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Quality Improvements in Product Design and Development with Knowledge Capitalization/

Imbunătățirea calității în proiectarea și dezvoltarea produsului folosind capitalizarea cunoștințelor

REZUMAT/ ABSTRACT

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Table of Contents

Preface

Nowadays manufacturing industry needs to change its approach from cost-cutting to knowledge-based value adding, in order to achieve sustainable and competitive growth.

Advanced automation, precision robotics, just-in-time delivery – these technologies represent enormous achievements in automotive production. But in today's global business climate, with traditional markets stagnating and competition from emerging economies increasing, automotive manufacturers must look beyond production to maintain their position in world markets. Automotive manufacturers represent a huge percentage of manufacturers' total assets and annual investments. Not only must today's companies be flexible enough to accommodate multiple product series and short product lifecycles, but periodically a significant design change may require a complete reconfiguration, or the construction of an entirely new facility. Thus, the research literature reveals an outburst of studies proposed and proven methods and strategies that facilitate the process of globalization despite the obstacles, be they political, economic, demographic or otherwise.

The achievements and studies are focused on automation of activities, any kind of activities from manufacturing industry. These flexible and automated manufacturing industry need to incorporate a lot of knowledge in the daily activities, from workers' knowledge to engineers' knowledge.

The main purpose of this study is a knowledge–oriented approach that will support the quality performance in manufacturing industry. The model developed is helping the multinational companies or the companies that have outsourced some processes to collect, during the manufacturing process, specific knowledge, knowledge that must be reusable, shareable and maintainable.

Typically, companies manufacturing automotive components have very well organized processes following the quality systems; however, these processes do not directly target the reuse of knowledge.

The present research aims to find a solution, a method that supports improvement of the quality in manufacturing industry by collecting the specific knowledge, knowledge that can be reused, shared and maintained. Thus, the system developed finds the applicability in the largest Romanian exporter automotive company that produces spare parts. The lack of such a system was identified in the various issues that appear during the planning and running of production, by communication difficulties among the members involved in the planning, by reuse of knowledge already existing in the company, by capturing knowledge from the skilled people that leave the company. With all the difficulties of a global market, interest in such a system has proven to be from inside of the company but implementation efforts have proven to be beneficial to the company.

This PhD thesis brings contributions in developing a knowledge oriented system that will capitalize the know-how of the engineers, system that will increase the quality in the design and development product phase.

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1. Introduction: thesis objectives and research methodology

Today's manufacturing industry needs to change its approach from cost-cutting to knowledge-based value adding, in order to achieve sustainable and competitive growth.

Advanced automation, precision robotics, just-in-time delivery – these technologies represent enormous achievements in automotive production. But in today's global business climate, with traditional markets stagnating and competition from emerging economies increasing, automotive manufacturers must look beyond production to maintain their position in world markets. Not only must today's companies be flexible enough to accommodate multiple product series and short product lifecycles, but periodically a significant design change may require a complete reconfiguration, or the construction of an entirely new facility.

Thus, the interrelationship between the products, factory, and processes presents a high need of involvement and interdependence among different actors. The product demanded by the increasingly competitive market determines the process characteristics and configuration, such as equipment, organization, and product volume and, all of these must be mixed together for best quality and low prices of goods. The process determines the factory layout and its equipment, the support facilities and services that individuals operate, control and supervise; and accordingly, the factory determines the product volume. The change of one component results in changes to other components. All these elements apply to production facilities as well as to an entire factory. If a small change appears in the chain above, everything must start from the beginning.

The research aims to study the **quality improvements** in product design and development phase by **knowledge capitalization** in this variety of changes and modifications of processes, equipment, facilities, individuals, components and customers' requests.

Analysis is the essential activity of an engineer; it is what differentiates the engineer from the technician. Engineering analysis supports the decision-making and guides the design process. Failure mode and effects analysis (FMEA) is a powerful and documented method used to define, identify and eliminate known and/or potential failures, problems and errors from the system, design, process and/or service before they reach the customer, even before they reach the mass production.

The collecting and organizing of knowledge obtained from FMEA will be helpful to reuse and share with the actors involved in the FMEA process but also with all actors from organization that need this kind of information. The pertinent use of FMEA knowledge throughout the manufacturing process is an assurance of continuous improvement of quality in manufacturing process.

For the multinational companies or for the companies that have outsourced some processes from design and planning activity arises the need for the possibility to collect during the manufacturing process the FMEA specific knowledge, knowledge that must be reusable, shareable, and maintainable.

Manufacturing is being shaped by the paradigm shift from mass production to on demand dictated, personalised, customer-driven and knowledge-based proactive production. Thus, shorter product life cycles, an increased number of product varieties, high performance processes and flexible production systems result in an increased complexity in the product design, process development, factory and production planning and factory operation.

The limitations of FMEA procedure outline by the engineers are:

- the length of time that is needed to initially complete the FMEA procedure.
- the time spend on arguing about wording and not on investigating the recommended action
- the FMEA documents are usually filed but not used throughout the design process.
- valuable job-related information leaves the company together with the employee
- meaning of the FMEA items depends on the interpretation of the team/ a team member who performs the FMEA
- de-localization of the team members
- interfering with daily activities of the actors involved in FMEA process

The FMEA procedure is the method that is applied during the design and planning phase, and in this phase there are 80% of knowledge related to the product development process: from machines to operators, and processes.

Case Based Reasoning (CBR) is a methodology for problem solving based on past experiences. This technique tries to solve a new problem by employing a process of retrieval and adaptation of previously known solutions for similar problems. CBR system is based on knowledge and is required to select useful cases with respect to the current problem situation. This selection of useful cases rely on the core assumption of CBR: similar problems have similar solutions.

This means that a specific problem can be resolved by reusing solutions that have been applied to similar problems in the past. Hence the problem that must be resolved has to be compared with older problems described in the cases. The solutions contained in the cases that represent very similar problems are then considered to be the best applicants for solving the current problem.

This research is focused on how to reuse the knowledge already existing in the organisation in a way that does not interrupt the daily activities of the people involved in order improving the quality inside of product design and development phase. In order to reuse the knowledge, a system able to capture the knowledge is necessary; such a system is presented in the following chapters.

The results of this study consist of the development of a FMEA- driven knowledge related system, as part of the product design and development phase, to ensure flawless running of the production line and ensure the quality of products according to customer requirements.

This study presents an analysis of the FMEA process and of the Case Based Reasoning methodology, followed by the implementation and evaluation of different algorithms for a comparative analysis about the reuse of knowledge inside the product design and development phase.

The objectives were defined during the period of research and were pursued to achieve their final stages of implementation. These objectives can be listed as follows:

- to build a system that improves the quality of the final product by capitalization and reuse of the specific knowledge from the design and planning phase of production;
- to build a system that reduces the time of the FMEA process and allows a truly collaboration among the different departments involved in the FMEA process;
- to build knowledge FMEA-driven system with CBR approach;
- to identify the best algorithms necessary for the retrieval of knowledge;
- improving the quality inside the product design and development phase
- eliminating the risk of disrupting the daily activities with usage of software tools
- improving the quality of the documents created during the product design and development phase
  - eliminating abbreviations and limiting the different descriptions of the same events
  - reducing the impact of mobility of the team on the outcome of product design and development phase
- improving the quality of the outcome of product design and development phase by assuring the easy access/retrieve to up-to-date knowledge
- integration and adaptation of the system inside one of the largest Romanian manufacturing automotive components company;

The research aims to develop a knowledge driven system FEMA as an integral element of the product design and development phase in order to ensure the proper knowledge about production and high end products according to customer requirements.

