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Chemical Engineering Series

Capital Cost Estimation

Innovative Chemical Engineering

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Capital Cost Defined

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- Capital Cost: "Cost to Complete, Time to Finish" -- per definite objective: early variance due to estimating different things.
- Total Cost from now (or a future construction kick-off point) to a well defined operational kick off point.
- Present day value (or reference day value) of money available when needed throughout the construction. (cost of money!)

Cost Defined

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- A resolution of the gap between asking price and bidding price.
- Unlike ‘weight’ or ‘color’, cost is not a fixed property of a product or a service: it reflects the cross-over of interests between buyer and seller at the moment of the transaction.
- Cost appears stable if either side deals with many of the opposite side. (one seller to many buyers, or one buyer from many sellers. e.g.: McDonald’s fries, cost of Mortgage).

Capital Cost Estimation Stages

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- **Conceptual**: little is known, poor credibility estimates, an innovative challenge.
- **Definitive**: Take off accounting
- **Mid-Range**: a mix of the above two.

- **The Key: Don't omit, and don't double!**

Cost Estimation Defined

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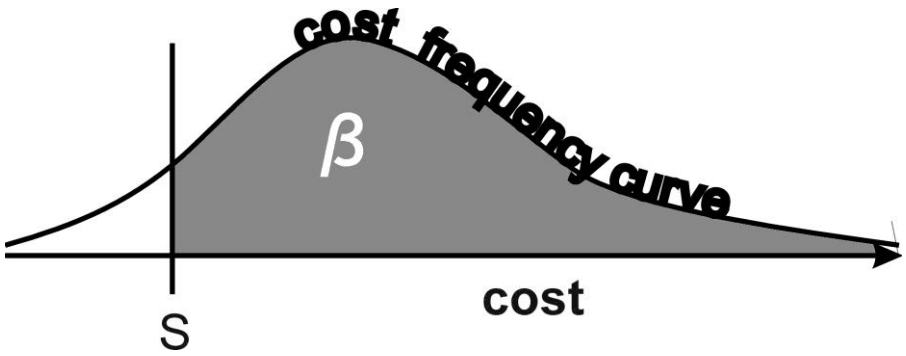
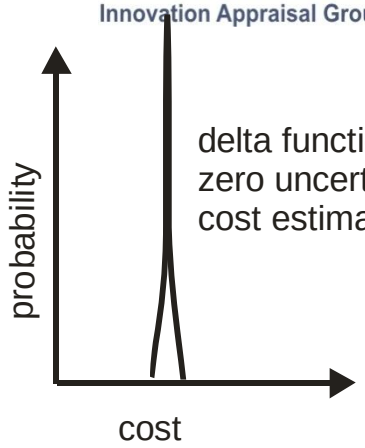
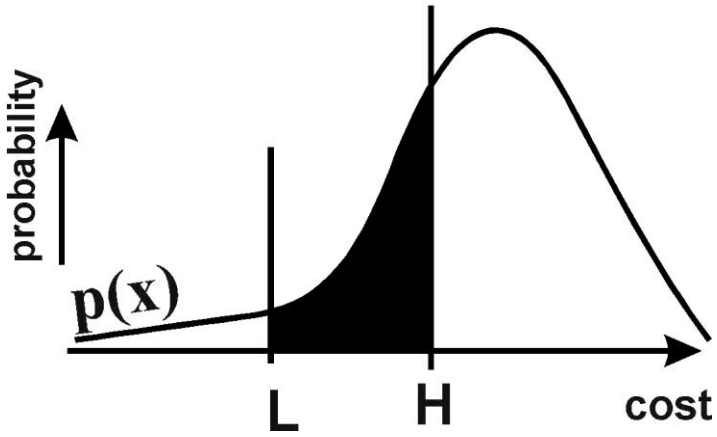




$$P(L,H) = \int_{x=L}^{x=H} p(x)\,dx$$



Interval of Indifference (IOI)

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- For any given cost estimate, $Xe, there is an interval of cost, I, such that the user of the estimate is indifferent as to where within I, the actual cost happens to be, Designate: I=IOI.
- If the actual cost Xa satisfies:

$$X_{LOW} \leq Xa \leq X_{HIGH}$$

Such that $X_{LOW} \leq Xe \leq X_{HIGH}$

And $X_{HIGH}-X_{LOW}=IOI$

Then Xe is a functionally accurate (100%) estimate.

Single Value Cost Estimate

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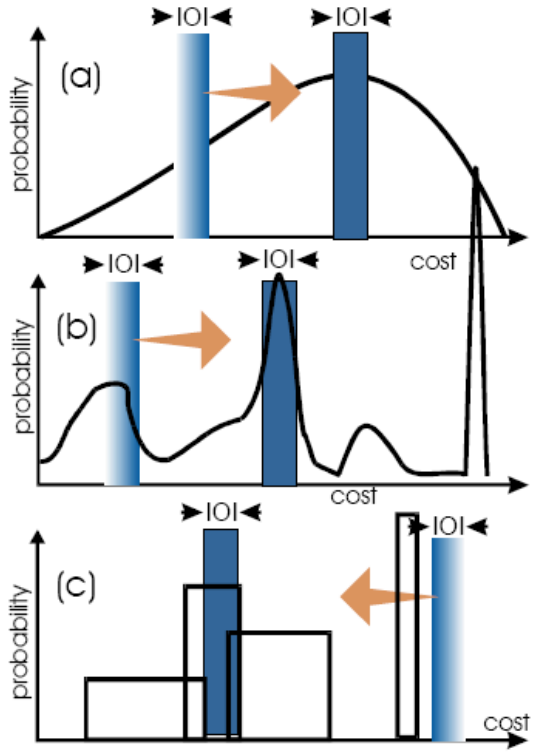
IOI Moves Along Cost Frequency Curve

Fig. 2

Effective for a smooth curve, (a), a complicated curve, (b), or a bar diagram, (c). The IOI interval can always be fit to cover max area



Estimate Validity(*) (V)

