INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN
ICED 03 STOCKHOLM, AUGUST 19-21, 2003

COORDINATION AND CONTROLLING OF DISTRIBUTED PRODUCT DEVELOPMENT PROCESSES

Christoph Baumberger, Udo Pulm, and Udo Lindemann

Abstract

Distribution, both geographical and due to outsourcing, plays a major role as a strategic consideration and instrument to advance product quality, to reduce development time, and even to save costs. That applies in particular for the automotive industry, where a large number of participants, divisions, and suppliers have to work together, developing a highly complex and sophisticated product which is characterized by an immense market pressure. However a lot of problems are associated with distribution such as increased development complexity, additional expenditure for coordination and communication, and problems due to different educational and cultural backgrounds.

To support related management activities, e. g. planning, organizing, and decision making, a tool set will be introduced in the following. It consists of a tool monitoring the project status, a protocol system, and an information platform and may help to plan and realize distributed development processes more efficiently and flexible. By providing transparency of processes finally redundancy and double work shall be avoided, synchronization improved as well as best possible requirements fulfilment and product quality reached.

Keywords: Design information management, design management, interfacing to suppliers, project-global, work organization.

1 Introduction

Product development processes mainly are characterized by a large number of participants working together in a locally and temporally distributed environment. Especially that applies for automotive industry where designers and engineers have to collaborate to create a highly interconnected and complex product [1]. Furthermore product development in the automotive industry is characterized and driven by high market pressure, both in the meaning of strong global competition as well as increasing customer demands. Moreover these requirements create an increasing complexity of products, and hence of the development process too. One reaction to product complexity might be systems modularisation and outsourcing, i.e. the decomposition of products, processes as well as the companies' organization and the development and production of single modules or subassemblies by competent suppliers [2], [3].

The management and coordination of these particular development processes is focus of our regard. In collaboration with a leading German automotive company a number of methods, strategies, and respective tools have been developed in order to support these distributed management activities.

As prerequisites relating to that management tasks a modular, planned process structure, a defined product structure as well as a clear organizational structures can be seen. It's the basis for a supporting computer tool too. In the following we would like to present some of these tools which are

- a project monitoring system containing all relevant data for controlling such as cost, weight, dates, etc.. It points out the so called project status as well as a (technical) development maturity, thus revealing the progress of a distributed development project to all participants;
- a protocol system, based on mutual but highly adjusted information exchange, thus optimising the information flow;
- a requirement specification system as a general basis for the development, and
- a comprehensive information platform for the integration and exchange of all just mentioned elements.

In the following the single elements will be described in detail.

2 Research Approach

The article is based on long term collaboration between a German premium automotive company and a research institute. The initial point of the presented research was a thorough survey on the developed products including their components and variants (exemplarily we focused on the seats and the cockpit) and on the development processes with special regard of the distribution aspect, i.e. the relations between the company's divisions as well as the interfaces to co-developers and suppliers.

This analysis resulted in a number of problem fields connected with distributed product development. In a next step ideas to sum up and solve relating problems were collected. The most promising ideas were implemented later within the concerned product development department. The effects of these methods and supporting tools on development processes were analyzed again and in so doing we were enabled to improve respective tools continuously.

3 Methods and Tools for Coordination and Controlling in Distributed Development

Generally product structure, process, as well as the organisational framework appear as the key issues in coordinating and controlling distributed development processes. A systematic product structure is the core of this methodology [4], which to set up is supported by functional regards [5] or design structure matrices [6]. The general methods how the latter topics are treated within this paper shall be introduced in the following section.

At this, four scopes mainly come into question, which have to be examined in more detail. These are communication, coordination, willingness to cooperate, and the controlling of the entire process. Following these four main aspects adjusted guide lines, methods, and tools have been developed to support respective activities, such as a consistent and integrated visualization of the project status mainly on the project level (time, costs) and on the functional level (e. g. regarding special requirements).

Within the aspects of communication and coordination we suggest two instruments: Since meetings of teams, which represent the action level in contrast to the level of results [7], are of crucial importance within the distributed development process, topics discussed and recorded herein are an excellent source of information. Therefore we suggest building up an information basis which contains the minutes in detail (topics, dates, contacts) and acts as a reference for further development. This concept is implemented as a protocol system in a central database (as an information junction), so every authorized person is able to get required information easily.

