Development of Cost Estimate for Engineering, Procurement and Construction (EPC) Project in 3 Steps[1]

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ABSTRACT

Cost estimate is a product of a project planning activities, project here including the Engineering, Procurement, and Construction (EPC) project. As a planning document, cost estimates must be reliable, which is develop by considering various aspects, that are the scope of work, Uncertainty and Risks, as well as other factors including market conditions in which the EPC Project will be auctioned off.

For this reason, a cost estimate calculation method was developed to accommodate these various aspects, which carried out in 3 steps.

The first step is calculation of the base estimate which is solely based on the predetermined scope of work of the project. The result is a cost estimate in a certain single value, so it is also called as a deterministic cost estimate.

The second step is running Monte Carlo simulation to analyze the effect of Uncertainties and Risks on the base estimate value resulted in the first step. Monte Carlo simulation results the cost estimate value in the form of a probability distribution. When in the first step we got the cost estimate in a single value, then the simulation in this second step produces the cost estimate in the form of a range of values and their probabilities.

The third step is to develop a bidding model, to map other factors related to the project including market condition into a value equivalent to the cumulative probability value of the cost estimate resulted in the second step. So that it can be determined which value in the range is used as the cost estimate (recommended cost estimate).

I. Introduction

In order to achieve the target in a project as it desired, implementation of the project must begin with good planning. Planning in various aspects, including one important aspect of the project, namely cost.

As a project document, the cost estimate contains details of the approximate cost of a project, a work or an activity to be carried out. Cost estimate is result of a cost estimating process, which is the process to predict the cost of the project. As the product of a prediction process, the cost estimate contains uncertainty. Uncertainty could come from the scope of work that has not been completely defined, it could also be due to variation

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in prices, error in cost modeling used in cost estimating process, and change in price that may occur before or during project execution.

Executing a project is not easy, there are many factors that influence it, both external and internal, which may have a negative impact to the project, which in the end could cause target was set in the planning is not achieved. These factors are known as project risks. Project risks have a negative impact on the project, including a decrease in the quality of the work products, delays in completion of the project and an increase in the final project costs. Mitigation of project risks is generally always carried out, however mitigation itself can usually only reduce the risk, it does not eliminate the risk completely, there is always a residual risk left there.

In general, projects are carried out by contractors, it is very rare that a project to be done by the owner himself. The appointment of a contractor to carry out a project is usually done through a bidding, which is participated by many bidders. During bidding, contractor always adds a number of costs in addition to the base cost of the project, which depends on the current market conditions. When the market is lonely with projects, where the level of competition is high, the contractor tends to reduce the cost of the project in order to win the competition. Conversely, when a project is in abundance in the market, the contractor will tend to increase the bid value.

Therefore, in order to obtain a reliable value, development of cost estimate for EPC project must take into account all of the above factors, namely const estimating uncertainty, project risks and market condition.

This paper will describe process of preparing a cost estimate, especially cost estimate for an engineering procurement construction (EPC) project in the oil & gas sector. As per the title of this paper, preparation of cost estimate is carry out in three steps, namely the preparation of a base estimate or deterministic cost estimate, Monte Carlo simulation to analyze impact of uncertainty and project risks, and development of bidding model to know the influence of market conditions (and other project related factors) to the project costs.

II. Deterministic Cost Estimate

Cost estimating is a process for predicting the cost of a project, a work, or an activity. For the project owner, the cost estimating result, which is cost estimate, can be used for various purposes, including as an owner's estimate in the bidding process or as an engineering estimate for budgeting purposes or other needs.

A cost estimate that is developed using a single specific value (single point estimate) for both price and quantity of the work is referred to as a deterministic cost estimate and is used as a base estimate[2].

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[2] The term “Base Estimate” here is different from term “Cost Baseline” used in the A Guide to The PMBOK 6th Edition. If in the PMBOK, the Cost Base line is defined as the Work Package Cost plus the Contingency Reserve, then the Base Estimate in this paper can be compared to the Work Package Cost, without any Contingency.

Cost estimate, especially for CapEx (Capital Expenditure) estimate, is generally made in the form of a standard structure, with each cost component being standardized as well.

This standardization is useful for preventing confusing during development of cost estimate and also accelerating the process of development cost estimates itself. With standardization of structure, it is easier to evaluate the reasonable price of each component, and to identify which component can be optimized. In addition, the standard structure allows us to build a cost model.

The following table shows one of the cost estimate standard structures that is often used.

