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.

Terms and definitions

FEED Front End Engineering and Design
MTO Material Take Off
P&ID Piping and Instrumentation Diagram
TIC Total Installed Cost
Cost Factor A cost relationship in which cost is directly proportional to one independent variable as a percentage or multiplication factor.
Characteristic value Characteristic values are normalized historical quantitative relationships. (For example: a meter of pipe for a specific application and certain specific technical properties normally has so many fittings or valves. The same term is also used for quantitative relationships on higher levels, e.g. a specific type of equipment under certain conditions, normally requires so many meters of pipe and / or so many lighting fixtures.)
Metrics Project specific characteristic value.
Composite rate Captures the cost of various independent cost elements into one estimate value to simplify calculations. The term is used for instance for combinations of installation activities (as for example cable supply + installation + termination etc. or a combination of materials and activities required for the installation of one (1) lighting fixture).
Key quantity 1. A quantity derived from completed projects in order to develop metrics and composite rate relations. / 2. A quantity developed for new to be estimated projects by applying characteristic values to composites or assemblies. This will generated the associated costs.
Assembly & composites A standard small MTO package that can be input as a single entry into an estimating system resulting in the individual pricing of all the materials and work activities included in the assembly applying the composite rate for that same MTO package.

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 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.

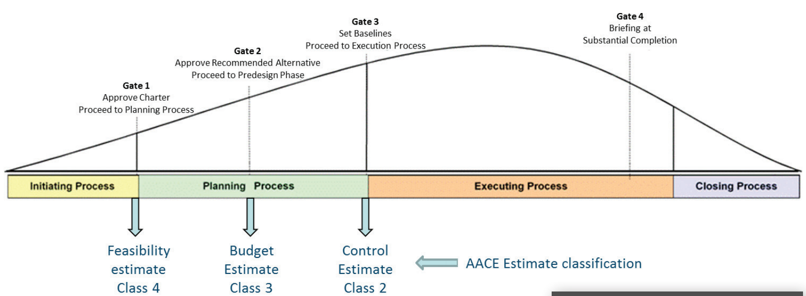


Figure 1 - Project Life Cycle.

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.

Table 1 - Example characteristic values

Description	Metric
Length of pipe per main equipment item:	150 m pipe/eq.
Number of fittings per length of pipe:	0,6 fitting/m pipe = Fitting Factor

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

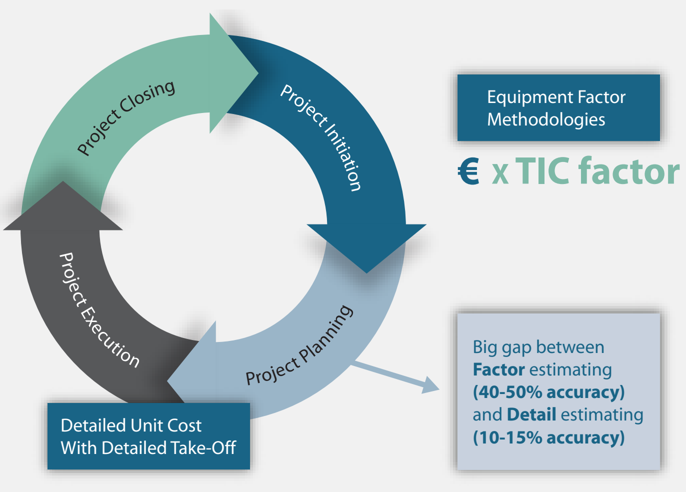


Figure 2 - Estimating methodologies during the Project Life Cycle.

Table 2 - Pros and cons object oriented estimating

Pros	Cons
• Quantities are per project more or less fixed units, which can be used year after year. • Quantities are not influenced by inflation, currency fluctuation or other economic factors. • Quantities are well understood by the engineer which improves communication. • Location impact is more clear. • Gives a more accurate estimate. • Fine tuning of the estimates can be argued based on tangible data (quantities).	• It is more complex than the cost factor method. • More time required to prepare the estimate. • More time must be spent at subsequent calculation and organization of the price database. All prices must be organized in units of measurements identical to method. E.g. if the metric gives m of pipe, the cost database should be based on pipe length as well. • The risk of too many details. • Different methods of measurement for each discipline (kg, m3, m etc.).

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.

