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Article

Comparison of variations in EPC/turnkey oil and gas projects depending on tender methods

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ABSTRACT

Variations are inevitable in construction projects. Therefore, owners try to predict potential variations in the project preparation phase and try to adopt the most appropriate project strategies and contract provisions that can help to mitigate variation-related risks. In general, turnkey lump sum contracts are preferred when undertaking large or medium-sized oil and gas projects. These contracts cover the Engineering, Procurement, and Construction (EPC) phases of the project. Once the conceptualisation is completed and the basic engineering design package has been prepared, owners may prefer to award the EPC/Turnkey contract directly (i), or have a front-end engineering design (FEED) study done first, and award the EPC/Turnkey contract afterward (ii), or set up a convertible contract and convert it to EPC/Turnkey after an open book cost estimate (OBCE) process (iii). In this study, after a general overview of the variation concept, the common tendering methods used in EPC/Turnkey oil and gas projects are reviewed. In order to analyse the effects of the tender methods on potential variations, four EPC Lump Sum Turnkey (LSTK) projects which were awarded using different tendering methods, namely single-stage tender (direct EPC) and two-stage tender (OBCE+EPC), are compared. Finally, the frequency and content of the variations are studied according to their tendering methods. The primary findings reveal that the variation ratio experienced in the two-stage tender case is comparatively less than the variation ratio in single-stage tender cases.

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INTRODUCTION

Since variations may have a direct impact on the cost and completion dates of construction projects, many studies have been conducted on their causes and effects. Researchers have focused on the subject using different approaches to tackle the problem. Some of them preferred to study variations regardless of the project type. For example, Alnuaimi et al. (2010) and Al Maamari and Khan (2021) analysed variations in construction projects of Oman. An and Ma (2019) concentrated their research on Chinese construction projects. Memon and Rahman (2014) highlighted the major causes and effects of variation in construction projects in Malaysia. Bhadmus et al. (2015)

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studied the causes of variations in the construction industry of Nigeria. Keane et al. (2010) reviewed several articles in the literature and grouped the causes of variations based on the contracting parties.

On the other side, some researchers preferred to focus on the type of the project when they investigated the causes of variations. For example, Babalola and Idehen (2011), Muhammad et al. (2015), and Perera et al. (2020) studied the subject in residential projects, Kassim and Loong (2002) on sewerage projects, Priyantha et al. (2011) in road projects, and Halwatura and Ranasinghe (2013) in infrastructure projects.

Surprisingly, it is difficult to find similar research studies conducted in industrial projects even though industrial construction is subject to significant variation risk. For example, large and medium-sized oil and gas projects involve high risks and are prone to frequent and substantial variations. In addition to being large, oil and gas projects are highly complex, have a multi-disciplinary structure, and are generally managed in a fast-track manner by overlapping engineering, procurement and construction in order to shorten otherwise long project durations (Komurlu and Er, 2018). These features expose oil and gas projects to high risks relative to the frequency and substance of the variations. Al Hammadi's (2009) work specifically focuses on oil and gas projects constructed in the UAE.

This paper is expected to contribute to the subject by comparing the variations in EPC/Turnkey oil and gas projects with a specific perspective that takes into account their tendering methods. Thus, the findings of this study are expected to add value to the variations literature by complementing the limited amount of research in oil and gas projects.

A research methodology that involves case studies is used in the study. Four completed large-scale oil and gas projects with similar characteristics apart from their tendering methods were considered in the study. All projects were commissioned by the Turkish Petroleum Refineries Corporation (TÜPRAŞ) which is the largest refinery company in Turkey and the 7th largest in Europe. They are typical refinery projects that include process and utility units and off-site connections to existing refinery facilities. Detailed information about these projects is presented in the Case Study section of the paper. The research team had access to variation order records that included enough information relevant to the study. The causes of variations were identified and classified by the researchers. In order to ensure the reliability of the data, the findings were also reviewed by an expert.