The most important aspect of the key performance indicators is time. The time allocated to the product design and development phase is most often delayed due to many inconveniences but mostly based on the limited access to the right knowledge at the right time by the right people.

It is not enough to just capture the knowledge of the engineers inside a software tool or on paper, but the rapid access to this knowledge is crucial during the product design and development phase, and also the up-to-date knowledge used is one of the most important challenges during this phase.

2. Product design and development phase

2.1 Design analysis process and APQP

Analysis is the essential activity of an engineer; it is what differentiates the engineer from the technician. Engineering analysis supports the decision-making and guides the design process.

Advanced product quality planning (or APQP) is a framework of procedures and techniques used to develop products in industry, particularly the automotive industry. According to the Automotive Industry Action Group (AIAG), the purpose of APQP is "to produce a product quality plan which will support development of a product or service that will satisfy the customer". The process is described in the AIAG manual, (www.aiag.org).

Methods like APQP are necessary in order to forward the information flow across the organization, within projects, but also from project to project, reducing the paperwork at the same time (E. Mitchell, 2001). Brewer (Brewer, 2002) outlines that the power of APQP is better estimated during project planning by unifing all the requirements development information early, instead redesigning and reworking the new product during manufacturing.

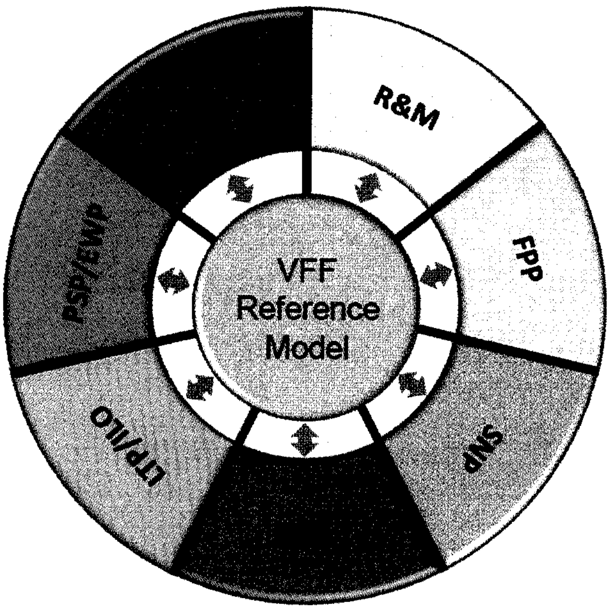
It's important to recognize that the APQP process is not a sequential, or even linear, process. Many of the activities and tasks can and should be done concurrently.

2.2 Related research in the reference model factory

Reference models in factory planning are great knowledge repositories and provide a map of interlinked concepts that describe a particular problem space. The reference models are built by experts, in a particular field of interest, and provide a visual aid greatly facilitates comprehension and knowledge dissemination among individuals (Scheer & Güngöz, 2007).

The Virtual Factory Framework project (VFF) is a Collaborative Research Project funded by the European Commission under the 7th Framework Programme (FPVII-NMP #228595). The project had a consortium composed by 29 partners across Europe and the main objective of the project was to create an object-oriented collaborative virtualised environment, representing various factory activities meant to facilitate the sharing of resources, manufacturing information and knowledge.

The VFF Reference Model is extensible and open for implementing additional data in the planning activities, when detailing the planning phases into tasks and activities (Westkämper, 2009). At the same time the VFF Reference Model is clear and well defined and structured through the use of a common modelling method. The VFF Reference Model for Factory and Process Planning is separated in seven planning phases that cover the whole factory and process planning process. An overview of the whole Reference Model is given in Figure 1.



R&M: Requirements Management and KPI Specification
FPP: Factory Performance Planning
SNP: Site and Network Planning
BIM: Building, Infrastructure and Media Planning
LTP: Layout Planning
ILO: Internal Logistics
PSP: Process Planning
EWP: Equipment and Workplace Planning
RUP: Ramp up

Figure 1 VFF Reference Model for Factory and Process Planning

The identified, established and defined planning phases and their steps do not have to be processed sequentially. A predefined sequence is not the objective of the VFF Reference Model. However, there are dependencies and information exchanges between its planning phases. The planning activities represented in the workflow have to be detailed, adapted and situation-based (re)arranged in a certain planning project. Therefore, single planning phases can be left out or integrated in an individual planning project. Furthermore, the planning workflow has to be as detailed as possible and as generic as necessary, in order to apply the VFF Reference Model in different industry sectors (Constantinescu, 2010).

2.3 Knowledge management in design process analysis

Knowledge Management (KM) that was considered at first as a scientist stake becomes an industrial stake in this economic struggle. It is a complex activity that can be nailed from several viewpoints: socio-organizational, financial and economical, technical, human and legal and it refers to the theoretical and practical know-how of (groups of) people in the organization. Several researchers studied knowledge management and focused on defining methods in order to build corporate memories, other researchers considered organizational memory as an "explicit, disembodied, persistent representation of knowledge and information in an organization" (Van Heijst, 1997), some researchers focused on capitalizing the past experience. Other studies worked on how to keep track of an activity and especially a project, the challenge persuades of knowledge capitalization without interfering in daily activities and in workplace.

The company knowledge consists of tangible elements (data bases, procedures, drawings, models, algorithms, documents used for analyzing and synthesizing data.) and intangible elements (people's abilities, professional knack, "trade secrets", "routines" - unwritten rules of individual -, knowledge of the company history and decision-making contexts, knowledge of the company environment (clients, competitors, technologies, influential socio-economic factors). The tangible and intangible elements are real even if the company recognizes them like knowledge or not.

Knowledge Management (KM) literature review reveals IT as the element useful for storage of explicit knowledge, but less helpful for sharing tacit knowledge and stimulating the use and creation of knowledge. Managing this knowledge has become an important issue in the research community and several authors have explored its nature, concepts, frameworks, architectures, methodologies, tools, functions, and as a result there are several frameworks that have been defined to manage knowledge.

Based on research (Shaobo L., 2010), we can say that KM in product development overlays a vast spectrum of activities and operations at different levels from the individual to the whole enterprise. Effective KM can be accomplished addressing not only technological solutions but also people, process and links of core business activities

What is capitalization of knowledge?

Catchphrases such as knowledge-based economy, knowledge-based organizations, education based on knowledge are often used today, when the Internet changes our world every day and embracing the digital age is a challenge for all organizations. Instead of useful knowledge, organizations have available huge amounts of raw data stored in databases, file systems and different archiving systems, but not always have available knowledge.

Knowledge represents a very volatile intellectual capital for any company. Small and medium-sized enterprises are considerably weakened whenever one of their staff members leaves as these results in a loss of knowledge (Wong et al., 2004; McAdam et al., 2001). This loss of knowledge could be counterbalanced if companies were able to capitalize this knowledge and the skills of the person concerned. Knowledge, even more than capital and physical resources, has become the essential ingredient for creating value (Rikowski, 2003).

