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Market Driven Merger of E-Business, Enterprise Resource, and Product Management Systems in the PLM-Loop

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Abstract: The engineering lifecycle of products should contain a pre-process concerning the client-specific market demand especially in e-business. Therefore a general bidirectional process chain is overlaid with local control loops in cascading process sequences. To evaluate the stated theoretical approach, the modelling of the application system is reflected on the implementation of a real system represented by a PLM research laboratory. The backward and forward chaining of information and product data is explored in a multi-vendor environment. The well integrated field of computer aided design, part management, and product data management needs to be merged with the business processes and data of the enterprise resource planning systems and the e-commerce solutions via the creation of a market cross-linking system in the triangle of engineering, business, and commercial functions and processes. The presented economic- and customer behaviour-feedback loops seem to be the cornerstones of the merger between e-business, enterprise resource, and product management systems.

1. Introduction

In the last years the intensified market and customer orientation of businesses led to turning away from the functional to the process understanding in enterprises [1]. It comes along with the implementation of integrated information systems in the framework of information logistics solutions instead of the use of isolated applications. The integrated process and information flow approach shall be accompanied by the systemic understanding of dynamic changes in the product development, product use, and product recycling joined together in the Product Lifecycle Management (PLM).

Recently, the situation in the product lifecycle management is characterised by separate or semi-integrated functions connected by related information and software solutions via interfaces to process-oriented applications. The cooperation of the stakeholder of the whole process is partly interdisciplinary but also characterised by focussing on activities of specialists to separate sections of the product lifecycle. The result is a fragmentary support of the product lifecycle by existing software applications. They admit to realise a unidirectional information flow either forward from the product design to the product distribution or backward from the product sales to the product or project management. So far, the integration of the information systems service and support for product management, enterprise resource management, and e-business is only fragmentary developed [2].

[3] outlines that future research lies in the holistic view and system-wide solutions. More specifically [and in relation to e-business], product family design needs to incorporate more front-end issues such as explicit customer modelling and integration [here: configurator plus customer behaviour feedback loop], product demand and market segmentation, along with the economic evaluation of product families [the economic

feedback loop]. [Also], past research has not addressed or has even ignored the knowledge discovery from customer needs, product specifications and configuration alternatives synthetically, nor has actual practice availed to formulate effective means [4].

2. Objectives

The engineering lifecycle of modern products as complex objects normally begins with the product design followed by the product shop fabrication, the product distribution and sales, discharging into the product use, maintenance, and disposal. It could be described as a unidirectional, sectional procedure with several related partners as a classic supply chain. But there is a very essential pre-process concerning the client-specific market demand especially in business processes based on e-business information systems. It is backward directed to the functions, sub-processes, and information systems of the Enterprise Resource Planning (ERP) including manufacturing, the Part Management (PM), and the product development. The general solution is, based on understanding, to model a bidirectional market-driven process characterised by the two dominating chains. The first is coming from the market and the second is directed to the market including all essential pre-stages of the product lifecycle.

