METHODS AND TOOLS TO IMPLEMENT PLM-INTEGRATED MACHINE AND PLANT CONFIGURATORS

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Abstract

This paper summarizes project experiences gained in integrating and building unified product models for sales engineering support of investment goods. The core of such a product- and project-oriented CRM solution for the discrete industry is a graphical machine and plant configurator, fostering knowledge-driven automation in the order acquisition and basic engineering phase.

Critical factors and best practices are reflected concerning master data harmonization, classification of product elements, integration of geometric and logistic product dependencies, preparation of lightweight 3D visualization data, BOM structuring, fusion of technical with commercial calculation, and the acquisition and maintenance of product logic. Beside technical aspects and the support by IT editing tools, organizational responsibilities and best practices in configuration project management are covered.

Keywords

Master Data Management, Product Knowledge Management, 3D Product Configuration, Product Life-cycle Management

1 Introduction to Machine and Plant Configurators

In today's discrete industries a clear trend towards development and marketing of modular products can be recognized. The specific needs of selling technical products to international B-to-B customers in the context of growing global competition forces many manufacturers to address rationalization and differentiation potentials in their sales and basic engineering processes. Producers of machines and plants are therefore shifting from unprofitable design-to-order models to individually configurable product systems based on reusable modules and assemble-to-order (ATO) fulfillment. While consumer goods may be delivered in a pure ATO approach, investment goods typically need 10-50% of custom-specific redesign, new design and layout planning.

2 PLM as Integration Issue

Companies shift their focus from technology-oriented innovation support to enterprise-wide Product Lifecycle Management (PLM) regarding requirements from production, procurement, marketing, sales and service processes. The basic engineering typically has to be delivered for free in the acquisition phase. To streamline the sales engineering process between design teams, sales people, project engineers, planning partners and customers, the relevant product information has to be handled in an integrated and collaborative way that bridges distributed CAD, PDM, ERP and CRM systems.

While the product development process is well-supported by 3D CAD tools and the production process profits from well-established ERP and PPS tools, machine and plant manufacturers often suffer by the missing digital link inbetween, where product management, sales and custom-specific engineering takes place. Implementation projects of machine and plant configurators (Figure 1) realized with P'X5 [Perspectix] are therefore mainly concerned with the integration of processes, products, tools, and data [Ackermann, 2004].

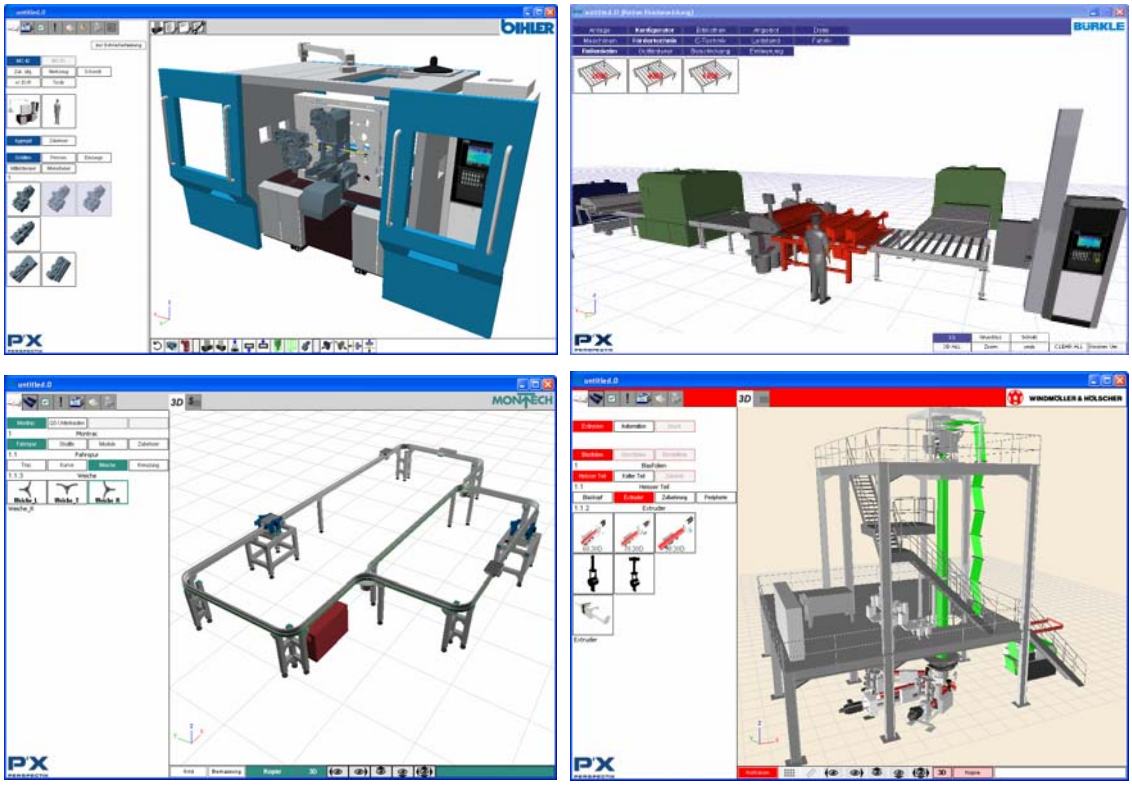

Figure 1: Examples of machine and plant configurators with P'X5.