The product development has become a knowledge intensive process, and it consists of transformation process information. At the enterprise level the knowledge can be found from individual, to group or also to external resources, in all activities undertaken. An individual resource of knowledge means professional qualifications, personal experiences, and capacity to transform information in knowledge. Instead, group resources of knowledge imply patent acts, models, concepts, enterprise culture and management. The total resources of individual and group knowledge are internal resources of the enterprise. In contrast to internal resources, external resources are defined by relationships with customers, suppliers and partners. Tacit and explicit knowledge is transferred between these resources, and the knowledge is often transformed from a resource to another.

2.4 Failure Mode and Effects Analysis

Failure mode and effects analysis (FMEA) is a powerful and documented method used to define, identify and eliminate known and/or potential failures, problems and errors from the system, design, process and/or service before they reach the customer, even before they reach the mass production. Today, FMEA is in widespread use by a multitude of industries, many of which have begun imposing FMEA standards.

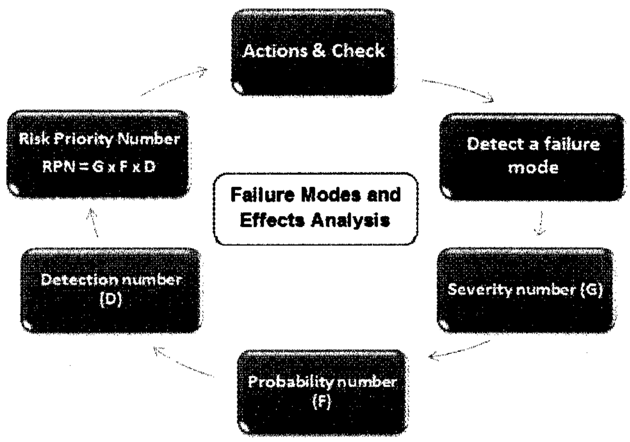


Figure 2 Main steps of FMEA

To shorten the process of FMEA development and earning results, the knowledge included in already developed FMEA has to be reused and the first step is to capitalize the knowledge. The capitalization will not just shorten the FMEA process but will prevent that valuable job-related information that will leave the company together with the employee.

The FMEA knowledge reuse endures from a major short-coming mentioned by Wirth et al. (Wirth, 1996): the FMEA-related information is acquired in natural language and is not much reusable because the systematized components, functions and failure modes are not made explicit. The meaning depends on the interpretation of the team / a team member who performs the FMEA and can fluctuate when another team reuses this FMEA, or even if the same team tries to reuse it on a later occasion.

Although one person is in charge of coordinating the FMEA process, all FMEAs are team based processes. The scope for a FMEA team is to gather a range of perspectives and experiences in the project. Because each FMEA is unique in dealing with different aspects of the product or process (production, engineering, logistic, marketing, support), FMEA teams are formed and dispersed when needed. Based on this variety of requested people another short-coming is set by the unavailability (de-located team, overlap of membership between the teams) of team members to attend at FMEA meeting.

Potential failure modes and Effects Analysis (based on FMEA methodology) processes are based on worksheets that contain important information about the system / component of a system/process, such as the revision date, the team involved in this process, the names of the component analysed, the responsible person of the FMEA process. On these worksheets all the items or functions of the subject should be listed in a logical manner, based on the block diagram. For a systematic approach the system/component/process analysed is split in groups of operations (e.g. welding, washing, etc.). For each item or function, the possible failure modes, effect and causes are listed and each of them are graded for their severity (S), frequency of occurrence (F), and detection rating (D). Afterwards, the Risk Priority Number (RPN) is calculated by multiplying S, F and D. Once this is done it is easy to determine the areas of greatest concern. This has to be done for the entire process and/or design and the items that have the highest RPN should be given the highest priority for corrective action. After these values are allocated, recommended actions with targets, responsibility and dates of implementation are noted on the worksheets.

Dittmann (Dittmann et al., 2007) shows the potentials of combining IT-based systems of knowledge and quality engineering, particularly in FMEA procedure. As a results of this research the authors consider that the technique of ontologies is able to facilitate the FMEA proceeding and can solve the main shortcomings: the reuse of knowledge, keeping the knowledge in the knowledge base up to date, especially to avoid redundant work.

Also Molhanec (Molhanec et al., 2012) explores the usage of ontology in FMEA procedure, but specialised the research in Soldering Process. In this study there was confirmed that ontology offers a common understanding of the domain and further the knowledge held in the ontology based model can be computationally processed.

Xiuxu (Xiuxu Z., 2012) studied the practical need to acquire FMEA knowledge in manufacturing process and succeeded to acquisition, storage and retrieval of FMEA knowledge during manufacturing process for a continuous improvement of quality.

But there are still areas that need further research. Common sense ontology is needed to provide parts of standardized components and functional taxonomy. It would be helpful to count on common consent of industry and technical research. The integration of FMEA into existing knowledge bases has not been examined exhaustively.

3. Case-based reasoning approach

This chapter will review the fundamentals of case-based reasoning (CBR) from a different viewpoint compared to the traditional studies of CBR, and examine the relationship of expert systems (ESs) and CBR systems.

Case-based Reasoning is an approach to problem solving based on the solutions of similar past problems, by solving new problem means using the solution used in the past or adapt the older solution for the newer problem. The CBR systems are a unique type of analogical reasoning system and in the last years the specialized software with application in different fields increased (Aamodt A., 1994; Dubois D., 1999; Maher M.L., 1997; Schank RC. 1982; Schank RC, 1989; Watson I. 1997). CBR research has tighten around issues such as process models (Aamodt A., 1994), the case-based planning (Hammond, 1989), the organization of case bases (McCartney R, Sanders K.E. 1990), the efficient algorithms for case retrieval (Bartsch-Spörl B., et al., 1999), the assessment of the similarity of cases (Hüllermeier E, et al., 2001). The literature review reveals that methodologies for CBR have been developed based on soft computing in the last few years (Pal S.K., et al., 2001).

3.1 Knowledge and experience

In order to define knowledge, usually we must distinguish between data, information, understanding and knowledge (Nooteboom, 1996).

- Data. "External sign materially produced by events".
- Information. "Interpretation entails the production of meaning, which transforms data into information".

- Understanding. "Connects and transforms information into beliefs or claims of causal or deductive insight".
- Knowledge is "a meaningfully ordered stock of information (interpreted data), and understanding, plus ability to transform it into actions, which yields performance".

In order to provide the appropriate knowledge to support product development, it is necessary to capture the appropriate knowledge.

Engineers engaging in new product development bring to their work the formal and articulated expertise of their disciplines that have been socially constructed through time by particular professional or academic communities. This knowledge initially frames their attention when they approach a problem; however by making sense of a particular problem and of the information they encounter, and by taking action and revising their interpretations, they develop, analyze and create new knowledge. The knowledge that is created and shared amongst organizational members can be categorized into two typical forms of knowledge – Tacit and Explicit.

Tacit knowledge is highly personal, fastened in personal experience and involves intangible factors, context-specific and therefore hard to formalize and communicate. This type of knowledge is stored in the human brain, such as in personal belief, expertise, perspective and values formed as a result of experience.

Explicit Knowledge is defined as public knowledge, it covers those aspects of knowledge that can be articulated in formal language and can be easily transmitted among individuals using information technology, easily processed by a computer, easily stored in databases. Explicit knowledge can be expressed into formal language, including grammatical statements (words and numbers), mathematical expressions, specifications, manuals, etc.