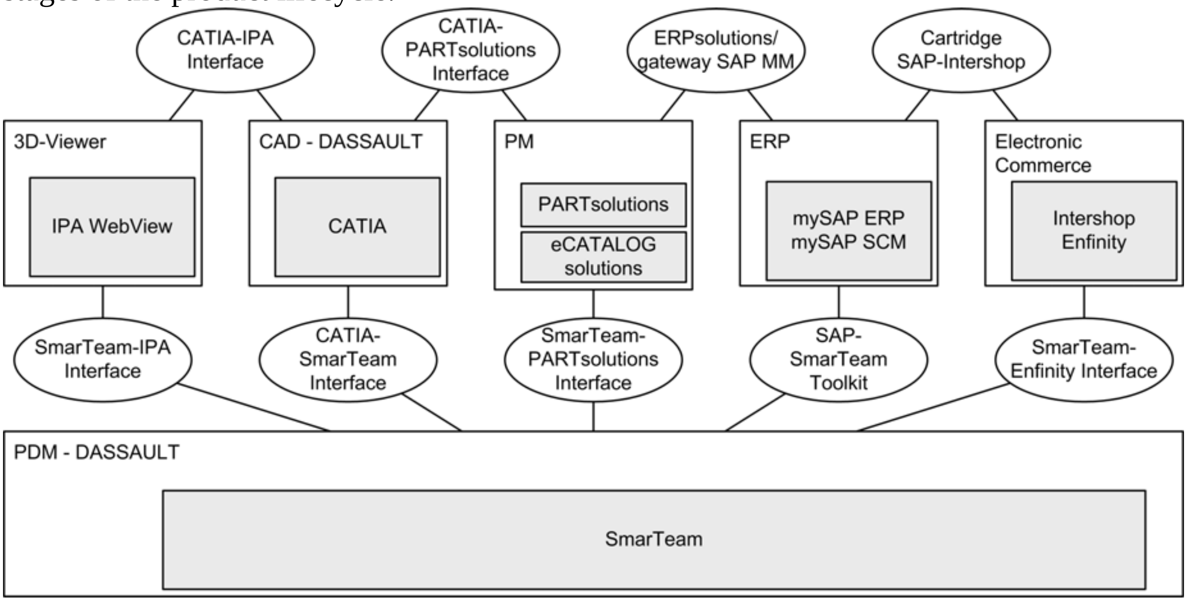

Figure 1: Laboratory Architecture "Dassault"

Because of the complexity of processes, the model has additionally to consider important systemic aspects:

- Multiple human-beings create value in the product lifecycle. This means, that service processes and supporting systems have to promote collaborative and interdisciplinary work. The best way to do so is in generating integrated processes and user friendly applications.
- The general bidirectional process chain will be overlaid with local control loops in cascading process sequences. This is the precondition for generating quality in the PLM brought into line with the main rules of systems engineering management.
- The overall model will be a multilayer network approach consisting of nodes and links in the collaborative working layer, the multifunctional process layer, and the integrated information system and data layer.

Therefore, it is necessary to describe the challenging market conditions, to define restrictions for the collaborative and interdisciplinary work, to model the processes and the network dependencies, and to create the integrated information system and product data model base for the multidirectional information flow. Beginning with the product design and leading to the market access of the product results in an extended approach for the job scheduling and design as well as in higher process transparency, integration, and efficiency of the information system architecture for the first part of the product lifecycle.

For evaluating the theoretical approach, the modelling of the application system will be reflected on the implementation of real systems represented by a PLM research laboratory solution (Figure 1) as well as an industrial system approach for a medium-sized global market leader [5].

The sustainability of the further development is guaranteed by a PLM research and application competence group formed by research and educational institutions, system software developers, and an ICT stakeholder network of users, especially from SME. The related regional VDI “Part Management” group with more than 60 members is already established and operating.

3. Related Work

Any main element of this paper could be found and is thoroughly discussed in several international papers. In this work those elements (product data models, configurators, and collaboration agents) are brought into line to solve the stated problem of bidirectional data integration. Therefore this paragraph is going to give a short overview of related work with respect to the elements presented in this paper.

Beginning with the research on defining appropriate data models capturing the whole product lifecycle, there are two main tendencies. The 1^{st} and more common is a product feature-based approach as objective for the product description. [6, 7] admit the usage of a product feature level on the bottom of the hierarchy, then component level, several assembly levels, and finally up to the product level on the top. While [6] is claiming Aggregate Product Models (APM) to be a vital element of creating design representations that are conducive to rapid, automatic evaluation and focusing on the early design stages in terms of widely used manufacturability metrics such as Quality, Cost and Delivery (QCD), [7] adopts a wider view including product definition and design, manufacturing process planning and optimisation, operations management, cost estimate and optimal control, and logistics management named “product production structure”. Especially [6] outlines the model ability to uncertainty in product feature dimensions during embodiment design and the possibility in adding new information sets, e.g. detailed product design features. This issue is transferred to the Sales Product Data Model (SPDM) presented here and explained later on. The 2^{nd} trend solves the need to create an active product program or model as opposed to the traditional passive product structure by using specific product-related [...] agents based on artificial intelligence: A system where the designer creates a product model as an active community of [product-related] agents rather than a passive data structure, resulting in a model that is capable of ensuring manufacturability through a global (component level) emergent behaviour [8]. Therefore each [feature-based agent] is a stand-alone entity, usually linked to known machining operations or groups of operations on known machines. Compared to this product-related agents on a feature level [9] approaches the concept of “one product, one agent”, which means that every single [part] (or lot of identical [parts]) is represented by a software agent, on a component level. [9] could be concluded as the shifting from a series-oriented to a product-oriented approach, in the SPDM case moreover to a product-class-oriented approach.

