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PROJECT BENEFITS

KEYWORDS
Project Management • Contracting strategy • Complex systems modelling • Risk and vulnerability analysis • Oil and gas projects

Assistance in selecting a project CONTRACTING STRATEGY by combining COMPLEX SYSTEMS theory and risk and vulnerability analysis.

• ABSTRACT •

Oil and gas development projects involve many contracts for engineering studies, item procurement, construction workforce, installation or commissioning. One key component of such projects is the definition of a contracting strategy, which consists of breaking the project down into work packages that will be awarded to contractors with specific remuneration and supervision modes. Indeed, it links global design with the local contracts and internal activities that must be undertaken to deliver the results. Risks are associated with every contract as well as with the interfaces between the client and contractor and between the contractors themselves. The problem is then to select an adequate contracting strategy, considering the risks that may occur before or after signing a contract, with direct and possibly indirect and higher impacts. This communication aims to present a method for analyzing the risks of such contracting strategies. The analysis focuses on technical and organizational interfaces, notably contractual ones that exist within these alternative strategies. The expected result is a risk analysis process and tool, which is included in the global project contracting strategy selection process. An industrial application in an international oil and gas company will be presented.

1. INTRODUCTION

Oil and gas development projects involve a great many contracts (Jin and Jorion, 2006); (Olsen and al, 2008) for engineering studies, item procurement, construction workforce, installation or commissioning. The subcontracted part of a project's budget and effort may be up to 80%. Projects themselves represent hundreds of millions to tens of billions of euros and can last several years before the first oil and the beginning of the operations phase. The risks associated with the preparation, awarding and execution of such contracts are huge, especially once they are signed (Furstenberg, 1969); (Posner, 2003). The reason is twofold: first, the project enters the most contributive phase of its lifecycle, development, which includes construction and installation; second, changes on signed contracts are more expensive than changes on a design draft or an intentional statement of work. One key moment for such projects is the definition of the contracting strategy (Ramsay and Wilson, 1990); (Cook and Hancher, 1990); (Bayraktar and Hastak, 2009), since it links the global design of the oil and gas installation to the more precise contracts (and internal activities) that will have to be undertaken to deliver the results. Risks are associated with each contract as well as with the interfaces between the client and contractor, between contractors and subcontractors (or suppliers), and between contractors themselves. (Griffiths, 1989) states that "the contract establishes the risks to be carried by each party. The general principle suggested is that risks should be carried by the party best able to either control or estimate them." This complexity justifies the use of a systems-oriented interaction-based approach to model and analyze potential issues associated with the different "set of contractual strategies" (Chan and Ann, 2005).

Several authors have defined the term contractual/contract strategy:

- "Contract strategy deals with the division of the project into separate contracts, and the form and the conditions of the contract most likely to encourage satisfactory completion, whilst providing controls and opportunities to the owner or contractor to rectify problems before they cause serious difficulty to the project" (Griffiths, 1989).
- The contract strategy defines the relationships, duties, obligations and policies which are directed/engineered towards the desired successful total project delivery in accordance with the project planning, financial strategy, project brief, and consents and permits (Abdul-kadir and Price, 1995).

In our case, a contracting strategy consists of breaking the project down into work packages that will be awarded to contractors, with specific remuneration and supervision modes. This paper aims to present a method for analyzing the risks of such contracting strategies. The analysis focuses on technical and organizational interfaces (Jin and Robey, 2008), notably contractual (Williamson, 1988); (Petrucco, 2002); (Ventroux, 2016), that exist between the elementary pieces of work within these alternative strategies.

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A systems-based matrix model is introduced in Section 3 to analyze the dynamics of the project as a combination of interdependent contracts. The expected result is a risk analysis process and tool based on the vulnerability approach presented at Section 4. This helps to compare alternative strategies and enhances communication and common vision-sharing between the different actors implicated in this process, as illustrated in Section 5. An industrial application will be presented in Section 6, and the discussion and conclusions will be presented in Section 7.

2. METHODOLOGY

The aim of the methodology is to assist the choice of a contractual strategy by considering its risks and vulnerability at the execution phase. Selecting a contractual strategy consists in making the three following decisions:

- Breaking the project down into several possibly interdependent contracts,
- Selecting for each contract the most appropriate contractor according to the scope and contractual interfaces,
- Selecting the remuneration mode to be used for each contract.

Each of these decisions is based on modeling (dynamic systems) and estimation of risks by vulnerability approach in order to select an alternative according to its performance and robustness. Therefore, a comprehensive analysis of risks associated with these decisions is made. It highlights the direct and indirect consequences of the selection of one contracting strategy alternative or another, not only on direct performance indicators such as cost and time but also in terms of risks related to the contract breakdown and associated interfaces. It allows one to prepare for the implementation of the chosen contractual strategy and to justify the non-inclusion of unselected alternatives.

There are two levels of modelling and analysis: the global level (project) and the local level (contract). We will use complementary ways of descending and ascending approaches to navigate from one to the other and to study the consequences of a decision, for example, at the local level, and of other decisions either at a global or at a local level, but in another section of the project. For example, the selection of contractors and remuneration modes is done at the local level but can have repercussions at the global level if, for example, a contractor cannot work at an interface with another contractor on another contract. This means that each decision is not considered as isolated and independent from the others, but interfaces (technical between product items, physical between construction site areas, or temporal between lifecycle phases) are taken into account to anticipate the influence of one choice over other choices somewhere else in the project.

3. MODELLING PROJECT AS A COMBINATION OF INTERDEPENDENT CONTRACTS

The execution phase (after the signing of the contract) of an oil and gas complex project can be represented by a contractual strategy developed by several interdependent contracts (Figure 1). This phase is structured through the contracting phase where the contractual strategy is elaborated and validated. This phase is essential for the project because it limits the risks concerning the contractual relations between the stakeholders. (Zaghloul and Hartman, 2002) explain that the "current contractual relationships are mainly based on confrontational situations that reflect the level of trust (or mistrust) in the contract documents. This can be the driver to increase the total cost of a specific project and affect the overall relationship between the contracting parties." It is therefore important to analyze and anticipate the risks, either in signing contracts (cost at signature, date of signature) or related to their future execution (final cost and delivery date). Contract scope may vary from one contractual strategy alternative to another, as do the risks associated with this contract and their management. For instance, a risk associated with a technical interface may consist of a single contract or may be a contractual interface between two separate contracts. The existence and magnitude of some risks, or of the risk-sharing between buyer and contractor, may be influenced by some factors, like size (Dey, 2001) and remuneration mode (Hartman and Snelgrove, 1996), (Pfeffer, 2010). A last factor is the number of contractors (Jefferies and al, 2004), (Corvellec, 2009) that may potentially respond to a Call For Tender, depending on the characteristics of the contract and its position in the contracting strategy. This justifies using interactions-based modelling techniques, such as graphs and matrices. The method here consists of modelling and analyzing risks related to contracts and their internal and external interactions, based on a DSM (Dependency and Structure Modelling) approach (Steward, 1981); (Marle et Vidal, 2008); (Eppinger and Browning, 2012).

The following sections describe three matrixes that model the problem at two detail levels: the project level and the contract level.

--- 3.1. The Contracting Strategy (CS) matrix (project level) ---

The first matrix, called CS, defines the cells Cij at the intersection of Work Package WPi and the Phase Pj (Fig. 1). A contract can be a single cell or an assemblage of several cells, either several phases of the same Work Package and/or several Work Packages in the same Phase. Fig. 1 describes an example of a deep offshore oil and gas project with a description of Packages and Work Packages, as well as examples of contracts characterized by different colors. This is how contractual strategies are currently represented in the company.

