Cost Estimate Classes for the German Process Industry -

Required Documents and Expected Accuracy

Guesstimate

Estimate

Calculate

Thomas Rieckmann Prof. Dr.-Ing.

Cologne University of Applied Sciences, Germany
Institute for Process Engineering and Plant Design
Betzdorfer Str. 2, D-50679 Cologne

thomas.rieckmann@fh-koeln.de

Curriculum Vitae - Thomas Rieckmann Prof. Dr.-Ing.

Cologne University of Applied Sciences
Chemical Reaction Engineering and Process Development,
Polymer Engineering, PET Synthesis and Recycling,
Cost Engineering

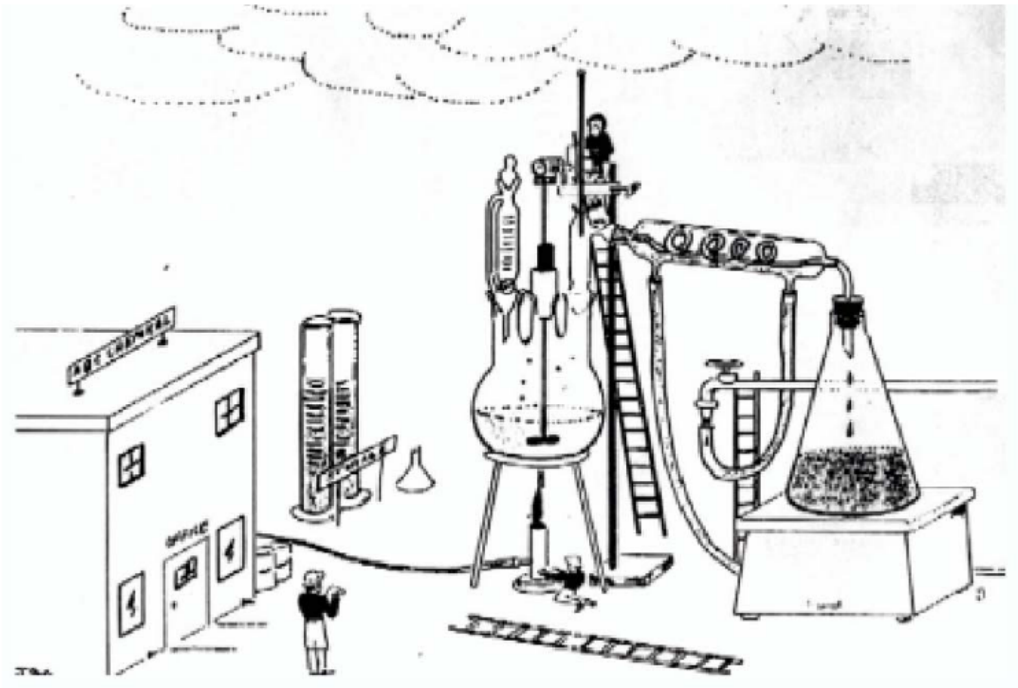
PET and Chemical Engineering Consulting 42 Engineering

John Brown Deutsche Engineering GmbH
Process Engineer and Head of R&D
Process Development, PET Synthesis, Processing and Recycling

Doctorate, Dr.-Ing.,
"About the Reduction of Diesel Engine Emissions"
Technical University of Clausthal, Germany

Study, Dipl.-Ing. Verfahrenstechnik (Process Engineering),
Chemical Reaction Engineering
Technical University of Clausthal, Germany

„The bench scale results were so good that we by-passed the pilot-plant"

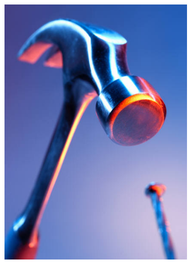


... trust me, I'm a chemist.

Stitt, E.H. *Chem. Eng. J.* **90** (2002) 47

Agenda - Cost Estimate Classes for the Process Industry

Conclusion



Goal

Motivation - Cost Estimate Classes for the Process Industry

Fachhochschule Köln
Cologne University of Applied Sciences

The risk of misunderstanding between contract parties and project failure is reduced when engineering tasks are defined within a mutual accepted frame.

Well defined estimate classes can efficiently assist the contract parties to agree upon a specific scope for cost engineering tasks.

Although major chemical and process industries together with a number of internationally operating engineering companies are located in the country, Germany is still lacking a mutually accepted framework of cost estimate classes.

Due to differences in industrial culture and work organization, the estimate classes, proposed by the AACE can't be adapted without modifications.

The available tools and work organization of process engineering are constantly improving and getting more efficient.

- task forces, members working at different locations and time zones
- data base driven information management (e.g. COMOS)
- process simulation and 3D layout planning are state-of-the-art technology

Goal - Cost Estimate Classes for the Process Industry

Fachhochschule Köln
Cologne University of Applied Sciences

The goal of this project is to propose a framework of estimate classes together with the required documents and expected accuracy ranges for the German Process Industry.

