KNOWLEDGE MANAGEMENT FOR RAMP-UP

Approach for Knowledge Management for Ramp-up in the Automotive Industry

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Abstract: Enterprises in the automotive industry are facing new challenges from increasing product diversification, decreasing product life cycle times and permanent need for cost reduction. The ramp-up as linking phase between development phase and production phase has a crucial role for the success of a project. The performance of a ramp-up depends on the maturity of the product and manufacturing processes. Knowledge management is an extraordinary driver for maturity of both product and manufacturing process. The existing solutions for knowledge management show insufficient results. The new approach bases on the cycle of organizational learning. The cycle consists of four phases: socialization, externalization, combination and internalization. The cycle of organizational learning is also known as SECI cycle. It provides opportunities to improve ramp-up performance in the automotive industry. Part of the new approach is a sophisticated concept for a solution using Information Technology as enabler for Knowledge management.

1 INTRODUCTION

1.1 Automotive Industry

The current situation in the automotive industry is characterized by increasing requirements from the customer side on quality and individualization of products and upcoming pressure on product prices at the same time. Car manufacturers create new product segments and enrich existing segments with more possibilities for individualization. The product diversification is combined with ongoing reduction of product life cycle times and an acceleration of innovation.

The product diversification and the reduction of product life cycle times determine the shortening of development phases and an increasing number of product launches. Product diversification and innovation lead to increasing complexity in both products and manufacturing processes.

The car manufacturers or original equipment manufacturers (OEM) are at the top of the supply pyramid. The pyramid consists of three levels:

1. Supplier of modules and systems (1st Tier)
2. Supplier of sub-assemblies (2nd Tier)
3. Supplier of components (3rd Tier)

Especially the supplier of systems (e.g. steering system) and modules (e.g. front-end module) are totally involved in development and manufacturing processes from the beginning of a car project till the end of the life-cycle. The suppliers are facing an increasing demand for product innovations and development services from the car manufacturers. They have to supply just-in-time or just-in-sequence with high reliability and high quality. Furthermore there is a permanent need for cost reduction.

1.2 Ramp-up

The generic life cycle of products in the automotive industry comprises the development phase and the serial production phase. As shown in figure 1

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(Wangenheim, 1998) the development phase consists of several steps belonging to the main processes of product development and development of the manufacturing process.

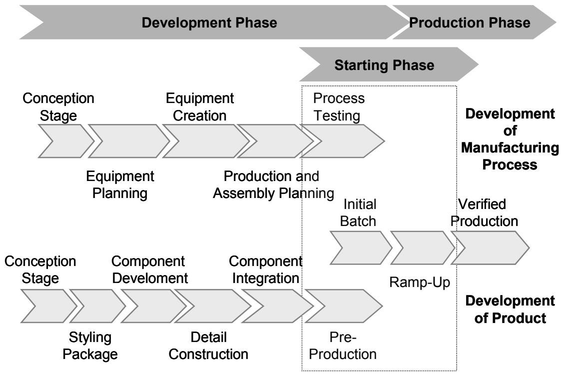

Figure 1: Development and production phase.

One of the most critical phases of the entire product life cycle is the ramp-up phase. It is the linking process between development phase and the subsequent serial production phase. The ramp-up is a transition phase. Before the ramp-up starts only a few products exist. These products are prototypes and samples, manufactured with high effort in job-shop production, a lot of them manually. In contrast to the production of prototypes and samples, the ramp-up is the beginning of the serial production. The products are manufactured on conditions of the serial production. That means using technology, machines, tools, materials, staff etc. from serial production. It is also characterized by the demand of increasing production output from the customer side. That is the reason for the importance of the ramp-up for the success of the entire project. Any problem or interruption (e.g. caused by hidden failures) in the manufacturing process has a negative impact on efforts and costs. For the financial success of a product a minimized time-to-market is very important. Any delay during ramp-up leads to lower sales in the entire life cycle time. Delays and problems during ramp-up could turn the whole project from a success into a loss. Therefore the performance of a ramp-up is one of the keys to success in the automotive industry. High performance means to carry out a ramp-up within the planned time frame and by the planned ramp-up budget or less. The production output is increased steadily and achieves the goals defined in the ramp-up curve. There is less or no trouble shooting necessary which would cause unplanned costs and efforts.

1.3 Experience and Knowledge

The performance of a ramp-up is positively influenced by the maturity of the product and of the manufacturing process at the end of the development phase (Weber, 1999). Both depend on the output of the two key processes of development phase in the automotive industry: product development and development of the manufacturing process.