Close to that tool, another database was developed containing the requirements specifications for the particular products-to-be. In automotive development processes such specifications are very extensive documents which are often linked to other documents such as testing plans, legal regulations, etc. Additionally a lot of parties are involved on drawing such a requirements specification. Therefore our approach tends on standardization and modularisation here as well, so that single items can be arranged according to the introduced levels.

In the matter of assessing the willingness to cooperate, we suggest a survey basing on a questionnaire, which has to be elaborated farther. Another approach to that issue might be the use of the concept of capability maturity to reveal willingness to cooperate within the company and to encourage improvement.

The fourth partition of our information and coordination concept is a project monitor, which allows controlling and visualizing the actual status of a project, to estimate future trends and to take appropriate measures. This tool complements the rather formal process planning and scheduling by e.g. process building blocks [8] or SADT [9], which is not completely possible [10], but shall offer a reference and "driver" for the process. Other approaches try to implement a dynamic process planning [11]. Similarly, this tool consists of a flexible project scheduling, a cost and weight monitoring, a quality list (containing problems, causes, and measures), a test schedule (containing specific tests, results, and milestones), and a design and functions indicator, which gives an overview on the state of fulfilment of the requirements specification and the technical progress respectively maturity of the single project. Thus it shows in a simplified sense, how far the project has advanced. Of course, it does not make much sense to derive a single key figure (e.g. 50 or 90 percent) due to the fact that in complex product development processes no workflow can be described precisely and much other information are to record, such as problems, decisions, etc. The project monitor is strongly connected to the information basis (protocol system) and a system for the requirement specifications. The respective tools are described beneath.

3.1 Protocol System

In meetings a great part of the information flow takes places within complex product development processes [12]. Beyond many decisions are made here. Drawing on that that, the protocols of a meeting become a major information pool. They are spread around the company and build a strict basis for further development. But since protocols often are not standardized, consistent or appropriately exchanged a so called Interactive Protocol and Analysis System (IPAS) has been developed [13].

This system is based on agenda items, which in fact can be elements of the comprehensive product structure. To each item one or more entries will be allocated, respective to the meetings the item was discussed. For example an item may be a problem concerning crash tests at the back rest of an automotive seat and the respective entries may be the recognition of the problem, a description of the cause, measures, new test results, etc.

The entries can be classified into information, decisions, problems and causes, as well as activities and measures. They are furthermore specified by dates, open and finished, the concerned person and division, etc. (v. Fig. 1). The entries can be “frozen”, so that there are no more changes possible and the protocol becomes a reliable document.

It is also possible to analyze the entries for cause and effects chains, presence in the meetings, frequency of a specific topic which can be an indicator for the efficiency of the team or the process, etc. By that further conclusions can be derived from the data pool, e.g. a high frequency of a topic discussed might be an indicator for related problems. There are approaches analyzing protocols in order to find items that have already been discussed before. The intention is to see if there is already a solution for a problem when it is discussed in order to avoid redundant work. The protocol system shall also change the organization of a meeting by presenting the actual aspects and leading through them. The direct record in front of all participants shall secure the consensus concerning a decision or entry.

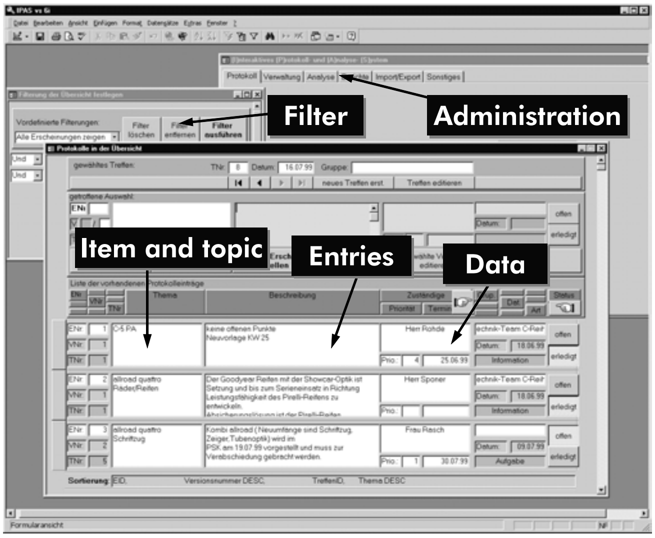

Figure 1: Protocol system

3.2 Requirement Specification

The requirement specification is not only important for the clarification of the task and by that for the whole development; it is also the basis for contracts with suppliers [14]. In automotive industry, the specifications are extensive documents mainly describing which tests the product has to fulfill. To compile the requirements specification for a new product needs high efforts even though many parts are taken over from previous projects. Yet consistency is not guaranteed, which becomes even worse by later changes. Another problem is to decide between a product oriented structure, which is important for an overview of parts or assemblies including the particular person in charge, and a functional oriented structure, which is more recommended for specific activities, such as design and testing, or characteristic product properties such as weight, safety, quality, etc.

