THE MISSING LINK - OBJECT ORIENTED ESTIMATING

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During the decision making process of investment projects, it is often not possible to wait for the final cost estimate, due to the preparation time. By using ‘characteristic values’ based on executed projects, the estimate accuracy can be significantly improved while reducing the time and effort needed to develop the cost estimate.

This object oriented estimating methodology requires a good understanding of the cost drivers in a project and how they can be related to the project specific process equipment. This article provides insight in the development and application of ‘characteristic values’, to improve the estimate accuracy during the project’s conceptual phase.

1. INTRODUCTION

One of the challenges cost engineers/estimators are facing continuously, is the contradiction between the required accuracy of an estimate and the time and effort required or given to get to this accuracy.

For this reason different estimate approaches are required, depending on the phase of the project and the information available. The level of effort and available information will determine the resulting accuracy. The intention of this paper is to present a possible estimating methodology with improved estimate accuracy by using characteristic values to estimate the project costs, and save valuable time and resources by defining the quantities without a full MTO preparation.

After reading this paper, I hope cost engineers will look different at their projects and recognize all possible
metrics that will help them to improve their estimating process in the future.

2. ESTIMATING METHODOLOGIES

2.1 Covering complete Project Life Cycle estimating
As the PMBOK (Project Management Body of Knowledge) from the Project Management Institute (PMI) indicates, the execution of projects involves a certain degree of risk because each project is unique. Therefore, companies performing projects will generally subdivide their projects into project phases to have better management control. These project phases together are called the project life-cycle. Figure 1 gives a representation of the project lifecycle according to the Project Management Institute showing the different phases in combination with the timing of the different AACE estimate classes. Furthermore it shows the formal gate approvals where the decision is made to continue to the following phase. In order to make these decisions estimates are required to support the approval process. The effort of preparing the estimate should be in balance with the phase the project is in and the estimate accuracy required.

When decisions are made about potential investments in new projects, it is often not possible to wait until the final investment budget has been prepared, because of the time and effort required to draw up a detailed estimate. In addition, cost estimates regularly have to be prepared under tight deadlines, which means it is not always possible to prepare a full and detailed budget. During the feasibility phase a lot of studies are made and process options evaluated to come to the best business case for capital investments. Because resources are scarce and also many projects and ideas will fail to succeed to the next gate, people have been looking for estimating methods that involve fewer resources to prepare the estimate. This will result in lower estimate accuracy, which is acceptable for this phase of the project.

For the alternatives selection at the beginning of the planning process phase, very often (selection) budget estimates are prepared with a plus or minus 30% accuracy. This is executed before the final budget (10-15% accuracy) preparation in order to select the scenario with the best business case.

For this type of estimate, factor estimating approaches (Class 4 estimates) are in some cases not sufficient, due to the complexity or technology of the project. Never the less a more deterministic estimating approach for all alternatives might be an unnecessary use of the resources if other estimating methodologies could give the same required estimate accuracy. One of the methods that might fit this phase of the project would be the object oriented estimating method, as described in the following paragraphs.

2.2 The missing link Cost Factor estimating
Focusing on the project initiation phase, the most common estimating methodologies are equipment Cost Factor methodologies (reference 1, 2, 3 and 4). Fortunately techniques have been developed and correlations drawn that have resulted in a number of general estimating methods that can be used for (petro-)chemical plants. The use of these methods results in a generally accepted term, “Factor estimating”.

The factor estimate methodology derives its name from the principle that it applies costs factors for the preparation of the estimate, based on the correlation that has been found between the total installed costs (TIC) of a project and the total equipment costs. Two of the best
known methods are the Hand and Lang Cost Factor methodologies. Based on the equipment costs they have defined costs factors for different types of plants or equipment types to derive the total installed costs. The minimum inputs required in order to establish this type of estimate, is an equipment list and a preliminary plot plan with optional a first draft Process Flow Diagram.

**Detailed estimating**

Somewhere in the planning process phase a 10% accurate estimate is made, which is based on detailed material take offs, identified during the FEED to establish the project baseline. In order to support this estimate, extensive level of engineering involvement is required to define all required documents. Typical documents that need to be available are P&IDs, completed plot plans and material take-off.

**Filling the gap**

As indicated in figure 2 there is a need during project planning process for improved estimating accuracy, without going into a detailed unit cost estimate with detailed take-off. Looking at the common estimating methodologies, a possible approach could be, that engineering is involved to prepare high level material take offs, which will not go to the level of the 10% MTO. For this still a lot of resources are required in order to derive a 30% accurate estimate.

