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IDENTIFICATION OF THE CRITICAL PHASES AND DECISION-MAKING CRITERIA FOR THE SHUTDOWN OF CHEMICAL PROCESSING PLANTS CASE STUDIES: SOUTH AMERICA, SPAIN AND PORTUGAL

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Normally, chemical processing plants work at 95% of their capacity productive. In order to avoid delays or a reduction in their capacity, they develop a maintenance and replacement strategic plan of equipment, carried out by plant shutdown projects. The success of these will depend on the correct management and the effectiveness of the decisions taken by the responsible team. This paper aims to describe the decision making process, to identify the most critical phases in this projects, in addition to establishing the required parameters. This study has been conducted in 53 chemical processing enterprises with 78 experts in this type of project. Results allow to concluded that the most critical phases are the early stages definition and planning. The sense of a lack of information expressed by experts confirm that the present management requires a conceptual base which integrates the different and disperse data available in an organised manner.

Keywords: Plant shutdown; Decision making; Critical phases; Main criteria; Project management.

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1. INTRODUCTION

In order to satisfy demand, the chemical processing industry aims to ensure that the productive capacity of its plants is not reduced. This is particularly important when demand is high or the petrol supply is low. A diminishing in the productive capacity of the plants, even if very small (1-2%), has a negative effect on the achievement of the benefits expected by the organisation, the strategic plan and the fulfilment of company objectives. This decline can be due to unexpected equipment failure which necessitates the cease of operations and the emergency procedure of an unplanned plant shutdown. In such cases, the daily cost due to the cease of operations can oscillate between $320,000 and $754,000 (depending on installation size). For this reason, in order to ensure the operational continuity of the plant, a Shutdown Strategic Plan is developed (with a likelihood of 8 to 10 years) or the SPM (strategic plan for the maintenance and replacement of equipment) is introduced. This plan is carried out by means of plant shutdown projects [1-2], which offer specific allocated time slots for carrying out the maintenance and replacement of working equipment, which can not be carried out during the normal production period [3-4]. The length of a plant shutdown is usually 30 days, although this period depends on the established shutdown range (defined by the type of work to be carried out) and the type of industry. The average estimated budget is between 8 to 10 million dollars [1].

The SPM is the referential framework employed by the team responsible for the shutdown process to evaluate the requirements of the plant and to define the risks, challenges, opportunities and actions to be carried out [5]. This team must be a multi-disciplinary team, integrated by representatives from all departments: operations, maintenance, processes, plant engineering, quality, projects, finance, human resources, materials, safety and hygiene and environment. This stipulation will offer a global perspective and the efficient integration of the project in order to be able to achieve the best possible results for the shutdown [6]. This team must balance the extent of the plant shutdown (use of the shutdown time to carry out the required work) with the requirements and priorities of the enterprise without affecting the mechanical integrity or the operational reliability of the equipment.

These projects are implemented in four phases: integration of the strategy, description of the work objectives, execution and closure [7-8-9-10]. Historically speaking, much emphasis has been placed on the execution phase of plant shutdowns. However, this approach led to few satisfactory results [1]. Leading corporations in this area dedicate 65% of the total effort to the planning of the shutdown, 33% to the execution and 2% to the collection and documentation of the lessons learnt [7]. The process of plant shutdown management, divided into the four previously mentioned phases, favours a systematic approach which leads to consistent practices and results. However, most project work teams are unaware of this [2]. A brief description of each phase will now be outlined.

Phase I "Integration of the strategy", the main objectives of which are the formulation of the performance criteria, the definition of key objectives and shutdown indicators, identification of critical aspects and potential risks, in addition to the

definition of successful initiatives to maximize the performance: to define the criteria needed to define and optimise the extent, to define the direction to be followed in order to develop the contracting strategy, the organisational structure, the matrix of responsibility, the master schedule and the work programme [11-12-13]. The process of defining the extent of the plant shutdown project starts with the generation of work orders (by the enterprise departments) from the moment in which the previous phase finishes (phase IV, Closure) [14].

The objective of Phase II, "Description of the Work Objectives" is the logistic management of all resources associated with the shutdown project, identifying, planning, programming, directing and executing all activities which must be carried out from the previous works to the closure of the shutdown [15]. It must be pointed out that this phase uses WBS (Work Breakdown Structure) to itemise the project in such a way that it facilitates the evaluation of shutdown preparation [16]. As a prior step to the execution of the shutdown, some pre-shutdown work is conducted. This accounts for 15% to 20% of the total extent of the shutdown (depending on the magnitude and complexity of the work). This work can begin 12 or 14 months in advance of the date set for the plant shutdown [17-18].

