Elicitation of Requirements for a Knowledge Management Concept in Decentralized Production Planning

S. Minhas, C. Juzek, U. Berger

Abstract**—**The planning in manufacturing system is becoming complicated day by day due to the expanding networks and shortage of skilled people to manage change. Consequently, faster lead time and rising demands for eco-efficient evaluation of manufacturing products and processes need exploitation of new and intelligent knowledge management concepts for manufacturing planning. This paper highlights motivation for incorporation of new features in the manufacturing planning system. Furthermore, it elaborates requirements for the development of intelligent knowledge management concept to support planning related decisions. Afterwards, the derived concept is presented in this paper considering two case studies. The first case study is concerned with the automotive ramp-up planning. The second case study specifies requirements for knowledge management system to support decisions in eco-efficient evaluation of manufacturing products and processes.

Keywords**—**Ramp-up, Environmental impact, Knowledge management.

I. Introduction

THE manufacturing industry has witnessed a drastic change in its environment due to rapid globalization and product individualization, which has been characterized by high cost pressures, gradually reducing product life cycle, increasing diversity of car models as well as the varying volume. Consequently, the original equipment manufacturers are no more capable of fulfilling individualized customer demands and bring innovative products to various heterogeneous markets across the globe in cost effective manner. In addition, the pressure has mounted on the manufacturers from the government and environmental regulatory authorities to limit their factory emissions as well as in their supply chain networks. During the course of paradigm shift from traditional mass manufacturing to mass customization, the manufacturers have always tried to consolidate their manufacturing facilities with new resources to be able to address collective demands of segmented markets across the globe as well as the individualized customer demands. But despite consolidating resources, tremendous amount of inefficiencies and complexities have been observed during adaptation of manufacturing facilities for customized manufacturing. This is mainly due to two mainly factors. The first factor is the lack of skilled workforce to deal with the configuration process and second factor is the absence of knowledgebase decision support system to conduct precise decision in an unknown or in uncertain situations. The shortage of skilled workers has hampered the diffusion of new technologies related to knowledge management inside production systems to control production as well as other business activities with other stakeholders outside the company, to bring quick innovations. Furthermore, the manufacturers are relying on adopting high outsourcing strategies to carry out production and development activities. In this respect, increasing outsourcing strategies are being adopted by manufacturers widely across the global horizon. The original equipment manufacturers are compelled to collaborate intensively with external suppliers to develop products under extreme time and cost pressures. Such collaboration is however, not possible due to inherent incapability of current manufacturing systems to adapt them to newly defined manufacturing conditions. It is due to absence of systematic and intelligent planning methodologies as well as strategies to use existing resources optimally. As a result, the configuration or re-configuration of existing manufacturing systems to new manufacturing requirements is accompanied by numerous complexities. This situation has induced several technical and economic complexities in the optimal configuration of supply chain as well as the ramp-up of production in a distributed production environment. Therefore, manufacturers have to organize their supply chains for manufacturing of various vehicle variants at different locations. In addition to that, the rise in the number of vehicle models and their variants and shorter product lifecycles has increased frequency of product ramp-ups to large extent [1]-[4]. The complexities in product ramp-ups may result in huge loss of investment therefore successful handling of production ramp-ups is one of the most important key factors in the automotive industry. The change in product material, process as well as other associated production technologies along with the associated competition between the manufacturers has emphasized building, retaining and automation of skills and knowledge besides intensive collaboration between several suppliers and system integrators. Consequently, successful ramp-up management will even more important than today

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[2], [5]. Typically, production ramp-up processes have a lot of interfaces with several departments (e.g. Research & Development, Procurement, Planning, Logistics, Quality Assurance, and Sales etc.) which are directly or indirectly linked to ramp-up processes. Due to this reason, ramp-up processes are often accompanied by lot of complexities as discussed in [2]. Therefore, it is crucial to take into account the economic impact of these complexities and concrete steps must be taken to enable effective and efficient ramp-up management. Furthermore, it is crucial to take into account the economic effects of these complexities and therefore the large significance of ramp-up management for the success of companies.

Ramp-up management has a direct influence on three important aspects [6]:

- Lost sales
- Quality issues
- Additional Costs

Loss of sales is the result of a delayed reaching of the targeted production rate after SOP (start of production). Due to small product yields, which are common for most of the present products in automotive industries, it is very difficult to compensate the lost sales which occur in the beginning of the life cycle time of product. This fact will be more amplified by shorter lifecycle times of the products [1], [3], [7]-[9]. The second issue is related to quality, which has direct impact on customer satisfaction. The errors and mistakes that are made during the ramp-up phase are usually identified after product is sold to the customer. This is usually followed by big recall actions which are extremely expensive and blow to manufacturer's image [2], [10]. Thirdly, resolving complexities in ramp-up phase are often resulted in more expenditures such as additional shifts (personal costs) and enhanced resource capacities in order to reach production targets.

