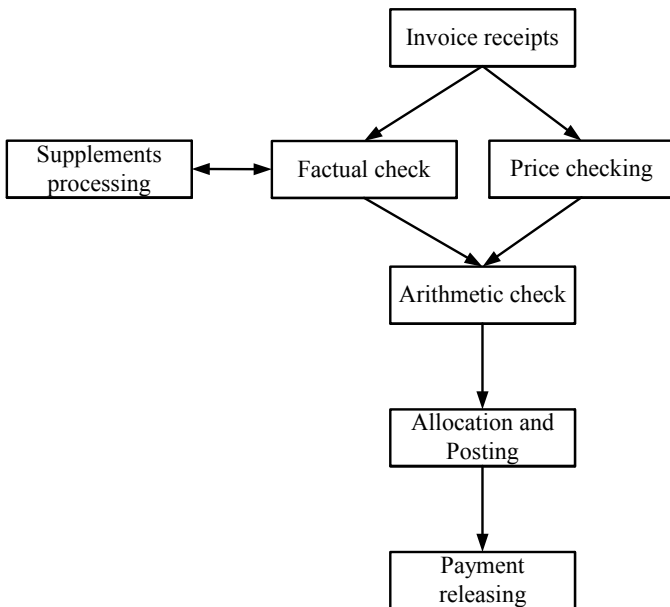


Figure 2: Subprocesses of the audit in a construction company

These subprocesses can be divided furthermore into several single activities.

For the process modelling it is important that their destinations are known at the beginning so that the model does not supply any false results. The elements and characteristics of the modelled processes and their level of detail reflect the destinations of the modelling. The basic pattern of the process modelling consists of elements which are joined to each other by means of directed arrows or flow lines. Thus, all important elements of the business processes can be represented, as activities, resources and other process objects together with their relationships to each other. Every project should include information which is necessary for the later analysis and evaluation of the described business process. First of all, an informal model must be created

which represents all elements of the examined processes with initial data. After that all parameters, which are relevant for the evaluation of the business processes, must be conceptually modified. They give an indication of how a business process is to be estimated from the viewpoint of the costs, time and quality.

In addition, the variables of the informal model are classified as follows:

- Structure-dependent variables,
- Time-dependent variables,
- Cost-dependent variables,
- Quality-dependent variables.

In chart 3 the structure-dependent variables introduced in the model are summarized, for example, as resources, employees, technology and invoice type. Thus the available structure of the audit can be easily adapted to changes.

Structure-dependent variables	Symbol
• invoice number	n_{rech}
• invoice type	a_{rech}
• position number	n_{pos}
• supplement number	n_{nach}
• page number of invoice	n_s
• copy number of invoice	n_k
• employee number	n_{ma}
• involved employee	b_{ma}
• resource number	n_{res}
• resource type	a_{res}
• contract type	a_{ver}
• transport type	a_{trans}

Chart 3: Abstract of the introduced structure-dependent variables

The informal model must be then converted into a CPN-model. For this purpose all determined and modelled data of the running time, costs, quality and resources with corresponding variables of the influencing variables must be integrated in the CPN-model.

The CPN-model is displayed by a hierarchy tree (see figure 3).



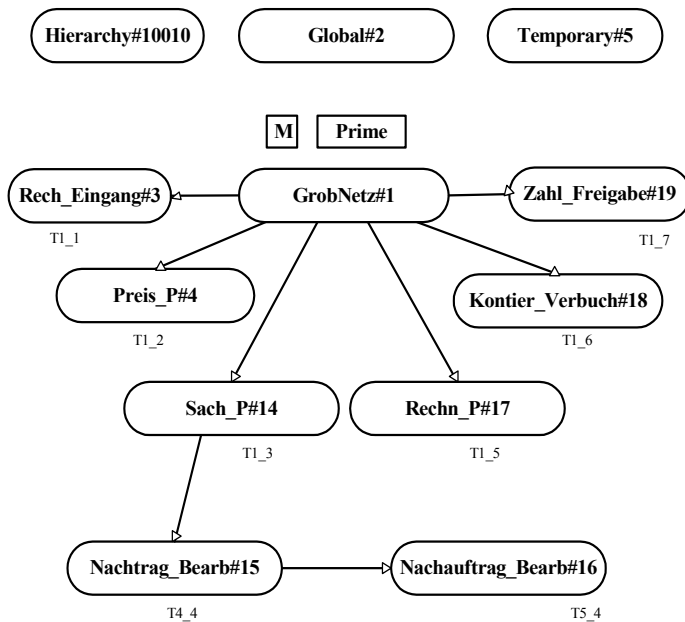


Figure 3: Hierarchy tree of CPN-Models

5 PROCESS ASSESSMENT AND RESULTS

The following cases can be examined on the basis of modeling with CPN:

- What is rate of utilization of every employee. Thus it can be evaluated, which employee in the construction company is overloaded, fully or partly loaded for a specific extent of the documentation received in one year.
- How much time and cost the business process takes, depending on the annual number of documents on the one hand and on the other hand depending on the technology used.
- How high is the quality of the business processes in relation to the cost and time for specific technology and for a specific extent of documentation.

