Supporting Decisions on Industrial Plant Modularization: A Case Study Approach in the Oil and Gas Sector

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***Abstract*—This paper aims at filling the gap between academic and practitioner view and knowledge on modularisation in the oil and gas sector. It shows how a theoretical framework on modularisation has been successfully applied in two case studies. A replicable methodology is given to illustrate how to customize the proposed framework in an operative context. The purpose is to increase both awareness and knowledge of a firm about the potential of the modular approach and to offer a proper support for decision makers along the overall project delivery chain and under the different stakeholders' point of view. The comparison among theoretical studies about the modular approach and the real practice in EPC field allows finding further tactical and strategic developments of industrial plant projects execution.**

Keywords—modularisation; ontology; knowledge; case study; EPC companies; oil and gas sector; off site construction

I. Introduction

Modularisation is a quite recent technique in the oil and gas sector. Since the beginning of the new millennium EPC companies had to face an increasing number of challenges, such as the continuous reduction of both project delivery time and overall cost, and the increased number of unconventional locations where the construction process becomes physically impossible or really slow and expensive. Thus, plant modularisation, for example, allows to perform construction works simultaneously in several different locations, enabling the postponement of the assembly of the modules at the site [1]. The modular approach has been introduced trying to win challenges like the construction of LNG plants in Australia [2] or the Kashagan projects [3]. The awareness given by the multitude of advantages in the first modular projects brought an increasing number of followers. As the number of modular projects is increasing, more benefits are originated from the adoption of such approach, and this is because more and more companies are interested in better understanding the potential of this modular execution mode. Nevertheless, there is still relevant issues, such as the misalignment and the low awareness level of both EPC contractors and clients on the implications of modularisation, and on the optimal way to manage a modular project. It can be guessed that a full understanding of the modular approach would probably lead to adopt it as a standard practice, reducing the amount of the so-called stick built work in the fields. Modularisation is widely used in many fields, so a deep study of the way to approach a modular solution could help the EPC sector to overcome the barriers that are avoiding its usage as a standard successful approach. The aim of this work is to fill this knowledge gap, to increase companies' awareness on how to adopt a modular approach, and to explicit all the implications arising from modularisation. To fully understand possible benefits, decision makers need a solid framework as an analysis and decision-making support on the potential use of modularisation in a project. This study observes modularisation from a theoretical point of view, and analyses how modularisation is applied in EPC companies given the theoretical model, highlighting strengths, weaknesses, opportunities and threats. Such a wide and complete study is still missing in the literature, and companies need a purposeful tool to better understand all the implications of modularisation to succeed in this innovative approach.

The paper is structured in four sections. The Background section contains the description of both the nowadays literature [4] [5] [6] [7] [8] and an Ontology [9] [10] to describe how this theoretical model could be applied in a company. The Research Methodology section explains the replicable methodology that could be applied both for further studies and for the use of the Ontology in a company. The Case Study section contains two cases assessed in an Italian EPC company; the analysis is done both within a single case (to compare the theoretical model and the company's practice), and cross-case (to highlight similarities and differences between cases). Finally, the Conclusion section summarizes the key findings of the research: how the model fits in a company, the real benefits achieved after the case study analysis, and considerations about future implementations.

II. Background

There are many definitions on modularisation in the literature [11] [12] [13] [14] still they do not cover all the aspect of modularisation. Three main items emerged as fundamentals of modularisation: Architecture breakdown, Use of standards, and Existence (and management) of interfaces.

Architecture breakdown regards both physical and functional aspects. The use of standards concerns with matters as commonality, compatibility, interchangeability. The existence of interfaces is set as the major issue in modularisation, since connection nodes connect independent modules. In order to overcome the lack of generalisability of the majority of collected definitions, a new definition has been used as main reference for this study [9] which defines the concept of modularisation as:

"a configuration of a socio-technical system through its physical and/or organizational architecture breakdown into standard functional subsystems and/or processes, which are interfaced to operate together as a whole and may impact on all the system's life cycle. Both its achievement and justification should arise from a life cycle-oriented decision-making process."

