

Occupational health and safety in construction projects: a case study on chemical industry sector

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Abstract

Background: This study was conducted to demonstrate the importance of occupational health and safety (OHS) management in construction project environments, taking into account the successful development of those projects. The associated problems in OHS management projects were also studied, as substantial empirical research has shown this is a complex theme with a large number of associated factors. Methods: In this study, three projects developed in the Portuguese petrochemical industry were analyzed using documentary analysis, ongoing interaction with workers and direct observations of work activity. A systematic literature review was also carried out. Results: Strengths and weaknesses related to OHS management of the three analyzed projects were identified. Grounded on the case studies results, a proposal of OHS management in construction projects, in a recommendations format, is also presented. Conclusion: Good results from OHS management in projects can be obtained as long as it is focused on success factors such as top management commitment, line responsibility, involvement of all employees, and, mainly, of direct and indirect managers. Well-defined OHS responsibilities, a well-sized and structured organization and the creation of an honest, healthy, motivating and useful OHS environment team with a competent and dynamic coordinator leader are also important success factors.

1. INTRODUCTION

Decent work is safe work (ILO, 2018). According to ILO (2018), people die every day as a result of occupational accidents or work-related diseases – more than 2.78 million deaths per year. Additionally, there are some 374 million non-fatal work-related injuries and illnesses each year, many of these resulting in extended absences from work. The human cost of this daily adversity is vast, and the economic burden of poor occupational safety and health practices is estimated at 3.94 per cent of the global Gross Domestic Product each year.

It is very important to create awareness of this data - which is not encouraging - as it affects each and every worker, regardless of their role within an organization, as they may very well become part of this dimension of data.

A 2012 study conducted by the Aberdeen Group revealed that EHS (Environment, Health, and Safety) professionals shoulder the responsibility for the "sustainability strategy" in their respective organizations, compared with operations, engineering, facilities, quality, corporate compliance and corporate sustainability (Ismail and Hashim, 2012).

Occupational health and safety are generally defined as the science of the anticipation, recognition, evaluation and control of hazards arising in or from the workplace that could impair the health and well-being of workers, taking into account the possible impact on the surrounding communities and the general environment. This domain is necessarily vast, encompassing a large number of disciplines and numerous workplace and environmental hazards. A wide range of structures, skills, knowledge and analytical capacities are needed to coordinate and implement all of the "building blocks" that allows national OHS systems to extend the protection to both workers and the environment (Alli, 2008, ILO, 2011).

In the midst of business survival and performance improvement, companies are faced with a different dynamic of management, with global competitiveness and their sustainability, as a constant challenge supported in the organizations by the area of OHS management.

Over time, the present study sought to justify the topic through a summary analysis of the presence of the OHS subject in literature, which reveals its relevance for researchers. Also, it aims to identify the emerging challenges vs impacts that OHS management can face in distinct contexts, such as globally, nationally, in organizations, industrial construction projects or the chemical industry.

Recent studies (Koivupalo et al., 2015; Walter, 2017) regarding OHS management emphasize the importance of case studies to identify good safety and health practices at the workplace and the main difficulties encountered in their management, thus contributing to improving OHS management performance.

The research question that guided this study was: which OHS management practices should be adopted in construction projects regarding the chemical industry, aiming to improve their performance?

Regardless of the principles of OHS management, based on ILO-OSH 2001, as well as selected good practices in the construction sector; this study has a general objective of producing a proposal of OHS management practices for projects in the chemical industry.

This study will contribute towards:

- the development, systematization and consolidation of theoretical knowledge concerning OHS management in projects;
- establishing significant relations of association between several conditions of the study of OHS management in projects analyzing eventual cause-effect relations, proposing solutions;
- guiding the definition of strategies for OHS management in projects.

OHS management in construction projects is the main scope of this study. It analyses from the early engineering stage, passing through construction until the commission and start-up phase. The selected case studies comprise the development of three projects from the chemical industry in Portugal of different nature and dimensions. For this study, an exploratory methodological approach was applied, using the case study methodology.

2. LITERATURE REVIEW

In terms of theoretical support, it was sought to address the issue of OHS management in projects, to frame it, on the one hand, and also emphasize the importance of OHS management in organizations and projects. In another subchapter, an attempt was made to briefly address the sector of activity under study and its particularities in terms of risk – the chemical industry sector.

2.1. OHS management in projects

OHS management in projects is a matter that is not frequently applied in the conception and development of projects.

It is an interesting topic due to the importance given to a discipline that is normally classified as secondary. However, many times it is fundamental for a project to be successful.

Due to inadequate OHS management in projects and the lack of the importance that the OHS discipline deserves in project management, the present study aims to provide some contributions on this subject.

In the framework of OHS management in projects, it is important to focus on some underlying themes, such as:

- What is a project?
- What is project management?
- Which parameters are important for OHS management in projects?
- Search for the answer about the importance that OHS has in projects.

All the themes mentioned above may eventually have other analyses and/or approaches according to other perspectives. However, the approach presented by the authors was the one that deserved more relevance to them.

- What is a project?

"A project is a temporary endeavor commitment in creating a product, service or result" (PMI, 2004).

"A project consists of a unique set of processes consisting of coordinated and controlled activities with start and end dates, performed to achieve project objectives. Achievement of the project objectives requires the provision of deliverables conforming to specific requirements" (ISO, 2012).

A project is something that wants to create, produced. It can have many images.

An example of the application of the project in the chemical industry might be: the development of a chemical treatment plant starts with the process engineering that defines the characteristics of the process. These characteristics are used to design the processing units. This information becomes the basis for design engineering, which defines the detailed plant layout and mechanical characteristics of the process units and subordinate utilities. All these results lead to construction drawings. During construction, changes are made when necessary and subject to approval. In the end, updates will be considered in "as-built" drawings.