To overcome these problems, we implemented a specifications systematic also based on the document management system. The requirement specification has been standardized and modularized into a general part (independent to a particular project or car model), a general testing part structured by the main subassemblies, and a product specific part, again differentiated into a general and a subassembly oriented testing part. This is completed by links to other documents, e.g. concerning comfort standards or other regulations.

Finally the project-related requirement specification now can be easily derived and specifically adapted from the single predefined modules.

3.3 Project Monitor

The so called project monitor [15] as the core of our information platform concept focuses on target and result oriented coordination of planning, scheduling, and controlling, as well as the provision of all relevant information within the project [16]. Again, monitoring means the collection of information on the current project status, its comparison to the planned targets, the realisation of deviations, and the analysis of respective causes and effects [17], which is implemented in a control loop [18], as which the product development process can be regarded from a management point of view.

The controlling of development processes from a technical point of view shall cover all relevant data for the management of the project. Thus the tool monitors for costs, weight, dates and milestones, occurring problems, and the status of tests, design, and functions.

Cost and Weight: Cost is one of the most important key figures of the final product. At this direct, investment, and development costs have to be regarded. Afterwards these costs are assigned to the parts and subassemblies of the product structure. The hierarchic structure allows summating the costs for assemblies, modules, or even the whole product. For each change of the costs, a new dataset stores the current values with the cause of the change, assigned to the respective date. Next to the actual values, the targets, which can also change within the process, are stored in the table. From these entries, percentage changes and trends of the cost development can be derived. Weight is monitored in the same way, the only difference is that there is only one kind of weight, the actual direct value, which is either calculated or weighed.

Project Schedule: The project schedule in form of a follow up chart represents the progress of the process by showing relevant dates for each necessary part, assembly, or module. It contains milestones e.g. for releases with the respective target as well as the actual or forecasted date.

The comparison of target and actual date leads to a status in form of a traffic light ("green" means no delay, "yellow" means no delay due to measures or delay not critical and "red" means critical delay that requires strong measures). Though the milestones are predefined references and indicators for the process, they can easily be changed, as well as further milestones can be integrated. For an effective and efficient development, it is important to understand that these milestones do not only contain appropriate results, but also demand a clear decision for further development. The project schedule with milestones can be supplemented by a list of tasks which are to fulfill for the design of the part or assembly. Each task can be rated how far it has been worked out, and by that a general status can be estimated.

Problem List: A problem list, also called quality list, is another important document for later phases of the product development process, i.e. the detailed embodiment design, the serial production planning, as well as production and customer service, since during that stages problems from product development mainly occur. The problems are documented related to the elements of the product structure. The problem itself is described with separate entries; furthermore its cause and respective measures shall be added. Additionally, costs of the problem and the progress of its treatment, dates, and persons in charge can be appended

Testing Status: In automotive development, nearly each part and assembly has to be tested with regard to the fulfilment its requirements. These single tests concerning endurance, function, safety, misuse, etc., as well as the large amount of tests in total has to be controlled accurately. At this it has to be differentiated between the tests themselves, the concerned parts and assemblies, as well as the design status (e.g. models, prototypes or finished products).

