THE IMPORTANCE OF ARTIFICIAL INTELLIGENCE-EXPERT SYSTEMS- IN COMPUTER INTEGRATED MANUFACTURING

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Introduction

In order to maintain their competitiveness, companies feel compelled to adopt productivi ty increasing measures. Yet, they cannot relinquish the flexibility their production cycles need in order to improve their response, and thus, their positioning in the market. To achieve this, companies must combine these two seemingly opposed principles. Thanks to new technological advances, this combination is already a working reality in some companies. It is made possible today by the implementation of Computer Integrated Manufacturing (CIM) and Artificial Intelligence (AI) techniques, fundamentally by means of Expert Systems (EESS) and robotics.

Depending on how these (AI/CIM) techniques contribute to automation, their immediate effects are an increase in productivity and cost reductions. Yet also, the system's flexibility allows for easier adaptation and, as a result, an increased ability to generate value, in other words, competitiveness is improved. We have analyzed three studies to identify the possible benefits or advantages, as well as the inconveniences, that this type of techniques may bring to the companies, specifically in the production field. Although the scope of the studies and their approach differ from one to the other, their joint contribution can be of unquestionable value in order to understand a little better the importance of Expert Systems within the production system.

I.- Computer Integrated Manufacturing and Expert Systems

Computer Integrated Manufacturing (CIM) is a way of, directly or indirectly, coordinating all the elements involved in the production process: Computer Aided Manufacturing (CAM), Computer Aided Design (CAD), Computer Aided Production (CAP), etc., in order to achieve the strategical objectives set by the company's management (Hitomi, 1994).

The CIM concept might be one of the hardest to define. This is due mainly to the different approaches taken by the studious of this acronym. Some authors believe that CIM is a software package sold on the market. Others look for the integration of computer and automation technologies only, and exclusively, within the area of production. For others, CIM is a production technique that automates the whole company, a state-of-the-art technology, a business concept, etc. We can state that CIM is all of this, and more.

CIM is not a product that can be acquired on the market, it is rather a philosophy aimed at obtaining objectives (Weston, 1994). Unlike convencional automation projects (flexible manufacturing systems, numerical control machines, robots, etc.), CIM is a complex and long-term project because, apart from the technical structures, it is necessary to also consider the organizing ones (Rowlinson, Procter and Hassard, 1994).

So, CIM must be a part of the company's strategy that contributes to improving its competitiveness. It is company specific and should respond to the markets requirements by means of specific technical and economic objectives (Thomas and Wainwright, 1994).

Artificial Intelligence is a science and a technology that deals with the comprehension of intelligence and the design of intelligent machines. These machines are those that present characteristics normally associated with human understanding such as reasoning, written and spoken language comprehension, decision making, et al. (Valle, Barbera, and Ros, 1984).

Within AI, Expert Systems constitute the most important field of study. We can define them as computer systems designed to collect and register both, the aspects of the human expert which are necessary for decision making in order to ease problem solving in specific domains, and the expert's behavior when faced with such situations. One of these areas, production, is the our object of study in this article. The main reason for the use of this technique can be found in the type of problems that must be solved. Situations that, although repetitive, are not completely structured because, even if the problem happens again, the circumstances surrounding it might vary.

II.- Areas In Which Expert Systems Can Be Applied Within Production

Although there are many areas in which Expert System prototypes can be developed (ES) -as many as problems or domains can be identified- in practice these techniques have been shown to be more applicable to structured and semi-structured problems.

Rao and Lingaraj (1988) classify the areas focusing on two dimensions: on one hand the temporary horizon (that they identify as tactical or strategic) in which they will have to be developed; on the other hand, depending on the function that the decisions to be adopted represent: operation management (production, programming, quality, etc.) or resources (machines, personnel, etc.).

In Table 1 we see the four quarters that result from this classification. The numbers between parenthesis indicate those areas that can be moved from one quarter to another, focusing solely on the temporary horizon. It all depends on the implication of, and the frequency with which, such decisions are made. The maintenance function could be transferred to the first quarter, and the design of posts to the third quarter, depending on how wide a meaning we want to attach to the words.

As far as the areas of implementation go, Rao and Lingaraj (1988) in their work mention that companies rarely adopt decisions concerning plant distribution (layout), post design and location. For this reason, efforts to develop Expert Systems in such areas are not important, economically speaking they would not be justified. However production programming (scheduling), capacity planning, product and process design, and maintenance are seen as the most promising areas for the application of Expert Systems within the production field.

