



A proposal to incorporate the Value Analysis/Value Engineering techniques into a PLM system

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Abstract

The aim of this paper is the development of a conceptual framework for the incorporation of the Value Analysis/Value Engineering techniques into a Product Lifecycle Management (PLM) system. This proposal would help to systematize the flow of knowledge and innovation, both internal and external, among all processes inside an industrial company, particularly those related to design and manufacturing. As a result of such incorporation, those techniques would contribute with their potential to a continuous improvement process of the company's competitive position by means of increasing the ratio between the product's quality as perceived by the customer and its cost.

1 Introduction

The current situation of worldwide competition in which companies are immersed today takes place within a context in which the off shoring of production to developing countries causes them to be very difficult to compete by offering lower prices. Therefore, in order to hold or improve its competitive position in the global market, the manufacturing companies in developed countries are forced to develop a constant attitude towards innovation. It must be present at every level and function of the enterprise, and especially in the design and manufacturing activities. Also, customers in developed markets are demanding a progressively increasing level of quality of products, and are not willing to accept a corresponding increase in prices, thus contributing to the pressure on manufacturing companies.

On the other hand, the increase of product complexity and the maximization of the economies of scale by manufacturing companies led to the "virtual supply chain" (VCS) and "extended enterprise" concepts. They refer to a production configuration in which the product manufacturing process is distributed among different companies -multi-tier suppliers-, a typical situation in mature industrial sectors such as automotive, aerospace or shipbuilding industries. This makes more difficult the use of collaborative engineering (CE) techniques to the whole product, due to the required product information flows and the associated confidentiality and security requirements. So, the term "virtual collaborative engineering" (VCE) was created to define a situation in which the concurrent engineering process spans across several companies that are involved in the design and manufacturing of a product or family of products, with an intensive support of information technologies.

At the same time, the request for fulfilling different national environmental requirements and the customer sensitivity on sustainability is forcing the companies to focus on the "extended product lifecycle". In that approach, the whole product lifecycle is considered: beginning of life (BOL) -design, manufacturing-, middle of life (MOL) -distribution, use, support- and end of life (EOL) -retirement-, when traditionally the enterprise management systems were mainly focused on product design, manufacturing and logistics management.

That is happening on a context of financial crises, with decreasing numbers in sales and benefits, and where the companies face serious difficulties to get funding for costly innovative projects. Thus, companies are constrained to look for improvement mainly through the better use of their own current assets, both tangible and intangible.

By those reasons explained above, it becomes essential for industrial enterprises the implementation of those techniques, processes, organizational models, etc. that would allow them to reach a certain competitive level, good enough to guarantee a key position in its sector globally. Both the current products/markets combination and the launching of new products/expansion to new markets are to be taken into account for such strategic approach. To fulfil those objectives it's necessary for the company to keep high the level of its products' quality as perceived by current/potential customers, while staying competitive in pricing -which involves containing the design, manufacturing and distribution costs-, and at the same time offering a short delivery time -which compels the firm to optimize itself wholly at process level-.

Since its development as an organized approach in 1947, Value Methodology (VM) -commonly applied as Value Analysis (VA), Value Engineering (VE) and Value Management- is defined as a systematic method to improve the "value" of goods or products and services for

the users by focusing on their “functions”. VM has shown beyond expectations its effectiveness as a tool to improve both the quality and the cost of products/services in those companies that used it, allowing them to channel their knowledge and their creative flow in a systematic way, turning them into efficient competitive advantages.

In spite of that, VM implementation in companies of the industrial sector is often fragmentary, punctual, and uncoordinated with the rest of the elements is the supply chain of the finished product. Thus, the full advantages of an integral implementation are not completely taken advantage of.

Many firms already use Product Lifecycle Management (PLM) systems, but often the implementations are little ambitious, partial and/or badly integrated. Incorporation of VA and VE to PLM systems would contribute in an outstanding way to the manufacturing companies to make better use of their innovation capabilities, with an implementation that wouldn't be very complex or expensive. Such innovation could be oriented in different ways -product, process, markets, logistics, etc.-, and could be based on the firm's assets: resources, technology, experience, explicit or implicit knowledge

In this proposal, adding the power of VA-VE to PLM systems would contribute to facilitate the transformation of those companies, not only allowing them to survive but helping them to evolution in the positive direction in this new global competition scenario.

2 The Value methodologies

The basics of VM were established by Lawrence D. Miles in 1947 when he was working at General Electric Co. He developed “Value Analysis” (VA) and began to use it as a novel way to apply innovation to redesigning industrial products, looking to reduce their manufacturing cost.

Miles realized that customers did not demand objects to manufacturing companies, but rather demanded their capability to satisfy specific needs at a reasonable cost, and he set that as the basic foundation of VM. By that reason, if the company is able to produce functions at a low price, it will be selling products which have a high “value” for the customer. In fact, this is the central topic and the main objective of VA and VE.