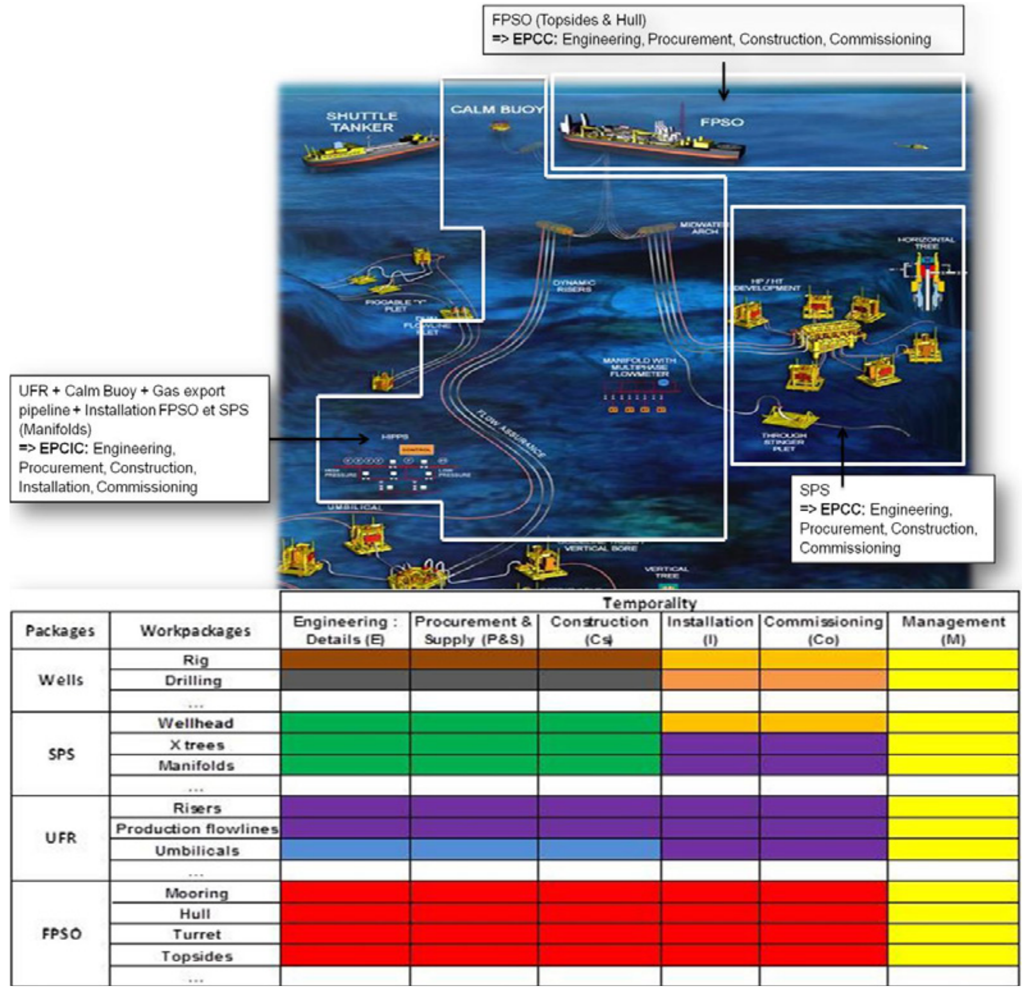

FIGURA 01. Example of a Contracting Strategy (CS) for a deep offshore oil and gas project

The following section introduces detailed information for each cell of the CS matrix, knowing that a contract is made of one or several cells.

--- 3.2. The Risks / Cells (RC) matrix (contract level) ---

The second matrix RC is developed in order to estimate the internal vulnerability of each of the contractual activities (contractual cells). It is structured in the following manner (Fig. 2):

- In the columns, the different contractual cells constituting the execution phase of the project (after contracting phase) are listed.
- In the rows, the risks and constraints that may impact a cell of the contractual strategy are identified.

To facilitate the use of this matrix, a list of risks and constraints has been defined (Ventroux, 2016). For this, we relied on project feedback from the TOTAL company as well as on the literature: (Chapman et Ward, 1996), (Cooper and al, 2005), (Arain et Low, 2006), (Petit, 2008), (Bernard et al,

		Detail Engineering									
		Riser Pull-in System	Topsides	Hull	Mooring	Tandem Offloading	OLS, OOL...	PCM and HPU modules	SSU Umbilicals	No SSU Umbilicals	Riser
	Risks & Constraints										
	Engineering										
R1	Design criteria (Consistency, Lack of data, Change in specifications)										
R2	Quantities Définition (Ratios, Basis for calculation, Scaling factors, interfaces...)										
R..	...										
R6	Changes in scope (Late modifications, Re-design, Re-work, Compatibility, Maturité du design)										
R...	...										
	Fabrication & Construction										
R8	Fiabilité : Infrastructures & Matériels										
R9	Capacity of production & fabrication (Concurrences de ressources matérielles avec d'autres projets)										
R..	...										
	Installation										
R11	Site selection and preparation (Civil works, Earth movements, Foundations, Piling, Load capacity ...)										
R12	Simultaneous operations - SIMOPS (Hot works permits, Shut down partiel, forage, POB capacity) et COMOPS (Commande operation)										
R..	...										
	Commissioning										
R17	Commissioning & Hand over (Equipment Contrôle and Test, Reworks, Start-up, Handover to operations)										
	Procurement (logistique & achat...) "Fourniture"										
R18	Non respect of the quantity ordered										
R19	Non-compliance with the delivery date - Delivery Planning (long lead items, interfaces)										
R..	...										

FIGURA 02. Example of a Risks / Cells matrix (RC) for a deep offshore oil and gas project

2009), (Maders et Masselin, 2009). To keep the analysis simple to use and limited in effort and time, we were restricted to 60 criteria (combining risks and constraints). Moreover, this list follows the Pareto law: 80% of the risks and constraints can be used in other projects, and the remaining 20% are risks that are specific for the context of the project.

The model theoretically includes several dozens of rows and columns, but it does not aim at being manipulated as it is. Indeed, the studies are conducted with a more local scope for one or several cells (which may constitute a contract). This can allow for detecting the presence of the same risk in several cells, which could indicate a common or even chronic vulnerable phenomenon that should be treated.

--- 3.3. The Cells / Cells (CC) matrix (contract level) ---

The third matrix CC focuses on the interactions between contractual cells that could impact the success of the project. Each cell is thus subject to an interaction study in CC as well as a risk analysis via the previous RC matrix.

The CC matrix exists in a binary version and a weighted version. At the intersection of row i and column j, CCij=1 when there is a potential influence of the element i to the element j. Similarly, the weighted CC matrix contains the vulnerability evaluation of the element CCij for the potential influence that element i may have on element j.

--- 3.4. The new CS matrix, including information from RC and CC ---

After modelling the three matrices, by combining the risk-based and interaction-based visions, we propose an updated version of the CS matrix (Fig. 1), consisting of estimating several vulnerabilities per cell, regarding the following:

• Input vulnerability (what upstream failures/causes is the cell vulnerable to?),

• Internal vulnerability (in distinguishing those linked intrinsically to the activity to be undertaken and those more contextually linked to the contractor who performs the activity),

• Output vulnerability (which activity/who is vulnerable to cell failures?).

An example will be shown in the Application Section.

--- 3.5. Analyze of dynamics systems ---

The analysis of the dynamics in a project is not used very much in the companies. Despite the important contributions in the literature realized among others by: (De Rosnay, 1975), (Le Moigne, 1990), (Le Moigne, 1994), (Rodrigues and Bowers, 1996), (Chapman, 1998), (Maylor et al., 2013), (Davies and Brady, 2016), (Ventroux, 2016), (Wang and al, 2017)... This may be due to the difficulty of taking into account dynamic phenomena in a system composed of multiple elements (products, actors, activities, etc.).

The state of a project, the state of its elements and their interactions, is constantly changing over time. The behavior of a complex project is characterized by a chaotic linear or non-linear behavior, with loops of feedback or amplification, emerging phenomena... As for loops, a feedback loop is defined as "A mechanism for returning system information that is directly dependent on the output of the system" (Donnadieu et al., 2003); (De Rosnay, 1975). Within this article, we will identify, analyze and seek to master these dynamic phenomena in order to avoid bringing the project towards instability and chaos.

4. ESTIMATING VULNERABILITY AT THE CONTRACT AND PROJECT LEVELS

--- 4.1. Definition ---

The vulnerability method allows studying simultaneously the risk (uncertainty) and the targets of these risks (ability to resist, to be resilient and to adapt to hazards). The vulnerability concept in the literature is used in several domains, such as health, environment and climate (Adger, 2006), and socioeconomic (Allison et al, 2009), and appears to be an exciting and innovative concept for effective risk management, particularly in the context of project management (Zhang, 2007), (Vidal, 2009). It helps in particular to take into account the many interactions between elements (Marle and al, 2013), (Chung and Crawford, 2016), (Yang and al, 2016).

(Vidal, 2009) explains that the vulnerability allows the risk analysis process (identification and estimation) to be more tangible for members of the project team instead of working on potential events. This implies that a target may be somewhat vulnerable, although the event to which it may be exposed (source) can be critical, as a result of the target having a high capacity for resistance and/or resilience to absorb the criticality of this source event. The information is richer since it is about a couple (event, element potentially affected by the event).

--- 4.2. Estimation scales ---

To obtain the capacity to estimate the vulnerability of a target, we propose to use the following scale (Fig. 3). This was defined and validated by decision-makers from the oil and gas company. During use, we recommend taking into account several criteria:

• Criticality of the source: Gravity and occurrence

• Mastery of the target: Own capacity to defend itself (resistance), Available resources (human, financial, time, technology...), Performance management, notably for reaction (resilience).

This enables one to distinguish between the immediate impact and the recovery after impact to be made. This allows for estimating the vulnerability of a target relative to a source. A cell or a contract can be both.

