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Process and organizational innovation based on a reference model for mechanical engineering companies

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Abstract. Currently there is a great need for process and organizational innovation for the project execution in customer-specific machinery and plant engineering. Drawbacks result from inefficient project execution processes, insufficient information flow or inappropriate computer systems. As a result, the productivity of enterprises is diminished. The main reason for the unused potential in this domain is the lack of standards for the project execution. In this paper we present some solutions to overcome this lack of standards.

Key words: innovation, standardization, project execution, reference model, procedure model.

1. INITIAL SITUATION

The implications of the lack of standards for the project execution are the non-transparent diversity of information, inconsistent data and the loss of information. This leads to unnecessary additional work and respective additional expenditure of time for the project execution. Not only information is lost in projects due to insufficient documentation, but also knowledge is not appropriately exploited in other projects. Therefore the transfer of knowledge to succeeding projects is limited. This derogates further improvement of processes as well as of machines and plants. Another result of the lack of standardization is poor coordination between the producers and users of machinery and equipment. Costly errors and modifications during the project execution result from this [1–5].

Figure 1 shows typical problems and their potential causes resulting from the described lack of standardization in project execution. Within the context of standardization the described initial situation is to be improved by an innovative approach.

Typical problems	Possible causes
Losses due to improper calculation of costs	Neglect of price-related factors in proposal preparation
Time expenditure on project execution is too high	Duplication and multiple inputs
Insufficient cooperation and Information break-ups	Inconsistent database
Delays within start-up	Insufficient acceptance tests
Repeated errors	Insufficient use of know-how/empirical knowledge

Fig. 1. Problems in project execution and their possible causes.

2. STANDARDIZATION VS INNOVATION

A research project at the department of Factory Planning and Factory Management of Chemnitz University of Technology has addressed this initial situation. The project was realized together with a special-purpose machinery manufacturer and a software company. Beyond this the results of this project have been further developed in the scope of a doctorate research [6], the results of which are presented in this paper. At the end an innovation in project execution by the standardization of processes and information flows was achieved. In order to illustrate how standardization can lead to innovation, first these two terms need to be defined.

The term **standard** is defined as the best solution for tasks of the same kind [7]. **Standardization** is defined as a harmonization of measures, types, processes and further issues concerning standards [8]. Hereby, unified best practices are developed, implemented and evaluated for recurring tasks [9]. Furthermore, processes and methods are defined or recommended in the context of standardization. In the scope of this article, standardization refers to the execution of processes [10].

Innovation means an invention and its sustainable economic use [11]. Innovation can result from the development of a new product and/or process that has firstly been implemented in the respective company [12]. In this article innovation means organizational changes in the company, in order to renew processes and to eliminate problems [13].

At first sight, it could be assumed that **standardization** and **innovation** contradict to each other. Taking a closer look one may say that standards can provide a basis for innovation. It turns out that standardized processes clarify and simplify the project execution for complex customer-specific products.

3. CHALLENGES

The challenge of using standardized approach in order to improve the initial situation in this case refers to the special field of application, which is the customer-specific machinery and plant engineering.

Projects in this area are characterized by the requirements of the customer, which lead to specifications for the planning and manufacturing of the machinery and plants. These machinery and plants are either custom-built or manufactured in very small quantities. They offer a high degree of technological novelty.

Special-purpose machinery and plants can be planned for a vast amount of purposes. There are, for example, special-purpose machine tools, assembly and handling plants. Special-purpose machinery is designed for the manufacturing of only one product or a limited family of parts. This limited field of application, however, is counterbalanced by high productivity [14,15].

A comprehensive literature research showed that approaches or software systems, which completely solve all problems of the initial situation, are still missing. Thereby different methodologies, concerning, e.g., reference processes, and a whole variety of existing software solutions of project or document management have been investigated and evaluated [6].

In spite of the novelty grade and diversity of the machinery and plants, standardized and innovative approaches could be developed for their project execution. Thus the elimination of the above-mentioned problems is possible.

4. REFERENCE MODEL FOR PROJECT EXECUTION

For the standardization of the project execution, a reference model has been developed. This model illustrates connections in a simplified way. The resulting schematization allows a reasonable degree of standardization, in spite of the highly complex processes in customer-specific machinery and plant engineering.

4.1. Overview

Figure 2 gives an overview of the constituent parts of the reference model.

The first main focus of the developed reference model is on the existing methodological basis, which includes, for example, simultaneous and requirements engineering.

Phases and respective reference processes of project execution represent further parts of the reference model. Referring to this, typical project phases have been defined for the customer-specific machinery and plant engineering. The next step consists of specifying these phases in the reference processes.

Information flows and intersections between documents represent further parts of the reference model. For this purpose documents were subdivided into information modules. These modules were then visualized and described in detail.