- What is project management?

Considering that project management is an application of knowledge, skills, tools, and techniques to fulfil project requirements (PMI, 2004); is the application of methods, tools, techniques and competencies to a project (ISO, 2012), it is important to create the intersection of this perspectives.

Knowledge, skills and processes are not always uniformly applied. In collaboration with his team, the project manager is always responsible for determining which processes are appropriate and the degree of rigor for each process in each project.

Good practice means that there is general agreement on the correct application of skills, tools and techniques that can enhance opportunities for success on a wide range of different projects. However, it does not mean that the knowledge acquired is always applied uniformly in all projects. The project management team is once again responsible for determining what is appropriate for each project (UNESCO, 2017).

- Which parameters are important for OHS management in projects?
- Search for the answer about the importance that OHS has in projects.

It is also important to understand what OHS is and its purpose. Literature can provide some definitions, such as follows.

"OHS are conditions and factors that affect, or could affect, the health and safety of employees or other workers (including temporary workers and contractor personnel), visitors, or any other person in the workplace" (BSI, 2007).

"OHS is a discipline dealing with the prevention of work-related injuries and diseases as well as the protection and promotion of the health of workers. It aims at the improvement of working conditions and the environment. Occupational health entails the promotion and maintenance of the highest degree of physical and mental health and social well-being of workers in all occupations." (ILO, 2011). OHS works to prevent work-related injury and ill health to workers and provide safe and healthy workplaces (ISO, 2018).

Seeing the acting of the OHS discipline as a system, its management requires coordinating activities to manage and control an organization (ISO, 2015) or part of it (e.g. project). The term "management" involves planning, organizing, leading and controlling function (Robbins and Judge, 2012).

An OHS management system (OHSMS) is either a system used to manage and control OHS or a management system specifically aimed at OHS. Taking three perspectives, i.e. management, system and OHS, an OHSMS is the intersection of these (Li and Guldenmund, 2018).

There are no magic formulas for OHS Management Systems, but some elements are important to try to achieve good performance either in organizations or in projects.

ILO guidelines and normative support on OHS came to give importance to the OHS discipline.

Standards such as OHSAS 18001 (BSI, 2007) and ISO 45001 (ISO, 2018) based on the PDCA (Plan-Do-Check-Act) methodology can be a good guidance tool in OHS management.

The consequences tend to be positive in terms of OHS management in projects if the organizations related to the project are certified. There is a commitment to controlling OHS risks, considering the defined policies and objectives, and positively impacting OHS management in projects.

According to a research (written survey) performed to 47 project managers (PMs), who are members of the Project Management Institute of South Africa (PMISA), about "the role of project managers in construction occupational health and safety", the findings indicate, among others: inadequate or the lack of OHS increases project risk, and negatively affects cost, productivity, quality, schedule, the environment, and client satisfaction, procurement systems, project duration, design, detail and specification influence OHS, and project managers influence OHS during all phases of a construction project (Smallwood, 1999).

The view of these members is so important in the entire process of a project. The OHS discipline does not live alone, and the interaction between other disciplines in the project gives rise to the overall management of the project.

OHS should be specially identified and addressed in detail in the PMBOK (Project Management Body Knowledge) in order to give it real importance in the project.

According to ILO (2011, 2018), for all areas of human activity, a balance has to be made between benefits and costs of risk-taking. Regarding OHS, this complex balance is influenced by many factors such as rapid scientific and technological progress, a very diverse and continuously changing world of work, and economics. The fact that the application of OHS principles implies the mobilization of all social and scientific disciplines is a clear extent of the complexity of this field and, also, of its importance.

In some specific contexts, OHS can be defined in more practical terms, assuming different approaches, being this fact one of the challenges faced when studying and developing those matters. For diverse contexts, different management approaches to OHS (Dhillon, 2010; Wu et al., 2010) or models (Hale et al., 1997) should be addressed.

According to EU-OSHA (2012) occupational health and safety (OHS) systems are designed to identify and minimize workplace hazards.

The main ingredient in OHS management process there is the importance that must be given to the OHS discipline throughout the project's development.

Health and safety should be both an organizational and project value, as opposed to a priority, as priorities may change.

2.2. Construction projects vs Chemical industry sector

Managing OHS is a comprehensive effort and needs an organization to determine its system in different contexts. This is not an exception in a construction projects context on the chemical industry that is the scope of this paper. This is a particular context of developing OHS management, combining the perspective of OHS management, construction projects and the chemical industry sector in Portugal.

The construction industry (associated with the development of construction projects) plays a significant role in many countries economies. However, the construction industry is regarded as a highly hazardous industry, and it is usually the main contributor to labor casualties in many countries (Tutesigensi and Phung, 2011). Construction also accounts for a significant number of occupational-related ill health and absence from work (Nguyen et al., 2015).

The construction industry plays a significant role in contributing to the economy and development globally. During the construction process, various hazards, along with the unique nature of the industry, contribute to high incident rates, namely mortality (Jaafar et al., 2017).

Construction projects in the chemical industry also further, other particularities such as: sometimes the construction is carried out in a production environment, that must be carefully controlled according to the specificity of the hazards from the environment of the chemical industry, particular stages of pre-commissioning and commissioning, concurrency of activities in reduced physical environment, very ambitious working time windows.

Effective OHS management gives improvements to the reduction of construction accidents. This is partly because OHS management practices introduced by the adoption of OHSMS and other associated practices by contractors are increasingly becoming important (Fewings, 2013). Construction Project Features (CPFs) generally have a moderate or high potential to influence accident occurrence (Manu et al., 2014).