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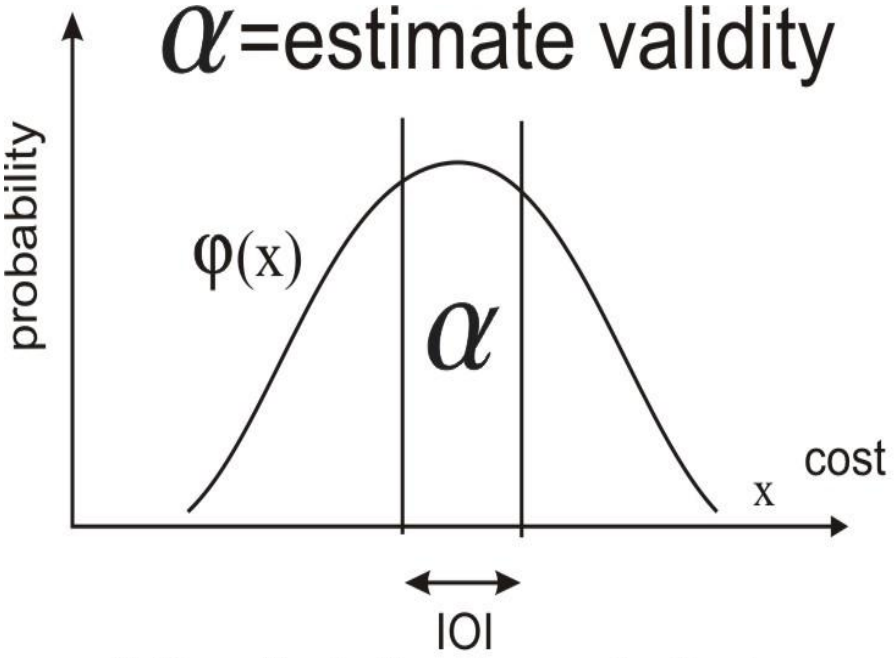
- The area under the cost probability curve, and between the IOI verticals, and the cost-axis.
- $0 \le V \le 1$
- Low validity means that the chance for the actual cost to be within the IOI is small.



validity reflects the chance for the true cost to be within IOI of the estimated cost.

(*) This is the single estimate validity, which is distinct from interval validity, not discussed here.

Past Perfect Estimates

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- Estimates free of accounting errors, human oversight, and negligence, where all uncertainty is rooted in project knowledge deficiency.
- One approaches PPE to measure project progress.

Interval of Futility

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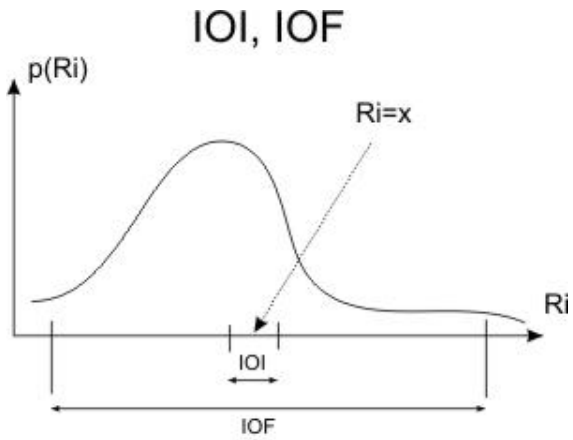
IOF: Interval of Futility: For any given point on the cost axis there is symmetrically placed interval so large that the knowledge that the point representing the true cost is in it, is of no practical use – futile.

The only intervals of interests are the ones that range between IOI and IOF.



Interval of indifference, IOI
Interval of Futility, IOF
Defined over the resource, Ri, probability
Estimation function.

IOI choice

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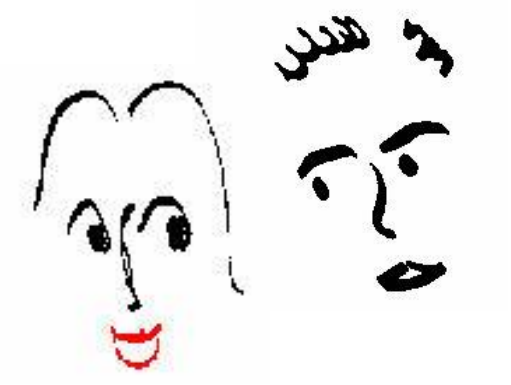
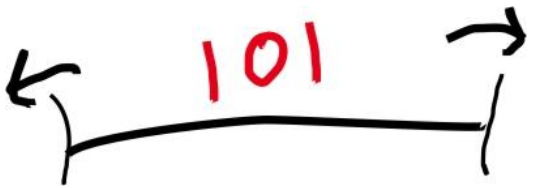
- Pick the largest sensible IOI – to secure a maximum credibility estimate.
- Novices refine estimates they can refine, although no refinement is needed.
- Novices stay away from estimates they can't readily refine, although refinement is needed.





IOI Calculus (2 variables)

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$$c = f(x, y)$$

$$dc = (\frac{\partial c}{\partial x})dx + (\frac{\partial c}{\partial y})dy = \Delta x + \Delta y$$

If Δx given, then $\Delta y = \mu \Delta x$ is ok for $\mu < 0.1$

$$dy = \mu \Delta x(\frac{\partial y}{\partial c}) = \frac{IOI_y}{2}$$

Example: c = x+y; dc=dx+dy. If dx=$10,000

Then dy=$1000 and IOIy=$2000

IOI Calculus (multi variable)

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$$c = f(x_1, x_2, \ldots . x_n)$$

The variable with the highest given interval will dictate to all others:

$$dc = \Delta x_1 + \Delta x_2 + \ldots\ldots \Delta x_n$$

All other IOI are set to impose a fraction of the anchor variable that offers the highest fixed error.