Table 1: Cost Estimate Standard Structures

Direct Costs	**All costs related to the physical parts of the plant.**
1. Equipment Cost	Equipment cost including equipment allowance, freight, taxes, insurance, and duties. Equipment consist of pump, compressor, heat exchanger, tank, column/vessel, fire heater, boiler, reactor, spare parts, etc.
2. Bulk Material Cost	Bulk material cost that consist of site work, concrete, structure steel, building/architectural, piping, electrical, instrumentation/control system, painting/coating, fireproofing, insulation, scaffolding, etc.
3. Installation Cost	Installation cost consist of labor cost for installation and material cost for structural supports, including setting and calibration.
Indirect Cost	**All costs related to non-physical parts of the plant.**
1. Indirect Field Cost	All costs associated with temporary construction facilities; construction services; supplies and consumables; field staff and subsistence expenses; payroll, benefits; insurance; construction equipment/heavy lift and tools.
2. Home Office Cost	All costs associated with project management, controls and estimating criteria, procurement, construction management, engineering and design, and home-office expenses.
3. Other Cost	Contractor fee dan contingency.

There are a number of cost estimate method that can be used in estimating project cost. The use of certain method will depend on several things, including design maturity, purpose of estimate, project complexity, and availability of references data.

In the earlier phase of the project, where the availability of information is still very limited, the method used to calculate the cost estimate is of course different from the later phases where the engineering documents are more complete.

AACE International Recommended Practice No. The 18R-97 describes this mater very well in tabular form as shown in the following table.

Table 2: Cost Estimate Classification Matrix for The Process Industries[3]

	Primary Characteristic	*Secondary Characteristic*		
ESTIMATE CLASS	MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES Expressed as % of complete definition	END USAGE Typical purpose of estimate	METHODOLOGY Typical estimating method	EXPECTED ACCURACY RANGE Typical variation in low and high ranges [a]
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Notes: [a] The state of process technology, availability of applicable reference cost data, and many other risks affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.

Based on the table, it can be seen that in the initial project phase, where the engineering deliverables were still very limited (at 0% to 15% completed), the estimation method that used is a factored estimate, either capacity factored, parametric or equipment factored. Even if objective data are not available, more subjective methods such as analogy and judgment can be used. As the engineering deliverable becomes more complete (at 10% to 40% completed), the estimate method used also changes to a semi-detailed unit cost, or a detailed unit cost if 75% or 100% of the engineering deliverables are available.

In addition, the cost estimate method used also depends on the purpose of estimates to be developed. For budgetary purposes, the method that used is a factored estimate, on the other hand, if it is needed for bidding, the method that used is a semi-detailed or a detailed one. Factorized cost estimate is also often used as a comparison tool to verify the estimate result which developing using the semi-detailed or detailed method.

The level of detail in which a cost estimate is made depends on the complexity of the project or work. For a less complex project, let say the scope is only consist of few pieces of equipment, the cost estimate can be very detailed, piping system for example, it may be up to the level of flanges & fittings. On the other hand for complex projects, let say for building a new refinery, the cost estimate made is not as detailed as the cost estimate for installing the equipment as mentioned above, the quantity for piping system may be made in tonnage without specifying the number of flanges and fittings.

[3] AACE International, Recommended Practice No. 18R-97. (2011). Cost Estimate Classification System – As Applied
in Engineering, Procurement, and Construction for The Process Industries, AACE International, Morgantown, WV.

The estimate method used also depends on the availability of price data, whether in the form of in-house data, or commercial data base or vendor quotation. The use of these price data references must first be adjusted to the project requirements, such as the size of the equipment, the project location, and the project schedule. Particularly for the price reference from vendor (vendor quotation), the terms and conditions need to be considered, to ensure that these terms and conditions are in line with the project requirements.

III. Uncertainty and Risk.

Before discussing further as to cost estimate and its relationship with uncertainty, risk, and the market, we will first discuss the terms of uncertainty and risk considering that there is some confusion within the cost estimating profession regarding with both terms. Most of them equate these two terms, so that their usage is often interchangeable.

I begin this discussion by citing the definition of *risk* stated in ISO 31000: 2018[4], in which *risk* is defined as the effect of *uncertainty* on objectives. From this definition it is clear that the trigger for occurrence of *risk* is *uncertainty*. Every *risk* must be (the effect of) *uncertainty*, but not all *uncertainty* is a *risk*. The world is full of uncertainties, every day we are faced with tens, hundreds or even thousands of uncertainties. Does this mean that we are automatically faced with thousands of risks? Of course, it does not; when we create a risk register for a project, for example, what is listed as risk is at most 10 to 20 items. This is because that of the many uncertainties that exist, those that fall into the risk category are just those that have an impact on (the objectives of) the project.

An uncertainty can be a risk for one person and not for others. Will it rain this afternoon? It could be "yes", it could also be "no", it is an uncertainty. For John who would being at home, he doesn't care whether it would rain or not. For him, raining or not in the afternoon, it will remain as uncertainty, not turn into a risk. However, for Jack who everyday walks to the office, this is a risk. Therefore, in his backpack, there is always an umbrella as a mitigation measure.

