COMPARISON OF PIPING CALCULATION METHODS

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Description of the calculation methods

Table 1 shows an overview of all the different calculation methods that will be evaluated.

The classification of the different methods has multiple reasons:

- Chronological. This is more or less the order in which I discovered (and also started to use) the different methods.
- Source: A and B are calculation methods used by contractors, C to F are originate from literature.
- Necessary level of information: A to D are able to provide a cost with (very) limited information and/or a few assumptions, while E and F really require more detailed information. This will also reflect in the effort required to obtain a piping cost.

Table 2 shows are more detailed comparison of all 6 methods.

	Author	Abbr	Title	Publication details
A	Contractor A	ECA	Quick calculation sheet	-
B	Contractor B	ECB	Detailed calculation sheet	-
C	Dutch Association of Cost Engineers (DACE)	DACE	DACE-Price booklet	Published by Reed Business BV, May 2011, ISBN 978-90-5895-051-2
D	Interscience Publishers BV	IP	Cost Estimation Handbook for Industrial Pipe Lines – Material: Carbon Steel	Published in 2002
E	Regional Development Company West-Brabant (REWIN)	RND	Unit Rate Descriptions for Piping	Published by Foundation NAP/DACE, March 2004.
F	Oil and Chemical Plant Constructors' Association (OCPCA)	OCP	Data Bank of Estimating Norms	1986 Edition

Table 1: Overview of the Piping Calculation Methods.

Comparison procedure

This chapter will discuss the comparison procedure: the selection of the projects, the calculation of the projects with the different methods, the calculation of the effort and finally the determination of the cost benchmarks.

Selection of the projects

Eight projects were selected for this exercise. This was the result of a screening of approximately 20 available projects in the oil and gas sector from the last years. From these projects only those which could be calculated by all calculation methods and for which detailed cost information was available were withheld. In reality this means only projects from smaller pressure classes (150 and 300 lbs), without any "exotic" materials (duplex steel, plastics, ...) and sizes up to 20" have survived the cut.

Still these selection criteria have resulted in a wide range of projects:

- Scope: ranging from completely in unit with more bends and tees than straight lengths up to completely off plot, on pipe racks with hardly any bends and tees.
- Magnitude: from 50 kEUR up to 5 MEUR.
- Size: everything between 0.5 and 20".

Calculation of the project costs

The comparison on the previous page shows that only one method can provide a (recent) installed cost: C (DACE). D could provide an installed cost as well, but its price level was 10 years ago. Therefore I decided not to use this aggregated installed cost result. Instead I calculated the installed cost by calculation D

Dit artikel is een samenvatting van de afstudeerscriptie die de auteur in 2012 schreef voor de DACE opleiding tot Certified Cost Engineer (CCE). Het artikel beschrijft ook de zoektocht naar geschikte benchmark gegevens. Vele Cost Engineers zullen die zoektocht herkennen. Doe uw voordeel met deze ervaringen van de auteur (redactie).

Samenvatting Het doel van dit artikel is om de zes verschillende methoden te vergelijken met betrekking tot nauwkeurigheid van de raming en met betrekking tot de inspanning de nodig is om de raming te maken. De basis voor de ramingen zijn de standaard "material take off's" van recentelijk uitgevoerde piping projecten (zowel in unit als off plot, dus zowel binnen fabrieken als tussen fabrieken), zoals die beschikbaar waren bij de aanbestedingen aan gegadigden (piping onderaannemers). Op basis van deze materiaallijsten heb ik elk van de 6 begrotingsmethoden toegepast. De begrotingsresultaten heb ik onderling vergeleken, maar ook met het daadwerkelijke opdrachtbedrag Piping in het betreffende project. Aldus kan ik in aan het einde van dit artikel een beeld presenteren van de trefzekerheid van de verschillende begrotingsmethoden en van de inspanning die nodig is om de begrotingen te maken. Daaruit volgt een advies welke het beste past bij welk type raming of projectfase.

through the same procedure as by methods A,B, E and F, that is by splitting the installed cost into material and labour (installation cost):

- Labour hours were calculated using each specific calculation method. These hours were then multiplied by hourly labour rates (based on recent projects).
- The material cost was calculated from the total piping weight by multiplying it with average material costs (again based on recent projects). If the method could provide the total piping weight, this weight was used (A and D). Otherwise a detailed weight calculation was made by using the weights from VOMI's "Fitterszakboekje" (B, E and F).