For Meyer (1990, p. 308) there are three main areas in which Expert Systems are applied, diagnosis, process planning and production programming. In project EP932 (Meyer, 1990 pp. 305-314), as we will later comment, 55 knowledge-based systems are developed, tested and implemented in the functions of production planning, quality control and maintenance. The distribution amongst each of the areas is enlightening, almost half of the systems, 49%, are established in the production planning area, 18% in the maintenance area, and 7% in that of quality control. So 74% of the systems were developed in one sole area. The remaining 26% belong to more than one area. This fact shows that there is no significant percentage of Expert Systems that might be favoured by the benefits of knowledge integration. Work is done in well delimited domains to solve specific problems.

		Application Orientation	
		Strategic	Tactical
Applic. Emphasis	Operations	2 Aggregate Planning (1) Forecasting (1)	Scheduling Capacity Planning (2) Layout Process and Product Desing (2) Quality Control Job Design
	Resources	3 Location	Inventory Control Maintenance and Realiability

Table 1. Two-dimensional classification of Production/Operations Management applications (Rao y Lingaraj, 1988)

On the other hand, the European Auerbach report (Chip, 1989, pp. 80-81) recognizes six categories as a result of the study the most regularly used Expert Systems in industry. Most applications are included in any one of them: diagnosis and interpretation of data, planning and programming, design, process monitoring, simulation and prediction, and intelligent tutoring.

Of all the 46 areas in which Seai Tech. Publ. (1990) classifies the world's knowledge-based systems, of the 10 first only 3 directly affect the object of our study (see Table 2).

Ranking	AREA	%
2	Diagnosis and Maintenance	8,5
6	Production Planning and Management	3,8
7	CAD/CAM/CIM	3,3

Table 2. Areas of aplication (production) of the EESS in the world

However, this study forecasts an important change within the next few years in the areas with the best perspectives for the application of knowledge-based systems. Thus, from among the ten first areas, 5 fall completely within the production field, ousting medicine from first place and substituting it with diagnosis and maintenance (Table 3).

Ranking	AREA	Valuation
1	Diagnosis and Maintenance	8,7
3	Ingineering	8,0
4	CAD/CAM	8,0
6	Flow-Shop Process	7,2
7	Job-Shop Process	7,2

Table 3. Areas with the best perspectives for the application of EESS (production area)

The evolution is clear, the growth potential of Expert Systems, due to the type of problems they aim to address within the field of production, is a reality taking place in many countries while in Spain its still taking its time. Nevertheless, there seems to be a certain consensus among different AI experts which will result in a notable advance of Expert Systems within production, "a great effort will be devoted during the next few years to implementing Expert Systems within the production methods, to develop, firstly, tasks of interpretation, diagnosis, planning, configuration, monitoring, and control, prediction and acquisition of knowledge" (Andrés Puente 1993, p. 21).

III.- The Potential Benefits of Applying Expert Systems to Production

We often find, in specialized literature, news concerning the benefits that some Expert Systems bring to their respective domains, specifically within the production field[1]. This is not so when failures occurring while developing some of them are concerned. The benefits, such as the ones we have already identified, tend to increase productivity, but at the same time make the productive process much more flexible through a more fluid information flow. Their origin stems many times from a cost reduction, accompanied by an increase in the operativeness of the system, brought along by reduced execution times.

Although production systems might be a promising area for the development of Expert Systems, and many companies have already installed them, there is very little information available on use of Expert Systems within production from a business standpoint, much less than from the technical perspective. "An atmosphere of secrecy and privacy has surrounded the development of production directed Expert Systems within private organizations. Although these private organizations are developing Expert Systems, literature contains very little empirical information on their application and implications" (Byrd, 1993, p. 119).

Thus, we can identify three types of complementary reasons, all clearly defined albeit not mutually excluding, under which the main benefits that justify the implementation of Expert Systems and of other AI techniques in a specific domain (CIM) may be grouped (López Sánchez, 1995): those based on the need for **automation**, those based on **competitive factors** and finally, those motivated by the **type of problems** that must be solved and, thus, the type of decisions that must be adopted within the production system itself, as well as in the company as a whole. Knowledge-based systems add a new dimension to problem solving within the CIM field that other types of techniques did not contemplate: **knowledge**.

