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Business process modelling in industry—the powerful tool in enterprise management

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Abstract

The article presents some findings and experience about the power of enterprise modelling as experienced in the implementation of an industrial project to improve the process of new product development. The project had two goals: (1) to reengineer the product development process and its management (in terms of its functional, decisional and organisational aspects) and (2) to design a reference model of the development process and its management which model can be re-used in subsequent development projects.

The article emphasises the importance of process modelling as a tool that allows the capturing, externalisation, formalisation and structuring of knowledge about enterprise processes. Furthermore, business process modelling is demonstrated to be a powerful tool and approach to knowledge management.

We also explain how reference models of business processes can be helpful in project- or process design, process re-engineering, management and execution.

Finally, we present findings acquired in the re-engineering of the process of new product development that included an AS-IS model for analysis and the definition of a TO-BE model.

Keywords: Project enterprise; Business process modelling; Business process re-engineering; Reference model; Knowledge management

1. Introduction

Globalisation as the process of creating of a common, world-wide and free market no doubt represents one of the key features of the external environment of our business systems today. Globalisation as the result of the rapid development of information and communication technologies (fast access to accurate and reliable data), transport systems and consideration of common standards (which provide the world-wide comparability and compatibility of the products) [23] also allows the fusion of local and national markets into a global one and is one reason for mergers of previous competitors.

Unpredictability and changeability in the internal and the external environment, is experienced by enterprises as *turbulence* [22], and requires responsiveness and flexibility in the organisation and in the execution of processes as well.

Customer orientation and *time needed to turn an idea into a final product* are increasingly important elements of competitiveness. Quality, technically sophistication and price competitiveness of a product is not sufficient

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today on the market. The product must be able to fulfil the individual customer demands as reflected in the increasing individualisation of the production.

A product represents today just a material base for the connection of an enterprise with customers. Therefore, enterprises are directed into the integration of all aspects of business activity from customers and suppliers covering all phases in the product life-cycle.

Information and *knowledge* are becoming strategic resources in addition to traditional ones, such as raw material, energy and food, which used to be basis of progress of national economies for decades [22]. Therefore, information and communication technologies can be considered today as strategic technologies, and knowledge is considered as the key capital of enterprises.

This in turn is the motivation for the development of so-called knowledge management (KM) and its supporting tools, called knowledge management systems (KMS). One aspect of KM is the objective to transform implicit and tacit knowledge into an explicit formal representation, and to distribute it throughout the organisation (availability and re-usability of the enterprise knowledge).

The rapid changes and development in the area of technologies, techniques and new materials (worldwide consideration of common standards, deep integration of customers and suppliers in the product life-cycle, virtual enterprises and project management, concurrent engineering, modern information systems and software, approaches in the product design, GroupWare tools, etc.) have provided rapid reduction of development time and rising of complexity and functionality even in most demanding products. For example, car manufacturers needed 7–10 years to develop a new car generation 15 years ago, compared with 30 month development cycle today.

Because of the extreme competitiveness on the global market mastering of the process of new product development becomes one of the key elements of competitiveness and success of an enterprise; product development is also becoming a major contributor to the new added value of the product.

Therefore, enterprises invest every day more and more into continuous improvement of the development process itself and into the provision of adequate support (information, methodological, organisational) for its execution.

The above relations, events and demands of the business environment were the motivation for our company (ETI Jt. St. Comp.) to set-up a project intended to improve and support the process of new product development with the following objectives:

- re-engineering of the development process and the definition of its transparent decisional structure and corresponding organisation (definition of key decisions in the process and the appropriate allocation of authorities and responsibilities to decision makers);
- design of a reference model of the process of new product development as a support for planning, scheduling, management and in execution of development projects.

In the first part of the article we give an introduction to the project background and objectives. Then we present the role of enterprise models (EMs) in the formalisation of enterprise knowledge. Therefore, we present business process modelling (BPM) (and in general enterprise modelling) as an important contribution and approach to the process of KM. BPM provides mechanisms for knowledge capturing, externalisation, formalisation, structuring and re-use.

Section four presents some findings and conclusions acquired in the re-engineering of the development process from the analysis phase (AS-IS model) to the design phase producing a TO-BE model.

In the last section, we emphasise the role of a reference model for the development process. We also expose the important difference between a project management reference model and an engineering process reference model for new product development.

2. Why renew the process of new product development

Company management were often faced with the following questions concerning new product development in the company:

- How would it be possible to reduce the time needed to turn an idea into a final product?
- Why are our competitors quicker to integrate new technical solutions into products and be first to market?

A number of cases at the company raised these questions, thus, it has been recognised that a generic solution to these is needed, rather then an intervention on a project by project basis. It has been realised that management often has not been able to put into practice the observation that a competitive product is the result and reflection of the state of development (often referred to as 'maturity') of an enterprise and not just a simple result of the efforts and knowledge of some individuals in the development department. Since management did not have available a transparent definition of these processes it has been very difficult to identify the real source of any deficiencies that might have to be addressed, given the many hidden/invisible factors in the process.

We have confirmed through these experiences that high quality, technically sophisticated products, directed to fulfil customer demands, can only be created in enterprises which are harmonically developed across all business functions (IT and IS, management, leadership, organisation, staffing, continuous improvement and development of professional competencies of employees, etc.).

The company was facing daily the presented issues. Therefore, at the start of the 1999 a project was launched intended to improve the engineering process and the management of new product development projects of the company. The project was to help find answers to some important questions:

- How to design business processes to be better, faster, efficient and more transparent?
- How to provide reliable answers about the cost of various projects in their planning phase?
- How to provide better planning of project resources and scheduling of activities?
- How to allocate authorities and responsibilities to decisions in the development process and empower people to be able to successfully execute tasks while at the same time providing enough control and transparency?
- Is it possible to streamline project management tailored to the problem, rather then adopting a generic a project management methodology which often proves to be cumbersome?

These questions have been identified though the observation of individual product development efforts at the company, and compounded observations confirmed a lack of company maturity regarding these questions. It is this case study approach that resulted the problem statement as exposed above. Thus, it seemed plausible to first attempt to improve the situation through (a) determining in more detail what exactly is needed to improve the new product development processes, (b) carrying out these changes through developing and introducing the use of defined but flexible process models for this activity (as what was available has been found insufficient), and (c) verifying the results through the application of the new models in practice, including the analysis of the lessons learned, as is typical of action research [8,10].

The theoretical framework used is in general the discipline of enterprise modelling, but in particular we have attempted to identify the role of enterprise models though considering how they embody and support the sharing of such company knowledge, because any tailored approach requires a better understanding by all stakeholders then a rigidly introduced new way of working.

The first task (a) of the project was to create an AS-IS model of the new product development process to the level of granularity that allowed us to identify and solve problems with the present engineering/new product development process, as well as with its management (including decisional tasks and the allocation of responsibilities).

The production of a renewed and improved process model (b) would then be developed as a process reference model (i.e. the definition of activities that must be carried out and the outcomes that must be produced in new product development). Such reference models, if applied in practice were believed to become an important contribution to quality, reliability and efficiency of the planning of product development projects, as also to their performance, management and control.

3. Enterprise modelling and knowledge management

While the methods for developing enterprise models have become established during the 1990s both for business process analysis and design these methods have concentrated on how such models can support analysis and design teams, and the question of how these models can be used for effective and efficient

sharing of information among other stakeholders (namely line managers and engineering practitioners) has been given less attention.