These two results were totalled to obtain the total cost.

For the calculations the remarks and guidelines for each method were followed as closely as possible: about the amount of prefabrication, about possible discounts for larger quantities, It was not the goal of this exercise to fine tune one or more calculation methods, the purpose was to see which one produced the best results "as is". All projects were initially planned to be calculated by the six different calculation methods. However only for A and B spread sheets are available. Because of this my first step was to produce an automated calculation for all other methods.

Two methods were not able to calculate all selected projects, and therefore had to be extended:

- C (DACE): Is only available up to 12". It was extrapolated up to 20".
- D (IP): is only available in pressure classes PN6, PN10 and PN16, while 300 lbs would correspond to PN40. For the first two projects, this would pose a problem, and a cost correction (in the range of 2.5 to 10%) was used.

Source	A	B	C	D	E	F
	ECA	ECB	DACE	IP	RND	OCPCA
Cost results						
Total Cost	-	-	√	√	-	-
Material Cost	-	-	-	√	-	-
Labour Cost	-	-	-	√	-	-
Price level	N/A	N/A	2011	2002	N/A	N/A
Exclusions	N/A	N/A	Components, supports	Components, supports	N/A	N/A
Extra information						
Weight	√	-	-	√	-	-
Workshop labour hours	-	√	-	-	√	√
Site labour hours	-	√	-	-	√	√
Total labour hours	√	-	-	√	-	-
Cost determination factors						
Length	√	-	√	√	√	√
Weight	-	√	-	-	-	-
Size	√	√	√	√	√	√
Schedule	√	√	-	-	√	√
Wall thickness	-	-	-	-	√	√
Pressure Class	-	-	√	√	-	-
Material	√	√	√	√	√	√
Number of bends/components	-	-	√	√	-	-
Installation location	√	√	-	-	√	√
Detailed activities:						
Preparations, measurements and cuts	-	-	-	-	√	√
Installation of pipes	-	-	-	-	√	√
Installation of components	-	-	-	-	√	√
Normal welds	-	-	-	-	√	√
Special welds	-	-	-	-	√	√
Tie-ins	-	-	-	-	√	√
Bending	-	-	-	-	√	√
Threaded connections	-	-	-	-	√	√
Flanges	-	-	-	-	√	√

Table 2 - Detailed comparison of the Piping Calculation Methods.

During the development of the different spread sheets, it quickly became clear that there was a problem with one of the six calculation methods: F, the method published by the OCPCA. This method consistently produced results that were (according to partial results for straight piping) between 33 and 50% lower than E (RND), which was the initial reference point before the actual benchmarks were calculated. When the results of the other methods A to D seemed to confirm the results of E and after a thorough check of the spread sheet (which did not reveal any errors or mistakes), it was decided to remove F from the comparison study and to continue the exercise with the five other methods A to E.

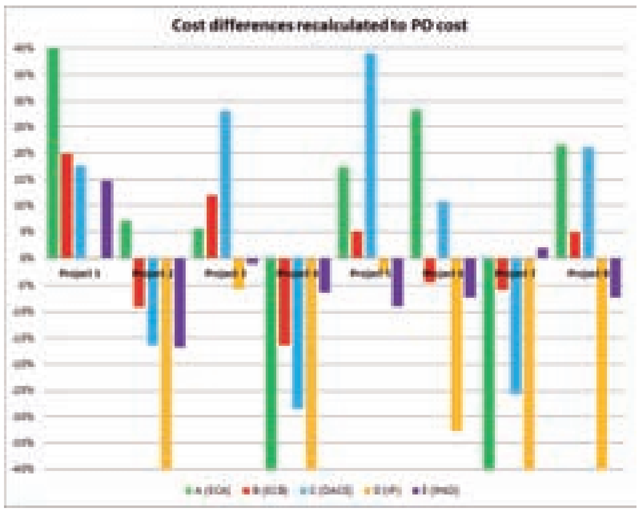
Assessment of the calculation effort

The second goal of this exercise was to compare the amount of effort required to use each method. However this proved not as easy as initially planned. The first approach was timing the calculation per method for each project and comparing these times. However it soon became soon apparent that "haste makes waste". The alternative was counting the required input values. Input values are all the values originating from the method, which need to be multiplied with the quantities of the MTO (Material Take Off). It is clear that a method which requires many input values (which have to be looked up in tables for most methods) will require much more time than one which needs limited input. In many cases the relationship is even linear: five times more input values will require in total approximately five times more effort to make the cost calculation.