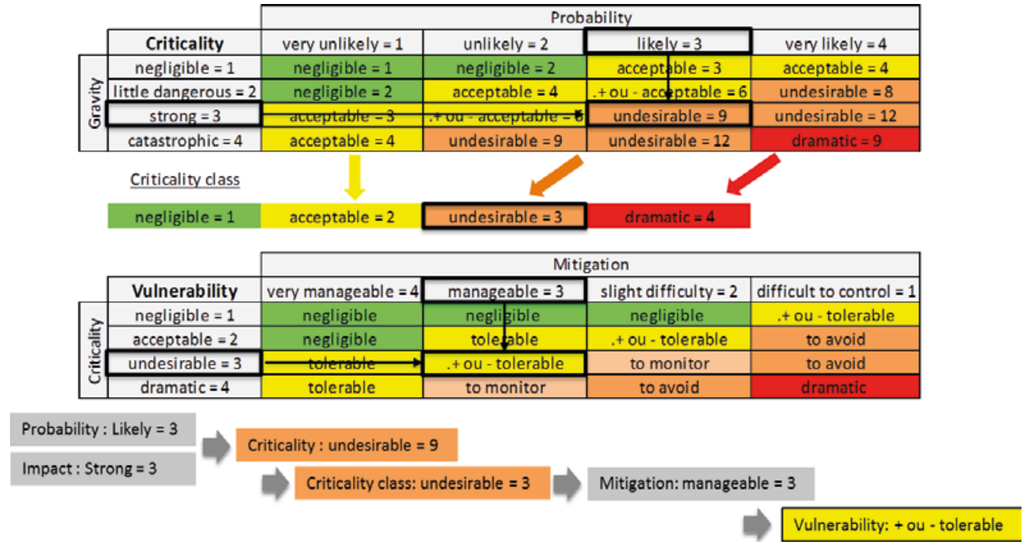

FIGURA 03. Example of vulnerability scale

--- 4.3. Estimation while considering internal and external vulnerabilities (input and output) ---

Two types of estimates are to be considered: internal and external vulnerabilities (either input or output, the type of estimate is similar). For this, we take the example of an activity, B, corresponding to a cell of the CS matrix. As shown in Fig. 4, activity B is subject to several risks: A, B, C, F, J and M. Each of these risks has some classical characteristics (occurrence or probability, and impact or gravity). The criticality is calculated as the product of both data, and a class of criticality is assigned using grids of Fig. 3. Then, depending on the capacity of the activity B to mitigate (either by resisting at impact or by recovering after impact), an estimate of vulnerability of activity B to each risk is given (right side of Fig. 4).

probabylity	gravity	criticality	Class of criticality	mitigation		activity F
4	3	12	3	3	risk A	1
3	1	3	2	4	risk B	0,5
2	2	4	2	3	risk C	0,67
1	2	2	2	3	risk F	0,67
3	3	9	3	2	risk J	1,5
4	3	12	3	1	risk M	3

Internal vulnerability : activity B (simple average)	1,22

FIGURA 04. Example of vulnerability in Internal of activity B

probabylity	gravity	criticality	Class of criticality	mitigation		activity F
2	3	6	2	3	activity A	0,67
4	1	4	2	4	activity C	0,5
4	4	16	4	1	activity E	4

Input vulnerability : activity B (simple average)	1,72

FIGURA 05. Example of vulnerability in Input of activity B

A similar analysis is made for inputs and outputs of each cell/contract, considering for instance the predecessors of B (activities A, C and E) and its vulnerability to these predecessors.

These scales can be used at different levels, either local (one cell or one contract) or global (project). The following section introduces the two complementary approaches to connect these levels.

--- 4.4. Estimation methodology combining top-down and bottom-up approaches ---

The first approach is to analyze the data at a global level. According to their vulnerability level, the analysis can be refined at a more detailed level. This method has the advantage of being less time-consuming and is simple to use. However, it has the disadvantage of not sufficiently highlighting the weak signals. The second approach starts from the most detailed level (local level) of analysis and is able to filter up the weak signals and aggregate the results to the global level (contractual strategy: project level). This allows for more precise results and can therefore be an effective aid to decision making. However, it is time-consuming, and its use is more complicated than the first approach.

In the Industrial Application Section 6, the modelling and analysis stages will be combined to present both approaches.

5. ANALYZING ALTERNATIVE SCENARIOS AND MAKING RECOMMENDATIONS

To improve the performance of the contractual strategy and mitigate its risks, is it preferable to follow a traditional pattern or to study more promising but never experienced alternatives? We argue that several alternatives should be built using elements from past experience as well as testing new configurations (for the three decisions about breakdown, contractor and remuneration mode selection). Elements of comparison are given, since no absolute score is appropriate in this case.

--- 5.1. Building alternative ---

For this, we asked different actors from the company, different actors with academic backgrounds, and we conducted a literature review on the subject of contractual strategy selection. The main questions are these:

• When a contractor is defined with respect to the cells of the contractual strategy, is it better to create a « big » contract in order to reduce costs (« wholesale price ») and to have the same contractor who manages a maximum of risks or to delegate some of these cells to other contractors, even if their vulnerability level can increase? Creating a "big" contract can make the contractor too influential for the project. The company may lose negotiation power and could barely influence decisions throughout the execution.

• Should we encourage the creation of small contracts (represented by a single cell) in order to promote the emergence of smaller contractors, such as local contractors?

• Is it better to group dangerous interfaces within the same contract or let the interaction between two contracts be managed by the company?

• If several contractors have vulnerabilities in relation to a contract but on different cells of this contract, which contractor should be prioritized?

• Should we necessarily define a contractor for each cell, or would it be possible to reintegrate some cells by directly managing subcontractors and suppliers?

• Is it better to perform mostly classical EPSCoICs (« turnkey contracts») or to split the contract into at least two contracts, such as ECoI (Engineering-Construction-Installation) and PSCs (Procurement-Supply-Commissioning)?

The next section introduces elements for comparing alternatives in order to eliminate the less appropriate (or even inappropriate) ones and to highlight those that could be interesting before a final round of selection.

--- 5.2. Comparing for screening out / prioritizing alternatives ---

Previous models and analyses serve as a basis to recommend appropriate alternatives. Details are given for each of the three decisions which contribute to the construction of a contractual strategy. However, it should be noticed that contrary to the sequential organization of this section, they are intertwined, and a decision about a contract's scope (project breakdown) may influence contractor selection, both for this contract but also for another interrelated contract.

5.2.1. Contractor selection

Several studies are currently underway on the selection of contractors (Holt, 1998), (Fong and Choi, 2000), (Cheng and Li, 2004), (Watt and al, 2010), (Chiang and al, 2017). Nevertheless, this selection can be further improved. To select a contractor, we propose to consider the vulnerability of the contract (one or several cells of the CS matrix) in addition to classical parameters as well as the vulnerabilities of its interfaces. Although two cells are not vulnerable, given their internal risks and proposed respective contractors, they can quickly evolve into chaos if a potentially dangerous relationship between these two cells (or contractors) is not properly considered. Let us consider the example of a company which believes in engineering performed by contractor A and manufacturing carried out by contractor B. These activities are both somewhat vulnerable. However, if the company has not taken into account that the two contractors do not speak the same language or even a common language (their English is not sufficiently fluent), this is likely to create great difficulties and significant delays in providing the expected shared outcomes and deliverables.

To select the best contractor in relation to a contractual perimeter, we propose a method based on analyses carried out internally within the TOTAL Company but also due to the use of ADRAI matrices: "Activities, Deliverables & Requirements, Actors and Interactions between actors" (input and output vulnerability) and RCCCS: "Risks & Constraints Cells vs the Contractual Strategy" (internal vulnerability).

5.2.2. Remuneration mode

The decision to select the most appropriate remuneration for the context of a contract is among the most important but also complex ones in the life cycle of the project. It is based primarily on the experiences and skills of the decision-makers. (Howard and al, 1997); (Bajari and al, 2001); (Turner and Simister, 2001); (Cooper and al, 2005); (Larson and Gray, 2007); (Antonioua and al, 2013) have studied the pros and cons of the remuneration mode which is used in the preparation of contracts: cost plus fixed fee, cost plus percentage fee, cost plus incentive fee, incentive/disincentive for time reduction, fixed price incentive, lump sum/fixed price, unit price method, open book.

To improve the selection of remuneration to be used with respect to the scope of a contract, we suggest not defining systematically a single remuneration for a contract, but possibly a remuneration mode that could be appropriate to each cell belonging to the contract (i.e., several remuneration modes for a contract).