The impact of risk can be estimated by multiplying the probability (probability of occurrence) by the impact. The probability of each risk has a value between the range of 0 - 1, which means that the risk may or may not occur. In fact, there are also types of risk that will definitely occur (probability value is 1), an example of this type of risk is the *inherent error* that exists in each cost model which affects the resulting cost estimate value. This *error* must exist, it's just that its value cannot be known for sure, all we can do is to estimate the value. Another example is the incompleteness of the project definition (let say, in the BED or FEED phase, even in the DED phase), which affects the cost estimate value.

[4] ISO 31000:2018, Risk Management – Guideline; is a standard that contains guidelines for implementing risk management in the organization.

Both types of risk must be distinguished, because they are handled differently. For simplicity, for the first type of risk we just call it *Risk* (with a capital R to distinguish it from risk in general), while the second type we call *Uncertainty* (with a capital U, to distinguish it from uncertainty in general).

Similar discussion related to this topic has been carried out by Knight[5]. According to Knight, there are two different types of uncertainty, the first is called measurable probability which is labelled as *Risk*. The second is still referred to as *Uncertainty* where the probability cannot be measured (unquantifiable ambiguity)[6]. This means that all risks of unknown-unknown and known-unknown types are also included in the *Uncertainty* category [please refer to next section for the explanation of the types of risk].

Apart from Knight, a similar explanation also was made by Melvin[7] and Dale[8]. According to Melvin, a *Risk* is a discrete event with a probability of occurrence. The *Risk* effect (impact) is only felt if/when the event occurs. On the other hand, there is no probability of occurrence with an *Uncertainty*, you know that you don't know the actual value of the input variable.

What needs to be interpreted from Melvin's explanation is that *Risk* is a discrete event that has a probability, may or may not happen. On the other hand, *Uncertainty* is not a discrete event so it has no probability (if probability is applied then the value is 1), in the sense that it will definitely happen. Melvin's explanation is similar to Dale which explains the difference between *Uncertainty* and *Risk* in the form of a probability and impact table as shown in the following table.

Table 3: Probability and Impact Matrix by Dale

Terminology	Probability of occurrence	Impact	
		Cost or Hours	Schedule
Baseline	100%	Deterministic estimate (Most Likely)	Deterministic estimate (Most Likely)
Uncertainty	100%	Three point estimate (Min-ML-Max)	Three point estimate (Min-ML-Max)
Risk	<100%	Three point estimate (Min-ML-Max)	Three point estimate (Min-ML-Max)

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5 Knight, F H. (1921). Risk, Uncertainty and Profit. New York, USA: Dover Publication.

6 It is adapted from Mundir A. H. (2018). Understanding Risk and Uncertainty in Project Management; European Journal of Economics, Law and Politics, ELP; March 2018 Edition, Vol.5, No 1.

7 Melvin R. Etheridge, Jr. Risk vs Uncertainty, What's the Difference? Presented at the 2016 ICEAA Professional Development & Training Workshop. By using a reference from "The American Heritage Dictionary, Second College Edition", and by taking the context of the management program, Melvin R.E, Jr distinguishes the terms risk and uncertainty as follows:

- A Risk is a discrete event with a probability of occurrence. The Risk effect (impact) is only felt if/when the event occurs.
- There is no probability of occurrence with an Uncertainty – you know that you don't know the actual value of the input variable.

8 Dale Shermon (2017). Uncertainty and Risk: defined through probability and impact!. Refer to https://www.linkedin.com/pulse/uncertainty-risk-defined-through-probability-impact-dale-shermon

In addition to the two terms *Uncertainty* and *Risk*, Dale also added one more term, namely *Baseline*.

The *Baseline* is an acknowledged activity to be conducted; it is required to complete the work package and as such is essential to the project. The probability of the project conducting this activity is 100%, it's part of the project, an essential step to completion, and it's possible to assign a resource (cost) or duration (schedule) impact necessary to conduct this baseline activity.

The *Uncertainty* is similar to the *Baseline*, as it has a probability of 100%, due to the need that the project requires this activity. The difference here is that the resources (cost) or duration (schedule) is defined using a three-point estimate or a range.

In case of Risk, the calculation of resources (cost) and duration (schedule) is the same as *Uncertainty*, namely using a three-point estimate, while the probability is less than 100%.

IV. Uncertainty in Cost Estimate

Uncertainty always exists in the cost estimate, it arises because of the inherent inaccuracy (inherent error) in the methodology used during preparing the cost estimate, especially in the cost model. For example, in pricing a piece of equipment, say a pump, by using the reference price from the previous project (in-house data), to adjust to the current conditions, the reference price must first be multiplied by one or more factors, for example the sizing factor if the size is different, the location factor if the project location is different, the escalation factor for correcting the project time, the material factor if the material type is different, and other factors. The value of these factors is obtained by statistical methods from the data set, where the results always have errors.