In the following sections, after a general discussion of variations in construction projects, the common tendering methods followed in EPC/Turnkey oil and gas projects are reviewed. In order to analyse the effects of tendering methods on variation orders, four EPC Lump Sum Turnkey (LSTK) projects were compared. One of these projects was awarded using a single-stage tendering (direct EPC) and three of them used a two-stage tendering (OBCE+EPC). Finally, the contents of the variation orders in projects awarded by direct EPC and OBCE+EPC were compared.

OVERVIEW OF VARIATIONS IN CONSTRUCTION PROJECTS

In general terms, variation refers to changes in the scope or work schedule of a project after the contract provisions between the owner and the contractor have become effective. These changes are not surprising due to the unpredictable nature of construction projects. If the preparation phase of a project is conducted in a well-planned and comprehensive manner, it will be less likely to encounter unforeseen situations during the implementation period. Nevertheless, it is not possible to totally eliminate such occurrences. Since construction projects are long-term activities involving numerous actors, they are open to several uncontrollable impacts such as changes in needs, financial fluctuations, extreme climate conditions, etc. throughout their lifetime. Although there are several ways of classifying variations in projects, one of the most preferred classifications focuses on the initiator of the variation, i.e., variations initiated by the owner, a consultant, the contractor, or other none of these parties. Table 1 shows Keane et al.'s (2010) classification of variations.

A "variation order" is the documented form of a variation. The term "change order" is frequently, while the term "adjustment order" is rarely used for the same purpose. Variation order/change order is defined by AACE (2017) as a document requesting and/or authorising a scope and/or baseline change in the project, which should be approved by both the owner and the contractor. For the project team, this document refers to a change in the project that is approved by senior management. For the contractor, it is an agreement between the owner and the contractor that compensates for a change in the scope or other terms of the contract (AACE, 2017).

Deviations in the delivery time of the project, especially the delayed deliveries cause damages to the construction owner and may threaten the feasibility of the endeavour. The contractor, however, faces additional direct and indirect costs (Figure 1, Syal and Bora, 2016). Direct costs are addressed in variation order documents, which involve a detailed description and documentation of the variation. Indirect costs, which are generally overhead expenses, may be distributed between line items in a multitude of approaches, which makes it difficult to assign indirect costs

Table 1. Classification of variations (Keane et al. 2010).

Owner-initiated Variations	Consultant-initiated Variations	Contractor-initiated Variations	Other Variations
Change of plans or scope (CII, 1990a)	Change in design (Fisk, 1997; Arain et al., 2004)	Lack of involvement in design (Arain et al., 2004)	Weather conditions (Fisk, 1997; O’Brien, 1998)
Insufficient planning at the project definition stage, or lack of involvement of the owner in the design phase (Arain et al., 2004)	Errors and omissions (Arain et al., 2004)	Unavailability of equipment (O’Brien, 1998)	Safety considerations (Clough and Sears, 1994)
Owners’ financial problems (Clough and Sears, 1994; O’Brien, 1998)	Conflicts in contract documents (CII, 1986)	Skills shortage (Arain et al., 2004)	Change in economic conditions (Fisk, 1997)
Inadequate project objectives (Ibbs and Allen, 1995)	Technology change (CII, 1994)	Financial problems (Thomas and Napolitan, 1995)	Sociocultural factors (O’Brien, 1998)
Substitution of materials/procedures (Chappell and Willis, 1996)	Value engineering (Dell’Isola, 1982)	Desired profitability (O’Brien, 1998)	Unforeseen problems (Clough and Sears, 1994; O’Brien, 1998)
Impediment of prompt decision-making process (Sanvido et al., 1992; Gray and Hughes, 2001)	Poor coordination (Arain et al., 2004)	Differing site conditions; poor workmanship (Fisk, 1997; O’Brien, 1998)	
Obstinate nature of owner (Wang, 2000; Arain et al., 2004)	Design complexity (Fisk, 1997; Arain et al., 2004)	Fast-track construction (Fisk, 1997)	
Change in specifications by owner (O’Brien, 1998)	Poor working drawing details (Geok, 2002; Arain et al., 2004)	Poor procurement process (Fisk, 1997)	
	Poor knowledge of available materials (Geok, 2002)	Lack of communication (Arain et al., 2004)	
	Lack of required data (Arain, 2002)	Lack of experience	
	Ambiguous design details) (O’Brien, 1998	Long-lead procurement (Fisk, 1997)	
	Poor design (CII, 1990b; Fisk, 1997)	Complex design and technology (Arain, 2002)	
	Change in specifications (O’Brien, 1998)	Lack of strategic planning (Clough and Sears, 1994)	

to a particular line item affected by a variation order. In order to prevent conflicts between parties, the true cause of any delay needs to be well known (Komurlu, 2018). With the loss of efficiency added to this, cost is the most important factor in disputes caused by variation orders. Thus, variations greatly affect a contractor's profitability (Goldsmith, 2016).