Computer-based tools represent another constituent part of the model. They have been designed in order to support the processes of project execution and related documentation as well as information flows.

Besides that, there are documents that have not been standardized and consequently are subdivided into modules (e.g., design documents). However, they have been integrated into the process and information flow evaluation, but in a simplified manner.

4.2. Reference processes

The development of reference processes was realized on the basis of technical literature [16–19]. Besides, existing reference models could be used to collect

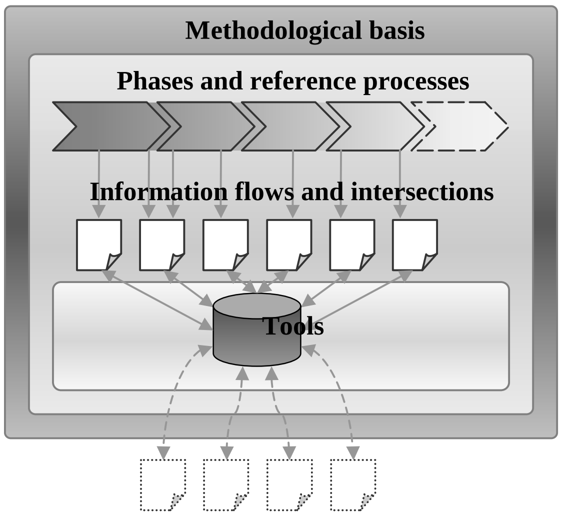

Fig. 2. Constituents of the reference model.

information about characteristics, potential information bases and modelling options. Furthermore, project execution processes were evaluated in operational practice and included in the development of the reference processes.

As a result, the following reference processes have been developed for project execution:

- bidding and contract conclusion;
- development, construction and process planning;
- manufacturing, assembly and start-up in-house (at the manufacturer's factory);
- delivery and start-up on-site (at the operator's factory);
- service and warranty (maintenance).

The reference processes were graphically represented and described in detail through activity diagrams of UML (Unified Modelling Language). An example for this graphical representation is shown in Fig. 3. It contains an excerpt from a reference process.

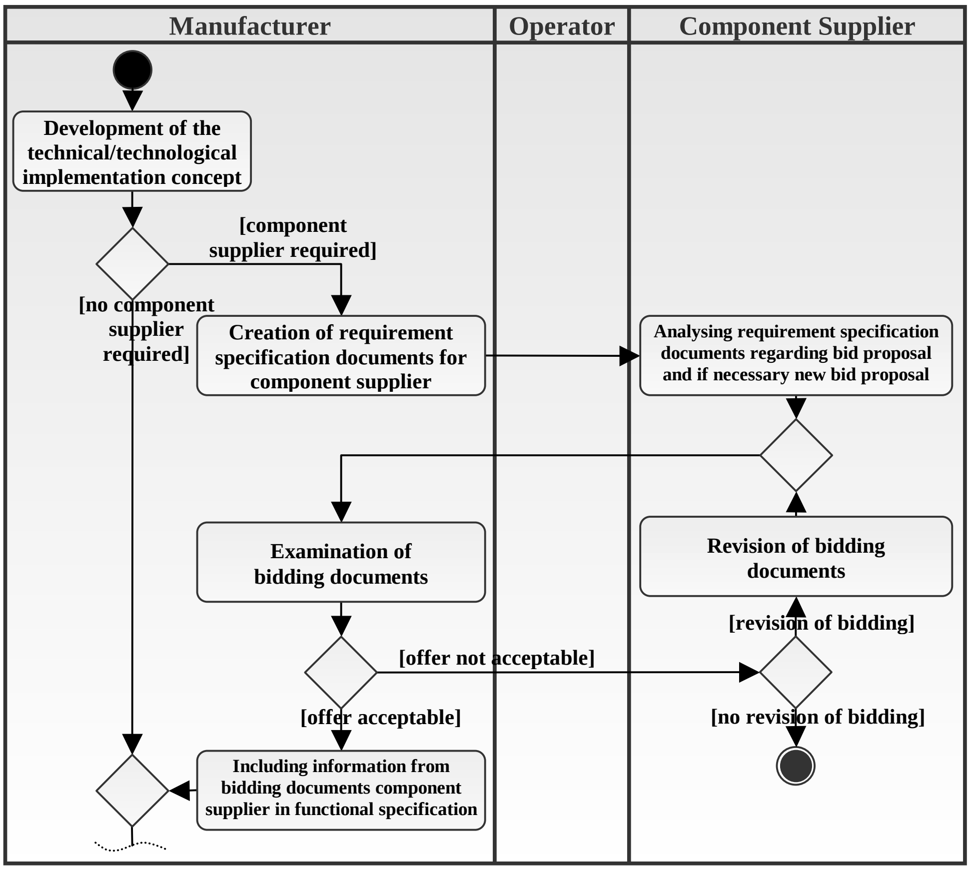

Fig. 3. Bidding and contract conclusion phase – bid proposal (part of the process stage).