Therefore, VM is a function-oriented methodology that works looking to improve the “value” for the user of a product, service or process. It does so by studying its constitutive elements and their associated costs, and then trying to improve the components, either reducing their cost or increasing the value of functions, or both of them if it is possible.

In this way, VM is applied by first establishing and then improving the “value” of a product/service through the understanding of its functions and their value, and the same is done to the constituting components and their attributed costs. All of it is carried out with the aim of both reducing costs and increasing the value of functions.

VA and VE can be used over and across all the design, manufacturing and purchasing phases towards a common objective: to obtain from a product an equivalent performance, or even improve it, in such a way that its cost is reduced. VM looks to get rid of fractions of unnecessary cost without either compromising the necessary function or making it cheaper no matter what. This cost reduction usually entails an improvement in the product quality and other product enhancements such as: lead-time reduction, weight cut, improved manufacturability, enhanced operation, increased safety,

etc. [1].

Literature on this subject treats as different the terms “Value Engineering” (VE) and “Value Analysis” (VA), depending if the Value Methodology is being applied to products in the design phase (VE), or to products which are already in the market with the objective of reducing costs or revitalize its commercial life (VA) [2][3]. By its side, the term “Value Management” applies to an enterprise management style in which the Value Methodology extends itself across the whole structure of the firm, looking to facilitate innovation into it with the objective of improving the global performance of the organization [4].

Even if VM kept always its fundamentally defining features since its emergence in the USA till now, its introduction into other countries, other activities and economic sectors gave way to different versions of itself, each having specific connotations. In this way, while the definition for the “Value” concept made by the Society of American Value Engineers (SAVE), the Society of Japanese Value Engineering (SJVE) and the U.K. Institute of Value Management (IVM) in their respective VM procedure guides is rigidly established as the minimum price to be paid to satisfy the function, the S.M.A.R.T. (Specific, Measurable, Attainable, Results Focused, Timed) variant of VM defines it as a compromise solution between quality and cost [5].

Companies and government agencies that decided to bank on this methodology obtained substantial and undeniable benefits from setting up VM projects, showing high values of return of investment (ROI). That led to the U.S. government asking since 1993 –it was already being encouraged since 1988- for a compulsory use by every department and federal agency of VE as a management tool, when applicable, in order to cut purchasing and maintenance costs. Also, VE has been adopted strongly in the fields of building and construction by developed countries such as Japan, United Kingdom and Australia [6], and more moderately by others such as France and Germany. Since the 1990's a trend towards stagnation in the use of VM could be noticed, considering it as an out fashioned method, possibly due to its heavy support on group dynamic techniques, to the exigency of a multidisciplinary approach -facing a reality of departmental information silos-, and to a frequent necessity of specialized external consulting along the development of the so-called VM “Job Plan” [1].

However, in the last decade an increase in academic literature about VM is shown, remarkably in developing countries such as the Arabic countries [7], India [8], Malaysia [9] and China [10]. An interest is shown also on updating the methodology, introducing the use of communication and information technology and bringing VM application in new fields.

2.1 Value methodology in Spain

In Spain, since the mid 1980's some regional organizations such as Instituto Andaluz de Tecnología (IAT) [11] and Instituto Tecnológico de Galicia (ITG) [12] work on the promotion and spreading of VM, the training of Value professionals, and the development of training resources and materials. Moreover, financially supported by governmental programs for promoting innovation specifically oriented to small and medium enterprises (SMEs) such as INNOVALOR, GESVALOR, CONVALOR, etc., those organizations collaborated with companies in setting up notably successful pilot VM experiences.

In 2004, IAT and ITG, together with other Spanish

regional associations and foundations, established the Centro para la Gestión del Valor (CGV) [13] as an organization for the certification of VM professionals.

Those experiences resulted in the development of their own variant of the Value Methodology for its application in SMEs, which has already been described by the authors in former INGEGRAF conference editions [14]. This variant has been eventually formalized in the form of several official Spanish standards published by Asociación Española de Normalización y Certificación (AENOR) [15][16].

The VM fundamental concepts that are defined in these standards, which match exactly with those included in the EN 12973 European standard, are the following [15]:

- **Value:** Ratio between the degree of satisfaction of needs and the amount of resources which are necessary to satisfy those needs (eq. 1).

$$Value \alpha \frac{Satisfaction\ of\ Needs}{Use\ of\ Resources} \quad (2)$$

The α symbol means the ratio is only a representation or equilibrium between both factors. Also, Value is not an absolute term, but it is relative to the circumstances of the Value study.

- **Need:** What is needed or wanted by the user when he's buying the product or service.
- **Functions:** The effects from the product or from its components.
- **Resources:** All that is required to satisfy the needs has to be included.
- **Value Comparison:** Once the degree of satisfaction of needs and the use of resources have been assessed, either in absolute or relative terms, its ratio gives a measure of value that may be used to compare and rank the different alternatives.

2.2 Stages in the VA-VE job plan

The mentioned VM methodology is strongly supported on the functional analysis and breakdown of the product/process to be studied, on a structured way, using the FAST (Function Analysis Systems Technique) diagram. This diagram is a basic element in studying the importance of the different functions, either related to the user or related to the product/service itself, and the existing relationships among them [17][18].