If the focus in this stage of the project is on the comparison of alternatives (to select the final project solution), we see a stepgap in estimating methodologies.

The proposed object oriented estimating methodology could fill this wide gap between factor and detailed estimating. This object oriented estimating method makes use of characteristic values or metrics determined from actual projects.

### 3 OBJECT ORIENTED ESTIMATING METHOD

#### 3.1 What are characteristic values?

Characteristic values are metrics used for object oriented estimating in order to determine the expected project quantities, without having to involve a full design team to determine these quantities. These characteristic values are correlations of quantities within projects, which are indicative for all similar type of projects, and derived from completed projects. The key is to understand the cost determining elements of a project and how these can be related to the heart of the installation: the main process equipment.

The major difference between Cost Factors and the object oriented method is that cost varies in time, where quantities are more or less fixed, and can be used year after year. Cost Factors fluctuate and are affected by price development, currency changes and location. Also they may be hard to correct when an engineering standard or specification is changed. Object oriented estimating using the

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**Table 1 - Example characteristic values**

<table>
<thead>
<tr>
<th>Description</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of pipe per main equipment item:</td>
<td>150 m pipe/eq.</td>
</tr>
<tr>
<td>Number of fittings per length of pipe:</td>
<td>0,6 fitting/m pipe = Fitting Factor</td>
</tr>
</tbody>
</table>

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**Figure 2 - Estimating methodologies during the Project Life Cycle.**
characteristic values methodology produces the generic equivalent of MTO quantities which can be priced using cost data bases for detailed estimating to arrive at total project cost. An advantage of focusing on quantities rather than cost is that these are understood by the engineers and designers and thus improve communication.

A simple example (see table 1): Analysis shows that the average total meter of pipe per piece of equipment is within a certain range. Of course this depends on the type of plant. The installation complexity of a plant piping system is determined by the so called Fitting Factor. The number of fittings and flanges per meter installed pipe. This then results in a number of welds which are required for constructing the piping system.

In order to develop these metrics and to ensure that these can be used for other projects, the characteristic values are defined within certain boundaries, the so called Inside Battery Limit (ISBL).

When these metrics are applied to your project parameters (like number of equipment items) which are already known in an early project phase, the outcome are quantities. The resulting quantities are in turn the input to the estimate.

3.2 The benefit of characteristic values
The benefit of using characteristic values developed from historical engineering data is that it gives a method to cost engineering in between the cost factor and detailed estimate approaches to support the evaluation of alternatives, without having to spend a lot of resources. Also the resulting estimate can be presented to engineering in a way they can associate with the technical particulars of the project.

3.3 Pros and cons of Object Oriented Estimating
The advantages and disadvantages of the object oriented estimating approach (using characteristic values) compared to cost factor estimates, are presented in table 2.

3.4 Analysis of completed projects
In order to develop the characteristic values from historical data, one should look at completed projects in a different way. Not only looking at it from a helicopter view, but divide the project in different
objects (figure 3). These objects represent the main equipment item with associated scope, like piping, instrumentation, electrical and civil. To a certain extent this is not different from Cost Factor methodologies, where a relation is made between the costs of the equipment and the total installed costs. The object oriented estimate approach gives the relation between the key quantities of the project and the main equipment count.

The green dashed boxes indicate the different objects in a project. Zooming into an object, the different characteristic values can be identified.

3.5 Converting objects into characteristic values

Similar to the Hand methodology (reference 1) the characteristics should be split-up by discipline.

**Piping**

One of the main cost drivers of most projects is piping, as shown in many studies. By looking at the relation of the total length of pipe and the number of equipment items the pipe scope can be determined.

One of the other key metrics needed to be able to estimate the piping, is the average piping diameter. This could be derived from similar executed project. Another possibility to derive this diameter is the relation that can be found in the average volume of the columns, reactors and vessel. The higher this average volume, the bigger the average piping diameter in the project will be.

You also need an indication of the metallurgy of the plant: is it mainly a SS (stainless steel) plant or CS (carbon steel) plant?

**Instrumentation**

Another key metric indicates the automation level, how many control valves there are per piece of equipment. This ranges from 0.8 to 1.3 control valve per main equipment item. Of course some pieces of equipment will have no control valves at all and others will have multiple control valves, but this method is based on weighted averages.