It is difficult to pinpoint what advantages or inconveniences are generated by the implementation of Expert Systems in an integrated production environment. This is not only due to how unknown they are, but to how hard it is to quantify them. Moreover, many of these, the company's image, the personnel's morale, the consistency in decision making, the increase in client satisfaction, etc. are **intangible**. For these reasons, the identification and later valuation of benefits is based on the opinions of experts and users from the companies that have implemented them. It is difficult to find perfectly quantified data comparing the conditions before and after their implementation.

Meyer (1990) y Byrd (1993) identify and value the advantages and inconveniences of implementing Expert Systems within the production field. The first one achieves it by studying the development, test and implementation of 55 knowledge-based systems within the functions of production planning, quality control and maintenance. He identifies the qualitative benefits

1 Some references in which benefits are described, and even different Expert Systems within the production field analyzed, are: Kusiak and Chen (1988); Rao and Lingaraj (1988); Meyer (1987); Cimworld (1992); Kusiak (ed.) (1988); Kusiak (ed.) (1992); Browne (ed.) (1989); Sviokla (1990); Kanet and Adelsberger (1987); Kerr and Ebsary (1988); Ghiaseddin, Matta and Sinha (1990); Mertens and Kanet (1986); Turban and Sepehri (1986); Mellichamp and Wahab (1987); Mellichamp, Kwon and Wahab (1990); Meyer (1990); Gupta and Ghosh (1988); Byrd and Hauser (1991); Chen and Bizruchak (1991); Lee et al (1992); Motiwalla and Gargeya (1992); Eom et al (1993); Sánchez Tomás (1993); Fry, Philipoom and Swiegart (1993); Chaturvedi (1993); Ajmal (1994); Price et al (1994); Silverman (1994); Wong et al (1994); Hooks, Rabelo and Velasco (1995); Eom (1996); Qiqin et al (1996).

(not measurable in monetary terms) and the quantitative ones (measurable in monetary terms) that result from the application of AI techniques within a CIM environment. He also studies the organization levels at which these techniques are used and the types of products that they turn out (standard, prototypes, internar exploitation and bought products). Concerning the analysis of the benefits that the aforementioned systems bring the companies, Meyer's work gathers the criteria that have been submitted to the different organizations in which Expert Systems have been implemented for valuation.

Eleven criteria for valuating the qualitative benefits have been describes. These are detailed in Table 4. The criteria are classified according to the importance their impact on the companies. The company's image is the one with the most impact, whilst the product variety is given the last place.

Num.	CRITERION	EXPLANATIONS
1	Company image	Customers's view of the company and its reputation
2	Production schedule flexibility	Adaptability of scheduling to real situations and their dynamic conditions
3	Labour morale	Job satisfation due to shifts in skills
4	Internal communications	Communication between departaments
5	Product quality	Standard of quality of finished products
6	Response to change	Response to changes in the external environment (market demand)
7	Risk	Uncertainty when making high level decisions
8	External communications	Communication with the suppliers and the customers
9	Product innovation	Supporing product development by feedback of information from production and quality control
10	Safety	Prevention of accidents
11	Product variety	Range of products that can be made

Table 4. Criteria selected for the qualitative value analysis (Meyer, 1990).

Within the five first criteria, we highlight the place obtained by the improvement of the company's image: first. Note that it has approximately the same impact in the three areas dealt with. It can be said that the improvement of the company's image is a direct result of the implementation of Expert Systems. The second criterion is the improvement in the production planning's adaptation to changing situations. In other words, an increase in the flexibility of the production system, not as much in the variety of products, as in route assignment, machine loading, posts, etc.

Twenty criterion have been describes under quantitative benefits (Table 5). Some of them are valuated through the cost reductions they bring to their respective entries. Valuation by criterion and area ranges from 1 to 20 (1 being the non-existence of benefits). The maximum value per criterion is 60 (the sum of all three areas). The absolute value depends on the value identified in that scale. Just as with qualitative benefits, the order in which the aforementioned criteria appear reflect how important the impact of each of them is.