One of the main challenges faced by organizations is how to acquire the required knowledge and manage sources of uncertainty in order to reduce the risk of failure of either the project or the resultant product. Acquiring the necessary knowledge to address problems, uncertainties, and potential causes of failure, assumptions and the relationship between them is difficult, maintaining that knowledge for use in further projects is even more difficult because of the volume of knowledge created during each new product development project.

Experience

It is hard to define what experience is, the same like it is to define the knowledge. Overall the experience can be seen as a previous knowledge or skill obtained in the daily activities. For example, Gabriela drove carefully through the main street yesterday, focusing on the driving, and avoided an accident. This is a normal experience from driving activities. Generally speaking, experience is previous knowledge which consists in problems that somebody met but also the successful solution of the problem.

More than 200 years ago, Plato believed that when we think that we discover or learn something, in fact, we are just recalling what we already knew in a previous existence (Newell A. et al., 1987). Strictly speaking, experience is the main part for intelligent activities.

In his paper Kolodner sustained that (Kolodner, 1993) a case is a contextualized piece of knowledge representing an experience that expresses an essential way to achieve the goal of the reason. Accordingly a case can be seen as an experience; this experience can be reused for solving other problems because it represents not just a short description of the solution for the previously solved problem.

3.2 The four steps of CBR

Each case from CBR consists of at least two components, a problem and its solution. Researchers added also other components such as justification and result; these are stored like additional knowledge (Recio-Garcia et. all, 2006; Massie et all, 2007).

Case Retrieval

Most of the earliest CBR systems such as PERSUADER (Sycara 1987, Sycara 1988), BATTLE PLANNER (Goodman 1989), CLAVIER (Hennessy & Hinkle 1992), CASCADE (Simoudis 1991, Simoudis 1992), ARCHIE-2 (Domeshek & Kolodner 1991, Domeshek & Kolodner 1992, Domeshek & Kolodner 1993) and ASK (Ferguson, Bareiss, Birnbaum & Osgood 1992) were systems oriented on retrieve only and, the other steps of CBR were left to be resolved by human users.

Case retrieval is the process of finding, within a case base, those cases that are the closest to the current case. To carry out effective case retrieval, there must be selection criteria that determine how a case is judged to be appropriate for retrieval and a mechanism to control how the case base is searched. The selection criteria are necessary to determine which the best case to be retrieved is, by determining how close to the cases stored the current case is.

Case Reuse

The reuse of the retrieved case solution in the context of the new case focuses on two aspects: the differences among the past and the current case; and what part of retrieved case can be transferred to the new case.

Recent works have led to the development of automated adaptation techniques but most remain domain dependent and computationally expensive (Craw, Wiratunga & Rowe 2006, Leake & Powell 2007, Cojan & Lieber 2008, Sugandh, Ontan'on & Ram 2008, Badra, Cordier & Lieber 2009, Leake & Kendall-Morwick 2009, Dufour-Lussier, Lieber, Nauer & Toussaint 2010, Leake & Powell 2010, Ontan'on & Plaza 2010).

Case Revision

When a case solution generated by the reuse phase is not correct, an opportunity for learning from failure arises. This phase is called case revision and consists of two tasks:

- Evaluate the case solution generated by reuse. If successful, learn from the success (case retention, see next section),
- Otherwise repair the case solution using domain-specific knowledge or user input.

Case Retention - Learning

This is the process of incorporating what is useful to retain from the new problem solving episode into the existing knowledge. Learning from success or failure of the proposed solution is triggered by the outcome of the evaluation and possible repair. It involves selecting which information to be retained from the case, in what form to retain it, how to index the case for later retrieval from similar problems, and how to integrate the new case in the memory structure.

3.3 Similarity concept

The meaning of similarity always depends on the underlying context of a particular application, and it does not convey a fixed characteristic that applies to any comparative context. In CBR, the computation of similarity becomes a very important issue in the case retrieval process. The effectiveness of a similarity measurement is determined by the usefulness of a retrieved case in solving a new problem. There are (broadly) two major retrieval approaches. The first is based on the computation of distance between cases, where the most similar case is determined by evaluation of a similarity measure (i.e., a metric). The second approach is related more to the representational/indexing structures of the cases. The indexing structure can be traversed in search of a similar case.

Weighted Euclidean Distance

The most common type of distance measure is based on the location of objects in Euclidean space (i.e., an ordered set of real numbers), where the distance is calculated as the square root of the sum of the squares of the arithmetical differences between the corresponding coordinates of two objects. More formally, the weighted Euclidean distance between cases can be expressed in the following manner. Let $CB = \{e_1, e_2, ..., e_N\}$ denote a case library having N cases. Each case in this library can be identified by an index of the corresponding features. In addition, each case has an associated action. More formally, we use a collection of features $\{F_j\,(j = 1,2,...,n)\}$ to index the cases and a variable V to denote the action. The i^{th} case e_i in the library can be represented as an (n + 1)-dimensional vector, that is $e_i = (x_{i1}, x_{i2}, ..., x_{in}, \theta_i)$, where x_{ij} corresponds to the value of feature $F_j\,(1 \le j \le n)$ and θ_i corresponds to the value of action V (i= 1, 2,…,N). Suppose that for each feature $F_j\,(1 \le j \le n)$, a weight $w_j\,(w_j \in [0,1])$ has been assigned to the j^{th} feature to indicate the importance of that feature. Then, for any pair of cases e_p and e_q in the library, a weighted distance metric can be defined as in formula no. 1

(1) $$d_{pq}^{(w)} = d^{(w)}(e_p, e_q) = \left[\sum_{j=1}^{n} w_j^2 (x_{pj} - x_{qj})^2 \right]^{1/2}$$

When all the weights are equal to 1, the weighted distance metric defined above degenerates to the Euclidean measure $d_{pq}^{(1)}$.

Cosine Coefficient for Text-Based Cases

In many practical applications, comparing text-based cases is necessary. This leads to a requirement for similarity metrics that can measure the relation among documents. In the field of information retrieval (IR), cluster analysis has been used to create groups of documents that have a high degree of association between members from the same group and a low degree between members from different groups.

Let $DT = \{s_1, s_2, ..., s_N\}$ denote an *N*-tuple of documents s_i, where s_i is a member of the set DT. Let $TT = \{t_1, t_2, ..., t_M\}$ denote an *M*-tuple of term types (i.e., specific words or phrases) t_j, where t_j is a member of the set TT. The term frequency, denoted by TF_{s_i,t_j} is the frequency of occurrence of term t_j in document s_i. The inverse document frequency, denoted by IDF_{DT,t_j} provides high values for rare words and low values for common words. It is defined as the logarithm (to base 2) of the ratio of the number of the documents in set DT to the number of documents s_i in set DT that contains at least one occurrence of term t_j. Each term is then assigned a score, called the weight of the term, which is defined as

(2) $$W_{s_i,t_j} = TF_{s_i,t_j} \times IDF_{DT,t_j}$$

The similarity of two documents S_i and S_j can be expressed as a cosine relationship (cosine coefficient):

(3)
$$\cos SM_{S_i S_j} = \frac{\sum_{j=1}^{m}\left(W_{s_i,t_j} W_{s_j,t_j}\right)}{\sqrt{\sum_{j=1}^{M}\left(W_{s_i,t_j}\right)^2 * \sum_{j=1}^{M}\left(W_{s_i,t_j}\right)^2}}$$

Vector space model

The vector space model of text documents is used to evaluate title, abstract, index terms, and body similarities between two documents. Consider a vocabulary T of atomic terms t that appear in each document. A document is represented as a vector of real numbers $v \in R^{|T|}$, where each element corresponds to a term. Let v_t denote an element of v that corresponds to the term t, $t \in T$. The value of v_t is related to the importance of t in the document represented by v. Using the Term Frequency-Inverse Document Frequency (TF-IDF) weighting scheme, v_t is defined as

(4)
$$v_t = \log\left(TF_{v,t} + 1\right) \times \log\left(IDF_t\right)$$

Where $TF_{v,t}$ is the number of times that term t occurs in the document represented by v, $IDF_t = N/n_t$, N is the total number of documents in the database, and n_t is the total number of documents in the database that contain the term t.

