Engineering-Related Causes Impacting Targets Of Construction Projects: Critical Review

1 Dr. Ahmed Salim Al Saeedi , 2 Dr. Asif Mahbub Karim

1 Ph.D, Senior Construction Engineer, Oman.

2 Dean, Binary Graduate School, Binary University, Malaysia.

Abstract

Time and cost overruns in construction projects are well known around the world. There are several fundamental root causes of such overruns. This paper addresses the engineering related causes which lead the project to miss its targets. Four main Factors were identified in the literatures; discrepancies, design errors, rework and variation order. It has been found that these factors are correlated to each other, and surely impacting the schedule and budget performance. Main engineering causes are somewhat similar between countries in the globe, and major change of design is very common. The study generates a conceptual framework of engineering related causes, to be investigated further in the future.

Key words: Construction delay factors, Time overrun, Design, and Engineering.

1. Introduction

Definition of project management has been discussed in many books and journals and one of these is:

“the application of knowledge, skills, tools and techniques to project activities to meet project requirements” (PMBOK, 2008)

One of the common requirements of a project is to avoid delay in its schedule. This delay has been defined by (Mubarak, 2005):
“delay is an event or a condition that results in work activity starting, or project completion, later than originally planned or an interruption or a hindrance to a planned program”.

And by (Memon, et al., 2011):

“refers to progress compared to baseline construction schedule. Baseline construction schedule refers to the schedule prepared by contractor before the start of the project and approved by the client”.

A study conducted in Saudi Arabia revealing that 70% of construction projects suffered from an overrun in schedule (A.Assaf & Al-Hejji, 2005). In more specific city, only 61% of Mecca projects were completed on time (Elawi, et al., 2015). Sometimes the delay reaches 90% like in Malaysia, in MARA projects (Memon, et al., 2011).

In a case study conducted by (S.Alnuaimi & Almohsin, 2013) in Omani Construction Projects the delay was around 59% in 2007-2008 period and 42 % in 2009-2010. And for the years after 2011 to 2014, in 40 construction public projects, 38 % of them suffered an over run in schedule (Ruqaishi & Bashir, 2014).

In oil and gas industry, 73% of mega projects suffer from time overrun, and middle east is the worst region in that department: 87% proportion of projects suffer from time overrun (EY report in 2014).

The major causes of delays are generated from different stakeholders involved in the project delivery (Client, Contractors and Consultant).

There has been a framework developed by (AlSaeedi & Karim, 2018) shown below, investigating the project schedule performance:
Based on this framework, one of the independent variables is Engineering Factors which have a linear effect into the schedule performance.

2. Literature Review

Engineering factors has been part of the major factors of time and budget overrun in many of the past studies; it includes the specification, drawings, design and others. These articles are, not limited to: (A.Assaf & Al-Hejji, 2005) found “Late in reviewing and approving design documents by owner” as the top 2 factor causing time overrun. (Doloi, et al., 2011) found 2nd top factor “non-availability of drawing/design on time”. (Hao, et al., 2008) found “design changes” one of the top five ranked. (Hwang, et al., 2012) found third top factor contributing a delay is “design changes by owners”. (S.Alnuaimi & Almohsin, 2013) found “change in initial design” is third important factor in commercial buildings in Oman. Some more recent papers are (Jarkas & Younes, 2014) found “frequent change/variation orders issued by the employer and lack of coordination among design disciplines” are the top third and fourth respectively while (Elawi, et al., 2015) found “Redesigning-line services” is the second top factor in Mecca construction projects. (Kalkani & Malek, 2016) found 2nd top factor in Indian projects are “Drawing revision and clearances from consultant/client/PMC”.

Thus, design issues are one of the main factors contributing to an expansion of the completion date of a project and could cause a cost overrun. The researcher suggested reclassifying heading of all factors related to design and technical issues to be an Engineering Factors.

3. Finding
3.1 Discrepancies

Discrepancy is one of the issues that face the industry in the Engineering, Technical and Design part: one study in Pakistan done on causes of “Discrepancies”, (Choudhry, et al., 2016) where they defined it as “a difference between the design and site conditions” used a questionnaire given to all stakeholders (client, main contractor and consultant) in the construction of buildings. The questionnaires consisted of possible 65 causes generated from the past studies on this matter.