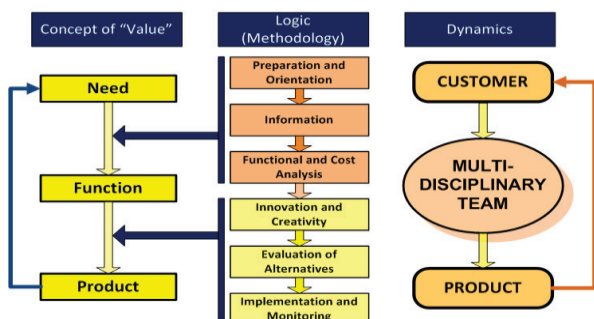


Fig. 1 Stages in the VA-VE job plan.

A specific multidisciplinary work team will have to be formed, with a recommended number of members between five and eight people from the company. Together, if necessary, with an external consultant, the team will go through the six basic stages which comprise the VA-VE job plan, as shown in fig. 1.

Along each from those successive stages, an information dossier will be assembled to include work data, analysis processes and results, and the conclusions reached. Standard forms will be used for data cards, matrices and tables [16], that will be incorporated to the final dossier of the Value study, in order to guarantee the traceability of the procedures carried out along its development.

The summarized contents of the stages in the VA-VE job plan [16] are as follows:

- **Stage I: Preparation and orientation:** Definition of the project details; selection of the members of the Value work team; job planning and scheduling.
- **Stage II: Information:** Compiling of internal and external data for the study; selection of data sources and customers; identification and weighting of needs and their associated costs.
- **Stage III: Functional and cost analysis:** Analysis of functions, their cost and contribution to the satisfaction of the customer's needs; calculation and interpretation of Value indices; determination of the associated equilibriums.
- **Stage IV: Innovation and creativity:** Generating ideas that increase the Value of the product/service; Grouping of alternatives.
- **Stage V: Evaluation of alternatives:** Evaluating alternatives by means of multi-criteria decision analysis; prioritization of alternatives according to their calculated Value indices.
- **Stage VI: Implementation and monitoring:** Planning for the implementation; monitoring of the implementation process.

Those consecutive basic stages admit to be broken out with more detail when scheduling the tasks to be carried out. According to their contents, some of these tasks are to be performed simultaneously and/or consecutively, either by the whole team or by selected sub-teams or individuals from the team.

The above mentioned six basic stages are to be considered in order to study the incorporation of the VA-VE methodology to a PLM system, regarding them as a coherent and basic work structure, backed up by recognized European and Spanish standards. This Value work structure is also easily expandable or broken down if it were necessary.

2.3 Integration of the Value Methodology

Along the literature found on VM, several proposals of integration with other recognized techniques and tools for innovation and quality improvement were found, either based on coincidence of procedures or based on their objectives. A non-exhaustive list of some of those proposals, which have been considered as relevant because of their interest in the proposed subject, is shown hereafter:

- Knowledge management (KM): stages II-V [8][19][20].
- Quality Function Deployment (QFD): stages II-V [21][22][23].
- Lean Manufacturing: stages III-V [24][25][26].
- Failure Modes and Effects Analysis (FMEA): stages IV, V [27].
- Target costing: stages III-V [28][29][30].
- Reverse Engineering/Benchmarking: stages IV, V [31].
- Information systems support: all stages [32].
- Concurrent Engineering (CE): all stages [33].

- TRIZ: stages IV, V [34][35][36].
- Kano method: stages II-V [28].

Nowadays these techniques mentioned are commonly accepted and widely used by companies, and even sometimes in certain sectors firms are forced by their customers to use them. Usually, world-class companies use on a constant basis many or all of those techniques into their internal procedures.

Many of the proposals of integration mentioned above open a wide range of possibilities to obtain synergies from using those techniques besides VM. Also, many of them have been already adapted by software developers to be integrated into commercial PLM systems. Thus, the incorporation of the VA-VE methodology into those systems would allow improving their competitive approach, and at the same time it would open new paths for innovation inside the enterprise.

3 Product Lifecycle Management and PLM systems

More than a technique, Product Lifecycle Management (PLM) for manufacturing companies is actually a philosophy of work and an enterprise management strategy. The basics of the PLM approach are the storage and the management of all the product data along its lifecycle, from the initial concepts until its retirement, with the aim of optimizing its costs, its quality and its time-to-market.

This concept appeared in the mid 1980's as a consequence of the evolution of the technology and of the market. Products become more complex every day: complex to design, complex to manufacture and complex to maintain: mechanics, electronics, world markets, global design and manufacturing, regulatory compliance, life cycle profitability, etc. adds to this complexity. The number of product configuration increases, design cycles shrink, and data is subject to a constant process of change along the design and manufacturing phases.

Tendency for manufacturing companies in the last two decades has been the increasing complexity both of the product on its own and of its manufacturing processes. Developing and supplying profitable products to the market has become for these firms an every time bigger challenge.