Num.	CRITERION	EXPLANATIONS
1	Productivity	Utilization levels of all resources
2	Production throughput	Amount of production per unit of time
3	Scrap	Amount of waste in the manufacturing systems
4	Labour	Staffing on the shop floor clerical and the other office staff
5	Financial management	Cash flow and general financial health
6	Work in process (WIP)	Materials, parts, components and subassemblies waiting to be processed
7	Flow time	Time needed to produce a finished product from the first operation to dispatch
8	Order delay	Number of orders delivered late
9	Market share	Proportion of the total market demand for products supplied
10	Materials handling	Equipement meeded to move materials and products around the site and the customers
11	Training	staff training
12	Finished goods	Stocks of finished products awaiting shipment
13	Capital	Assets held on the factory site
14	Tools	Utilization of machine tools
15	Customer support	Dealing with customer enquiries and complaints
16	Reworks	Parts, components and products that require remaking or repairing
17	Floor space	Floor area required for production
18	Equipment life	Life of equipment needed to build products, depending on the type of processing
19	Raw materials	Raw materials purchased or parts subcontracted
20	Energy consumption	Total energy consumed in the factory

Table 5. Criteria selected for the quantitative value analysis (Meyer, 1990).

Byrd (1993), unlike Meyer, does not study any particular system and tries to reflect the opinion of 74 Knowledge Engineers specialized in production from private companies, by means of a survey (Table 6). Among the issues dealt with we find: the important points to follow to successfully implement an Expert System; how and what are the Expert Systems being used for; what are the motivations behind the development of successful Expert Systems; identification and valuation of the benefits brought along by Expert Systems; the effects of Expert Systems on end users; and, what are the most commonly employed knowledge acquisition techniques.

Among the most important contributions of Expert Systems to the aforementioned domain are the growth of the company's image, more flexibility to production programming, and the dramatical increase of consistency in the decision making process and all of that without renouncing the system's efficiency and productivity.

It is important to note from Meyer's study (1990) the lack of Expert Systems on the market because, of the 55 systems studied, 89% are either not functioning (47% are prototypes) or, if they are (products exploited internally account for 42%), the amount of companies (generally from the same group) that benefit from these techniques is small. This situation is very similar to the one found in Spain where not very many Expert Systems are sold as products. The majority of them are developed and used inhouse.

BENEFIT Mean (0-5)		PROBLEM Mean (0-5)	
More consistency in decision making	3,72	Lower job satisfaction	4,25
Improved productivity	3,56	Decline in job attractiveness of end-user	4,15
More timely business reporting and decisions	2,95	Sabotage on the part of user	4,05
Workers free to do more creative work	2,95	EESS seen as dehumanizing	4,01
Improved competitiveness and market share	2,92	Increase in mental work load of end-user	3,95
More accurate business reporting and decisions	2,76	Deskilling of personnel	3,92
Reductions of workers doing rutine tasks	2,39	Role of human in decision-making process ambiguous	3,88
More educations and training accomplished	2,26	Over-reliance on EESS for final decisions	3,69
Reduction in operations personnel	1,78	Explanations of recommendations of EESS non sufficient	3,57
Easier access to computer networks	1,71	Lack of trust by users in EESS solutions	3,50

Table 6. Benefits and Problems of the EESS implementations (Byrd, 1993)

IV.- Result of a Study of Spanish Companies that Develop Expert Systems Within the CIM Context.

The study we discuss next, was undertaken because of the existing lack of research on Expert Systems in the production field (the CIM concept) within the national context. This derives from the fact that there are not very many national reports available in Spain. Our intention was to reveal the opinion of some of the experts concerning the ideas we maintain all throughout this work. We did this by sending out a survey to the twenty companies that develop these technologies in Spain (López Sánchez, 1998).

All the companies surveyed answered affirmatively to the question about the development of Expert Systems in any of their production areas. From this we can derive the existence of products which are undoubtedly not known, or that companies do not disclose. The datum concerning the type of applications used (custom-made or standard) is interesting: 70% of the companies surveyed develop more than half of their applications (Expert Systems/CIM) to suit to their own needs. These applications are normally produced on some of the best known development tools.

On the other hand, all companies act as consultants on this type of applications. A reason for this policy lies in the ignorance among the companies in relation to this kind of software which, not being convencional, needs more support from its developers.

The analysis of the possible areas of applicability of these systems, as gathered from the answers received, is reflected in Table 7, even though valuation (from 0 to 10) of each of the areas differs from one company to the next. What is important is that we can be sure that companies are clearly willing to bet on this type of technology.