The top finding was revealed that, in the design stage the engineers are not given complete information or data to deliver an error free document. Understandably, this factor of discrepancy has been ranked first by the client, but what was surprising is that the consultant ranked it first as well. This implies the importance of such factor that needed to be paid more attention to. Moreover, the researcher appreciates the unbiased response from the consultant of the project as sometimes the blame goes to other stakeholders especially to the client. The authors found that the reason behind this factor is that the consultant rushes their engineers to finish the design because they made a promise to the owner of some specific deadline. This will have more pressure to the workforce which results in a design that is mediocre and incomplete.

The second top factor of discrepancies in construction in the same study is still within the design phase. The factor is failure to review the structure design not being according to standards and governmental laws. The design not only has to be following the standards but also to the local regulations. (Choudhry, et al., 2016) explicitly states that this phase, that is design phase, is the phase that is more likely to be the source of the discrepancies and the results backed this up.

The third top cause is; discrepancies take place when there is a change ordered by the client. This change is triggered by the financial difficulties that the owner faces. This factor found during construction phase where the client goes through a difficulty in budget and tend to change some design in the project to save some money. Unfortunately, this results in a discrepancy in the work package.

One of the important factors mentioned also, the unrealistic period given to complete the design stage. This factor has been identified by the consultant as the second top and the seventh by the client. In other words, there is an acknowledgement by the owner that it is an important aspect in causing the discrepancies which caused by the client themselves. They are sometimes unaware that engineering & design phase takes time and in order to get a complete and higher quality design. Moreover, they need to give the consultant some slack and let them work and create drawings within a reasonable time frame, not too little and not too much.
In addition, the consultant has pointed a finger at the construction contractor in this study. They ranked the incompetent personnel within this contractor as the fourth top factor in causing discrepancies in the project. Consultant thinks despite that sometimes they have short period of time of design to deliver drawings and documents, they still feel the main construction contractor plays big role in causing mismatches. Overall, this factor is the top sixth in the list. (Choudhry, et al., 2016) at the end, recommended that all parties involved in the project must be aligned and they should communicate effectively among themselves to eliminate many discrepancies.

3.2 Errors
(Lopez, et al., 2010) conducted a peer review on the various definitions of design errors. Out of all these meanings, the researcher leans toward (Hagan & Mays, 1981) and (Busby, 2001) because of their relevance to the construction industry. According to the selected authors, definition of error is “a failure of the human to do a designed task within specified limits of exactness” and “which is unexpected, and which could not be attributed entirely to chance” and “failure to deliver client requirement”.

When a group of designers given a design task, they spend some time into the activity to deliver some specific product, i.e. a drawing. The background and experience of each and every one in this group varies. Also, the work environment they are in, sometimes is different from others. Therefore, (Busby, 2001) stated that it is not coincidence that these incidents take place, there are actually factors and causes of errors that occurs mostly in design stage. (Lopez, et al., 2010) shed the light on causes of design errors that were mentioned in the previous studies, “lapses” was one of those causes. (Henriksen & Dayton, 2006), (Cheyne, et al., 2006) and (Carriere, et al., 2008) have discussed about this factor. they stated that this failure (making an error) could occur to most of us and it is not uncommon. While “Slips” occur when the needed information is available, but the execution is not done as per the plan, according to (Zhang, et al., 2004).

So, an example for lapses, it is seen almost every day during the design, a designer may be fatigued and working on some drawings, as a result, these drawings lack precision and quality. That is why it is recommended to have a review panel to go over such drawings or technical documents in order to ensure these “lapses” are captured and corrected immediately. According to (Sonnentag & Zijlstra, 2006), the more fatigue is there, the more short breaks are needed to get back to neutral state of mind and therefore there are less errors.

Another factor of design error learnt from (Lopez, et al., 2010) is how the organization handles such situations. In other words, does the organization track, monitor and control these errors? the author revealed an example in the building construction, where their
engineers don’t track the errors that took place and surly don’t learn from it. In oil and gas projects in Oman, the situation can be seen better in the researcher opinion. Not only there is a complete review team who is primarily goal to fetch any deviations and errors in the design but also there a lesson learnt tool. This tool includes the lesson (error made in the past), which disciplines/area and what the control/mitigation is, in order to avoid repetition. Also, there is a quality assurance team who is on top of every team member, performing audits to ensure the design up to the standard and this in line with (Love, et al., 2000) emphasis about quality assurance.