IOI Variability

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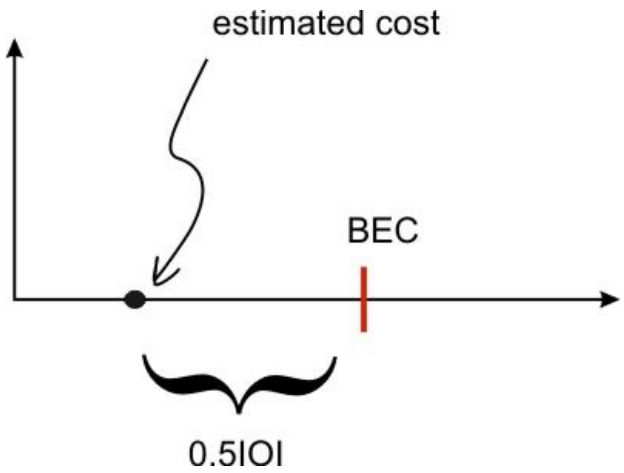
- May be fixed, or may be a function of the cost value IOI(c)
- E.g.: breakeven cost (BEC) determines:



Operational Principles of Cost Estimation

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- No Project is an exact repeat of another.
- No Project is completely dissimilar from all others.
- The challenge to learn as much as possible from the past, and applying it smartly -- not blindly.
- Your estimating history is your most important cost estimation source. Most firms don't preserve it to cover embarrassing misstatements – not realizing they are the raw material for better estimates in the future.
- Establish a formal capturing system for who estimated what, when, how does it compare to the eventual actual cost, and why the gap?
- Wisdom of crowds: no one, however brilliant, for the long run, is any match to the integrated wisdom of the community.

Material, Labor & Subcontracting

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- Cost = Material + Labor + Subcontracting
- Material – vendors.
- Labor – vendors, cost data services.
- Subcontracts – Subcontractors
- Credibility ranking: Subcontracting, Material, Labor
- Labor Credibility: Multisourcing – track factors
- The subcontracting estimating ‘scheme’

Material

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- List price v. quoted price
- Quotes with strings attached (quantity, other purchases, short expiration).
- Bait & Switch (quote low quality, sell high quality)
- The ‘discontinued’ trick – the new equivalent is more expensive than the quoted.
- What is included: delivery, warranty, on premises inspection, training, replacement policy, extended payment schedule.

Labor

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- Vendors underestimate
- Union v. Non-Union
- Cultural Differences (not PC!)
- Cohesiveness of the crew (first timers?)
- Space, access convenience, interim storage
- Design Quality

Subcontracting

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- Circumventing estimation challenge
- Apply for poor credibility estimates (What you can't estimate – you can't build!)
- Fake RFP Estimates
- Compare proposals (The three estimates method)
- Beware the small print assumptions and exclusions list

FACE:
Formal Advanced Cost Estimation

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- The 'Past' Method: cost + profits
- The 'Present' Method: comparables
- The 'Future' Method: buyer affordability.

In Capital cost estimation one starts with the 'future', continues with the 'present' and ends up with the 'past'.

FACE

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FACE: Formal Advanced Cost Estimation

Check List

Transference

Engagement

- ☐ Clarify Terms
- ☐ Evaluate Legality/Morality
- ☐ Develop Strategy
- ☐ Verify Resource Sufficency

Disengagement

- ☐ Summarize Valuation
- ☐ Adjust Terms vs. Results
- ☐ Submit Results
- ☐ Defend/Retract Results

Details:

Reference

Collect Data

- ☐ Identify Data Requirement
- ☐ Assess Existence of Data
- ☐ Develop Data Acquisition Plan
- ☐ Execute Data Acquisition Plan

Organize Collected Data

- ☐ Organize for Immediate Task
- ☐ Oragnize for Review and Critique
- ☐ Organize for Long Term needs

Details:

Inference

Assume

- ☐ Make a list of assumptions
- ☐ Minimize the assumption list
- ☐ Support the Assumptions
- ☐ Rate Arbitrariness

Deduce

- ☐ Maximize Logical Conclusions
- ☐ Minimize Illogical Conclusions

Details:

D&G Sciences -- Virginia Technology Corporation

www.dgsciences.com

Past Based Estimates

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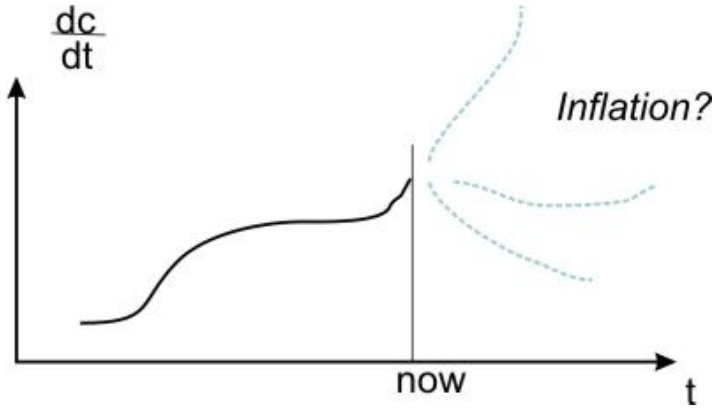
- Statement of the challenge:
- Given: $c_i = f(x_{1i}, x_{2i} \ldots x_{ni}, t_i)$ for i=1,2,….m
- Find: $c_0 = f(x_{1,0}, x_{2,0} \ldots x_{n0}, t_0)$
- Handled by a various algorithms and methods.
- Rank factors: $(\frac{\partial c}{\partial x_i}) > (\frac{\partial c}{\partial x_j})$
- Chase the highest!



Intimate Past

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- Your organizational actual past cost figures are (i) most relevant for your estimates, and (ii) unavailable elsewhere.
- Hire retirees or laid-off people with similar experience for cost consulting. Priceless!
- Suspect published reports of detailed cost figures for similar projects

Misleading Past

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- Companies will boost cost figures to minimize book profits and minimize taxes.
- Money Launderers will depress cost figures to launder funds.
- Transactions between a firm and its subsidiary are inherently suspect.

Comparables

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- List similar projects with known cost, or valid estimate.
- Identify cost-impacting parameters known or measurable early (at the time of the estimate), and known or appraised for all or some of the listed comparables.
- Model cost from the listed parameters.