3 Iterative Project Life-Cycles

The broad scope of an implementation project for a configurator - encompassing product, process, data and tools integration – enforces a corresponding project management approach. A lot of similarities exist with software projects implementing ERP or PLM systems. The project methodology used at Perspectix follows the example of common software engineering approaches – especially Unified Process [Jacobson, 2000] and the agile process of Extreme Programming [Beck, 2005] – and was adapted to address the specific challenges of PLM-integrated configuration projects. It is based on iterative project life-cycle phases (Figure 2).

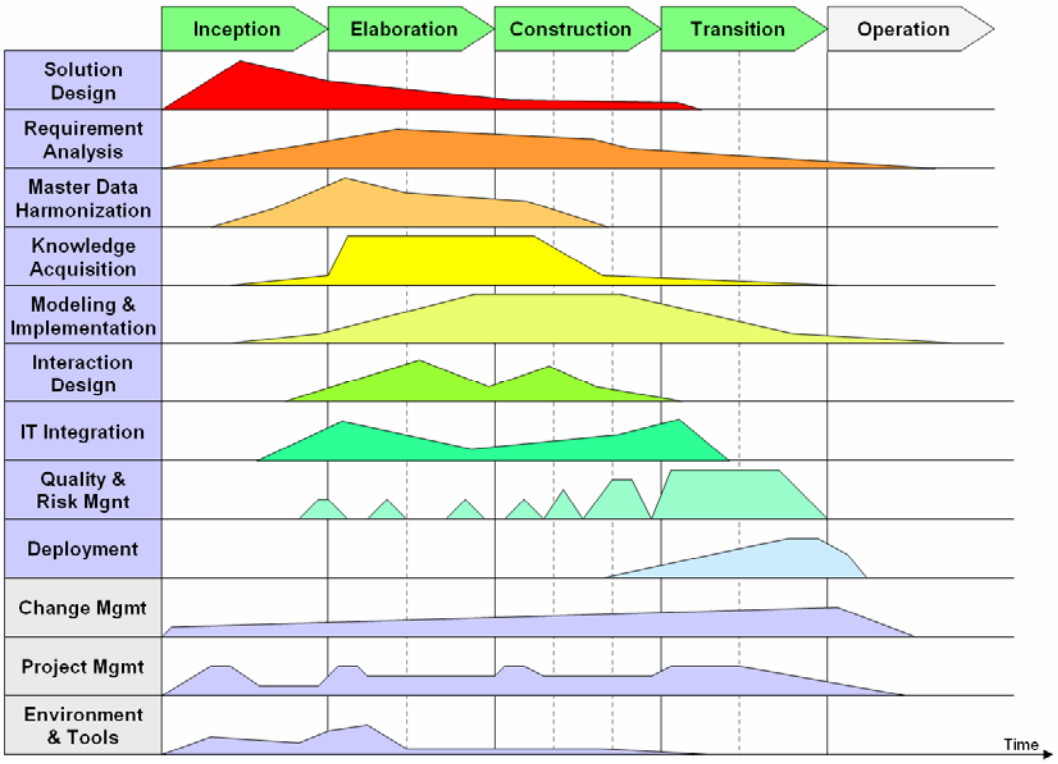

Figure 2: Iterative life-cycle model of the phases in a product configuration project.

In order to acquire all relevant requirements and the comprehensive knowledge needed to create an explicit product and process model, early involvement of all stake-holders is a key success factor. User involvement and participation is also important to create user acceptance. Stake-holders and key users represent roles from different departments including:

- Product managers
- Product developers
- Production specialists
- Sales managers / account managers
- Field sales
- Engineers / project managers
- IT specialists

Effective involvement needs early working prototypes which incrementally evolve in short iteration cycles. Because technical possibilities influence business opportunities, solution finding does not work in a pure sequential top-down approach. Therefore the following procedures are important for the service quality of configuration projects:

- Project life-cycle model in phases and iterations
- Empirical verification of conceptual paperwork within prototypical implementations
- Incremental prototyping with small releases for evolutionary improvements
- Continuous quality and risk management via continuous integration and testing
- Acceptance tests with key users to get feedback from business units

To foster the collaboration between stake-holders, key users and configuration experts, a mix of synchronous and asynchronous as well as “analog” and digital communication is used:

- web-based project support site
- email messages
- online data repositories with version and history control
- collective ownership of knowledge bases
- a working prototype of the configurator
- stand-up meetings at blackboard
- formal meeting protocols

4 Project Tasks in Implementing PLM-integrated Configurators

4.1 Solution Design and Requirement Analysis

The starting point of a configuration project is a workshop with the stake-holders where the existing processes, the product portfolio, and the IT infrastructure are analyzed. Potential improvements and expected benefits from applying a configurator are documented (Figure 3). In a solution sketch a rough functional specification and interface definitions to existing IT systems are depicted. A project plan with a cost/profit and ROI view complete the solution design.