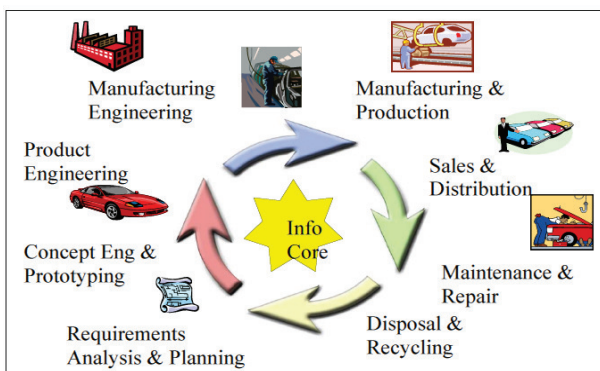


Fig. 2 The PLM model [37].

The term Product Lifecycle Management (PLM) has become very popular in the last decade, despite of having been subjected to different definitions according to its source: the potential user industry, PLM software companies or scientific literature. A reference in the PLM field, the consulting firm CIMdata [38] quotes Grieves [37] (fig. 2): "PLM is a strategic business approach that

applies a consistent set of business solutions in support of the collaborative creation, management, dissemination, and use of product definition information across the extended enterprise from concept to end of life, integrating people, processes, business systems, and information".

There is a certain consensus about the origins of PLM being in the Product Data Management (PDM) software, born in the mid 1980's with the aim of storing, relating and controlling changes in product data, mainly data about product design and manufacturing processes.

Unlike PDM, PLM isn't just "buy, install and use", but it is rather a strategy that the company has to develop in order to generate, manage, distribute and use the product data, by means of the collaboration of all the firm's departments, in order to improve its market position, to avoid inefficiencies and to ensure its aims are reached.

PLM technology provides the tools to centralize product data, standardize business processes, and speed up the data exchange among the product distributed design teams. PLM helps the manufacturing companies to face the market pressure and to keep its competitive advantage by means of shortening product development cycles, improving product quality and speeding up the time-to-market.

In this way, PLM constitutes an integral environment for sharing information and for ensuring that all the stakeholders have the right access level to accurate and actualized data. PLM software is programmed to manage product data across its whole life cycle, from concept to design, to manufacturing, to maintenance, and to retirement.

It is necessary to stress that PLM is not that much of a technology or a computer system than an enterprise strategy to take advantage of such technology, in which processes are at least as important as the data being managed. PLM systems must be able to integrate the different information islands that exist inside the company, caused by sequential and fragmentary processes. These processes are often based on unconnected information, require a lot of human intervention, cause slow product launchings, misuse resources that are scarce, have poor visibility, and are difficult to manage and monitor.

The first companies to apply PLM were, in the 1980's, the discrete products manufacturers, particularly the automotive and aeronautics firms, in which the development cycles and life cycles of products are very wide, and a big amount of agents take part in them all along.

3.1 PLM systems in the enterprise

PLM expands along the following dimensions [39]:



Fig. 3 Dimensions of PLM [39].

- People: Product development and product innovation expand across the firm towards more people from inside and outside the business.
- Product: A "product" consists of more than R&D or

engineering specifications, with a richer vision that includes commercial considerations in order to deal with the “product as a whole”. In addition, technical vision is growing, expanding on its scope to include mechanics, electronics and implanted software designs.

- **Lifecycle:** Processes related to the product are being integrated by means of functions formerly disperse, providing integral access to Supplies, Manufacturing, Service and other departments that previously did not have access to this kind of product data.
- **Process:** PLM processes are being expanded and integrated along these three directions above. It is this process extension and process integration what really provides the value of PLM, as without the processes the other three dimensions are just not possible.

Within an integral approach of the enterprise (e-enterprise), PLM systems are listed in the enterprise information systems category, together with the Enterprise Resource Planning (ERP) systems, the Customer Relationship Management (CRM) systems and the Supply Chain Management (SCM) systems (fig. 4). Some sources include also the Manufacturing Execution Systems (MES).

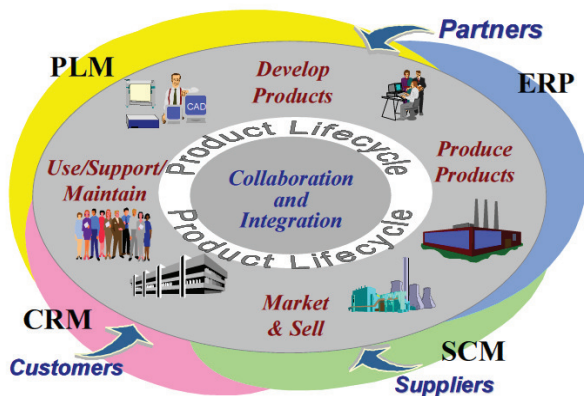


Fig. 4 Relationships among enterprise information systems according to CIMdata [38].