Another issue is related to the introduced product variety due to increasing mass customization and individualization, which has multiplied the complexities in optimal production planning and controlling. The quest for more and more innovative products has persuaded manufacturers to employ new materials and processes to enable high quality manufacturing in extremely cost and time related constraints. The huge outsourcing trends in the automotive sector in which parts, components, sub-assemblies and assemblies of products are manufactured by 1.tier suppliers or suppliers from other levels have enhanced number and nature of potential direct and indirect processes as well as alternatives. This increasing number of activities in a decentralized production environment resulted in increasing environmental impact in terms of several emissions and ecological wastes. The new environmental directives and regulations limiting the environmental impact of the potential production activities needs new metrics, advanced assessment methods and efficient environmental assessment tools for conducting holistic, reliable, quick and precise assessment. Furthermore, the addition or removal of certain environmental terms according to the new directives and changing assessment methods and unfamiliarity with the potential impact of combinations of materials, process and resources on the environmental impact of the production processes has made manufacturers to ignore this factor in production planning and optimization. Consequently, the production planning in distributed environment is not cost efficient any more. Reviewing the capabilities of ERP, MRP as well as in PLM systems, planning decisions based on cost, time related performance attributes are mainly supported due to incorporated databases and knowledge repositories. However all of these systems are less capable of managing process related knowledge [11]. Additionally, in case of new planning scenario in mass customized manufacturing, the engineers have to rely on their experiences and skills to make decisions. In case of unavailability of experienced planners, the accuracy of decisions is questionable and cannot be relied upon. The decision making based on potential environmental impact of selected materials and processes for customized manufacturing is strongly demanded in pursuit of green manufacturing concept. The fulfillment of this requirement is hindered due to the absence of environmental related knowledgebase and knowledge management tools that facilitate decision making based on potential environmental impact. The knowledge retention is a difficult task as it is continuously expanding with the expansion of manufacturing domain with new materials, processes, technologies, resources such as machines, environmental terms, regulations and assessment methods. This necessitates the need for new knowledge management systems that supports decisions based on environmental impact of customized manufacturing processes. The planners associated with the decentralized manufacturing planning must be furnished with knowledge assistance tools that can help them in making planning decisions considering environmental impact as one of the key performance indicator.

II. State of the Art

The state of the art is presented considering the two case studies from distinct areas where decentralized planning need knowledge management support. They are related to ramp-up of production and during environmental impact based decision making for optimization of potential production schemes.

A. **Case 1** refers to the knowledge management in production ramp-up and
B. **Case 2** refers to the knowledge management in decentralized production planning based on environmental impact assessment

A. Knowledge Management in Production Ramp-Up

After the development process of the product is completed, the following process is called production ramp-up. This process is the first phase of commercial production. Though, in practice, this is often not the typical cause of action due to late engineering changes during production ramp-ups or other problems like production disturbances, lack of training, and problems with materials supply [5], [7], [12], [13].

As already mentioned knowledge management is an important key factor regarding ramp-up processes. In scientific literature several definitions of the term knowledge management are discussed. For example, Puppe et al. define knowledge management as the management and controlling of all relevant processes in the company, which are linked to the utilization, creation, distribution and securing of know-how [14]. Since the identification, storage and practical distribution of expert knowledge is the main objective of this paper, the future research regarding this topic will follow the definition according to [14]

Next, the processes inside the company regarding knowledge management must be considered. At this point it is important to regard how knowledge can be developed in an organizational context. The acknowledged SECI model by Nonaka and Takeuchi describes how knowledge comes into being in a company. SECI stands for the four kinds of knowledge generation in this model [15]:

- Socialization
- Externalization
- Combination
- Internalization

First, Nonaka states that knowledge can only be generated by individuals, and that the creation of knowledge in an organization is not possible without them. At the same time, an exchange of knowledge or experience between various persons is often necessary to generate new ideas [16].

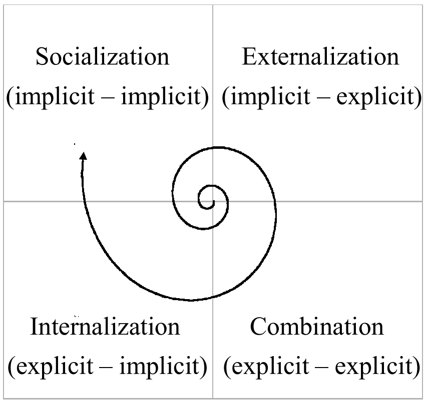

Fig. 1 Four types of knowledge conversion [15]

In the SECI model this knowledge exchange is represented as the spiral through which the four types of knowledge generation pass (Fig. 1). The conversion of implicit and explicit knowledge is seen as the foundation for broadening the organizational knowledge base. Explicit knowledge is that which is available and can be transferred through formal language. Implicit or tacit knowledge, on the other hand, is personal knowledge that is difficult to formalize and thus difficult to pass on [16].