Phase III, "Execution of the shutdown", is the main part of the project works, in which the working conditions are the central elements for an out of order installation, and the conditionings for their programming are reduced to the allocated dates of consignation of the installation stated by production. Here, it is very important to have an effectiveness control of the aspects: cost, time and quality in order to manage the changes conditions.

Finally, in phase IV, "Closure", all the activities to return the plant to normal operation are concentrated (that is, the culmination of the isolation and painting, execution of the list of unresolved activities, demobilisation and contractors, cleaning of the area and the closure of contracts). Finally, the work lists and the situation and history of the equipment for the next shutdown are prepared, as well as the documentation of the lessons regarding feedback and the performance evaluation of the work team, contractors and suppliers [19-20].

Each of these phases involves some critical decision making points and different criteria, which are considered in the decision making process, such as: the prioritization of the planned activities, the technical area, safety, environment, legal aspects, quality, economic aspects, human resources, terms, selection and the contracting of stakeholders, etc. Decision-making is not a centralized activity, but rather a distributed effort of a multitude of agents [21].

In the plant shutdown processes, as in any other project problem, there will always be the possibility of finding a set of potential solutions, which may help ensure a satisfactory outcome. Virtually any solution, difficult as it may appear, can be reached if a sufficient amount of funds and the necessary time are available. However, this condition very rarely arises. Therefore, in order to choose an alternative which optimises the "cost/benefit" relationship, the elaboration of a technical and economic feasibility study for each alternative is required, in the function of the particular conditions of this project. For this, in order to objectively evaluate each suggested alternative, it is necessary to have available both integrated and structured information which is relevant and which can facilitate the understanding of the problem [22-23-24].

The correct management of the decision making process and the quality with which the decisions are made are central to achieving success in plant shutdown projects. The adoption of good decisions is a very complex practice, which is crucial to the organization of project management [25], since it permits a move towards the stated objectives through the selection of the most suitable alternatives [26]. The size and the increasing complexity of the problems to be solved, an increasingly competitive environment and the legislative pressure with regards to safety and quality justify the particular attention which must be paid to the decision making process in projects [27]. However, in most cases, due to the indecisive nature of the objective factors and the poor management of intangible assets which affect the decision, the decision making is mainly carried out by way of a subjective process. The set of subjective factors which play a role in this are, to name a few: the evaluation of the circumstances in which the problem is presented, the ensuing consequences learnt from other similar occasions, and the results obtained when this type of decision was made in the past. These factors consolidate the level of tacit knowledge available to the person deciding upon the stated problem. This knowledge has been acquired in the function of previous experiences, and is not always sufficient for an accurate decision making process. Furthermore, there exists another series of factors inherent in the entire decision making process, which determine the manner of acting or deciding, these are: the extent of problem structuring, the inherent risk to the decision, the degree of uncertainty or certainty and the conflict or opposition generated by it [15-20].

This paper presents the study carried out for the analysis and description of the decision making process in plant shutdown processes in chemical processing industries in Spain, Portugal and South America. The aim of this research is to identify the most critical phases and points in addition to the identification of the criteria to be taken into consideration in the decision making process for such projects.

2. MATERIAL AND METHODS

The research was carried out using a questionnaire consisting of 10 questions, directed at the analysis of the decision making process in chemical plant shutdown projects, taking into consideration the 4 phases (see Fig. 1). These questions are a response to the concern shown by different groups of experts during international conferences related to engineering and

maintenance, in which questions related to this matter have been raised. Basically, the interest is focused upon three areas: the identification of the critical decision points, a description of the decision making process in this type of project and the need to have a method or tool to assist the decision making.

78 experts from 53 enterprises within the energy sector in Spain, Portugal and South America with an average length of work experience ranging between 15 to 20 years, in the planning, management and execution of this type of project, participated in the survey. Among the experts, 34 worked in the Petrochemical sector, 12 in the Refining sector and 32 in the Gas sector.

The questions posed in the questionnaire focused on the key areas mentioned above. As such, the survey investigates the identification of the critical decision making points and critical phases of the plant shutdown projects (questions 1, 2, 10), followed by questions concerning the identification of the type of model used by the industry in the decision making process (questions 3, 4, 5, 6 and 7). Finally, the degree of knowledge and frequency of use of specific techniques to help in multicriteria decision making and the need to have a mathematics-based tool to assist the decision making is examined (questions 8 and 9).