[10] uses different main views to define the need for product information including forecasting, quoting, ordering, scheduling, production, finished product, historical records and revival for warranty or service and introduces a Knowledge Maintenance System (KMS) in conjunction with a product configurator based upon a specific product definition language for communication and storage. This crossover approach between a product data

model and a configurator is adopted in this paper, while embedding parts of the SPDM into the configurator.

Regarding to [11] advanced configurators are emphatically the right tools to leverage both product- and market data. [11] differentiates into two automation approaches upon components and functionality, asks for architecting the configurability as a product tree or a component pool, and gives a sense on how to evaluate configurators by presenting an extended checklist. The presented SPDM-based configurator uses a mixture between the product tree and component or feature pool. Describing the need for a Configuration Knowledge Base (CKB), which is usually defined beforehand and is too rigid to satisfy the dynamic and changing customer needs in a timely manner, [4] focuses on the discovery of configuration rules from the purchased products according to customer groups and introduces data mining into engineering design. [12] deduces that the major challenge in traditional knowledge-based configuration system was the acquisition of rules and constraints. Therefore in the presented case different the rules and constraints are assigned to the participating domains.

Collaboration agents or direct feedback loops are the main entity of multi-agent systems. Generally agents could be distinguished between immortal agents persisting over time, and mortal agents, which terminate at the end of a mission or the expiration of resources such as time or money [13]. [14] is focusing on agents supporting the integration of manufacturing planning, predictive machining models, and manufacturing control. Those agents are based upon rules for process planning, service selection, and job execution. The customer behaviour agent and the economic feedback loop presented here focus on the optimisation of product ranges. The ones for an automated shop execution could be adopted at a later stage.

4. Methodology

The methodology is characterised by a holistic approach based on several years of research and application activities. The different views and key factors are bundled in a meta-model consisting of players, processes, functions and objects designed as multilayer network with subsystems related.

Firstly, the basis of the systemic approach is defined by the collaborative working methods and processes putting together specialists from different subjects in an interdisciplinary framework. The efficiency of processes in adding value will be mainly influenced through the well defined and described network of cooperating engineers, businessmen, and computer scientists from different special fields of research and application.

Secondly, the information flow, going through the pre-market procedures in the enterprise back to the customer, and the data network related to the collaborative working processes should be modelled with respect to the market challenges. Therefore, a set of related and linked software application components and systems is necessary (Figure 1).

Thirdly, the products as objects are modelled in the computer aided design (CAD) process, regarding the part management opportunities, the product data management (PDM) sphere as well as the enterprise resource management and the e-commerce (EC) system requirements, respecting market-related customer demands.

Fourthly, the comparatively well integrated field of CAD, PM, and PDM has to be merged with the business processes and data of the ERP systems and the e-commerce solutions via the creation and usage of a market cross-linking system in the “Bermuda” (T)riangle of engineering, business, and commercial functions and processes. As [7] noted the ERP system places its emphasis on the inventory and cash flow control in a company and therefore is an extension of the manufacturing resource planning (MRP II) system. Both systems, the ERP and PDM, which focuses on the product data flow management in a company, are useful […] and can be part of the system [representing the product data model] [7]. Replacing the weak human element of the loop [, especially where different humans with differing driving forces are involved and the efforts made are almost lead to a deadlock in the end,] is a natural progression [8].