Other benefits are:

- Support for estimate reviews; not only can these metrics be used for estimating, but also for the validation of estimates. By verifying the estimated quantities with the metrics, an analysis can be made of the quality of the MTOs.
- Assesses company performance against industry norms. By comparing these characteristic values between different projects, an analysis can be made and company's performance can be measured against industry norms.
- Supports calibration and improvement of company tools and databases. By continuous reviewing the developed metrics, tools and databases can be calibrated and improved.
- Improves asset cost evaluation and concept development. Not only the estimate accuracy can be improved, but also maximum use is made of the scarce resources. Therefore more time is available for other development projects.
- It gives physically meaningful factors and therefore it improves communication with engineers

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.

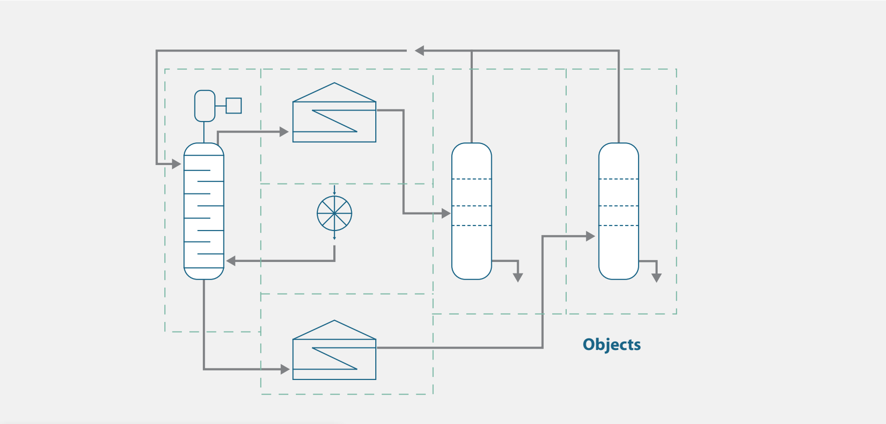


Figure 3 - Project divided into objects.

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

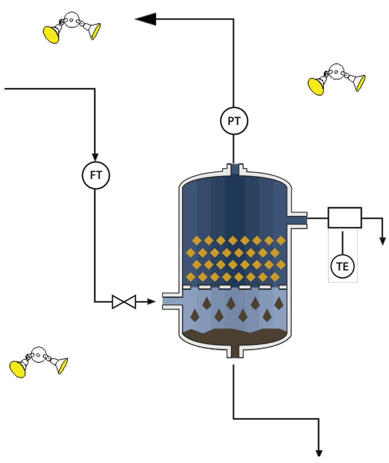
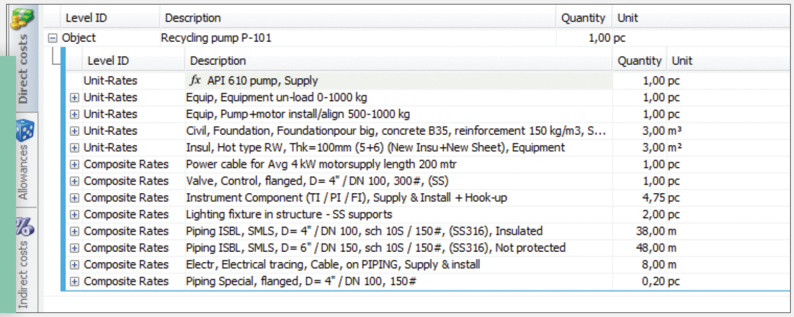


Figure 4 - Determination of characteristic values (example).

Characteristic values of an object

- 150 m CS pipe
- Average 4.5" pipe
- 0.9 - 1.2 Control valves
- 5.5 Field instruments
- 3 lighting fixtures



Level ID	Description	Quantity	Unit
Object	Recycling pump P-101	1,00	pc

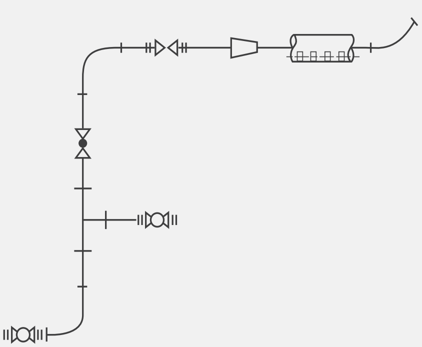
Level ID	Description	Quantity	Unit
Unit-Rates	fx API 610 pump, Supply	1,00	pc
Unit-Rates	Equip, Equipment un-load 0-1000 kg	1,00	pc
Unit-Rates	Equip, Pump+motor install/align 500-1000 kg	1,00	pc
Unit-Rates	Civil, Foundation, Foundationpour big, concrete B35, reinforcement 150 kg/m3, S...	3,00	m³
Unit-Rates	Insul, Hot type RW, Thk=100mm (5+6) (New Insu+New Sheet), Equipment	3,00	m²
Composite Rates	Power cable for Avg 4 kW motorsupply length 200 mtr	1,00	pc
Composite Rates	Valve, Control, flanged, D= 4" / DN 100, 300#, (SS)	1,00	pc
Composite Rates	Instrument Component (TI / PI / FI), Supply & Install + Hook-up	4,75	pc
Composite Rates	Lighting fixture in structure - SS supports	2,00	pc
Composite Rates	Piping ISBL, SMLS, D= 4" / DN 100, sch 10S / 150#, (SS316), Insulated	38,00	m
Composite Rates	Piping ISBL, SMLS, D= 6" / DN 150, sch 10S / 150#, (SS316), Not protected	48,00	m
Composite Rates	Electr, Electrical tracing, Cable, on PIPING, Supply & install	8,00	m
Composite Rates	Piping Special, flanged, D= 4" / DN 100, 150#	0,20	pc