(Lopez, et al., 2010) (Feld & Carper, 1996) (Tilley & McFallan, 2000) and (Love, et al., 2008) have all agreed on the obvious factor of design error, sometimes, which is the incompetency of the engineers. When an organization hires incompetent designers, they get what they pay for, a bad quality drawings and documents. What is interesting that these authors coupled the factor of incompetency with the notion of lowest bid tendering. They explained that because engineering firms attempts to secure a contract, they tend to lower their bid. Lowering the bids leads to hiring mediocre and low experience designers which results in error prone documents. If engineering firms hires experienced designers, they are obligated to pay them what they deserve, and that might exceed the bidding price. Therefore, the previously mentioned authors share some of the blames (error causes) to the tendering process that grants the lowest bid not of the best bid.

The last factor (Lopez, et al., 2010) shed the light on, and by no means it is not the least, is communication and coordination. That could be communication between client and designers where sometimes the designer deliver something that is not what owner desires, or that coordination and integration between design phase and construction stage. When there are projects contracted two separate contractors for design and construction, there is less coordination between the two and consequently the design errors are likely to occur. Having said that, still, (Lopez, et al., 2010) unfortunately found in Australia buildings projects, that even though the design and build contracts (assigned to one contractor) still lacks coordination between design and construction team. Although theoretically, the latter contracts, the communication among the two teams are improved. (Arditi, et al., 2002) argue that even if the design package has been awarded to one contractor and the construction is to another, errors can be minimized by adopting the philosophy of “constructability”. Such philosophy helps the designers see through a model as if it is real, at site, to reflect on their work which leads to a higher quality of design. (Arditi, et al., 2002) found around only 50% engineering firms have adopted constructability concept, and that led to increase in number of errors.

(Lopez, et al., 2010) have discussed many of the major accidents that resulted in many fatalities and injuries. These accidents were mainly caused by engineering errors especially
structural design. While safety is the main concern, (Lopez, et al., 2010) also implicitly mentioned that design error eventually will affect project overall schedule and budget.

3.3 Rework

It is true that there are some other factors contributing to rework in construction projects, like the contract document not being written correctly or fully (Rounce, 1998) & (Yogeswaran, 1998), but there are other factors that have been discussed earlier which are the main triggers of rework: design errors.

(Manavazhi, 2004) and (Tilley, et al., 1997) suggested that a vital factor leading to rework is the errors that occur in design stage. (Rounce, 1998) looked at the whole design practices and found flaws that lead to errors and eventually rework. These flaws may include shortage of drawings and deliverables, and the incompetence of design procedures. Rework has been defined by (Love, 2002): is the process to re-perform or redo some task that has been done before. (Sun, et al., 2004) states that this task or activity was not done in the right way at the first time. (Hao, et al., 2008) have called rework “a pure waste” and it would appear because of its total negative impact on the project. Most of the rework comes in a form of change orders in to be executed formally according to (Hao, et al., 2008), and the subject of such phenomena, will be discussed later.

A study conducted by (Love, et al., 2006) investigating the concept of rework which occurs during the project cycle especially design and construction. 420 questionnaires were distributed to random engineering organizations, 161 returned and used for the data analysis.

It was found that the first ranked factor contributing to rework is lack of coordination within the design team, from the perspective of engineers themselves and the construction contractor. It is brave to see the consultant designers admit that they need to improve communication among themselves to avoid rework in the project. Losing staff within the design stage was ranked second overall cause of rework according to (Love, et al., 2006) study. It would appear this is a problem that most construction industry suffer from. When a full team of design is working on a piece of work, and then suddenly one of the main engineers goes to another firm, this leaves a vacuum in the place. This team will try to fill in this vacuum by sharing the left engineer’s roles and responsibilities and during all this process, a rework would creep in.

“Incomplete design at the time of tender” was ranked third overall cause of rework in Australian projects. Putting some much pressure on teams, and giving them unrealistic duration to complete their tasks, is definitely resulting in “incomplete” works. When the design is not finalized totally, and it is presented at the tendering stage to go ahead for construction, some packages in the plant will be missed. It means that some other party has to do it, and that is more likely to be the construction contractor. Although, (Love, et al.,
2006) confirms explicitly that in the design stage, most of rework is “originated”, and so much less of rework accounted by the main construction contractor. The contractor is not fully competent to design and build or install, therefore rework is the likely result.