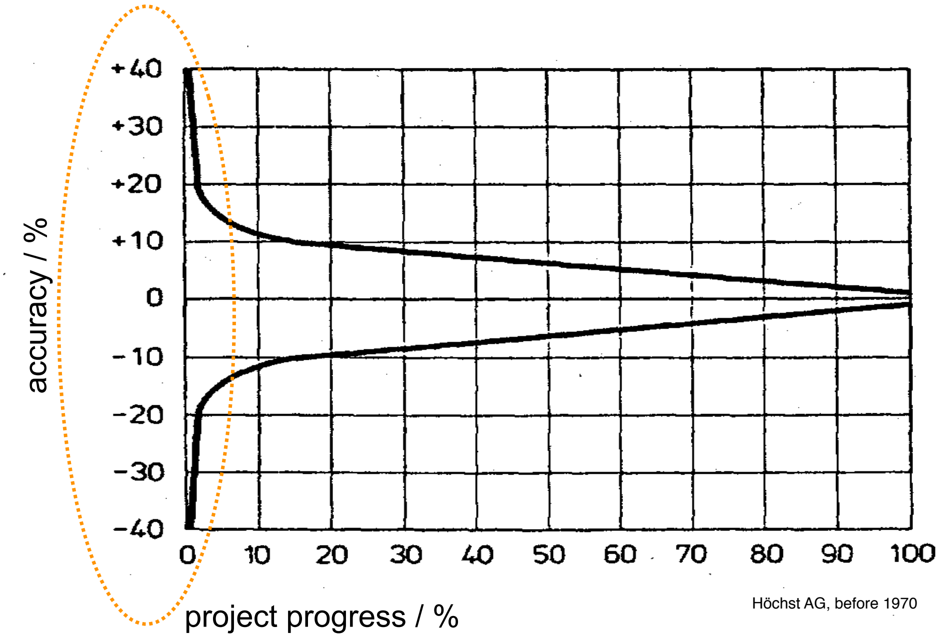
The focus will be laid on cost estimation in early project phases.

Early project phases can be distinguished in two typical cases

- Known process, new project, scale-up required.
  - Costing bases on a "process design package"
- New process, process development, massive scale-up required.
  - Costing bases on preliminary documents as well as on heuristics and short-cut design methods

Accuracy of Cost Estimation vs. Project Progress

Fachhochschule Köln
Cologne University of Applied Sciences



Höchst AG, before 1970

... a symmetrical confidence interval - a dream?

→ In early project phases, small progress leads to big improvements in accuracy

International Estimate Classes

Fachhochschule Köln
Cologne University of Applied Sciences

INCREASING PROJECT DEFINITION

AACE Classification Standard	ANSI Standard Z94.0	AACE Pre-1972	Association of Cost Engineers (UK) ACostE	Norwegian Project Management Association (NFP)	American Society of Professional Estimators (ASPE)
Class 5	Order of Magnitude Estimate -30/+50	Order of Magnitude Estimate	Order of Magnitude Estimate Class IV -30/+30	Concession Estimate Exploration Estimate Feasibility Estimate	Level 1
Class 4	Budget Estimate -15/+30	Study Estimate	Study Estimate Class III -20/+20	Authorization Estimate	Level 2
Class 3		Preliminary Estimate	Budget Estimate Class II -10/+10	Master Control Estimate	Level 3
Class 2	Definitive Estimate -5/+15	Definitive Estimate	Definitive Estimate Class I -5/+5	Current Control Estimate	Level 4
Class 1		Detailed Estimate			Level 5 Level 6

AACE International Recommended Practice No. 18R-9, 2005

AACE Estimate Classes

Fachhochschule Köln
Cologne University of Applied Sciences

	Primary Characteristic	*Secondary Characteristic*			
ESTIMATE CLASS	**LEVEL OF PROJECT DEFINITION** 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]	**PREPARATION EFFORT** Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Concept Screening	Capacity Factored, Parametric Models, Judgment, or Analogy	L: -20% to -50% H: +30% to +100%	1
Class 4	1% to 15%	Study or Feasibility	Equipment Factored or Parametric Models	L: -15% to -30% H: +20% to +50%	2 to 4
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%	3 to 10
Class 2	30% to 70%	Control or Bid/ Tender	Detailed Unit Cost with Forced Detailed Take-Off	L: -5% to -15% H: +5% to +20%	4 to 20
Class 1	50% to 100%	Check Estimate or Bid/Tender	Detailed Unit Cost with Detailed Take-Off	L: -3% to -10% H: +3% to +15%	5 to 100

Notes: [a] The state of process technology and availability of applicable reference cost data 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.
[b] If the range index value of "1" represents 0.005% of project costs, then an index value of 100 represents 0.5%. Estimate preparation effort is highly dependent upon the size of the project and the quality of estimating data and tools.

stochastic

deterministic

AACE International Recommended Practice No. 18R-9, 2005

AACE Estimate Classes - Class 4 Estimate

Fachhochschule Köln
Cologne University of Applied Sciences

CLASS 4 ESTIMATE

Description:
Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Typically, engineering is from 1% to 15% complete, and would comprise at a minimum the following: plant capacity, block schematics, indicated layout, process flow diagrams (PFDs) for main process systems, and preliminary engineered process and utility equipment lists.