5.2.3. Work Breakdown contracts

The decomposition of the contractual strategy of the project is carried out taking into account the effort of monitoring to be provided in order to follow the performance of contractors, the relative strengths of each contractor and the company operator during the signing (before and after signing the contract), as well as the risk levels of each contractual cell.

5.2.4. Decision-aid comparison

In the end, when making decisions, comparisons of contractual strategies are performed by estimating the internal hazards and interface risks. The comparisons aim at selecting the least vulnerable configurations. At this stage, we remind the reader that each of the above points (cutting, contractor, remuneration) are interdependent. For example, the selection of a specific contractor may or may not increase the risks in the project for successive reasons:

• This contractor is less competent to perform the technical and contractual scope;

• This perimeter is being transmitted to a less competent contractor, and the perimeter has a high probability of becoming riskier;

• Being riskier, this perimeter requires a more appropriate remuneration mode. For example, this scope might require a more flexible remuneration, one that offers more margin of manpower to the contractor.

5.2.5. Consequences on setting contracts

When drafting a contract between the TOTAL Company and a contractor, a partner or with the local oil and Gas Company, two parts should be included:

• Agreement: this parts consists of several sub-parts, such as definitions and objectives of the agreement, financials, shared responsibility and the different insurance (...), and

• Exhibits: this second part consists of contractual documents, such as specifications, payment schedule and work to be performed, work performance conditions to achieve, lists of subcontractors and suppliers (...).

(Rouvière, 2010) stipulates that some parts of the « Exhibits » section are sometimes recognized as purely informative and not like normative. Through the analysis of previous risk, we propose to improve the "Exhibit" section with the inclusion of vulnerable elements and interactions, as well as with the low-intensity signals underlined so all the stakeholders can have a better perception and share a common vision of the project. Several studies have been performed on the topic of the stakeholders' perceptions (Alinsiku and Akinsulire, 2012), (Davis, 2014), (Mok and al, 2014).

Recommendations for the elaboration of contracts (scope, type of remunerations, elements and interactions most dangerous to the project) as well as the management of contracts and of contracts between them will be proposed.

6. CASE STUDY IN THE OIL AND GAS INDUSTRY

The approach was applied a posteriori to a large offshore project. The data were anonymized. The exploration area includes four subsea reservoirs located approximately 40 km from the coast of a West African country, 200 km from the shore base and between 600 m and 1 200 m of water depth. The delivery date of the project was 44 months for 200 000 barrels of oil per day and a budget of several billion dollars. The FPSO (Floating Production, Storage and Offloading) was the largest in the world with a complex submarine network (600 square km). Technological innovations were introduced regarding the separation of gas on the seabed and the pumping of liquids by the FPSO. These innovative technologies were essential to overcoming the main challenge of the project: the production of heavy, viscous oil from the Miocene reservoirs, which represented two-thirds of the reserves. Many new technologies have been proven and qualified through the project and are now available to the oil industry worldwide.

Note: due to confidentiality and to the difficulty in making them readable (some matrices consist of more than 10 000 cells), it is difficult to adhere completely to the traditional A4 format of an article. Nevertheless, some zooms will be done in order to justify our results and/or methods.

--- 6.1. Descending approach ---

6.1.1. Global level

In this first approach, we start by considering several different contractual strategies (Fig. 6). The number of contractual strategies depends mainly on the number of bidders and the number of possible contractual cuttings. In this analysis, some internal cells are not estimated because they are not within our scope (a focus on the FPSO and interactions). This is why some cells are marked NA (Not Applicable).