This definition highlights the fact that modularisation is a system configuration that has to be part of a structured decision-making process, and that it has strong impact on all the system lifecycle. Moreover to define an operative Decision Support System for industrial plant modularization, the ontology proposed by Micheli et al. [9] has also been used as the basis of this paper. The ontology, methodologically based on Protégé-2000 [15], consists of three main elements: classes – core concepts of the domain of discourse; slots – describing attributes and properties of a class (or of a subclass); and facets – describing the features of the value that the slots can take. The identified classes are: "Enabling factors", "Barriers", "Mechanisms", and "Impacts". The implementation of the ontology is shown in the figure below (Fig. 1).

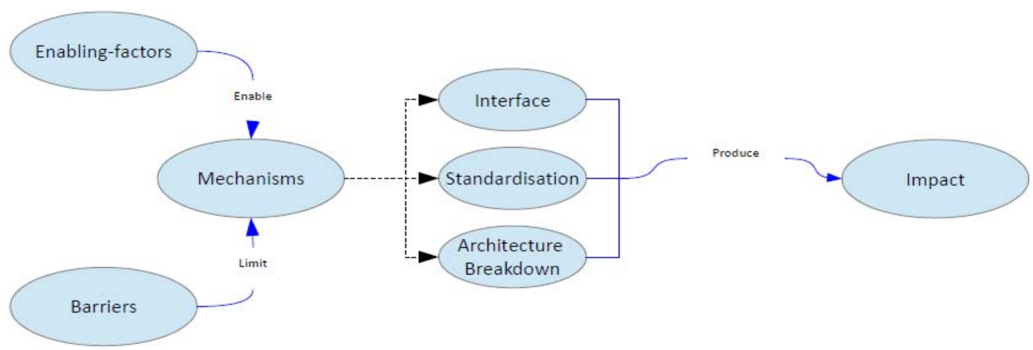

Fig. 1. Implementation of the ontology: how to connect ontology's classes

A mechanism is defined as a combination of actions in at least one of the three main areas Architecture Breakdown, Interfaces and Standardization, which are the same three subclasses of the Mechanisms. In table 1, all the mechanisms are listed and related to the three modularization areas. The Impact class summarises every aspect that modularisation may be accountable of in each point of the system life cycle. It includes positive and negative impact outcome in specific firm's performance. The Barriers identify the limits, the difficulties and the prerogatives of modular application. The Enabling Factors express what can induce the good conditions to use modularisation (the major activators). This category shows the elements that a decision maker has to take into account when he decides to modularise a system. In certain condition the difference between an enabling factor and a barrier can be not so clear.

TABLE 1 LIST OF IDENTIFIED MECHANISMS IN MODULARISATION BASED ON THE THREE PILLARS

Mechanism name	Architecture Breakdown	Standardization	Interfaces
Modules design	X		
Modules standardization		X	
Interfaces design			X
System physical decomposition	X		
System functional decoupling	X		
Platform design	X	X	X
Bus architecture	X	X	X
Modules swapping	X	X	X
Modules Sharing	X	X	X
Minimize inter-module interactions	X		X
Aggregation into cell modules	X		X
Modular consortium	X		X
Sectional modularity	X		X
Interfaces Standardization		X	X

Design for Postponement			X

The execution of a single mechanism could bring to achieve many impacts, but, as shown in Fig. 1, it is influenced by different barriers and enabling factors.

Mancini et al. [10] went one-step further fulfilling all the other entities – impacts, barriers, enabling factors – through a deep literature review based on more than 250 papers. The literature analysis provides the identification of 187 impact items, 43 barriers and 58 enabling factors and related connections representing the full development of the decision-making-driven Ontology on modularization. The connections among entities are often difficult to interpret for overlaps and inconsistencies. Since all instances had to be linked with at least one mechanism, the further step of the implementation of the Ontology was a critical discussion about these missing connection and then several implicit links have been created.

The aim of the Ontology is to become an instrument as a guideline between a feasibility study and the process of decision-making, which is the process of making choices by setting goals, gathering information, and assessing alternative occupations.

The decision-making-driven Ontology can be read from two perspectives, as explained below and shown in Fig.2.

- Target-driven perspective: starting from the most desired impacts it highlights what barrier items have to be fallen and what enabling factor items have to be activated;
- Context-driven perspective: starting from the status of the firm in terms of barrier and enabling-factor, it highlights what impact could be achieved.