The following is a more detailed explanation of the four types of knowledge conversion according to Nonaka and Takeuchi [15]:

- *Socialization* refers to the transfer of tacit knowledge through interaction between individuals. The knowledge is not verbally described, but passed on through observation, imitation, or practice. In this process, then, tacit knowledge is converted again to tacit knowledge.
- In the case of *Externalization*, tacit knowledge is converted into explicit knowledge through verbalization. The knowledge must thus be formulated or visualized. Since this is often not directly possible, techniques such as metaphors or analogies may be used for support.
- The processing and preparation of explicit knowledge that leads to new explicit knowledge is known as *Combination*. This may take place through sorting, enriching, or categorizing knowledge in meetings or telephone conferences, for example.
- The *Internalization* of explicit knowledge describes its conversion into implicit knowledge through learning by doing. Explicitly available knowledge in an organization is thus internalized through practice or training.

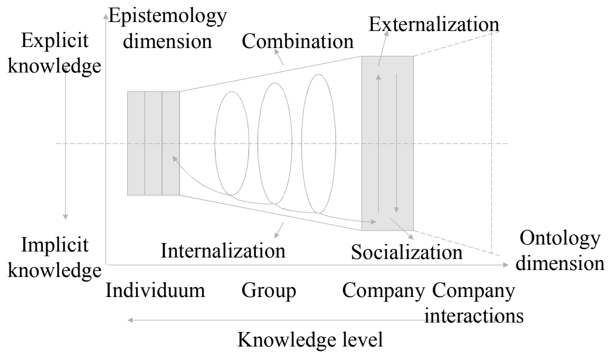

Fig. 2 Spiral of knowledge generation in a company [15]

The extended knowledge spiral (Fig. 2) was developed by Nonaka and Takeuchi based on the four types of knowledge conversion. It shows the conversion of implicit and explicit knowledge as well as the transfer from an individual to a group or a company. With the help of all types of communication, an employee makes his or her knowledge available (Externalization) and creates the opportunity for other people to acquire it (Internalization). Through an ongoing switch between Externalization and Internalization with regard to an individual employee, a group, a department, a company, and even beyond the borders of the system, knowledge is first made accessible for all participants. Further, a gain in knowledge can be said to take place for the company in so far as the communication between employees and the use of existing techniques in communication and information technology are given. With regard to this SECI model, one focus of the present academic paper is on the process of Externalization. Implicitly present expert knowledge is to be made available for problem solving processes in the ramp-up processes.

Likewise in other key fields where knowledge is reused to make decisions in the planning activities, the ramp-up phase is also accompanied by knowledge based planning. The knowledge is gathered after identification, processing, storage and usage of workforce know-how as discussed in [17], [18]. However, this knowledge is generally restricted and limited in scope and will be insufficient to be reused for planning decisions. It is particularly important to consider when the shortage of identified personnel is expected to be intensified in the future. Therefore, it is crucial to secure the know-how of the experienced employees in order to use this information to train and qualify new inexperienced employees [19]. Another reason for the significance of knowledge management in ramp-up processes is the fact that the teams are usually working together until the ramp-up process is successfully finished. After this phase, people are often reinstated in their previous working fields. Therefore, the obtained know-how and expertise of the experienced personnel is no longer available in the following projects. As a result, in following ramp-up processes, it is quite likely, that the experiences learned in previous projects cannot be efficiently used for tasks in new projects. Hence, mistakes and faults are probably being repeated again and again. Moreover, standard procedures are worked out several times. However, the same task has been handled sufficiently in a previous project. But because of an inadequate knowledge management, it cannot be used in following projects. Therefore, the systematic knowledge management in ramp-up processes is highly recommended The know-how which is directly linked to certain people must be identified, processed, stored in order to provide further training opportunities to new employees [2], [18], [19].

The benefit of such a knowledge management can be divided into two categories:

- Performance (number of units, product quality and timeline)
- Costs (direct and indirect ramp-up costs)

Fig. 3 explains these categories in detail. On one hand, the purpose of a systematic knowledge management is to avoid failures which have been done in earlier projects. On the other hand, methods or approaches applied in previous projects should be used again in current or future ramp-ups. But such an avoidance or reuse of applied methods is not a natural course of action [19], [20]. Insufficient problem solving skills of the employees can be one reason for this challenge. Especially, the usage of ramp-up know-how, which is directly linked to certain people, is often a huge problem for companies. This difficulty will be bigger, because problem solving in ramp-up processes requires usually the application of the know-how of experienced personnel [21].