4. The CBR integrated in a FMEA knowledge driven system

The system is meant to be a product in which intelligence assists the users in taking decision regarding the plan and design of product and process. The system will be web-based application, meaning that must be accessible from any computer with Internet connection, independently about the browser used and based on an account and password.

4.1 A proposed framework to capitalize the knowledge in FMEA process using the CBR

The present research started from the basic assumptions:

- Useful knowledge comes in a variety of forms
- People have a hard time building good queries

- People would rather be guided to useful content than go fishing
- People expect high precision and recall in their searches
- People need to trust results
- People involved in FMEA process are from different department and are not available all at the same time
- Problems can be interpreted in different way based on natural language description
- The valuable knowledge must be capitalized inside the organisation.

4.2 Intelligent FMEA with CBR

The ultimate purpose of the FMEA procedure is to help designers and engineers to eliminate or reduce failures and because of this goal, the FMEA process and FMEA document is never completed. It is a living document that should be constantly used throughout all of the phases of the product life cycle.

Like any program management tool, the FMEA is as good as the information that is contained in it. To secure the high quality of FMEA document, the procedure should be accomplished by a team of people that includes all of the experts involved in the design or process. This approach will allow for a fresh eyes approach and a thorough brainstorming session to be used.The use of cases for manufacturing problems is a success story of the CBR usage. In this research we will use the CBR integrated in the FMEA process.

The system researched and proposed in this paper follows the four steps of a CBR system: retrieve, reuse, revise and retain, but there will be some adjustments done based on the FMEA process. The FMEA items contain: Piece / part / process / function / operation / feature, Potential failure mode (deficiency), Potential Failure Effects, Potential Causes, Verification measures to prevent, Verification measures to detect, Recommended actions, Responsible for performing the recommended actions, time frame to perform and deliver the results of the recommended actions.

If at the beginning the FMEA process was paper oriented, then table oriented, nowadays, in this global market with global companies, the FMEA process must be pushed to the next step: web-based system FMEA – knowledge driven, accessible to the right people, at the right time with the right knowledge. In the Figure 3 the FMEA steps and the integrated CBR methodology are presented. For the proposed system, solution we consider the recommended measurements and for the problem part we consider the rest of the fields from FMEA item.

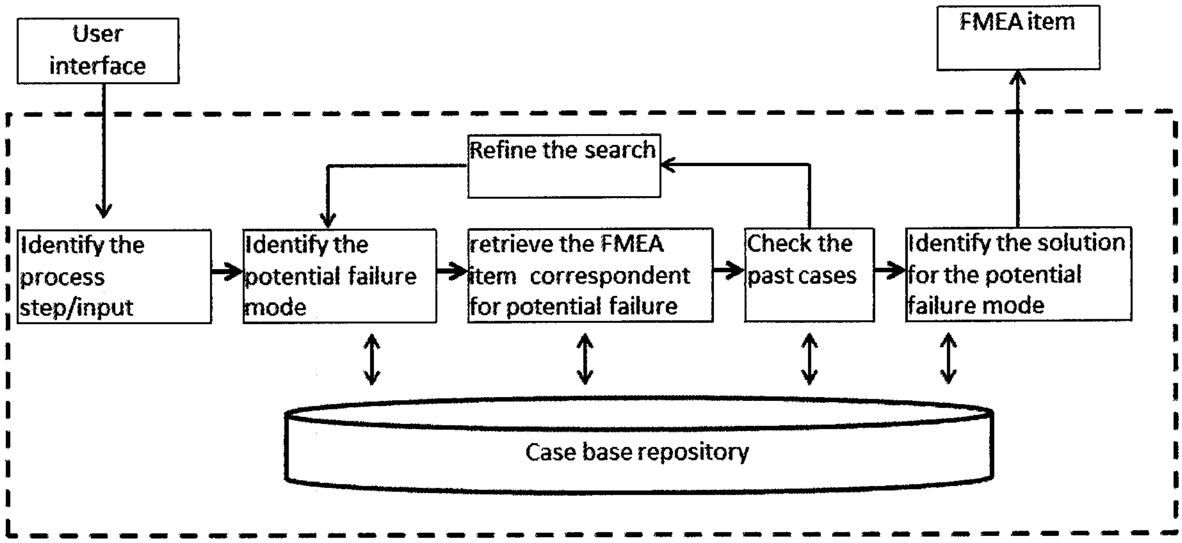


Figure 3 CBR integrated in FMEA process

4.3 General overview of the proposed framework

The system is designed to be a web-based system with client-server architecture and the access is done based on specific rights. The access of the projects is allowed based on account and password and the modifications are settled based on the role of the account. The visualisation of the items can be chosen by the user: table like or Gantt like. In the image bellow (Figure 4) the main interface of the system is presented followed by a detailed description in the next chapters of this report.

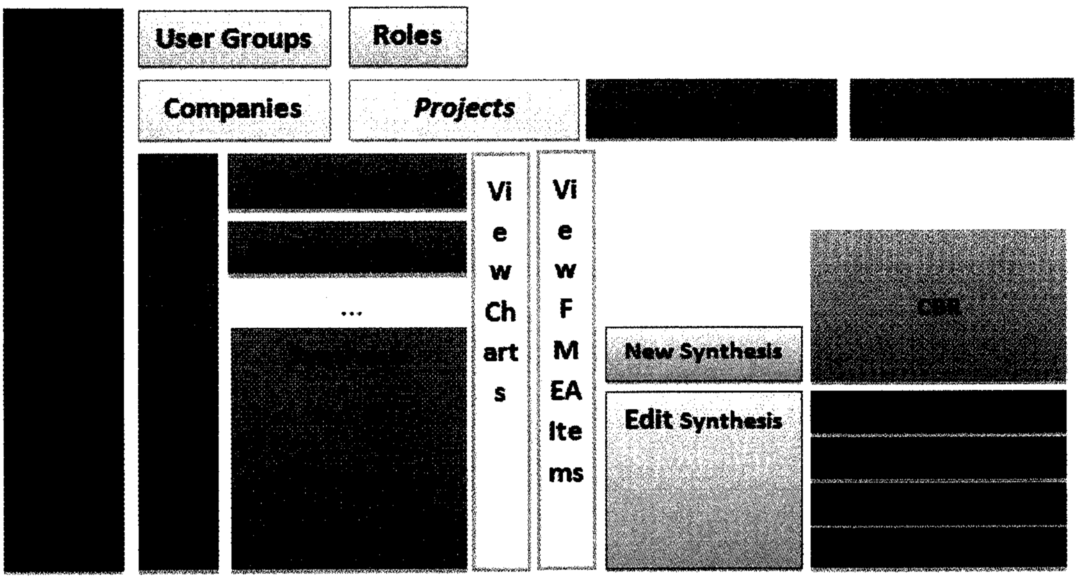


Figure 4 General overview of the system

The functional requirements are:

- Login – the access at the FMEA items are based on account and password.
- View FMEA items – the information is visible based on the role assigned to each account. The FMEA information is viewed in three ways (chosen by the user): in the form of tree on several levels, in tabular form and as a Gantt chart type.
- Search of the information can be performed in the database or in the CBR
- Filtering the information is possible based on the column of FMEA
- The synthesis information are managed by the FMEA coordinator (add a new synthesis when a new meeting takes place; modify and save – there is a multi-user architecture and there will be a lock mechanism at the beginning of the activity and a release at the end of editing).
- The nomenclatures are used in order to avoid the language disadvantage and will be managed by a special account.
- Reports will be generated based on the user's role and request.
- The CBR methodology integrated enhances the system functionality by trying to resolve new situations based on past situations, already resolved with success.