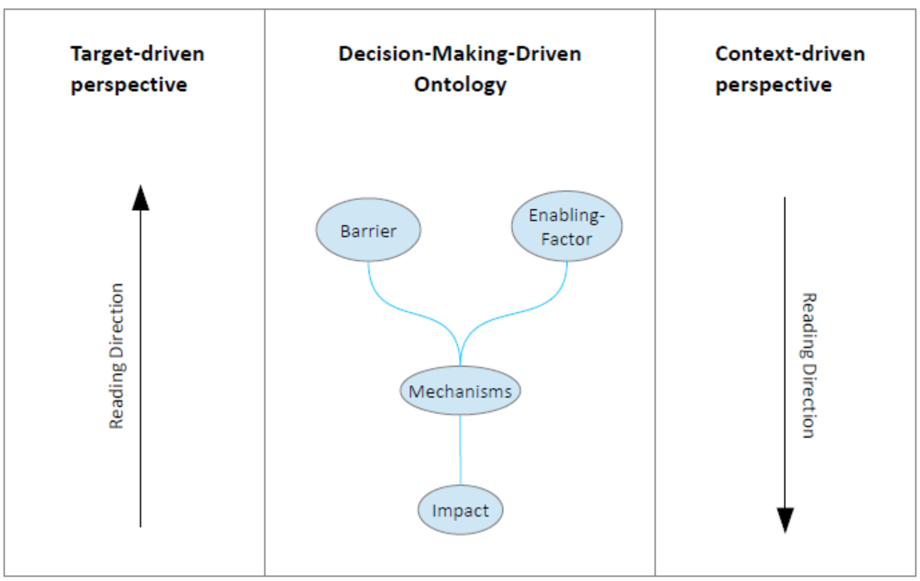

Fig. 2. Ontology's perspectives: reading directions for target-driven and context-driven

Most of the companies do not have a clear and overall view of all the aspects involved in a modular approach. All their actions are still implicit in their modus operandi. Because of that, the most proper way to use the Ontology in this work is adopting a Target-Context-driven perspective. It means to start from the impacts that the company wants to achieve, and then, analyse which mechanisms they are using, to achieve their main impacts. Next step is to be aware of which enabling factors and barriers are involved in a specific project. This was a sort of Target-driven perspective. Then, starting from the activated mechanisms, find out which impacts (called secondary impacts) are achieved by the company as a consequence of their actions and activated mechanisms.

In order to make the model a running decision making support system, further steps are required. First, the model needs to be customized for the Oil and Gas sector, not only from a scientific perspective but also from a practitioner one [16]. Then, from the company point of view, it is important to understand which are the internal practices in the modularisation adoption. This is also important to highlight the possible gaps to fill in order to improve benefits from the modular approach and to acquire a competitive advantage.

Following these process it will possible to achieve the goal of this work and so to deliver a ready-to-use instrument to EPC companies.

III. Research Methodology

The work starts from the tuning of a theoretical ontology and progressively develops in the creation of a decision model that could support the decision about a modular approach against a stick build approach in plant design and construction, both in on shore and off shore projects. It is necessary to look at the problem into its context to consider all the aspects that have an influence on decisions. The case study method is the chosen methodology because it allows to answer to "why, what and how questions" [17] and it enables a deep understanding of the reasons behind specific decisions. Finally, starting from a theoretical framework, it was necessary to deeply analyse variables and factors that have not been totally understood until that moment by the company. As Glaser et al. [18] stated, the cases are chosen for theoretical, not statistical reasons. They may be chosen to replicate previous case or extend emergent theory, or they may be chosen to fill theoretical categories and provide examples of polar types [19]. Each case should be selected so that it either predict similar results (a literal replication) or produces contrary results but for predictable reasons (theoretical replication).

Two different cases were chosen into the same firm – Rosetti Marino – in order to cover the principal features of the projects in the same context and to underline analogies and differences. For this reason, the cases have to respect this characteristics: company's standards must be well represented and modularisation have to influence in a relevant way the projects, possibly in more than one level. In the mentioned company, the first level of modularisation concerns modules over 150 tons of weight and the contract is between the client and the company, while the second level of modularisation concerns skid under 150 tons and the responsibility of engineering, building, and testing the skid is delegated entirely to the supplier with a lump sum contract. Moreover, the chosen case studies have to be in the closing phase, to trace easily complete material and available personnel, and they must have clear differences (results, developments, environments) to generalize within the firm.