Figure 5 - Example Object with metrics.

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.

Figure 6 - Piping composite example.



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

Level ID	Description	Quantity	Unit	Total non…
Object	Recycling pump P-101	1,00	pc	97.777,6

Level ID	Description	Quantity	Unit
Unit-Rates	*fx* API 610 pump, Supply	1,00	pc
Unit-Rates	Equip, Equipment un-load 0-1000 kg	1,00	pc
Unit-Rates	Equip, Pump+motor install/align 500-1000 kg	1,00	pc
Unit-Rates	Civil, Foundation, Foundationpour big, concrete B35, reinforcement 150 kg/m3, S…	3,00	m³
Unit-Rates	Insul, Hot type RW, Thk=100mm (5+6) (New Insu+New Sheet), Equipment	3,00	m²
Composite Rates	Power cable for Avg 4 kW motorsupply length 200 mtr	1,00	pc
Composite Rates	Valve, Control, flanged, D= 4" / DN 100, 300#, (SS)	1,00	pc
Composite Rates	Instrument Component (TI / PI / FI), Supply & Install + Hook-up	4,75	pc
Composite Rates	Lighting fixture in structure - SS supports	2,00	pc
Composite Rates	Piping ISBL, SMLS, D= 4" / DN 100, sch 10S / 150#, (SS316), Insulated	38,00	m

Level ID	Description	Quantity	Unit	Cost	Labour hours	Custom factor
BOQ-Rates	Pipe, SMLS, Install ISBL, D= 4" / DN 100, sch 10S, (SS316), Insulate…	1,00	m	203,74	1,33	1,00
BOQ-Rates	Valve, Ball, FB flanged, D= 4" / DN 100, 150#, (SS316), Insulated (7…	0,02	pc	2.446,98	4,22	1,00
BOQ-Rates	Valve, Check, Swing, flanged, D= 4" / DN 100, 150#, (SS316), Insul…	0,03	pc	1.045,19	4,22	1,00
BOQ-Rates	Valve, Gate, Flanged, D= 4" / DN 100, 150#, (SS316), Insulated (70…	0,02	pc	1.312,95	4,22	1,00
BOQ-Rates	Elbow, LR,90 Deg, BW (SMLS), D= 4" / DN 100, sch 10S, (SS316), In…	0,18	pc	434,95	5,59	1,00
BOQ-Rates	Tee, Equal, BW (SMLS), D= 4" / DN 100, sch 10S, (SS316), Insulated…	0,09	pc	559,99	6,77	1,00
BOQ-Rates	Reducer, Conc, BW (SMLS), D= 4" / DN 100 (sch 10S) x D= 3" / DN 8…	0,06	pc	360,77	4,58	1,00
BOQ-Rates	Branch, O-let, Weldolet, D= 1 1/2" / DN 40, sch STD, (SS316), Insul…	0,03	pc	303,60	3,03	1,00
Unit-Rates	Piping, Field Butt weld SS f=1,3, sch=10S D= 4" / DN 100	0,01	pc	126,91	1,73	1,00
Unit-Rates	Piping, Field NDT X-Ray D= 4" / DN 100	0,00	pc	102,40	1,06	1,00
Unit-Rates	Piping, Field Butt weld SS f=1,3, sch=10S D= 3" / DN 80	0,00	pc	103,72	1,41	1,00
Unit-Rates	Piping, Field NDT X-Ray D= 3" / DN 80	0,00	pc	86,02	1,05	1,00

Level ID	Description	Quantity	Unit
Composite Rates	Piping ISBL, SMLS, D= 6" / DN 150, sch 10S / 150#, (SS316), Not protected	48,00	m
		8,00	m
		0,20	pc

Figure 7 -Example Composites within an object.