Some studies argue that it is essential to identify and strengthen OHS management elements and practices among contractors, as they have an impact on OHS management when addressing OHS issues in the workplace (Manu et al., 2017). Researchers also emphasize the need of being aware that subcontracting is noted for its adverse OHS influence in construction (Manu et al., 2013). Implementation of some OHS management practices could be associated with the contractor vs company dimension (Kheni et al., 2008; Bonafede et al., 2016).

Safety management information and safety management committees have a significant contribution to project performance, but the safety management process has no noteworthy relationship with project performance, although the construction practitioners perceived the safety management process as being the most important (Cheng et al., 2012).

Projects and their management can have several analyses, taking into account various contexts, such as business through, for example, economic principle or social context, and constraints, such as the availability of the project budget, factors related to health

and safety of personnel, the level of acceptable risk exposure, between others (ISO, 2012). Furthermore, one must note that project management as a whole must incorporate the management of the OHS discipline and that it will necessarily contribute to its overall performance.

3. METHODOLOGY

The empirical approach chosen for the development of this study is qualitative, and the method used is the case study. This research is the result of three case studies, particularly three projects which were developed in the OHS area, through which the necessary information to be selected was gathered and treated, giving an accurate picture of the situation and understanding of the projects (Yin, 2009; 2010; Fortin, 2009). As Yin (2003) points out, the multi-case study technique can bring considerable contributions to the current theory or even modify it through the contribution of the study of that subject to the specific product sector.

By using qualitative methodology prevails the understanding of the complex interrelationships between everything that exists (Stake, 2012); however, it is subjective.

The collected data were obtained through bibliographical research, general and systematic observations at the workplace (in order to apprehend all OHS practices and tools which were used in the case studies projects), ongoing interaction with the organization's project manager and other particular workers (with several roles and responsibilities within OHS management project in order to understand their current practices), and documental analysis (company data). The company data is supported through several registers, and the intervening information is handed over by those responsible for the management of the company project and checked by them.

The methodology used in the case studies has gone through a selection phase and the treatment/presentation of the OHS information contained in those studies to make it compatible with the information collected. Significant content was removed and systematically organized to adapt it to OHS systems.

The case studies represent three projects in the chemical industry area, which is the scope of this study. The information and presentation have taken into account the relevancy of this area through the approach of subjects that support the study, and the data is easy to read with the comparison of the presented information through tables.

The cases represent three projects developed in the Portuguese chemical industry¹ related to OHS management.

Each case/project was characterized, and several items were taken into account in order to give knowledge of its coverage of development in OHS management terms. Also, they were based on OHS Standard – ISO 45001:2018 (ISO, 2018) main elements and nature of construction project structure, as follows:

A- Scope (to understand the project dimension)

B- General characteristics of the project

Place (to understand the restricted conditions, mainly in the place of construction)

Global Investment / OHS Budget (to understand in economic terms the importance of the OHS discipline in project's global investment)

Main risks involved (to understand the level of risk involved in the project)

No. Labor Hours – LH (to understand the dimension of the project in manpower terms)

C- Stages of each main phase of the project

¹The Company is a petrochemical complex that is part of a group. Its geographical location is in Portugal. The petrochemical complex consists of several factories that belong to the area of Olefins and Polyolefins.

The different phases of each project and, for each one of them, the tasks or sub-phases from an OHS perspective are presented in [Table 1](#).

Table 1. Engineering Phase / Construction Phase (Items/Project)

Engineering phase	<ul style="list-style-type: none">- Sub-Phases of Project involved- OHS Objectives (definition and balance)- OHS Planning (forecast/real; OHS inclusion)- Definition of Human Resources- Evaluation of Material Resources- Specialities Involved- OHS Tools Applied (balance)- Monitoring Instruments Used- OHS Involvement (where it started, visible aspects)
Construction phase	<ul style="list-style-type: none">- Sub-Phases of Project involved- OHS Objectives (definition and balance)- OHS Planning (forecast/real; OHS inclusion)- Human Resources (no. of staff involved; qualification; level of subcontractors; with higher level of concern with 'safety culture' subjects or not, for example: involvement; leadership; communication; safety behaviours)- Equipment, Materials Resources (type; conditions; suitability)- Type of Works (to understand eventual danger)- OHS Tools Applied (balance)- Monitoring Instruments Used / Key Performance Indicators for OHS (KPI for OHS)- OHS Involvement (where it started, visible aspects)

The general research process followed in this study and the empirical study developed to explore and describe the case studies to obtain potential findings in accordance with the study goal are described in [Figure 1](#).