“Inadequate client brief to prepare detailed contract” has been ranked tenth overall cause of rework in (Love, et al., 2006) study. It would suggest that quality of contract document has small significance in generating rework in projects in Australia. As matter of fact, (Love, et al., 2006) confirms by statistics tool that there is no correlation between the document of the contract and rework, and that is unlike of (Rounce, 1998); (Yogeswaran, 1998), where they found that the contract document plays significant role in getting number of rework higher.

(Love, et al., 2006) then recommend in order to reduce the amount of rework, that the design team shall “cross check and referenced with other projects” which is not happening greatly in Australia construction section. And as discussed in design error section of this study, the activity of double checking or reviews of the work done during design, is not there because of tendency of clients going for the lowest bid. Lowest bidders engineering firms will likely give a below par services, incompletes ones. Moreover, for the same purpose (Love, et al., 2006) recommend reducing number of revisions in one drawing which may lead to confusions and eventually rework.

3.4 Variations Orders

The researcher would start with the article of (Lu & Issa, 2005) that suggested that the primary cause of change order is the change of design, and they believed that it is the more common source for change order. Change of design is believed to be the most dangerous factor that would hurt project targets of time and cost according to (Lu & Issa, 2005). Is this true? Let’s find out by going through other literature in the same topic.

Before going into the details, it would appear that change order and variation order are almost the same; the past literature doesn’t cover if there is a difference between them. Although, one of the early interviews conducted by the researcher to one of the rich experience professionals in this business, stated that there is a minor difference. Variation order is a wider term than change order, they are all the same, but variation has a bigger scope. Nevertheless, we will go with the assumption that change order is the same as variation order since as mentioned, the past literature suggests there is no difference. One example, When (Enshassi, et al., 2010) referenced from (A.Assaf & Al-Hejji, 2005) paper, they called it variation order, although (A.Assaf & Al-Hejji, 2005) called it change order in their article. Also, almost all literature gone through, whenever the authors explain variations, immediately the word change comes in the sentence.

In addition, the researcher found a study by (Zaneldin, 2006) where he ranked the causes of claims. The top cause was change orders and, in the list, he stated it as “Change or
Variation orders”. This support the researcher argument that change, and variations are meant the same in the context of project management. The same found in (Adeyemi & Segwabe, 2016) article in the same topic where called it “Change or Variation orders”, as it is the fifth ranked cause of claims in Botswana.

One of the early studies of variation orders was done by (Hibberd, 1986) and he implied that it is an order of change in the quality or the quantity of any of the deliverables assigned to the contractor, that are explicitly mentioned in the project contract. Changes in a project are inevitable, occur in any stage of a project, because of a wide range of reasons, they vary from being small change or a large one (Hao, et al., 2008). However, what is important in the change whether this change has a small impact on project performance or severe!

According to (Hao, et al., 2008), almost all changes don’t occur because somebody plans to change, they happen unexpectedly and what is important is that there is a mutual agreement among all who are involved in these changes and variations.

(Hao, et al., 2008) state that agreement must be well documented and to be officially and formally recorded. This agreement is as if starts to be part of the construction contract, that is between the owner and the main construction contractor (O’Brien, 1998), (FIDIC, 2005) and (Arain & Pheng, 2005). It is believed that change order costs up to 15% of project budget in most projects worldwide (Desi, et al., 2015) and (Diekmann & Nelson, 1985).

(Enshassi, et al., 2010) have studied the construction project in Gaza, Palestine. They have used questionnaires spread to different stakeholders to collect their data of top factors contributing to change orders, out of 64 identified from the previous literature. The findings shown in below table. It could be seen that design issues are dominating the findings and “change in design” is the top of those issues. Moreover, if it was not for the special circumstances Gaza has been at, change of design which is second overall, would be first top factor of variation order in Gaza. A siege has been placed on this city of Palestine as explained by (Enshassi, et al., 2010), thus it affects the results. Getting materials and equipment in and out of the city has been challenging.

Back to “change in design” factor, it was unsurprisingly agreed by all stakeholders to be the 2nd top factor. It shows its obvious frequency and consequences in variation order topic.

