"Managing product/process knowledge in the Concurrent/simultaneous Enterprise Environment"

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ABSTRACT

This paper introduces the work done up to now for our team in the field of managing the knowledge related to product/process in the Concurrent/simultaneous Enterprise Environment. The main business aim is to produce a leap forward in industrial design performance in Companies. Knowledge useful to design engineers comes in many forms and useful knowledge can come from many sources inside and outside the Enterprise. A common need is to be able to acquire and process this knowledge so that a greater, richer, centralized source of knowledge and information is available to produce better designs, faster, with greater innovation, and with less re-inventing of the wheel. The most important needs with regard to design are to get good products to the marketplace quicker, and to reduce costs related to design.

The team is coordinating two relevant European projects within the 5^th^ and 6^th^ Framework of the European Commission: AIM (Acceleration of Innovative Ideas into the Market), an IMS project (including partners outside Europe) with the goal of developing a system to support the collection of innovative ideas and relevant knowledge throughout the extended enterprise for new and existing process and product developments, and to develop these ideas and knowledge into a means of fostering industrial innovations.

And a new project (starting November 2004) focusing to the same subject specifically oriented to SMEs: ASSIST. This project is aimed at achieving a breakthrough in the use of advanced agent-based knowledge management techniques in real industrial practice, within an innovative ICT solution affordable to SMEs.

1. INTRODUCTION

Lead Time or *Time to market* has been generally admitted to be one of the most important keys for success in manufacturing companies. Combination of factors such as ever changing market needs and expectations, rough competition and emerging technologies among others, challenges industrial companies to continuously increase the rate of new products to the market to fulfil all these requirements.

Besides that**,** Innovation is becoming the most important key issue for company's success in the XXI century. Former advantages based on aspects as costs reduction, natural resources, geographical situation and so on are no more valuable since globalization is flattening these issues and furthermore, needed natural resources are usually coming from outside. We must always be meaningful of the need of fostering innovation fighting against usual themes as: "cut your costs", "get focused". Nowadays motto should be "Innovate or lose".

New situation needs to introduce relevant changes in the way the companies are working. One of these changes has to be accomplished in the field of new products development which is the basis of the success of manufacturing companies.

New ways of working move ineluctably towards the extended enterprise. **Extended enterprise** concept in parallel with the **Concurrent Enterprising** looks for how to add value to the product by incorporating to it knowledge and expertise coming from all participants on the product value chain. Manufacturers need to benefit from **'Extended Enterprise'** techniques by involving all people from throughout the product life cycle (suppliers, customers, design, production and servicing) to provide their product knowledge to enhance product development and support. This knowledge needs to be saved and managed. Loss of this knowledge results in increased costs, longer time-to-market, reduced quality of products and services. By improving products and customer support manufacturing companies will be more competitive, and employment will increase. In following paragraphs we will discuss the semantic difference between both terms.

Manufacturing companies need to shift towards the use of extended enterprise technologies and knowledge management for customer/product support. This new paradigm implies a quite new scenario: knowledge capturing and sharing, new forms of interrelationship between companies and persons, etc.

Companies need to be able to extend their own enterprises, (by removing barriers of geographic location and human resource problems) to encompass the customer's operations where the supplied industrial products are being used. They need to provide the expertise to support the products in situ (including problem solving support, and diagnostic analysis of customer feedback), just as though the company's expert was there with the customer solving the problems.

This new paradigm addresses issues of significant importance to EU industry: the use of e-Business technologies for extended enterprise product knowledge systems permitting ubiquitous human interaction, across and beyond industrial organisations, getting organisations to work better with each other. It will have a significant contribution to the EU policies on competition, employment, working conditions, internal market and free circulation of goods, health, environment, transport, innovation and long-term sustainable growth.

The key idea behind the Extended Enterprise concept is to develop means supporting the collection of all useful knowledge throughout the extended enterprise for new and existing process and product developments, and to develop this knowledge into a means of fostering industrial innovations. Innovation by combining the ideas and feedback from all parts of the product life cycle, including customer interaction with existing products and new product ideas, and including customer service and field engineers, including suppliers, and including pooling of knowledge between multiple sites. Innovation is a critical factor in the success of industrial companies.