To achieve this high maturity the use of knowledge and experience during development phase is a crucial factor. It comprises the knowledge on technologies e.g. material science, physics, chemistry, electronics and software as well as experiences in estimating feasibility and reliability, planning and project management.

Therefore knowledge management has an extraordinary leverage for the improvement of ramp-up performance.

2 STATE-OF-THE-ART

Due to the importance of the ramp-up for financial success of a product several research activities have focused this problem field.

German research institutes identified in cooperation with leading companies ramp-up's five levers (Kuhn, Wiendahl, Eversheim, Schuh, 2002):

1. Planning, controlling and organization of ramp-up's
2. Robust manufacturing systems
3. Change management during ramp-up phase
4. Models for cooperation and reference
5. Knowledge management and training

The first four topics were widely covered by research activities in recent years. The first topic concerning planning, controlling and organization of ramp-up`s was improved by the development and implementation of sophisticated project management solution. These solutions include reporting systems, with figures, early warning indicators and escalation paths.

For the second issue, nowadays solutions are available. They focus on standardization and guidelines for manufacturing systems. A lot of companies in the automotive industry developed and implemented production systems, some of them copied ideas from the almost legendary Toyota Production System (TPS).

The third topic could be regarded as part of the common project management. Change management mainly requires coordination and standardized processes in the organization. Therefore workflows and guidelines for the approval of changes in specification of product and manufacturing process are available today.

Collaborative Engineering and Supply Chain Management (SCM) contribute to the fourth issue concerning models for cooperation and reference. Nevertheless, needs for a comprehensive research effort in the area of Collaborative Networked Organizations (CNO) still exist (Camarinha-Matos, Afsarmanesh 2004).

However the fifth issue concerning knowledge management and training is still unsolved. Industrial experience has shown that existing methods and technologies such as Document Management Systems (DMS), Content Management Systems (CMS) reached insufficient results. The well-known search engines from the internet improved the access to information, but could not meet the special requirements for systemic knowledge in the background of the automotive industry. Even when search engines make it possible to find any particular piece of information, it is very hard to combine this information with any other piece of information (Stuckenschmidt, Harmelen, 2005). This means that Information Technology is still unable to process the linking of new and existing explicit knowledge.

An existing method in the automotive sector for gathering and sharing knowledge especially experience is the Failure Mode and Effect Analysis (FMEA). The FMEA was originally developed for risk analysis but became more and more a knowledge base. FMEA`s in the automotive industry usually refer to the guidelines of the German VDA 4.2 (Verband der Automobilindustrie, volume 4 part 2, 1996), the QS-9000 (Quality Systems Requirements) of the AIAG (Automotive Industry Action Group, 1998) or the ISO/TS 16949 (International Organization for Standardization, 2002).

The two kinds of FMEA`s focus on the design of a product or on the manufacturing process. Both consist of a system structure, a functional net, a failure net and several additional characteristics. The system structure is a model of the product or the manufacturing process. The parts of the model bear functions, failures and characteristics. The functional net is a model of the required functions of the product or the manufacturing process. From the perspective of risk analysis the failure net is more interesting. It shows what kind of failures might happen and what their effects could be. Therefore all triple combinations of causes, failures and effects existing in the failure net are rated. The result is an action plan including modifications in design of the product or the manufacturing process.

The FMEA is a so-called living document, which goes along with the product and the manufacturing process from the first draft till the end of the product life cycle. All information about problems e.g. during ramp-up or serial production, complaints and revisions are added to the FMEA documents. The development of new product and manufacturing processes uses the FMEA documents of previous similar projects as basis. Therefore the FMEA seems to be an extraordinary effective tool for the gathering and reuse of experience and knowledge. Even the described structure of the FMEA meets the requirements for systemic knowledge in the automotive industry.

In practice the FMEA is far less effective in gathering and sharing experience and knowledge as expected. The reasons are quite simple. The FMEA is a separate type of document. Many companies use special software tools to create and revise these documents. For the employees the FMEA causes extra efforts. The main problem is the redundancy of data. All information in the FMEA about product and manufacturing processes exists already in drawings, specifications, process flow diagrams and many documents. Even the information about other problems concerning similar products or manufacturing processes in the past exists already in complaint management systems or documents for continuous improvement.