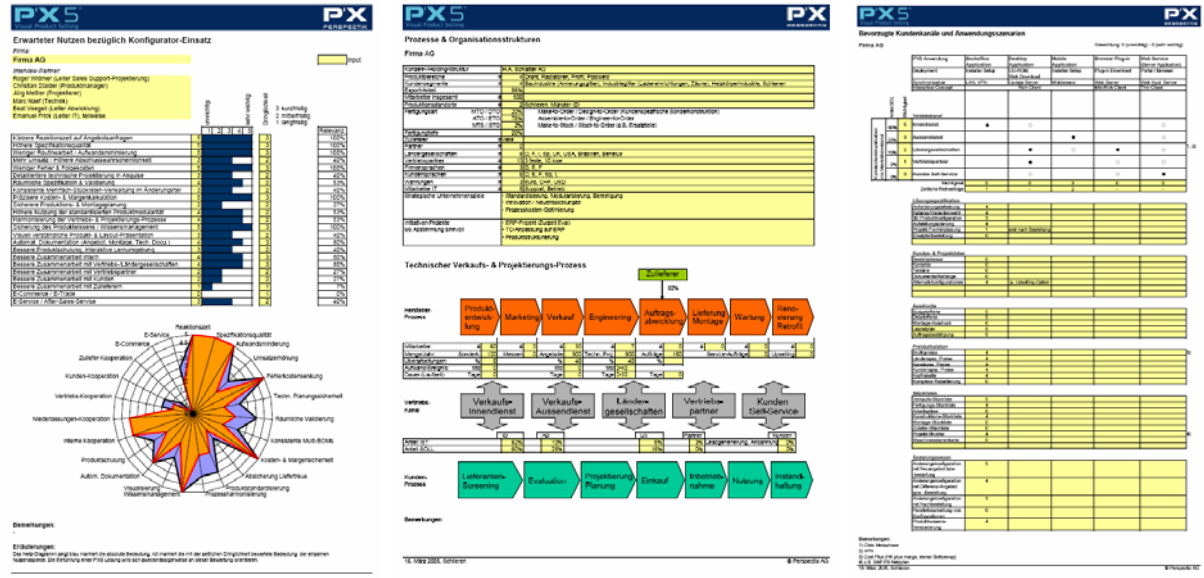

Figure 3: Documentation of workshop results.

4.2 Master Data Harmonization

The main sources of relevant product information are CAD, PDM and ERP systems. These federated product master data need harmonization towards sales engineering because they often reflect the specific views of product development and production. On top of these data sources, additional meta-data is specified such as unit categories, attribute types, value domains, classification hierarchies, prices and language translations.

4.2.1 Standardization and Classification of Sales Engineering Systematics

During the enrichment of master data, the added meta-data helps in analyzing data consistency, in checking for duplicates, and in validating the referential integrity. Media files such as images, 3D graphics, and PDF documents are linked to the product entities. These tasks are typically executed by product managers, therefore a role-specific tool (Figure 4) is provided that supports the preparation of product information which are used by the configurator as well as print catalogs, online catalogs and spare-part catalogs. The “Product Management Tool” supports the process to acquire, harmonize, enrich, and publish product information that are organized in a sales and project planning systematics. Table 1 lists typical tasks supported by the product management tool.