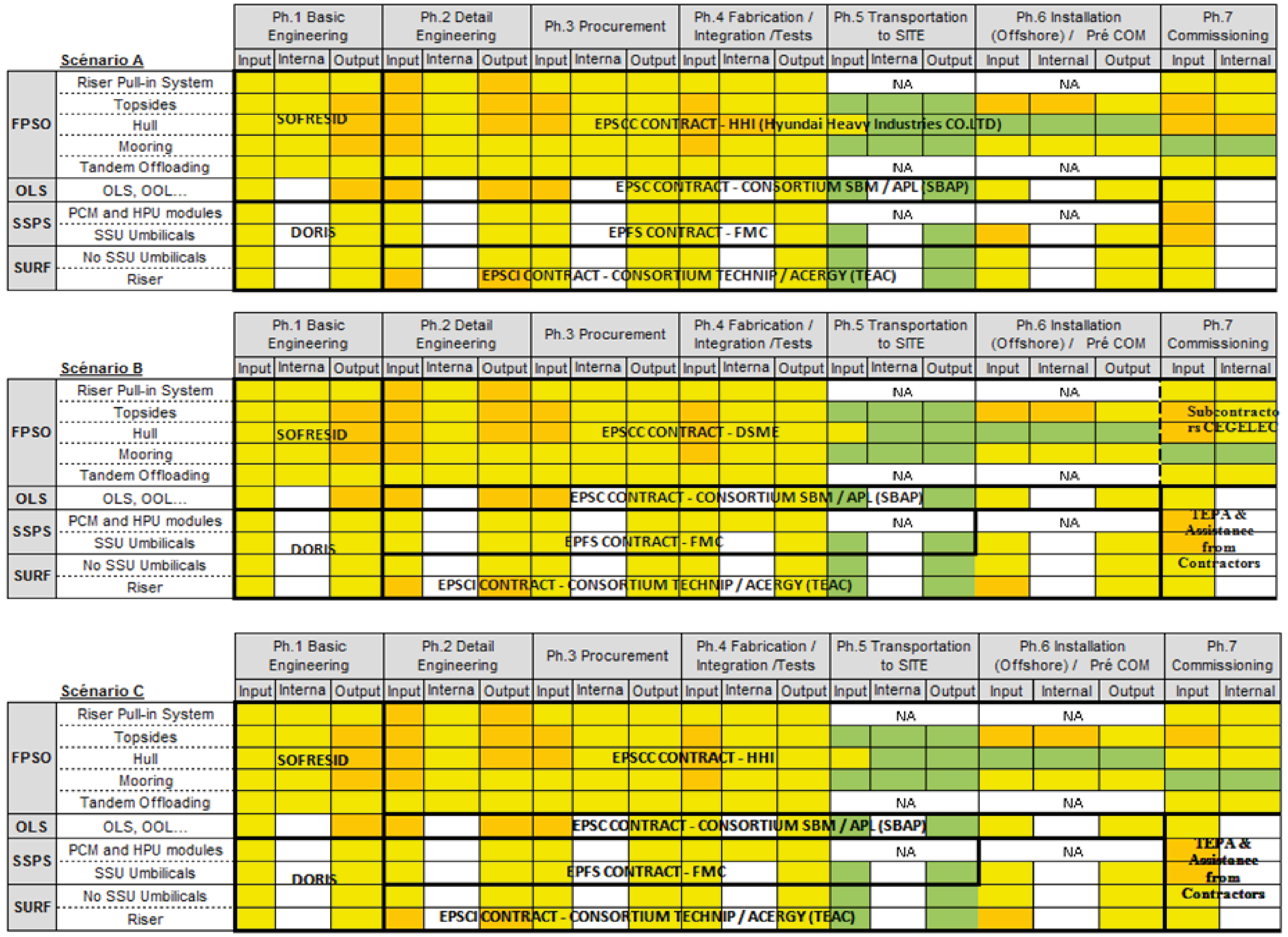

FIGURA 06. Example: different contractual strategies to be evaluated

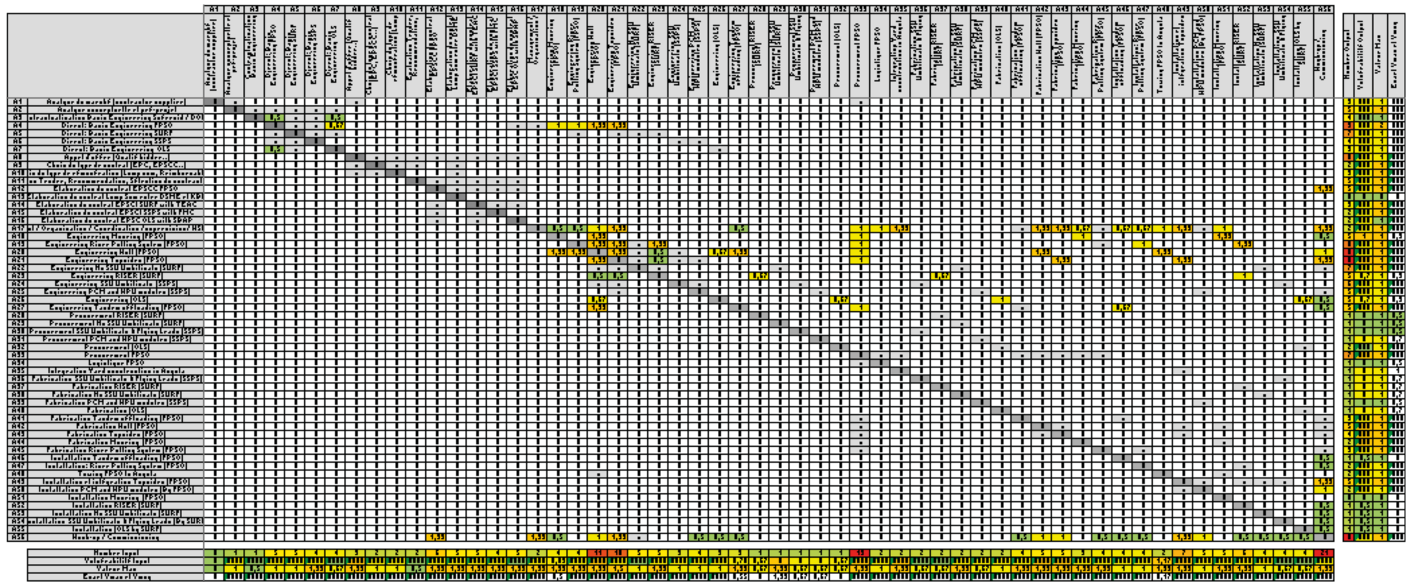

FIGURA 07. Estimation of ADRAI matrix compared to the vulnerable cells of the contractual strategy of scenario C

After realizing the various estimations, we can highlight that the least vulnerable contractual strategy for the Pazflor Project regarding the FPSO was scenario C, notably because a specific subcontractor had not been assigned to the commissioning phase and this scenario was the one with the less vulnerable cells.

6.1.2. Local Level

We are now analyzing in more detail the cells that should be monitored (Light Oragne). For this, we use the ADRAI matrix for the cells: input and output (Fig. 7) and the RCCCS matrix for the internal cells (Fig. 8).

During this study, only the RCCCS matrix had a single contractual cell, which was estimated vulnerable (to be monitored): "Installation /Pre Com of Topsides".

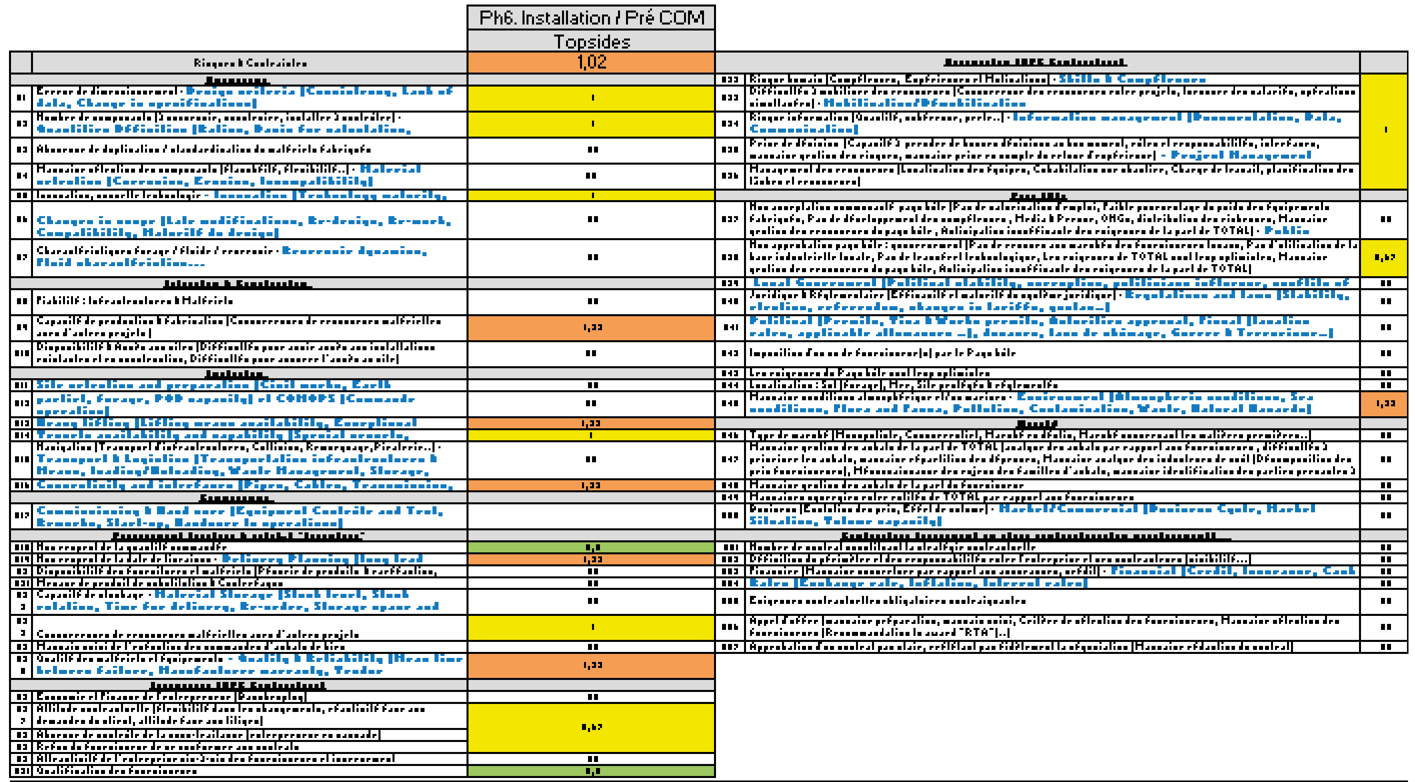

FIGURA 08. Estimation of the RCCCS matrix compared to the vulnerable cells of the contractual strategy of scenario C

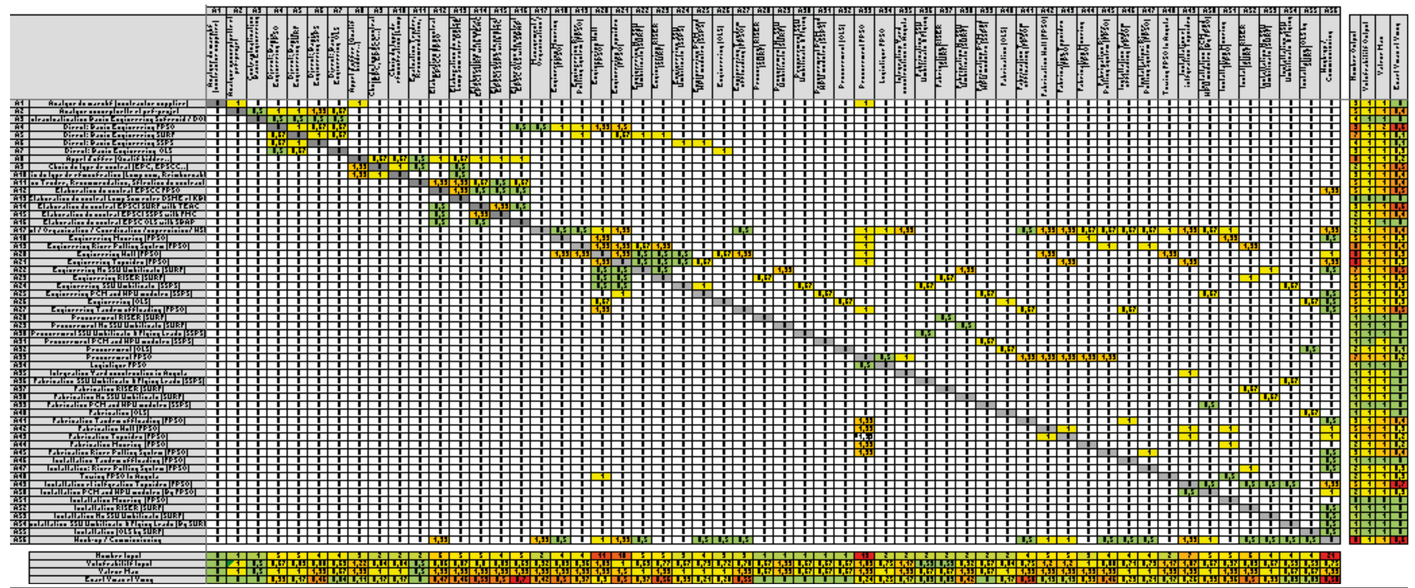

FIGURA 09. Matrix Activities/Activities of the ADRAI matrix of the Pazflor Project (regarding the FPSO) and their interactions

-- 6.2. Second approach: ascending --

This second approach consists in estimating the vulnerabilities of ADRAI matrix (Fig. 9) and RCCCS (Fig. 10) first. Once the estimates are made for each of these matrices, the values are aggregated to the contractual strategy matrix (Fig. 11).