The scope and approaches of these other four systems are substantially different to those formerly mentioned for PLM:

- **Enterprise Resource Planning (ERP):** Integrates the internal and external management information across the whole organization (accounting/finances, storage, manufacturing, sales, service, etc.). ERP does that using a specific software system working on a common database set, with the aim of facilitating the information flow across all the business functions in the firm.
- **Customer Relationship Management (CRM):** Manages the interaction of the organization with customers, users and sales agents, using technological solutions to organize, automate and synchronize the business processes, mainly commercial but also marketing activities. CRM’s objective is to find, attract and gain new customers, take care of and retain those the company already have, get back former customers on the client list, and reduce marketing and client service costs.
- **Supply Chain Management (SCM):** Manages the interconnected business net implicated in the

ultimate supply of a product or service demanded by final customers. SCM covers all movement and storage of raw materials, on-going inventory, and finished product from point of origin to point of consumption (supply chain), aiming at creating net value for the company building a competitive logistic structure, synchronizing supply and demand and measuring globally the firm’s performance.

- **Manufacturing Execution System (MES):** Sometimes also called Manufacturing Enterprise System, it manages the manufacturing operations in the factories. MES include activities such as: product definitions management, resources management, production processes scheduling, launching of manufacturing orders, execution of manufacturing orders, production data collection, manufacturing performance analysis, manufacturing process monitoring, etc.

Similarity between PLM and ERP information systems as data storage systems is only apparent, as ERP is “data centric” and works fundamentally with financial data, human resources data, material resources data, etc. –“flat data”-. Meanwhile, PLM is “workflow-centric” and the data it handles are more complex –“smart objects”- where information reflects design data, specifications, configurations, etc.

Anyway, PLM implementation in its integral concept requires of the integration with those information systems already mentioned. Data must flow among them inside the “360° PLM concept” of the company to guarantee all the profits from such integration are obtained.

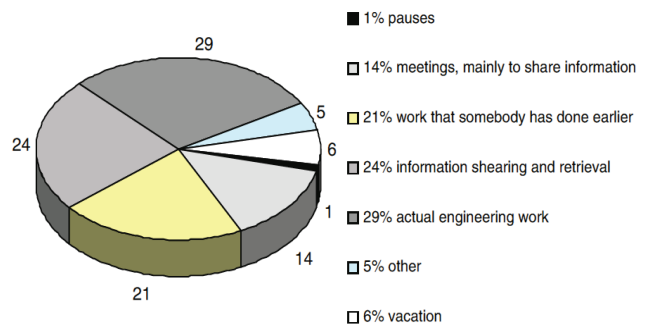


Fig. 5 The engineers’ use of time [40].

From the design processes point of view, the PLM system contributes radically to raise productivity, by making available to the engineer all the information the company has in relation with the product or products in each of the life cycle stages, actualized and in real time. Moreover, in collaborative engineering environments this system guarantees that all team members work on an already validated version of the design, giving warnings about possible inconsistencies. At the same time, PLM systems allow the access to product data to be filtered according to the system user’s access type and/or access level.

This is a way to try to get rid to a great extent of the time waste inherent to the practice of traditional design activities (fig. 5). In this aspect, by cutting unnecessary costs PLM systems allow to take the “lean” strategy to each of the company’s departments.

3.2 Structure of a PLM system

In the same way that the definition of PLM varies according to its source, the same happens with respect to the structure of the PLM systems (fig. 6). Three main

approaches exist among the developers of these software systems:

- The **“from ERP” approach**: Considers the PLM system as an additional module to be added to, and integrated into, the ERP system of the developer, with direct access to its databases. This is the case of PLM systems from SAP® and ORACLE®. Access to product data must be done either by using legacy software outside the PLM system or by using visualizing tools, but on the other hand ERP can “see” directly product data.
- The **“from CAD” approach**: The PLM system is built around the developer’s CAD/PDM system, integrating their databases into PLM’s database. Thus, the access to product data can be done from the PLM system itself, as it incorporates CAD/PDM functionalities. However, access to data from/to the ERP system would have to be done through some interconnecting “middleware” software. This is the case with DASSAULT SYSTEMES PLM solutions.
- The **independent approach**: Typical of PLM software developers that define their product as an unattached business software solution, with capabilities for linking to other developers’ ERP and CAD/PDM software, access to product data is done using specific software or visualization tools. This is the case with SIEMENS TEAMCENTER®.

- Avoidance of information loss during updating.
- Backup management.
- History/System log.
- File vault (electronic vault).

Even if there are specific PLM solutions oriented to specific sectors available in the market -textile, shoemaking, shipbuilding, etc.-, the most used PLM systems offer implantations that can be adapted to a wide range of enterprise sectors. This flexibility is usually reached using a modular approach, with developers that sometimes even offer their customers the possibility of buying additional modules on-line in real time depending on the user’s needs (Software on Demand, SoD). In other cases the developer offers to host the PLM system in his servers, with the customers acceding via Web, paying a service fee according to their actual use of the resources made available to them (Software as a Service, SaaS).