On this framework industry in the XXI century has to face these challenges by using techniques to deal with aspects as:

Extended enterprise: Enterprises are surpassing physical boundaries and are establishing durable links with other companies: engineering, sub-contractor, providers but they are mostly at a loss on how to deal with customers in both ends of the chain. The customer is clearly a very relevant actor at the conceptual phase of the product life where the designer has to understand customer's needs and feelings as well as at the other end of it when the extended product has to live together with the user along its operating live.

Concurrent Enterprising: As the idea of Extended enterprise refers to a longer time frame, Concurrent Enterprising focuses more in the specific relationship among companies to set up new operations: new product development and launch, marketing activities covering a wider range than only the physical product by itself (extended product) and others.

Extended Product: Product is rapidly changing from physical tangible product to a plus of intangible assets related to fulfilling requirements, fitting the right product to the right needs, servicing the product and maintaining it through its life, empowering the user to get the best form it and lastly facilitating the product retrieval and eventual replacement in a environmental friendly manner.

Support of ICTs: Besides some psychosocial changes, the technical challenge is related to the massive use and incorporation in industry of the new IT and internet based technologies. There is a strong human implication in the users about getting used to the new technologies and changing the way the work has to be performed.

From this basis, the new trends should be to extend the e-Working systems to the whole life-cycle of the extended product. In such way, new working methods will be able of supporting the "**Extended Enterprise**" to monitor and capture knowledge from the "**extended product**" all through his life cycle. This will cover from the conception of the product/service to its disposal and back to "re-incarnation", that's to say: launching improved new extended products based on the knowledge collected from the existing ones.

As it has been mentioned above, knowledge useful to design engineers comes in many forms and useful knowledge can come from many sources inside and outside the Company. A common need amongst Companies is to be able to acquire and process this knowledge so that a greater, richer, centralised source of knowledge and information is available to produce better designs, faster, with greater innovation, and with less re-inventing of the wheel. The most important needs of manufacturing companies with regard to design are to get good products to the marketplace quicker, and to reduce costs related to design.

This paper introduces the achievements from the IST/IMS project AIM with the goal of fostering industrial innovations throughout the extended enterprise for new and existing process and products by supporting the collection of Corporate Knowledge and Innovative Ideas; and the ASSIST project which is in its early life stages (started in November 2004).

In AIM system, ideas and knowledge are later developed supporting industrial innovations. Such system provides a means to collect, store and use/develop innovative ideas over the extended enterprise, and it will “accelerate” innovation into the market. In addition, Team Work is enhanced by co-operation among manufacturers, customers and suppliers by means of the Internet facilities provided by the AIM System. The AIM system is described, focusing on the module for the assessment of ideas collected throughout the extended enterprise. Besides this, the paper describes one of the technologies used to support this assessment, Case-Based Reasoning.

ASSIST on its side is focusing mores specifically in the needs of Small and Medium Enterprises (SMEs) and aims to make the best use of **the extended knowledge resource of SMEs**, by involving customers, shop-floor employees, field engineers, and suppliers (where appropriate), in the design process. The ASSIST system will manage all that. The most challenging objective is to implement a multi-agent based KM support for the innovative solution reuse in the new designs.

2. AIM.

The Project AIM: Acceleration of Innovative ideas to Market (IST-2001-52222) has started in June 2002. It runs under IMS programme with partners from Australia, Korea, Europe and Switzerland (considered as non-European region within the IMS scope).

The project goal is to develop a system to support the collection of all useful knowledge throughout the extended enterprise for new and existing process and product developments, and to develop this knowledge into a means of fostering industrial innovations. Innovation by combining the ideas and feedback from all parts of the product life cycle, including customer interaction with existing products and new product ideas, and including customer service and field engineers, including suppliers, and including pooling of knowledge between multiple sites. Innovation is a critical factor in the success of industrial companies

The objectives of the project are:

- To develop a means of stimulating the creation of innovative ideas and collecting them from people involved with the products and processes. Specifically to increase the number of innovative suggestions, concepts and new designs by 50% in all user companies.
- To develop a way of processing these ideas and storing them into a structured knowledge repository. To ensure that all useful knowledge (innovative information) is saved.
- To develop a means of analysing innovative knowledge to determine which is useful, and which is not. That is, to enable the viability of ideas to be assessed.
- To develop the best means of delivering the innovative ideas to product and process designers for maximum effect.