5. Technology and Business Case Description

The initial point was a business case in a company as global market leader. The deficits of the successful extension of the market access were scrutinized according to the bidirectional working processes and information flows from and to the market. They were caused by problems in the collaborative work as well as the insufficient product modelling and information system support. Now, an integrated bidirectional process solution is implemented in the medium-sized enterprise.

The business case was the basis for further research activities completing the bidirectional approach under the conditions of a research laboratory. The backward and forward chaining of information and product data is explored in a multi-vendor (Siemens PLM and Dassault Systems) environment. Especially, the integration of different software-based sub-processes (PM, CAD, PDM, ERP, and EC) is realised by means of a defined product and product data model. Procedures in the first period of the product lifecycle management up to the market access are evaluated to improve the interaction of developers, users, models and systems in the network.

The next step will be to create and describe a market cross-linking system for the cooperation of product development, product management, product distribution and sales systems in the framework of applied research projects. It could be defined as a process and data hub controlling the interfaces for backward and forward information flows between the enterprise business and engineering processes on one side and the electronic-supported market access via e-commerce systems on the other side.

6. Developments and Results

Based on the implementation of the PLM research laboratory, while a nearly complete set of corporate information systems was implemented, one of the first conclusions was just to use a subset to reduce the complexity of the total system. The ones not taken into account in the first place will be included within the future steps of research (Figure 3).

Elements of the inner circle (PDM, ERP, and PM) are used in the primary step, because they include the main functions needed to design the first proprietary feedback loop.

The catalogue software eCATALOGsolutions was used to create a Sales Product Data Model (SPDM) which includes geometric as well as product information data [15]. The model is packed in a configurator to give the customer some scope for design. After the SPDM is defined it is made available within PARTsolutions. The customer can create a SPDM-based configuration which satisfies his requirements. After the customer deploys the order within the PM-system a routine saves the generated engineering BOM customer-related into the PDM data base. Normally in this procedure an e-commerce or shop-system should be involved, for instance to handle customer information and access. This should not be the case in the primary step of evaluation. The PM system offers also the opportunity to save the configuration being made in different CAD-formats via ‘native’ data export. Primarily based on the BOM and the included order quantity the ERP-system initiates the costumer-based job execution in the production. Also the customer data passes the interface and is ready for accounting.

To fulfil the first part of the merger a direct feedback loop, the economic feedback loop, from the ERP system into the SPDM as part of the product management system, initially defined at the setup of the system, is needed. Economic metrics, which affect the loop primarily in relation to cost optimization of the resources, i.e. production, involved, are evaluated and defined.

Closing the first or inner circle by implementing bidirectional interfaces provides the basis for the next step. It contains the implementation of a new customer interface in the form of an EC system. Via monitoring the interaction between the potential customer and the shown product range and by using data mining methods the EC system offers the opportunity to gain more customer-metrics beyond the SPDM. Those metrics are known as e-metrics.

The SPDM could be deeply optimized with respect to customer requirements using SPDM-customer data (a selected order) and e-metrics in the first stage of expansion of the system. Figure 2 (stages to order according to [16]) shows the overall corporate goal, which is to satisfy customer demand while handling economic orders.