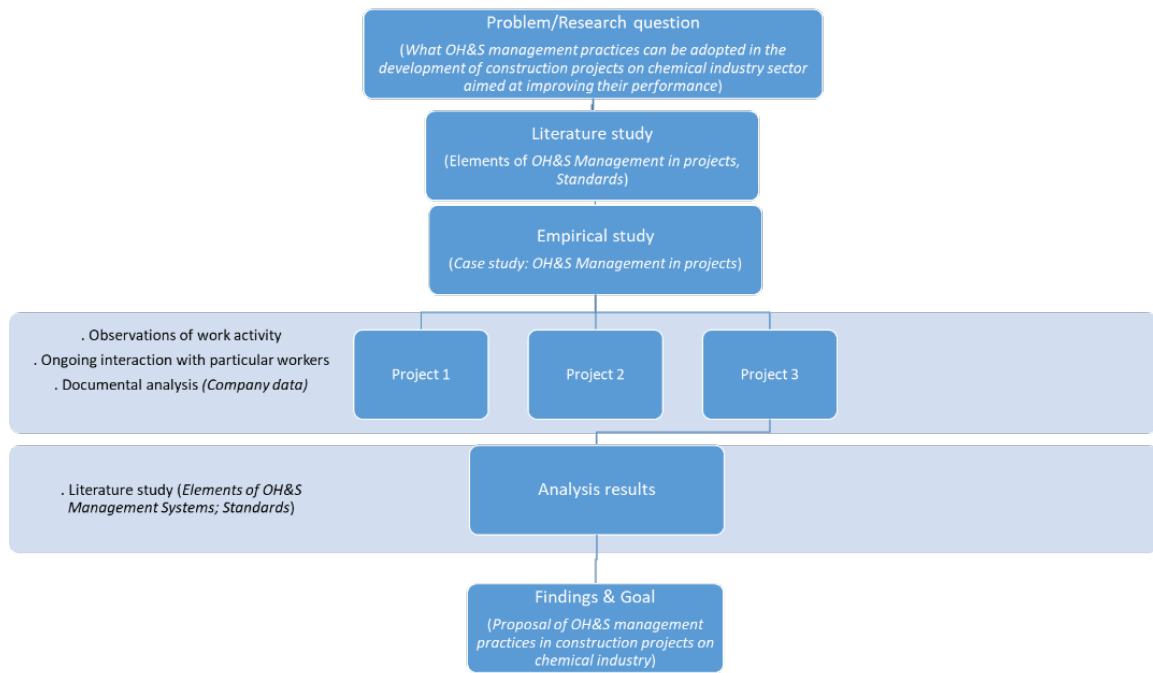


Figure 1. Research process

4. CASE STUDY RESULTS

The proposed analysis of OHS Management in construction projects was subject to description (of OHS management) for three projects developed in the chemical industry sector. The results are presented below following the previously structure given in section 3. For each case, a brief description of it is made to indicate the period along which the project was carried out. In addition, a detailed characterization of the project in accordance with section 3 is performed. Specifically, in Table 2, the scope of the project and the period during which the cases were developed are indicated; and for each one of them, the different phases, presented in Table 1, as well as features of each project (global investment and the investment share related to survey the main risks associated with the development of the project and labor hours) are also presented. The projects took place at Site's (company) premises in its industrial complex in Portugal.

It is precisely through the identification and survey of these features that the involvement of OHS management in each project is being assessed, and the results of the study sustained.

The description of part C for the three study cases was only shown as excerpt due to its size. But it was essential content to accomplish section 5 - Discussion.

5. RESULTS ANALYSIS AND DISCUSSION

This section is divided into two subsections. Subsection 5.1 is dedicated to the analysis of the case studies results by comparing it with the literature, in the form of strong and less strong points identified in OHS management. The other subsection, subsection 5.2, aims to present a set of recommendations for OHS management in construction projects, which tends to contribute to the intent of the study.

5.1. Strengths and weaknesses of OHS management in construction projects

On Table 3 and Table 4 the strengths and weaknesses that resulted from the case studies are presented, taking into account the added value that they can give to the OHS management system in projects, through theoretical sustentation originating from the analysis of the cases, notwithstanding the subjective level that the topic offers.

Table 2. Case studies – projects

	CASE 1²: STEAM CRACKER CAPACITY CREEP PROJECT	CASE 2³: ACCESS OF PIPELINES	CASE 3⁴: RGP 3rd PHASE
A-Scope Dimension / Period	Building a tank to store pyrolysis gasoline (18,000 m ³ of capacity) and increase the ethylene production capacity in Site plant (from 375 kt to 425 kt ethylene/year, nominal capacities). Installation of 35 equipment (ex: drums; exchanges; pumps; ± 450t equipment); 350 lines of piping and change internal plates in nine distillation columns. 18 months plus 13 months (Project/Engineering phase and Construction phase).	Fencing with net for approximately 18 km throughout the industrial and logistic pipelines in the zone of Sines. Solar panels were installed in 49 gates throughout the accesses. 14 months plus 13 months (Project/Engineering phase and Construction phase).	Retain processing of RGP (refinery grade propylene) in PGP (polymer grade propylene) and increase reception capacity of PGP in the Harbour Terminal. The main equipment that has been loaded: 2 exchanges, 1 drier (balloon with interns) with spare; 1 pump; changes in one existent drum. Piping and associated instrumentation was also loaded. 6 months plus 11 months (Project/Engineering phase and Construction phase).
B-General features of the project Place	Engineering Phase: Lisbon (headquarters of the engineering company), and visits to the workplace, and Construction Phase: Petrochemical complex in Portugal, chemical Industry with high risk (presence of hydrocarbons).	Engineering Phase: Lisbon (headquarters of the engineering company) and visits to the workplace, and Construction Phase: industrial and logistic pipelines in the zone of Sines, with high risk (presence of hydrocarbons).	Engineering Phase: Lisbon (headquarters of the engineering company) with visits to the workplace, and Construction Phase: two places: petrochemical complex in Portugal, and Harbour Terminal (area under responsibility of the Company. Chemical Industry with high risk (presence of hydrocarbons).
Global investment/OHS Budget	20 M€ / 1,5% (2.5% increase in addition related to ergonomic problems identified during the construction phase).	6 M€ / 0,8% (1.5% increase in addition related to safety access improvement; drainage identified during the construction phase).	3 M€ / 3% (5% increase in addition related to ergonomic problems identified during the construction phase).

²The information presented in the characterization case is supported through several registers (ex: Final Report HSE Project Creep.) and the intervening information handed over by those responsible for the management of the Project.