As Yin [20] affirms, data collected may come from six sources (documents, archival record, interview, direct observation, participant observation and physical artefacts) and any data collection has to respect three essential principles (multiple sources of evidence, a case study database and a chain of evidence). The most important sources for the analysis are the interviews; in the first meeting is preferred the focused interview [21] (a rigidly structured), at a later stage open-ended nature. In this first interview, a respondent is interviewed for a short period of time, assumed about 2 hours per person, in which it is followed a certain set of questions derived from the case study protocol. In open-ended interviews, starting from the considerations made after the first interview and after a detailed description of the project (by the interviewed), the aim is to deeply understand the entities (barriers, enabling factors, mechanisms and impacts) and links between them.

Having more than a single observer brings to increase the reliability of emerged evidences. Eisenhardt [19] points out that the use of multiple investigators can have other advantages. They can enhance the creative potential of the teams and convergence of observation increase confidence in the findings. Multiple respondents were chosen because events studied may have different interpretations or point of views and the observations are prone to subjectivity and biases. It is also very important to seek out all the people involved in the decision making process who are best informed about data being researched. It is important to interview people involved in the decision-making process, such as Project Manager, Construction Manager, Engineering Manager, Procurement Manager and Commissioning Manager. During the analysis process, many other people were interviewed, but only people involved in the decision making process were able to contribute significantly to the tuning of the model.

Collected data allows the analysis of these in three differ levels with the double target of validating the used ontology and having a better understanding of modular approach characteristics: the analysis within cases, a theoretical comparison and a comparison between the cases.

All the achievable impacts with the mechanisms enabled by the company are listed, and then they are compared with the impacts cited by the firm (the impact is considered as achievable if at least one mechanism is enabled by the company). Using the same technique, it could be possible conduct the analysis with enabling factors and barriers, as it is shown in Fig. 3.

The theoretical comparison is followed by an analysis between cases, essentially for enhancing the generalisability of conclusion gathered. From this comparison, many general considerations and base-context predictable differences emerge.

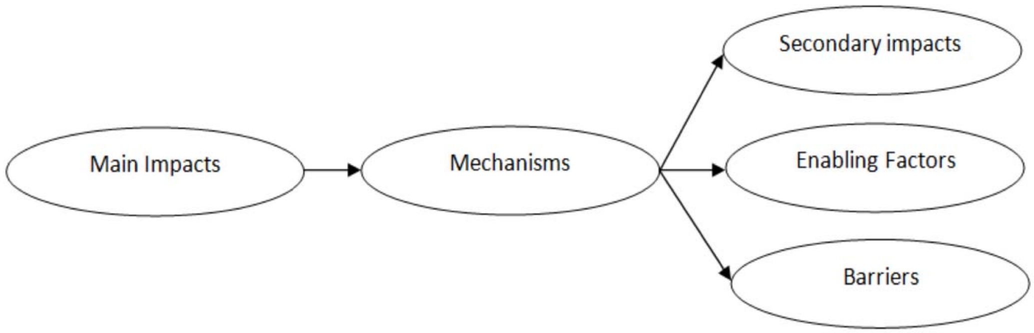

Fig. 3. Reading direction adopted in the case study analysis

IV. CASES STUDY

Two cases are analyzed in this paper. Still, the entire work analyzes a larger number of cases in order to increase the reliability of results. The two chosen projects are briefly introduced below and a representative picture is shown in Fig. 4.

1. MARLIN: Engineering, Procurement and supply of all material and equipment, prefabrication, fabrication and assembly, pre-commissioning, commissioning load out, site hook-up, site commissioning and assistance for start-up of: one 4-legged jacket, four skirt piles and three deck level platform. The platform will be located offshore Ivory Coast, and the yard is in Italy;
2. PETROBALTIC: Conversion of drilling rig from MODU to production centre that will operate offshore Poland. Engineering, Procurement services, management and HUC works. The construction yard is in Poland.

Fig. 4. Left: Marlin project in the transportation phase. Right: Petrobaltic project in construction phase

In the first level of modularisation, for the Marlin project the main driver was the reduction of costs, while for Petrobaltic the main driver was the reduction of time through parallelisation of construction operations. A brief explanation of the results of the interviews is shown below (Fig. 5).