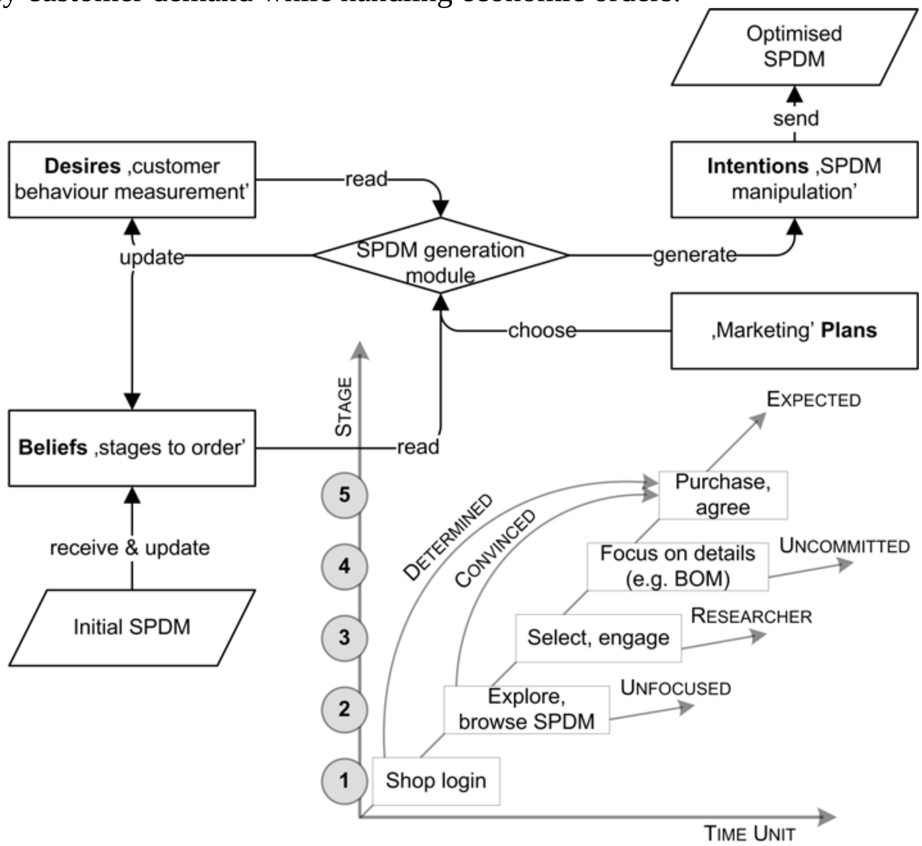

Figure 2: The BDI SPDM Generation Module and the Belief in Stages to Order

The optimising customer behaviour feedback loop is implemented via applying the BDI (Beliefs – Desires – Intentions) scheme, which is according to [8] one of various agent architectures available. The belief database contains, as shown in Figure 2, the estimations on customer behaviour in proceeding the stages to order or customer satisfaction. Those beliefs are provided initially and need to be revised upon new perceptions. The desire database collects the customer behaviour tracking data as an image of customer desire. The database concerning plans is the steering point of the overall loop and is almost driven by marketing efforts.

Now each of the loops influences the product range (Figure 3) with respect to the mentioned "obstacles". The overall optimum for the to-be shaped product range is in between the defined sub-optima and needs to be adjusted and thoroughly researched.

Finally, to achieve an overall bidirectional integration of the participating business information systems the PM system should be replaced by an integrated CAD system. At present this is the last step (outer circle in Figure 3) towards an integrated bidirectional corporate information system.