This leading to the following business benefits:

- Reduction of product innovation cycle-time by at least 30% (specifically for SME business case no. 1, and business case 3 for engineering services, and business case 5 electronic industry)
- Reduction of time and efforts for solving product/process problems by at least 25 % (all business cases)
- Improvement of process efficiency by 15 % and reduction of wastes by 12 % (specifically within manufacturing process in business cases no. 2 and 4).

The key idea behind the project is to develop means supporting the collection of all useful knowledge throughout the extended enterprise for new and existing process and product developments. This knowledge will then be developed into a means of fostering industrial innovations.

The project fits into the objectives of both IST (II.1.2 Knowledge Management) and Sustainable Growth (Targeted Research Action 1.7 “Extended Enterprise”) programmes and directly addresses the IMS technical themes: Corporate technical memory and "Virtual / extended enterprise issues". The project is novel as it seeks to encourage innovation creation in all people who are involved with the product lifecycle, and the production processes. It also encourages team working between people from different sites (and working off-site), and between organisations, customers and suppliers.

The accelerated pace of technological development continuously increases time and market pressures on manufacturers' capacity to innovate new products and designs and to develop the manufacturing processes that produce these products. The relentless race to develop new, higher quality products, simultaneously reducing time to market, reduce product cost, improve quality is a major challenge for all companies. Many companies lack the financial capacity either to invest in the latest technology as it reaches the market or to hire specialists to integrate new methodologies and systematically to improve their products.

Many companies have the required corporate breadth-of-experience to improve their products and their processes if they could only make best use of their knowledge resources internally and in partnership with their suppliers and customers. Stimulation of 'Innovation' is a means by which these knowledge resources could be channelled.

Major difficulties for innovation are related with two main topics (which will be addressed by this project):

a. Intangibility of the inventive knowledge. The inventive capacity is usually considered more as an inherent property of the genius than something that may be learnt. Intangibility makes the inventive knowledge difficult to accumulate and transfer. Emerging theories say that the capacity for innovation observed in some inventors is not more than an instinctively applied methodology for abstraction, which gives sense to the words "inventive knowledge" (or "innovative knowledge"), defined here as "the knowledge necessary for finding solutions at any abstraction level". Therefore intangibility will be overcome by establishing rules, methodologies and tools for abstraction and concretion of problems, allowing to accumulate them and their solutions in a hierarchical database with the abstraction level as hierarchy separator.

b. Individualisation of the innovation process. Investigations performed during the last 20 years have demonstrated that innovation is better achieved by working in team. In the first conceptualisation steps the working teams should include the best experts in several fields available world-wide which is completely impractical for many manufacturing companies. Due to this problem, innovation thinking is usually tried by individuals on their own, which becomes almost impossible in the current stressed and time limited working environments.

Such problems could be minimised by employing innovation methodologies during the development process and incorporating tools to support innovation along the process. However, even when enterprises try to incorporate new methodologies, many problems appear due to human- and methodology-specific factors. Human factors include problems of encouraging and convincing people to use new and innovative methodologies. It is noted that new methodologies, however enthusiastically received, are frequently discarded in favour of familiar methods shortly after they are taught and personnel trained. Implementation of new methodologies is also frequently inefficient in time-management terms due to complexity, dependence on worker experience and interpretation, as well as processing of results. Methodology factors: available engineering methodologies are frequently theory-overloaded and do not integrate well with one another, if at all. In the chain of methodologies there is lack of transparency in planning, cost, technological and quality data's.

3. ASSIST.

On the other hand, the ASSIST project has started in November 2004. ASSIST aims at achieving a breakthrough in the use of advanced agent-based knowledge management techniques in real industrial practice, within an innovative ICT solution affordable to SMEs. The main business aim is to produce a leap forward in industrial design performance in SMEs.