In general terms, a variation alters the agreed terms or scope of the contract. However, a claim normally involves a change in the way that the contracted work is delivered (Sergeant, 2015). For example, a change in the design parameters by the owner in a later stage of a project may end up with reengineering or construction changes. Thus, such variations should be managed by means of a variation order. However, additional costs incurred by the contractor due to the late owner approval of the design will be subject to a claim. Some other differences between variation order and claim could be listed below:

- Variations are normally initiated by the owner, whereas claims are mostly initiated by the contractor.
- Claims should be preceded by a written notice in order to allow the other party to take action to mitigate the effects of the situation (Sergeant, 2015).
- Variation and claim provisions are usually defined under different clauses in a contract since they have different workflows and approval processes.
- Scope variations are usually performed after mutual agreement, while contractors cannot stop the work because of a claim (Komurlu and Arditi, 2017).
- Contracts often include additional sections that set unit rates to be used for variation orders. However, claims are normally compensated by reference to costs that should be proven to the owner with proper documentation (Sergeant, 2015).
- Claims can arise when there is a conflict between the owner and the contractor about the need for a variation (Komurlu and Arditi, 2017).

In some instances, acceleration of the work may be required to overcome the delays which are not caused by the contractor's fault (Komurlu and Arditi, 2017). In such a case, the extra cost associated with the acceleration is requested by the contractor. However, the need for a variation order or the cost of the proposed variation order can cause disputes between the owner and the contractor (Wallwork, 2003). If these disputes are not resolved to the mutual satisfaction of the parties, their effects could cause new disputes (Figure 2, Iyer et al., 2007).

Since claims and the resulting disputes have substantial economic, relational and operational consequences, they have to be managed properly throughout the project. Claim management aims to establish the necessary structures, first to prevent counter claims, and then pursue potential entitlements in an efficient manner. The main processes of claim management involve prevention, mitigation, pursuance, and resolution (Mirza, 2005).

Following the occurrence of a variation, for the proper management of the process, the contract should be evaluated for related clauses, the variation should be identified, a timely notification should be submitted, a request regarding the variation should be prepared, and the variation request should be resolved (Molly, 2007). Variation order management consists of tracking, monitoring and analysis of the variation (Stone et al., 2011). In order to minimise the negative effects of the variation order, these orders should be processed in a timely manner. A method for determining the cost and the stipulation of a fixed fee increases the likelihood of mutual agreement. In addition to the cost, the time implications of the variation should be agreed upon by the owner and the contractor to avoid potential claims and disputes (Kettlewell, 2003). Any claim that is not resolved amicably may lead to disputes that have to be tried in courts of law, a process that involves significant attorney fees and major aggravation for the parties involved in the contract. This situation can be avoided if precautions are taken to avoid variations and variation order management is well defined in the contract documents (Komurlu and Arditi, 2016).

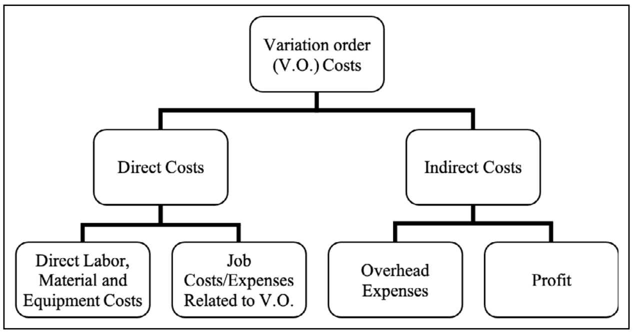

Figure 1. Variation order costs (Syal and Bora, 2016).