Comparables Math

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- Find k similar projects
- Identify n qualified parameters: P1,P2,..Pn
- Develop a rational model, f, to compute cost.
- Statistically Compute g

$$\left.\begin{aligned} C1 &= Z*f(P11, P21, \ldots\ldots\ Pn1) \\ C2 &= Z*f(P12, P22, \ldots\ldots\ Pn2) \\ &\vdots \\ Ck &= Z*f(P1k, P2k, \ldots\ldots\ Pnk) \end{aligned}\right\} \text{Reference Base}$$

The better, f, the more Z => 1

$$\left.\begin{aligned} Z_1 &= g(P11, P21, \ldots\ldots\ Pn1) \\ Z_2 &= g(P12, P22, \ldots\ldots\ Pn2) \\ &\vdots \\ Zn &= g(P1k, P2k, \ldots\ldots\ Pnk) \end{aligned}\right\}$$

$$Co = g(P1o, P2o, \ldots\ldots\ Pno) * f(P1o, P2o, \ldots\ldots\ Pno)$$

Modeling f

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- **Monotonic Parameters**: various size indicators (throughput, number of people involved, area of ops), Intensive attributes: (e.g.: viscosity, molecular complexity).

  - Cost = aX^b+c

- **Confluent Parameters**: Program modeling:
- *If 'so' and 'such' then 'whatever', else 'different'*

- **Destimation**: Design Estimation

Destimation

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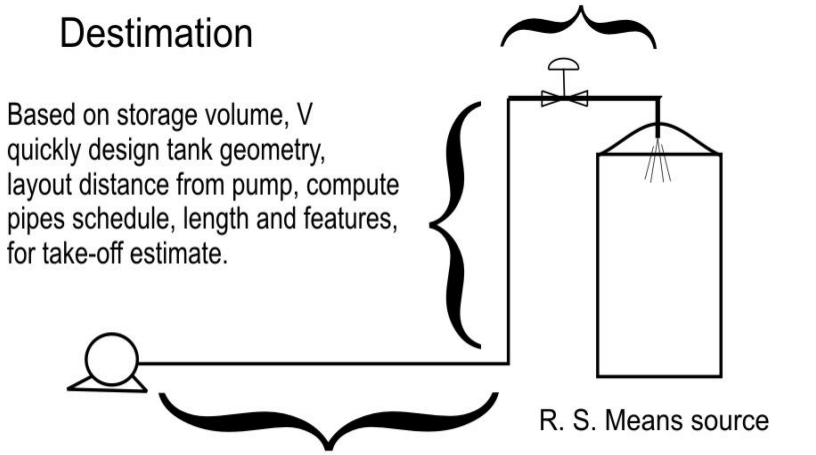
- Design one or more quick layouts, definitively estimate each, rate likelihood, and compute cost:
- ***Σ [design cost]*[design likelihood]***

- Illustration: Lang Factors: piping around a storage vessel is 50% of vessel installed cost. Destimation will layout piping, valves, knees, and "definitively" estimate cost.



More accurate than lang: pipe cost: 50% of tank

Modeling g

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- Multi-Variate Analysis
- Factor Analysis
- Cluster Analysis

- *Skewed by arbitrary inputs!*

- ***BiPSA***
- ***Monte Carlo***

- *Low arbitrary input*

Feature Space

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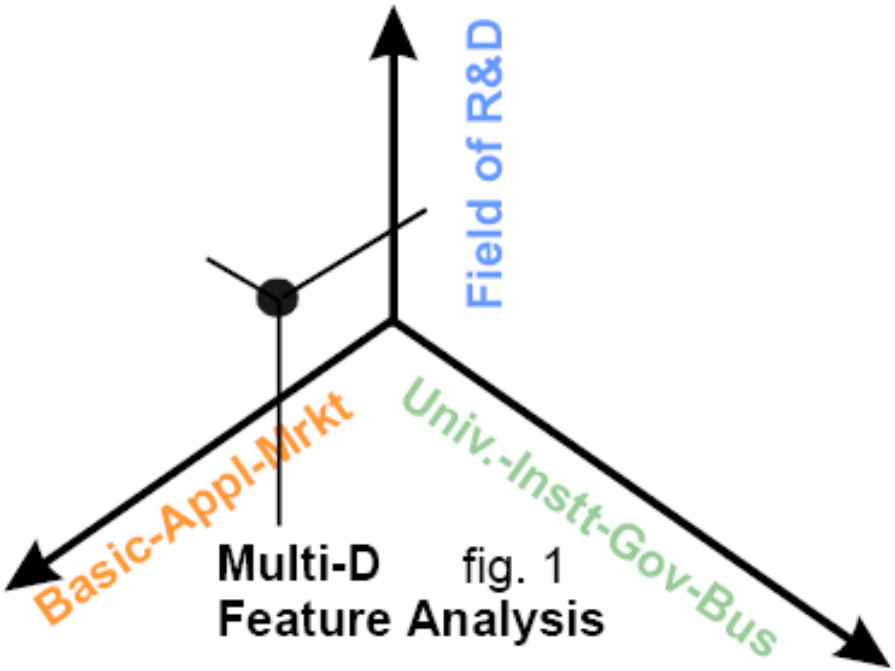
- Each cost impact parameter becomes a dimension, so each pr becomes a point in tha space – associated wi cost. Pattern sought.
- Computational Intensi
- High Arbitrariness: rel scale up of dimension