The use of a more updated reference price, namely from the vendor quotation is also the same. If we get quotation prices from several vendors, these prices are never equal, this shows that the quotation price also contains uncertainty.

In a project scale, the use of the factor (equipment factor) to calculate other cost components of the equipment price, such as the Lang, Happel, Hand, Hackney, Guthrie factor, etc., or the use of the capacity factor to calculate the price of a process unit also contains uncertainty. These factors are also derived by using statistical methods which have errors.

Uncertainty itself means the absence of certainty, so that the uncertainty value is not a single number (point value), but it is random in a certain range. The most appropriate tool for analyzing it is by using a Monte Carlo simulation.

V. Project Risk and Cost Estimate

Project risk could have an impact on project objectives including project costs. In general, project risk can be grouped into 4 (four) types which are described in the form of a quadrant model. In the quadrant model, there are two aspects to be seen, namely "identification" and "certainty"[9], as shown in the following table [10]:

Table 4: Risk Classification Matrix

Identification \ Certainty	Certain (known)	Uncertain (Unknown)
Identified (known)	Known – Known (Identified Knowledge)	Known – Unknown (Identified Risk)
Unidentified (Unknown)	Unknown – Known (Untapped Knowledge)	Unknown – Unknown (Unidentified Risk)

In above table, if the nature of an event is certain, it is more like a fact or knowledge. It could be what we already know, i.e., *known known*, or what we don't know yet, i.e., *unknown known*. If the nature of an event is uncertain, the occurrence can be uncertain, i.e., probability of occurrence is less than 1, and the impact can be uncertain as well[11].

All risks that have been correctly identified and measured properly fall into the *known-known* category. There are risks that we already know because they have been well identified, but cannot be measured accurately, this type of risks is included in the *known-unknown* category. There are also risks that could not be measured and even the risks themself could not be properly identified. This type of risk is included in the *unknown-unknown* category.

The last type of risk, namely *unknown-known*, is very rare, but that does not mean it does not exist. These are things that exist and have been influencing our life and our approach to reality, but we are unaware of knowing them, or we do not realize their value, or worst we refuse to acknowledge knowing them[12].

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[9] Risk classification can also be based on aspects of *occurrence* and *impact*, i.e. *known-known* (knowledge); *unknown-known* (untapped knowledge); *known-unknown* (risk); *unknown-unknown* (unfathomable uncertainty)

[10] Kim S.D. (2012). Characterizing Unknown Unknowns. Paper Presented at PMI Global Congress 2012 – North America, Vancouver, British Columbia, Canada. Newtown Square. It is cited from https://www.pmi.org/learning/library/characterizing-unknown-unknowns-6077

[11] Ibid

[12] https://kyotoreview.org/issue-15/known-knowns-known-unknowns-unknown-unknowns-and-unknown-knowns-in-the-south-china-sea-disputes/ . In this website, the author tried to describe the disputes in the South China Sea using the *known-known, known unknown, unknown and unknown known* approach. He quoted Slavoj Zizek, a Slovenian Marxist philosopher, that *what is most important to mankind is what he calls "unknown knowns*". Furthermore he explained that these are things that exist and have been influencing our life and our approach to reality, but we are unaware of knowing them, or we do not realize their value, or worst we refuse to acknowledge knowing them. These things fall into the *unknown-known* category. To illustrate this thing, he took the case of ASEAN's position in the South China Sea dispute, especially in relation to competition between China and the USA.

To reduce its impact on the project, all these risks need to be managed, namely by identifying and understanding project risk, especially for risks included in the *known-unknown* and *unknown-known* categories, and trying to shift them into the first category, *known-known*.

The first step in risk management is to identify risks by developing a project risk register. The risk registers also include probability and consequences for each risk. By using probability and impact, risk is categorized based on its level of significance. For high significant risks, it will be completed with mitigation action to reduce the significant level become lower. Any costs incurred in connection with the mitigation program are included as a component of project costs and are part of the deterministic base estimate.

Mitigation cannot eliminate all risks; this activity can only reduce risk to a certain level called residual risk. This residual risk also needs to be accommodated in preparing the cost estimate which is carried out through the Monte Carlo simulation.

VI. Market Condition and Cost Estimate.

One method to accommodate Uncertainty and Risk in the cost estimate is through the Monte Carlo simulation. Result of Monte Carlo simulation is total project costs in the form of ranges on the probability distribution graph. Base (deterministic) estimate is only one point in the range.