If enterprise models, such as business process models, represent process knowledge then, it was concluded, we must better understand to what extent and how existing process knowledge can be externalised in form of models, and we must also understand the conditions under which these models may be effectively communicated among shareholders. Such analysis may reveal why the same model that is perfectly suitable for a business process analyst or designer may not be appropriate for end users in management and engineering. Thus, we must adopt a theoretical framework which allows us to consider how enterprise models capture and allow the sharing of the knowledge of processes as possessed by individuals or groups of individuals in the company. The framework will then allow us to avoid false expectations regarding the effects of our effort.

Knowledge is widely recognised as being the key capital of enterprises that contributes to enterprise competitiveness and provides the basis for long term growth, development and existence.

Therefore, one of the major questions is how to make more efficient use of knowledge in the enterprise (in terms of sharing or acquiring). It is a well known fact that much of existing information and knowledge, which is extremely valuable, is not made explicit, externalised or formalised and is consequently not available for use by other individuals, and sometimes it can even be lost for the enterprise. Therefore, how can informal enterprise knowledge be captured, formalised, organised, spread and reused?

KM, as a part of an answer to the above question, is not something entirely new. We have seen several previous approaches to help people capture and share their knowledge, experience and expertise. Why is then that KM (besides business process re-engineering) became one of the hottest topics today? We believe that the development of Intranet GroupWare has really brought for the first time in history the technical solution which gives us an affordable infrastructure for sharing of enterprise intellectual capital. Namely, Intranet GroupWare integrates simple and efficient services for KM. However, without an understanding of what and how can be shared this infrastructure can not be used to its potential.

Therefore, we define the key *objective* and *purpose* of a KMS as:

- externalisation of knowledge of individuals or groups, and consequently spreading, sharing and reusing of knowledge;
- providing access to the desired information and knowledge to support innovation, responsiveness, productivity and competency of all employees, and consequently leveraging the enterprise's intellectual capital [9].

3.1. The nature of knowledge and its sharing

Several different definitions of knowledge can be found in literature [1,3,6]. According to [14] knowledge can be defined as the meaningful structured accumulation of information.

Zack and Serino [24] divide knowledge into two groups: explicit knowledge and tacit knowledge.

Explicit knowledge is knowledge that has been formally articulated and written down. Therefore, such knowledge can be shared and spread.

Tacit knowledge is developed and derives from the practical environment (therefore, it can be also called knowledge from practice). Such knowledge is usually highly pragmatic and specific to situations in which it developed. Tacit knowledge is subconscious, it is understood and used, but at the same time difficult to formalise (albeit not always impossible to externalise—tacit knowledge is, for example, suitable for exchange through direct conversation, telling of stories, and going through joint experience).

3.2. The knowledge life-cycle model

Fig. 1 introduces a simple model of knowledge life-cycle, extending (detailing) the models proposed by Nonaka and Takeuchi, and Zack and Serino. Our extension is based on [4], which treats enterprise models as objects for semantic interpretation by participants in a conversation and establishes the criteria for uniform understanding. This, of course is most important in knowledge sharing. After all if a model of company knowledge that can only be interpreted correctly by the person who produced it is of limited use for anyone else. Moreover, misinterpretation may not always be apparent, thus, through the lack of

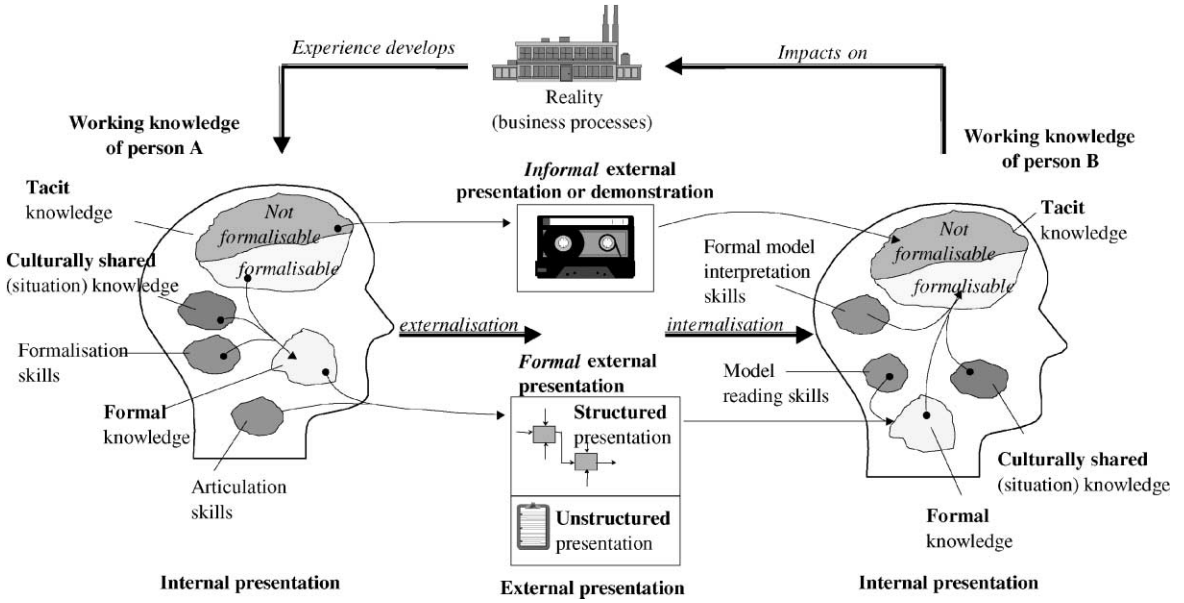

Fig. 1. The knowledge life-cycle model.

shared interpretation of enterprise models (and lack of guarantees to this effect) may cause damage. This model (Fig. 1) represents relations between different types of knowledge.

Below we briefly discuss the model in Fig. 1, which is used as our theoretical framework.

In order for employees to be able to execute business or decisional processes they must possess some 'working knowledge' (e.g. about process functionality, required process inputs and delivered outputs, organisation, management, etc.). Working knowledge is constantly developed and updated through receiving information from the internal environment (i.e. through the execution of business and decisional processes) and from the external environment.

Therefore, capturing of working knowledge of employees (the knowledge which we would like to spread and share through the organisation) represents the main objective of KM.

Working knowledge usually has (from the perspective of the knowledge holder) the characteristics of tacit knowledge. Namely knowledge holders do not necessarily see or use the possessed knowledge as explicit, formal and structured information. They simply understand and know what they are doing and how they have to carry out their tasks.

According to the suitability for formalisation and structuring such working knowledge can be divided into two groups: formalisable and not formalisable knowledge.

Such division of knowledge into two broad categories seems to closely correspond to how much the process can be structured, i.e. to be decomposed into a set of interrelated lower level constituent processes. This characteristics can be observed when considering knowledge about different typical business process types.

The formalisation and structural description of innovative and creative processes, such as some management, engineering and design processes (or in general the group of ad hoc processes), is a difficult task, due to the fact that the set of constituent processes is not predefined, nor is the exact nature of their combination well understood by those who have the knowledge. Consequently, knowledge about this type of processes is considered not formalisable.

In contrast to the characteristics of the group of ad hoc processes the group of ill-structured and structured (repetitive or algorithmic) processes can be formalised and structured at least to a degree; consequently the knowledge about these processes is considered formalisable. Illustrations of such processes are management, engineering and design on the level

of co-ordination between activities performed by separately acting individuals or groups, and repetitive business and manufacturing activities.