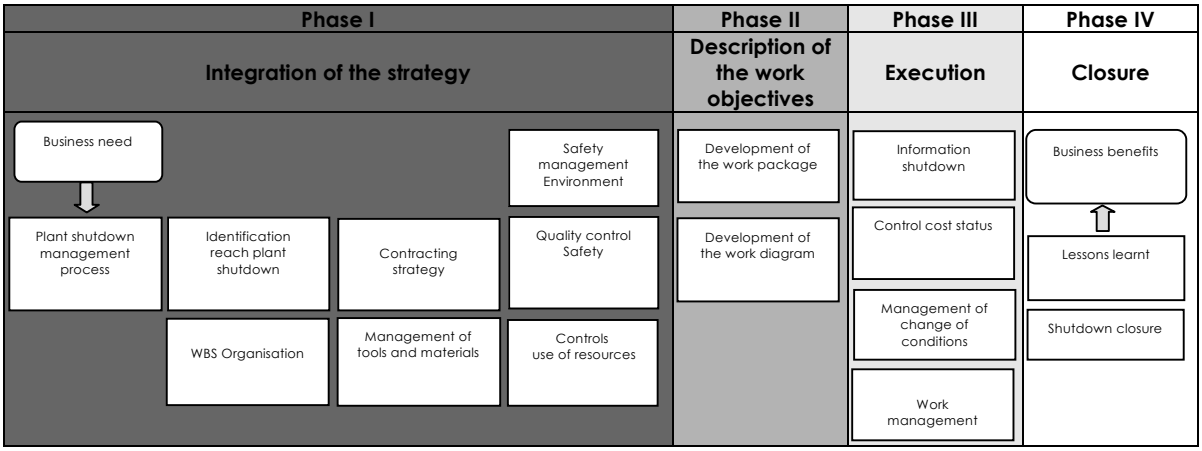

Figure 1. Phases of the Plant Shutdown Process [7]

Basically, the survey was designed using open questions, with the exception of questions 6, 8 and 9, which were closed questions, and questions 2 and 7, since, in addition to the options given for responding, the experts were also able to write any observations they considered appropriate. To manage the range of answers expressed in the open questions and the observations, all those related to the same concept were grouped. The criterion used was based upon representing the answers by the smallest possible number of categories. For this, three sessions were held, in which two experts in project management, one expert in decision making and one expert in plant shutdowns participated. The affinity diagrams were used as a grouping technique.

Since there were experts representing the Petrochemical, Refining and Gas sectors, the responses were divided according to the function of the sector in order to compare the results obtained in the different areas of activity.

Next, the intended objective of each question within each area of interest is briefly explained.

Study area: ***Identification of the critical decision making points***

Question number 1: What is the current level of performance of your plant shutdowns? The aim is to determine the level of execution presented by the plant shutdown projects and identify whether or not they meet the success factors. For this, three levels were specified as possible answers (High, Medium and Low), in the function of the criteria described in Table 1.

Table 1. Description of the Levels of Performance in the Plant Shutdown Projects

LEVELS	DESCRIPTION
High	The project team meets the cost, terms and quality planned and carries out an adequate risk management assessment.
Medium	The team lacks a satisfactory execution in some of the success factors (cost, terms, quality and risk management).
Low	The project team experiences problems related to more than one of the success factors (cost, terms, quality and risk management).

Question number 2: Where do you think the critical points are in the decision of plant shutdown projects? In this case, the aim is to identify the areas and/or activities, inherent in the four phases of the plant shutdown process (Fig. 1), which are considered by the experts to be the most critical in the direction and execution of these projects. This question proposed 5 alternatives and the experts could select as many alternatives as they considered appropriate. The specific alternatives were: 1. The phase of formulation and integration of the strategy, 2. Programming, planning of activities and responsibilities, 3. Phase of service contracting to execute certain tasks, 4. Closure of the shutdown and 5. Other areas (offering freedom for the experts to indicate any other critical point in the decision making not found in the options listed).

Question number 10: According to your own experience what are the critical decisions? The aim was to identify in which aspects of the plant shutdown projects the critical decisions were concentrated. In this question, the Paretto analysis was conducted for each sector, in order to analyse and compare the critical decisions considered with greater frequency by the experts from the three industries.

Study Area: ***Description of the decision making process***

Questions number 3: As the manager of plant shutdown projects, how do you perceive the decision making processes?, number 4: How are decisions made? and number 5: How are decisions registered and implemented?. With these three questions the aim is to identify characteristics in the decision making process through the perception of the project managers, to establish the model or structure used to execute the decision making process and to identify to what extent the information management is formalised at the time of decision making.