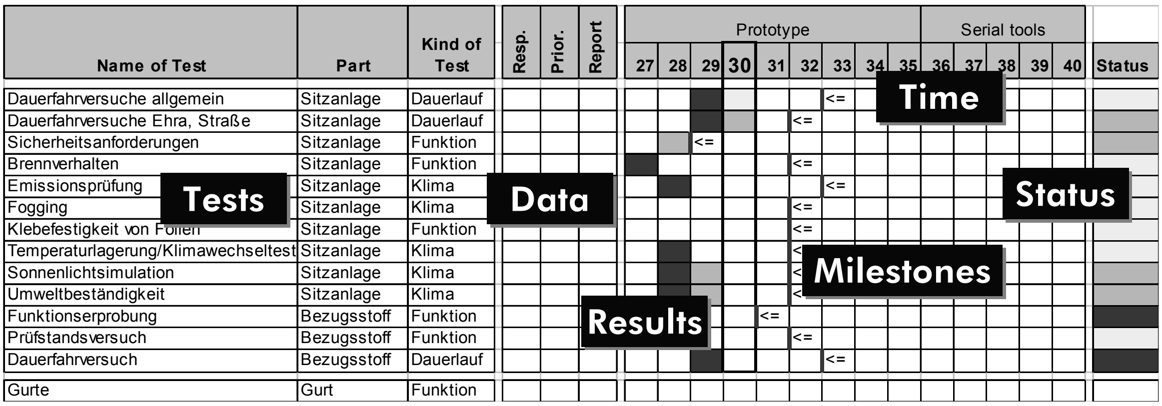

Figure 2: Testing status

A database approach allows ordering these aspects in any way, completed by dates, persons in charge, comments, reports, values, etc. There has to be a differentiation between the status of the single tests ("green" if test passed, "yellow" if test failed but this is not critical and measures are initiated, "red" if test failed critically, and "white" if test has not been done yet but will be done in time) and the status of the object itself. This means, a failed test at an early date need not mean a critical status, but a not yet done test can result in a critical overall status, if there is not enough time e.g. for reaching the next milestone (cp. Fig. 2).

Design and Functions: Finally the design status represents the completeness of documentation within the design process, primarily CAD-files for each part, part lists, or assembly instructions for example. Similarly to a key figure for the completeness of a product, the design status is a necessary basis for any digital mock-up, (i.e. a complete virtual model of the product), and for further examinations, e.g. collision or design space analyses.

Similar to the tasks within the project schedule, another possible project status may be established by the regard of the product functions and requirements. At this, technical functions, legal constraints, comfort, quality, optics, process reliability, stability, etc. are considered on a more detailed level. These criteria can be weighted and separately rated on their fulfillment (0 – 100 %). At last the whole status can be calculated (similar to evaluation on weighted criteria). Admittedly such a key figure must not be understood as a precise value, it is just an indication for the progress of the process.

3.4 Human factors

In how far product development can be precisely described by a process or an algorithm, or how far it is driven by the experience, capability, and flexibility of the involved people and employees will not be discussed in this contribution. Nevertheless, flexibility provided both by the organization and the individual is crucial. In this way, the emphasis of the individual has been increased by explicitly regarding the human factors as central element in each organization. Some of these human factors are human needs and their fulfilment (basic needs, security, social needs, and self-realization), leadership, motivation and pressure, qualification and promotion, competition benefits, and status as well as tasks, functions, interactions, targets, norms, and values. In general these factors contribute significantly to what is called working atmosphere and corporate culture.

Apparently they are important for management and product development, both for regarding and organizing projects. They cannot be discussed here in detail but they may be taken into account as soft facts standing next to the above monitored hard facts when controlling the distributed development. In fact, they may be used as not quantifiable aspects of a project to build up a controlling system too. Such a system would base on surveys from the employees, e.g. containing questions like "In how far will management decisions change the design?", "How much efforts are necessary to solve that problem?", or "When will the project be finished?". By such surveys it might be possible to reveal even more of the (also technical) potentials and problems within the project. To controlling these soft facts cannot substitute the hard facts' controlling, but it is a necessary supplement. But one may not forget that these soft facts are even harder to acquire than the hard facts due to different reasons, such as psychological or hierarchical barriers.

3.5 Integration of Single Elements

As mentioned before, the information platform consists of a protocol system, the requirement specification, and a project monitor. These tools were described separately, but they become even more effective if they are regarded together. Possibilities of their integration are considered afterwards.

First of all the tools should be integrated in one database thus contributing to an integrated instrument for coordinating and controlling distributed development processes. For further development we may suggest an additional tool which is associated with the Balanced Scorecard. Within this concept metrics and key figures regarding distributed development and the status of a product development are summarized and allow the appropriate management and improvement of that processes.

Using an integrated database, it would be possible to implement a comprehensive target management in the following. Since the above described tools have many cross connections among each other, an integrated database implementation should allow relating and summarizing these specific elements in order to come to one comprehensive view instead of an amount of detailed perceptions with overlaps, contradictions, redundancies.