The formalisable part of knowledge is extremely important and valuable for KM, because this may be distributed and, thus, shared with relative ease. Namely, *the process of transformation of the formalisable part of working—tacit knowledge into formal knowledge* (which could be also called the *explicit* knowledge) represents one of the crucial processes in KM. We believe that the cost of KM (measured by the level of reuse and return of investment to the enterprise) in case of explicit knowledge is lower than in case of tacit (*implicit*) knowledge, simply because the sharing of the latter is a slow and involved process.

To be able to perform the aforementioned *formalisation process* we need additional knowledge known as *culturally shared* or *situation knowledge* (e.g. about mechanical engineering, accounting, process engineering, etc.). Culturally shared knowledge plays an essential role in the understanding of the process or entity in question and in its formalisation and structuring. The definition of an accounting process can only be done by an individual who understands accounting itself, but this formalisation will be interpreted by other individuals who must have an assumed prior culturally shared and situational knowledge that is *not* part of the formal representation [4].

As we already mentioned a key objective of KM is the externalisation of knowledge. Regarding the type of knowledge (tacit and explicit) different tools and approaches in knowledge capturing may be used, such as:

- tacit and not formalisable knowledge can be captured and presented in form of *informal external presentations* (e.g. multimedia records, personal accounts of experience, or demonstration);
- tacit and formalisable knowledge can be captured and presented in *formal external presentations*. A formal external presentation may be in unstructured form or in structured form. A textual description, like in quality procedure documents (ISO 9000), can be considered as an example of the representation of process knowledge in unstructured form while different enterprise models (e.g. functional business process models) are an example of structured form of knowledge.

The advantage of using structured models for process description is the *quality of captured and formalised knowledge* (see Section 4.2.1 comparing the properties of structured process models with textual descriptions thereof).

To actually perform this formalisation of knowledge (e.g. BPM) formalisation (i.e. BPM) skills are needed.

The above presented process of knowledge externalisation has to be complemented by a matching process of knowledge *internalisation* that is necessary for the reuse of available knowledge.

According to the type and form of externalised knowledge different internalisation processes (and corresponding skills) are necessary:

- *informal external presentation* of knowledge accompanied with its interpretation (e.g. interpretation of the presented story) can directly build our working (tacit) knowledge;
- structured, or *formal external presentation*, for instance a business process model developed in the IDEF0 (ICAM DEFinition) modelling language [12], must be first interpreted to be of use. To interpret the content of information captured in a formal model, formal model interpretation skills are needed. Such formal knowledge must be further interpreted by reference to culturally shared, prior assumed knowledge so that the content of the formal knowledge (information captured in the business process model) can be understood and interpreted in the intended way, and thus, integrated in our working knowledge (to improve our competencies).

The reuse of formal externalised knowledge could have an impact on the execution of the process in terms of its efficiency, according to the well known fact that formally learnt processes must undergo an internalisation process after which they are not used in a step-by-step manner. Thus, transfer of formal knowledge into informal knowledge is a ‘natural’ process [4], and is necessary for efficiency. The internalisation of externalised formal knowledge thereby closes the loop of the knowledge life-cycle.

In the surveyed literature on the development of a knowledge life-cycle model authors offered several definitions of tacit and explicit knowledge [2,11,15,

16,19]. Based on the investigation of certain characteristics of the knowledge life-cycle we concluded that the majority of existing definitions are not explicit enough to be followed and used in practice as a guideline for categorising knowledge.

The presented knowledge life-cycle model proposes two criteria for knowledge categorisation according to (a) the suitability of knowledge for abstraction and structuring (formalisable and not-formalisable) and (b) the state of appearance of knowledge (internalised and externalised).

We also believe that researchers should provide a sufficiently formalised ontology and framework for knowledge categorisation for a proposed knowledge life-cycle model to be of practical use.

3.3. Business process modelling and knowledge management

In general, we can say that KMSs are primarily focused on solutions for the capture, organisation and distribution of tacit formalisable knowledge. We feel that current KM approaches focus on techniques and tools that make captured information available and relatively little attention is paid to those tools and techniques that ensure that the captured information is of high quality or that it can be interpreted in the intended way.

Based on the presented features of enterprise modelling we conclude that enterspise modelling (including BPM), if other necessary components are available, facilitates the transformation of informal knowledge into an externalised form and in turn allows the externalised form to be interpreted and be used to build internalised pragmatic knowledge. EMs are a formalised, structured and externalised form of knowledge intended to be shared and spread throughout the organisation.

The company used BPM for the capturing and distribution of the knowledge of its business processes, namely, new product development. Business process modes have been published and distributed through the Intranet system where process models are presented in form of web pages (see Fig. 2).

Note that the native formats of process models, designed using different modelling languages, are not suitable for the distribution and review by final users (they require the installation of modelling tools which are usually expensive and not designed to be used as model browsers or viewers). Therefore, the process models are translated into HTML pages made accessible to final users through simple web-browsers.

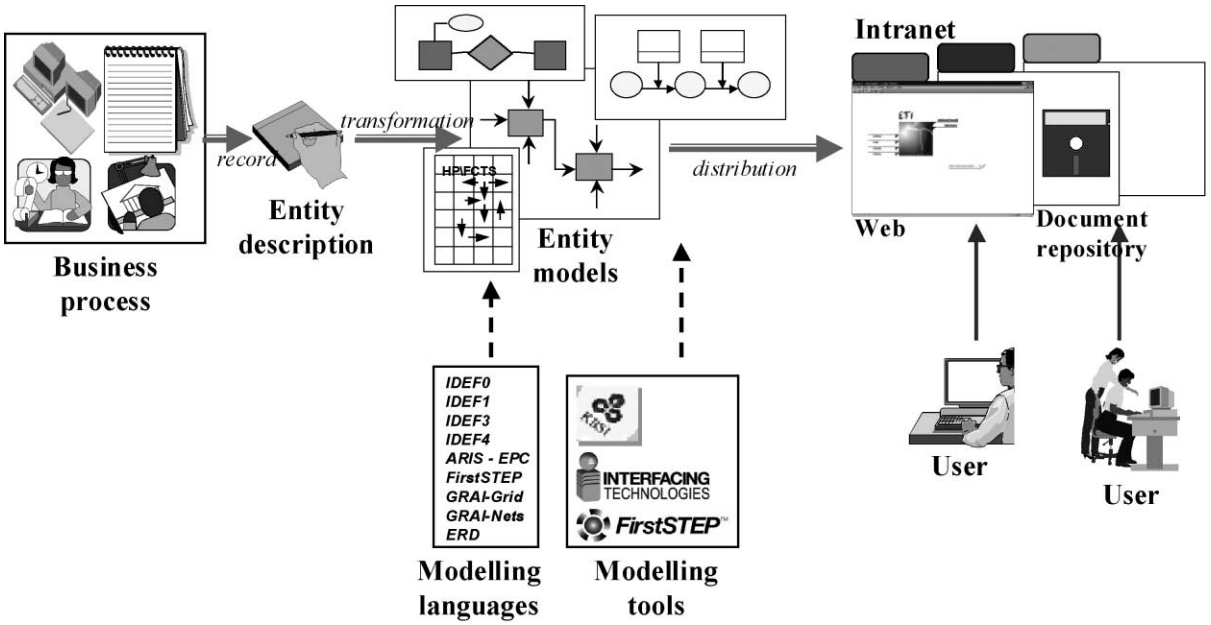

Fig. 2. The process of formalisation and knowledge distribution.