³ The information presented in the characterization case is supported through several registers (ex: Final Report HSE Project Pipelines) and the intervening information handed over by those responsible for the management of the EGEO. (EGEO is the owner – composed of four companies).

⁴The information presented in the characterization case is supported through several registers (ex: Final Report HSE Project RGP 3rd phase) and the intervening information handed over by those responsible for the management of the Company Project.

	CASE 1⁵: STEAM CRACKER CAPACITY CREEP PROJECT	CASE 2⁶: ACCESS OF PIPELINES	CASE 3⁷: RGP 3rd PHASE
Main risks involved	Explosion; fire; falls at height and at different levels; burial; crushing; asphyxia; electrocution; works done in the proximity of plants in service (high and low temperatures and pressures; hazardous products); works carried out during turnaround period; night work; work subject to weather conditions.	Explosion; fire; falls at different levels; burial; crushing; work subject to weather conditions.	Explosion; fire; falls at height and at different levels; burial; crushing; asphyxia; electrocution; works done in the proximity of plants in service (high temperatures and pressures; hazardous products); work subject to weather conditions.
No Labor Hours (construction Phase)	356,752	100,022	43,038
C- Stages of each main project phase	<i>Only an excerpt of all information because of its size, with focus on construction phase items.</i>		
OHS Objectives	Were defined before construction phase such as: general, specific and quantitative (n ^o inspections; n ^o incident reports issued; n ^o 1 st aid;)		
OHS Planning	Delay on both phases, except for construction phase – case 3. Include some items such as: perform risk assessment; HSE Plan; programmed meetings, HSE Inspections.		
Human resources	<p>OHS discipline was not managed by qualified professional since engineering phase.</p> <p>The appointment of the safety coordinator – engineering phase - was made close to the start date of the construction phase, but timely to construction phase.</p> <p>The owner demonstrated concerns about safety culture components such as: involvement, communication, leadership, safety behaviours. But less concern from contractors.</p> <p>The owner and safety coordinator were the same for 3 projects.</p> <p>High subcontracting chain.</p>		
	<ul style="list-style-type: none"> . Peak of employees involved in the project: 500 . OHS team: 16 (1 safety coordinator and 15 safety officers and safety engineers) 	<ul style="list-style-type: none"> . Peak of employees involved in the project: 100 . OHS team: 3 (1 safety coordinator and 2 safety officers) 	<ul style="list-style-type: none"> . Peak of employees involved in the project: 100 . OHS team: 4 (1 safety coordinator and 3 safety officers)

⁵The information presented in the characterization case is supported through several registers (ex: Final Report HSE Project Creep.) and the intervening information handed over by those responsible for the management of the Project.

⁶ The information presented in the characterization case is supported through several registers (ex: Final Report HSE Project Pipelines) and the intervening information handed over by those responsible for the management of the EGEO. (EGEO is the owner – composed of four companies).

⁷The information presented in the characterization case is supported through several registers (ex: Final Report HSE Project RGP 3rd phase) and the intervening information handed over by those responsible for the management of the Company Project.

	CASE 1⁸: STEAM CRACKER CAPACITY CREEP PROJECT	CASE 2⁹: ACCESS OF PIPELINES	CASE 3¹⁰: RGP 3rd PHASE
Equipment / Material resources	. Certified scaffolding (case 1 and 3); material and equipment inspection performed before any intervention. . Availability of use of specific certified measuring equipment.		
Type of works	. Excavations, work at height, welding, civil, manual and mechanical cargo handling, assembly of equipment, confined spaces, night work, tests.	. Civil, welding, painting, manual and mechanical cargo handling, assembly of equipment.	. Excavations, work at height, welding, civil, painting, manual and mechanical cargo handling, assembly of equipment, confined spaces.
OHS Tools Applied (balance)	. Engineering phase: 14 risk assessment (HAZOP, SIL, Change control) . Construction phase: 22 risk assessment; 105 HSE Inspections; 52 Behavioural Observations; 448 Toolbox talks (TBT); 4346 training hours; 42 HSE meetings; 123 construction meetings; 0 campaign; 421 incident reports issued; 0 investigation incident; Engineering phase: 1 risk assessment . Construction phase: 2 risk assessment; 38 HSE Inspections; 21 Behavioural Observations; 201 TBT; 1314 training hours; 15 HSE meetings; 48 construction meetings, 2 campaigns; 100 incident reports issued; 4 investigation incident; Engineering phase: 4 risk assessment (HAZOP, SIL, Change control) . Construction phase: 5 risk assessment; 35 HSE Inspections; 23 Behavioural Observations; 54 TBT; 430 training hours; 14 HSE meetings; 40 construction meetings; 2 campaigns; 43 incident reports issued; 3 investigation incident; ...
	. HSE Plan; . Key controlled performance indicators, such as and through monthly report issued by safety professionals (follow up objectives, OH&S tools applied, incidents rate calculation and its analysis), evaluation of OHS initiatives.		
Monitoring instruments used / Key Performance Indicators for OHS	<p><i>Pro-Active Indicators (forecast/real)</i></p> <ul style="list-style-type: none"> . NO HSE Inspections: 109/105 (95%) . NO Behavioural Observations: 152/52 (34%) . NO Incident Reports Issued: 420/421 (100%) <p><i>Re-Active Indicators (forecast/real)</i></p> <ul style="list-style-type: none"> . LTIFR¹¹: 0/0 (100%) . MTCFR¹²: 0/0 (100%) . NO First Aid Case (FAC): 5/7 (71%) 	<p><i>Pro-Active Indicators (forecast/real)</i></p> <ul style="list-style-type: none"> . NO HSE Inspections: 26/38 (146%) . NO Behavioural Observations: 26/21 (77%) . NO Incident Reports Issued: 57/100 (175%) . NO TBT: 26/201 (773%) . NO Campaigns: 1/2 (50%) <p><i>Re-Active Indicators (forecast/real)</i></p> <ul style="list-style-type: none"> . LTIFR: 0/0 (100%) 	<p><i>Pro-Active Indicators (forecast/real)</i></p> <ul style="list-style-type: none"> . NO HSE Inspections: 32/35 (109%) . NO Behavioural Observations: 32/23 (72%) . NO Incident Reports Issued: 32/43 (134%) . NO TBT: 35/54 (154%) . NO Campaigns: 2/2 (100%) . NO Participation in incident investigation: 5/3 (60%) . NO OHS Meetings: 5/14 (280%) . NO Construction Meetings with OHS agenda: 32/41 (128%)