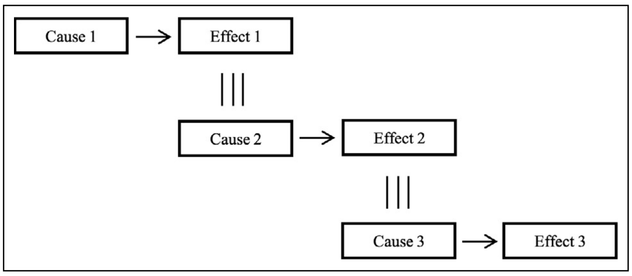

Figure 2. Cause and effect relationship of disputes (Iyer et al., 2007).

EFFECTS OF TENDERING DURATION ON VARIATIONS

According to Jawad et al. (2009), cost overruns caused by variation orders account for 5–10% of the original contract value, whereas delays represent less than 10% of the original contract duration in large building projects. In a similar study, Hanif et al. (2016) reported a 31% cost overrun and 20% delay in mega hydropower projects. It is not surprising that the impact of variations in building projects is less than the impact of variations in infrastructure projects because building projects are generally awarded after a detailed design is completed, which provides a much clearer scope at the tendering stage. However, big-scale energy or oil and gas projects are generally executed with EPC contracts which means they are more open to variation risks since the scope is not as well defined in EPC tendering.

Despite the negative impact mentioned above, considering the characteristics of medium or large-scale oil and gas projects, EPC/Turnkey contracting appears to be the most advantageous contracting strategy for owners (Komurlu and Er, 2018) because EPC/Turnkey contracting provides the most reliable budget to owners. In this method, engineering, procurement and construction activities are managed by the same contractor. Additionally, engineering continues during both the procurement and construction phases, improving the budget continuously. Thus, phases can be overlapped in the work schedule and projects can be completed in the shortest time. Owners can also manage the projects with a smaller organisation due to less interference because in multi-contractor cases all interconnections between contractors should be managed by the owner. McNair (2016) pointed out the advantages of EPC LSTK contracts as follows;

- Single point of responsibility
- Fixed contract price
- Fixed completion date
- Strong accountability of contractors due to performance guarantees, liabilities, defect liability period, etc.
- Use of internationally well-known contracts containing regulations against sophisticated problems such as variations, intellectual property, suspension, termination, performance specifications, etc.

On the other hand, this strategy has a number of disadvantages, the most important of which are maximum contingency in the contract price and less involvement of the owner in the detailed design. It may also require more time for tendering, especially considering the preparation of the tender package, disclosure of the questions prior to technical tender and final negotiations before contracting. Finally, the project scope should reach an adequate level of maturity before the tendering phase to mitigate variation risk during the EPC phase. Despite all these disadvantages, considering the benefits of the aforementioned advantages, owners commonly prefer EPC LSTK contracts in the oil and gas sector (Al-Hammadi, 2009).

EPC/TURNKEY TENDERING METHODS

As shown in Figure 3, an EPC/Turnkey contract can be awarded using different tendering methods. Owners may prefer to award the EPC/Turnkey contract directly (i), have a front-end engineering design (FEED) study done first and award the EPC/Turnkey contract afterward (ii), or set up a convertible contract and convert it to EPC/ Turnkey after an open book cost estimate process (iii). The last two methods have been developed to minimise the disadvantages of EPC/Turnkey contracting over the