6.2.1. Local level

Regarding the estimation of the RCCCS matrix, the vulnerability of contractual cells is estimated following the aggregation of the estimates based on risks and constraints that may arise during the implementation of a contractual cell.

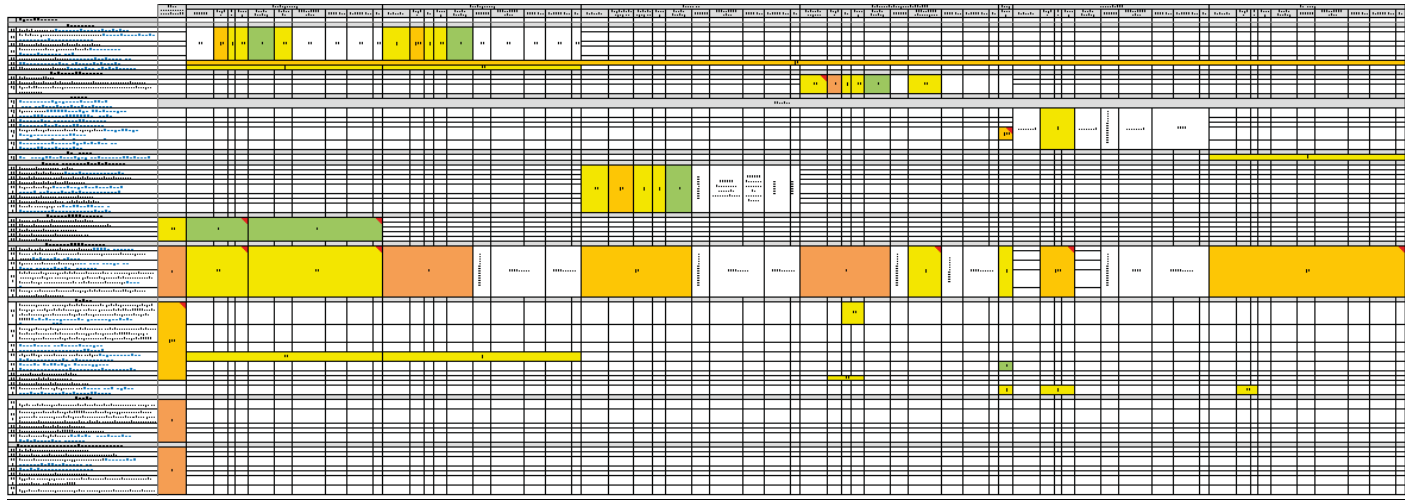

FIGURA 10. RCCSC matrix of the Pazflor Project (regarding the FPSO) and their interactions

6.2.2. Global level

Fig. 11 represents the estimated contractual strategy following the aggregation of data from the local level. During the aggregation of the data, several methods can be used (Maystre and al, 1994), (Guitouni and Martel, 1998), (Clivillé, 2004), (Ennaouri, 2010). During our case study, following a brainstorming session with the actors of the TOTAL company, we chose to use the simple calculation of the unweighted mean because of its ease of use and the desired level of detail.

Deuxième approche Agrégée suite aux matrices ALEAI et RCCSC		Ph.1 Basic Engineering			Ph.2 Detail Engineering			Ph.3 Procurement			Ph.4 Fabrication / Integration /Tests			Ph.5 Transportation to SITE			Ph.6 Installation (Offshore) / Pré COM			Ph.7 Commissioning	
		Input	Internal	Output	Input	Internal	Output	Input	Internal	Output	Input	Internal	Output	Input	Internal	Output	Input	Internal	Output	Input	Internal
FPSO	Riser Pull-in System	0,67	0,84	0,89	0,83	1,43	0,96	1,09	1,25	1,16	0,88	1,23	0,94		NA			NA		0,50	1,33
	Topsides	0,67	0,97	0,89	0,98	1,5	1,04	1,09	1,5	1,16	1,20	1,73	1,08				1,07	1,21	0,67	1,33	1,33
	Hull	0,67	0,89	0,89	1,03	1,38	0,98	1,09	1,33	1,16	1,20	1,3	1,07				1,17	1,21	0,75	1,00	1,33
	Mooring	0,67	0,84	0,89	0,83	1,37	1,03	1,09	1,33	1,16	1,00	1,3	1,17	1,17	1	0,75	0,97	1,21	0,00	0,00	1,33
	Tandem Offloading	0,67	0,81	0,89	0,78	1,33	0,83	1,09	1,17	1,16	0,75	1,2	0,94		NA			NA		0,50	1,33
OLS	OLS, OOL...	0,63		0,72	0,72		0,70	0,67		0,59	0,84		0,67				0,59		0,50	0,50	
SSPS	PCM and HPU modules	0,88		0,92	0,79		0,70	0,67		0,67	0,67	0,8	0,50		NA			NA		1,00	
	SSU Umbilicals	0,88		0,92	0,67		0,67	0,67		0,50	0,59		0,67				0,59		0,50	0,50	
SURF	No SSU Umbilicals	0,83		0,86	0,63		0,81	1,33		0,50	0,92		0,67				0,67		0,50	0,50	
	Riser	0,83		0,86	0,77		0,67	0,67		0,50	0,59		0,67				0,83		0,50	0,50	

FIGURA 11. Contractual strategy matrix (aggregated) of the Pazflor Project focused on the FPSO and their interactions

--- 6.3. Project Dynamics ---

The analysis of the dynamics of the project is carried out on each of the two levels (Global and Local levels) and between the two levels. It allows to analyze the hidden weak signals within the project and to have indications on how to better control them in order to avoid instability. A weak signal may be slightly vulnerable (negligible) but it can strongly impact the project if it occurs. The 4 main phenomena to take into account are:

- Amplification / Non linear reaction: Action to increase the vulnerability of at least one element or interaction;
- Linear Reaction - Chain - Cascade (Thompson, 1967): Action to propagate an initial risk through a sequence of interrelated events;
- Multiple effects: Action to generate multiple risks;
- Feedback loops - (Donnadieu and al, 2003): Action to generate the amplification of an element, an interaction, a scenario feeding itself as in the case of a "snowball" phenomenon (Nasirzadeh and Nojedehi, 2013), (Sterman, 2001), (Lin and al, 2006), (Yang and al, 2014), (Ackermann and Alexander, 2016).

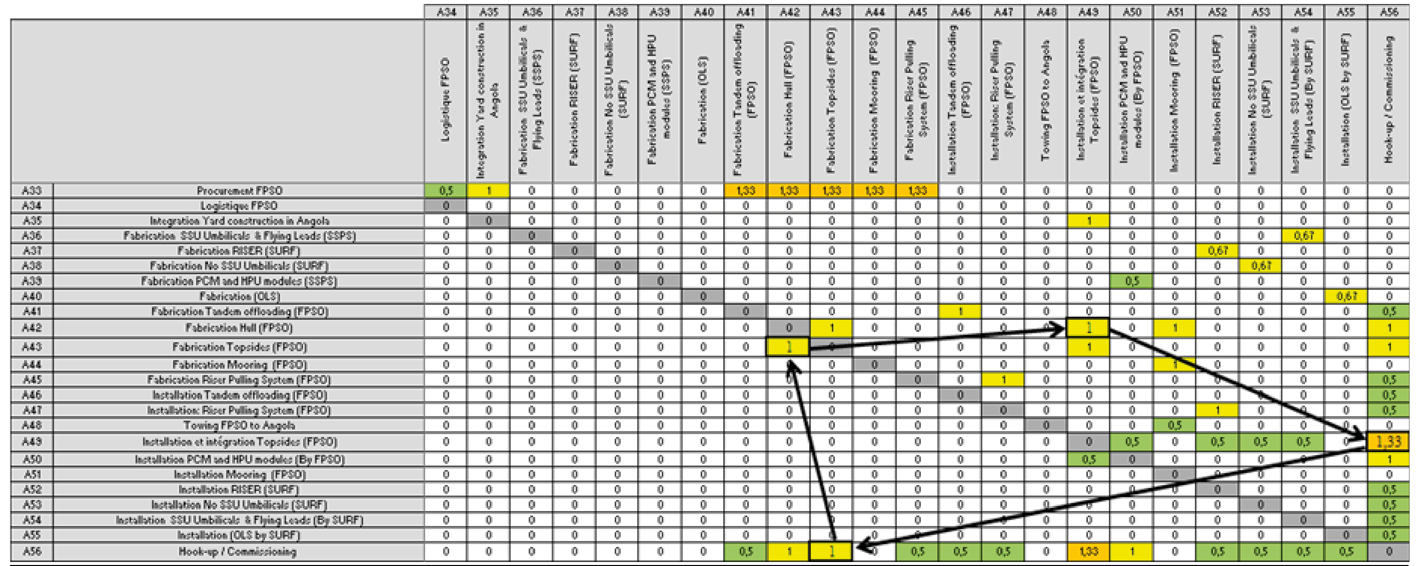

FIGURA 12. Example of feedback loop at global level

This analysis Fig. 12 illustrates an example of a loop that may occur in a project: Fabrication Topside => Fabrication Hull => Topside installation => Hook-Up / Commissioning => Fabrication Topside.