Production planning is the acquisition, utilization and allocation of production resources to satisfy customer requirements in the most efficient and effective way. It is defined as the process of selecting and sequencing manufacturing processes such that they achieve one or more goals and satisfy a set of domain constraints [22]. It is a purposeful, dynamic activity meant for attaining intended goals and targets [23]. Furthermore, it refers to the process of finding tentative plans for manufacturing products or delivering services in various time horizons while achieving performance goals.

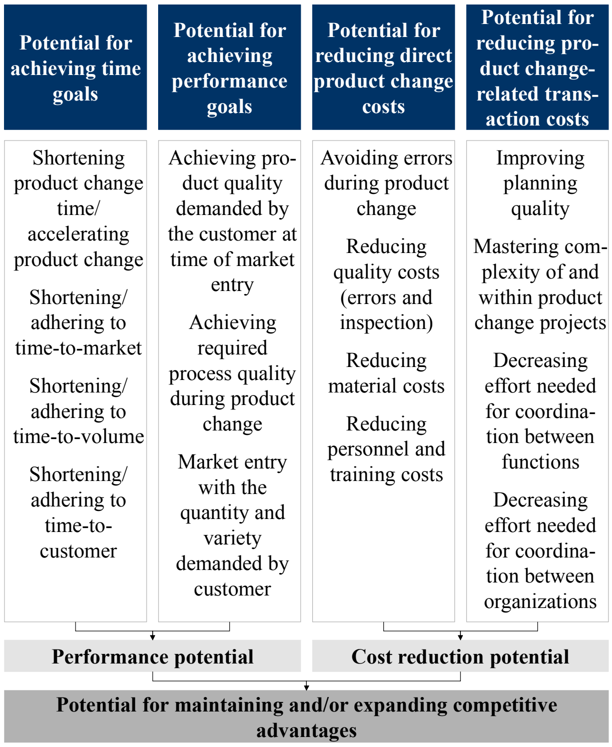

Fig. 3 Potential benefits of knowledge management [21]

B. Knowledge Management for Decentralized Planning

These goals are generally related to cost, time, quality and flexibility. The production planning is extremely difficult task as it needs to plan all activities that convert raw materials into final products of desired quality with lower cost and time. Several methods have been proposed in the literature concerning production planning mentioned in [24]-[32]. A limited number of contributions have focused on planning issues in the distributed manufacturing environment and their optimization based on eco-efficiency. Coordination of local schedulers using heuristics algorithms have been proposed by [33]. Agent based concept has emerged as an innovative solution to solve planning and control problems in distributed production systems. Lima et al. [34] presents a model for agent based production planning and control to dynamically adapt local and distributed utilization of production resources and materials. In a highly individualized customer demand scenario i.e. one-of-a-kind production, incremental process planning has been proposed for extension or modification of primitive plan incrementally according to the new product features [35]. Likewise, agent based approach is used to enable manufacturing organizations dynamically and cost effectively integrate, optimize, configure, simulate and restructure their manufacturing system as well as supply networks [36]. Agent based approaches are more flexible, efficient and adaptable to dynamic and distributed manufacturing environment. It must be emphasized that despite of lot of contributions in the area of manufacturing planning, none of the contributed work has addressed planning based on emerging strategic production goals. The decision support systems allow planners to make decisions considering traditional performance indictors like cost, time and quality.