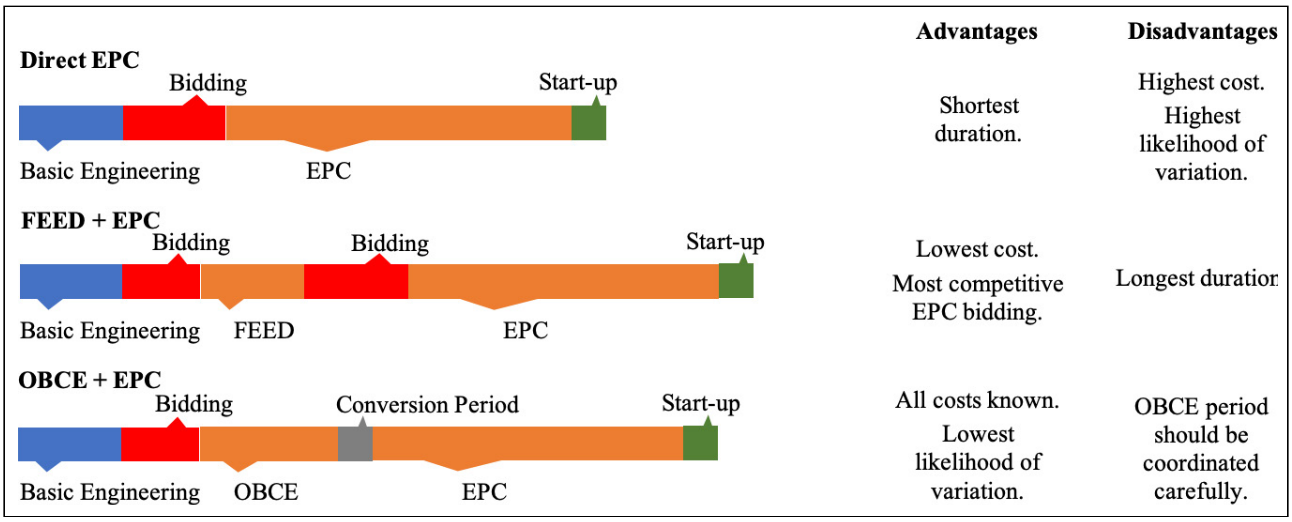

Figure 3. Comparison of EPC/Turnkey tendering methods.

course of time.

In the case of direct EPC/Turnkey contracting, the owner defines the scope of the project and hires a contractor to execute all engineering, procurement and construction activities accordingly. The role of the owner is mainly limited to project controls and contract administration. The contractor bears the risks and responsibilities of the project. Therefore, the lump sum contract price includes maximum contingency. If the scope of the project is not clearly defined in the tendering documents, possible design changes may result in significant variation orders. However, the total project duration will be the minimum because EPC allows for phased construction.

To minimise the drawbacks mentioned above, owners may prefer to have a front-end engineering design (FEED) contract first and award the EPC/Turnkey contract afterward. The aim of the FEED contract is to improve the scope of the project by enhancing the basic engineering documents and to produce more detailed technical documents to facilitate the implementation of the project (Moazzami et al., 2015). This way, design development is expected to reach a reasonable level of maturity before an EPC/Turnkey contract is awarded. In such cases, the cost of the project can be estimated precisely because cost deviation is inversely proportional to the level of information. At this stage, material requisitions of long lead items become ready for purchase orders and drawings and lists are more detailed. Thus, major equipment prices and quantities can be estimated most accurately. However, the FEED+EPC method of tendering requires two tendering periods, one for the FEED contract, and another for the EPC contract. If the EPC contractor selected in the second tendering is different than the FEED contractor picked in the first tendering, a discontinuity will be created in the process. In this case, some owners may request the EPC contractor to endorse the existing FEED documents.

In convertible contracts, different contract price arrangements such as reimbursable costs, unit rates, and lump sum are used at different stages of the project to distribute cost and performance risks between the contracting parties (Moazzami et al., 2015). Therefore, the disadvantage of discontinuity observed in the FEED+EPC Turnkey method can be eliminated in a convertible contract. In this process, the owner and the contractor agree on a two-stage contract. In the first stage, a detailed design is developed up to a certain level where a reasonable cost estimate can be estimated. The calculation of the cost estimate should be transparent and traceable for the owner. So, both the contractor and the owner participate in developing the cost estimate with full access to all cost information. This process is called the open book cost estimate (OBCE) and can be an effective way to estimate an accurate and reliable EPC lump sum price (Patty and Denton, 2010). During the OBCE stage, the contractor can receive payment in a price adjustment structure. Later on, the contract is converted into an EPC lump sum contract following the conversion method previously defined in the tendering process. This way, all project costs, the contingency, and the contractor's profit are all known by the owner. Moreover, the contractor can proceed to the second stage immediately after the conversion with no interruptions.