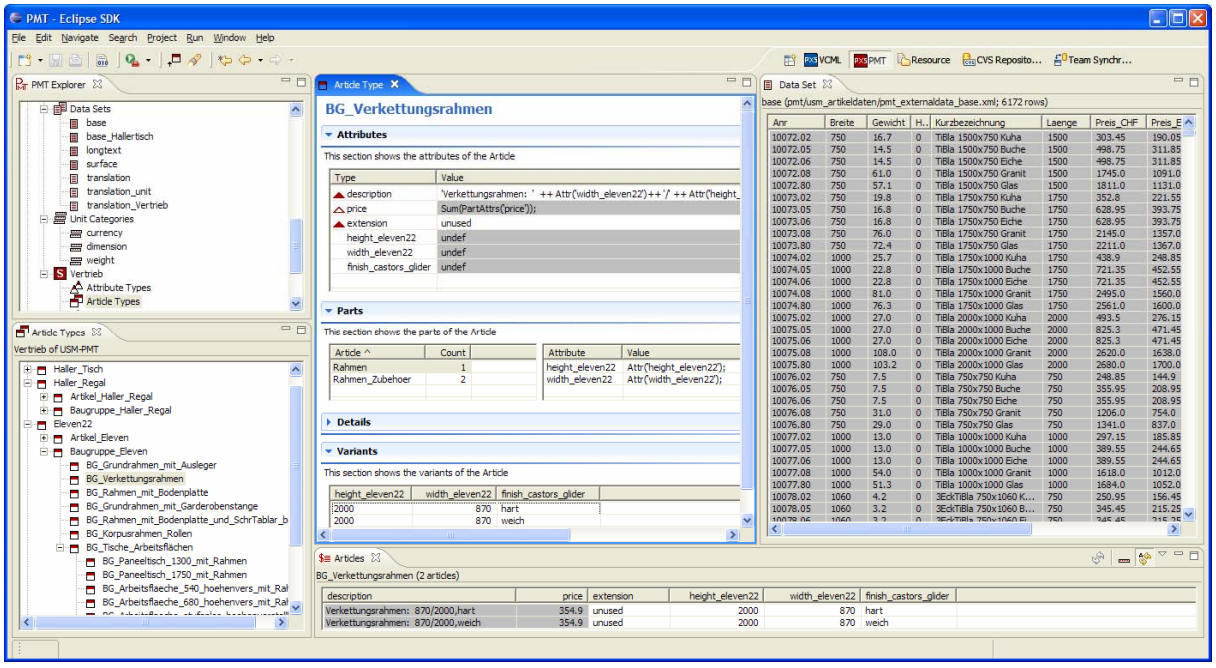

Figure 4: “Product Management Tool” to harmonize and classify product data and structures.

merge	import product master data from different sources (tables, XML, images, 3D, PDF, …)
model	define meta-data on product entities such as unit categories, attribute types & domains
browse	search, sort and filter product data; navigate by classification trees
edit	create, delete and change product information; add annotations/comments
map	relate data fields across tables; extract and normalize data fields into attributes
classify	organize entities in inheritance hierarchies with attribute assignments
structure	define assemblies with part-of relations; generate variants over attribute options
calculate	define cost and price calculation schemes; sum-up along product structures
segment	build product groups, e.g., for product catalog structures
analyze	check for data consistency, duplicates, and referential integrity
release	control versions and change history
publish	export the enriched product data to online catalogues, configurators, ERP system, …
print	generate print catalogues

Table 1: Tasks supported by the Product Management Tool.

The structuring and classifying of product-oriented master data includes multiple aspects of an integrated product-service mix: mechanics, pneumatics, hydraulics, electronics, software, and services. Each aspect has its own classification but all need a modularization into an integrated platform or modular construction system. The presentation in catalogs requires customer-oriented structuring of the classified elements into product lines and product groups.

4.2.2 Preparation of Visualization Data

Beside formal, table-based master data, graphical representations such as schematic 2D or virtual 3D geometries are handled in a PLM-integrated approach as master data as well. 3D visualization geometry is typically derived from solid models in CAD systems and has reduced complexity (only facets of the hull, filtered features, no construction history). 3D visualization data has to reflect the product structure used in sales and engineering, therefore they need to map to sales assemblies and planning modules. Additionally, the 3D modules may define geometrical interfaces such as snap points. The P'X5 CAD Plug-in allows the geometric specification of classified module interfaces in order to capture the design intent of a 3D part within a modular building system.

Similar to the process of generating exploded 2D drawings for technical documentation, the preparation of lightweight 3D visualization data becomes a common task of the development department. The lightweight 3D geometry is used in the down-stream process for 3D catalogs, layout planning, 3D product configuration, and 3D spare part management. Because they are used in customer communication processes, they are prepared to look realistic by defining correct colors and by adding textures.