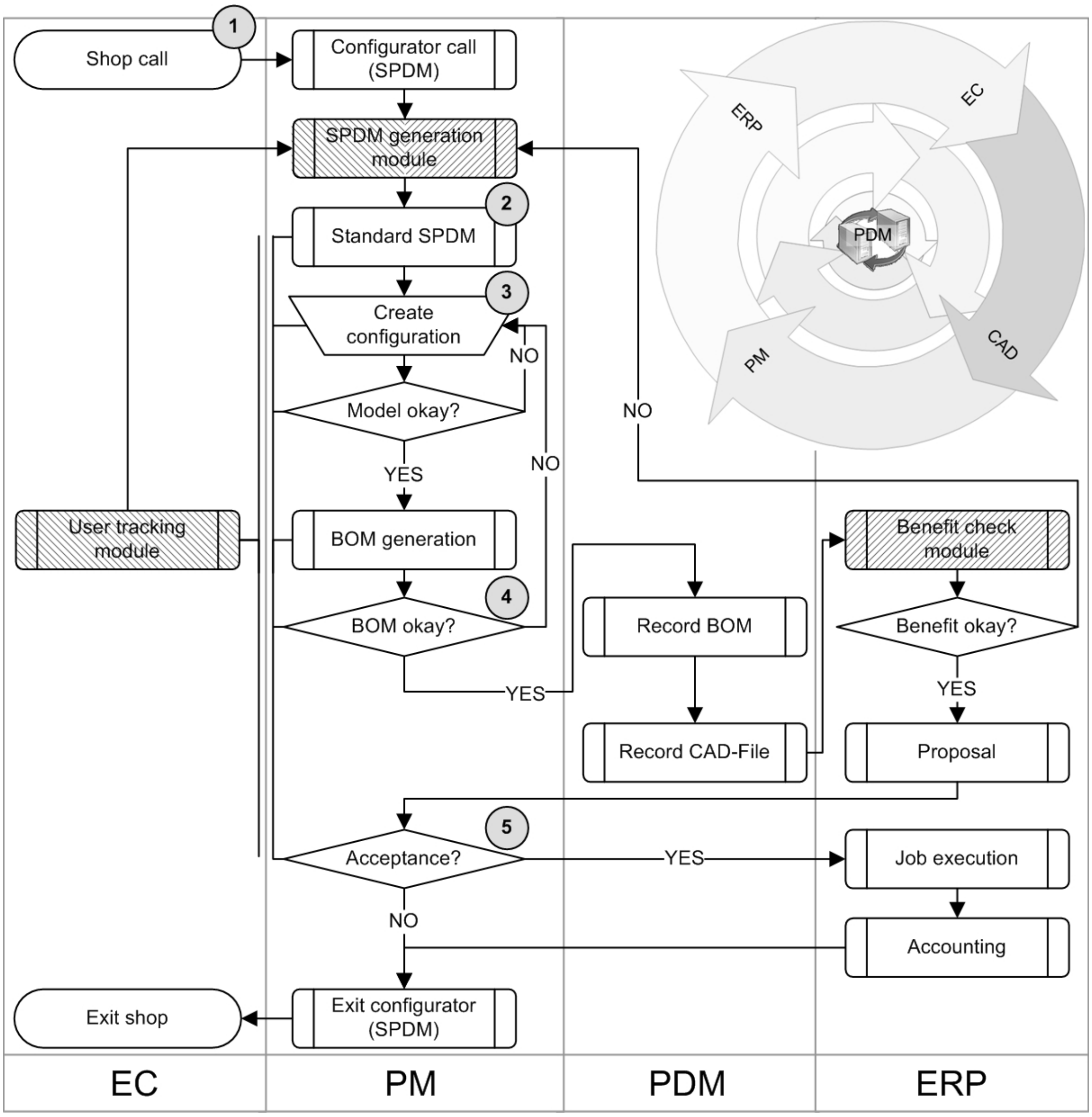

Figure 3: Bi-directional Flow-Chart Including Steps of Research

As the main result of research the starting points and the objectives of the market cross-linking system are being defined. The economic (Benefit check module) and the customer behaviour-feedback loop (User tracking module) seem to be the cornerstones of the merger between e-business, enterprise resource, and product management systems. Depending on the defined metrics and upon rules the offered product range in the form of a SPDM could be optimised with respect to fast changing market conditions.

The SPDM data structure also helps companies to facilitate the communications between engineering, marketing, and operations management. These data, discussions and operational data constitute the knowledge of a company and are very useful for new products development in future [7]. Finally, within the SPDM all the data associated with a customer-driven development is automatically captured.

7. Conclusion

As this paper shows, the traditional monolithic CAD application is no longer at the centre of the design phase. Instead, the product data model is transformed into a product program model [8]. As [9], the main drawback is, that the system becomes [product-class]-dependent, which brings new problems, such as an increment of the network load. On the other hand the system is very scalable, and an increase in the number of product [class] agents does not result in an increased complexity of the individual system components. [11] comes to the point, that being "run" by configurators – all of these software offerings being fine-tuned solutions for specific customer-businesses in specific industry sectors.