4. The process of new product development

The target of this research has been the externalisation of new product development process in form of process models and the sharing of this knowledge across all stakeholders of the organisation involved in carrying out or managing new product development. Below we describe the analysis of the present process and the design of the new process, which model also is to be usable by all stakeholders in the day-to-day operation of the enterprise. This last point is an important one, because we did not intend to standardise on a single process, rather we intended to develop a reference model based on which each individual project may design its own, tailored process. Should it have been the aim to institute one standard process, it would have been enough to design such a uniform process and then implement each of its components wherever necessary in the enterprise (this would not, of course, have been a process that is not necessarily understood overall by anyone but the designer of this process).

4.1. Some characteristics of the new product development process

We define *new product development* as the process, which integrates different business functions and requires their mutual co-operation and co-ordination with the objective to transform a product idea into a final product available for production and distribution on the market.

The process of new product development has a wider scope than the design process of a new product. Guideline 2223 of VDI [21] defines the design process as:

> The design process consists primarily of the predominantly creative intellectual conceptualisation of technical products utilising knowledge and experience, and endeavours to find optimal solutions. It involves the determination of the functional and structural characteristics of a product and the generation of definitive production documentation.c

Therefore, the design process consists of the typical engineering process, with iterative nature, focussed on the definition of functional and geometric characteristics of the product (activities are based mainly on the participation of a development department with intensive co-operation of other technical departments). In contrast to the design process, the process of new product development is more complex and wider in scope. This process integrates, in addition to the design activities, technological, control, technical, marketing, purchasing (new suppliers acquisition) and accounting activities (pre- and post-calculations) required to be 'product ready', i.e. for production and distribution to customers except activities of implementation (manufacturing phase of the product).

Based on the traditional approach to the division of labour in the process of new product development the following stages can be identified (which involve a number of product life-cycle activities):

- Requirement definition stage aiming at the transformation of product ideas into concrete requirements and features of the product (the leading activity of this stage is requirements definition, but additional design, or even prototyping activities may be needed to complete this stage in order to confirm the feasibility of the requirements).
- Preliminary design stage aiming at the definition of the product to the level which allows the company to make informed decision about the cost, risk, and time involved in the subsequent stages of product development. This stage is composed of activities of high-level product design as well as the selection of manufacturing technologies that may be suitable for the production of the product. This sometimes necessitates the manufacturing of prototypes (potentially with alternative technologies) for the development of alternative solutions and their assessment.
- Detailed design stage aiming at the concretisation of proposed concepts, execution of design, form of product model and prototypes, evaluation of concrete solutions, detail design of entire product and its components and its final checking, as well as the design of production processes.

4.2. Re-engineering of the process of new product development

The term business process re-engineering (BPR) has been widely used in recent years. BPR is mainly focused on a definition of a methodical approach to the

development of new business processes or on radical improvement to existing ones and on the change of processes affecting the enterprise organisation [5].

We followed a simple three-steep approach to BPR composed of:

- *description* phase of a business process (capturing the AS-IS process model);
- *analysis* phase focused on the investigation of facts and characteristics of the existing process;
- *redesign* phase where the process model is redesigned based on findings of the analysis phase and predefined objectives.

The reason to select this approach was due to the fact that we already had an informally defined process, that was more likely in the need of improvement and alignment with new objectives than of complete change.

For the purpose of BPR we have utilised the functional modelling language IDEF0. The functional modelling language was well suited (in our case) for the description of the new product development process (creation of AS-IS model, its analysis and redesign). This is because the main question was to identify the interfaces and co-operation between elementary activities, rather then the development of step by step process model which would have been very difficult due to the nature of engineering and design activities and the variety in projects that would have needed different sequences of steps according to the product development problem at hand.

In the development of a business process model we are often faced with the question how in-depth the process in question should be described? A general answer to the question could not be given because the level of granularity in process description (modelling) depends on the model (modelling) purpose. According to Uppington and Bernus the level of granularity in BPM is driven by understanding of the current state of affairs and limited to the pragmatic needs of the subsequent phase of the change process and the personnel involved [20].

In our case we followed two requirements: the business process model should provide the identification of main process functions and activities, main decisions and decision makers and allow the re-use of a model as a guide-line for future process planning, management and control.

4.2.1. The AS-IS model

As mentioned, the first step (a) in the development of our process model was the acquisition of elementary information about the process in question. The basic source of information about the development process was the documentation of the company's quality assurance system ISO 9001 [7] (Chapter 4 of the quality manual and corresponding 'Quality Procedures').

In the creation of the AS-IS process model we were soon faced with typical problems which appear in the development of business process models. Based on available documents of the quality assurance system (composed of textual description and simple charts) it has been very difficult to reconstruct the content of the process and to fully understand its functionalities, sequence of activities, their dependencies and required inputs and delivered outputs, or to identify the key decisions or allocation of authorities over these decisions. This confirmed the general observation that while the developers and assessors of the quality manual were comfortable with the completeness of this description (the company has earlier received an ISO qualification), the intended audience of the quality manual was not the practitioners of the company.

These issues regarding the available description of business processes in the quality assurance system are often present in practice. Namely, the use of textual descriptions and the use of simple chart techniques do not guarantee an understandable, transparent and unequivocal description of business processes. Therefore, the employment of BPM supported by the formal modelling languages, tools and methodologies are needed to provide a systematic, standard, unequivocal, interpretable and holistic description of features and information about processes, the involved entities, functionality and behaviour. Such formal models play an essential role in the quality description of business processes.

Regarding the incompleteness of information captured in informal documents of the quality assurance system the missing information was added by additional interpretation by process owners. Therefore, the acquisition of the lacking information was carried out based on interviews.

The captured information provided a solid base for the development of a preliminary AS-IS model of the process. During the development of the AS-IS model

we could often perceive how difficult it is for people to express their implicit knowledge of the process. Therefore, capturing of information about the process is a difficult and time-consuming task.

At the same time the functional process model proved to be an adequate base and communication vehicle for the exchange, presentation and agreement on the interpretation of facts about the process between process owner and the person who performed the modelling.

The experience gained in creating the AS-IS process model has shown that a basic understanding of the modelling language syntax and semantics is required if we want to achieve an efficient exchange of information about the process captured in the model. Therefore, a short introduction of syntax and semantics of the modelling language used in process modelling was given first.

The design of the process model is usually an iterative process where, based on the process model, the exchange of information and understanding of model content is to be achieved between the process owner and process designer/analyst. The process designer/analyst and process owner iterated this modelling process until the process model was mutually agreed and confirmed as a credible and relevant snapshot of the existing product development process. It is to be noted that the mere fact that his analysis was carried out had an effect on the process owners as well, thus, the uniform interpretability of the resulting AS-IS models (and subsequent TO-BE models need scrutiny as for how they can be interpreted by other people who were not participants of this process.

Two different approaches in process model development are usually referred to: the bottom-up and the top-down approach [12].

In the bottom-up approach, the building of business process models is started from the most detailed description (operations or activities) up to a more general description (sub-processes or processes). This way of building of process model is often proposed for the development of AS-IS models (i.e. the modelling of existing processes).

The top-down approach develops the process description from the definition of basic features, or so called high—level functional definition, into a detailed description, or low—level definition. This approach is often proposed for the creation and definition of radically new TO-BE models or models of a future state or system behaviour.

Often the combination of both approaches is used in process modelling practice. For example, in the development of an AS-IS model first the high-level or general description of the process was carried out (rough definition of processes and roles of employees, to define the context and scope of modelling), followed by the detailed definition of process activities and lower process entities on the basis of actual tasks that are performed in the company.