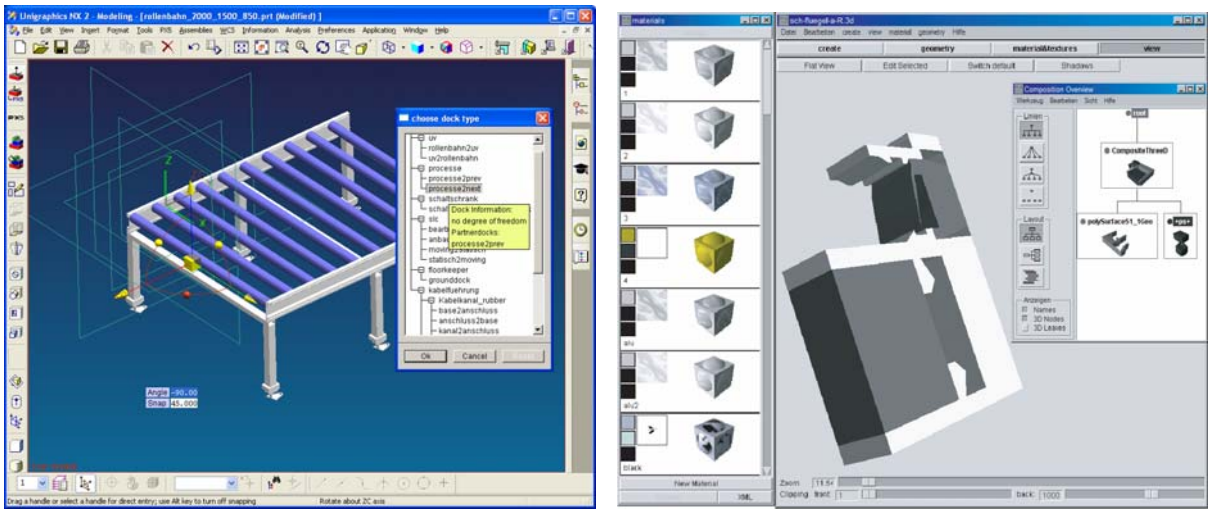

Figure 5: CAD Plug-in for module interface definition and a visualization data editor.

4.3 Acquisition of Product Knowledge

The performance and acceptance of a configurator depends directly on the quality of the knowledge acquired. Determining the domain and scope of the knowledge base is not a static definition but changes during the iterative project life-cycles. Managing knowledge is therefore an ongoing process in order to maintain and improve the corporate knowledge.

The steps to build a product knowledge base are:

- determine domain and scope
- enumerate important entities with their terms
- organize terms in classes and class hierarchies
- define properties and interfaces (e.g., geometric connection points) of classes
- capture dependencies by rules, constraints, and formula expressions

By following a PLM-integrated approach, knowledge acquisition is a difficult task because diverse people, roles, departments and their specific requirements have to be harmonized into a consensual understanding. A first task in acquiring product and project knowledge is to identify the departments, systems and foremost people that can make this information available. Shared conceptualization of process steps and portfolio entities within a common vocabulary is needed by enumerating important terms. In addition to capture know-how from experts, the unifying of knowledge is an important work in order to gain benefits in knowledge-driven automation that bridge mental and organizational boundaries in collaborative business processes.

4.4 Modeling of Logic and Behaviour

In modern approaches, the explicit modeling of product knowledge bases heavily depends on object-oriented classification and descriptive logic encoding. The use of modeling patterns such as inheritance, property propagation, declarative rules, etc. requires formal and abstract thinking but fosters the building of an elaborated product information architecture that facilitates reuse, integrative consistency, generic logic definitions and ease of maintenance.

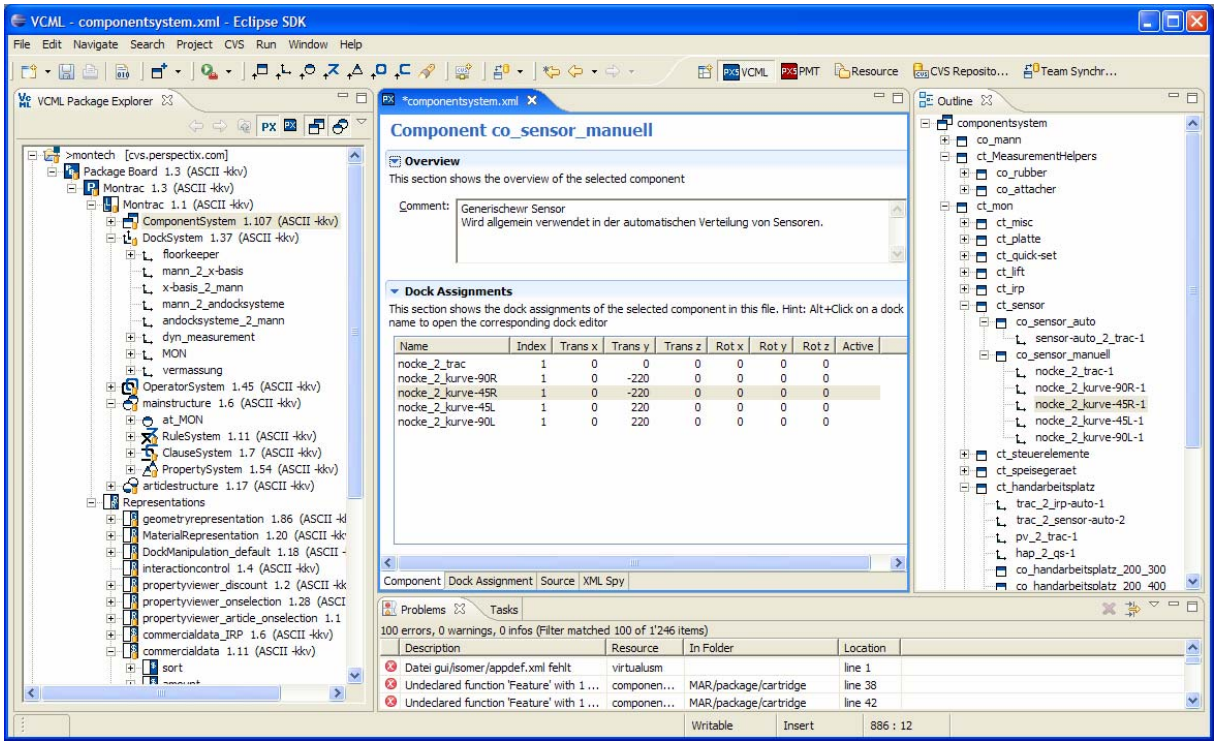

Figure 6: Authoring workbench for product knowledge management.