Multi-D Feature Analysis fig. 1

Cluster Analysis

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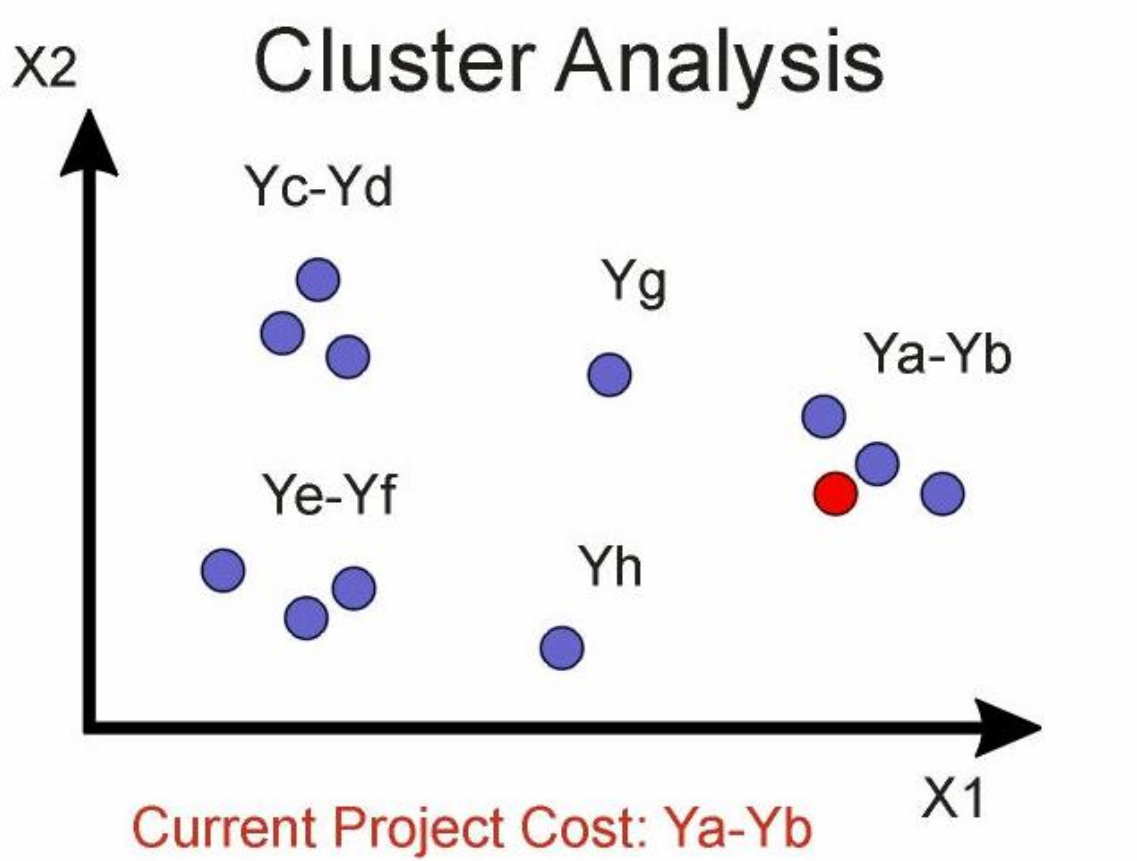

Distance MV Estimation

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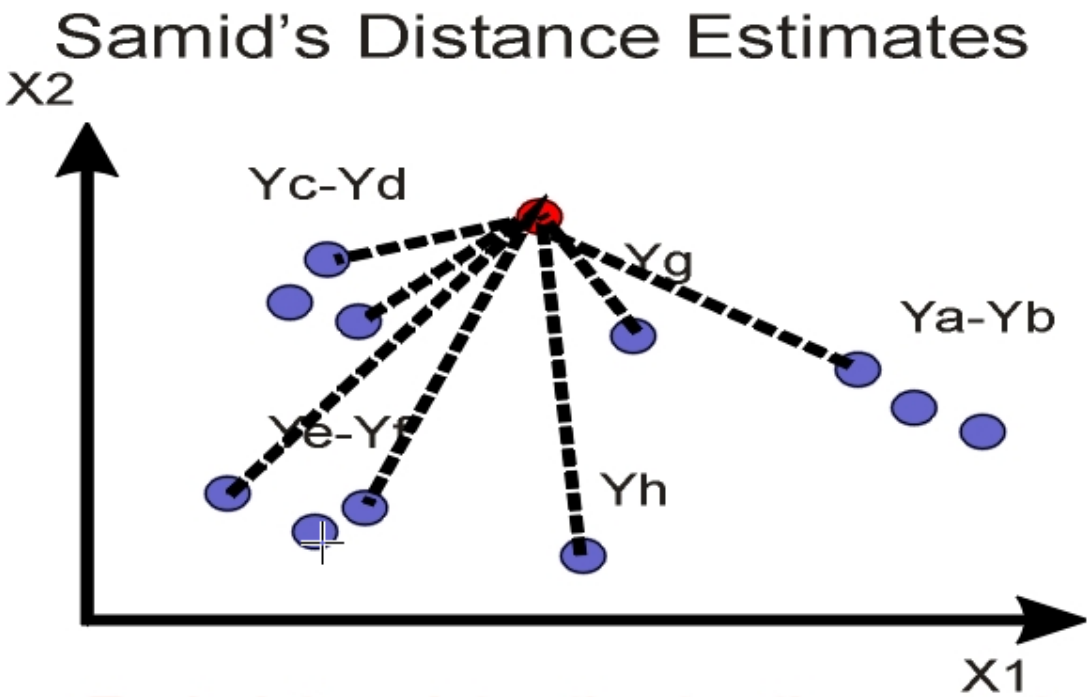

Each data point estimates the current point independently, and its impact is inversely proportional to its distance from the current point