CASE STUDY

Four large-scale oil and gas projects constructed in TÜPRAŞ are used as case studies to observe the effect of EPC/Turnkey tendering methods on the variations experienced during the projects. Some of the characteristics of these projects are as follows:

1. The owner was the same on all four projects.
2. The same contract was signed with only minor differences in the EPC phase of the projects.
3. The project management practices of the owner's project management teams assigned to the four projects were similar to each other.
4. Contractors were equally qualified to do the work and some of them were involved in more than one of the four projects.
5. The contractors were organised in similar consortium structures in the projects whereby the consortium leaders were foreign companies that handled engineering, procurement and project management whereas responsibility for the construction rested with the Turkish consortium members.
6. The contract value of each of the four projects was $100 million or more.
7. The refinery units built in the projects were equally complex.
8. All projects were conducted in Turkiye.
9. Three of those projects were awarded directly as EPC LSTK after basic engineering in a single-stage tender. In the remaining one two-stage tendering was preferred. An open book cost estimate (OBCE) process was performed over basic engineering and the project was converted to EPC LSTK afterward.

Considering the above-mentioned points, it is clear that most of the characteristics of the projects are the same except for the tendering methods used, hence assuring a sample of projects that provides meaningful data for the purpose of comparing the effects of tendering methods in the study.

In this study, the project variations recorded by the owner were examined. It was observed that there were no deficiencies in the records and that the records were kept regularly. In the first step, the effect of the EPC/Turnkey tendering method on the variation ratio (measured by dividing the cost of variations in a project by the contract price) were studied. Afterward, the variations were classified according to their causes presented in Table 1 to compare the effects of the EPC/Turnkey contract methods on the causes of variations. It is found that only six of those causes were encountered in the studied projects. The findings are as follows:

a. The variation ratio (i.e., the cost of the variations divided by the contract price)

The variation rate of each project was found to be less than 10%. This result agrees with the findings of a similar study conducted by Al Hammadi (2009) that involved oil and gas projects in the UAE.

Figure 4 shows the variation ratios in each case project. In the Direct EPC projects (i.e., Projects 1, 2, and 3) the variation ratios range from 1.6% to 6.1%, while in the OBCE+EPC project (i.e., Project 4) it is 1.2%. Furthermore, Direct EPC projects with a higher contract value have a higher variation ratio. However, in the OBCE+EPC project, although the contract price is very high compared to the others, the variation ratio is much lower than in the other projects. Overall, it can be concluded that Direct EPC projects require a rigorously defined scope, which in turn reduces the risk of costly variations, but it is more difficult to have fewer variations with a smaller cost as the size of the contract, and by implication, the scope of the project grows. On the other hand, even in mega projects such as the OBCE+EPC project (i.e., Project 4), the engineering study carried out during the OBCE period ensures that the scope is much clearer and consequently the cost of variations is much lower than in the Direct EPC projects (i.e., Projects 1, 2, and 3).

b. Effects of the tender methods on the causes of variations

In Table 2, the variations in the case projects are compared based on their causes. The projects are grouped according to the tender methods and the percentages of the causes

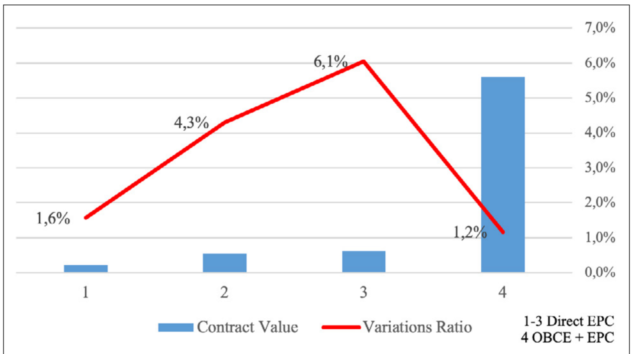

Figure 4. Variation ratios in the case projects.

of variations in each group are calculated by considering the number of variations and the cost of variations in each group.