4.3. Information modules and flows

In order to provide a basic understanding of our model, these two terms will be defined first.

An **information module** represents the grouping of information. The purpose is a reutilization of coherent information, in order to depict intersections between documents.

Information flow means the transfer of information or, respectively, information modules between organizational units and documents, both within the company and externally. The transfer includes computer-based as well as manual transmission and conversion.

Relevant documents have already been named within the scope of process stages of the developed reference processes. In the next step these documents had to be identified in detail, which was followed by the specification of their content. Consequently, the structuring of documents was carried out by means of information modules. Additionally, intersections and connections between documents were described with the help of information flows. Therefore specific types of information flows, as for example transmission, selection and conversion, had to be defined. Figure 4 illustrates this approach. However, in this case it is strongly simplified and only shows four exemplary documents.

As shown in Fig. 4, a legend was prepared for the graphical representation of connections between documents and related modules.

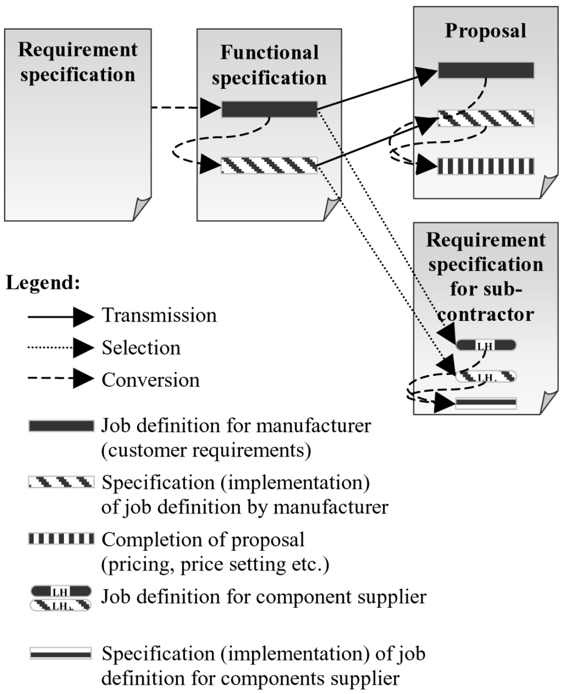

Fig. 4. Information modules and flows.

4.4. Extended process view

The next step was to specify the reference processes through the reflection of documents and information flows. This is how the extended process view was developed. Process steps were extended in detail by documents, information modules and appropriate information flows.

In this context, activity diagrams of the modelling language UML were modified. The modification concentrated especially on the modelling element activity, which was subdivided into three sections by means of dotted lines. The upper section contains the actual activity that already exists in the unmodified version. The two lower sections represent an extension. They contain input or, respectively, output of the activities, i.e. documents, test results or other information, according to processed or modified information of the current activity. In the scope of UML modelling, rectangles show the activities in which input and output parameters are described. This representation is also modified by integrating the developed information modules in place of the rectangles. Documents, their structure and modifications within different process steps as well as their interaction with test results can now be described in detail. The above mentioned modification is schematically shown in Fig. 5.

Besides, further information modules had to be introduced for the reflection of documents and information flows. These are, for example, modules for test results or documents that appear optionally.

4.5. Tools

In order to establish reference processes and related information flows with minimal effort in (operational) practice, computer-based tools are needed. They have also been derived from the reference model and are, for example:

- questionnaires;
- document configurator;
- extended document configurator (for checklists);
- change log and evaluation tool.

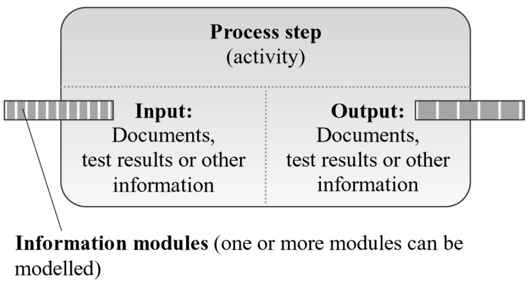

Fig. 5. Extension of process steps.

Tasks, the area of application as well as essential requirements have been defined for those tools. On this basis, tools were assigned to those reference processes they can be applied in. Besides, the interaction between tools was explained. As tools are planned to be adaptable to different basic conditions and business activities of companies, there was still the need to describe requirements for the configuration.

5. PRACTICAL IMPLEMENTATION

For the introduction and implementation of the reference model in different companies a guideline has been worked out, which describes a systematic approach. Figure 6 shows an excerpt from this recommendation.