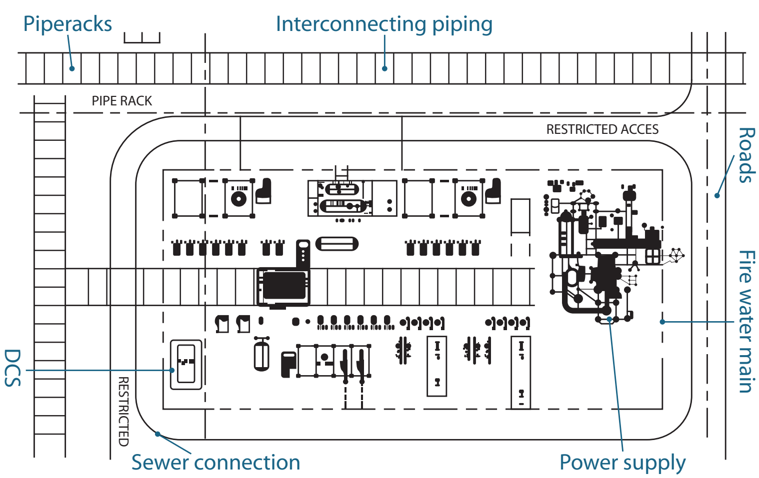


Figure 8 - Battery limits (boundaries).

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

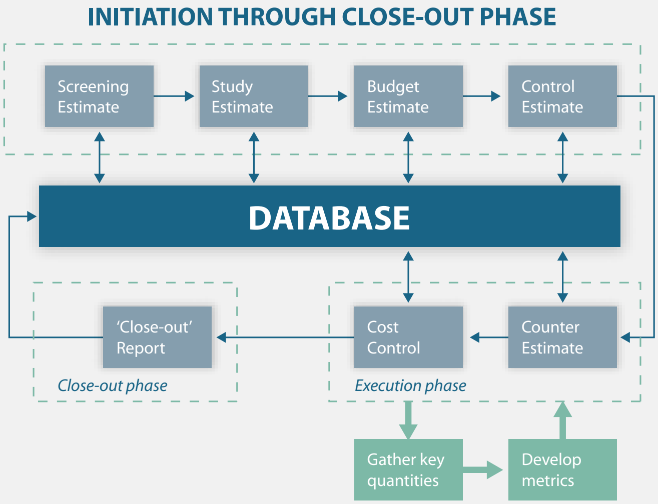


Figure 9 - Continuous improvement – Data gathering.

Figure 10 - Example Object with metrics.

Pivot table | All base components

Drop Filter Fields Here

Grand total quantity | per p of equip | ISBL-OSBL

Key quantities	Unit	ISBL - Inside Battery Limit: Grand total ...	ISBL - Inside Battery Limit: per p of equip
01 - Number of Mechanical Equipment	pc	54	1
02 - Number of field erected equipment	pc	3	0
03 - Number of piles	pc	339	6
04 - Roads and paving	m^2	1.210	22
05 - Concrete volume - foundation	m^3	1.853	34
06 - Concrete volume - elevated floors	m^3	251	5
07 - Length of underground piping	m	250	5
08 - Excavation volume	m^3	4.318	80
09 - Backfill volume	m^3	2.160	40
10 - Structural Steel - structure	kg	190.715	3.532
11 - Structural Steel - grating	m^2	285	5
12 - Structural Steel - stairs and ladders	m	38	1
13 - Structural Steel - handrail	m	479	9
14 - Length of pipe	m	8.550	158
15 - Number of fittings	pc	4.130	76
16 - Number of valves - manual	pc	599	11
17 - Number of valves - control valves	pc	68	1
18 - Number of field instruments	pc	257	5
19 - Number of welds	pc	7.309	135
20 - Number of x-rayed welds	pc	731	14
21 - Insulation - Equipment	m^2	4.295	80
22 - Insulation - Pipe	m	6.413	119
23 - Painting - Pipe	m	6.840	127
24 - Fire proofing	m^2	114	2
26 - Number of JB - Instrumentation	pc	41	1
27 - Number of JB - Electrical	pc	86	2
28 - Cable length multicore - Instrumen...	m	12.184	226
29 - Cable length singles - Instrumenta...	m	6.498	120
31 - Cable length - Electrical LV	m	21.330	395
32 - Trace Heating Cable length	m	6.384	118
33 - Length of trays	m	2.619	49
34 - Length of conduits	m	855	16
35 - Length of tubing	m	3.249	60
36 - Number of lighting fixtures	pc	171	3

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

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