Level of Project Definition Required:
1% to 15% of full project definition.

End Usage:
Class 4 estimates are prepared for a number of purposes, such as but not limited to, detailed strategic planning, business development, project screening at more developed stages, alternative scheme analysis, confirmation of economic and/or technical feasibility, and preliminary budget approval or approval to proceed to next stage.

Estimating Methods Used:
Class 4 estimates virtually always use stochastic estimating methods such as equipment factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, the Miller method, gross unit costs/ratios, and other parametric and modeling techniques.

Expected Accuracy Range:
Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances.

Effort to Prepare (for US$20MM project):
Typically, as little as 20 hours or less to perhaps more than 300 hours, depending on the project and the estimating methodology used.

ANSI Standard Reference Z94.2-1989 Name:
Budget estimate (typically -15% to + 30%).

Alternate Estimate Names, Terms, Expressions, Synonyms:
Screening, top-down, feasibility, authorization, factored, pre-design, pre-study.

AACE International Recommended Practice No. 18R-9, 2005

Lang Factors for an Average Process Plant

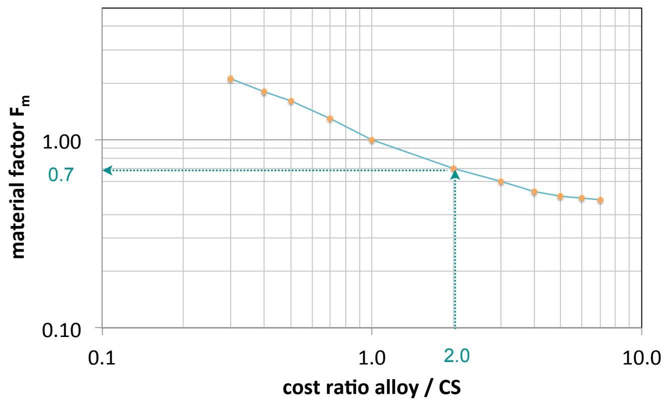
Fachhochschule Köln
Cologne University of Applied Sciences

$$\text{Capital cost} = \text{Lang factor} \cdot F_m \cdot F_i \cdot F_p \sum(\text{Equipment cost})$$

F_m = Material adjustment factors = f(ratio alloy / CS); range: 2.0 ... 0.4

F_i = Instrumentation factor
local controls: 1.15
typical bulk chemical process: 1.35
extensive controls: 1.55

F_P = Place factor (in 1996)
USA: 1.0
PR China: 0.97
Germany: 1.05
Saudi Arabia: 1.3



published 1947,
based on the analysis of 14 plants

Brown, T.: Engineering Economics and Economic Design for Chemical Engineers, CRC Press (2007)

Modified Lang Factors for an Average Process Plant

Fachhochschule Köln
Cologne University of Applied Sciences

Type of plant	new plant new site	new unit at existing site	expansion at existing site
solids	4.0	3.5	3.4
solids/fluids	4.3	3.9	3.7
fluids	5.0	4.4	4.3

„gras roots“ „brown field“

modified by Thane Brown (2007), in Peters/Timmerhaus/West (2003)

Hand Factors for an Individual Process Plant (up-dated 1992)

Equipment	factor
column, destillation and extraction, shell	4.0
column, destillation and extraction, tray	2.5
pressure vessel	3.5
heat exchanger	3.5
oven	2.5
pump	4.0
compressor	3.0
instruments	3.5

Humphreys, K. K, Project and Cost Engineers Handbook, Marcel Dekker (2005)

Hand Factors for an Individual Process Plant

$$\text{Capital cost} = F_i \cdot F_b \cdot F_p \sum \left(\text{Equipment cost} \cdot \text{Hand factor} \cdot F_m \right)$$

F_b = building factor

Type of plant	new plant / new site	new unit at existing site	expansion at existing site
solids	1.68	1.25	1.15
solids and fluids	1.47	1.29	1.07
fluids	1.45	1.11	1.06

„gras roots" „brown field"

published 1958

Brown, T.: Engineering Economics and Economic Design for Chemical Engineers, CRC Press (2007)

Path to a German Framework of Cost Estimation Classes

Fachhochschule Köln
Cologne University of Applied Sciences

Member of Dechema working party "Cost Engineering"

DECHEMA
Gesellschaft für Chemische Technik und Biotechnologie e.V.