Tool support in an integrated authoring workbench (Figure 6) is a prerequisite to manage the complexity in modeling product knowledge bases and to enable collaborative editing in expert teams including specialists from product development, product management, sales, project engineering, production, and service. Product knowledge modeling is an iterative process consisting of data integration, logic definition, and validation. Interactive validation and automatic testing is supported in a run-time environment (Figure 7). Simultaneous work by distributed modeling team members is synchronized by committing to and updating from a shared repository of the unified product knowledge base.

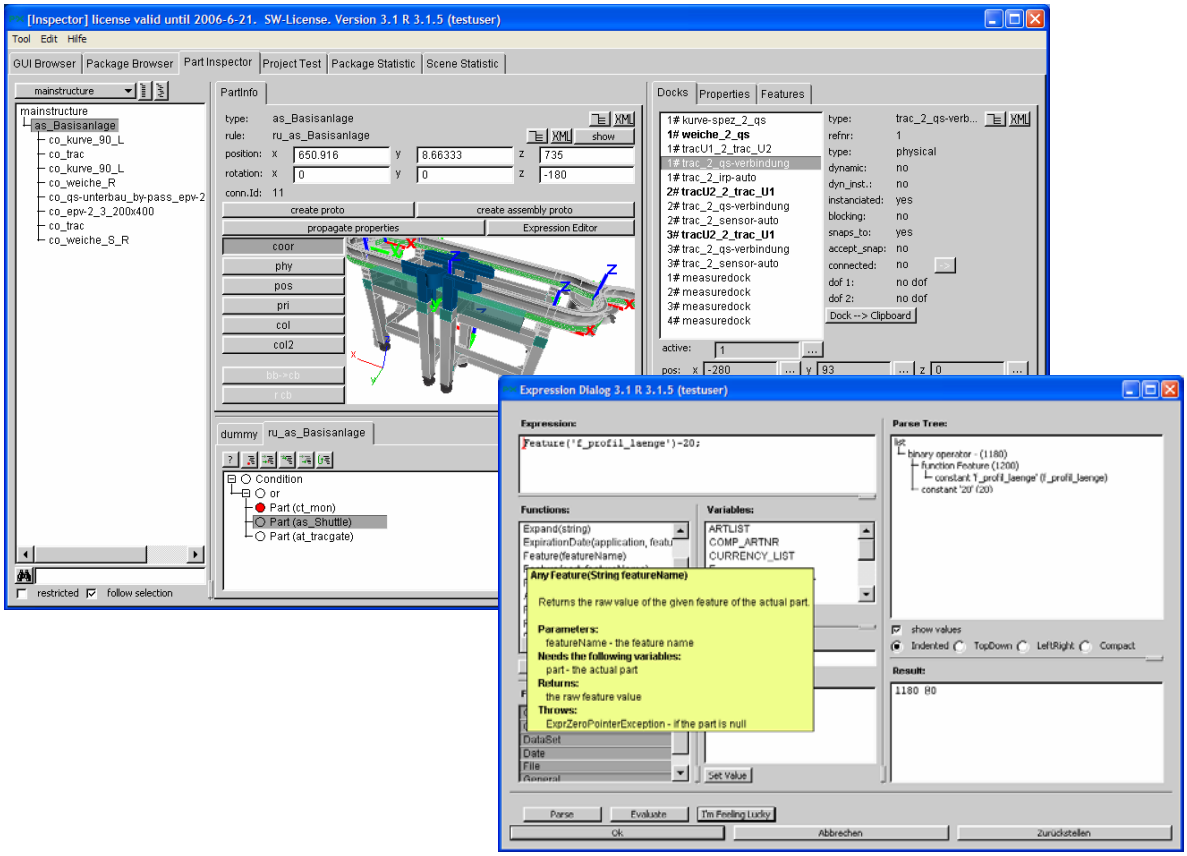

Figure 7: Run-time environment for testing rules, constraints, and formula expressions.

4.5 Interaction Design

By clearly separating model from view – or in other words: logic from representation – the interaction design of the configurator can be customized to the needs of different user categories, application scenarios, sales channels, and distribution media [Ackermann, 2001]. Task requirements and product complexity define the best use of product representations such as options, text descriptions, schematic 2D, virtual 3D, or a mix of them. Interaction elements depend on the chosen product representations and the desired knowledge-driven automation which may be different for professional users (such as project engineers) than for casual users (such as field sales) or even web users (such as customer self-service). The level of automatisms built into the configurator typically rises during the iterative project phases, therefore some redesigns of the interaction design and the user interface are common.