There seems to be a certain consensus as to which areas lack possibilities or are less favourable for the application of Expert systems, among them: laboratory management, data set up and acquisition and Electronic Data Interchange (EDI). As far as the rest of them go, there are disparate opinions, but we can assure that the most requested ones are those which tradicional studies done in other countries describe: finite capacity programming (scheduling), process simulation and plant distribution, management and quality control, logistics and distribution, production control and management, and maintenance.

AREAS	Mean	Std. Dev.
Maintenance	8,10	0,70
Production Control and Management	8,00	0,89
Logistics and Distribution	7,90	0,94
Scheduling	7,90	0,83
Process Simulate and Layout	7,60	1,11
Administration	7,00	1,00
Quality Control	7,00	1,18
CAD/CAM/CAE	6,20	0,98
Automate Storage	6,10	0,70
Electronic Data Interchange	4,20	0,60
Data Capture	4,20	1,17
Laboratory Management	3,10	0,70

Table 7. Valuation of EESS implementation in the production areas

The time required to implement an application does not exceed a year in any of the companies surveyed: ninety percent achieves it in between 6 months and a year, the remaining 10% in less than 6 months. This time period depends basically on the companies' experts ability and the degree of understanding between the Knowledge Engineers and them.

After having analyzed the data, our opinion is that, according to investigators, Expert Systems offer the companies important advantages (Table 8). These advantages can be translated as an increase in productivity and an improvement in management of the whole productive process in general. Nevertheless, in this study we have not analyzed the quantitative valuation that the mentioned advantages contribute to the companies which implement them. Our study simply shows the favourable opinion that a series of experts have concerning the possible repercussions of these techniques.

Regarding possible problems (Table 9), two of them stand out from all the rest: the high investment volume (high cost) and the unawareness of the system's potential benefits. These two problems are the basic cause of the low number of Expert Systems implemented within our companies. We should maybe comment that in many cases it is not only that companies do not know their potential benefits, but that they are unaware of the existence of Artificial Intelligence techniques and that these can be implemented within their activities.

ADVANTAGE	Mean (0-10)	Std. Dev.
Scheduling improve	8,90	0,54
Increase in productivity	8,40	1,02
Reduction of supervision	8,10	0,83
Improvement on product quality	8,00	1,18
Increase of customer's satisfation	8,00	1,00
Improvement on management	7,60	0,92
Integration sinergy	7,50	1,20
Reduction of breakdowns	7,50	0,92
Reduction of marketing cycle	7,50	1,12
Operations Flexibility	7,40	1,20
Reduction of losses	7,40	0,92
Increase of product fiability	7,30	1,27
Increase of labour morale	7,30	1,55
Reduction of stocks	7,20	1,25
Reduction of labour force	6,80	0,98
Increase of security	6,70	1,00
Reduction of transport costs	5,80	1,72
Reduction of suppliers	3,80	1,08

Table 8 Advantages of the EESS/CIM to the companies

PROBLEM	Mean (0-10)	Std. Dev.
High investment volume	8,30	0,90
Unawareness of the system's benefit	8,30	0,78
Human factor	5,50	1,20
Training of team	4,50	1,50
Integration difficulty	4,20	1,25
Lack of appropiate software	4,10	1,70
Operation costs (maintenance, supervision...)	3,20	0,87

Table 9 Companies problems in the EESS/CIM implementation

V.-Conclusions

We have analyzed three studies from different global locations (United States, Europe and Spain). Despite their different orientations, the general conclusions extracted from them confirm how relevant Artificial Intelligence Techniques are to the field of production within the CIM context. Specifically the use of Expert Systems.

Although there are many areas in which Expert System prototypes can be developed -as many as problems or domains we might be able to identify-practice has demonstrated that semistructured problems are the ones to which these types of techniques can best respond. Situations that, although repetitive cannot be considere completely structured because, even though the problem shows up again, the circumstances that surround it can vary (maintenance, production management and control, logistics and distribution, programming, process simulation, etc.).

According to the companies that manufacture them, the most important contributions of Expert Systems to the production field are their ability to add flexibility to production programming, and the way in which they substantially increase the consistency of the decision making process -all of this without relinquishing the production system's efficiency and productivity. However, the amount of companies using this type of technology is evident, yet moderate, and is experiencing no spectacular increases. The reasons being how little known they are and their high cost.

Companies will gradually implement them, but only to ease the solution of partial and clearly specific problems. The next step will be to totally integrase them within the production system, with the rest of the automation systems, as a connective technology that finally achieves the total operation of the productive system, with less and less intervention by the human operative.

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