E.g. many improvements in weight or cost reduction actually concern both aspects. By merging the potentials with all their effects, targets can be balanced against each other. Furthermore the entries in the protocol systems are often identical to the items in the problem list. Strong deviations between actual and target values could directly generate an entry in the protocol system or the problem list respectively. As already annotated, the functions of a product or the tasks of a project can be regarded as milestones, as well as the completeness of the documentation, and by that combined with the project schedule too. The requirement specifications system again can be the basis for the previous mentioned functions, as well as for the testing status.

The system can be extended by other aspects of managing distributed product development processes, due to the modular design of the tool. Nevertheless, the integration of these aspects helps to build up a comprehensive overview of the whole system and its targets, which can be called target management.

Even though there are many approaches to achieve a specific target, e.g. Target Costing [19] or Design for X [20] a comprehensive and integrated regard of the cross connections between the requirements and targets of the product is missing. This corresponds with practical experiences, where specific managers or promoters mainly focus on one aspect.

On the other hand the above described connections within the controlling system do allow balancing some characteristics and requirements against each other An even more differentiated embodiment of the requirements within the specification system, e.g. not only containing technical tests, would lead to a kind of comprehensive target management. Similar to target costing, it might consist of splitting, committing, and control certain targets. The controlling is supported by our approach, but should be extended by a clear method for balancing the single aspects. At last the splitting of the target should not only depend on the product structure, (compared to target costing), but emanate from a higher level of abstraction, e.g. from functional structuring.

4 Implementation of the Systematic

Concerning the implementation of the introduced systematic, there are two main aspects to regard. The first one is the implementation in an application and the use in general. This yet was described. The other aspect is how to introduce and integrate the application into running development processes. Still both aspects are of course closely connected to each other.

For the implementation and integration of the introduced tools in industrial practice the aspect of developing, maintaining, and adapting the tools to changing situations is crucial for the success of adoption. Thus for the acceptance and usability of the methodology it has to be a main objective that the tool itself retains a certain flexibility and that this flexibility is understood by the users [21], e.g. including that the tool can be somehow adapted by the user. Consequently the tool and the methodology behind have to be made transparent and intelligible and the employees and users have to be trained respectively.

This directly leads to the introduction of the method into running business processes comprising the steps of initiation of the method implementation, analysis of the product development system, choice and adaptation of methods, the actual implementation of methods, and the evaluation of the impact [22]. Here the actual implementation is critically in particular and ones should pay special regard on imparting, introducing and anchoring the methods, as well as the involvement of employees and improvement of practice.

In practice our implementation strategy bases on standardized electronic document that are exchanged via internet and an existing document management system called "documentum 4i". By that email exchange between single persons can be reduced and information can be fed by responsible and quickly distributed to concerned employees. This approach is driven by the idea that employees who want to publish information are to place it at disposal in some kind of marketplace. Otherwise employees requiring certain information have to gather it from that central location where all the information is stored. By that, the risk of redundant or even outdated information shall be reduced. Of course special data security is required provided by a special network, ENX, which was set up especially for the European automotive industry. Beyond the introduced tools the document management system can also serve for the general exchange of any information or document. The second step to do will be to set up an intranet database as well which contains the above described tools and respective information. The information platform currently is implemented within in two divisions and first experiences and insight from practical application will be gain here.

5 Conclusion and summary

Distributed product development, e.g. in the form of outsourcing, becomes more and more important for any industry in order to cope with the high requirements of the market, both of customers and competitors. It is a strategy in order to handle the complexity of products and processes and it implicates potentials as well as risks.

In the contribution at hand we have presented strategies and tools in order to support the management, in detail focussing on controlling and coordination of distributed development processes. The introduced set of methods consists of a project monitor, which delivers a current project status regarding costs, weights, milestones as well as development progress. Further tools we introduced are a requirement system, giving an overview of the product and process targets, and a protocol system, which captures the course of the project. In fact elements of these instruments are already in use in every company but we centred on the integration of these methods, their continuous and systematic use and an appropriate implementation.

Next to the controlling of distributed processes, there is another strategic aspect, i.e. which part of the product or the process should be outsourced and in which way, and the operational aspect of management, i.e. how to enable designers and engineers to work together on single tasks. Further aspects, which have to be regarded in the future, are a systematic planning and balancing of the requirements, which we like to call target management, as well as a systematic planning, scheduling, and processing of the evaluation and testing of product properties as a basis of the development process. An extension towards variant management and mass customization is intended as well, since the variants of a product are a major part of the complexity within product development and by that a main task for management nowadays. A respective structure planning process together with appropriate tools has to be described for early phases of the development process.