Question number 6: Do you use specialised consultancies in the plant shutdown projects? With this question the aim is to establish whether the experts feel the need to turn to external services to manage some of their tasks.

Question number 7: Do you consider multiple criteria in most of the decisions you make and, if so, what are these? Due to the great amount of factors (operations, maintenance, processes, plant engineering, inspection, projects, financial, human resources, materials, etc.), actors, interests and requirements which play a role in the plant shutdown projects, the aim here is to establish the criteria considered in the decision making process, taking into account the four phases which integrate plant shutdown projects (Fig. 1). In this case, the criteria designed by the experts will be grouped according to the function of the areas involved in this type of project.

Study area: ***To identify the degree of familiarisation with the specific techniques to help in the decision and the need to have a tool to assist in the decision making process.*** In this case, the aim was to establish the level of knowledge of such techniques (question 8), as well as the need to create a mathematics-based technique to assist the decision making process (question 9).

Question number 8: Are you aware of any specific techniques which can help in multicriteria decision making? If so, please indicate how often you use them.

Question number 9: Do you believe that a mathematics-based tool to help decision making would be useful?

The data obtained by means of the survey have been analysed in accordance with the following procedure. The percentage of the answers for each of the presented alternatives for each and every answer, according to the sectors, has been calculated. Thus, $\%_i$ has been obtained from the calculation of N_i (see Ec. 1 and 2), where "*i*" represents each of the options to be chosen by the experts in the closed questions and each of the groups of answers obtained after the classification carried out as previously described in the case of open and mixed questions. With this approach, the relative importance of each of these alternatives for each individual sector (Petrochemical, Refining and Gas) can be observed. Subsequently, the differences and similarities which exist among the sectors can be compared in the function of the results. As mentioned above, the "*Total Sample per Industry*" consisted of 34 experts from the Petrochemical sector, 12 from the Refining sector and 32 from the Gas sector.

$$N_i = \left(\sum Answers / TotalSampleperIndustry \right) * 100 \quad \ldots \quad (1)$$

$$\%_i = \frac{(N_i x 100)}{\sum N_i} \quad \ldots \quad (2)$$

3. RESULTS AND DISCUSSION

Most experts in the three industries are willing to agree that they achieve a medium level of performance in plant shutdown projects. It is only in the case of the Refining industry, where 44.5% of the experts are under the impression that high performance values are achieved (see Table 2). These results highlight the fact that most of these project managers are of the opinion that a considerable margin for improvement still exists with regards to reaching an appropriate management of the shutdowns.

Table 2. Performance level of the plant shutdowns

		PETROCHEMICAL		REFINING		GAS	
		N_i	$\%_i$	N_i	$\%_i$	N_i	$\%_i$
What is the current level of performance of your plant shutdowns?	High	11,8	36,4	33,3	44,5	9,4	17,6
	Medium	17,6	54,5	33,3	44,5	37,5	70,6
	Low	2,9	9,1	8,3	11,0	6,3	11,8

In addition, the consensus reached between the experts, when stressing that the critical points in the decision making are mainly located in the initial phases of planning and programming (see Table 3), should also be highlighted. Most experts in Project Management are aware of the importance of these initial phases [6-20], and therefore, it is not surprising that they coincide over the criticality of the decisions made at this stage. The strategic planning is very compromising, since repercussions regarding the decisions made at this stage can be very severe. From the very start, accuracy in the decision making is the key point for ensuring that everything develops within the acceptable limits of performance. However, it is in this phase where the greatest level of uncertainty lies [28]. The existence of multiple influencing factors makes it difficult to reach a consensus with regards to the proposed solutions between the departments with conflicting interests. Moreover, the amount of information which must be taken into consideration is vast, and poor management of this can imply astronomical losses. These features coincide with the general perception of the decision making process expressed by the experts (see Table 4): in the three sectors, they are aware of the value of information (3), the experts belonging to the Petrochemical and Gas Industries consider the data available at present to be insufficient (1) and all are of the opinion that the search for a consensus is necessary when it comes to deciding (5).

