62 KNOWLEDGE MANAGEMENT FOR DYNAMIC AUTOMOTIVE NETWORKS

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The automotive industry is facing new challenges from increasing product diversification and complexity, decreasing product live cycle times and the permanent need for cost reduction. Car Manufacturers are assigning more and more development tasks and manufacturing orders to suppliers. Suppliers need to create temporary alliances of organizations to share skills, competences and resources. These dynamic automotive networks are facing similar challenges like Dynamic Virtual Organizations (DVO) do.
The ramp-up as linking phase between development phase and manufacturing phase has a crucial role for the success of the network. The whole system has to switch from a development network to a supply chain. The performance of a ramp-up depends on the maturity of the product and the manufacturing process. Knowledge management is an extraordinary driver for both.
Making the relevant knowledge of all enterprises accessible to the members of the network requires more than existing methods and tools in single enterprises could provide. The new approach considers methods and technologies to weave knowledge nets for entire dynamic automotive networks.

1. INTRODUCTION

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 (Kuhn, Wiendahl, Eversheim, Schuh, 2002).

At the same time the competition between suppliers is turning increasingly to a competition among supplier networks. These networks consist of several independent enterprises, co-operating flexible with a common goal. Each member of this network concentrates on its core competencies in order to develop, manufacture and sell jointly products. They pursue the strategy of extensive outsourcing and act based on a common business comprehensive (Camarinha-Matos, Afsarmanesh,

2004). The described dynamic automotive networks have several characteristics of dynamic virtual organizations (DVO), however there is no unified definition for these kinds of organizations.

The dynamic automotive networks are facing new challenges from the increasing number of product launches. Especially the ramp-up is one of the most critical phases of the entire product life cycle in the automotive industry. Generally the product life cycle in the automotive industry comprises the development phase and the serial production phase. The development phase consists of several steps belonging to the main processes of product development and development of the manufacturing process (Wangenheim, 1998). The ramp-up is the linking process between development phase and the subsequent serial production phase. It is a transition phase for each enterprise and even for the entire dynamic automotive network. Before serial production starts only few products e.g. samples and prototypes exist. The ramp-up is characterized by the demand for an increasing production output from the customer side. The whole system has to change from a development network to a supply chain.

Therefore the ramp-up has a crucial role for the financial success of the entire project. Problems in the network could cause extraordinary additional efforts for trouble shooting. Delays in the network could lead to lost sales.

Several research activities pay attention to the importance of the ramp-up for financial success. German research institutes (Kuhn, Wiendahl, Eversheim, Schuh, 2002) identified five levers:

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

Research activities in recent years covered the first four topics widely. Sophisticated project-management tools, reporting systems including escalation paths and early warning indicators provide solutions for planning, controlling, organization and change management. A lot of enterprises developed production systems similar to the Toyota Production System (TPS) with standardization guidelines to achieve robust manufacturing systems. Collaborative Engineering, Supply Chain Management (SCM) and Supplier Relationship Management (SRM) are examples for solutions to issue four. Nevertheless, needs for research concerning knowledge management and training still exist.

In this paper, the concept for knowledge management in a dynamic automotive network is described, in order to provide solutions for the improvement of ramp-up performance.

2. STATE OF THE ART

In order to support and improve the exchange of data and information among enterprises, several technologies and standards are available.

2.1 Data and Information Exchange among Enterprises

For the exchange of geometrical data (e.g. CAD) enterprises use tools based on the interface standards STEP (Standard for the Exchange of Product model data) or IGES (Initial Graphics Exchange Specification). The exchanged data comprises 3D models (solid models, surface models, wire frame models and combination models), drawings and assemblies. The exchange process includes the correction of conversion errors. (PROSTEP, 2006)

For the exchange of data concerning business processes among enterprises (e.g. customer and supplier), EDI (Electronic Data Interchange) or Web-IDE is established. The classical EDI uses protocol standards OFTP (Odette File Transfer Protocol) and EDIFACT (Electronic Data Interchange for Administration, Commerce and Transport) as message type. Typical cases for the use of Web-EDI are internet market places (e.g. SupplyOn).

Concerning quality data the new interface QDX (Quality Data eXchange) is available. QDX bases on XML (eXtensible Markup Language) and provides a neutral standard for data exchange among CAQ–Systems (Computer Aided Quality). QDX supports both preventive activities during product development and corrective activities during serial production (VDA-QMC, 2006).

2.2 Web-based Supplier Relationship Management (SRM)

Nowadays several enterprises of the automotive industry operate communication platforms. They use standards mentioned before for data and information exchange with their partners in the network. In most of the cases the enterprises on the customer site operate communication platforms and define the standards and rules of communication for their suppliers. Most of the communication platforms support one or more of the following processes: Project management, development and assurance, change management, prototype management and purchasing (Gottwald, 2005).

Some of these functions are also offered by neutral service providers such as the operator of internet market places mentioned.