Monte Carlo

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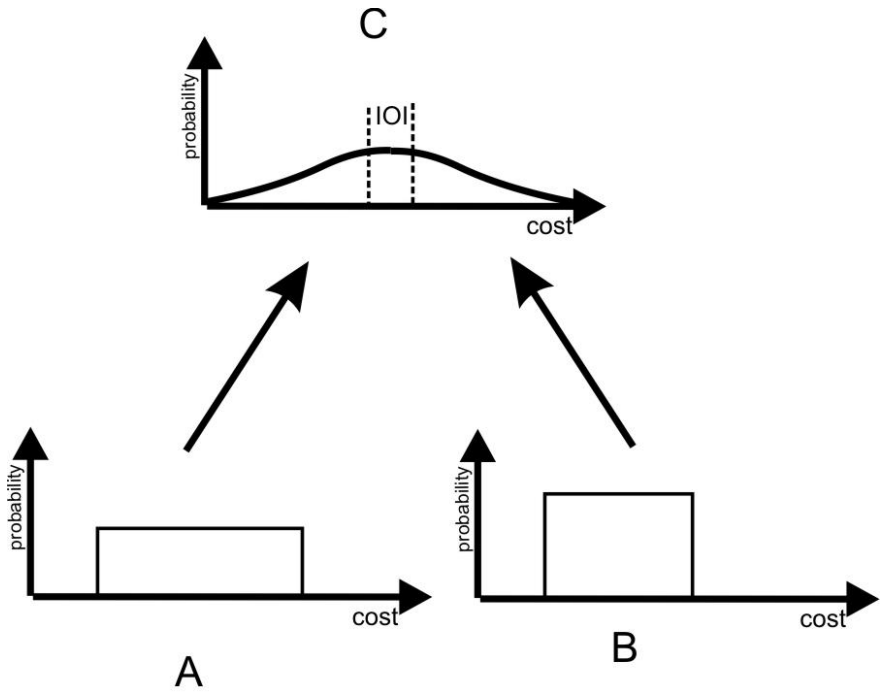
- Quick, low-arbitrariness method to develop cost frequency curve:



Random pick from A, plus random pick from B, add -- repeat to form a C cost histogram

BiPSA Multi-Variate

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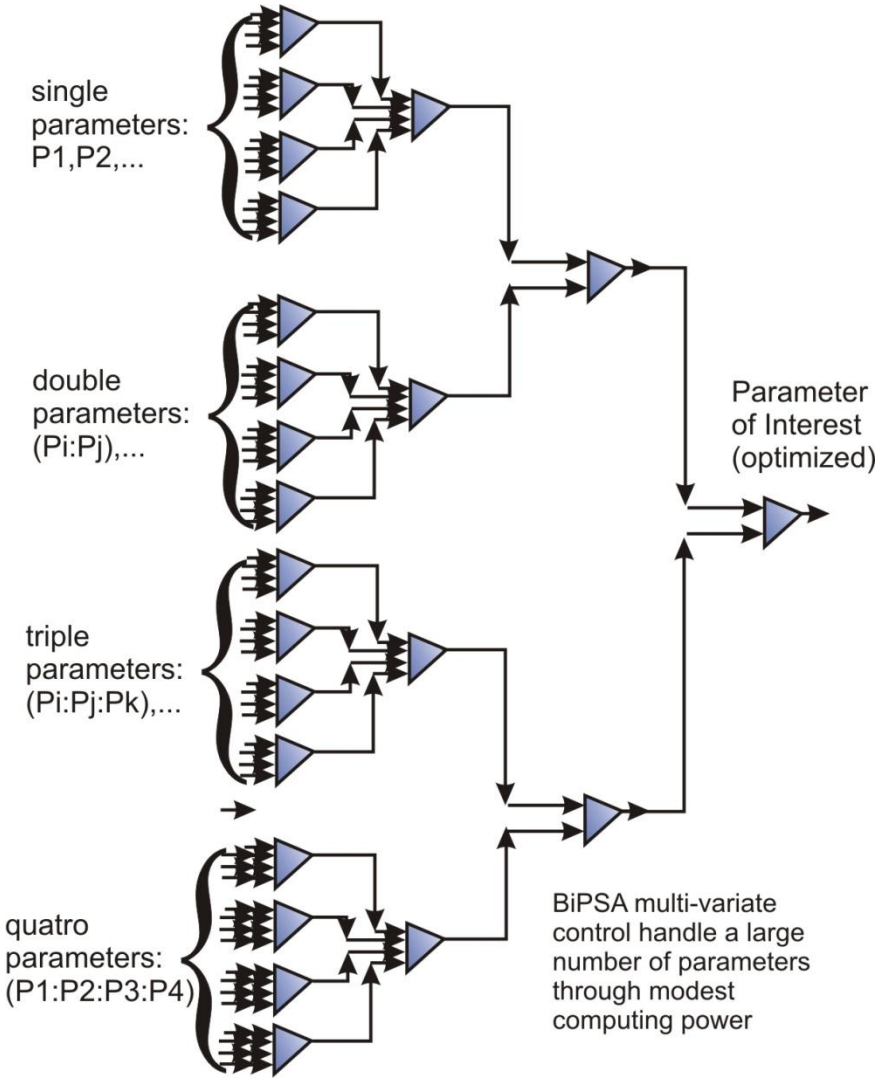

Community Tapping

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- Uncertainty best handled by tapping the relevant community. For the long run, no ‘genius’ is a match to community wisdom.
- E.g.: jury trials, second doctor opinion, The Stock Market, US Congress, The Concept of Democracy
- Tapping community wisdom creates team spirit, creates stakeholders, creates motivation.

Group Cost Estimation

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- Question: the project will cost no more than $X dollars (or last no longer than T months).
- Use the posted BiPSA form:
- http://wennovate.net/bipsa-gdf.php
- Find value x=Low the group definitely thinks is too low, and x=High, the group definitely thinks it's sufficient.
- If the gap= [High-Low] is getting smaller over time, it's a sign of progress! Worrisome otherwise!

Procedure:

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- Binarization

Every issue of uncertainty can be expressed as a cascade of binary (yes/no) issues.

- Community setup

The team, managers, consultants, lateral peers, retirees, WEB-hunt. Train, Engage!