All input values were counted per method and per project and then totalled for all projects per calculation method.

Calculation of the benchmark:
Purchase order costs

It would have been easy if the benchmark costs could be simply read from the purchase order of each project. In reality there were however a few difficulties:



Graph 1 - Cost differences for each project, recalculated to purchase order cost. (percentages of actual cost, + meaning above actual cost, - meaning below).

1. All purchase orders were polluted with costs for items such as scaffolding, painting, NDE (Non Destructive Examination), supporting, … Since not all methods provided calculations for these additional items, they fell out of the scope of this exercise and therefore had to be removed. Here is where the detailed cost information was required. Projects for which the costs were not split up sufficiently could not be used.
2. Not all projects were offered (and executed) in recent months. In the search for a sufficient number of projects, I had to go back to 2011, 2010 and even 2009. This left with two possibilities: either each method was calculated using unit costs from the moment of the purchase order (which would make the exercise more time consuming) or all costs had to be corrected to the same price level.

The decision was made to go for the second option: all costs were corrected to a price level of early 2012. Fortunately some of the quotes contained a price correction clause which is quite uniform in Belgium thanks to the efforts of Agoria on this issue. A supplier can propose a price correction by using one or more sub indexes. In this case the sub index for half thick plates as index for the material cost (weight: 30%) and the reference wages for the Antwerp region as index for the labour cost (weight: 70%). were used. This price correction clause was assumed to be valid for all projects, and therefore all prices were corrected using this basket of sub indexes.

Results

This chapter presents the results of the calculations. As previously mentioned, two different parameters were investigated: the accuracy and the required effort to obtain the result. These will be discussed in two separate paragraphs, starting with the accuracy.

Accuracy

In this paragraph the results are limited to the summary and more specifically to the coparison of the estimated costs according to the different methods with the (corrected) actual (purchase order) cost. Graph 1 shows each individual calculation method compared to the actual cost.

In graph 1 each method has a specific colour, and the smaller the bars are, the smaller the difference with the actuals and the better the accuracy. To keep the graph as readable as possible, the choice was made to end the graph at plus and minus 40%, since the precise difference is no longer of major importance once a bar passes these markers.
After a quick look and without a detailed comparison, it is already clear that in total the best result is achieved by B (red) and E (purple). On the other hand, the worst results are for A (green) and D (orange), since these are the only methods that have multiple bars that go "off the chart". A remark has to be made regarding these results. One might remember that in two calculation methods extrapolation was used to be able to calculate the entire scope of all eight projects:
- C, which was extended from 12 to 20".
- D, which was only able to calculate 150 lbs piping and should be corrected for 300 lbs piping.

Is a systematic error in the extrapolation perhaps the cause of their lower accuracy? A detailed research revealed following considerations:
- C: The four projects which have a cost majority in sizes above 12", are projects 3, 4, 5 and 7. All four have an absolute difference between 20 and 40%, but two of those differences are positive, while two are negative.
- D: The two projects in 300 lbs piping are projects 1 and 2. One has a very large negative difference, the other one is spot on the corrected PO cost. A correction on both results with a rather small factor will therefore not improve the average accuracy of both results.

Both considerations seem to suggest that there is no systematic error in one of both methods that causes deterioration of their accuracy.