4.6 IT Integration

A PLM-integrated product configurator has potential interfaces to CAD, PDM, ERP, and CRM systems of the manufacturer's IT backbone. In order to support the distributed and collaborative nature of sales engineering projects, a middleware has to provide mechanisms for online/offline synchronization, data replication, and project hand-over between back-office, field sales, partners and customers. Network-based file and database services for workgroups as well as Internet-based technologies such as web services and web portals provide seamless collaboration. Security concerns have to be addressed due to the strategic relevance of the content within the knowledge base. The alignment with the existing IT infrastructure and the customizing of the system interfaces have to be planned and executed carefully in order to establish an integral digital value chain. The XML-based representation of the P'X5 product knowledge base serves very well as an integration middleware for different IT systems.

4.7 Deployment and Launch

The deployment workflow delivers the configurator with its knowledge base along with additional materials necessary to assist the end-user in learning, using, and maintaining the configurator. Beside information on how to install and operate the configurator software, user manuals and training tutorials mostly address the handling of the modeled product complexity, the new process how to configure custom-specific solutions and the corresponding workflow. Typically, the key users of the implementation project develop the training materials and documentations. The launch of the configurator is often embedded in marketing events for partners and customers such as trade fairs or sales meetings which need additional marketing-related materials such as brochures, email announcements, web support sites, CD-ROM packages, and press releases.

4.8 Quality and Risk Management

Quality standards and procedures have to be followed to ensure the required level of technical quality of the product knowledge base, the knowledge-driven automatisms, the application usability, and the data flow of integrated IT systems. Continuous integration and testing of the prototype application to get key user feedback (see Chapter 3) are vital for an effective quality management. At the end of each iteration phase, quality and risk issues are measured and documented in check lists and validated within the project progress (Figure 8 on the left).

Besides technical quality risks, organizational project risks have to be handled carefully. Typical risks in a configurator project are:

- Strategic and operational relevance of the configurator project in terms of standardization and integration of processes, product portfolio, master data and IT tools is not clear to all
- No active sponsorship from top management to enforce the strategic project goals
- Weak position of product management to define an integrated, modular product platform in line with market requirements
- Project manager prefers his own one-sided optimization view and jeopardizes integration benefits

- Lack of direct access to relevant experts and key people due to work overload or competing projects (e.g., 3D CAD/PDM implementation or ERP migration)
- Unwillingness of information holders to provide their knowledge
- Underestimating the harmonization, modularization and modeling workload
- High cascade of test, feedback and formal protocols after each project iteration phase is not understood as fundamental part of the specification and quality insurance process and therefore participation is suboptimal

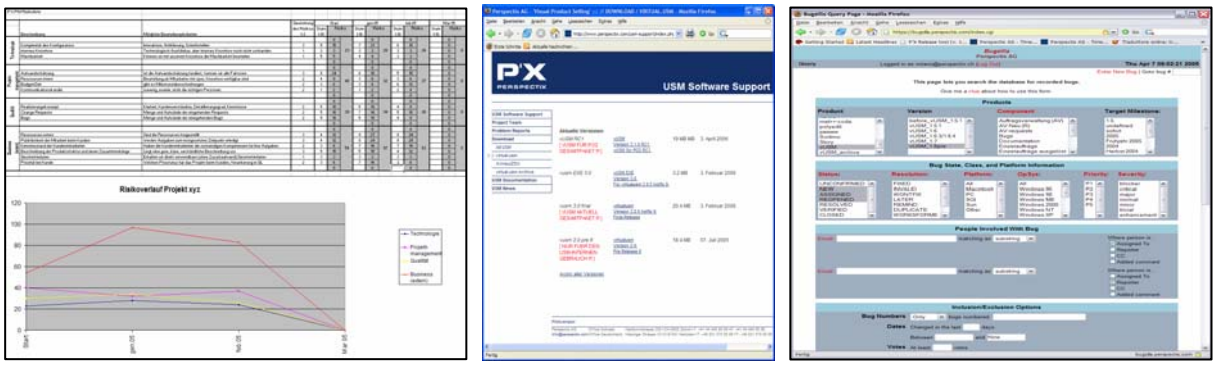

Figure 8: Risk analysis tool, web support site, and web-based requirements & error tracking.

4.9 Project and Change Management

A configurator project needs general project management for planning, coordinating and controlling resources, tasks and milestones. An important task of the project manager is a proactive change management [Møldrup, 2004]. By modeling a knowledge base, many issues concerning the product portfolio and the fulfillment process become explicit and have to be clarified and unified in enterprise-wide discussion forums involving all relevant key people.

Portfolio change issues caused by product & service modeling/reengineering are

- What is our active product portfolio? What is standard, what is specific?
- Which product elements are obsolete and can be removed from our catalog?
- Product standardization, product modularization, redesign of product platform
- What is our product-service-mix? What are our modular services?
- What is our standard cost and pricing calculation scheme? What discounts are allowed?