Similarly, when directly questioned about the most critical decisions (see Table 5), the definition of strategies and scopes (2) once again directed their answers, together with those related to the execution times (9), and followed at a short distance by the risks associated with restarting after the shutdowns (3). Thus, it can be said that the uncertainty of the initial phases and the sensation of a lack of control by the project managers generate doubts concerning everything related to the suitability of restarting and its programming. This may be the reason why managers try to reach consensus in their decisions (see Table 6 option 2). Consensus guarantees the approval of the individuals responsible for the different areas which, indirectly gives them the sensation of control, minimises the risk of the decision and allows for the decision-making responsibilities to be somehow shared. Obviously, the degree in which this can occur will depend on the type of existing organisational culture and the nature of the business. To this regard, it must be pointed out that this research has not taken into account the relationships between the decision making processes and the type of organisation, its degree of maturity [28], the role played by the project manager and the different types of leadership he or she can follow [20].

Table 3. Critical points in the decision making of plant shutdown projects

		PETROCHEMICAL		REFINING		GAS	
		N_i	$\%_i$	N_i	$\%_i$	N_i	$\%_i$
Where do the critical points in the decision making of plant shutdown projects lie?	1. In the phase of strategy formulation and the extent of the shutdown (Phase 1)	67,6	39,0	58,3	30,4	65,6	35,6
	2. In the phase of programming of the shutdown tasks (Phase 2)	67,6	39,0	58,3	30,4	90,6	49,2
	3. In the phase of service contracting to execute certain projects (Phase 3)	23,5	13,5	50,0	26,1	21,9	11,9
	4. In the phase of restarting the plant after shutdown (Phase 4)	14,7	8,5	25,0	13,1	6,3	3,3

Table 4. Perception of the decision making process

		PETROCHEMICAL		REFINING		GAS	
		N_i	$\%_i$	N_i	$\%_i$	N_i	$\%_i$
As the manager of plant shutdown projects, how do you perceive the decision making processes?	1. A process which does not have adequate solid information for its correct execution	17,6	14,0	0,0	0,0	12,5	11,7
	2. A tool which facilitates the acquisition of the necessary information to support the decision making process is required	11,8	9,3	8,3	5,5	3,1	3,1
	3. A vast amount of information for the correct execution in an effective and efficient manner is necessary	20,6	16,3	41,7	27,8	34,4	32,3
	4. A complex process	11,8	9,3	16,7	11,1	6,3	5,9
	5. Consensus must be reached between the parties involved balancing the interests and eliminating the conflicts in order to move towards the global objective	41,2	32,5	58,3	39,0	31,3	29,4
	6. It must have the support of the management	11,8	9,3	8,3	5,5	6,3	5,9
	7.Other perceptions	11,8	9,3	16,7	11,1	12,5	11,7

Table 5. According to your own personal experience what are the critical decisions?

		PETROCHEMICAL		REFINING		GAS	
		N_i	$\%_i$	N_i	$\%_i$	N_i	$\%_i$
According to your own experience what are the critical decisions? Those which have an impact on :	1. Quality	5,9	3,0	0,0	0,0	6,3	4,2
	2. Definition of strategies/extent and fulfilment	38,2	19,9	41,7	19,1	28,1	19,1
	3. Risks (plant restarting, unforeseen events)	23,5	12,1	16,7	7,7	18,8	12,8
	4. Production	8,8	4,5	0,0	0,0	6,3	4,3
	5. Maintenance	17,6	9,0	25,0	11,5	18,8	12,8
	6. Safety	8,8	4,5	0,0	0,0	6,3	4,3
	7. Environment	2,9	1,5	0,0	0,0	3,1	2,1
	8. Financing	26,5	13,6	33,3	15,4	9,4	6,3
	9. Execution time	38,2	19,9	41,7	19,1	21,9	14,9
	10. Human Resources Management	8,8	4,5	25,0	11,5	6,3	4,3
	11. Materials and equipment (buying)	5,9	3,0	8,3	4,0	6,3	4,3
	12. Contractors (defining actions and adjudication)	5,9	3,0	16,7	7,7	12,5	8,5
	13. Critical path	2,9	1,5	0,0	0,0	0,0	0,0
	14. Control of work orders	0,0	0,0	8,3	4,0	0,0	0,0
	15. Critical chain	0,0	0,0	0,0	0,0	3,1	2,1