“errors in design” comes fourth in the top ranked factors, and again it is part of the design issues that affects variation order. (Enshassi, et al., 2010) urged to minimize those errors in design so that construction team would not suffer from many orders of change.

(Halwatura & Ranasinghe, 2013) used both questionnaires and case studies of 11 road projects in Sri Lanka. The grouping of the factors was the same of (Enshassi, et al., 2010) study except for the “donor” group. The latter group would appear to be available in areas
where living is hard and expensive to the degree that some external person “donates” the project.

(Halwatura & Ranasinghe, 2013) finding seems different from any other country in the world as shown in the table. However, the researcher could still see these factors of variation order caused by the consultant. It could be interpreted that “estimation” as the very early design and plan of the project. If the data collected from the site visits are not proper followed up by inadequate design, then the inevitable will occur: a change order. Nevertheless, (Halwatura & Ranasinghe, 2013) stated client related factors are the leading ones as they are supposed to double check and review the consultant works. Plus, the authors pointed out that the consultant and contractors are hesitant to admit in the paper of the case study that “political pressure” applied by the owner is one of the main causes of variation order. It has been explained that they seem to be afraid to come forward, in order to a guarantee contracts from the owner and therefore, the consultant and main contractor don’t want to upset the owner.

(Assbeihat & Sweis, 2015) Investigated the public projects in Jordan to find out the top factors that causes order of change. The authors of this study change the group naming slightly, to “Input Factors, Internal Environment, and Exogenous Factors”. The IF would be about the resources, either human or material & equipment. IE involves the different stakeholder, the owners, consultant, and main contractor. EF would the other factors or external factors like weather or governmental laws. As shown in the below table, the top ranked factors are all design related issues, whose accountability is by the owner and the consultant. Modification of design and extra works sits upfront in the importance list which signifies its role in causing the change orders in Jordanian projects.

(Assbeihat & Sweis, 2015) have emphasized that these factors could be applicable for all developing countries, and it would appear to be true in Oman as well. Actually this is in line with (Ali S. Alnuaimi, et al., 2010) who confirmed with their studies that extra works that are imposed by the client is the main top factor casing variation order in Oman public construction projects.

A recent paper by (Kolawole, et al., 2016) who studied building construction projects in Northern Nigeria and their causes of variation order. They adopted the same methodology of the mentioned articles: questionnaires whose response rate among the highest the researcher found; it was more than 80%. On the top three ranked factors of change order were yet again related to with the change in design and errors as seen in (Assbeihat & Sweis, 2015) & (Halwatura & Ranasinghe, 2013) and (Enshassi, et al., 2010). As matter of fact (Kolawole, et al., 2016) found that the design and errors to be ranked first, similarly to the selected above articles of change orders, the top ranked group responsible for variation order were the consultant and owners.
3.4.1 Change Order in Oman

(Ali S. Alnuaimi, et al., 2010) have investigated various public construction projects in Oman. They have used questionnaires along with four case studies as their research methods.

(Ali S. Alnuaimi, et al., 2010) have found that the change order in one of the case studies investigated caused a project to be delayed 100% which is the double duration of the original baseline plan. Other case studies showed the time overrun percentage ranges between 8% to 33%. In other words, all of the construction projects studied by (Ali S. Alnuaimi, et al., 2010) have suffered from time overrun because of variation order.

The authors not only have investigated the causes, and effects but also the most stakeholders who is “benefiting” from the variation order. It has been found the contractor is the one gaining from this issue and because they are getting extra works and thus additional revenue.

Looking in depth in the top three ranked factors of variation order in Oman, the first two factors are exactly the same as (Assbeihat & Sweis, 2015) findings in Jordan projects. Extra and additional works is the top factor overall, and at the same time all the different stakeholders have placed this as the first factor from their point of view. It would appear that there is a lack of investigation at very early stage of the project, lack of basic design as called in oil and gas projects. When there is a very little design done at the beginning of the project and then this design is given to a construction contractor, additional works would be definitely there. This extra work is a continuation of design that is supposed to be done before. Consequently, there is the 2nd factor, where the client would have to order to have a modification in the design to complete the project.

What the researcher noticed in the findings, there was one factor ranked third among the contractor perception which is “Unrealistic design periods”. It seems that the contractor would feel the period given to the design stage is not enough and that what causes extra works and modification. This mentioned factor has been found also as the top first factors in studies of time overrun causes in many articles the researcher gone through like (Fallahnejad, 2012), (Alshamsi, et al., 2019) and (Naimi, et al., 2008).