The explanation of recommended steps is, in addition to this, exemplified by a pilot application at a special-purpose machinery manufacturer. Thus a part of the practical implementation is described. A further part of the practical implementation is a computer-based prototype, which has been developed on the basis of the explanations concerning the drafted tools. As a result, a prototype for a computer system has become available, which supports the standardization of the project execution.

This prototype revealed both its limits of application as well as its tremendous benefits for project execution of customer-specific machinery and plant engineering. Thereby the application was only limited by the effort to maintain the system and to train its users, the processing speed or its usability.

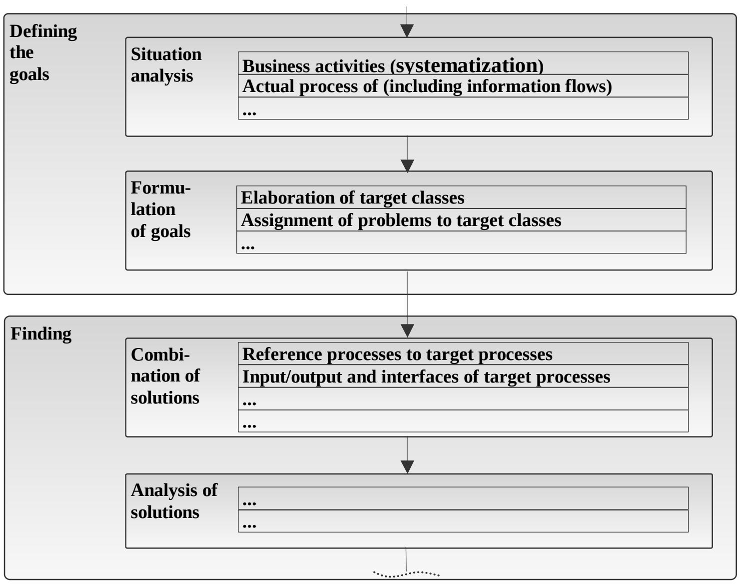

Fig. 6. Guideline (excerpt).

The software's main benefits were characterized by a reduction of the proposal preparation time, optimization of communication within the project as well as by decreased effort for revision and failures. By generating documents semi-automatically, redundant data input and unnecessary work have been eliminated additionally.

6. SUMMARY

One of the results that have been described in the article is a reference model for the standardization of project execution in the aforementioned domain. The model contains standardized processes and respective information flows. Computer-based tools were drafted for their support. Another result of the project is a guideline, describing a systematic procedure for the introduction and implementation of the reference model in the enterprise. The results were evaluated through a pilot application at a special-purpose machinery manufacturer. For this purpose, the drafted tools were implemented by a software company.

7. OUTLOOK

In the presented project the solution (i.e. reference model, guideline and computer-based prototype) has been carried out from a manufacturer's point of view. Thus we assume that the requirement specification was developed by the operator of machinery and plants, which implies that structure and content of the document mainly represent the customer's point of view. Such requirement specifications often seem to be incomplete and thus are unclear to a manufacturer. For that reason, standardization begins with a systematic data capturing and identification of missing or incomplete information concerning the preparation of requirement specifications.

Furthermore, it seems to be reasonable to analyse if it could make sense to directly support the plant operator in preparing the requirements' specification, which would be the task of the manufacturer.

In this case standardization would be moved forward and the operator would even be more involved in the respective processes. A web-based platform that would be provided by the manufacturer could be an appropriate solution. Thus the operator receives guidance and support in defining various complex requirements of customer-specific machinery and plants [20].

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Masinaehitusettevõtete jaoks välja töötatud “teatismudelil” põhinev protsessi- ja organisatsiooniline uuendus

Ulf Wagner, Ralph Riedel ja Egon Müller

Käesoleval ajal on tungiv vajadus protsessi- ja organisatsiooniliseks uuenduseks projektide teostamise valdkonnas masina- ning metallitööstuses. Vajaka-

jäämised põhjustavad projektide teostamise protsesside ebaefektiivsust, ebapiisavaid infovoogusid ja ebasobivaid arvutisüsteeme. Selle tulemusel kannatab ettevõtete tootlikkus. Ärakasutamata potentsiaali peamiseks põhjuseks on projektide teostamise standardite puudumine. Käesolevas artiklis on esitatud lahendused standardite puudumise korvamiseks. Selleks on “teatismudel”, mis sisaldab standardiseeritud protsesse ja vastavaid infovoogusid, mida toetavad vastavad infotehnoloogilised lahendused. Projekti teiseks tulemuseks on juhised, mis kirjeldavad süstemaatilisi protseduure “teatismudeli” juurutamiseks ja rakendamiseks ettevõttes.