Conversely, despite the significant coincidence existing between experts in their preference for seeking consensus as opposed to centralised decision making, some differences between the sectors can be found, which are worthy of mention. Although it is true that in all the cases studied, decisions based upon experience is normally the most common approach to decision making, the high percentage of experts in the Petrochemical sector who confirm that they make decisions in an unplanned way (see Table 6 option 7), must also be highlighted. This may be a direct result of the fact that they perceive deficiencies in the level of information management necessary for planning, as mentioned in the previous paragraph. In addition, this justifies the fact that the responsibility for executing the decisions finally falls upon the managers who occupy a higher hierarchical level, as they themselves point out (see Table 6). This is, doubtlessly, a worrying feature, due to the well documented advantages derived from the correct planning of the actions to be carried out before decision making. In the case of the Refining industry, the execution depends more on the development of plant activities. The operations related to the manufacturing, maintenance and safety take priority in this sector, where, despite having confidence in the experience of the individual responsible for making the decision, nevertheless, the economic aspects, and those related to

the environment are controlled. However, the most significant aspect can be found in the Gas sector, where most experts state that they make their decisions in function of the analysis of the information available, which highlights the importance given to the control tasks of their plant shutdown processes. This fact is further ratified when they state that their decision depends upon the advance notice of the project, which definitely differentiates them from the other two sectors, where the contemplation of possible deviations, with respect to the programming, is not mentioned.

Table 6. Execution of the decision making

			PETROCHEMICAL		REFINING		GAS	
			N_i	$\%_i$	N_i	$\%_i$	N_i	$\%_i$
How are decisions made?	1	In a centralised way	14,7	14,3	16,7	11,1	9,4	8,1
	2	Consensus reaching (via a committee)	52,9	51,4	50,0	33,3	53,1	45,9
	3	Based on experience	5,88	5,71	16,67	11,11	9,38	8,11
	4	Using a hierarchical order and order of responsibilities	5,88	5,71	8,33	5,56	3,13	2,70
	5	By means of the improvement in information and analysis	0,00	0,00	0,00	0,00	12,50	10,81
	6	Giving priority to production over shelf life of the equipment	5,88	5,71	0,00	0,00	0,00	0,00
	7	In an unplanned way	8,82	8,57	0,00	0,00	0,00	0,00
	8	Evaluating the safety, environment, and economic aspects	0,00	0,00	16,67	11,11	9,38	8,11
	9	According to the extent of advance	0,00	0,00	0,00	0,00	6,25	5,41
	10	Giving priority to the manufacturing, maintenance, safety and operation teams	2,94	2,86	25,00	16,67	9,38	8,11
	11	Reaching consensus, depending upon the magnitude of the decision to be made	5,88	5,71	16,67	11,11	3,13	2,70

From all that has been stated, it could be concluded that the method of executing the decisions which comes closest to being the most desirable method would be that carried out by the Gas sector, followed at a distance by the Petrochemical, and Refining Sector. In this regard, the latter presents the most problems. This may be due to the fact that the gas generation process is simpler than the other two sectors, which can reduce management tasks and facilitate the decision making process.

Concerning the manner in which the decisions are formalised and registered (question 5), in the three cases procedures exist whereby a written document finally appears. However, this practice is more frequent in the Refining sector (superior to 70%); in the other two sectors the option is to implement decisions in an informal manner (around 60%). This can be due to the fact that the Refining industry has a more complex operation process, which could cause serious environmental problems in the event of an irregularity occurring, which could lead them to have their activities more closely documented.

In contrast, it can be said that the demand for assessment is considerable in the three sectors. More than half of the experts confirm the use of external consultancies (question 6), which underlines the opinion of the specialists - that qualified external support can contribute to the improvement of the indexes currently obtained by plant shutdowns.

About question 7, the results show that the experts from the Refining sector (80%) and Gas sector (77%) consider multiple factors when it comes to making a decision in almost all cases [30]. Once again, it could be said that this is an indicator of the complexity involved in the management of this type of project. However, in the Petrochemical sector, at almost 35% of experts who make decisions while taking into account a small number of criteria is higher (see table 7). Once Again, this fact could be due to the lack of information which they proclaim to have regarding their shutdown process, which could lead them to obviate data and factors which may be relevant when making the correct decision. In Figure 2, in which the criteria mentioned by the specialists' areas are grouped according to the differences, it can be observed that Finances, Technical Area and Production are the areas that contemplate a greater number of factors. This can be viewed as normal when taking into account the financial repercussion implied by each unproductive day and, from the technical perspective, the high level of exigency involved in the shutdown and inspection of a chemical processing plant.