Cost engineering professionals from German chemical and engineering companies were asked

- 1) to fill in a questionnaire and
- 2) to list type and quality of the required documents for an AACE class 4 estimate
- 3) to note comments and heuristics on costing in early project phases

Purpose of the survey:

- to widen the perspective
- to involve both sides of the coin - customer and contractor
- to benefit from the experience of other cost engineering professionals

Translation of the Survey's Main Questions

Fachhochschule Köln
Cologne University of Applied Sciences

Should the 5 AACE cost estimate classes be used without modification?

Should the 5 AACE cost estimate classes be adapted to the requirements of the German Process Industry?

Do you think, that 3 estimate classes are sufficient?

Should an estimate class like the AACE class 5 base on analogy or related processes?

Should an estimate class like the AACE class 4 base on stochastic methods such as Land Factors or Hand Factors?

Should an estimate class like the AACE class 3 base on deterministic estimating methods for the significant areas of the process?

Is it possible, to achieve a confidence interval of ± 25 % applying techniques of a AACE class 4 estimate?

Are confidence intervals symmetrical, e.g. ± 25 %?

Are confidence intervals non-symmetrical, e.g. -30 % / + 50 %?

Are well chosen allowances a way to achieve symmetrical confidence intervals?

Survey - Main Results

Question	4	3	2	1	Result
Should the 5 AACE cost estimate classes be used without modification?					2.3
Should the 5 AACE cost estimate classes be adapted to the requirements of the German Process Industry?					3.1
Do you think, that 3 estimate classes are sufficient?					1.6
Should an estimate class like the AACE class 5 base on analogy or related processes?					3.7
Should an estimate class like the AACE class 4 base on stochastic methods such as Land Factors or Hand Factors?					3.3

Fachhochschule Köln
Cologne University of Applied Sciences

Survey - Main Results

Question	4	3	2	1	Result
Should an estimate class like the AACE class 3 base on deterministic estimating methods for the significant areas of the process?					3.5
Is it possible, to achieve a confidence interval of ± 25 %, applying techniques of a AACE class 4 estimate?					2.9
Are confidence intervals symmetrical, e.g. ± 25 %?					1.3
Are confidence intervals non-symmetrical, e.g. -30 % / + 50 %?					3.6
Are well chosen allowances a way to achieve symmetrical confidence intervals?					2.9

Proposal of a German Framework of Cost Estimation Classes

Breaking down the cost estimation in early project phases in 3 classes:

Class 5 - Guesstimate

- no defined method involved, back of the envelope calculations, educated guesses, crystal ball, order of magnitude, degression coefficients

Class 4 - Estimate

- stochastic estimation methods

Class 3 - Estimate

- deterministic estimation methods for significant process equipment

Class 2 - Estimate

- deterministic estimation methods for all process equipment, requires complete basic engineering, control estimate

Class 1 - Calculation

- requires complete detailed engineering, control estimate

so, what is different?

Class 4 Estimate - Information and Required Documents

... it is the necessary information, document quality and expected confidence interval.

Document	Quality	Remarks
location, capacity	preliminary	T cooling water, fuel
process description	preliminary	battery limits
process flow diagram	preliminary	not finalized
equipment list	preliminary	spread sheet
material and energy balances	preliminary	process simulator
electric motor list	preliminary	spread sheet
utilities	preliminary	
process control	concept	
layout plan	concept	3 D

wording re document quality: concept < preliminary < specified

Conclusion

Achievable confidence levels are defined by the required documents and their level of maturity (as well as their availability)

Costing classes can be derived from the available documents and their respective level of maturity

The quality of a class 4 estimate depends mainly on

- the quality of the process engineers work, filling gaps by proper educated guesses
- the maturity of the process flow diagram
- the quality of the energy and material balances, obtained by process simulation
- up-to-date equipment cost data base (e.g. DACE price booklet)
- the quality of suitable equipment factors (e.g. modified Hand Factors)
- the reasonable incorporation of deterministic methods, in case the process at hand deviates form an average model process

Conclusion

Fachhochschule Köln
Cologne University of Applied Sciences

For a known process - but new project - the scale-up bases on production data and rigorous process modeling

For a new process, massive scale-up with higher safety margins is required. The process design in early project phases bases on heuristics, short-cut models and the application of the similitude theory

A German Costing framework should be a modification of the AACE practice with 5 estimate classes

- class 5 bases on back of the envelope calculations
- class 4 and class 3 are valuable for process development and revamp projects
- stochastic methods are used to achieve the quality of a class 4 estimate
- deterministic methods for significant process equipment / unit operations are used to achieve the quality of a class 3 estimate
- class 2 and class 1 estimates are mainly used for control purposes of a contract in execution