Also experience showed that during the development of the AS-IS model some demands and ideas about the process modification are already integrated into the model. Therefore, parts of the AS-IS model often was not simply a snapshot of the existing process, but also integrated some elements of the TO-BE model (confirming the fact that merely analysing the process has an impact on its present state).

4.2.2. Analysis and re-design of the functional process model

Depending on the practical situation at hand different AS-IS modelling needs exist [20]. In our case, the description of the process played an essential role and was one of the key elements of the success of the re-engineering process.

The business process model provided an opportunity to present the complex process structure to process owners and managers, and provided an adequate basis for its renewal and the definition of a decisional structure and corresponding organisation.

Figs. 3 and 4 represent the ‘high-level’ functional model of a process of new product development (the complete functional model of the process has been developed up to a level of activities that was adequate for common understanding among stakeholders). As Fig. 3 shows the first part of the process integrates the following activities:

- triggering, collecting and first selection of ideas about a new product;
- design of a project proposal for new product development with definition of market, technical, technological, environmental and purchasing definition of the product, product pre-calculation, and definition of other project proposal elements (main project activities, their plan and schedule, project cost

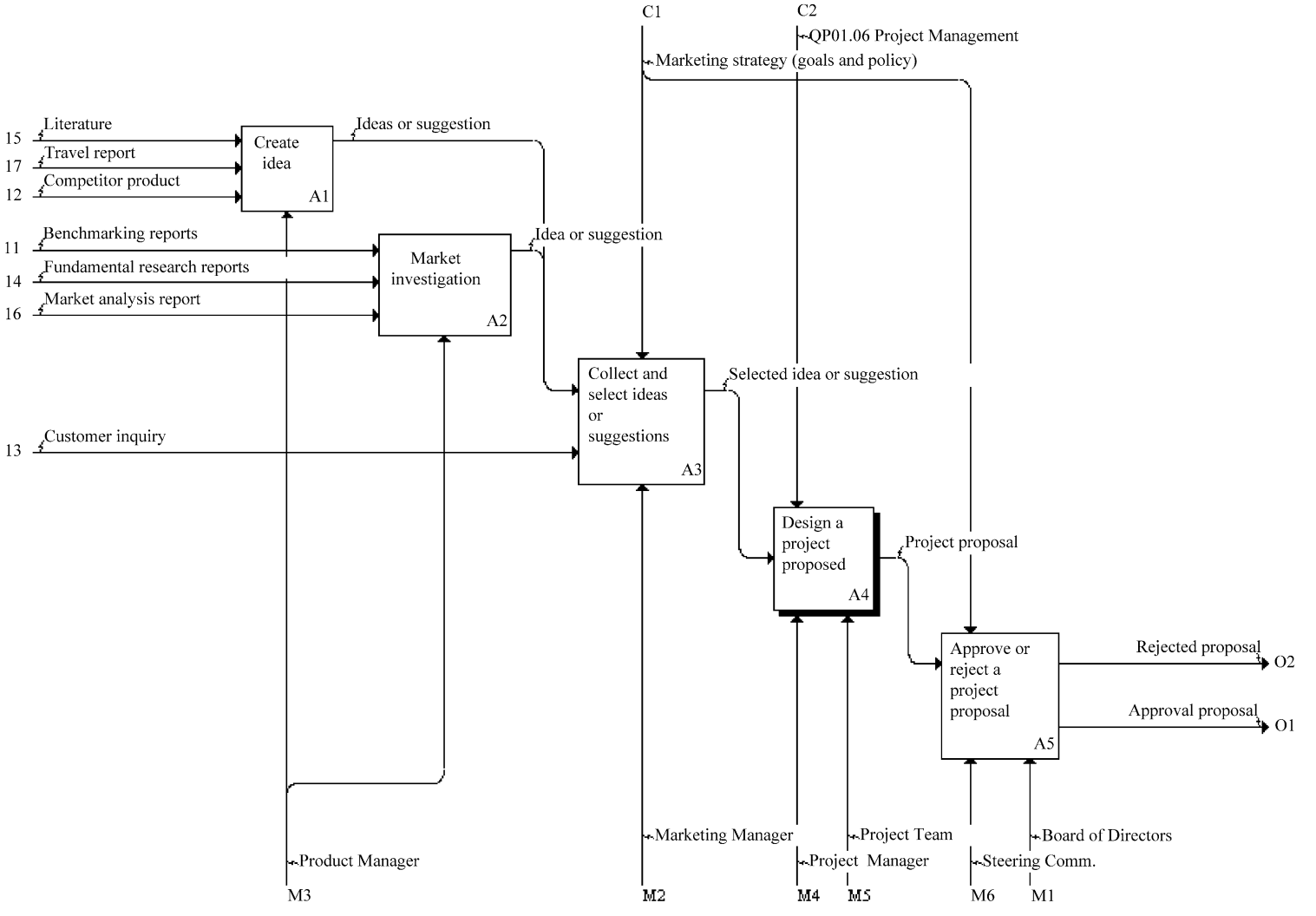

Fig. 3. Capture, design and approve a new product development proposal.