The main consequence of the presence of a loop is the modification of the data (engineering, fabrication, installation, etc.), which can lead to "Change Order" and therefore an increase in project times and costs.

--- 6.4. Contractor selection ---

The analysis for the selection of contractors carrying out some scope of the contractual strategy is paramount to developing the least vulnerable contractual strategies. The study of the bidders for the FPSO package was completed with some project return of experience (internal documentation TOTAL during the contracting phase, i.e., the same data the decision-makers had) and skills and experiences of the actors of the TOTAL Company.

The selection of contractor(s) is performed after the analysis of the specific vulnerability of each bidder and the analysis of the vulnerabilities of their interfaces. Their own vulnerability analysis of a bidder is made according to several criteria (Fig. 13) defined by the TOTAL company and the literature.

Fig. 14 represents the ADRAI matrix with the estimation of input and output vulnerabilities of the bidders in order to compare them. A row/column intersection represents the impact a contractor will have on its targets (activities, delivera-

		Results		
		DSME	HHI	Consortium
	EPC Contracteur	0,9	0,83	1,03
R26	Economy and Finance (Banckruptcy...)	0,67	0,67	1
R27	Lack of control of subcontracting (cascade contractor)	1,33	1	1,33
R28	Supplier's refusal to comply with contracts	1	1	1
R29	Attractiveness of the company compared to suppliers and vice versa	1	1	1,33
R30	Qualification	0,5	0,5	0,5
	Organisation (EPC Contracteur)	1,13	1,07	1,33
R31	Skills & Compétences	1,33	1,33	1,33
R32	Difficulties in mobilizing resources (Competition for resources between projects, turnover of employees, simultaneous operations) - Mobilisation/Démobilisation	1	1	1,33
R33	Risk information (quantity, consistency, loss ...) - Management Information (Documentation, Data, Communication)	1	1	1,33
R34	Decision making (ability to make good decisions at the right time, roles and responsibilities, interfaces, poor risk management, inadequate consideration of feedback, contractual Attitude (flexibility in the changes, responsiveness to customer requests, attitude to litigation)) - Project Management	1,33	1	1,33
R35	Resource Management (Location of teams Cohabitation on site, workload, work planning and resources)	1	1	1,33
	TOTAL	1,02	0,95	1,18

FIGURA 13. Evaluation of own vulnerability FPSO contractors

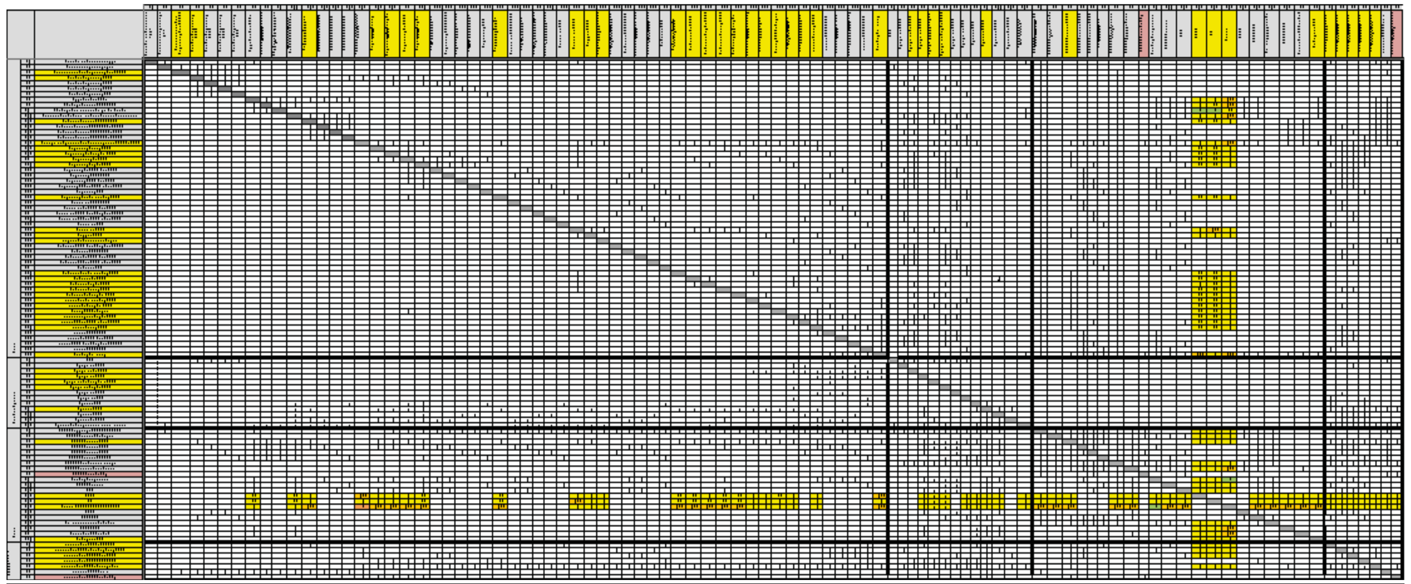

FIGURA 14. ADRAI matrix comparing the vulnerabilities (input and output) of FPSO « bidders »

bles and requirements, actors, interactions between actors), while a column/row intersection represents the vulnerabilities of the contractor regarding a source which can impact it (activities, deliverables and requirements, actors, interactions between actors).

The following results allow for a decision-helper which is more efficient and robust. The overall vulnerability of each of the bidders is assessed by adding their three vulnerabilities (input, internal and output).

DSME: ≈ 0.87 (input) + 0.95 (output) + 1.02 (internal) = 2.84

HHI: ≈ 0.85 + 0.95 + 0.95 = 2.75

Consortium: ≈ 1.04 + 1.17 + 1.18 = 3.39

--- 6.5. Recommendations ---

The modelling and analysis of the three main decisions (decomposition of contractual strategy, contractor selection and remuneration selection) at two levels (global and local) allow one to make decisions more calmly because the modelling and analysis are more efficient and robust. It is important to understand that the decisions at a global level (decomposition of contractual strategy) can impact the decisions at the local level (contractor selection and remuneration selection) and vice versa.

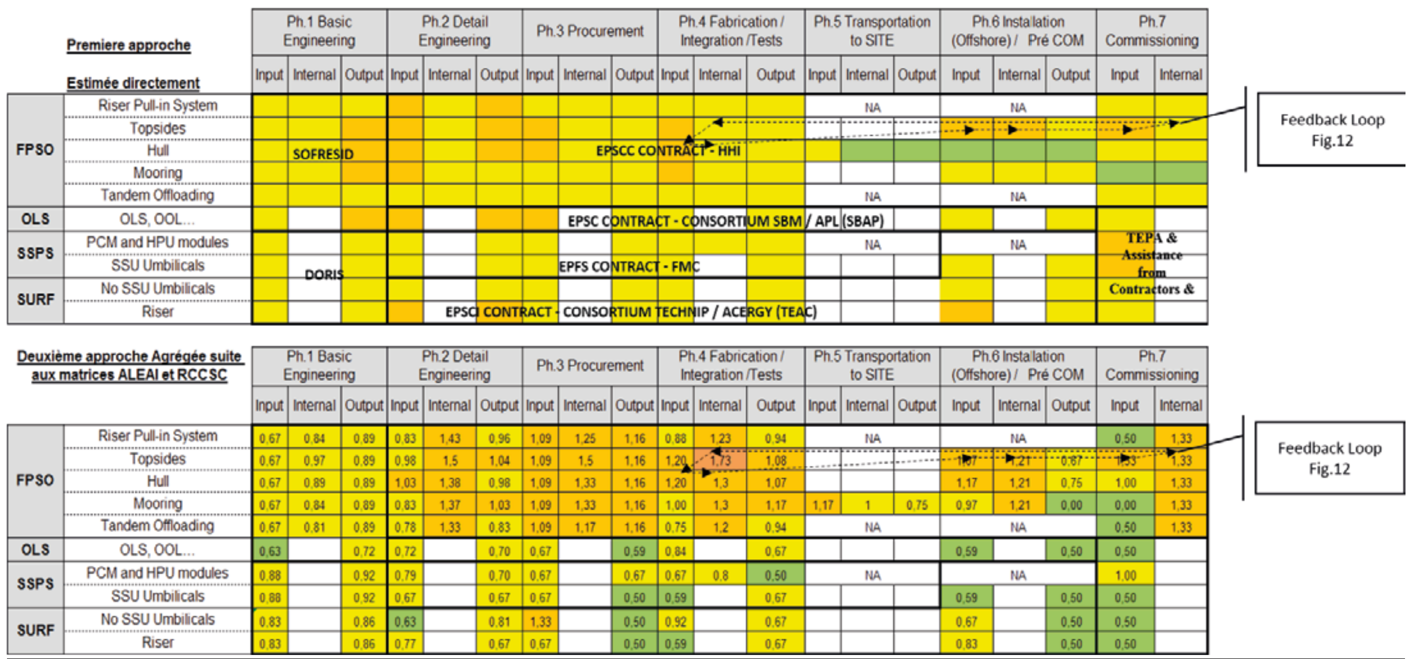

FIGURA 15. Comparison of the two contractual strategies carried out by two different approaches

6.5.1. Global level: contractual strategy

Although the a posteriori analysis shows some bias, the purpose of this section is to show what could be done by taking into account the additional analyses previously introduced.