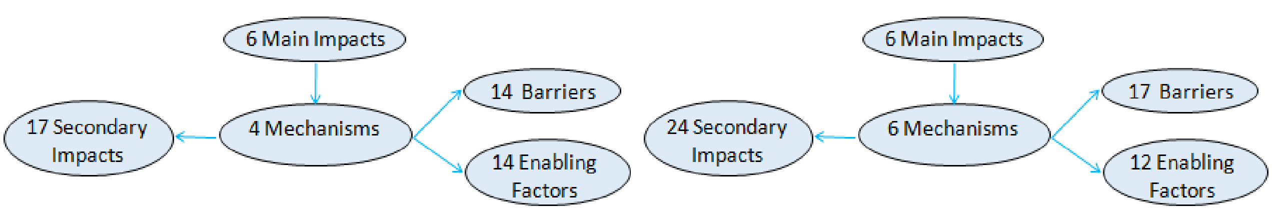

Fig. 5. Entities involved in Marlin project (left) and Petrobaltic project (right) for first level of modularisation

The main results emerging from these analyses concern both impacts and mechanisms and the most important impacts concern both time and cost, recognized coherently by all the interviewees. The main activated mechanisms are "Module Design", "Interfaces Design", "System Physical Decomposition", and "System Functional Decoupling"; all the mechanisms concerning standardisation are not considered by the company, because in the context of the mentioned company, the client has very specific requirements that make the standardization of any technical solution impossible. The fact that every project is considered by the company as a prototype, on one side it is a powerful strength, because it makes them be flexible and accomplish every specific requirement of the client. On the other side, it requires a huge amount of effort, because each project has to start from a zero, even if the company has already developed very similar project in the past.

The main results for the second level of modularisation are shown in Fig. 6. The main drivers for the second level of modularisation concern both the reduction of the schedule, enabling the work parallelisation of all the skids, and an increase of the degree of autonomy and responsibility of the suppliers in skids engineering, construction and testing, so that for the contractor it is easier to manage all the skids as "black boxes", and all the effort is given to suppliers. In this second level, more mechanisms are used comparing to the first one, in fact suppliers can standardise some big items or some technical solutions, and more benefits from this standardisation (not adopted in the first level), will affect also the contractor. The involvement of suppliers allows the company to put less effort in engineering and construction, but it requires more effort in the management of the project, and in relationship management.

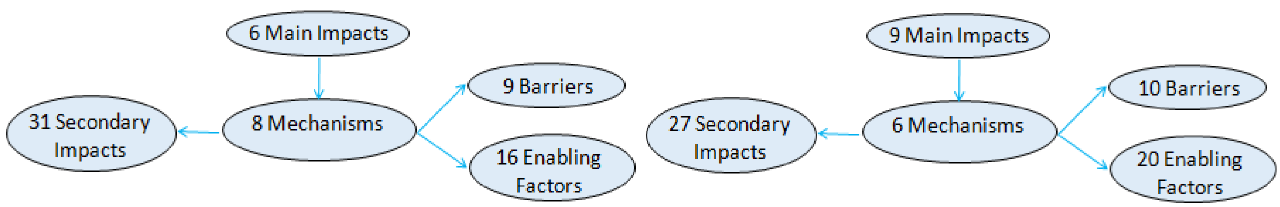

Fig. 6. Entities involved in Marlin project (left) and Petrobaltic project (right) for second level of modularisation

A brief list of the main entities cited by the company is shown later in the paper (tables 3, 4 and 5). After the results gathering from interviews, it is important to understand analogies and differences between theoretical model and practice. Starting from the main impacts, mechanisms involved according to the model are identified. Then, looking at the mechanisms activated by the company, impacts, enablers and barriers predicted by the model are listed, in order to make a comparison between all the classes. Results of the comparisons are shown below in table 2. Numbers in brackets mean entities cited but not enabled (if enabling factors) or overcome (if barriers). Moreover, in one project (first level of Petrobaltic, as shown in the table in square bracket) interviewees pointed out a new barrier concerning "constructability", not listed in the theoretical framework, so added in the optimized model.