Experiences database

The experience database is proposed to provide an easy to use component by the knowledge engineer and by other software modules.

A CBR system involves reasoning from prior examples, memorizing previous problems and associated solutions and solving new problems by referencing to that knowledge.The problem-solving life cycle in our CBR system consists essentially of the following four parts (the Aamodt-Plaza Model).

- Retrieving similar previously experienced cases (e.g., problem–solution–outcome triples) whose problem is judged to be similar
- Reusing the cases by copying or integrating the solutions from the cases retrieved
- Revising or adapting the solution(s) retrieved in an attempt to solve the new problem
- Retaining the new solution once it has been confirmed or validated

4.4 The algorithms implemented for case retrieval

In the present research were implemented four algorithms: Vector Space Model (Salton et al. 1975), Latent Semantic Indexing, two approaches (S. Deerwester et all, 1990) and (Berry et all, 1994), and Fast Case Retrieval Net (Chakraborti et al., 2006).

Regardless of the method applied the documents are represented as vectors in t-dimensional space, where t is the number of indexed terms in the collection of documents. A collection of d documents described by t terms can be represented as a $t \times d$ matrix A called term-document matrix. Each element a_{ij} of the term-document matrix represents the degree of relationship between term i and document j, the column vectors of A, represents the document vectors, and the row vectors of A, represents the term vectors.

4.4.1 Vector Space Model (VSM)

In the Vector Space Model (Salton et al., 1975), documents are encoded by means of a very large vector, the elements which represent the weight of a specific term of the index vocabulary for that document:

(5) $$d_j^T = [a_{1j}, a_{2j}, \ldots, a_{mj}] \text{ where } j = \overrightarrow{1..n}.$$

In the Vector Space Model, a query is represented by a vector in the column space of the term-document matrix. This means that the query can be treated as a pseudo-document. In the process of query matching, documents must be selected, and their vectors are geometrically closest to the query vector. A common measure of similarity between two vectors is the cosine of the angle between them. In a $m \times n$ term-document matrix A, the cosine between document vector d_j and the query vector q is:

(6) $$\cos \alpha_j = \frac{q^T * d_j}{\|q\| * \|d_j\|} = \frac{\sum_{i=1}^{m} q_i * a_{ij}}{\sqrt{\sum_{i=1}^{m} q_i^2} * \sqrt{\sum_{i=1}^{m} a_{ij}^2}}$$

We can conclude that VSM retrieve only cases which contain information entities (IEs) from the query vector, indifferent of the method with which build the term-document matrix.

Limitations of Vector Space Model: if a query and a document contain disjoint sets of IEs, then the vectors representing the query and the document are orthogonal to each other and any reasonable measure should indicate that they have zero similarity to each other. If, however, two or more terms are synonymous to each other, then the two documents should have non-zero similarity. Such problems often occur because in many situations the terms are related one to each other and during search one wants to consider these relationships. In the next section we will see that this problem is solved if we use the Latent Semantic Indexing algorithm.

4.4.2 Latent Semantic Indexing (LSI)

Latent Semantic Indexing (LSI) is a method for automatic indexing and retrieval of documents based on the notion of concept used in Information Retrieval. LSI was designed to retrieve documents based on concept pairing and not on index term pairing. The pairing based on concept allows documents to be identified and retrieved even though they are not indexed by the query index terms. This mechanism is possible because of the data is build based on a latent semantic structure. Thus, LSI overcomes the deficiencies of term-matching retrieval observed as a statistical problem in term-document association. Then, to estimate the latent structure and remove the "noise" from statistical techniques, LSI uses the matrix method Singular Value Decomposition (SVD). Within SVD, a semantic space is built from a large matrix of term-document association data, and then the original matrix is replaced with three minor matrices, a left and a right singular vector matrix, and a diagonal matrix of singular values (Hendrickson, 2006). The dimensionality reduction aims to reduce 'noise' in the term-by-document matrix, resulting in a richer word relationship structure. In the semantic space the terms and documents that are closely associated, are placed near each other (Scott, 1990; Lu, 1999). The semantic space contains a term-concept space and a document concept space; the left and right singular vector matrices, respectively.

Often LSI is applied in search and retrieval activities (Deerwester, 1990; Dumais, 1992), classification (Zelikovitz, 2001), and filtering (Dumais, 1992, Dumais, 1994).

In traditional Informational Retrieval, documents and queries are represented as vectors in t-dimensional space, where t is the number of indexed terms in the collection. Latent Semantic Indexing (LSI) is a variant of VSM in which the original term-document matrix is decomposed, using Singular Value Decomposition (SVD), into three matrices: U, a term by dimension matrix (m×m), S a singular value matrix (dimension by dimension, (m×n)), and V, a document by dimension matrix (n×n). The original matrix can be obtained, through matrix multiplication of U*S*VT=A. (A is a (m×n) matrix).

In a LSI algorithm, the U, S and V matrices are truncated to k dimensions. The purpose of dimensionality reduction is to reduce the noise in the latent space, resulting in a richer word relationship structure that reveals latent semantics present in the collection.

LSI relies on a parameter k, for dimensionality reduction. The optimal k is determined empirically for each collection. In general, smaller k values are preferred when using LSI, due to the computational cost associated with the SVD algorithm, as well as the cost of storing and comparing large dimension vectors.

In some sense, the SVD can be viewed as a technique for deriving a set of uncorrelated indexing variables or factors, whereby each term and document are represented by a vector in k-space using elements of the left or right singular vectors.

The amount of dimension reduction, i.e., the choice of *k*, is critical to our work. It is important for the LSI method that the derived A_k matrix does not reconstruct the original term document matrix A exactly. The truncated SVD, in one sense, captures most of the important underlying structure in the association of terms and documents, yet at the same time it removes the noise or variability in word usage that plagues word-based retrieval methods.

First approach of LSI algorithm

Having the k-rank approximation A_k of the term-document matrix, the query matching can be performed by calculating the cosine of the angle between the query vector after the column length normalization and the column vectors of the A_k matrix.

Second approach of LSI algorithm

This second approach of LSI algorithm consists in fact after the SVD decomposition of matrix A, the documents and query can be represented in k-dimensional space (Berry et all, 1994).

4.4.3 Fast Case Retrieval Net (FCRN)

FCRN has emerged as a result of research in text mining domain and aims to facilitate the retrieval and reuse of knowledge in the context of growing volumes of textual documents over the web and corporate repositories.