Therefore the FMEA is only an incomplete copy of the gathered knowledge and experience of the enterprise. It depends on the individual situation in each project whether the employees can afford to spend time on the revision of the FMEA. A gap between the state of the FMEA and the actual state of knowledge and experience makes the FMEA totally ineffective. The knowledge and experience from previous project could not be used in the development phase. Without using experience during development it is extraordinary difficult to achieve the required high level of maturity for product and manufacturing process. This could cause a low performance for the ramp-up as mentioned before.

The MSR (Manufacturer Supplier Relationship Consortium, 2005), a work group founded by leading German car manufacturers and suppliers, provides an attempt to solve the problem of data exchange. They are developing a Document Type Description (DTD) using the Standard Generalized Mark up Language (SGML) to simplify data exchange between FMEA and other data sources.

The usual software tools for FMEA already offer several interfaces like ODBC (Open Database Connectivity), RTF (Rich Text Format), WMF (Windows Metafile) or CSV (Colon Separated Values).

These attempts do not solve the problem of redundancy of data. Unfortunately these activities do not pay any attention to the findings of research concerning organizational learning and organizational knowledge management.

Especially experience and knowledge stored in less standardized format will stay unusable. Natural language documents like reports and minutes of meetings comprise a lot of important experiences. People tend to gather and share experiences in these special kinds of learning histories (Kleiner, Roth, 1998).

The described attempts and solutions are not covering the open issues concerning knowledge management for ramp-up in the automotive industry.

3 CYCLE OF ORGANIZATIONAL LEARNING

3.1 Scientific Baseline

The cycle of organizational learning (Nonaka, Takeuchi, 1995) consists of four phases: socialization, externalization, combination and internalization (SECI).

During the first phase named socialization the employees start sharing their experiences, attitudes and perspectives. Based on common experiences from the past they begin to trust each other.

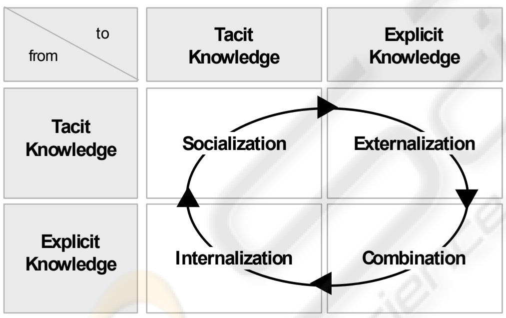

Figure 2: Cycle of Organizational Learning.

In the second phase called externalization the employees begin to exchange their thoughts and ideas. Hidden tacit knowledge from their minds becomes explicit knowledge by dialogue. Ideas and thoughts are transformed into drafts and models During phase three called combination employees combine the new explicit knowledge with existing explicit knowledge. The combination leads to so-called systemic knowledge, which has to be recorded in documentation e.g. drawings, specifications and procedures. The documentation supports the distribution of new knowledge through the entire organization.

In the phase of internalization the new explicit knowledge is transformed into tacit knowledge. The new knowledge becomes part of the daily work and the employees embed the new knowledge into their routines.

3.2 Empirical Confirmation

Long-term empirical investigation (Dyck et. al., 2005) provided several evidences for the existence of the model in usual enterprises, shown in the case of a small car manufacturer. The data from the surveys supports the existence of all four phases of the SECI cycle. The survey data suggests that the intra-organizational knowledge flows are greater during redesign than during the steady state. However, this result is in contrast to the interview data. It is also mentioned that there is a need to examine whether and how certain kinds of organizational structures and information systems facilitate the kind of knowledge transfers that are required.

The research on management of organizational knowledge creation in new product development process (Schulze, 2004) reaffirms the cycle of organizational learning in almost the same manner. The investigation underlines the existence of the SECI elements and their impact. One of the results is, that all four knowledge creation modes could be operationalized. Every SECI mode could clearly be observed in practice. An empirical evidence of the existence of all modes was provided.

The research model for measuring the impact of SECI on project results comprises a generic product development process. The process consists of four phases:

– Idea generation
– Concept development, evaluation and selection
– Technical development
– Product launch

The research revealed several important interrelations between SECI modes and the results of product development. The socialization has a positive influence on the efficiency of technical development. It contributes to finish the development within planned time and budget. The combination during the phase of technical development has positive influence on quality of development. Combination also has a positive impact on the quality of product launches, including ramp-up phase (Schulze, 2004).

The results of this research provide great opportunities for improving performance of product development processes and ramp-up processes by using knowledge management considering cycle of organizational learning (SECI).

4 PREPARATION OF THEORY SET-UP

4.1 Background

The described cycle of organizational learning (SECI) offers extraordinary opportunities for the automotive industry. The reason is that the SECI model provides a holistic approach, paying attention to both tacit and explicit knowledge.