TABLE 2 COMPARISON BETWEEN CASE STUDY ANALYSIS AND THEORETICAL FRAMEWORK

		Only in the company	**Both model and company**	**Only in the model**
MARLIN First level	Mechanisms	1	3	7
	Secondary impacts	4	13	48
	Barriers	0	14 (2)	13
	Enabling Factors	0	14 (2)	16
MARLIN Second level	Mechanisms	0	8	11
	Secondary impacts	7	21	51
	Barriers	2	7 (2)	18
	Enabling Factors	2	14 (1)	23
PETROBALTIC First level	Mechanisms	0	6	6
	Secondary impacts	6	18	48
	Barriers	2 [1 new]	15 (2)	8
	Enabling Factors	0	15 (3)	14
PETROBALTIC Second level	Mechanisms	0	6	8
	Secondary impacts	8	19	48
	Barriers	1	12 (3)	15
	Enabling Factors	3	19 (2)	15

Many findings are pointed out by this comparison. First of all, the model predicts many more entities than the ones cited by the company. This is due to the fact that the model is completely generic, so many entities do not concern EPC sector, or many entities concern only one of the two level of modularisation. This is extremely useful to facilitate knowledge and best practice among different industrial sector. This work will provide a complete but not overabundant list of entities involved in the modular approach. Moreover, few entities are cited by the company but not identified by the model. This could be explained in two ways. The first is the company has activated more mechanisms with an implicit knowledge and implicit behaviours, so it might be that the company could activate some mechanisms without even being aware of it. The second hypothesis is the lack of accuracy in the model's connections among entities. This is because connections were established only on a literature base. This work will fill this gap, considering all the entities in the EPC sector, gathering information both from literature and real practice.

Mechanisms involved are always "Module Design", "Interfaces Design", "System Physical Decomposition", and "System Functional Decoupling", sometimes in addiction to some other mechanisms which have lower importance, such as "Minimise Inter Module Interactions" or "Interfaces Standardisation". All the mechanisms concerning standardisation, in the first level of standardization, are ignored by the company modus operandi. This is also in accordance with the entities in brackets. Emerged existing barriers are mainly the absence of "Use of repetitive component in the design", "Use of standard procedures", "Project Repetitiveness", and the "High levels of customisation required" for both projects; the first three could be also seen as enabling factors if activated. These entities have prevented a complete modular approach: standardisation is a pillar of modularisation, and these entities has lead to a "non-optimum" modular approach. Moreover, each project faced specific problems, connected to specific entities, such as "Incapability to timely freeze the basic design", "Design constraints established in the early design phases", "Well defined project scope and budget", "Early availability of information" (in Petrobaltic), and "Lack of coordination and collaboration between stakeholders" (in Marlin). The entities specifically related to a single project, are entities that it is very important to keep under control for the successful outcome of the modular approach. It is easy to lose the control of one of these entities, and it could bring to a delay (and/or extra cost) of the project.

The previous mentioned "within case" analysis has lead to the conclusion that in the EPC sector, only few entities are involved in the modular approach, but they have strong impact on the success of the project. It is so necessary to well understand all the involved entities, so that decision makers could focus on those. A further important result concerns the mechanisms. There is a strong difference between theoretical modularisation and real practice, with the lack of standardisation. Each project is a prototype, even if the scope of different projects could be similar. Clients have the bargaining power to impose their needs and their specifications. Moreover, suppliers have their standardised solutions (big items, or technical solutions that require a specific amount of space or weight), so the contractor adapts its solutions according also to the suppliers' needs. A higher ratio of standardisation could bring to advantages in terms of costs and time, but it will be necessary to negotiate with the client to win his resistance.

Comparing the results gathered from the two cases, specific results (tables 3, 4 and 5) are presented in order to create a first draft of the optimised model. From this list of impacts, it is possible to highlight the main positive aspects of a modular approach. For the first level, the model points out the following characteristics:

- COST: many entities concern costs. Modularisation brings to both reduction and increase of some kind of costs, as shown in the list of entities. The overall result is a reduction of total cost;
- TIME: work parallelisation leads to a reduction of the overall lead time of the project, even if more time is required for transportation and engineering;
- MANAGEMENT: the management of the project could be easier due to high reliability of estimates of single modules, but it could be difficult to manage the fact that the design must be done and frozen before the starting of the construction;
- SAFETY: an increase of safety due to controlled environments, comfortable positions;
- ASSET: an easier maintenance and disposal is possible, but modules bring to an increase of material and weight.