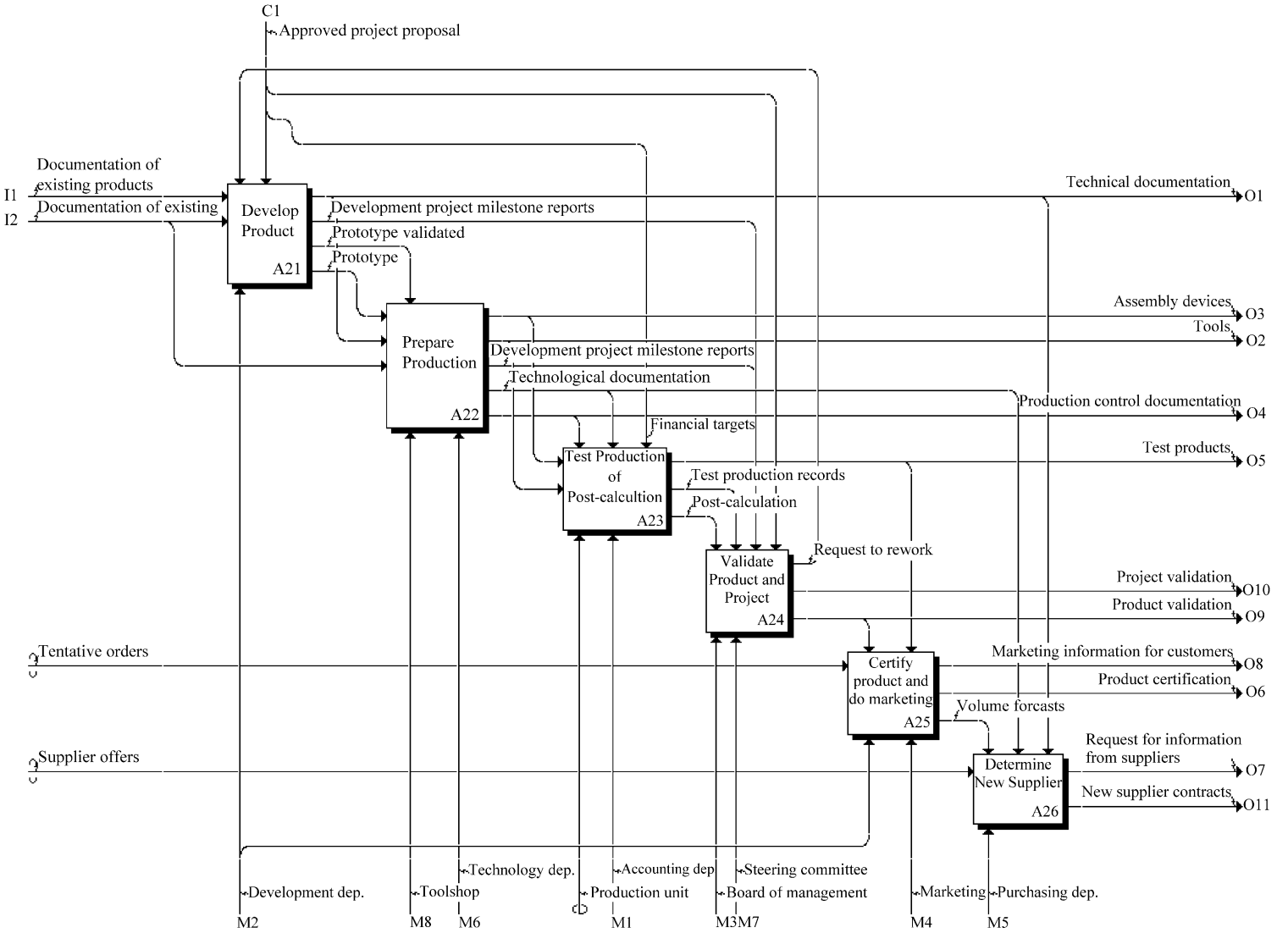

Fig. 4. The process of new product development.

planning, and definition of project organisation, etc.);
- Decision making (approval or rejection of the project proposal).

The second part of the process (see Fig. 4) integrates activities concerned with:

- product design;
- design and manufacturing of tools, machines and devices required in the product manufacturing stage;
- planning of technological and management procedures;
- marketing activities and acquisition of new suppliers
- certification of the product;
- validation and verification of the product and project.

During the re-engineering process we were often faced with questions concerning the adequacy of functional, decisional and organisational structure of the process, such as:

- Is the functional structure of the process appropriate or do additional activities need to be carried out?
- Does the process of new product development contain all relevant decisions required for the process—project success?
- Who has the authority and responsibility over the key decisions in the process?
- Have we adequately empowered our employees with authority and competency for their tasks to be successfully carried out and goals achieved?

In re-engineering of the business process, modelling and analysis of the functional structure play an important role, because they provide the definition of activities that must be executed to achieve the mission and objectives of the process.

The second important task in the re-engineering process is analysing of the decisional structure of the process. The analysis of the decisional structure is primarily focused on searching for answers such as: which important decisions are made in the process, does the process integrate all required decisions or should some decisions be added.

During the analysis of the decisional system (in our case) which is part of the process, we identified needs to change parts of the decisional structure. An interesting example is the need to split the validation of the project and the validation of the product (in this case the validation represents the decision):

- the validation of the *product* can be carried out when the product fulfils certain pre-defined characteristics and criteria (for example, the achievement of the product certificate from an authorised institution or confirmation of the customer represents the proof about the achievement of pre-defined characteristics);
- the validation of the *project* is based on the achievement of pre-defined project characteristics (time, costs and quality).

Therefore, we can be often faced in practice with a situation where the validation of the product is successfully done (what is usually considered the end of the project), but the project validation cannot be achieved (for example, the project expenses or planned dynamics of activities have not been reached).

Based on the design of the process model, we could identify what were the project's decision centres and what conditions existed for them to make informed decisions.

As the logical continuation of decisional structure analysis the issue about the adequacy of the *organisational structure* has arisen. Namely, the precise definition of authorities and responsibilities over the decisions is essential for the successful and transparent execution of the process.

In the presented example (the site of our action research), based on the analysis of the organisation, we have found that authorities and responsibilities of individual players are not clearly defined and they do not empower people enough. Two organisational design goals have been set: the definition of transparent organisational structure and the decentralisation and flattening of the organisation. Incidentally, this also triggered a separate change project aiming at the definition and separation of project organisation within the enterprise from the functional units.

Based on the output of this stage the roles of enterprise management and project management have been clearly defined and separated. Enterprise management confirms the project proposal of new product development (definition of product functional specification and project content) and consequently put in

requests for the 'development service' to be executed by the development department. In turn, the development service is carried out by a product development project set-up by the development department. At the same time a steering committee verifies the product development at defined project milestones and enterprise management validates both the product and the project.

As demonstrated above re-engineering of business processes is not limited to changes and renewal of the functional structure of the process, but it also affects the decision and organisation structure of the process.

Beside its functional complexity the new product development process is also interesting for another reason. Based on a simple analysis of the process model we could see that the process integrates activities implemented by resources directly allocated to the project, and activities provided by resources external to the project (such as usual services of the company's operation). Some activities are typically operational (support functions)—such as daily activities executed by different departments (e.g. market investigation and marketing activities carried out by the marketing department, study of technical literature and other activities concerned with creating ideas carried out in the development department, searching for new suppliers of material, components or other services). Some, but not all of these activities are performed and managed as project activities. Therefore, new product development relies on the co-operation of two types of organisation: functional and project.

Based on experience acquired in our industrial case we have found that a functional process model was more suitable for creating a reengineered process reference model then behavioural models. Namely, functional models express the general nature of the processes and they are primarily oriented towards the definition of the functional structure, information flows and functional dependencies. In contrast, behavioural models define the control flow of the process (the sequence of activities or process logic) and consequently bear more characteristics of the particular nature of any individual process. While behavioural process models would be possible to develop as reference models for some process types (those where individual processes can be executed similarly and procedurally), in case of high variability between individual projects' processes this is not practicable (except on the highest levels of synchronisation and co-ordination of activities).

5. Reference model of the new product development process

Ensuring the quality of planning and scheduling of projects is a demanding and time consuming task. However, the successful fulfilment of the mission and the achievement of individual goals of product development projects is critically dependent on the quality of the project planning stage.

Therefore, an adequate support of activities dedicated to project execution and project management is not enough. The support should be also provided to activities concerning the design and planning phase of the project.

The process of project planning, its execution and decomposition could be highly formalised in an organisation, in the form of various documents such as a Project Manual, organisational procedures, project User Manual, etc. All of these support the project manager in the execution and management of project activities. The mentioned documents, which define the project work in the organisation, can be considered as a non-formal project reference model (relative to the use of formal modelling languages suitable for the description of key processes, resources, and other aspects of the project).

What is a reference model? In most business environments there exist common (business) processes, which are similar or the same no matter what is the function or mission of the enterprise. Therefore, the adoption of such common *reusable* enterprise models (also called *partial models*), is a significant improvement in the efficiency and quality of the planning of new, or redesigning of existing, processes [13].

Descriptions of concrete processes, which are, however, similar to other cases (and thus can be treated as typical) may also be reused; we call these paradigmatic (reference) models.

We now introduce the terms process type and process instance. A *process type* is a structure consisting of activities or functions (e.g. 'the processes of product development') each defined by the function's name and signature (inputs and outputs and conditions

of execution), as well as the relationships between these (e.g. input–output relationships and possibly some rules for execution).

A process instance is the execution in time of transformations on a set of concrete objects as defined by the activity types (or functions) in that process type. The transformations are executed according to the rules as defined in the process type to which the instance belongs. A process instance is the real process following the rules and structure of a given process type [18].