<table>
<thead>
<tr>
<th>Study</th>
<th>Factors of Variation Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determinants of Change Orders in Building Construction Projects in</td>
<td>Design and Document Related factors</td>
</tr>
<tr>
<td>Northern Nigeria</td>
<td>Error and Omission</td>
</tr>
<tr>
<td>(Kolawole, et al., 2016)</td>
<td>Change of Specification by owner</td>
</tr>
<tr>
<td></td>
<td>Bogus Contingency sum Prime cost Sums</td>
</tr>
</tbody>
</table>
Factors Affecting Change Orders In Public Construction Projects  
(Assbeihat & Sweis, 2015)  
Jordan  
Owner instructs modification to design  
Owner instructs additional works  
Ambiguities and mistakes in specifications and drawings

Causes of Variation Orders in Road Construction Projects in Sri Lanka  
(Halwatura & Ranasinghe, 2013)  
Questionneers:  
Poor estimation, Unforeseen site conditions, Political pressure”  
Case study:  
Poor estimation, Poor investigation, unforeseen site conditions, change in design by consultant/design changes

Causes of Variation Orders in Construction Projects in the Gaza Strip  
(Enshassi, et al., 2010)  
Lack of construction materials and equipment spare parts due to closure and siege  
Change in design by consultant  
Lack of consultant's knowledge of available materials and equipment  
Errors and omission in design

Causes, Effects, Benefits, and Remedies of Change Orders on Public Construction Projects in Oman  
(Ali S. Alnuaimi, et al., 2010)  
Owner instructs additional works  
Owner instructs modification to design  
Non availability of construction manuals and procedures for project construction in Oman

Table 1: Variation Order Causes

3.4.2 Change of Design in Oil and Gas Sector

There are limited numbers of studies discussing design changes in oil and gas sector. The following article has been found and to be investigated thoroughly by the researcher. As
seen previously, one of the important and common sources of variation order is the change in design. This factor will more likely contribute to rework, and definitely a change order and eventually a time and cost overrun into the construction project. Variation orders (change of design part of these orders) occur more in “large projects” than the smaller ones according to (Hao, et al., 2008) and the oil and gas projects are large and complex compared to some other type of projects; Thus the following paper is to be examined.

(Zadeh, et al., 2014) defined the “design changes” as “any addition, omission or adjustment to established project design requirements, documents, drawings or specifications”. In other words, for ongoing project, that is already running whether in design or construction stage, if a change in design occur, it is considered a design change. This change might be an addition of a drawing or deletion of such drawing, or any revisions in any of the design documents.

(Zadeh, et al., 2014) conducted a study on the major factors causing design changes in oil and gas projects. A questionnaire developed after examined by experts in the industry in Canada who have more than 20 years’ experience. The questionnaire got finalized with 28 factors that could cause the design changes and it is spread to 115 “practitioners” in the oil and gas sector. Categorization of such factors has been into the following: “project management practices”, “project related”, “Change- related” and “human related”. Although there was 48% response rate, the authors suggested that it is ok since more than 60% of the respondents have had more than 10 years’ experience in the same field of the study.

The top ranked factor contributing to design changes found by (Zadeh, et al., 2014) was related to “project management practices”. It has been found that the scope of project is not well defined and this is the main source to design changes in oil and gas projects in Canada. If the scope is incomplete or vague or generic for that matter, the design team will tend to guess how a particular package should be designed. Then later on, the client comes in and suggests that this is not what is wanted, well the scope of work is not that clear, can be claimed.

(Zadeh, et al., 2014) discussed some other literatures reviewers who listed and agreed this factor as one of the causes of design changes, as well.

The second top factor among the list is the overlap of schedules or called by others fast track projects. What happens in the fast track projects, is the parallel activities that are running are the same time. For example, civil and piping works start at site without electrical or instrument works has yet to complete its design. There is a big chance that there will be a change in the design when projects are run this way, this happens quite often in some projects in GCC. There was one building that had been already constructed while still the design of electrical and instrument are still in progress. After conclusion of the
design of electrical & instrument, the site team has found that the number of panels to be entered in this finished building can’t be accommodated. Thus, the whole project team needed to figure out a way to solve the issue and make change in the design!