ASSIST is a unique agent-based knowledge management approach meeting these needs. Knowledge is key to this, as the right knowledge and ideas in a well-structured manner will help designers to improve their design performance. With the wide diversity of knowledge to be acquired, managed and processed, this requires research into the latest thinking in terms of semantic and context sensitive knowledge. It requires the investigation into agent-based knowledge management systems that can understand the knowledge and the environment it comes from.

ASSIST will develop an approach to be able to understand the semantics of the knowledge that it acquires to be able to effectively manage it for the designers. This will enable ASSIST to effectively process context-specific knowledge, which exists in the industrial design domain, and to be able to process it into useful forms and present it to designers in a structured manner. The results will be the ASSIST methodology and prototype ASSIST system, implemented in 7 demonstrators.

4. AIM SYSTEM CONCEPT

As it has been mentioned before, AIM has started in July 2002 and is bound to end by September 2005. In consequence we may develop in deeper detail its achievements and developments. AIM system includes methods and tools (modules) for collecting innovative ideas and knowledge on products/processes. The system also contemplates another important source of innovative knowledge coming from problems and potential improvements. The system also supports assessment on these innovative ideas and helps to manage them in order to provide the best way of using them for innovative product and process designs. These ideas and knowledge will later be developed into a means of fostering industrial innovations. It will enable organisational learning by providing means to collect, store and use/develop innovative ideas over the extended enterprise. The System is thought as a process of innovation, as presented in Figure 1.

Main RTD challenges faced along it contemplate basically the combination of advanced methods for generating innovative ideas with "classical" methods for collection of knowledge on products/processes and their problems. It also includes the development of specific ontologies needed to enable efficient exchange of ideas between different experts/actors within an extended enterprise. The AIM system comprehends several modules:

- Innovation Repository: This repository classifies ideas by using an 'innovation' meta classification, and will store them for rapid access. The overall meta classification of the ideas and innovations will be defined as a basis for all AIM modules, enabling appropriate classification for different specific products and processes, as well as within a specific company concept. This will include knowledge on products/processes, problems/potential improvements, (innovative) ideas and innovations.

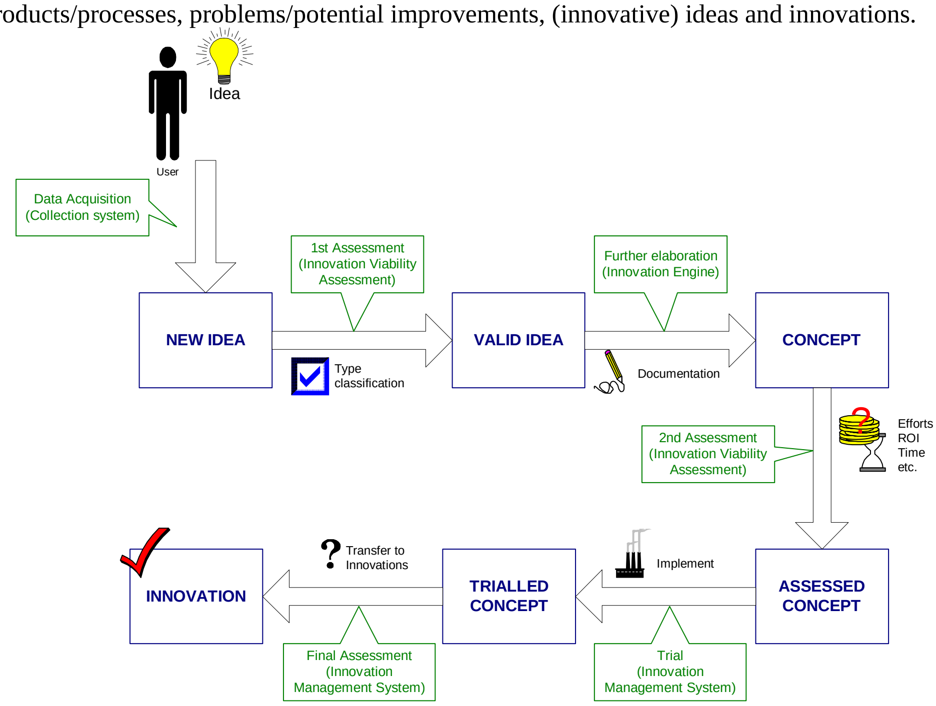

Figure 1: Life Cycle of Innovation.