Based on our findings about the product development process and its project environment we concluded that projects in the target organisation demonstrated several common characteristics no matter what the mission of the project in question (new product development, information system implementation, software development, reorganisation of the enterprise, etc.) simply because the model had little specific detail to reflect these differences. The common features of projects (important activities, their inputs and outputs, etc. in the project life-cycle) could be integrated and presented with relative ease in the form of a common reference model of projects.

Nevertheless, depending on the project mission there were also many tasks which were not common across all projects. We, therefore, distinguished two reference models: (1) reference models of the processes as implemented by the project to fulfil the project's mission (as for example the process of a new product development, implementation of information system, etc.), and (2) project management reference models covering the entire life of projects.

The company developed both types of reference models:

- *The Project Management Reference Model* (see Fig. 5) is formalised and presented in a Project User Manual (and is also made part of the relevant organisational procedures and instructions).

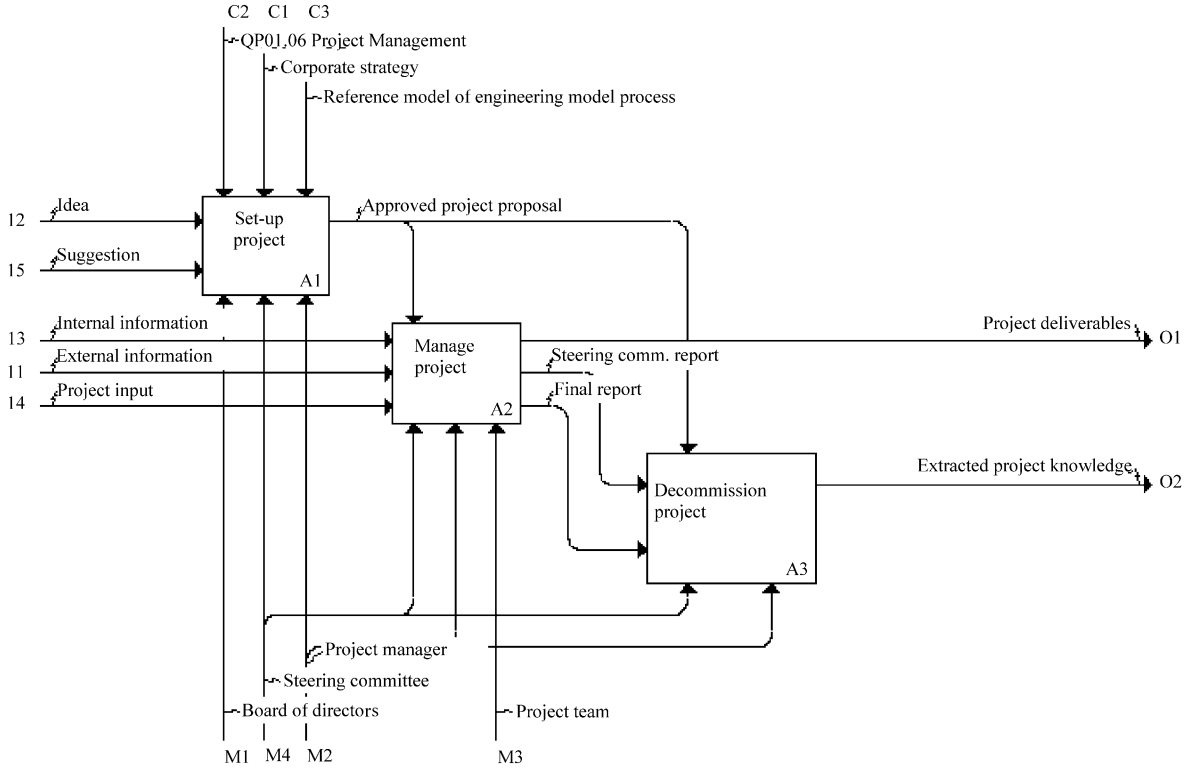

Fig. 5. The top-level functional reference model of project management.

- A set of *Process Reference Models*. These processes are usually managed and executed by projects (e.g. new product development, tool development, information system and software development and implementation).

Process reference models have been developed in the form of functional process models (using the IDEF0 modelling language—see Figs. 3 and 4) and they present a complete set of process models (with integrated alternative scenarios) for usual project types in the company. These process reference models can be easily adapted (with consideration of particular requirements) to the individual, particular cases (process instance).

Through this exercise we have been able to create to key ingredients of the efficient and quality planning of the company's project activities, both for the definition of project control flow and activity scheduling, and for project execution (see Fig. 6).

So far the development of process reference models, as implemented by individual projects, proved to be appropriate for projects that have a repetitive nature, i.e. where the product development is following a relatively predictable path. How projects with high level of innovative content can benefit from functional process reference models remains to be investigated.

The benefit of the development was verified through practical application, and enabled us to conclude that reusable process reference models provide benefit to the company though the following gains:

- supporting project planning, and scheduling of activities and resources, etc. therefore, the mentioned activities do not start from scratch;
- improving the efficiency and quality of project planning and scheduling;
- providing a repository of knowledge and experience for the planning phase of projects (through the formalisation and reuse of this knowledge);

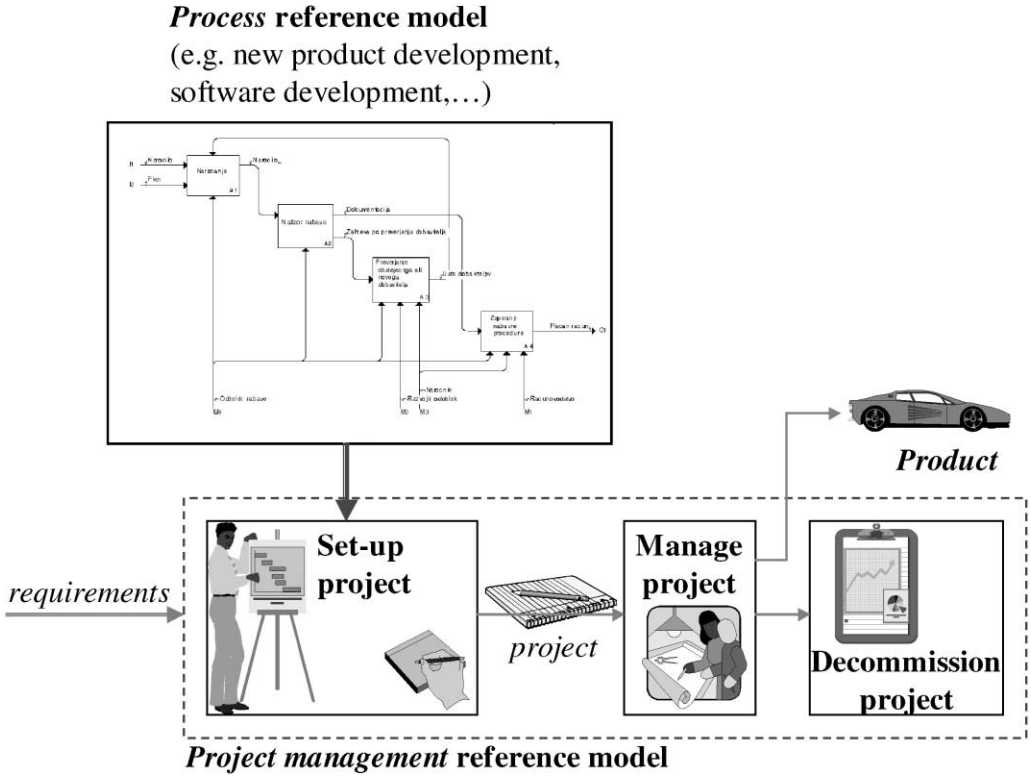

Fig. 6. Reference models in the project environment.