The focus on mass customization and just in time practices has flourished adoption of build-to-order supply chain concepts [22]. These supply chains allows manufacturers to collaborate with external supply chain partners to handle small-lot, high variety production as well as supply and manufacture one-of-a-kind products at a cost effective and efficient manner [23]. The effective utilization of knowledge is considered as a crucial component in the success of every organization belonging to any field or business area. Knowledge is considered as the means for adding value to the business functions and improves performance as it enables the planners to handle complicated issues inherent in supply chains efficiently [37]. Several attempts have been made by researchers to resolve complicated issues in distinct areas of supply chain management through knowledge management practices. In this case various methods and tools have also been developed to achieve better business performance in uncertain situations. These relates to supporting all activities from procurement to delivery of final products in the supply chain. E-procurement system has been introduced in [38] which has based on MS Sql server system that contains categorized business rules and cases concerned with market situation, human resource involved and the tenders. The information retrieval from the knowledge repository is made through back end application developed in visual basic environment. The system is assisted by case base reasoning module to evaluate performance of suppliers in terms of cost, time and quality. The suppliers are selected based on their capabilities to share information and on-time delivers. This demands reduced product development cycles at suppliers' side. To deal with shorter product development cycles and ensure effective collaboration several portals have been developed with knowledge support capabilities in collaborative environment. WeBid knowledge portal developed for such cause allows planners to evaluate suppliers involved in the design process [39]. Additionally, manufacturers have initiated efficient distribution channels in the global supply chains by exploiting web-technologies, e-commerce and information technologies [40]. In connection with the mass customization production principles, manufacturers are compelled to focus on flexibility in customized manufacturing. The flexibility in resources complicates situation for planners as they have to consider all the possible alternatives while selecting for optimal materials and processes for customized products. Furthermore, in traditional PLM and ERP systems, the information concerning process and resources is sorted under material or product list which does not allow dynamic link between materials, processes and resources to generate alternatives. Additionally, the potential environmental impact of each individual manufacturing and supply process is not included in optimization planning decisions because of complexity in handling knowledge related to the potential environmental impact of each individual process which is affected by product specifications, resource specifications and technological information about processes. Algorithms known from graph theory are used typically for evaluating alternatives. Heuristic rules are employed to limit the computational complexity in evaluating alternative against key performance indicators. The inclusion of environmental impact as key performance indicator maintains the potential for increasing complexities in optimization process. Moreover, the planning decisions will undergo laborious and time intensive environmental assessment of manufacturing processes before decision is made. This is because of the simulation of each distinct manufacturing case using traditional LCA tools. Additionally, optimization planning considering cost, time, quality and flexibility is quite complicated due to expanding and certain heuristic rules are employed to limit computational complexity in evaluating alternatives in optimization processes. However, it is noteworthy to mention that neither the environmental impact of potential production processes is evaluated nor their weightage is considered in final optimization considering all key performance indicators for production.

In the light of these mentioned factors, an intelligent knowledge management concept needs to be exploited to enable quick decision making based on eco-efficient evaluation of environmental impact of each production process scheme in mass customization scenario. The value of overall environmental impact will be used later in final decision making in optimization of production process schemes based on key performance indicators. The concept of knowledge management system is based on the knowledge management framework supporting manufacturing system design introduced by [11], to support factory planning activities. The proposed framework introduces four main parts of the knowledge management system i.e. semantic based repository, the knowledge association engine being responsible for comparing similarities and the inference rules definition and execution. The extended work to this framework is described in work presented in [41], in which the ontology for the manufacturing system is defined. The proposed ontology determines an overall scheme for describing manufacturing knowledge concerning the performance indicators (cost, time, quality and flexibility), the product, the orders and the plant. This work however defines the cost and time assessment rules thereby enriching the reasoning capabilities and facilitating the decision making process.

III. Requirement Analysis

Due to these described challenges in Section II, a systematic knowledge management approach must be adopted in decentralized planning processes to get precise and quick decision making. The analyzed requirements for ramp-up management and eco-efficient planning in decentralized production will be presented separately.

A. Knowledge Management in Production Ramp-Up

In Production Ramp-up process, the intention should be the identification, processing, storage and specific usage of ramp-up knowledge of the experienced employees. At this point, some researches identify a lack of software based information and communication tools. For example management information tools for storage and administration of information and knowledge in the organizational knowledge base. Furthermore, content based systems which provide information and knowledge in the organizational knowledge base or in product change projects. Moreover, artificial intelligence systems in order to access or prepare product change specific knowledge from external sources. Last but not least, project management systems which support the preparation, execution, and follow-up of product change projects through the action-oriented provision of information and knowledge. Other systems are used for the simplification of application of primary systems and supplementary functions. But it must be stated, that the application of these presented tools are not a complete solution to the challenges referred before. As a matter of fact, they are thoroughly useful as supporting tools to enhance knowledge management processes in companies. Table I summarizes and categorizes some of these mentioned tools.

TABLE I
SOFTWARE BASED INFORMATION AND COMMUNICATION TOOLS [21]

Management Information Systems	Content based Systems	Artificial Intelligence System	Project Management Systems	Others
Data Ware House System, OLAP System, Data Mining System	Document Management System, Content Management System, Portal System, PLM System	Agent System, Text Mining System, Expert System	Relational Project Management Software System, Groupware Systems, Distributed Project Information System, …..	Search Services, Visualization System

However, neither in scientific researches nor in practical fields, sufficient software based tools are available for the know-how consolidation regarding experiences of the employees to enhance the problem solving processes in automotive ramp-ups procedures. This statement can be explained by insufficient organizational conditions and instruments for an accelerating know-how creation (e.g. defined activities, straight instructions, and lessons learned workshops for training the personnel in the field of problem solving skills). Furthermore, a strategy to reach these goals does not exist in most cases. Typically, documentation of implicit know-how of the employees is neither suitable nor appropriate. Since, most of the ramp-up know-how is tied directly to definite people and only saved as their experience [21].