- Collection of innovative ideas and product/process knowledge: This module is based on combination of 'classical' approaches/commercial tools together with new developments required to provide means to efficiently collect innovative ideas, but also to collect knowledge on product and process problems for which the innovative ideas are needed. This module includes appropriate user interfaces to introduce ideas and knowledge on products/process and about the identified problems.

- Innovation Engine: This is a collection of methods oriented to finding innovative solutions following a systematic methodology. This facility provides a structured means for the development of ideas into innovation concepts, by sharing and working on these ideas in a structured framework. The ideas collected within previous module and stored in the repository will be further developed. The specific requirement is to provide robust solutions to be applied in the industrial environment. TRIZ methodology serves as a baseline approach for this module, where the in-depth analysis of technical requirements and manufacturing failure situations is performed, structured knowledge is delivered, and graphical aids for team working and creation of Concepts are provided.

- Innovation Viability Assessment: This facility provides a structure (based on rapid consulting within the company of evaluation of developments and risks, combined with a multi-criteria decision support) to assist users in assessing the feasibility of new ideas at the collection stage, and innovation assessment facilities for design teams. It is important to focus on feasible, good innovative knowledge, and develop this.

- Innovation Management System: This is a means of providing an efficient way for planning and monitoring the use of the innovation knowledge during design activities and a structured delivery of the innovations/ideas to the process and product Design Teams. This module will assist graphically the work of the Design Teams in designing new process and products in the companies.

This architecture has been finally deployed following a multi-level architecture based on Internet technologies. Integration with other tools inside each enterprise is carefully being studied and adapted to specific needs. Here the Innovation Viability Assessment module will be explained in more detail.

4.1. TECHNOLOGY AND SYSTEM CONCEPT

The main asset of the AIM System is to provide means of efficient delivering Corporate Knowledge and Ideas (by integrating a WorkFlow Tool), collected throughout the extended enterprise (by offering web-based applications to customers, clients etc.) and stored in a structured repository. Therefore, the information and collective knowledge have to be structured in such a way that it is easy to access and re-use.

The AIM System combines existing tools and technologies in an innovative way, in order to fulfil the stated objectives. AIM fosters creativity by combining classical reasoning methods, Case-Based Reasoning (CBR) and Rule-Based Reasoning (RBR), which focus on the Company's Business Objectives with an innovation supporting method, Theory for Inventive Problem Solving (TRIZ), and graphical aids for combination of concepts, within the context of specific products/processes, formalised by the use of continuously adapted ontologies. Although the main technologies mentioned are available in the market, the results of the analysis of the state-of-the-art conclude that methods and tools for capturing and structuring knowledge and innovative ideas, over extended enterprise, in a way that enables product/process innovative practical means are missing.

CBR, for example, is used in three different modules of the AIM System: Collection, Innovation Viability Assessment and Innovation Engine. Therefore, the functionality of CBR has to be flexible and adjustable to fulfil the functionality in the different modules. CBR is used to search similar problems and/or ideas. For each of these entities, cases have to be built, with the information that will be considered to evaluate similarity. The functionality will be used for problems, to identify the respective causes, and in ideas to support an effective collection of knowledge and appropriate assessment. One of the main challenges of the AIM project is the great variety of problems, ideas or situations the system should be able to deal with. In many CBR applications, the domain is bounded in the sense that all influencing conditions (attributes) and their ranges are known and it is assumed that all occurring ideas/problems could be described by these conditions. This assumption may not hold in AIM. The system may not need only to learn possible problem/idea situations and their causes but also to learn possible descriptions of problems or ideas. For this reason, the common structure of cases has to be more generic than in conventional CBR systems.

In conventional CBR systems, the description of a problem or idea (case) is given in a "flat" table. When information has to be entered into the structure, where no attributes are defined, the structure needs to be extended. The problem in AIM is that it is not known in advance which information is accessible in case of a problem or idea and how it is structured. Therefore, a more generic approach is also considered, based on object-oriented Design. The generic structure assumes that every case occurs during an operation which takes one or more objects as input, provides one or more objects as output and is performed by one or more objects as operators (human operator, machines etc.). In one case, all the objects could be instantiated as often as needed to describe the current situation. For both operations and objects, different conditions could hold. Neither the type of significant conditions nor its value is known in advance. Therefore, these conditions could also be instantiated by objects and operations as often as needed.