- providing the user/project manager with a checklist of important activities in the project development (bill of activities);
- helping to create a common communication platform, and providing for the entire organisation a greater chance of understanding what is represented in the project plan. Thus, the models have not only been used to support a change process, but become a tool for setting up and managing projects.

In the development of our company-specific reference model for new product development projects we have integrated some information and examples of best practice available from partner companies and reference models available in literature [17].

6. Conclusion

Globalisation, turbulence, customer orientation and the reduction of the time required to turn an idea into a final product are certainly the most significant attributes describing the situation of today's market. Because of the extreme competitiveness on the global market the mastering of an efficient process for new product development became one of the key elements of competitiveness and success of an enterprise.

The New Product Development, regarding its functional complexity, is one of the most demanding processes and it can be considered as the 'parade' process of the enterprise. This process is also characterised by a high amount of creative and innovative work and by a great variety of involved business functions.

In the beginning of 1999, the company launched a project focussed on re-engineering of the process of new product development and its mapping into the reference model.

The re-engineering of the process concentrated on the functional, decisional and organisational structures of product development. The renewed process model has been used as the reference model in the product development process and proved to be an important contribution to the quality, reliability and efficiency of planning of product development projects as well as their performance, management and control.

As was demonstrated, business process engineering is not limited to changes aiming at the renewal of the functional structure of the process, but it also is applicable to the decision and organisation structure of the process.

The article presented BPM not only as an important tool for process engineering but also as an approach that allows the transformation of informal knowledge into the form of a pragmatic, formalised and structured knowledge that could be spread and shared throughout the organisation. Therefore, BPM can be considered as an important tool for KM in the business environment.

Based on our findings some general guidelines may be stated (these might be followed and considered in the implementation of a similar change initiative):

- *Level of granularity of business process models*. Practice has shown that granularity in process modelling depends on the model (modelling) purpose. As a consequence, the authors of the model must be aware of the context in which the model will be used, and of the background knowledge of those people who will be users of the model. For any part of the model (such as the name of an activity, the name of a process or data element) there must be an adequate explanation included in the model, which ensures that the lowest level elements of the model are uniformly interpreted by everyone using the model. Completeness of a reference model is a relative term, a model is complete *relative to* its intended use and the user community involved in interpreting it. In the case of a single company there are many shared contextual elements that allow a simple model to be produced, which is still pragmatically complete [4]. In the context of an industry either the context of use must be defined in more detail (such as defining the necessary assumed knowledge and experience of the users of the reference model), or the model itself should be more detailed.
- *Use of formal modelling languages*. Perform BPM and BPR using formal modelling languages, tools and methodologies to provide a common communication vehicle for all stakeholders and ensure the reusability of created models. The experience gained in the design and use of business process models has shown that a basic understanding of the modelling language syntax and semantics for all stakeholders is required. This may seem as an obvious statement, but since enterprise models are

mostly graphical, they can be interpreted by untrained stakeholders as just illustrative 'figures' or 'pictures' and as a consequence part of the information in these graphically represented models may not be conveyed (and this fact may remain unnoticed).

- *Reference models*. In the development of business process reference models or in BPR authors propose that in many cases functional process models are more satisfactory then behavioural ones. Namely, functional reference models express a general nature of the processes and can be instantiated according to the particular needs. Behavioural models are useful for the purposes of simulation and certain analysis tasks, but can only be produced if the business activity is procedural in nature. This means that some functional models (those which are fully implemented in an automated way) may be further detailed using a behavioural model. Also high-level behavioural models may be constructed to describe certain procedures, lowest level activities of which, however, are not procedural and are, thus, need to be treated as elementary from the behavioural point of view.
- *Distribution infrastructure*. Easy accessibility and distribution of business process models is one of the key factors for a successful deployment of EM practice in organisations. Organisations can use a variety of information infrastructure and technologies (usually already available and present in organisations) such as Intranet, web technology, etc. Using such a distribution mechanism process models can me made available to all stakeholders, and their access can be made platform (software and hardware) independent.

The presented project is one of the continuos improvement and development processes in the company. For the successful execution of the development process in the organisation we concluded that adequate conditions, or 'development environment', must be established composed of the following three components (Fig. 7):

- organisational conditions (acknowledging the project enterprise as a separate type of enterprise entity, or organisation) which can provide an environment for innovative and creative tasks present in the development process;

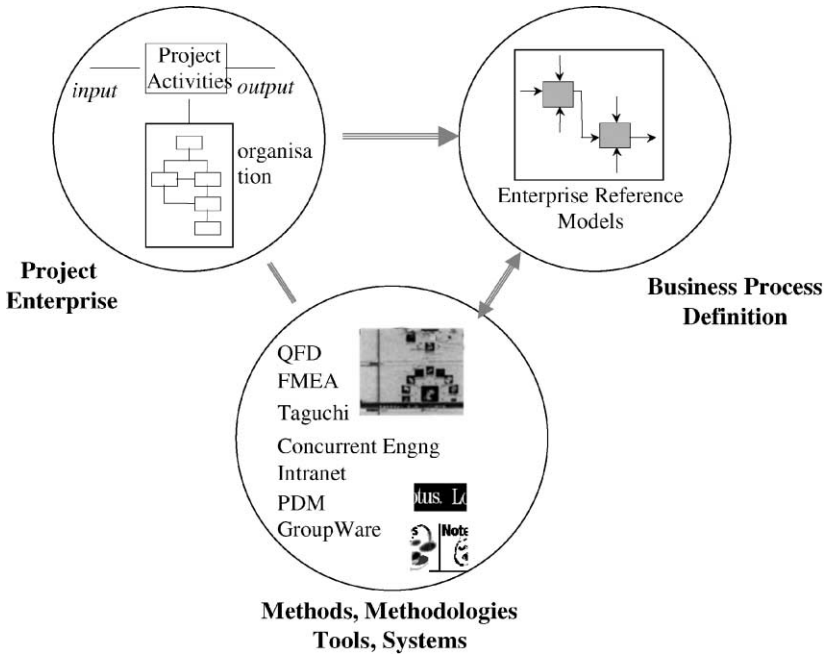

Fig. 7. The model of the environment of new product development.

- definition of key business processes (such as in form of reference models) for the improvement of process execution and management;
- incorporation into the reference model of world best practice methods, tools and systems to improve the efficiency, quality and value of results of the development process. Some of these are: Quality Function Deployment (QFD, used in the requirement definition phase for the improvement of the functional characteristics of the product according with customer requirements), Failure Mode and Effect Analysis (FMEA, to reduce the probability of failure in our products and processes in development phase), IT tools and solutions (Product Data Management (PDM), Intranets, GroupWare solutions), concurrent engineering (to reduce development cycle), etc.

Regarding the successful implementation of the first two components of the presented model our further projects will be directed on the company-wide implementation of different methods and tools for the improvement of results of the development process. Our project reference model may be used to identify the *location* and *scope* of change initiatives regarding the application of methods, tools and techniques listed in the third bullet point above.

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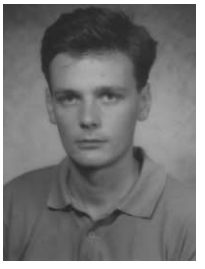

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