- Tapping

BiPSA. E.g: ***http://www.PeakOilWhen.org***

http://wennovate.net/bipsa-qdf.php

- Learning

BiPSA

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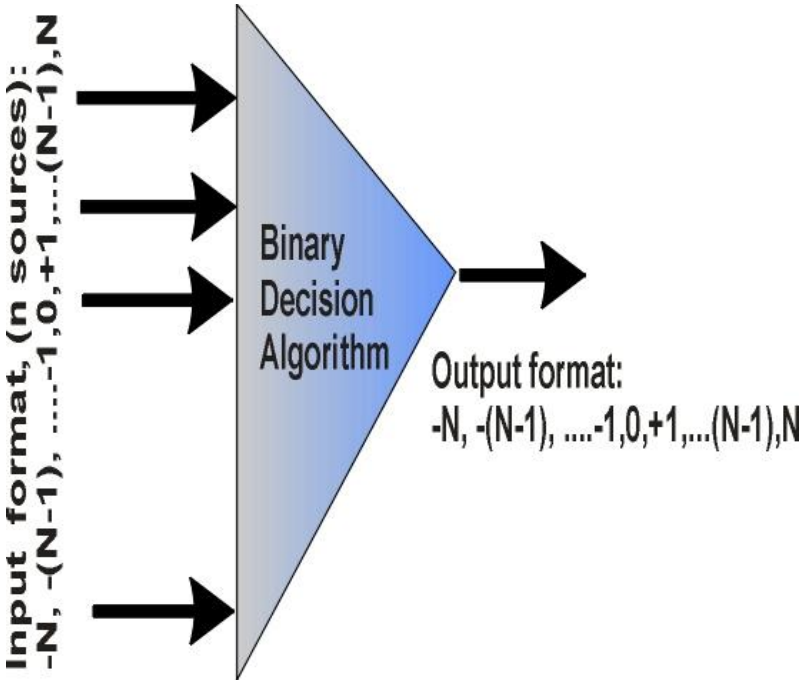
- Mathematical Paradigm to facilitate high-credibility binary decision through low arbitrarines processing of input data consisting of binary votes from a set of respondents where each respondent indicates his or her level of confidence in his vote, and each respondent is rated per his or her relative impact on the question in point.
- Votes are expressed via integers: sign is the binary decision (zero=indecision), and absolute value represents degree of confidence.
- Illustration: Input: 5,0,-1. Arithmetic mean: 1.33, geometric mean: 0, BiPSA: 2



Accounting for Voter's Impact

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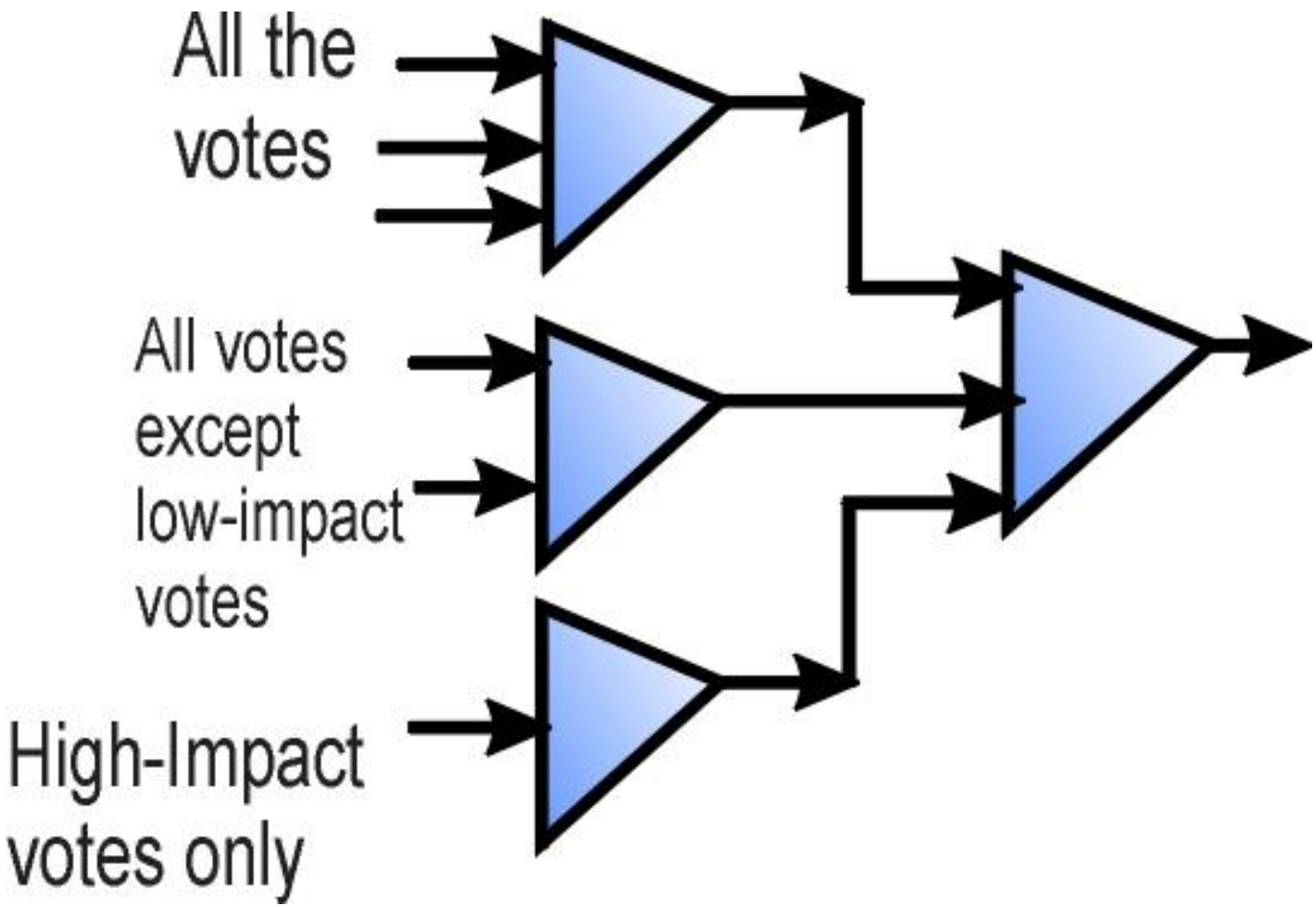