In general, the value to be used as formal cost estimate is at P50 (50% probability) which is almost always greater than the base estimate, so that to get the P50 figure there needs to be an additional cost component that is added in the base estimate, which is commonly referred to as the contingency.

Are we sure with this P50 value? For the project owner who is going to bid his project, this is an important question that must be answered.

If the cost estimate is too low, the bidding process may fail, and the owner will lose a lot of time to re-bid. On the other hand, if the cost estimate is too high, the project may become unfeasible.

He explained that at the national level, individual ASEAN Member States may be pro-China, or pro-US, or sitting on the fence. But when they come together as a group in ASEAN, they say they will try to keep ASEAN neutral and constructive. They want ASEAN to be the center of dialogue and cooperation, friendly to all major powers. The question is how effective can ASEAN neutrality and centrality be? And for how long? Will the China-US rivalry cause a serious split in ASEAN, or worse a breakup of the 47-year-old organization? This is a concern that most ASEAN Member States do not even want to think about, this is an ***unknown known***.
Another *unknown known* is the continuing failure of EAS Leaders to help address the various island disputes. Apart from the South China Sea case, there are disputes between China and Japan over Diaoyu/Senkaku, between Japan and the RoK over Takeshima/Dokdo, and between Japan and Russia over the Northern Territories/Kurils. These island disputes are sources of tensions, which can create instability. But they seem to be an unknown known to most of the EAS Leaders.

In addition, in certain bidding procedures, a cost estimate that is too high will make the owner's bargaining position to become weak.

Up to this point, our attention is on the market conditions of the project which influence the contractor to decide whether to bid or not bid; and if they decided to bid, what is the bid figure.

Many studies, related to the factors that influence the contractor's decision to bid or not bid including determining the amount of the markup on the bid price, have been carried out. One of these studies was carryout by Wang[13]. Based on the interviews with two senior Taiwanese government officials, Wang concluded that there are several factors that influence the price of a project (ceiling price), which are grouped into 3 (three) categories, as follows:

Category	***Factor***
Environment	*Estimator's accuracy*
	Historical bidding ratio
	Market conditions
Owner	*Tendering urgency*
	Budget tightness
	Avoiding controversy
Project	*Bidder's qualifications*
	Project duration
	Project complexity

After knowing the factors that influence the contractor's decision to bid or not bid, further a model for determining the target cost estimate (bidding model) is developed by using these factors. Regarding the bidding model, many techniques have been developed to build the model, including modeling using utility theory, Fuzzy Logic, Neural Network, multi criteria decision, statistical regression, etc. In his paper, Wang uses utility theory to develop a bidding model.

Utility Model for Determining Cost Estimate.

The utility theory was originally used in economics to quantify a person's preference for a product, either in the form of goods or in the form of services.

Utility theory provides a methodological framework for the evaluation of alternative choices made by individuals, firms and organizations. Utility refers to the satisfaction that each choice provides to the decisionmaker. Thus, utility theory assumes that any decision is made based on the utility maximization principle, according to which the best choices the one that provides the highest utility (satisfaction) to the decision maker[14].

[13] Wei-Chi Wang "SIM-UTILITY: Model for Project Ceiling Price Determination"; Journal of Construction Engineering and Management; January/February 2002.128:76-84.
[14] http://www.referenceforbusiness.com/management/Tr-Z/Utility-Theory.html

Apart from determining preferences in the economic field, utility theory can also be used in other fields as long as it is still related to individual or organizational preferences, one of which is in determining the cost estimate value.

Development of the Utility Model for Determination of Cost Estimates

The use of utility theory in determining owner estimate is carried out through a utility model. Model development begins with determining of the criteria that are considered to influence the contractor's bid value as described above, then the utility function of each criterion is determined. Further, determine the upper and lower limits of the model based on the best case and worst-case evaluations of each criterion. The utility value of the most preferred point and the threshold point also determined, by using certain conditions of each criterion.

Based on these values, especially the worst-case value, the threshold value and the most desired value, a utility model is then constructed which can be either straight line or exponential.

After the model is formed, the current condition of each criterion related to a project is evaluated to obtain a certain value of cost estimate for the project.

The determination of the cost estimate using the utility model is done by mapping the current condition of all the criteria in the model, as illustrated in Figure 2.