The simple structure described seems to be sufficient to store all possible problems/ideas, but it is being further elaborated and refined. In classical flat structures, the similarity between cases is computed via similarity functions, attribute by attribute, and a weighted mean value over all outcomes of the functions. The difficulty lies in determining the similarity functions and the weights for the mean value. Another problem arises especially in the selected object-oriented approach because cases do not only differ in the value of their attributes but also in the existence of attributes.

Similarity of ideas is based on five fields of information: Idea Type, User who reported the Idea, Involved Generics (processes, products and tools), Involved Problems, and Involved Technologies. Similarity of Problems is based on the following information: Generics involved in the problem (processes, products and tools), and Actual State Items defined for the problem (values). When two ideas/problems are analysed to ascertain their similarity, each of the fields is compared to check if the respective information is the same in both cases. The comparison of each field provides a result (in percentage), which is afterwards computed in a total percentage, representing the similarity of the two ideas/problems. CBR considers that an undefined value is more similar to a defined value, than two different defined values. The several parameters that constitute the similarity criteria of each entity can be adjusted by the user, each time CBR is used to obtain similar ideas/problems. This allows the users to perform a more flexible search, and obtaining appropriate results. The priority given to each field is a value within Ignore, Lowest, Below Normal, Normal, Above Normal and Highest (see an example of Interface for this search in the AIM System, in Figure 2). Furthermore, it is possible to filter ideas on the similarity comparison by selecting specific status that should be ignored (e.g. the user can choose to ignore in the analysis all the ideas marked as Invalid).

AIM uses the tool ReCall from ISoft for the implementation of the CBR module. This decision was based on the analysis of the existing market available tools for CBR, and on laboratory tests carried applying this tool, which provided positive results.