The results can be compared in an even better way if they are fitted into an estimate accuracy range. For this exercise, the classification system of The (British) Association of Cost Engineers (ACostE) was chosen, because they provide fixed accuracy ranges, from Class IV up to Class I.
Statistics learn that the actual cost of an estimated project has to lie between the given ranges (between - 1 and +1 standard deviation) in 70% of the cases. In this case, that would mean that 70% of the results of a certain method would have to be within the given range to conclude that this one can be used for this accuracy range. 70% of 8 projects equals 5.6 out of 8, which

means that all methods that have at least 6 results within the given range can be considered as suitable for this range (green), where 5 results out of 8 might be suitable (orange), and all results below 5 indicate that this method is not accurate enough for this range (red).

Table 3 gives a more clear overview, although the results are more or less the same: E and B can be used for classes IV to II, C and A only for class IV, while D provides even worse results and is not even advised for use with the lowest accuracy range.

Effort

The second goal of my research was comparing the amount of effort with the obtained accuracy. As explained above the amount of effort was measured by counting the total number of input values needed to make a calculation.
The separation between the general and the more detailed calculation methods is clear: The three general calculations (A, C and D) required on average less than 100 values. The two detailed calculations (B and E) required five to thirteen times more input.

It has to be noted that the high input numbers for the detailed methods are partly caused by the fact that the total material weight had to be calculated separately (app. 400 values). This detailed calculation is however needed to obtain the high cost accuracy that the detailed calculation methods provide.

References

- Agoria *Market prices of materials: Half thick plates, AE235* *http://tinyurl.com/n9k2aua.*
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- Association of Cost Engineers (AcostE) *Terminology Document* (pdf). *www.acoste.org.uk/uploads/terminology.pdf.*
- VOMI *Fitterszakboekje* 4th edition, published by Reed Business BV, september 2008.

Methods ECA and ECB

An important note to these conclusions is about the methods ECA and ECB. They were described at the start of this article as calculations sheets used by contractors (and therefore with "proven track record"), as opposite to the other methods which are based on literature.
However during research for this paper I found a reference work that contained an explanation of a similar calculation method (calculation based on piping weight and piping properties such as size, material, wall thickness) with the same level of detail but with citation of a publicly available origin: 3R International of April 1985.
Since I could not retrieve this source information online (and therefore assess its true value), I have chosen not to mention it as a reference. But it does indicate that it is possible for anyone to implement this kind of calculation method using publicly

Conclusions

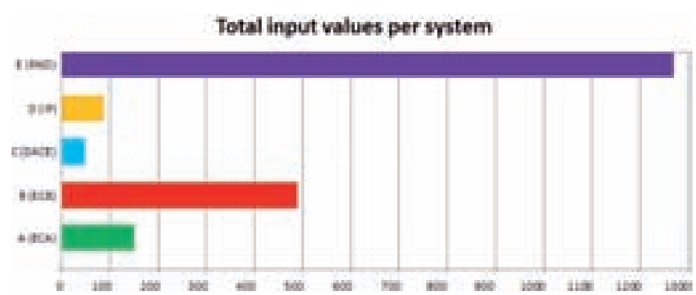
In most cases the results of the calculation methods A, B, C and E are more or less in line with the final purchase order costs. So these can be used for estimates according to ACostE's Class IV. Method D was not able to provide acceptable results for even the lowest accuracy range. Method F did not even pass the test phase because the differences with all other methods (and with the PO cost) were simply too large.
The next conclusion is that only more detailed calculations from B and E can be used for the higher accuracy classes (ACostE class III and II). The simplified, quick methods simply cannot produce that level of accuracy.

If we take into account the required effort (input), the general methods B and (especially) C require so much less effort than the detailed ones, that they are the preferred choice for estimates with low(er) accuracies during conceptual and feasibility phases. During these phases both the time and the available information are often too limited to use a detailed calculation method anyhow.

Taking the effort into account means that B gets a slight advantage over its competitor E. The difference in effort is substantial and compensates a possible slight difference in accuracy that might exist in favour of E.

Within range	A (ECA)	B (ECB)	C (DACE)	D (IP)	E (RND)	Accuracy level
-30% / + 30%	5	8	7	3	8	Class IV
-20% / + 20%	3	8	3	3	8	Class III
-10% / + 10%	2	5	0	3	6	Class II
- 5% / + 5%	0	2	0	2	2	Class I

Table 3 - Adaptation of the results into the ACostE classif cation method.



Graph 2 - Total amount of input values per method.