The BiPSA Network

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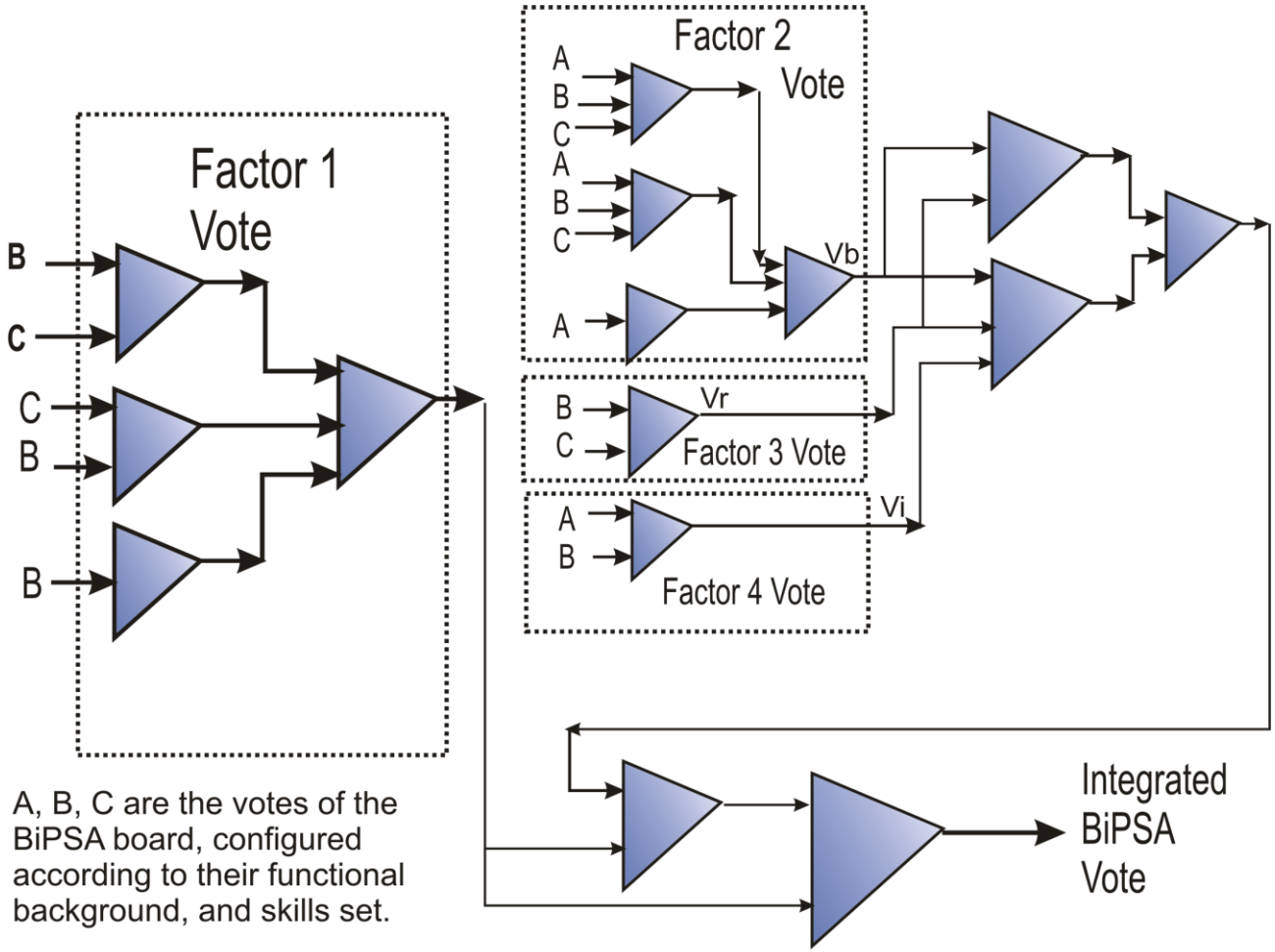

A, B, C are the votes of the BiPSA board, configured according to their functional background, and skills set.

Future Based Cost Estimates

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- Applicable to one-of-a-kind items (e.g. specialty reactors)
- Hide or show affordability to supplier
- Present or hide your affordability estimates to your buyer
- Compute your own (secret) affordability limit.
- Multiple scenarios, check convergence, specify assumptions.

Rethinking Cost Estimation

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- Commonly a necessary evil, postponed, relegated, shrugged off
- Use as a knowledge metric, progress monitor, development guide!
- Use to attract investment, win over management
- Use to hire good people (hypesters ill-estimate!)

The Cost of Cost Estimation

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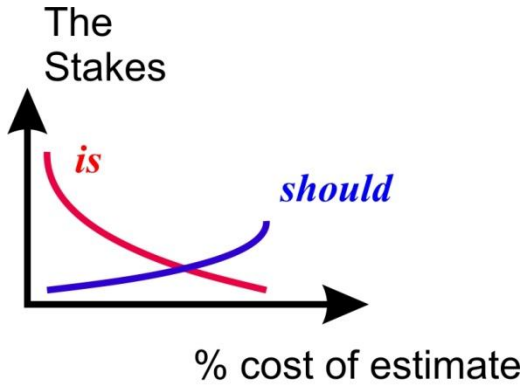
- When the stakes are high the estimate cost tends to be too low – mind it!
- When the stakes are low, the estimate cost tends to be too high – mind it!

Don't' fuss the small stuff!

BiPSize the important stuff!



Seminar Offerings

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- Engineering is Cost Engineering
- Chemical Engineering for Innovative Chemistry
- Innovation Acceleration Methodologies
- The Universal Theory of Innovation
- Innovation Management
- BiPSA: Management by Inclusion
- Nurturing the Culture of Innovation

Seminars range from a single evening overview, a dedicated Saturday; six, ten, and thirty hours on a weekly or bi-weekly basis, and per-case arrangements.

Seminars are offered (1) online, (2) at Case Western Reserve University, (3) on the road, (4) on customer's location.

Contact:

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