At the global level, after performing the analysis from the two approaches, we can see differences when estimating contractual strategies (Fig. 15).

Note: the values of vulnerability between [1.01 and 1.1] can be defined as tolerable, given the reason and common sense of the decision-makers.

The two major differences that we can perceive are the underestimation and/or overestimation of the cells of one approach over another.

Underestimation: The underestimation is mainly due to the participants having neglected some low-intensity signal (for instance, the potential impact of the manufacturing "Topsides Hull" and "Mooring" on other cells (manufacturing vulnerabilities – Output)). Other examples where low-intensity signals were neglected in the first approach can be found. The second approach is also likely to underestimate some low intensity signals when aggregating values, since some vulnerable values may be hidden by other less vulnerable values. Let us take the example of the contractual cell "Production – No SSU umbilicals – Input". Whether in the first or second approach, this cell is estimated as tolerable, but in the second approach (using the ADRAI matrix), we can identify the following low-intensity signal which was estimated as "to be monitored" (vulnerable – Value: 1.33): "Details Engineering – no SSU umbilicals – Output" can impact the cell "Production – no SSU umbilicals – Input", and this impact cannot be controlled.

Overestimation: When performing the test case Pazflor (Focus FPSO), we can also see the contractual cells can be overestimated, as shown in the first approach, with estimates of phase "Commissioning – SSPS – Input", "Basic Engineering – Topsides / Hull / Mooring Output"...

With the second approach, overestimation is performed on almost all the contractual cells of the phases of the project in regard to the "internal" criterion. This is mainly due to the recognition of the vulnerability of the organization of the EPC contractor. This overestimation makes us consider whether it is important to aggregate the vulnerability of the organization of the EPC contractor with the other vulnerabilities, or whether it should be taken into account separately (and then have it underlined in the contractual strategy). Our decision was to break down the "Internal" criterion into two parts (Fig. 16): Internal vulnerability of a phase (A) and vulnerability of the organization of EPC contractor with respect to a phase (B). This decomposition is of help to decision-makers and permits them to have a direct vision of the organization of the EPC contractor (skills, experiences, motivations, resources, resource management...).

Deuxième approche Agrégée suite aux matrices ALEAI et RCCSC		Ph.1 Basic Engineering			Ph.2 Detail Engineering			Ph.3 Procurement			Ph.4 Fabrication / Integration /Tests			Ph.5 Transportation to SITE			Ph.6 Installation (Offshore) / Pré COM			Ph.7 Commissioning	
		Input	Internal	Output	Input	Internal	Output	Input	Internal	Output	Input	Internal	Output	Input	Internal	Output	Input	Internal	Output	Input	Internal
FPSO	Riser Pull-in System	0,67	0,84	0,89	0,83	1,43	0,96	1,09	1,25	1,16	0,88	1,23	0,94		NA			NA		0,50	1,33
	Topsides	0,67	0,97	0,89	0,98	1,5	1,04	1,09	1,5	1,16	1,20	1,73	1,08				1,07	1,21	0,67	1,33	1,33
	Hull	0,67	0,89	0,89	1,03	1,38	0,98	1,09	1,33	1,16	1,20	1,3	1,07				1,17	1,21	0,75	1,00	1,33
	Mooring	0,67	0,84	0,89	0,83	1,37	1,03	1,09	1,33	1,16	1,00	1,3	1,17	1,17	1	0,75	0,97	1,21	0,00	0,00	1,33
	Tandem Offloading	0,67	0,81	0,89	0,78	1,33	0,83	1,09	1,17	1,16	0,75	1,2	0,94		NA			NA		0,50	1,33
OLS	OLS, OOL...	0,63		0,72	0,72		0,70	0,67		0,59	0,84		0,67				0,59		0,50	0,50	
SSPS	PCM and HPU modules	0,88		0,92	0,79		0,70	0,67		0,67	0,67	0,8	0,50		NA			NA		1,00	
	SSU Umbilicals	0,88		0,92	0,67		0,67	0,67		0,50	0,59		0,67				0,59		0,50	0,50	
SURF	No SSU Umbilicals	0,83		0,86	0,63		0,81	1,33		0,50	0,92		0,67				0,67		0,50	0,50	
	Riser	0,83		0,86	0,77		0,67	0,67		0,50	0,59		0,67				0,83		0,50	0,50	

FIGURA 16. Aggregation of contractual strategy including the differentiation of the vulnerability of the organization of the EPC contractor

Underestimation and/or overestimation can be sources of hazards for the project. Underestimation tends to cause the occurrence of risks that will increase costs and delay the project, while overestimation tends to limit and control risks that may arise during the project. However, overestimation is likely to generate additional costs and delays, since actors will be used for unnecessary activities. It is therefore important that the "common sense" of decision-makers is still used to achieve the right balance between estimates.

6.5.2. Local level

Contractor selection

Following the preceding results calculated in the analysis phase, we estimate that the HHI bidder is the more appropriate one. The internal document (TOTAL): Recommendation To Award the FPSO of the Pazflor Project also suggested the selection of HHI, underlining the following benefits:

- The schedule and costs are consistent with the estimate of the TOTAL company,
- HHI has good references in Angola to achieve similar projects,
- SOFRESID (contractor of « Basic engineering ») approves HHI,
- Subcontracting is limited and the subcontractor is well known and approved ...

All of these advantages are reflected in our analysis. However, during the execution phase, another subcontractor, DSME, performed the activities instead of HHI, notably because the host country encouraged it. Since the evaluation of DSME was very close to the evaluation of HHI, we believe that TOTAL decided to favor the relationship with the host country rather than selecting HHI, which already had other ongoing projects with the TOTAL Company.

Moreover, when performing this case study, we were surprised by the fact that the TOTAL Company did not contract directly with CEGELEC for commissioning activities but imposed it on DSME as a subcontractor. Actually, for TOTAL this choice made sense, since it permitted them to use and deploy fewer resources from TOTAL to monitor CEGELEC, since the contracting was done directly by DSME. Nevertheless, this choice had drawbacks: paying more for the contract with DSME and losing visibility on commissioning activities.

Selecting the type of remuneration

In the case of the FPSO of the Paflor Project (but also for other projects), we recommend selecting a remuneration mode depending on the vulnerability of a contractual cell or group of cells forming a part of a contract. The more vulnerable the cell, the more TOTAL will have to select a "reimbursable" remuneration to prevent uncertainties and "Change Orders". The less vulnerable the contractual cell, the more TOTAL should select a "Lump sum" remuneration in order to control the costs.

7. DISCUSSION

The expected result is a risk analysis method that will be a decision aid for decision makers to select the less vulnerable contractual strategy for a specific project context. This method will be connected to existing cost and time analyses to help anticipate changes in tasks and interactions that were not predictable with traditional laws of probability. It will also be connected to traditional project management tools, particularly risk registers. Finally, it will identify situations where the contractual interfaces are both important and difficult to define in terms of contribution to the project risks. Alternative contractual strategies that will not be retained will be recorded in order to avoid going back to discover the reasons for their refusal. In addition, the tools allow everyone to share the visions of different actors of the project.

This article has as one of its objectives to highlight the fact that a contract should not be perceived as a fixed document because it is characterized by its own construction and dynamics that can influence or be influenced by Other contracts or by the project environment.

Various discussions are in progress regarding the possibility of making the analysis of unanticipated events and the estimation of events more automatic and applicable using vulnerability to improve our approach:

- How can one estimate the level of resilience of the target to return to its initial value during and after an impact? Which formulation should be used to estimate vulnerability? How important is vulnerability in the study of propagation?
- How improve the analysis of the "project dynamics"? Despite the fact that this analysis provides additional support in selecting the contractual strategy to be used, it remains to be improved. It is important to highlight the link between the project dynamics and the contractual strategy in order to better understand the steps to be taken.
- Can we assemble the cells of the contractual strategy using a clustering method? ◆

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