2.3 Failure Mode and Effect Analysis (FMEA) as Knowledge Base

The Failure Mode and Effect Analysis (FMEA) belongs to the standard methods in the automotive sector. It has a certain role for gathering and sharing knowledge especially experience. The FMEA was originally developed for risk analysis but became more and more a knowledge base. In the automotive industry FMEA`s 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 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. Suppliers normally provide an insight into the FMEA document for customers.

In practice many companies use special software tools to create and revise these documents. Different tools with different standards make data exchange difficult. 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.

All concepts are characterized by customer-client-relations from one node of the network to another. There are several highly specialized standards available for the exchange of specific kinds of data and information. Regarding the challenges of distributed information and knowledge in dynamic automotive networks, there is no sufficient solution available. Dynamic automotive networks have to act like a single enterprise, using all the knowledge and experience of its members. Therefore a new approach covering the entire net of enterprises is needed.

3. SCIENTIFIC BASELINE

The theory concerning the cycle of organizational learning (Nonaka, Takeuchi, 1995) distinguishes two kinds of knowledge: Explicit knowledge is knowledge that easily can be formalized and visualized. It is easy to transfer that knowledge (e.g. specific "if-then-rules"). On the other hand tacit knowledge comprises all abilities and skills that are hardly or not at all describable by the knowledgeable person (Schulze, 2004). According to the theory there is an ongoing conversion from explicit to tacit and from tacit back to explicit knowledge in organizations running through 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. 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.

The existence of the model is confirmed by long-term empirical investigation at a small car manufacturing enterprise (Dyck et al., 2005). Research on management of organizational knowledge creation in new product development process (Schulze, 2004) also reaffirms the existence of the cycle of organizational learning. The research model comprised a generic product development process and revealed several important interrelations between phases of the cycle 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).

According to further research, 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 a wide knowledge field covering technologies e.g. material science, physics, chemistry, electronics and software as well as methods for estimating feasibility and reliability, planning and project management. Even from that perspective, knowledge management has an extraordinary leverage for the improvement of ramp-up performance.

4. PREPARATION OF THEORY SET-UP

Information Technology (IT) embedded in an organizational frame could be regarded as enabler for knowledge management. In case of dynamic automotive networks an adequate organizational frame or model as meta-structure is needed.

The automotive pyramid is a well-known model which describes the basic structure of supplier-customer relations in the automotive industry. Enterprises typically can be categorized by their products. The car manufacturers or original equipment manufacturers (OEM) are at the top of the supply pyramid. The pyramid consists of three further levels:
−   Supplier of modules and systems (1st Tier)
−   Supplier of sub-assemblies (2nd Tier)
−   Supplier of components (3rd Tier)
Examples for products of 1st tier suppliers are front-end module, braking-system, transmission-system and for the 2nd tier supplier shock-absorbers and electric motors. Development competences, manufacturing capabilities, knowledge and experience in particular refer to the basic structure of the automotive pyramid.

Regarding IT as enabler for knowledge management of dynamic automotive networks, two leverages on the described cycle of organizational learning could be identified: IT can simplify the identification of people with specific knowledge and connect them with communication functions. Both support socialization. IT can offer easy accesses to information and provide tools for efficient handling and effective distribution of information. These functions support the combination-phase of the cycle of organizational learning.

A model description comprising the meta-structure of dynamic automotive networks and the identified access points to leverage of improvement for ramp-up performance at the same time, offers ontology-based information sharing. Because of the differences in granularity of data belonging to enterprises of dynamic automotive networks, a hybrid model consisting of global and additional local ontologies would be the best choice in general (Stuckenschmidt, Harmelen, 2005).

The solution described in this paper focuses on global structures and do not pay attention to additional local ontologies which might be necessary in specific cases.

5. SOLUTION

In order to support the access to knowledge and experience for all members of the dynamic automotive network, a net of objects and relations is designed based on ontologies. The net consists of typical objects of the automotive business such as customers, materials or products, suppliers, employees, and production lines. These set of objects is linked with specific relations like "belongs to", "has part" and "is part of".