Also, the number of field instruments are depending on the automation level. This number could be between 4 and 7 per main equipment item.

**Electrical**

Another relation that can be found is for instance the number of lighting fixtures per piece of equipment. This could also be based on the number of lighting fixtures per project plot area. Figure 4 and 5 show examples of a characteristic value that describes an entire object (in the estimate), related to one piece of main equipment. Please realize that not just one method is the right one, within this approach different correlations are possible for the same item. Of course there are many more characteristic values to be determined.

- Average volume of concrete per piece of equipment.
- Average length of cable tray/conduit per piece of instrument
- Number of i/o’s per piece of equipment

Figure 3 - Project divided into objects.

Figure 4 - Determination of characteristic values (example).
3.6 Standardize your measurement methods
Based on the characteristic values, quantities can be determined and subsequently their cost can be estimated. A requirement for this is a cost database that is built-up in line with the developed quantities. If the metric is “meters of pipe”, the cost database should be aligned, in such a way that the characteristic values for this metric can be easily estimated. If the cost database is based on weight of pipe instead of length of pipe, there would not be a match to this metric. Meaning either the metric should be adapted to follow the cost database, or the database should be aligned with the metric.

3.7 Composites
Because the outcome of this object oriented estimating methodology are high level MTO’s, composites become very useful for fast and easy estimating. A composite is an assembly of activities that are combined in order to support this estimating methodology. Of course different composites are required to distinguish: material, size and pound rating, with or without painting or insulation.

The piping composite (figure 6 and 7) then includes the supply of all the materials, the handling, the welds and the testing, possibly painting, insulation and or tracing. Which are all translated back to one meter of pipe. So when the characteristic value indicates 150 m of pipe is needed, this then can be easily estimated with the assembly price. It is the combination of the characteristic values that will give quantities, and the composite cost database, which will ensure quick estimating possibilities. Next to piping composites, assemblies can be made for e.g. instrumentation hook-ups, electrical lighting fixtures, steel structures and foundations.

3.8 Importance of definition
For the development of these metrics, boundaries must be defined, in order to be able to apply the characteristic values to other projects. These boundaries are also known as Inside Battery Limit (ISBL), as shown in figure 8.

The definition of what is included in the metric is very important. The boundaries are important to ensure that it is known what is included in the metric scope. If the boundaries are set too broad you will find a high diversity of the rates. For instance, what is normally excluded and should be estimated separately are...
interconnecting piping and pipe-racks, roads, power supply, sewer connections etc.

4. CONTINUOUS IMPROVEMENTS
What is not visible in the PMI Project Life Cycle, which is a very important part for developing estimating knowledge, is how the continuous improvement cycle of projects work; how do projects close the information loop. During project close-out, lessons learned need to be registered in order to improve future project execution and estimating.

In order to ensure that data is gathered to continuously develop and verify the characteristic values, it is important that this is embedded in the cost engineering process (figure 9). By establishing procedures for all projects, so that key quantities are routinely reported, the foundation for the object oriented estimating method is made.

Figure 10 gives an overview of the key quantities for the ISBL part of a chemical plant. This example also shows the key quantities per main equipment item. Of course per discipline we need to understand the correlations of quantities. For example, the length of trays does not have a relation with the length of pipe. The metrics should be defined with common sense and knowledge of the characteristics.

5. CONCLUSION
By using the defined characteristic values, derived from key quantities of completed projects (historical data), the object oriented estimating method is a benefit to the planning phase of a new project.

The proposed method will improve the estimating accuracy in the planning phase, while reducing the effort that otherwise would be needed for MTO development. In that sense it is the missing link between the existing estimating methodologies (i.e. Cost Factor estimating and detailed calculations). It is important to ensure that the available cost database is built-up in line with the required metrics. Also the applied composites should match this method for fast estimating.

Except for estimating, the characteristic values can also be used for the validation of estimates and for benchmarking of a project. An important benefit of characteristic values is that it helps to improve
communication between discipline engineers. Moreover it supports transparent fine tuning of your estimate in order to derive to a well-founded solution.

The object oriented estimating methodology should give cost engineers in the process industry another perspective of how to benefit from their historical project data. I hope cost engineers will look different at their completed projects and recognize in them all the possible metrics that could help them to make better estimates in the future.

“The object oriented estimating method is an added value during the planning phase.”

6. REFERENCES
5. Recommended Practice 18R-97, Cost Estimate classification system – As applied in Engineering, Procurement, and Construction for the process industries, AACE.