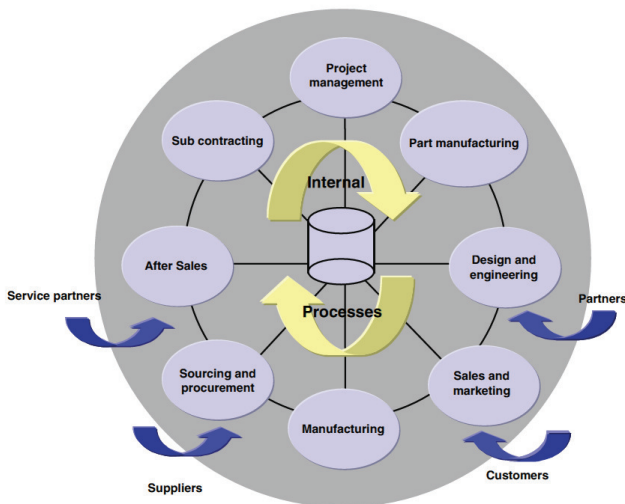


Fig. 6 Structure of a PLM system [40].

From the PLM system architecture point of view, three basic components exist: the **Data Vault** that stores all data, the **Metadata Base** that guarantees data integrity, and the **Application** that performs the management functions of the other two, and interacts with the user.

With regard to the functions a PLM system must perform (fig. 7), in spite of the disparity of versions the following require to be mentioned [40]:

- Item management (information, status and processes).
- Product structure management and maintenance.
- User privilege management.
- Maintenance of the state or status of documents and items.
- Information retrieval.
- Change management.
- Configuration management.
- Management of tasks (messages), also known as workflow management.
- File/document management.

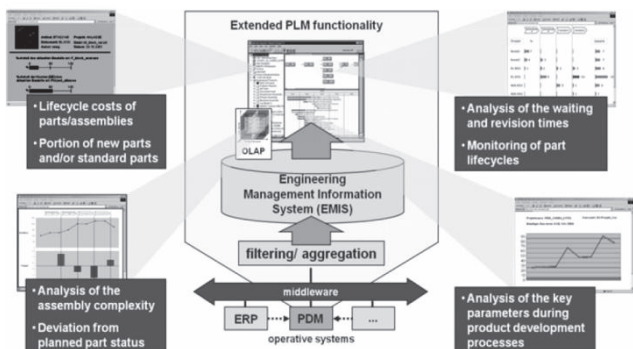


Fig. 7 Functions in a PLM system [41].

Furthermore, it is extremely relevant the possibility of customizing the PLM system in order to fine-tune it to the actual enterprise’s needs, processes and internal functions. This is usually done using standard programming languages by means of Application Programming Interfaces (APIs), defined as “a particular set of rules and specifications that a software program can follow to access and make use of the services and resources provided by another particular software program that implements that API, serving as an interface between different software programs and facilitating their interaction”. Thus, APIs allow both the PLM systems to be linked to other enterprise information systems that no translator is available for, and to develop new functional modules adapted to the particular needs of the continuously changing businesses processes of the user firm.

3.3 Research trends on PLM systems

The consulted academic and commercial literature on PLM systems is quite diverse, and some of it deals with the following research trends, that are seen as of interest for the objectives of this paper [42]:

- Virtual Collaborative Engineering [43], allows design teams from different partner companies to collaborate along the Virtual Supply Chain inside the extended enterprise model, keeping the right conditions of security and confidentiality of data [44][45].
- PLM integration with other enterprise information systems [46][47][48][49].
- Model-based definition (MBD), incorporation of design knowledge to CAD models and its traceability [50][51].
- Multi-module products, multi-lifecycle management and holistic PLM [52].

- Ontology-based data integration [53].
- PLM 2.0, SOA, and cloud computing [54][55][56].
- Closed-Loop PLM and Product Embedded Information Devices (PEID) [57][58].
- Digital/Virtual Manufacturing [59][60].

4 Integrating VM into PLM systems

To carry out the design of the proposal for a methodology to integrate VM on PLM systems, a generic process-oriented [61] PLM system will be considered in order to evaluate the feasibility of incorporating Value Analysis (VA)¹ into it, following the job plan and the procedures and stages established by the mentioned literature [15][16].

Thus, the minimum requirements to be satisfied in order to carry out successfully that integration will be studied, in such a way that it makes possible to fulfil correctly each of the VA stages shown in section 2.2. Those requirements will be classified according to the two following categories:

- **Data:** Data and other information necessary to deal with and fulfil each of the stages of the Value methodology. It can be already available in the PLM system itself or not, in which case it will have to be obtained from other sources.
- **Functions:** Processes that are necessary in order to carry out properly each of the mentioned VA stages, which can be implemented on the PLM system itself or by using alternative approaches -"middleware", etc.- if its results are more efficient. Also, some of the functions will span and will have to be made available across all stages of the VM study.

It will be also necessary to mention the possible sources where to obtain the considered data, both if it is internal and if it is external to the company. In case the data is external, the appropriate enterprise information system to be used in order to obtain such data will be mentioned.