Lack of experience of designers and engineers has been found the third top factor causing design changes by the study of (Zadeh, et al., 2014). It is given, that the design team must be experience enough to make an engineering of a building or plant especially with a complex project like in the oil and gas. Having inexperience and incompetent crew will likely to have a below par design which eventfully causes a rework and change. This factor has been brought up by (Lopez, et al., 2010) study when they were analyzing design errors in projects. It could be concluded that incompetency of the design team causes errors and design changes which jeopardize the project overall schedule.

Zadeh et al. (2014) and Alshamsi et al. (2019) has stated explicitly within their article that design changes will likely make the overall schedule of the project miss its deadline and causes cost overrun. Moreover, one of the key factors that contribute to design changes was the overlap tasks between design and construction. This factor has been suggested to lead to time overrun of in oil and gas sector.

4. Engineering Factors Impact on Project Targets

4.1 Impact of Errors

(Tilley, et al., 1997) have expressed the positive correlation between design errors and delay in overall project schedule. They stated that design errors lead to design changes, and these changes results in time overrun. (Lopez, et al., 2010) have discussed design errors in details and concluded that “project performance” will be impacted if number of design errors are increased. Project performance has been known across the industry, to include time and cost of the project.

For the Budget, (Lopez & Love., 2012) have set up questionnaires to include the respondents’ experience in projects there were involved in. Respondents needed to list the causes of the error that take place in design phase and how much the error costs the project. The cost includes both indirect and direct ones. The indirect cost as explained by the authors are ones that have to do with the aftermath of error event itself like decrease in productivity and claims. (Lopez & Love., 2012) found that the impact of the design errors was different from one project to another. In some projects the error costs 1% out of the value of the contract while others reach up to 90%. However, the authors measured the mean of all these findings, and found the cost of the design error to be around 14% as a total. The direct cost and the indirect ones are almost the same 7 % each.

The following a framework of design errors based on the discussed literature review above:
Figure 2: Conceptual Framework of Design Errors

4.2 Impact of Reworks

(Love, et al., 2006) explicitly stated that rework has a negative effect on completion date of the project, the same author, in another paper written (Love, 2002) stated rework does influence project targets of time and cost in Australian construction projects. The influence unfortunately is negative, it pushes the project overall schedule beyond the target date.

4.3 Impact of Variation Order

(Desi, et al., 2015), (Halwatura & Ranasinghe, 2013), (Enshassi, et al., 2010) (Assbeihat & Sweis, 2015) and (Kolawole, et al., 2016) have stated that change order affects both time and cost performance. In addition, in a study by (Ali S. Alnuaimi, et al., 2010) in Oman public construction projects, found that the most effect of change order in Oman, is the time overrun and over budget in the baselines of the project.

Moreover (Memon, et al., 2014) have investigated the variations order and its effect on time and budget performance using Average Index Method. The first finding was that variation order impacts both the project schedule and budget.

Interestingly (Memon, et al., 2014) study showed that there is an agreement by the client, consultant and main construction contractors that “changes in design” affects time performance. They all ranked this variation order factor to be the first one under the category of “design issues” that will cause delay in the project. It would suggest that such
factor is vital to be controlled and monitored closely otherwise it would definitely give the project team a hard time completing the project as planned.

![Conceptual Framework of Engineering Related Factors](image)

**Figure 3: Conceptual Framework of Engineering Related Factors.**

### 5. Conclusion

This paper reviewed the Engineering Factors contributing to time and cost overrun in projects and it also presented the conceptual framework that can be utilized for future studies.

In the past reviewed studies, Engineering Factors have been found to play a vital role in schedule and budget performance, which are: Discrepancies, Errors, Reworks and Variation Orders. Most of these factors are correlated to each other. For example, correlation of Design Errors is not limited to time and cost overrun only, but also to rework, Variation Order and accidents. Variation Order could lead to increase of number of claims, discrepancies and rework. The most common source of variation order is the design issues, whether be change in design, errors and extra works imposed in the design phase.

Lastly, it is observed that very few articles were found to investigate the Engineering Factors in oil and gas projects in the world.

### Bibliography


http://www.webology.org


Hao, Q., Shen, W. & Joseph, 2008. CHANGE MANAGEMENT IN CONSTRUCTION PROJECTS. s.l., s.n.