For the evaluation of the utilization rate of every employee the percentage utilization degree of every employee can be calculated through the simulation which can be related to the document number per year (see figure 4 - columns show different functions).

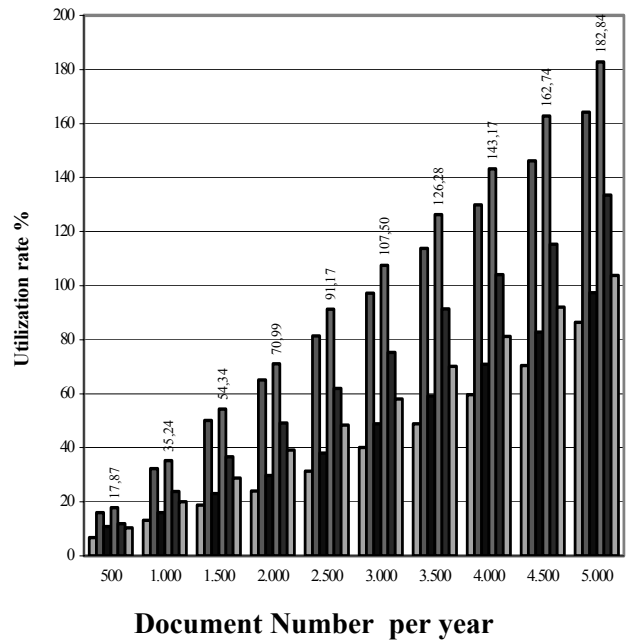


Figure 4: Calculation of the employee utilization

In the same way the running time of the process can be evaluated from the simulation results with varying numbers of documents per year and for a determined personnel structure in a construction company (see figure 5).

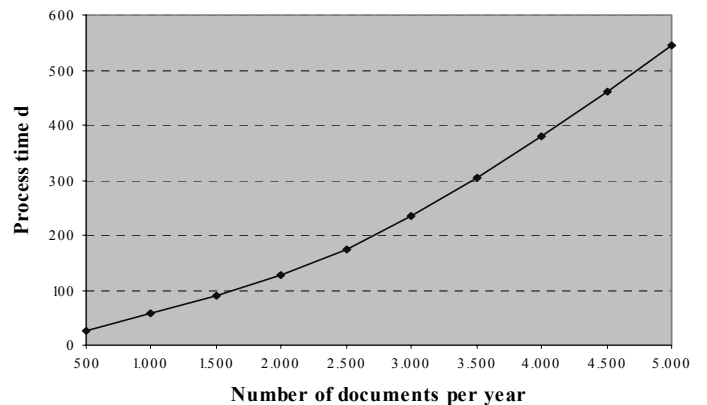


Figure 5: Calculation of running time of process

With increasing numbers of documents per year, the complexity of the processing increases considerable due to the variety and the expenditure of the processing options. The errors and the resulting error correction costs therefore increase exponentially and it can be determined through the simulation (see chart 4).



Document number per year	Error costs (€)	Part from total costs (%)
500	70,11	0,39
1.000	164,07	0,44
1.500	255,28	0,46
2.000	372,30	0,57
2.500	502,60	0,68
3.000	657,03	0,85
3.500	821,27	1,01
4.000	1.105,73	1,31
4.500	1.335,60	1,51
5.000	1.682,99	1,83

evolution in the building industry. Thus, on the basis of the evaluation of different work flows of business processes the improvement potentials of the company structure can be examined.

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Chart 4: Part of the error correction costs from the total costs

A qualitative evaluation for the modelled business processes can also be carried out. By means of a detailed analysis of the modelled business processes, a concrete investigation of the quality criteria can be carried out. The values of the process quality can be determined from the simulation for different document numbers per year (see figure 6).

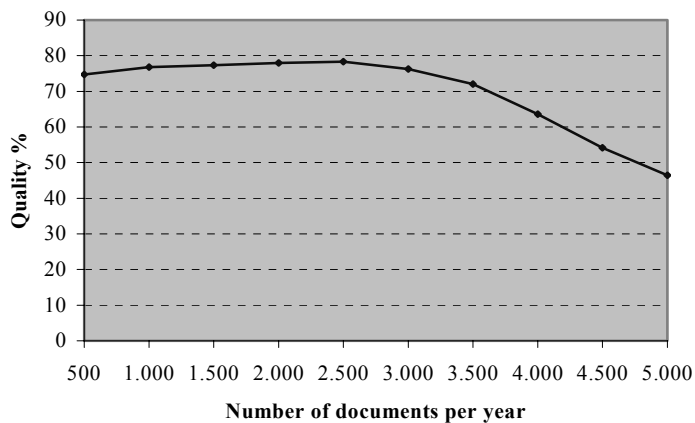


Figure 6: Process quality for different numbers of documents per year

6 SUMMARY AND OUTLOOK

Business processes in construction companies are evaluated up to now mainly qualitatively. However the quantitative evaluation factors also have exceptional importance, for example, for the definition of the business process costs. The modelling of business processes by means of CPN represents an excellent opportunity to carry out both qualitative and quantitative evaluation of the business processes in construction companies. The evaluation of the either existing or restructured business processes in construction companies is seen as a basis for the fulfillment of the requirements, which increase with the