⁸The information presented in the characterization case is supported through several registers (ex: Final Report HSE Project Creep.) and the intervening information handed over by those responsible for the management of the Project.

⁹ The information presented in the characterization case is supported through several registers (ex: Final Report HSE Project Pipelines) and the intervening information handed over by those responsible for the management of the EGEO. (EGEO is the owner – composed of four companies).

¹⁰The information presented in the characterization case is supported through several registers (ex: Final Report HSE Project RGP 3rd phase) and the intervening information handed over by those responsible for the management of the Company Project.

¹¹ LTIFR: Lost Time Incidents Frequency Rate (calculations without FAC´s data)

¹² MTCFR: Medical Treatment Case Frequency Rate

	<ul style="list-style-type: none"> . MTCFR: 0/1 . NO First Aid Case (FAC): 3/3 (100%) 	<p><i>Re-Active Indicators (forecast/real)</i></p> <ul style="list-style-type: none"> . LTIFR: 0/0 (100%) . MTCFR: 0/0 (100%) . NO First Aid Case (FAC): 3/0
OHS Involvement	<ul style="list-style-type: none"> . Low involvement on engineering phase. . High involvement in the construction phase by the owner (project manager) and safety coordinator. Other safety professionals were gradually demonstrating involvement. . Low voluntary involvement by managers of contractors. 	<ul style="list-style-type: none"> . Lack of involvement on engineering phase. . High involvement in the construction phase by the owner (project manager), safety coordinator and contractors.

Table 3. Strengths of OHS Management in Construction Projects

IT	Strengths of OHS Management in Construction Projects
1	<p>Safety coordination in the Construction phase, with a true assumption of the function. Great involvement and participation in the process of OHS management.</p> <p>Owner with real involvement in OHS management.</p> <p>As the owner and safety coordinator were the same for the three projects, and both had strong commitments and involvement in OHS management process, it was possible to improve, for example, in the implementation of more OHS tools, in the identification of more proactive indicators (as is evident in the results presented) and in OHS performance.</p>
2	<p>Health and Safety Plan – project phase elaborated in accordance with the reality of the plan and the restrictive conditions of the owner, with the following exceptions for this project: fencing and access of pipelines.</p> <p>According to Badri et al. (2012), the integration of OHS risk is not systematic in all industrial fields.</p> <p>It must be noted this was a result of a study about the integration of OHS risk into project management, focusing on the construction industry.</p> <p>Each project is unique and different to the others. It is important to be realistic about each one.</p>
3	<p>Definition of strategy of OHS operation, in coordination with the owner (head of project) and the safety coordinator, through:</p> <ul style="list-style-type: none"> - definition of measurable OH&S objectives, and OHS indicators with more emphasis on proactive indicators; - definition of OHS teamwork and respective roles and responsibilities; - selection of OHS tools to use, and forms of their implementation and control; <p>Management and managers must set the direction and the health and safety management strategy in their organizations (EU-OSHA, 2014a).</p>
4	<p>Timely transmission of OHS requirements required for the execution of the work/project, defined by the owner, to be applied by performing entities/contractors, including OHS indicators and not only the traditional lagging (reactive) indicators of safety performance.</p> <p>According to Hinze et al. (2013), the conclusions about their study point out that a company that truly embraces the philosophy of zero injury will consider the use of other procedures, such as antecedent indicators.</p>
5	<p>Survey of OHS needs to be undertaken before the execution of the work/project by the owner (e.g. acquisition of equipment to the measurement of gases effect; acquisition of radios; requesting telephone lines; information placards for OHS indicators; room equipped for meetings/training; preparation of infrastructure for setting up of temporary site facilities for the performing entities/contractors) on time.</p> <p>Tappura et al. (2014) argue through their study that developing the resources, understandings, and competencies of managers in relation to essential OHS issues may considerably improve the quality of working life, innovativeness, and performance of organizations (Tappura et al., 2014).</p>
6	<p>Involvement of the owner, in the person of the head of the project, invisible aspects; for example, participation in task risk analyses, participation in department safety meetings, participation in safety inspections, participation in behavioural observations and 'toolbox talk'.</p> <p>Leadership is based on key principles such as strong and active leadership from the top, in terms of its visibility, active engagement, establishing communication systems at all levels and integration of good health and safety management with business decisions (HSE, 2013; ISO. 2018).</p>
7	<p>Involvement of OHS team.</p> <p>A review of international studies on the effectiveness of health and safety committees concludes that fundamental factors for effective performance include management commitment, communication, the inclusion of safety on the everyday management agenda, committee processes (frequency of meetings, size of committee and problem-solving ability), and the involvement of professional experts (Milgate et al., 2002).</p>