For the second level, most of the aspects are similar to the first level. In addition to that, in the second level, it emerges that the possibility to outsource an entire skid reduces the complexity of the project in its entirety, thanks to the commitment of an entire skid to a supplier as a black box, even if more effort is required in managing interfaces among skids.

For both the first and second level together, a total number of 57 impacts have been cited (28 for the first level, and 45 for the second level).

TABLE 3 LIST OF IMPACTS INVOLVED IN THE CASES

IMPACT	FIRST LEVEL		SECOND LEVEL	
	MARLIN	PETROB.	MARLIN	PETROB.
Increase of material use, mass and size	X	X	X	X

Enabling of work parallelisation	X	Main impact	X	Main impact
Reduction of delivery time	X		X	Main impact
Reduction of construction time	X	Main impact		
Increase of transportation cost	X	X		
Decreased of flexibility for on site modifications	X	X		Low
Simplification in retrofitting and revamping operations		Main impact		
Increase of safety	X	X	X	X
Reduction of technical risks	X	Low		
Simplification of planning and scheduling	X	Low	X	Low
Simplification of commissioning and start up	X	X	X	X
Improvement of disposal	X			
Increase of the need of special staff	X	X		
Reduction of site-based permits	X	Low		
Reduction of expat workers	X	Low		
Increase of productivity	X			
Increase of schedule robustness	X	Low		Low
Compression of the delivery schedule in procurement operations	X	X		X
Reduction of on site labour	Main impact			X
Reduction of procurement cost	Main impact			
Simplification of assembly/disassembly		X	X	X
Increase of bulk material cost		Low	X	X
Reduction of construction costs	Main impact	Low		
Reduction of costs of transporting workers	Main impact	Low		
Reduction of overall costs	Main impact	Low	X	
Reduction of manpower costs	Main impact	Low		X
Simplification of costs estimate generation		Low	X	Low
Reduction of plant complexity		Low		
Easier product diagnosis		Low	X	X
Increase of the degree of autonomy/responsibility of the suppliers in system Design			Main impact	Main impact
Increase of the degree of autonomy/responsibility of the suppliers in system Development			Main impact	Main impact
Increase of the degree of autonomy/responsibility of the suppliers in system Manufacturing/Assembly			Main impact	Main impact
Increase of the degree of autonomy/responsibility of the suppliers in system Testing			Main impact	
Reduction of development process complexity			X	Low
Improvement of quality control			X	X
Increase of testability			X	X
Increase of structural stability			X	
Initial design effort and time required to develop the product			X	X
Reduction of Lead-time				Main impact
Enabling of economies of learning			X	X
Reduction of engineering costs			X	Low
Improvement of capacity flexibility			X	X
Enabling of risk decoupling			X	X
Reduction of Manufacturing/Assembly process complexity			X	Low
Decrease of the need of coordination between developers			X	
Decrease in communication during the system design process			X	
Reduction of Coordination/Communication effort			X	
Increase of specialisation and labour division between the supply chain firms			X	Main impact
Enabling of arm's-length relationships between the company and its suppliers			X	Main impact
Increase of competition between modules suppliers			X	
Increase of outsourcing degree			X	Main impact
Increase of supply chain vulnerability			X	X
Increase of dependence on modular consortium partners			X	X

Increase of replacement parts availability			X	
Decrease uncertainties about completion date				Low
Enabling of economies of substitution				Low
Reduction of overall complexity				Low
Reduction of control processes complexity				Low

A similar analysis is done for both barriers and enabling factors, shown in table 4 and 5.

TABLE 4 LIST OF BARRIERS INVOLVED IN THE CASES

BARRIERS	**FIRST LEVEL**		**SECOND LEVEL**	
	MARLIN	**PETROB.**	**MARLIN**	**PETROB.**
Availability of storage areas for preassemblies and materials	X	X	X	
Lack of available fabrication yards	X	X		
Lack of Lifting and transport equipment at the construction/production site	X	X		
Design constraints established in the early design phases	X	X	X	Not broken
High probability of severe weather conditions that could affect transportation	X	Low		X
High transportation fees and tariffs	X	Low		
Lack of transport Infrastructure	X	Low		
Module size and weight limitations in transport	X	X		X
Internal aversion to organizational changes	X	X		
Lack of coordination and collaboration between stakeholders	X	X	Not broken	X
Lack of resource for extra staffing	X	X		
Site layout constraints	X	X		
Designers' aversion to modularity		X	X	
Lack of experience about modularisation		X		X
Lack of knowledge		X		X
Owner's aversion to modularisation		X		X
Scarce availability of time for product development	Not broken			
High level of customization required	Not broken	Not broken	X	Not broken
Incapability to timely freeze the basic design		Not broken	X	Not broken
High degree of dependence on client's knowledge of service developers firms			X	X
Unclear division of labor and competences			X	X
Lack of trust and collaboration between buyer and its suppliers			Not broken	X
Geometric, structural and functional constraints				X