Conclusively, the situation which has been presented can be summarized by the following key facts.

- The automotive industry will face significant growth in future.
- The frequency of product ramp-ups factories will increase.
- Ramp-up know-how (especially problem solving skills) is usually linked directly to the personnel.
- In future, there will be a shortage of qualified people.

Deducing from these facts, a systematic knowledge management model must be developed to save the employee experiences regarding ramp-up know-how and enhance the problem solving process in ramp-up procedures. Three key questions must be answered in order to reach this goal.

1) How can know-how be used for new problems and tasks in future ramp-up processes?
2) How can experiences linked to certain people be saved and edited for future applications?
3) For which areas of the ramp-up process, the know-how should be saved?

B. Knowledge Management for Decentralized Production Planning

The problems concerning decentralized production planning to evaluate performance of mass customized production taking into account the new key performance indicators has complicated the planning process. Additionally, the constantly falling number of skilled employees, time consuming LCA simulations to evaluate production performance and infiltration of planning concepts for decentralized production setups requires intelligent approach for managing explicit information in the knowledge repositories. The knowledge repositories are furnished with additional rules and restrictions to enable it to reason and derive information that the planner needs for making decisions on selection of production processes or schemes. Furthermore, the application developed for environmental knowledge retrieval must function on the web-based system to facilitate planners to access the knowledge from distributed locations in the manufacturing network. This leads to analyze the requirements for the following aspects of this intelligent knowledge management system.

1. Which aspects of the environmental knowledge are relevant and needed for eco-efficient evaluation of production processes and schemes?
2. How is this knowledge modeled and formalized to achieve inoperability with other legacy tools?
3. How will the environmental knowledge be extracted from LCA simulation tool and stored in knowledge repositories?
4. How will the knowledge be retrieved through easy navigation through the knowledge management system?
5. Which web-technologies are selected to implement this knowledge management system?
6. Which meaningful information must be exchange with the planning and optimization tools to enable eco-efficient evaluation of production schemes in decentralized system?

To answer these questions, a concept for knowledge management for environmental assessments must be devised, implemented and validated through case examples.

IV. Derivation of Concept

Based on the elaborated requirements, separate concepts for knowledge management have been derived for each case elaborated in the scope of this paper.

A. Knowledge Management in Production Ramp-Up

In the automotive production ramp-up process at various manufacturing locations in the distributed network need to be handled in a systematic and intelligent way to ensure well proceeding ramp-up process. This requires a systematic way of automating the experiences of personnel who have been involved in such ramp-up processes at various geographical locations. The development must be in the form of a tool that must ensure a pragmatic usage of the saved experiences for future problems. Therefore artificial intelligence methodologies must be exploited. In order to achieve these goals and answer the first key question of chapter III, the methodology of case-based reasoning (CBR) is to be applied (Fig. 4).

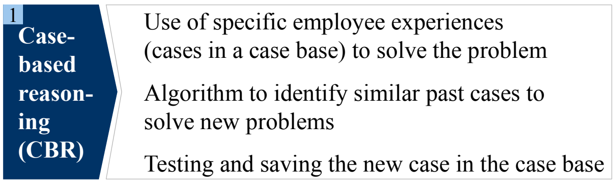

Fig. 4 Cased-based reasoning approach

With the help of this methodology, the practical knowledge of the employees is supposed to be stored systematically and to be used pragmatically in future vehicle projects. Case-based reasoning (CBR) tools are being used in other fields to enable quick and realistic decision making. The standard workflow of a CBR cycle is divided into four steps [42], [43]:

1. *Retrieve* the most similar cases compared to the new problem.
2. *Reuse* the listed similar cases in order to create the new solution.
3. *Revise* the suggested solution by testing in practice.
4. *Retain* the new case including the result into the case base for further usage.

A new case (problem description) will be compared with all cases (problems which occurred in previous ramp-up projects) stored in the case base of the CBR-System. This comparison is conducted according to specific mathematical algorithms which have to be adapted or developed. As a result the most similar cases are listed in an ascending order. Consequently, the most similar cases of this list can be analyzed to derive solutions for the new case/problem. Next, the new solution derived from the old cases must be tested in practical environment. Both the results of successful and not successful solutions will be described in new cases in order to store these new experiences in the case base of the CBR-System. Understandably, solutions which failed must also be stored in the case base to avoid mistakes or failures in future ramp-up projects.