4.1 Resources necessary for the VA stages

The necessity of those above mentioned two classes of minimum resources will be studied and evaluated stage by stage, according to the objectives of each stage. This study will be carried out using a generic approach, avoiding focusing on a particular kind of industry or on a certain sector. It will use an approach of minimum requirements, and it doesn't try to be exhaustive because of the wide variability of circumstances at companies.

- 1) **Stage I: Preparation and orientation.** The project definition begins with the selection of the product to be studied -Value Object-, often after performing an ABC analysis using for instance internal and external incident reports: quality issues, costs issues, sales issues, etc.

	Item	Source
Data	Enterprise Strategic Plan	SEMS ²
	Market positioning	CRM
	Quality reports	QMS ³ (ERP)
	Financial data	ERP
	Sales data	ERP

¹ The study of incorporating Value Engineering (VE) would involve only minor changes with respect to VA, which would not void this analysis: a little less complexity in the initial stages, more indetermination in the costs calculations, etc.

² Strategic Enterprise Management System

³ Quality Management System

	Regulatory compliance data Human and material resources Internal and external suggestions Maintenance reports Sick leave reports Fines/disciplinary measures Legal claims Relevant press articles	CRM / PLM ERP QMS (ERP) ERP ERP QMS (ERP) QMS (ERP) QMS (ERP)
Functions	Support to group dynamics problem-solving work. Support to procedure documentation. Statistical treatment of data. Multi-criteria analysis. Project planning. Project scheduling and monitoring. Assignment of tasks to people. Cost estimation.	

Tab. 1 Resources for Stage I.

- 2) **Stage II: Information.** All relevant data and information regarding the Value Object -internal or external to the company, historical or current, quantitative or qualitative- will be compiled with traceability criteria. Special attention will be given to the most qualified customers and information sources. All the customer needs regarding the Value Object will be identified and weighted, as will be all costs associated to it.

	Item	Source
Data	Technical data	PLM
	Technological information	SVS ⁴ / PLM
	Costs data	ERP
	Benchmarking reports	PLM
	Industrial property	PLM / SVS
	Laws and regulations	QMS (ERP)
	Market information	CRM / SCM
	Budget information	ERP
	Information from customers	CRM / SCM
Functions	Support to group dynamics problem-solving work. Support to procedure documentation. Statistical treatment of data. Product data management. Project scheduling and monitoring.	

Tab. 2 Resources for Stage II.

- 3) **Stage III: Functional and cost analysis.** The product will have to be broken down in its necessary functions, classifying them and establishing the target levels an acceptable variation ranges. For each of the functions its contribution to the whole product value for the customer will be calculated, as will be its contribution to the product cost.

	Item	Source
Data	User needs data	Stage II / QFD ⁵
	Functions data	Stage II / QFD
	Costs data	Stage II
	Industrial property	Stage II
	Laws and regulations	Stage II
Functions	Support to group dynamics problem-solving work. Support to procedure documentation. Product data management. Function diagrams (FAST) construction. Required product functional specification lists construction. Safety diagrams (FMEA) construction. Relations diagrams construction. Project scheduling and monitoring.	

Tab. 3 Resources for Stage III.

⁴ Strategic Vigilance System

⁵ Quality Function Deployment system

- 4) **Stage IV: Innovation and creativity.** Ideas to increase the value of the product will be generated and sorted, assembling them in the form of alternative proposals.

	Item	Source
Data	Function diagrams (FAST) Required product functional specification list Level of importance of functions Characterization of functions Cost of functions Value indices of functions VA matrices Objective cost of functions Undesired functions	Stage III
Functions	Support to group dynamics problem-solving work. Support to various creativity techniques. Support to procedure documentation. Product data management. Cost estimation. Project scheduling and monitoring.	

Tab. 4 Resources for Stage IV.

- 5) **Stage V: Evaluation of alternatives.** The alternatives generated in Stage IV will be evaluated using multi-criteria analysis, ranking them according to their value.

	Item	Source
Data	Design alternatives data Current product data Design alternatives value indices Current product value indices Industrial property Laws and regulations Human and material resources Financial data	Stage IV Stage II Stage IV Stage IV Stage IV Stage II Stage II Stage I
Functions	Support to group dynamics problem-solving work. Support to various creativity techniques. Multi-criteria analysis. Enterprise strategic and financial analysis. Support to procedure documentation. Product data management. Project planning. Project scheduling and monitoring.	

Tab. 5 Resources for Stage V.

- 6) **Stage VI: Implementation and monitoring.** The implementation of the proposed alternative will be planned, scheduled and monitored.

	Item	Source
Data	Full documentation about the selected alternative. Enterprise Strategic Plan Human and material resources	Stage V Stage I Stage I
Functions	Support to group dynamics problem-solving work. Project planning. Issue information to all the company staff. Support to procedure documentation. Product data management. Project scheduling and monitoring.	

Tab. 6 Resources for Stage VI.