The ontology net or knowledge net covers all enterprises the dynamic automotive net consists of. Therefore the range of this net is limited by the module, system, sub-assembly or component the dynamic automotive net develops and manufactures. For example in case of a braking system, the net would cover the developer and producer of the whole system and its suppliers for components and electronic devices. The net could be operated by one of the enterprises, for example by the enterprise with the highest position in the automotive pyramid. Because trust among enterprises is limited, in some cases a neutral service provider could be involved.
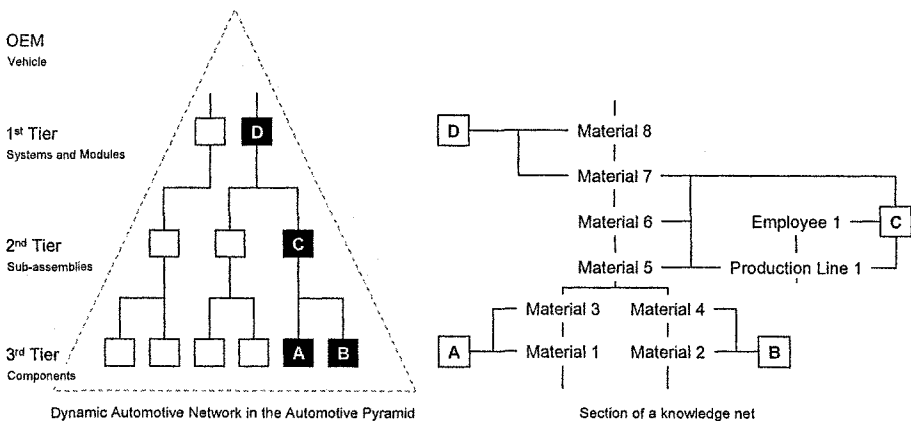

Figure 1 – Dynamic Automotive Network and Knowledge Net

The net itself offers basic objects and basic relations (see Figure 1). To weave a knowledge net master data from each enterprise involved in the dynamic automotive network is necessary. The master data is easily available from enterprise resource programs (ERP) and product data management (PDM) systems by export functions in usual data formats like CSV (Colon Separated Values). It is not intended to export large amounts of data from these databases. Only master data such as supplier name and ID, material name and ID, customer name and ID, production line etc. and their relations are necessary. To weave an extended net overlapping frontiers of the member enterprises, it is necessary to get match code data. These match code data

links between different names and ID's used for one material, supplier or customer in different systems of the involved enterprises. In case of materials usual ERP-Systems store both ID's the customer specific and the internal ID of the material. The net is completed by data concerning employees with relevant experiences concerning customer and supplier complaints, problems and faults on the shop-floor and similar topics.

After the initial creation and configuration of the net, relevant sources and contents have to be identified and selected. There are two possibilities to utilize this process: Employees of each enterprise could manually select certain pieces of information and link them to objects and relations of the net. The manually processing is very time-consuming but leads to high quality results. The second possibility is to use search engines well-known from the internet. These applications could search for all objects and relations of the created net in the databases of the enterprises. The automatically processing is very fast but includes the risk of unintended selecting of sensitive data. In both cases the result is a mapping from a common knowledge net to the distributed sources of the member enterprises (see Figure 2; dotted lines symbolize the mapping).

Natural language documents like reports, analysis and minutes of meetings have a particular meaning. They comprise a lot of important experiences, because people tend to gather and share experiences in these special kinds of learning histories (Kleiner, Roth, 1998).
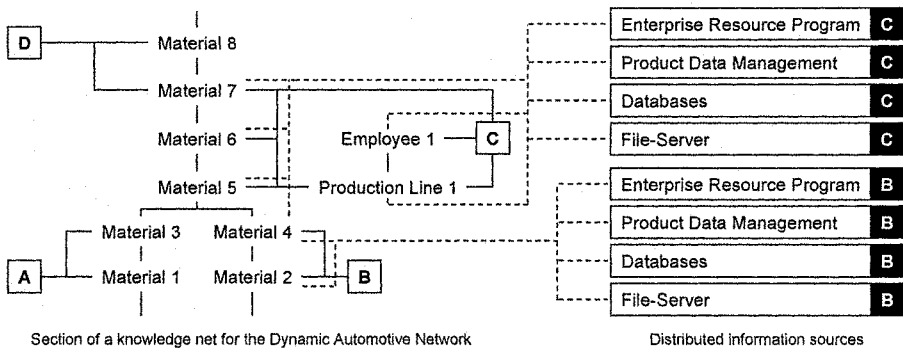

Figure 2 – Knowledge Net and distributed information sources

Authorization plays a crucial role concerning access to the entire or parts of the knowledge net. The degree of trust among enterprises is limited. In dynamic virtual organizations, enterprises have common goals and therefore may tend to have higher degrees of trust than usual customers and suppliers have. For the authorization rules several scenarios could be imagined. A conservative scenario would contain a limited insight for each enterprise to the information's linked to the net-area covering its direct suppliers. This would be similar to the information exchange between suppliers and customers nowadays. An advanced scenario would allow access to the entire net for all members of the dynamic automotive network. This scenario would provide a maximum of access possibilities to knowledge and experience but requires even a maximum of trust between the involved enterprises. Probably the most realistic scenarios lay between those extremes.

The new approach enables enterprises in dynamic automotive networks to share their knowledge flexibly and effectively. It overcomes the limited exchange of knowledge in usual supplier-customer-relations. The solution enables to improve ramp-up performance for entire networks based on extensive knowledge management.

6. OUTLOOK

The described solution will be implemented step-by-step in cooperation with enterprises of the automotive industry. The effectiveness of the concept to the performance of ramp-ups will be part of future research studies. Especially the fields of rapid ontology creation for temporary and flexible organizations need further research.

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