Case based reasoning approach is among the potential solution to enable quick and reliable decision making as the similarity comparison is quite practical. It is due to the fact that the problems that occur during ramp-up processes are usually similar but rarely identical. However, some prerequisites need to be created in order to develop a functioning CBR-system. Naturally, the CBR- system can only provide useful results as long as the case base is filled with high quality and representative cases. This is a difficulty of most CBR-systems [21], [44]. Therefore, a pragmatic solution to identify those cases must be found.

In order to give an answer to the second key question the case database must first be filled with a sufficient amount of high quality cases. To that end, an adjusted Delphi survey will be developed that can be used to derive and evaluate critical problems including solutions based on the experience of experts in the area of ramp-up management (Fig. 5). In the field of information systems research the Delphi method is largely common and acknowledged [45]-[53].

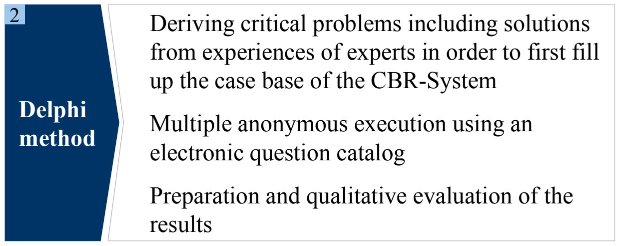

Fig. 5 Delphi method approach

In order to be able to save the first cases in the case database of this system, critical ramp-up problems must first be identified and solutions proven in practical application must be entered. In this context, the evaluation of problems by the respective experts regarding their frequency of occurrence and the damage they cause is important in order to be able to make a statement regarding the quality of the case database and to ensure that it is representative and filled with high quality cases. Therefore a Delphi questioning approach should be developed that allows the collection and evaluation of cases for an ontology-based CBR-system. Advantages of this method are the relatively small number of necessary experts, anonymity and recursively questioning. All experts can add information to the described cases in several loops. Furthermore, the monitoring team that supports implementation has the ability to summarize interim results and to obtain missing information in a targeted manner during the following loops of the Delphi survey. Also the Delphi survey can be conducted independent of location and allows a final evaluation of all cases by all experts involved while avoiding opinion leadership. Based on these characteristics, it is possible to detect high quality cases in a rather pragmatic way [45], [54], and [55]. These are important preconditions with regard to a successful implementation of a CBR-system to support the knowledge management in companies.

Referring to the third key question mentioned in chapter III, a method for structuring the ramp-up know-how must be defined. This method must also meet several conditions (Fig. 6). Firstly, it must be compatible and suitable to the CBR-system. In other words, the cases in the case base should be saved and stored along with this structure. Furthermore, the similarity comparison should also be based on that structure.

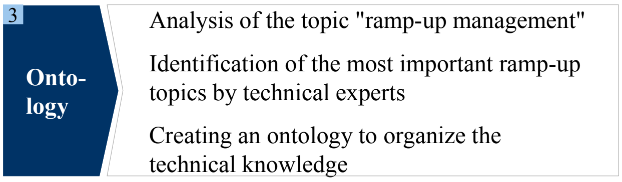

Fig. 6 Ontology approach

Both demands can be fulfilled by applying an ontology based approach to structure the ramp-up process. For structured storage, the vocabulary of an ontology can be used which describes the domain knowledge (expertise) and serves as indexing base for the cases (practical knowledge). In particular, the case-based similarity comparison based on domain ontology seems to work well for the problem solving processes in ramp-up management, since here problems keep occurring that are similar, but not identical to those in past vehicle ramp-ups. Therefore, with the help of ontology know-how can be organized in a very pragmatic and useful way [44].

Secondly, Delphi questionings must also be operationalized [21]. Ontologies are also helpful at this point. The questioning structure of the Delphi method should be built along with the ontology in order to store the identified cases corresponding to the case base structure. In summary, the pursued software based knowledge management model consists of three methods.

B. Knowledge Management for Decentralized Planning

In the decentralized production planning, the production of customized product comprises of several start and end points for material supply, delivery as well as for their manufacturing at several distributed locations. Hence for each customized product, there exist several alternatives for material supply, delivery and manufacturing locations. This depends on the number of suppliers and their locations, the number of manufacturers and their locations and the distributors and their locations, which are considered for manufacturing customized products. This constitutes a chain of production processes which can be called as production scheme.