The next steps of the further work aim at an improvement of the presented strategies and tools and an implementation on a broader basis. In addition, strategies for planning distributed product development processes as well as operational aspects are analyzed and integrated in the presented approach. By that, we like to synthesize to a flexible process building set and a comprehensive methodology for distributed product development.

6 Acknowledgments

We thank the DFG (Deutsche Forschungsgemeinschaft) for funding this project in the scope of the TFB 29, as well as our partners from industry for the good collaboration and their extensive support.

References

[1] Gierhardt, H., "Global verteilte Produktentwicklungsprojekte – Ein Vorgehensmodell auf der operativen Ebene", Ph.D. thesis, TUM, Munich, 2001.

[2] Bullinger, H.-J., Warschat, J., "Concurrent Simultaneous Engineering Systems", Springer, London, 1995.

[3] Wiendahl, H.-P., "Betriebsorganisation für Ingenieure", Hanser, Munich, 1997.

[4] Lindemann, U., Pulm, U., "Enhanced Product Structuring and Evaluation of Product Properties for Mass Customization", Proceedings of the World Congress on Mass Customization and Personalization, HKUST, Hong Kong, (CD-ROM), 2001.

[5] Otto, K., "A Process of Modularizing Product Families", Proceedings of ICED `01, Vol. Design Methods, Glasgow, 2001, pp. 523-530.

[6] Eppinger, S. D., Salminen, V. K., "Patterns of Product Development Interactions", Proceedings of ICED `01, Vol. Design Research, Glasgow, 2001, pp. 283-290.

[7] Lindemann, U., Wulf, J., 2001, "Action orientation in design methodology", Proceedings of ICED `01, Glasgow, 2001, pp. 131-138.

[8] Bichlmaier, C., "Methoden zur flexiblen Gestaltung von integrierten Entwicklungsprozessen", Ph.D. thesis, TUM, Munich, 2000.

[9] Marca, D. A., McGowan, L., "SADT – Structured Analysis and Design Technique", McGraw-Hill, New York, 1988.

[10] Pahl, G., Beitz, W., "Engineering Design – A Systematic Approach", Springer, London, 1996.

[11] Demers, M., "Methoden zur dynamischen Planung und Steuerung von Produktentwicklungsprozessen", Ph.D. thesis, TUM, Munich, 2000.

[12] Ambrosy, S., "Methoden und Werkzeuge für die integrierte Produktentwicklung", Shaker, Aachen, 1997.

[13] Lindemann, U., Ambrosy, S., Aßmann, G., Gmelch, T., "Managementwerkzeug für dezentrale Kooperationen - Online-Protokollierung IntraPAS", ZWF, Vol. 12, , 1999, pp. 716-719.

[14] Ehrlenspiel, K., "Integrierte Produktentwicklung", Hanser, Munich, 1995.

[15] Seng, T., Knapp, C., Hoffmann, J., "Project Monitoring," Betonwerk + Fertigteil-Technik, Vol. 12, 1998, pp. 57-62.

[16] Horváth, P., "Controlling", Vahlen, Munich, 1998.

[17] Süß, G., Ehrl-Gruber, B., "Projektmanagement", Weka, Augsburg, 1995.

[18] Wissler, F., "Entwicklungscontrolling im Produktentwicklungsprozess", In: Schraft, R. D., Westkämper, E., "Effizienzsteigerung in der Produktentwicklung", Fraunhofer IPA, Stuttgart, 2001.

[19] Stößer, R., "Zielkostenmanagement in integrierten Produkterstellungsprozessen", Ph.D. thesis, TUM, Munich, 1999.

[20] Huang, G.Q., "Design for X", Chapman & Hall, London, 1996.

[21] Zanker, W., "Situative Anpassung und Neukombination von Entwicklungsmethoden", Ph.D. thesis, TUM, Munich, 1999.

[22] Stetter, R., "Method Implementation in Integrated Product Development", Ph.D. thesis, TUM, Munich, 2000.

For more information contact:

Christoph Baumberger, Udo Pulm
Department of Product Development,
Technische Universitaet Muenchen,
Boltzmannstr. 15
D-85748 Garching,
Germany,
Tel: +49 (0)89 289 15153
Fax: +49 (0)89 289 15144
E-mail: baumberger@pe.mw.tum.de, pulm@pe.mw.tum.de,
URL: www.pe.mw.tum.de