The Case Retrieval Net (CRN) has been proposed as representation formalism for CBR in (Lenz, 1996). To illustrate the basic idea we consider our previous example with nine cases and ten IEs, and the corresponding equivalent FCRN (Chakraborti et al., 2006). The IEs (keywords) are along the rows of the matrix and each case is represented as a column. The keywords are treated as feature values, which are referred to as Information Entities (IEs).

The relevance is directly obtained from the term-documents matrix after column length normalization. In the original version of FCRN the term-documents matrix without column length normalization is used and the results are less accurate. IE nodes are related to each other by similarity arcs (circular arrows), which have numeric strengths denoting semantic similarity between two terms. In our example, we use LSI to compute the similarity between IEs, more precisely, the term-term matrix, which appears as the co-occurrence between IEs.

The formula used for the term-term matrix is

(7) $$T = U_k * S_k * (U_k * S_k)^T$$

where U_k is a term matrix (U) truncated to dimension k and S_k is a singular value matrix (S) truncated to dimension k (in the above example we used k=2), U and S were obtained after we applied the SVD process of the term-document matrix A = U*S*VT.

The second variant of Fast Case Retrieval Net (FCRN)

Description of functions:

- The relevance function ρ is defined as being the similarity (cosine) between document and each term.
- The similarity function σ is defined as being the similarity (cosine) between terms.
- The effective relevance function Λ is defined in the same way as in the original version of FCRN.

For computing the relevance function ρ and the similarity function σ we need the coordinates of documents and terms in k-dimensional space. The coordinates of documents in k-dimensional space are given by the lines of V_k matrix and the coordinates of terms are given by the lines of $U_k*S_k^{-1}$ matrix.

4.5 Testing and evaluation of the system proposed

The implementation of the system covers the following functionalities:

- The log-in functionality
- The users management functionality
- The projects management functionality (add, open, close project)
- The FMEA items management functionality (add, edit, delete FMEA item)
- The search of a potential failure mode in the database
- The synthesis management functionality
- The nomenclatures management functionality
- The CBR functionality (reuse of knowledge from past experiences or projects)

For the CBR functionality the main research was concentrated on what the best similarity function to be used is. What is the best structure case for FMEA? Should I add also another type of repository for knowledge (blue prints, documents, plans, designs), other than FMEA items? How will this system be tested and evaluated? Who is the best tester of the system? The final tests and evaluations were done for the Latent Semantic Indexing algorithm – both approaches and on Fast Case Retrieve Net algorithm.

Influence of the number of simultaneous users

In order to improve not just the results of the retrieval step of the CBR, but also the in terms of system operatively the influence of the number of simultaneous users on the CBR system was studied. We can conclude that the both approaches based on FCRN algorithms are good, mainly because on FCRN there are fewer calculations made with matrixes than LSI approaches.

Of course, this research started with focusing on problems regarding knowledge capitalization and reuse in an automotive company. Thus in our premises there is, from the start, the assumption that this system will be used by maximum 50 users on the same time. This number of simultaneous users was calculated taking in account that the maximum users involved in one FMEA meeting will be ten users from different departments, and at the same time can be maximum three or four FMEA meetings. The other users are just the users interested in searching different information.

The number of cases verified through a retrieval action

The size of case base depends on the domain where the case based reasoning is implemented. In the domain studied in this research (FMEA knowledge, and even more focus, in automotive domain) after analysis of the business logic, business flow and flow of data we estimate that the number of the cases from case base will be at the beginning around 1500 cases. The investigation revealed that almost 20% of the cases from the difference where in fact the redundancies of the recommended corrections that were already in the case base. In this point the nomenclatures designed at the beginning of the development of this system are justified. Because the responsible with the nomenclatures was vigilant and there were edited 193 cases.

For the four algorithms that were implemented they were tested to see the number of cases investigated for the retrieval of a case (for a search). The number of similar cases listed during the retrieval activity can be customized by the user. With the implementation of a log file, for each algorithm the mean number of cases examined during retrieval for a given case-base size was measured.

Influence the case base size on efficiency in the retrieval activity

Another point of view in our evaluation tests was the efficiency of the algorithms implemented. The following definition of efficiency was used from the beginning: the number of retrieve cases able to solve the problem and we measure the mean percentage of correct retrieval (it was considered correct retrieval if the user used the proposed similar case). The test runs for the four algorithms implemented for the retrieval activity. Was observed that the higher in number of cases the case base is, the best results we obtain. Based on the results obtained we can consider that is better to use one algorithm or another for the retrieval activity, but we have to consider all the advantages and all disadvantages in order to take a decision: which algorithm is better to be implemented.

In the present paper the analysis, design and implementation of the knowledge FMEA driven system integrated with a Case Based Reasoning is presented. The better way to analyse the performance of the whole system is to ask the users, because the log files capture just the technical activities, speed of the system, the efficiency of the search, etc.

Improvement of time allocated to FMEA process

The expression "time is money" how realistic it is it's a true word. Inside of the company everything can be translate in time and further in money. The system proposed in this research aims also to reduce the time allocated to the FMEA process, methodology that is well known as a time consuming process. During the analysis developed inside of the COMPA S.A. the engineers complained many times about the amount of time spent within this process and after more investigations the result of the quantity of time spent results from:

- Frequently meetings
- At the beginning of the meeting the last version of the FMEA sheets (MS Excel files) is always searched (is not clear where is stored the last version, who has the last version, etc.)
- Not all the members involved in the FMEA meeting are available at the same time (are not inside the factory) and the total time allocated to the FMEA process is increased
- There is a lot of time spent in searching a possible old FMEA item used in an old project and can be reutilized at the current project.

After the evaluation of the system proposed the following hours were obtained:

The difference between the hours spent is not very large but translated in money, how we discussed at the beginning of this section, became considerable. But from the administrative department of COMPA the decrease with 18% of time allocated to FMEA process is significant and the system can be implemented inside the company (there are evaluated the advantages and disadvantages of the system from many points of view: time to implement, time for training, maintenance of the system, equipment needed for the new system to run, and so on).

Improvement of the information's quality inside of FMEA process

Reducing the time spent on FMEA procedure is not the singular quality improvement that the systems proposed bring with this research. Also the quality of information that is circulated within this procedure is improved.

During the analysis developed inside of the COMPA S.A. company the engineers outline the small amount of knowledge that is reused from past project are because of how this knowledge is captured. After investigations about the knowledge circulated in side of FMEA project were identified the following imperfections of knowledge:

- During the meeting the knowledge reused is just the knowledge existed on the FMEA coordinator laptop, and he/she is the only one able to search in old FMEA project for a specific information;
- The knowledge that must be retrieved from the FMEA written on the paper usually is abandoned because it takes too much time to located and extracted from papers.
- Even if the knowledge is located and retrieve most of the time cannot be reused because the natural language is very personal to the writer, there are a lot of non-standard abbreviation, the knowledge is written in very short texts and only the writer can identify exactly the meaning of the text.

Thus, we discuss about imprecision, certainty, accessibility and incompleteness of the knowledge circulated inside of FMEA procedure. During the evaluation was investigated how easy to access the knowledge repository is, how much of the knowledge proposed by the system is accepted and used by the user of FMEA system.