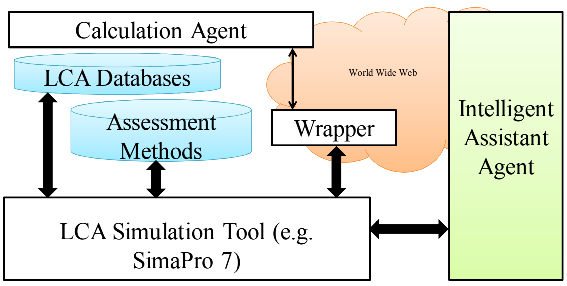

Fig. 7 Architecture for Environmental Assessment Module

The production scheme in the decentralized production network consists of several nodes. Each node is specified by the product information, the process technological information and the resource information corresponding to the process technology. For optimizing the production schemes based on their potential environmental impact, additional features such as knowledge repositories and inference rules must be incorporated in the tool named as intelligent assistance system. This system enhances flexibility for evaluation of production schemes in the planning system as it delivers add-on functionality to the existing legacy system. The architecture for environmental assessment module for planning system is shown in the Fig. 7. It consists of four basic modules namely LCA simulation tool (LCA simulation agent), the intelligent assistance system, a wrapper and a calculation agent. The LCA simulation tool is a commercial simulation tool like SimaPro 7 or Gabi4 widely used in automotive manufacturing industry. The tool must be connected to the LCA databases and assessment methods to retrieve information needed to simulate production process models. The LCA tool must be made accessible to external applications using standardized interfaces such as COM interfaces which can be used for the calculation of data in an understandable way. A wrapper must be developed which integrates the commercial LCA tool with the calculation agent. The results from the simulation tool as well as input to the simulation must be stored in a standard file format. This file needs to be imported in the intelligent assistance system to use it for expansion of knowledge repository. The expected functionality of intelligent assistance system is to store and infer knowledge concerning environmental impact of potential production schemes to manufacture customized products. The workflow for such as system is illustrated in Fig. 8.

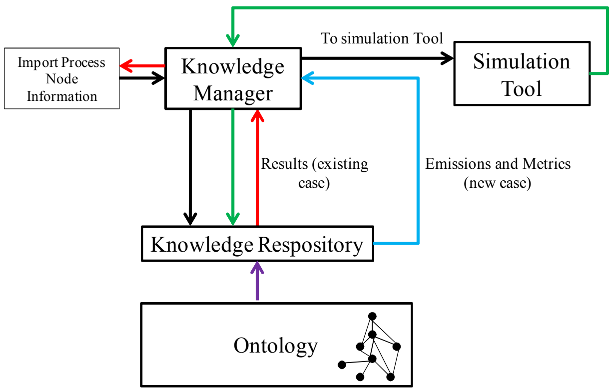

Fig. 8 Workflow for information retrieval (Intelligent Assistance Agent)

The potential production schemes generated from legacy system will be stored on the web-server to allow distributed planners to access them locally for evaluation. The information in the production scheme file will be parsed and segregated on nodal basis. Each node will describe the information about the part or product, operation and the resource related information. This information will be shared with the knowledge manager. The knowledge manager will generate a query based on the output information from the tool named as dynamic network module. Dynamic network module selects resources (related to manufacturing sites) and suppliers; taking real time information from its several databases and evaluates each production scheme based on the key performance indicators such as cost, time, quality and environmental impact. The knowledge manager queries the knowledge repository concerning the environmental impact of potential process node. The knowledge repository, which is enriched with the already existing simulated results of the potential production schemes, is navigated for the environmental impact results. The outcome of this navigation will be the results of the environmental impact of the same case stored in the knowledge repository or inferred from the similar cases. The results and the simulated case (input-output data) will be stored back inside the knowledge repository to enrich sematic information stored inside the system.

The input production scheme file will be stored in xml file format and xml parser will parse the information inside the file on node basis. Each node will be taken as input to the query generation part of the knowledge manager. The knowledge manager will generate a query in SPARQL format to query knowledge repository modeled as ontologies. A semantic web reasoner will be developed based on Jena Engine and enriched with semantic web-rules to consolidate inference capabilities of knowledge repository.

V. Conclusions

In this paper, the requirements for the knowledge management concept for two key areas of manufacturing planning namely production ramp-up and eco-efficient assessment of production schemes to produce customized products have been synthesized. For ramp-up knowledge management, the cases related to problems in ramp-up have been defined using case based reasoning approach, then Delphi surveys approach is selected to fill-up the knowledge-base. For identifying the important topics in ramp-up management and structure them in a taxonomic way, ontology based approach has been selected. In the second case study, the knowledge management for environmental impact, ontology based knowledge repository is being developed to store the simulated results as the inference rules inside the knowledgebase. A web-based application is expected to be developed in this case to allow distributed planners to share and utilize environmental knowledge and conduct quick decisions in mass customized production.

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