Table 7. Multiple Criteria

		PETROCHEMICAL		REFINING		GAS	
		N_i	$\%_i$	N_i	$\%_i$	N_i	$\%_i$
Do you consider multiple criteria in most of the decisions you make and, if so, what are these?	Yes	61,8	65,6	66,7	80,0	62,5	77,0
	No	32,4	34,4	16,7	20,0	18,8	23,0

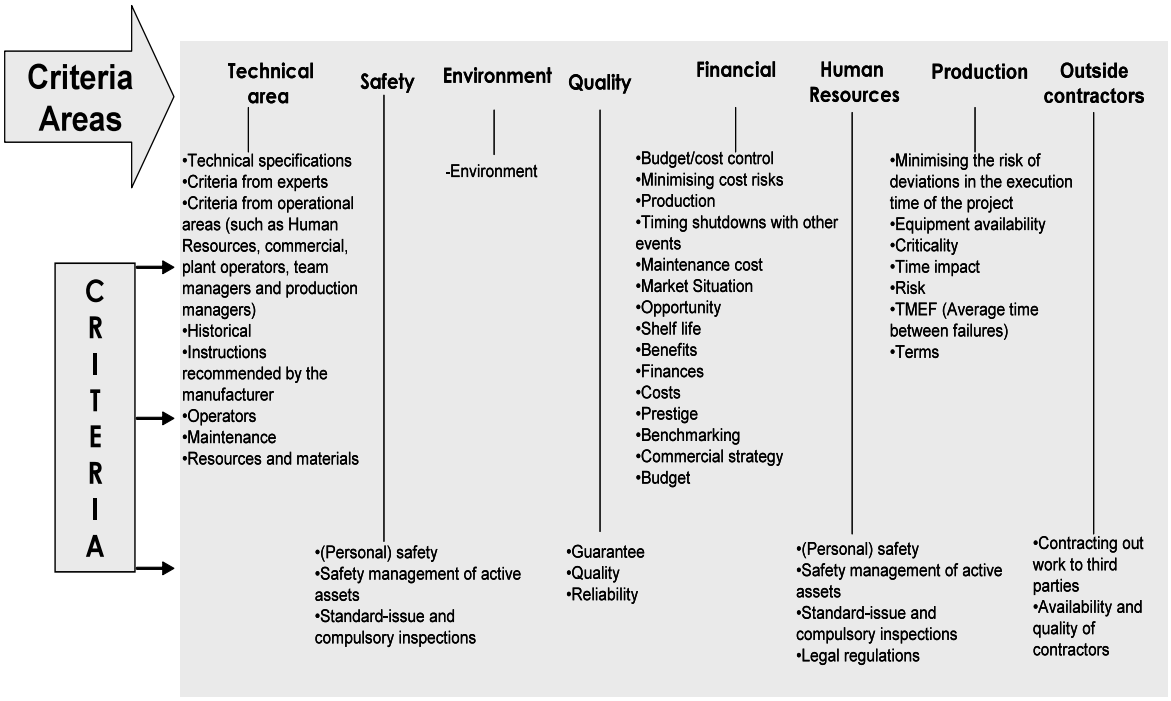

Figure 2. Criteria taken into consideration in the decision making per areas

With regard to the knowledge of the specific techniques to help multicriteria decision making, almost half of the experts demonstrated their ignorance of them (question 8). Furthermore, 95% of the experts who stated that they knew some techniques stated that they did not use them. Despite this, it can be observed that there is a high level of agreement between the experts with regard to the usefulness of the availability of a mathematics-based technique to assist in decision making. That is, experts think that it would be convenient to have tools to help the decision making process, but they do not use them, either because they are not aware of any, or because the techniques used do not respond to the particular needs of their decision-making problems, or because they consider their use to be inappropriate under the present circumstances. This fact could reveal a latent demand for training in these types of techniques as a prerequisite to their implantation in the present management models for this type of project.

The three sectors coincide with a percentage at above 60% with regards to the usefulness of having a mathematics-based technique as an aid to decision making (question 9). Obviously, to have a tool which would observe the criteria and interests of the different areas and help select the alternative which maximised the benefits would signify a very interesting aid for the central objective of our research. This would be of considerable use for objectivising influencing factors and to avoid making decisions in a hostile setting, succumbing to the diversity of interests based on individual suppositions or goals. In addition, the incorporation of techniques to assist decision making during the planning of the plant shutdown projects would help with the execution of previous diagnoses of the active assets within the installations, by improving the planning and management of the changes in their conditions over time.

When research is carried out with regard to the critical decisions (see Table 5), experts allude to those related to 15 factors, with all three sectors concurring in 8 of them (see Table 8). In addition, from the Paretto analysis, (Table 8), it can

be concluded that six of these factors are presented with frequency rates above 10%: the definition of the reach and fulfilment (1), execution time (2), financial aspects (3), risks (4), maintenance (5) and human resources management (8). Again, it can be seen that it is critical for the experts to make the decisions concerning the strategic definition and planning phases. It must be pointed out that in this research only the critical decisions have been identified, and the frequency with which the experts mentioned these has been measured without establishing a hierarchical order regarding the importance they bestowed upon them. Therefore, for future studies, it would be appropriate to carry out this weighing between the critical factors related to the decisions with the support of the experts from the three sectors.