5. Conclusions, contributions and directions of future research

5.1 Main findings

5.1.1 Integrated work within European research

The presented study can be easily integrated in a bigger research and work from data interoperability point of view. In 2009 the project Virtual Factory Framework[1] (VFF – a collaborative research project funded by the European Commission under the 7th Framework Programme) started and the author of the present research represented inside of the

[1] http://www.vff-project.eu/

consortium the current company (work place). The VFF project implements the framework for an object-oriented collaborative virtualised environment, representing various factory activities meant to facilitate the sharing of resources, manufacturing information and knowledge.

Starting from the poor interoperability among different software platforms using proprietary formats issues, a reference factory data model for the common representation of factory objects was developed inside of VFF project. But, the framework was supposed to deal with interaction among different activities and it is not sufficient to have just one snapshot of the real production plant inside the data model, but is necessary but it is necessary to take care of data evolution along the factory lifecycle phases. The VFF factory data model has been designed as ontology by adopting the OWL language. As ontology it defines all the *classes*, *properties* and *restrictions* that can be used to create *individuals* (factory objects) to be stored in the data repository. All the tools developed inside the VFF project were layout design tools, production optimising and simulator tools, factory layout viewer tool; these indeed exchange data using the framework but the end-users from consortium expected more tools to be developed. The Failure Mode and Effects Analysis tool was a tool requested by all five end-users and accordingly the presented research started with the knowledge representation of FMEA specific knowledge using ontology.

From factory data model, FMEA works with data related to projects, users, tasks (events) associated to FMEA process and lists usable in analysis (bill of materials, bill of processes etc). The research done in this project was presented in a paper (Candea et. all 2012).

5.1.2 Contribution of the thesis as a whole

This thesis is the results of 3.5 years of intensive studies developed in the Lucian Blaga University of Sibiu, Fraunhofer Institute for Industrial Engineering - IAO in Stuttgart, Germany, and an automotive factory in Sibiu (COMPA S.A.). During this research a number of aspects related to the reuse of FMEA knowledge, FMEA procedure and CBR approach were investigated and proposals for improvement are stipulated. For this purpose, insights were gained into use of FMEA in the process industry (chapter 2) and into problems with case base reasoning (chapter 3) and more specific into the text retrieval algorithms (chapter 5).

For a period of eight months, I was involved in the Virtual Factory Framework, Intelligent Manufacturing Projected, within Fraunhofer Institute for Industrial Engineering – IAO, in which a conglomerate of manufacturing enterprises, research organizations and ICT companies developed a new paradigm for factory planning. Following this experience, the study continued in Sibiu at the theoretical level inside the Lucian Blaga University and at the practical level inside of automotive manufacturing organization (COMPA S.A.).

Acquisition of knowledge from the engineers involved in the FMEA procedure is not always regarded as a useful (or cost-effective) activity (Smith and Hinchcliffe, 2004) which in turn makes the analysis, feedback, reuse and improvement very difficult. This situation needs to be resolved.

Therefore, we proposed a FMEA knowledge driven software (chapter 4) capable to capture the knowledge, easy to use and integrated in the daily activities, and we suggested empowering this system with a CBR approach for a better reuse of knowledge (chapter 5).

The main results of the research are: the FMEA Data Flow Diagram within CBR, The Organizational Knowledge Management Model and the Knowledge Management Model and Platform for Product and Process Design and Development.

The main theoretical contributions presented within this paper follow:

- definition and systematization of key terms and concepts utilized in this paper;
- bibliographical analysis and systemic collection of data;
- synthesis in regards to reference models utilized in factory planning;
- identification of the need for FMEA-related knowledge management integrated within manufacturing daily activities;
- synthesis in regards to retrieval algorithms used in text case based reasoning;
- identification of the main factors that influence the results of the FMEA procedure;
- identification of the best algorithms used in retrieval short-text data inside CBR;
- definition and systematization of the similarity functions used in retrieval activities inside the CBR systems;

Original practical contributions presented in this paper are:

- identification of the necessary requirements for the knowledge FMEA-driven system with CBR approach;
- modelling of the FMEA process flow integrated with CBR approach;
- theoretical and experimental application of the knowledge FMEA-driven system with CBR approach;
- mathematical simulation of the integrated system;
- creation and development of the knowledge FMEA-driven system with CBR for practical use;

- identification of factors which need to be considered in knowledge FMEA-driven system;
- outline the relationship between the short text and the algorithms necessary to implement in a CBR approach;
- analysis of the results obtained following the results of the tests of the system inside the manufacturing enterprise;
- recommendation for modification about the FCRN algorithm;
- validation of the knowledge FMEA driven system with CBR approach inside of a manufacturing enterprise.

The results of this paper will facilitate the research of this field at a more detailed level. They will represent a starting point for new integration efforts.

5.2 Directions for further research

In this section, directions for further research for the individual research objectives and for the presented paper as a whole are discussed. The test and evaluation, which took place inside COMPA S.A. from Sibiu, of the system led to some assumptions about the use of FMEA and CBR approach.

5.2.1 Failure Mode and Effect Analysis: knowledge capitalization

This study yields a number of opportunities for further research. Manufacturing organisations apply various quality control techniques to improve the quality of the process by reducing its variability. FMEA is one of these techniques and contains a different and reach knowledge. At the beginning of this research I started to identify what is the best method to represent the knowledge inside the system proposed and the directions of study gone to the ontology domain. Literature review reveals that this direction was very little studied and there are not practical results of implementations with ontology (Dittmann, et. all, 2004; Xiuxu, et. all, 2012).

Ontologies embody a language and the common understanding for heterogeneous information structures employees are concerned with. Because consistency is a requirement, it is necessary to agree on ontology and to refer to the meaning of the vocabulary.

Thus the next direction of the research will be on the ontology domain and more precisely how to represent the knowledge in order to reduce efforts and improve return on investment in the knowledge capitalization. Because the knowledge that is circulated inside FMEA procedure is vast and in more different formats those just free texts, such us: blue prints, procedures, plans, requirements, etc.

5.2.2 Failure Mode and Effect Analysis: Case base Reasoning approach

A new problem is solved by retrieving one or more previously experienced cases, reusing the case in one way or another, revising the solution based on reusing a previous case, and retaining the new experience by incorporating it into the existing knowledge-base (case-base).

In the system proposed the knowledge contained in the FMEA item fields is all concatenated and is processed. This solution was selected because in the FMEA procedure the users involved usually do not write much text and with few explicitly details and many times in engineering jargon. In the future research the aim is to further investigate a relation between the fields from FMEA items, the new system proposed and re-usage of the knowledge already placed in knowledge repository.

Other direction that will be covered by the future research is how the quality of the case-bases can be maintained. What are the best ways to identify and eliminate the bad cases but also the redundant cases?

5.2.3 Design of a FMEA knowledge driven system integrated with Case Base Reasoning

The system proposed and developed (described in chapter 4) was designed and tested in the process industry (in COMPA S.A. from Sibiu). The system proposed represents the starting point for the next evolved system where the future research will aim to study the quality of the knowledge from the system, but also of the knowledge acquired, and also the interoperability of information of the system with other functional system inside the company.

Regarding the interoperability of the systems some results already exist. There is some research and work done inside the project Virtual Factory Framework that study a new conceptual framework designed to implement the next generation Virtual Factory, constantly synchronized with the real one (Virtual Factory Framework (VFF) is a Collaborative Research Project funded by the European Commission under the 7th Framework Programme). The research done in this project was presented in a paper (Candea et. all 2012).

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