Those requirements above mentioned must allow a secure, fully traceable, auditable and verifiable storage of process data, subject to criteria of selective access restriction to all agents according to different authorization levels.

Also, the AV module itself will have to record accurately and with detail the use of all resources along each VA study -material, human, data access, use of IT resources, etc.-, in such a way that its final cost could be

determined and its ROI could be calculated.

4.2 Implementing the basic VA methodology

A quick analysis performed on the list of resources required for the VA implementation, as determined on section 4.1 above, shows clearly that their availability doesn't get into contradiction in any way with the PLM intrinsic strategy. It doesn't interfere either with the strategic or operative objectives of the enterprise, but it can clearly be used to help reaching them more efficiently.

The necessary functions to be implemented in order to attend the six stages of the VA study are basic in content and hardly complex, even if they must be programmed to manage a specific data type in each case, allowing to be used on a collaborative work environment.

In order to keep the coherence of the integration proposal into the PLM data structure and functions, it would be advisable to pack the set of VA functions into a "Module for VA studies" included in the PLM system software. This module could then be installed in the workstations of the potential users during the installation of such software, and the access could be limited dynamically to the members of the different VA work groups.

On their part, most of the necessary data for the VA process are already easily available inside PLM itself and the other corporative information systems. Accessing to them would only require setting up the right data interfaces, which should allow such access from the VA studies module according to the user's authorization level.

Regarding the information generated along the Value study, its strong links with the product subject to VA makes advisable to store it into the PDM database of the PLM system. The connections of the final product data with the initial data used in stages I, II and III, and the links with the information generated in stages IV, V and VI should be also stored on that database.

The dossier should include a final report containing all data relative to the Value study: name, position and contact of participants, duration in man-hours, total and broken down costs, and calculated value of ROI.

4.3 An advanced implementation of VA

Along the former sections of this paper, the feasibility of a basic implementation of the VA methodology in PLM systems has been studied and demonstrated, according to the concepts and job plan defined in the UNE standards [3][4][15][16].

Not having any doubt about the advantages which this basic integration of VA methodology would provide to enterprise innovation, its true performance potential would be radically increased by incorporating to the mentioned proposal a number of advanced functionalities that are already available in some commercial PLM systems, as follows:

- **Remote collaboration (VCE):** Makes possible for the Value group activities along the six VA stages to be carried out in "virtual meetings", either inside the PLM 2.0 system itself or by means of Web 2.0 specialized corporation platforms. Besides that, VCE creates new collaboration possibilities across the extended enterprise, allowing professionals from other partner companies in the product's Virtual Supply Chain to participate in the Value team, always keeping the necessary security and confidentiality safeguards.
- **Virtual Reality (VR):** Allows a better understanding of the product's geometry, features and operation along each of the VA stages.

- **Digital Manufacturing (DM):** Makes possible to improve the resources and costs estimation and to verify the feasibility of manufacturing processes for the different alternatives to be considered in stages IV and V.
- **Model-based definition (MBD):** By establishing a model definition of the product in terms of functions, it is very helpful along stages III and IV.
- **Knowledge management (KM):** Makes available a number of already validated design alternatives, and allows evaluating others against the requirements, for the different product functions in stages IV and V.
- **Quality Function Deployment (QFD):** Its initial phases can overlap with the first VA stages, as both of them use product information coming from customers, and define the product by means of a functional approach, providing a different viewpoint on the degree of satisfaction of the customer requirements.
- **Kano Method:** Provides relevant information about how the product functions satisfy the user needs, in stages III to V.
- **TRIZ:** Complements the creative approach in stage IV, contributing by means of systematic processes to identify inventive solutions for implementing the product functions.

This list is not intended to be exhaustive, but only to describe those functionalities which have a higher potential of contribution to increase the profitability for companies of the use of the Value Methodology integrated into PLM systems.

5 Conclusion

Value Methodology has proved along a history of more than 60 years to be a tool capable of improving the competitive situation of companies which have adopted it as an innovation technique.

PLM systems are increasingly present in industry, as they are a very powerful strategic tool that allows the companies to integrate in an only repository all information about the life cycle of their products. Such data is kept actualized and is made available to all departments in the company, breaking the classical departmental approach of "information silos".

The study carried out in this paper shows the possibility of integrating into a PLM system the necessary tools to perform at a basic level the six typical stages of the Value Methodology when applied to product innovation. Also, a proposal is suggested to make use of a number of advanced functionalities, already available in some commercial PLM 2.0 systems, which would allow VM to increase its potential for enterprise innovation with a reduced cost.

The use of PLM 2.0 virtual collaborative engineering (VCE), together with Web 2.0 tools, makes possible for the Value teams to carry out the different activities from the VM stages without having to meet physically in the same room, cutting displacement costs and times.

In the same way, it could be made the most of the potential for collaboration, inside the product virtual supply chain of the extended enterprise, by allowing the professionals from partner firms to participate in the Value team. With this approach the VM processes could reach new conceptual and development levels in product and process innovation, creating real value for all the companies involved in the collective process of "collaborative Value Methodology".

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