The cycle of SECI can be linked to the product life cycle structure of the automotive industry. As mentioned before, the product development processes in the automotive industry are highly standardized. Every development starts with the building of a team or work group. Employees with different knowledge, experiences and attitudes start working on new project task. Some of them know each other from previous projects. They share common experiences. Some of them do not know each other. They have to build up trust in other team members. This is parallel to the phase socialization of the SECI cycle. The developers continue their work with externalization of their ideas and thoughts to solve the common task. This activity could be directly linked to the phase externalization of the SECI cycle.

The next steps in the product development process comprise the work on drafts and concepts. The explicit knowledge that has been created during the discussion of thoughts and ideas is combined with already existing knowledge. Knowledge and experience from previous projects are part of this.

The new combined knowledge is used to create samples and prototypes of the product or to test new technologies for the manufacturing process. These activities belong to the SECI mode of combination. They continue with the documentation of the results. The documentation facilitates the distribution of the explicit knowledge.

During the work on the new manufacturing processes the explicit knowledge becomes tacit knowledge. The employees internalize the new knowledge which is part of the so-called SECI mode internalization.

Concerning the ramp-up phase the cycle of SECI provides direct opportunities to influence the performance in a positive manner. As mentioned before, the SECI mode socialization contributes to finish the development within planned budget and time. The combination has a positive impact on product quality and the ramp-up.

Therefore knowledge management for ramp-up in the automotive industry has to support the cycle of organizational learning and the SECI modes socialization and combination in particular.

4.2 Tools

Regarding Information Technology as enabler embedded in an organizational frame, it has to achieve several requirements from the cycle of organizational learning as shown in figure 3. To support the mode of socialization Information Technology should provide functions for the identification of persons with special important tacit knowledge.

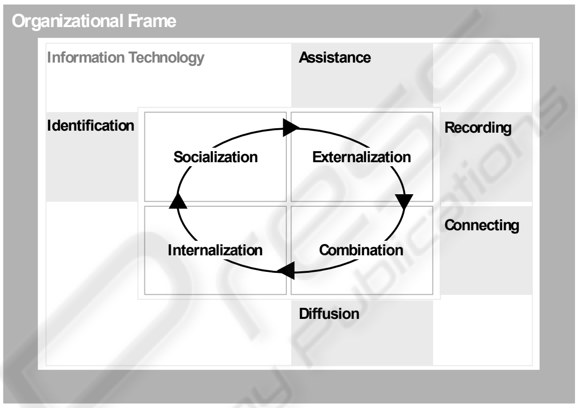

Figure 3: Information Technology supporting SECI.

During the phase of externalization, Information Technology bears the role of an assistance tool. It has to provide access to the entire data stock, to answer requests like usual search engines do. To avoid the reoccurrence of previous mistakes effectively, Information Technology has to provide recommendations based on former experiences online while the user is working with computer applications.

During ongoing externalization the recording function becomes more and more important for the storage of new knowledge. When old and new knowledge is combined, Information Technology has to provide possibilities to weave nets and to extend the existing net structures for the integration of new knowledge.

The support of the diffusion is a necessary prerequisite to enable the internalization of new knowledge in the entire organization effectively.

4.3 User Profiles

Information Technology must pay attention to the requirements of different user-types involved in the product development phase and the subsequent production phase.

According to the generic development process described before (Wangenheim 1998) three typical user profiles for Information Technology supporting the cycle of organizational learning could be identified.

Table 1: User profiles and needed information.

User profile	Examples for needed information
Development of Product	Information about previous products with similar specification, material, geometry. Customer Complaints and warranty cases of previous products, guidelines for construction, results from prototype tests
Development of Manufacturing Process	Information about complaints, trouble shooting on shop-floor-level, experiences from maintenance, action plans, processes and their reliability, modifications, best-practice, technology, machines, tools, equipments, capabilities
Production (shop-floor-level)	Information about complaints , trouble shooting on shop-floor-level, experiences from maintenance, action plans, customer complaints and warranty cases of those previous products

Table 1 shows examples for different user profiles and their demand for specific information. The first profile belongs to the product developer. His typical demand for information is focused on concepts, products, components, construction and the related technically specifications, materials and geometries. He needs information about failures, causes and solutions from customer complaints and warranty cases.

The developer of the manufacturing process (second profile) also has as an interest in complaints and warranty cases. Additionally he demands for information about trouble shooting on shop-floor level, maintenance, action plans for continuous improvement, process modification and best-practice.