Table 8. The most critical decisions in the Petrochemical, Refining and Gas Industries

Critical Decisions	% PETROCHEMICAL	Critical Decisions	% REFINING	Critical Decisions	% GAS
1	19,70	**1**	19,23	**1**	19,15
2	19,70	**2**	19,23	**2**	14,89
3	13,64	**3**	15,38	**4**	12,76
4	12,12	**5**	11,54	**5**	12,76
5	9,09	**8**	11,54	**11**	8,50
6	4,55	**4**	7,69	**3**	6,38
7	4,55	**11**	7,69	**6**	4,26
8	4,55	**10**	3,85	**7**	4,26
9	3,03	**14**	3,85	**8**	4,26
10	3,03	**6**	0,00	**9**	4,26
11	3,03	**7**	0,00	**10**	4,26
12	1,52	**9**	0,00	**13**	2,13
13	1,52	**12**	0,00	**15**	2,13
14	0,00	**13**	0,00	**12**	0,00
15	0,00	**15**	0,00	**14**	0,00

1.Definition of strategies/ range and fulfilment; **2.** Execution time;**3.**Financing;**4.**Risks (plant restarting, unforeseen events); **5.**Maintenance; **6.**Production; **7.**Safety; **8.**Human Resources Management; **9.**Quality; **10.**Materials and equipment (buying); **11.**Contractors (defining actions and adjudication); **12.**Critical path; **13.**Environment; **14.**Control of work orders; **15.**Critical chain

4. INSIGHTS FOR PRACTITIONERS

Once this point has been established, the existing need to improve the management and the decision making related to the tasks to be developed in the first phases of a plant shutdown seems obvious. It seems logical to think that the improvement of the management would lead to an improvement of the conditions in which the decisions must be made. In fact, the generation of helpful models in the strategic planning could contribute to standardizing and improving the management processes [6], which could finally favour the progressive development of relationships between project direction and management practices and the methodologies and procedures involved in the decision making process. Thereby, future research directed at the specific development of plant shutdown management, which contemplates the idiosyncratic factors for integration within its procedures and which scrutinizes tools to help the decision making process, would be justified.

Finally, it must be mentioned that, except for details related to the method of decision making, with regards to all the other factors measured in this research, no significant differences exist between the sectors studied. The various experts have agreed on the critical phases, the most delicate type of decisions, the criteria considered when the decision is made, etc. This state of affairs would lead to the confirmation that aspects related to the management of the shutdown of chemical processing plants present common problems regardless of the particular type of activity. This fact somehow leads to the conclusion that the design of the management model mentioned in the previous paragraph could be feasible for general application. Furthermore, this could be introduced in such a way that it could become the foundation for improving current performance levels for this type of project.

5. CONCLUSIONS

The results obtained in the study lead us to the conclusion that the most critical decisions and the main problems are concentrated in the early stages of definition and planning of plant shutdown projects (Phases I and II). Aspects related to the definition of scope, execution times, financial, risks and maintenance represent the main factors when it comes to making decisions. The experts agree upon the necessity to correctly manage a vast amount of data and affirm that at present they lack all the required information. In addition, and despite this, they do not have a formal model to help in the decision making processes, and do not use techniques to help in the decision although they consider that these could be of use. Hence, the decision making and searching for compromise solutions and consensus are mainly based on personal experience. The sense of a lack of information expressed by the experts serves to confirm that the present management of plant shutdowns requires a conceptual framework which can integrate the dispersed data, methods and techniques available in an organised manner, permitting an appraisal of the different criteria, minimising the conflicts and diminishing the uncertainty associated with the decision making process.

In conclusion the decision making criteria are mainly based on personal experience. In order to obtain high levels of performance in the plant shutdowns projects, the shutdowns project management may be based on a method or model through as can be integrated different criteria, processes and procedures for the efficient management of critical aspects (definition scope, execution times, financial, risk management and maintenance). This approach must take to implement solutions in those areas and critical aspect where the shutdown project team has greater difficulties (solutions custom-made "ad-hoc"). In this sense it must be generated models of trade-off analysis to diminish the conflicts and uncertainties associated to the decision-making process under a same criterion.

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