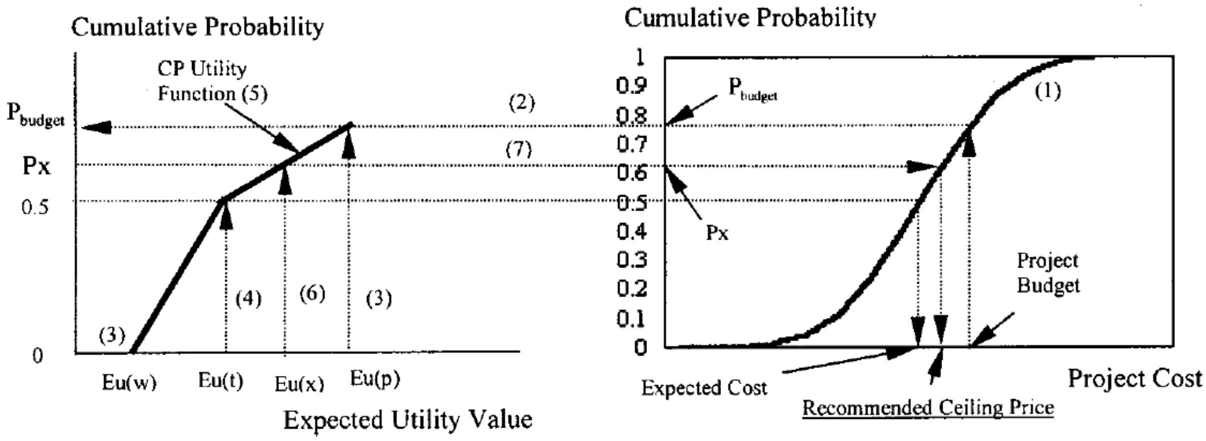


Figure 2. Determination of cost estimate / ceiling price using the Utility Model[15]

The left side of the figure is the expected utility function generated based on the three conditions as mentioned above. While the right side of the figure is the cumulative probability of the cost estimate, obtained from Monte Carlo simulation.

15 Ibid 12

The expected utility value of a project x, Eu (x), which is obtained from the quantification of user preferences for each criterion, and then mapped to the cumulative probability cost estimate, in order to obtain the recommended cost estimate value, namely on the probability Px.

VII. Calculation of Cost Estimate

As explained above, the cost estimate calculation in a project should consider the scope of work, *Uncertainty* which is also the inherent systemic risk during estimating, the project specific *Risks*, as well as market conditions related to the project bidding. It has also been explained that the cost estimate calculated based on the scope of works only is called as deterministic cost estimate or base estimate. *Uncertainty* and the project *Risk* are evaluated by using Monte Carlo simulation, to obtain the cumulative probability of the cost estimate.

Meanwhile, the bidding model is used to map the market conditions into the expected probability to obtain recommended cost estimate value.

This section will summarize the calculations of cost estimate, which consist of three steps calculation, i.e. calculation of the deterministic estimate, Monte Carlo simulation for *Uncertainty* and project Risks, and Development of bidding model to obtain recommended cost estimate.

In order to make it easier to understand, examples of calculations are also provided here.

Step 1: Calculation of Deterministic Cost Estimate.

The following table is an example of a deterministic cost estimate:

Table 5: Base Estimate or Deterministic Cost Estimate (for example)

NO	COST COMPONENT	EQUIPMENT (US$)	MATERIALS (US$)	LABOR (US$)	INDIRECT COST (US$)	TOTAL COST (US$)
1	**DIRECT COST**					
2	Equipments	44,000,000				44,000,000
3	Bulk Materials		87,000,000			87,000,000
4	Direct Labor			40,000,000		40,000,000
5	**INDIRECT COST**					
6	Indirect Field Cost				76,000,000	76,000,000
7	Home Office Cost				22,000,000	22,000,000
8	Other Cost				14,000,000	14,000,000
9	**TOTAL PROJECT COST**					**283,000,000**

This calculation is called deterministic because it refers to a certain scope of work, regardless of whether the scope is well defined or not. If there is any unclear scope, it will be considered in the next step, when we run Monte Carlo simulation to analyze the impact of *Uncertainty* and *Risk*.

From this table, the deterministic cost estimate is US $ 283,000,000.

Step 2: Monte Carlo Simulation.

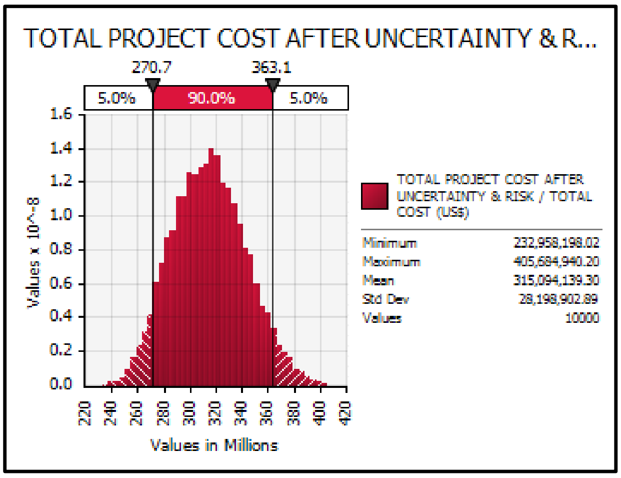
Uncertainty in cost estimate is triggered by the maturity level of the scope, quality of cost data and estimating method used. If we formulate the project cost as the multiplication of the volume / quantity of work and the unit price, then the maturity the of scope will have an impact on the volume of work, the quality of the price reference will have an impact on the unit price, while the methodology used could have an impact on both volume and unit price. Therefore, in performing Monte Carlo simulation for *Uncertainty*, both components the quantity and the unit price are used as random inputs.