In the future the complex interaction of product development, product management, and product market access will be controlled step-by-step through better system, process and information flow solutions. Meta- and sub-modelling of multilayer network architectures of objects such as products, processes and functions in a computer-based collaborative working environment permits to approach the models to the real conditions of the PLM loop. The interdisciplinary market-driven processes, especially with regard to time-to-market restrictions, will become more efficient, transparent, faster, and user-friendly. The next step of integration is the merger of e-business, ERP, product development, and management systems by a market cross-linking system. The perception process is influenced by business case studies, laboratory analysis, development work, and applied research projects. It is supported by the interdisciplinary cooperation of different stakeholders of the PLM.

References

[1] R. McLeod and G. P. Schell, Management information systems, 10th ed. Upper Saddle River, N.J.: Pearson/Prentice Hall, 2007.

[2] F. B. Vernadat, Enterprise modeling and integration. London: Chapman & Hall, 1996.

[3] J. Jiao, T. W. Simpson, and Z. Siddique, "Product family design and platform-based product development: a state-of-the-art review," Journal of Intelligent Manufacturing, vol. 18, pp. 5-29, 2007.

[4] X. Y. Shao, Z. H. Wang, P. G. Li, and C. X. J. Feng, "Integrating data mining and rough set for customer group-based discovery of product configuration rules," International Journal of Production Research, vol. 44, pp. 2789-2811, 2006.

[5] C.-A. Schumann and A. Rutsch, "An approach for an automated and market-driven optimisation of product ranges as part of the product lifecycle management framework," in 9th ASME Engineering Systems Design and Analysis Conference ESDA 2008, Haifa, 2008.

[6] P. G. Maropoulos, D. G. Bramall, P. Chapman, W. M. Cheung, K. R. McKay, and B. C. Rogers, "Digital enterprise technology in production networks," International Journal of Advanced Manufacturing Technology, vol. 30, pp. 911-916, 2006.

[7] Y. L. Tu, S. Q. Xie, and J. J. Kam, "Rapid one-of-a-kind production," The International Journal of Advanced Manufacturing Technology, vol. 29, pp. 499-510, 2005.

[8] D. Jacquel and J. Salmon, "Design for Manufacturability: A Feature-Based Agent-Driven Approach," Proceedings of the Institution of Mechanical Engineers -- Part B -- Engineering Manufacture, vol. 214, pp. 865-879, 2000.

[9] Y. K. Penya, A. Bratoukhine, and T. Sauter, "Agent-driven distributed-manufacturing model for mass customisation," Integrated Computer-Aided Engineering, vol. 10, pp. 139-150, 2003.

[10] P. R. Dean, Y. L. Tu, and D. Xue, "A framework for generating product production information for mass customization," The International Journal of Advanced Manufacturing Technology, vol. Online First, 2007.

[11] M. Kratochvíl and C. Carson, Growing Modular : Mass Customization of Complex Products, Services and Software. Berlin: Springer, 2005.

[12] D. Sabin and R. Weigel, "Product Configuration Frameworks -- A Survey," IEEE Expert Intelligent Systems & Their Applications, vol. 13, pp. 42-49, 1998.

[13] S. H. Kim, "Learning Agent Architecture for Design and Manufacturing Knowledge on the Web: An Extension of Enterprise Resource Planning Capabilities," International Journal of Intelligent Systems in Accounting Finance & Management, vol. 8, pp. 15-24, 1999.

[14] S. C. Feng, K. A. Stouffer, and K. K. Jurrens, "Manufacturing planning and predictive process model integration using software agents," Advanced Engineering Informatics, vol. 19, pp. 135-142, 2005.

[15] C.-A. Schumann and A. Rutsch, "Towards an integrated corporate information system – building up a sales product data model to cope with the emerging complexity of e-business," in 15th European Concurrent Engineering Conference 2008, Porto, 2008, pp. 74-78.

[16] J. Sterne, Web metrics : proven methods for measuring Web site success. New York: Wiley, 2002.