IT	Strengths of OHS Management in Construction Projects
	Implementation of OHS tools, such as campaigns, with strong involvement of the performing entities/contractors (as is evident in the results presented when going from one project to another).
8	According to Aldoory and Bonzo (2005), three factors influence campaigns: the level of involvement (also defined as perceived emotional connection), problem recognition and constraint recognition. They should be used to design different campaign messages for different audiences. This should be associated with the identification of needs to different audiences according to their level of involvement and constraint recognition. It was notorious when moving from project to project to add more OHS tools, such as campaigns (previously mentioned) and with associated OHS objectives and indicators, intending and managing, in this way, to improve its performance (as in the cases of TBT, investigation incident, OHS meetings).
9	Implementation of good practices such as, the execution of small specific procedures for situations considered to be more dangerous: for example, loading of some pieces of equipment and piping that require special access; in contiguous places; while the plant in operation; movement of dangerous loads. Another example is planning the application of OHS tools, such as setting times for inspections and OHS meetings. Delivery of OHS documentation for the performing entities/contractors for safety coordination, with regular and defined form. Vredenburg (2002) argues through his study that proactive management practices are more effective than reactive practices in contributing to injury reduction. This study used six management practices frequently included in safety programmes (management commitment, rewards, communication and feedback, selection, training, and participation) that contributed to a safe work environment for hospital employees). This is a study with particular focus that can be applied to other sectors.
10	Communication system: use of several means of communication and checking so that information is received by all those concerned, through meetings, with issuing and distribution of minutes of meetings; completion of OH&S performance reports; informative placards; emails, etc. Safety communication is essential to ensure the safety of workers (EU-OSHA, 2014c).

Table 4. Weaknesses of OHS Management in Construction Projects

IT	Weaknesses of OHS Management in Construction Projects
1	Preparation of health and safety plan – project phase often postponed, in order to not follow the development of the diverse phases of engineering in the project.
2	Health and safety plan not issued – project phase in the process of consultation of various services.
3	Absence of OHS involvement in phase of business selection of some services for the project.
4	Absence of application of the safety coordination position in the project/engineering phase. Poor planning with a focus on OHS.
5	If workers participate in an activity of the planning phase, it is more likely that problems and their causes will be identified, and it will help to find practical solutions and meet the ultimate goal (EU-OSHA, 2014b). Implementation of the tool behavioural observations (focus on behaviours). According to Ismail and Hashim (2012) through their study on a behavioural-based approach to safety in the oil and gas industry (through three case studies), the main results are in the direction of safety improvement.
6	The required steps to implement a safety behaviour tool should be taken into account related to the benefits seen. Cruthirds and Pittman (1996), cited by Ismail and Hashim (2012), recognize the success of the behaviour-based safety approach.
7	Absence of forms for analysis of effectiveness of some OHS tools, for example: safety inspections and behavioural observations. According to EU-OSHA (2012) a good evaluation system includes regular audits to assess the effectiveness of controls and risk management.
8	OHS involvement of a higher number of collaborators belonging to the owner's organization.

IT	Weaknesses of OHS Management in Construction Projects
	OHS involvement on the part of the execution of work/construction supervision.
9	Some of the results from a joint CPWR and NIOSH workshop about safety culture and climate in construction showed that bridging the gap between research and practice is related to supervisory leadership being a critical factor, which was perceived for a larger group as an important indicator of a climate of safety. A key factor that contributes to safety climate was identified as involvement of leadership with reinforcement from superintendent and foreman levels (Gillen et al., 2013).
10	OHS voluntary involvement by the performing entities/contractors, mainly the managers.
	High value in additional costs related to ergonomic problems, and others, on OHS (because they were not addressed in the design phase). According to Tappura et al. (2015), it is important to chart management accounting practices related to safety issues in order to improve current practices further. It is the way that we can perceive the quantification of costs and benefits of safety matters.
11	In safety-related investments, the monetary costs of an investment are usually well known, but the monetary value of the benefits is hard to calculate, and some particular areas such as ergonomics are not considered as much as they should be. The values of each project are directly proportional to the size of each project in hours worked, but not in relation to the associated OHS budget and additional costs. One of the potential reasons could be that, regardless of the size of the project, there will be an OHS cost that will always have to be ensured (shipyard, human resources, collective and personal protective equipment), and that may not significantly go beyond its dimension in temporal terms and hours worked. On the other hand, the issue of additional costs could be related to a potential deficient analysis in the design phase, which will be identified in the construction phase (namely regarding ergonomic aspects, e.g., access to valves).

5.2. Recommendations Proposal of OHS Management in Construction Projects on Chemical Industry

In order to reflect on / discuss this study in terms of a proposal of OHS Management in construction projects, on Table 5 some recommendations related OHS Management in Construction Projects are identified as a result from the present study.

Table 5. OHS Management Recommendations in Construction Projects

IT	OHS Management Recommendations in Construction Projects
1	The involvement of OHS discipline should began in the first project/engineering phase (in order to sustain capital gains for the entire project phase), and it is important that a safety coordinator in the project/engineering phase, or someone responsible for OHS discipline, is selected also at the beginning of the project/engineering phase.
2	Owner's involvement in health and safety issues. It gives much credibility to the health and safety management system. Leadership is a prerequisite for success. Any preventive approach can only be successful if it is supported by the board. This preventive approach can collect advice and input from a strong and visible leadership with managers engaged at all levels (EU-OSHA, 2012; ISO, 2018).
3	Stimulation and visible involvement of the OHS internal services of the owner (to give a good example).
4	Take account of OHS in the planning since the engineering phase. For example, it is expected that it considers the accomplishment of system audits, the implementation of OHS tools, etc.
5	Timely preparation of the project's health and safety plan, and in a sustainable way, according to the reality of the project (it is essential).
6	The health and safety plan should be an applicable and applied OHS tool matching to the reality of the project.
7	Definition of OHS requirements in detailed form, established within a contract, prevents conflicts between the involved parties, as it is clearly agreed. It avoids demands on one hand, and 'excuses' on the other.
8	Checking if the contractual information of the owner arrives in adequate form at the subcontractors, before the signing up of contracts with the main contractors.
9	Promotion of accomplishment of exclusive OHS inspections by the contractors.