Regarding the *Risk*, in this simulation we only look the residual risk, which is the remaining risk after mitigation.

Expected value of *Risks* is calculated by using the following formula: **EV = P x E**, where P is the probability of occurrence (likelihood), and E is the impact if the Risk occurs. Both P and E are uncertainties, so in a Monte Carlo simulation, they are random inputs.

In the evaluation of Risk, E is measured against each cost component that may be affected or it can also be measured against the total project cost.

Monte Carlo simulation is run simultaneously for both Uncertainty and Risk. Below is the output of Monte Carlo simulation, the simulation is run for the deterministic costs above (see table 5), where the inputs are Uncertainty and Risk.



Cost contingency = US$ 315M – US$ 283M = **US$ 32M**

Summary Statistics for TOTAL PROJECT COST AFTER			
Statistics		**Percentile**	
Minimum	232,958,198	**5%**	270,694,030
Maximum	405,684,940	**10%**	278,911,338
Mean	315,094,139	**15%**	284,718,971
Std Dev	28,198,903	**20%**	290,012,050
Variance	7.95178E+14	**25%**	294,572,854
Skewness	0.171088835	**30%**	298,828,232
Kurtosis	2.684302543	**35%**	302,832,146
Median	314,595,497	**40%**	306,880,082
Mode	318,598,325	**45%**	310,690,964
Left X	270,694,030	**50%**	314,595,497
Left P	5%	**55%**	318,308,693
Right X	363,087,095	**60%**	321,660,884
Right P	95%	**65%**	325,556,193
Diff X	92,393,065	**70%**	329,751,635
Diff P	90%	**75%**	334,344,153
#Errors	0	**80%**	339,221,157
Filter Min	Off	**85%**	345,258,598
Filter Max	Off	**90%**	352,466,699
#Filtered	0	**95%**	363,087,095

Figure 3. Monte Carlo Simulation Output

Step 3: Bidding Model Development.

Development of the bidding model begin with determining of the factors that influence the market (project market), further based on these factors the model is form. After the model is formed, it could then be used to evaluate the market conditions of a particular project, that is, running the model by assigning a value or weight to each factor according to the conditions when the project will be bid.

Next, it will be given an example of development of a bidding model by using the utility function. This model is the same as that developed by Wang[16] with a few modifications. The factors that are predicted to influence the project bidding market are the same as Wang, it's just that the weight of each of these factors is changed according to current conditions, so that it becomes as seen in the following table.

Table 6: Factors for Development of Bidding Model

Factor	Weight (Si)
1. Environment	
1.1 Estimator's Accuracy	0.062603831
1.2 Historical Bidding Ratio	0.012486857
1.3 Market Conditions	0.005522852
2. Owner	
2.1 Tendering Urgency	0.231554652
2.2 Budget Tightness	0.056538952
2.3 Avoiding Controversy	0.022773533
3. Project	
3.1 Bidder's Qualification	0.411726769
3.2 Project Duration	0.125165622
3.3 Project Complexity	0.050083352

Unlike Wang, the model using single straight line, the following table describes the model.

[16] Ibid 12

Table 7: Bidding Model

Factor	Criteria Evaluation	Range		Model Parameter	
		Low	High	Ai	Bi
1. Environment					
1.1 Estimator's Accuracy	Class I - Class V	0	1	1	0
1.2 Historical Bidding Ratio	-	0.3	1	1.4	-0.4
1.3 Market Conditions	Good - Poor	0	1	1	0
2. Owner					
2.1 Tendering Urgency	Lo - High	0	1	1	0
2.2 Budget Tightness	Loose - Tight	0	1	1	0
2.3 Avoiding Controversy	High - Low	0	1	1	0
3. Project					
3.1 Bidder's Qualification	Lo - High	0	1	1	0
3.2 Project Duration	Loose - Tight	0	1	1	0
3.3 Project Complexity	Lo - High	0	1	1	0

Below is the simulation result for the project being evaluated, where the recommended probability is P66, with a value of US $ 327,000,000. In other words, the contingency value is US $ 44,000,000 or 16% of the base estimate of US $ 238,000,000.

Table 8: Result of Bidding Model Simulation.