"Change of plans or scope" is found as the most significant reason, independent from the tender method, very much supported by the literature about causes of variations in construction projects (CII, 1990a; Arain and Pheng, 2005; Al Hammadi, 2009; Sunday, 2010; Mohammad et al., 2010; Hanif et al., 2016). "Change of plan or scope" occurs usually because of insufficient planning at the project definition stage or due to the lack of involvement of the owner in the design phase (Arain et al., 2004). Convertible contracts like OBCE+EPC offer the opportunity to minimise these risks. As described earlier, in OBCE+EPC projects, a detailed design is developed in the first stage before converting a contract to an EPC lump sum; so the scope is quite well-thought-out and quite well-defined in the first stage for use in the second stage. In contrast, Direct EPC projects are exposed to all variation risks due to the immature scope at the time of production. When the occurrence of "change of plans or scope" in the case projects are compared based on the tendering methods, the percentages of occurrence of "change of plans or scope" out of the total number of variations are 50% and 53% in Direct EPC projects and in OBCE+EPC projects, respectively. On the other hand, the percentages of the cost of "change of plans or scope" out of the total cost of variations are 83% and 33% in Direct EPC projects and in OBCE+EPC projects, respectively. Although the percentages based on the number of variations are similar, the percentages based on the cost of variations indicate that the cost of "change of plan or scope" is much higher in Direct EPC projects.

Concerning "change in design", the percentages based on the number of variations are 36% in the Direct EPC projects versus 15% in the OBCE+EPC project. Changes in design are experienced frequently in projects where the construction started before the design is completed (Fisk, 1997). Projects are affected in various ways and levels depending on the timing of the design change (Memon et al., 2014). Since detailed engineering is carried out at least one year before conversion in OBCE+EPC projects, fewer variations are expected in the EPC period. A similar trend is observed in the percentages based on the cost of variations, with 10% and 13% in Direct EPC projects and in OBCE+EPC projects, respectively. It has to be noted however that late design changes may affect the percentages based on the cost of variations negatively.

Although, variations due to "unforeseen problems" constitute approximately 10% of all variations in both Direct EPC and OBCE+EPC projects, the cost of variations compared to the total cost of variations is much higher in the OBCE+EPC project (14%) than in Direct EPC projects (1%). The surprising finding is that the number and cost of

Table 2. Comparison of the causes of variations

Causes of variations	Direct EPC		OBCE+EPC	
	% of number of variations	% of cost of variations	% of number of variations	% of cost of variations
Change in design	36	10	15	13
Change in specifications by the owner	2	6	7	21
Change of plans or scope	50	83	53	33
Conflicts in contract documents	0	0	14	9
Substitution of materials	0	0	3	9
Unforeseen problems	12	1	9	14
TOTAL	100	100	100	100

the variations caused by "change in specifications by owner" are considerably higher in the OBCE+EPC project (7% and 21%, respectively) than in the OBCE+EPC projects (2% and 6%, respectively). Soil and subsoil tests and studies made after the OBCE period may be a reason for this finding.

Variations caused by "conflicts in contract documents" and "substitution of materials" are recorded only in the OBCE+EPC project. This result is questionable since the engineering maturity observed in the OBCE+EPC project was quite high compared to the engineering process in the Direct EPC projects. When the events that caused "conflicts in contract documents" and "substitution of materials" are examined in detail, it is seen that these causes were triggered by unrelated project management decisions.

DISCUSSION

The primary finding of this study is that the variation ratio in the two-stage OBCE+EPC project is less than the variation ratio in the single-stage Direct EPC projects. This is an expected outcome because extensive engineering studies are conducted and procurement packages are evaluated in detail in the first stage of OBCE+EPC projects. This situation provides the advantages stated below:

1. The scope of the project becomes much clearer.
2. The amount of construction and the type and amount of materials to be used in the project are calculated much more accurately.
3. The datasheets for the components to be used in the mechanical/electrical systems are prepared and vendor proposals are obtained.
4. The owner and the contractor are able to prepare precise cost estimates.

As a result, project managers are in a better position to prevent potential problems by performing extensive engineering and preparation work way before the EPC stage. This finding is also supported by the findings related to the causes of variations identified in the four case projects. The data collected from the four case projects showed that for variations caused by "scope and plan changes", the percentage of the number of variations out of all the variations that occurred in the OBCE+EPC case project is significantly less than in Direct EPC projects. Similarly, the percentage of the cost of the variations compared to the cost of all the variations that occurred in the OBCE+EPC case project is also significantly less than in Direct EPC projects.