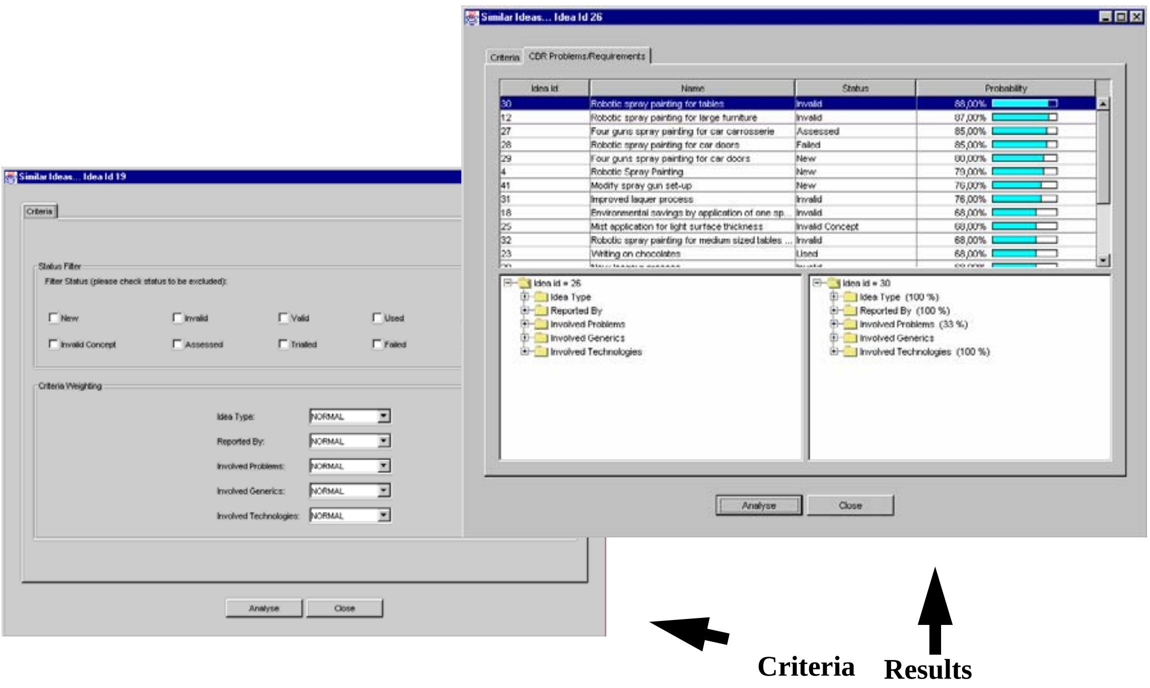

Figure 2: Searching Ideas Screen Example

4.2. RESULTS

An early prototype of the AIM system has been developed and tested in the three business cases described. The Project is currently realising integration tasks of the modules already developed, so new results and feedback from the utilisation by the end-users of the integrated system are expected.

Related to the use of the CBR for efficient search of ideas and problems, through the Innovation Repository of the AIM System, the results from the tests performed indicated improvements needed. To test the developed CBR functionality, in Business Case 2 several problems occurred in the manufacturing processes were stored, as well as ideas, providing the system the necessary information to reason. CBR uses information from problems stored in the system to provide the results. For Business Case 2 the rather flat case structure is designed and filled with cases. The weighting for attributes has been specifically defined for each problem type. The same information was also filled in the generic structure. The objective was to prove that the generic structure does not yield a loss of accuracy. The list of problems from production was used to test the CBR module. An example of problems for one of the business cases is provided in Table 1. The problems were structured both in a specific structure and in a generic structure in order to enable a comparison of appropriateness of these two structures. The tests performed considered ca. 350 problems. The results obtained are sets of cases with a high similarity. When the specific structure is applied, CBR identifies the reasons of problems in more than 90 % correctly (even with incomplete information) and the similarity achieved in the range of 75-99%. In the case of the generic structure, the identified problem causes are correct in more than 88%, while similarity is between 83-99%. This indicates that the proposed generic structure is appropriate for the cases and that CBR approach is likely to efficiently solve more than 80 % problems in the companies (a conservative estimate, taking into account that the considered cases are very typical for the companies).

Table 1: Problems/Ideas

Error	Process Step	Product Part	State Items	Cause	Idea/Action
Broken can V-Crash	WIM, Coater, Decorator	Bottom of the can	manual check, where the damaged bottom is identified (no available measu-rement of the air pres-sure of the machines)	Coater/WIM too high Base deformed	WIM/Coater control/reduce
Falt Batwings/Line fold	used tinplate (supplier process)	tinplate	tinplate strengths; (problems with) the coil in the front end (cupper/wim)	Soft metal plate	Increase lubrication impulse Sedimentation in the plate
Falt Line fold	IBO	inside lacquer	visual inspection-> bubbles in the inside lacquer; temperature inside oven too high?	Temperature (inside oven) inner lacquerer	

5.- CONCLUSIONS

The overall objective of the AIM project is twofold: increasing innovation and accelerating its introduction to the Market. This paper presents the approach developed in the project to fulfil this objective.

After the preliminary assessment of the benefits expected and already achieved, the three business cases are unanimous in presenting positive results. One of the common benefits expected is the reduction of time and efforts for solving product/process problems which already has achieved an improvement of 20% (15% in business case 2) but all expect to further improve this value. Other specific achievements expected out of the full implementation of the AIM system are the development of means of stimulating the creation of innovative ideas and collecting them from people at the extended enterprise level involved with the products and processes, the development of ways of processing these ideas and storing them into a structured knowledge repository (to ensure that all the useful knowledge, innovative information, is saved), the development of means of analysing innovative knowledge to determine which is useful, and which is not (to enable the viability of ideas to be assessed) and the development of means of delivering the innovative ideas to product and process designers for maximum effect. The changes on the companies to reach these specific achievements are still ongoing and can not still provide specific numbers on the overall improvement of the company, the assessment so far has shown signals of positive results. This should lead to important business benefits on the fields of reduction of product innovation cycle-time (by at least 30%) and the improvement of process efficiency (by at least 15%) and reduction of wastes (by 12%).

In the future, it is planned to finish integration with legacy systems, continue with the industrial testing and make the respective measurements to have the full assessment of the system.

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