Factor	Criterion Selection	Intepreted Scale (yi)	Ai	Bi	U(yi)	Si	Expected Utility Value (EU)
1. Environment							
1.1 Estimator's Accuracy	Class II	0.25	1	0	0.25	0.062604	0.015650958
1.2 Historical Bidding Ratio	0.7	0.7	1.428571	-0.42857	0.571429	0.012487	0.007135347
1.3 Market Conditions	Fair	0.5	1	0	0.5	0.005523	0.002761426
2. Owner							
2.1 Tendering Urgency	Moderately High	0.75	1	0	0.75	0.231555	0.173665989
2.2 Budget Tightness	Moderately Tight	0.75	1	0	0.75	0.056539	0.042404214
2.3 Avoiding Controversy	Average	0.5	1	0	0.5	0.022774	0.011386766
3. Project							
3.1 Bidder's Qualification	Moderately High	0.75	1	0	0.75	0.411727	0.308795077
3.2 Project Duration	Tight	0.5	1	0	0.5	0.125166	0.062582811
3.3 Project Complexity	Moderately High	0.75	1	0	0.75	0.050083	0.037562514
							0.661945102

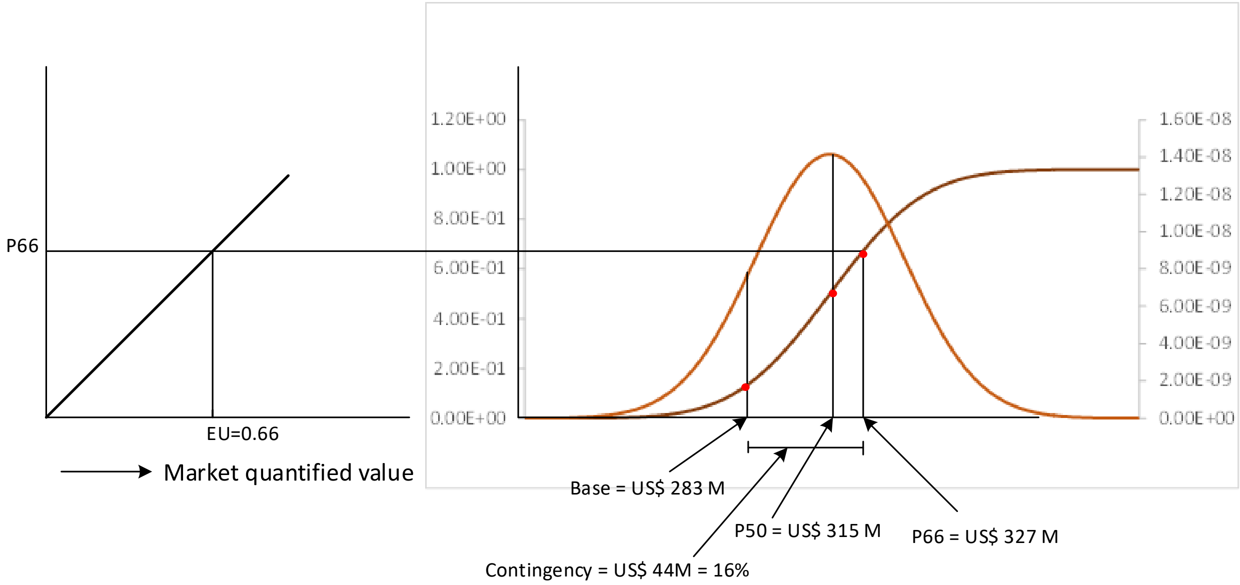


Figure 4. Determination of cost estimate using bidding model

VIII. Conclusions

In this paper, it has been explained how to develop cost estimate for an EPC project, which is consist of three steps.

The first step is calculating the base estimate, which is based on a predetermined scope of work. Base estimate has a single certain value; therefore, it is also called as deterministic cost estimate.

The second step is to conduct a Monte Carlo simulation to analyze the impact of Uncertainty and Risk on the base estimate value resulted in the first step. Monte Carlo simulation results are the cost estimate value in the form of a probability distribution. When in the first step we got the cost estimate in a single value, then the simulation in this second step produces the cost estimate in the form of a range of values and their probabilities. Further, which value in the range that to be used as the cost estimate? This question will be answered in the third stage.

The value of an EPC project also depends on other factors surrounding the project including market condition that tend to be very dynamic. When the market is rather quiet with the project, the price of a project will go down, conversely, if there are many projects there, the price tends to increase, that's the market mechanism. In the third step, a model called the bidding model is developed to map market conditions (and other project related factors) into a value equivalent to the cumulative probability value of the cost estimate resulted in the second step, so that it can be determined which value in the range is used as the cost estimate (recommended cost estimate).

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