Organizational change issues caused by process & project modeling/reengineering are:

- Strong, historically established traditions, cultural mindsets and mental borders between departments which prevent superior improvements, e.g. between sales and engineering
- What does customer orientation mean in our company?
- What implications are involved by converting from feature-based product selling to consulting-oriented solution selling?
- How do we enable our workforce when knowledge from in-house experts at the back-office shifts to field sales at the customer front?
- How to optimize our quote and order processes to become less time- and resource-consuming? How can we integrate the sales and engineering process?

- Personal resistance: Technicians who believe that their complex job can not be done by someone else (especially not by sales people or by a computer). Resistance of sales people using IT-based tools. Fear of change in general, fear of loosing status and power.

These issues are not tool-related but have to be answered by a strategic and managerial point of view. The person responsible for the change management within a PLM-integrated configurator project needs a good understanding of the whole enterprise and its spanning processes crossing development, marketing, sales, engineering, production, service, and IT departments.

4.10 Management of Authoring Environment and Tools

Some effort is required to maintain the tools (see Figure 4-7) and the IT infrastructure needed to implement a configurator. On the personal desktop of each knowledge base editor the following applications are in operation: authoring workbench, configurator run-time and test environment, visualization data editor, and optionally some CAD plug-ins. Server applications include a shared knowledge base repository, a synchronization & update server, as well as web-based project tools for change requirements, error tracking, and download areas (Figure 8). The installation, integration and operation of the server applications need some involvement of the IT support department.
The training of the authoring environment and the corresponding tools includes lessons on the user interface, the modeling methodology of the product knowledge base, typical modeling patterns, and coding guidelines.

5 Conclusions

The project methodology at Perspectix for PLM-integrated configurator projects distinguishes ten tasks described in Chapter 4. The experienced workload of machine and plant configurator projects realized in the last 5 years was analyzed and the statistics is shown in Figure 9.

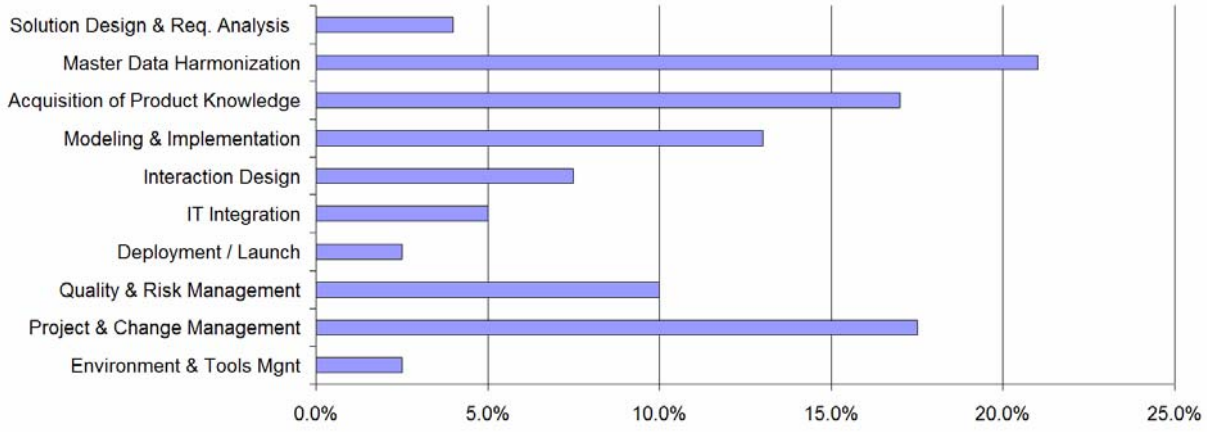

Figure 9: Workload by project tasks of configuration projects.

What may surprise is the fact, that the core tasks of implementing a product knowledge base – the establishing of an authoring environment and the actual modeling activities –only consume 15% of the total project effort. The biggest task deals with master data harmonization, something that top management often believe is already handled extensively within the existing IT backbone. The next two big tasks treat "soft factors" such as knowledge acquisition, as well as project and change management. Together with solution design and requirement analysis, these soft factors account for about 40% of the project expense. Although these cultural issues are often underestimated, it is worth to address these soft factors with the same seriousness as the "hard" implementation tasks. Only a solid technology implementation of the configurators's knowledge base together with the "soft" topics – corresponding organizational changes, a thorough modular product portfolio, and a unified product information architecture – lead to efficient and effective sales engineering processes.

The purpose of this line-up of project tasks in PLM-integrated configurator projects is to help investment goods manufacturers achieving the intended benefits from implementing their portfolio modularization and product configuration strategy. Ten main tasks are identified and critical concerns denominated. Methods and tools are demonstrated to successfully manage product knowledge and configuration strategies in technical industries.

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