From the analysis of enabling factors and barriers, main issues about modularisation concern site conditions, yard availability, transport infrastructure and special lifting and transport equipment. All these entities are necessary conditions for a modular approach. It is also necessary an early decision on the adoption of a modular approach, with the early involvement of all the stakeholders, and the availability of the information needed to make decisions. Some stakeholders are averse to a modular approach (e.g. designers, due to more effort in engineering and more effort in managing interfaces, or the client itself, which does not know deeply this approach), so it is important to successfully face their resistance.

In the second level, many entities concern relationships with suppliers, which are a key stakeholder in the project. It is important to cooperate with suppliers and to clearly defined and allocate responsibilities.

For both first and second level together, the analysis brings to consider 23 barriers (19 for the first level, and 15 for the second level) and 28 enabling factors (20 for the first level, and 26 for the second level).

Results from the analysis could be used to implement a complete, concrete and ready-to-use model in order to qualitatively support decision makers from the project feasibility study to the control of an ongoing project.

TABLE 5 LIST OF ENABLING FACTORS INVOLVED IN THE CASES

ENABLING FACTORS	FIRST LEVEL		SECOND LEVEL	
	MARLIN	PETROB.	MARLIN	PETROB.
Awareness of modularisation benefits	X	X	X	X
Early availability of information	X	Not enabled	X	Not enabled
Early decision on modularisation adoption	X	X	X	X
Early involvement of top management in the decisions about modularisation	X	X		
Extreme climatic conditions at site	X			Low
Scarce and/or high-cost labour at site	X	Low		
Sites in remote locations	X	Low		Low
Fabrication yard availability	X	X		X
Lifting and transport equipment capabilities availability at site	X	X		Low
Transport Infrastructure availability	X			Low
Site accessibility and attributes	X	Low		Low
Well defined project scope and budget	X	Not enabled	X	X
Project repetitiveness	Not enabled	Not enabled	X	Not enabled
Use of standard procedures	Not enabled	Not enabled	X	Not enabled
Use of repetitive components in the design	Not enabled		X	Not enabled
Communication, Coordination and Information sharing between stakeholders		X	X	
Stakeholders alignment		X		X
Organization/Contractor's familiarity and experience on modularisation		X	X	X
Owner's (Client) investments in early feasibility studies on modularisation		X		X
Suitability of design for modularisation		X		X
Clear division of labour and competences			X	X
Enduring relationships with suppliers			X	X
High level of prefabrication			X	X
Modular supply chain			X	X
OEMs and Technology Partners early involvement in the decision making process			X	
Supplier physical proximity			X	
Trust and collaboration between buyer and its supplier			Not enabled	X
Evaluation tools and data availability				X

V. CONCLUSIONS

This work fills the gap between the theoretical perception of modularisation, and real practice in EPC companies. The analysis of two cases has pointed out the lack of awareness about some of the modularisation relevant aspects. During interviews, it has been possible to recognize many issues concerning the application of the theoretical framework in the real practice. First of all, the identification of mechanisms, that represent the strategy of the company to deal with projects, was the most problematic issue. In a long term horizon, a consolidate and clear strategy will successfully affect performance of a company. Introducing the class of mechanisms in a company means to start a structured strategic thinking which can lead the company to manage their projects more effectively and efficiently. This work provides a model that include all the main issues about a modular approach in the Oil and Gas EPC context, starting from the entities involved in the realization of a modular project (actions to implement), in order to reach specific benefits and to limit all the negative issues. Moreover, the optimized Ontology will become a concrete, complete and ready-to-use support instrument for decision makers of project stakeholders. It could be also used as support for negotiation with the client. Future researches could increase the number of assessed cases, so that the model would be better tuned, even if main issues about modularisation could be pointed out also in a single case analysis.

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