Variations caused by "change in design" were expected to show similar behaviour. However, although there are fewer variations caused by "change in design", the cost of the variations is negatively affected by late design changes in OBCE+EPC projects.

It is understood from the literature review that the two causes cited above are quite common in most construction projects as evidenced by the many studies conducted in many countries including Oman, China, Nigeria, and Sri Lanka.

- Alnuaimi et al. (2010) stated that the first cause for the variations in construction projects undertaken in Oman is "owner's additional work". Al Maamari and Khan (2021) conducted a similar study in Oman and found "change of scope", "errors and omissions in design" and "insufficient logistics" as the primary causes of variations.
- According to An and Ma (2019) "incompleteness of design" and "continuous demand for project by client" are the first and second causes of variations in Chinese construction projects.
- The main findings of Babalola and Idehen (2011) who investigated the causes of variations in building construction projects in Nigeria are "change in plan or scope by owner" and "change in specification by owner". Muhammed et al. (2015) conducted a similar study in Nigeria and found "change of the original plan", "conflicting contract documents", "substation of materials" and "change in design" as the main causes of variations.

- Perera et al. (2020) examined building projects in Sri Lanka and found that the main causes of variations were "change of plans or scope", "inadequate working drawing details" and "design discrepancies". Priyantha et al. (2011) found "requirement increases of client" and "design changes of consultants" as the most often causes of variations in highway construction in Sri Lanka.

The surprising finding of the study was that the number of variations caused by "change in specification by owner" was significantly higher in OBCE+EPC projects. Soil tests and related changes made after the OBCE period seem to be the main reason for this finding. Variations that were caused by "changes in specifications by the owner", "conflicts in contract documents" and "substitution of materials" are mostly observed in the OBCE+EPC project.

CONCLUSION

In this study, variations in EPC/Turnkey oil and gas projects are analysed relative to their tendering methods. Four EPC LSTK projects which were awarded using the Direct EPC and the OBCE+EPC tendering methods are compared using four case projects. The variation ratio is 1.2% in the OBCE+EPC project, while this ratio ranges from 1.6% to 6.1% in the three Direct EPC projects. The variation rate is less than 10% in each case project, very much in sync with the findings of a similar research study conducted by Al Hammadi (2009) relative to oil and gas projects in the UAE.

Variations are classified according to their causes to analyse the effect of the tender methods on them. According to the data collected from the four case projects, "change of plan and scope" was found to be the most dominant cause for variations. The cost of the variations caused by "change of plan and scope" ranged between 33% in OBCE+EPC projects to 83% in Direct EPC projects. This finding highlights the importance of an accurate and reliable definition of the scope and a high level of engineering maturity prior to undertaking Direct EPC/Turnkey tendering, as evidenced by the lower cost of variations in OBCE+EPC projects where the scope is developed in the detailed engineering is thoroughly done in the OBCE stage, way before the EPC stage. It also supports the assertion of Dumont et al. (1997) about the negative effects of inadequate scope definition on project cost overruns. This finding also strengthens the idea of implementing a FEED study before the EPC phase.

"Change in design", "change in specifications by the owner", "conflicts in contract documents", substitution of materials", and "unforeseen problems" are other causes of variations which were found in the four case projects. These issues are also listed as major causes of variations by other researchers such as Mohammad et al. (2010) and Hanif et al. (2016) but in different types of projects other than oil and gas.

Unfortunately, there are only a few quantitative research studies that focus specifically on the causes of variations in oil and gas projects, even though billion dollars are invested in this industry. This situation makes it impossible to compare studies that investigated similar parameters for the same type of project. Therefore, additional studies have to be conducted to increase the reliability of the conclusions. Nevertheless, according to the results, the two-stage tendering method is recommended for large and medium-sized oil and gas projects.

This paper is expected to contribute to a better understanding of variations when owners are discussing investment strategies and provide benchmark data to other researchers for use in similar studies. The effect of the FEED+EPC tendering method on variations can be examined in future studies.

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