IT	OHS Management Recommendations in Construction Projects
10	Promoting specific training on 'safety behaviours', through the implementation of the tool behavioural observations. Implementation of a tool requires training to be provided and follow up / monitoring of its implementation. The training course must be compulsory on the part of all managers (e.g. team leaders, foreman, project director) pertaining to the involved entities in project.
11	Elaboration of campaigns procedure, whose objective is to help the accomplishment and promotion of OHS.
12	Pre-definition of part of the team (permanent) that will investigate incidents in order to acquire skills in a timely manner and to develop, when necessary, a better and professional work. It should be noted that the team should also be constituted by selected investigators at the time of investigation.
13	Monitoring the communication process Communication is the way that issues relating to safety can be made known, and there should be an open channel of communication between employees and superiors. It must include communication from employees, and be understood by all, and the organization should monitor the effectiveness of communication (Cooper, 1998; Glendon and Stanton, 2000; Flin, 2000).
14	Promoting of compulsory and regular meetings between performing entities, including contractors and subcontractors, to discuss OHS in the owner's premises, in order to 'guarantee' that information is received by all the project collaborators.
15	Promotion of industrial hygiene monitoring in projects.
16	Promotion of existing and new good practices, with special attention for those that come from the contractors' initiatives.
17	To be aware that it is very important that, both at national and enterprise levels, strict initiatives of prevention, of good practices, supported with adequate forms of information and inspection, and guided by the conventions, recommendations and practical codes of the ILO on health and safety in the workplace, are adopted.
18	To be constantly aware that petrochemicals have high standards of OHS preventive requirements, due to the nature of their hazards and risks, and that they must never be relinquished. The external means that are necessary to be developed in projects should not be evaluated in economic terms, as this can detract from the requirement.
19	The motivation of the team by its leader / manager / coordinator. It is very important for the success of the project performance. According to Lu and Yang (2010), a good leader will always encourage and motivate their subordinates to work effectively, to work efficiently, to work harder and always be responsible for their own safety, and that of their colleagues.
20	To be aware that a 'determined management' is distinguished by hindering organizational constraints as well as others that try to change the agenda.
21	To be aware that there are success factors when implementing OHS management, which are: <ul style="list-style-type: none"> • Top management commitment • 'Line' responsibility • Involvement of 'all', and mainly of direct and indirect managers • OHS responsibilities well defined • OHS organization well sized and structured • Creating OHS environment team; honest, healthy, motivating and useful • OHS coordinator leader, competent and dynamic

Hale (2000) argues that the concept of safety culture is vague. Safety culture can be an integrated part of the more general concept of organizational culture, influenced by attitudes and behaviours which have an impact on the level of safety in the organization.

A definition of organizational culture given by Schein (1990, 2004) is as a pattern of shared basic assumptions that a group has learned how to solve issues of external adaptation and internal integration. It gives people a frame of reference for how to act, think, and feel in uncertainty and change contexts.

It is of extreme importance the presence of 'an accented' level of concerns with the safety culture components, in organizations, in order to generate a safety climate that reflects good results such as, for example, the decrease of the number of accidents, as well as a reduction in the gravity of the injuries, and the most conscientious responsibility for the safety of each individual and that of their colleagues.

Although both concepts (safety culture and safety climate) are understood as shared perceptions created over time, culture is generally seen as a more abstract and stable construct than climate, which more easily lends itself to manipulation (Guldenmund, 2000).

Paying attention to OHS management in projects is an important sign of safety culture.

According to Nielsen's (2014) case study about safety culture, health and safety organizations (OHS departments), a company can improve safety culture by focusing on safety-related interactions.

There are some scientific papers related to the management of changes as a part of safety management (Hoff, 2013; Koivupalo et al., 2015; Kitajima et al., 2010), and there is a topic of safely managing organizational changes as a subject of some research reported in the literature (Gerbec, 2017).

The perspective of OHS management in construction projects as an organizational change is not the focus of our study but a potential way for companies (operating with projects) to manage those particular sub-process - OHS Management - within global project management.

The watchful eye to OHS is undoubtedly a plus tool in the OHS management process and global project management.

6. CONCLUSIONS

The current study aims to contribute to the safety literature, with three case studies on OHS management in project intervention showing some evidence for the application of success factors. More specifically, the study indicates that OHS management can improve project performance by focusing on success factors. It is essential to give importance to OHS management in projects to obtain a significant improvement in the performance of those projects. Moreover, this study also allowed to conclude that notorious results can be obtained through OHS management.

In the form of recommendations, this study intends to contribute to OHS management application.

Identifying and assessing the best way to manage the discipline of OHS in construction projects is inherent in a subjectivity influence. It is undeniably significant to analyze what is done with a critical sense to eventually change and improve. Change is not easy in any of the organizational aspects. In project management, particularly in OHS management in projects, there is no exception. However, this type of study aims to contribute to thinking over these matters, to value what is good and what can be changed and improved. It is also inherent to the subjectivity of the analysis process in this type of subjects vs. studies as a limitation of the study.

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