The third profile belongs to the operator on the shop-floor-level. According to his main tasks he needs an access to all information necessary to solve problems occurring in the manufacturing process. This information demand covers both product and the manufacturing process. The interest focuses on experiences from previous products and processes.

5 SOLUTION

The solution we developed is an enabler for the described cycle of organizational learning with focus on the special requirements concerning ramp-up`s in the automotive industry. It bases on a layer model as displayed in figure 4. The core consists of gathered experiences of the organization. This experience knowledge is stored into a knowledge management model, which is a further layer of the system. The tool layer provides access to the entire data stock of the organization. It is the link between knowledge management model and data-sources.

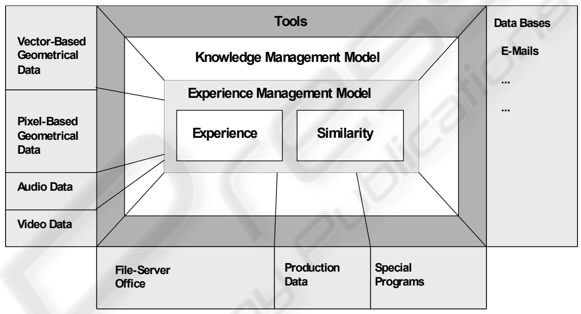

Figure 4: Knowledge Management Model.

As shown in figure 4 there are several different data sources, which are involved in both development and production phase. On the one side there are existing geometrical data like CAD (vector-based) and pictures. Additionally there are also some kinds of audio and/or video data. On the other side there are the data base based applications in terms of ERP (Enterprise Resource Planning), CRM (Customer Relationship Management), Groupware, E-Mail, etc. Furthermore there are lots of documents, which are stored in fileservers. Furthermore there exist monitoring data of the production and also data from special applications.

Based on the generic model shown in figure 4 we developed an extended solution displayed in figure 5. This more sophisticated model consists of four different layers. The enhancement is the consideration of different user groups with their related user profiles.

The first layer named application layer realizes the interface between the user and the system. It provides the interface and the functions to the users. These functions comprise the tools above mentioned for identification, assistance, recording, connecting and diffusion. The second layer called perspectives layer offers a user profile based view on the whole system. These perspectives refer to the user profiles mentioned before.

The following knowledge management layer consists of several parts and is of high importance. This layer is the core of the whole model, because it links different data source (DS) from the data layer to the domain model. According to this domain model the user can save and access different experiences. The domain model should use a standard ontological network (Lepratti, Berger, 2004) or similar kinds of representation formalism. The model represents the relation between different information objects in the whole data stock of an enterprise. An information object is a kind of class, to which different objects with the same structure and properties can be assigned. With its formalism all information object in the data layer (for example claims) can be assigned with relations to other information objects. The advantage of the varying views implemented in the perspectives layer is that the relations of a core domain model can be changed according to the requirements of the corresponding user profile (see additional relation in figure 5).

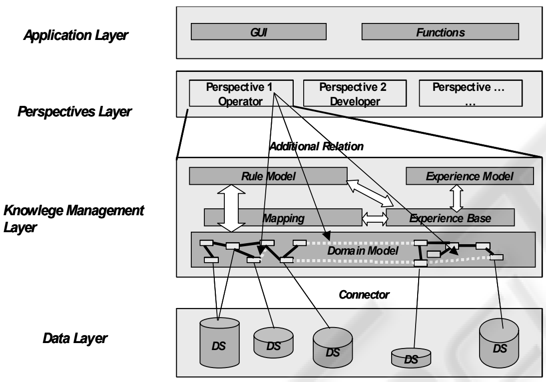

Figure 5: Extended Knowledge Management Model.

This makes it possible to “browse” through the whole data with different perspectives and connections between the information objects. A further extension is the possibility to store different experience with the help of the domain model. For that reason some more parts of the knowledge management layer are introduced. The part rule model and experience model realize the defining and combination of an experience in a formal way. Therefore the mapping is needed between the domain independent formal experience definition and the domain model. Thus, a concrete experience is kind of instance of an experience definition, which maps into the domain model. The connection between the knowledge management layer and the data source in the data layer are implemented by special connectors, which can access the data source.

6 OUTLOOK

The described solution deals with several fields of the Information Technology.

It will be implemented step-by-step in cooperation with an enterprise of the automotive industry. The effectiveness of the described solution to the performance of ramp-up`s will be investigated.

Especially the fields of ontology and the semantic web address strong needs for further research.

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