Quantifying the Effects of Budget Management on Project Cost and Success

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Outline

- The cost overrun problem and its causes
  - human behavior and organizational considerations
- A modified PCA
  - MAIMS principle
  - Two-level correlation model
  - Comparison with other approaches
- Analysis of a sample design/engineering project
- Budget allocation, contingency management, and project cost
- Future directions

The cost-overrun problem

> ***"Their judgment was based more on wishful thinking than on sound calculation of probabilities."***
> *Thucydides, 431 B.C.E.*

☝ **This observation is very insightful and still applicable today.**

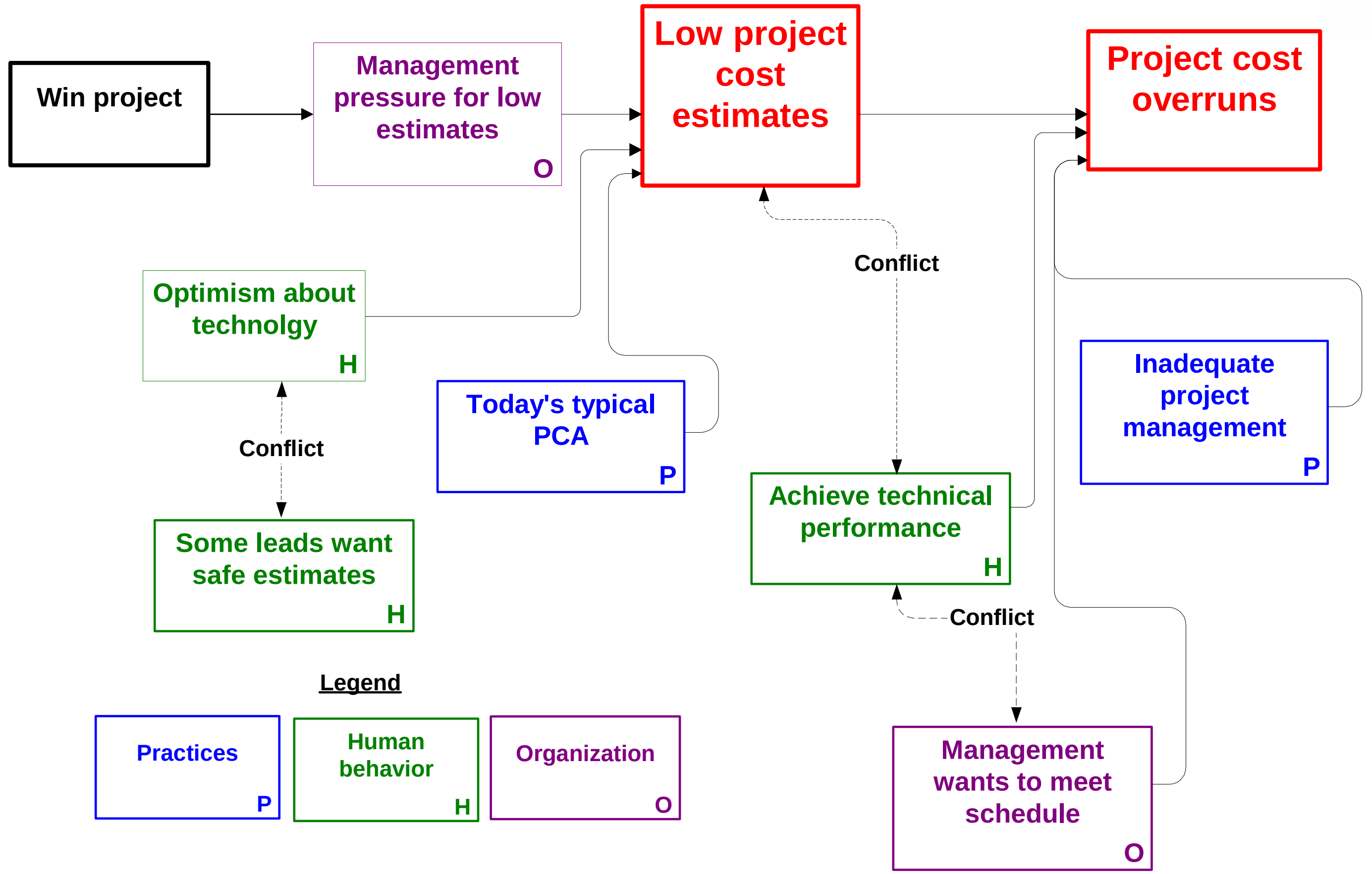
◆ **Common threads among the various "top 10" lists**

- **Institutional and organizational culture**
  - **Procurement process, management pressure, poor project definition**
- **Real Vs. idealized human behavior**
  - **Psychology is relevant to economics,decision-making,management,...**
  - ✋ **The "100% rational" person is a theoretical model that differs from reality.**
- **Inadequate analyses - Today's typical PCA**
  - **Ad-hoc data elicitation, improper distributions, omitted and/or limited dependencies, omitted high risk events & decision points**
  - ✋ **Shift from deterministic to probabilistic approach is NOT silver bullet!**
    - **Monte Carlo simulation is only a mathematical tool: GIGO.**
- **Poor management practices**
  - **Lack of appreciation of probabilistic concepts and psychological influences in budget allocation and control of management reserve**

☞ **Projects that come-in under cost do not necessarily deserve kudos.**

- **They may have carried excessively safe budgets.**

Do these conditions exist on any of your projects?



Our approach models these causes and effects to obtain realistic cost estimates and enhance project success.

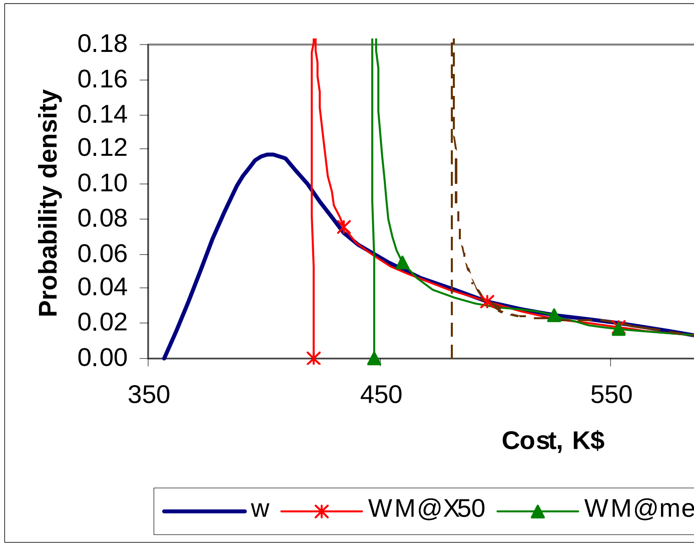
Psychology can teach us much about cost overruns

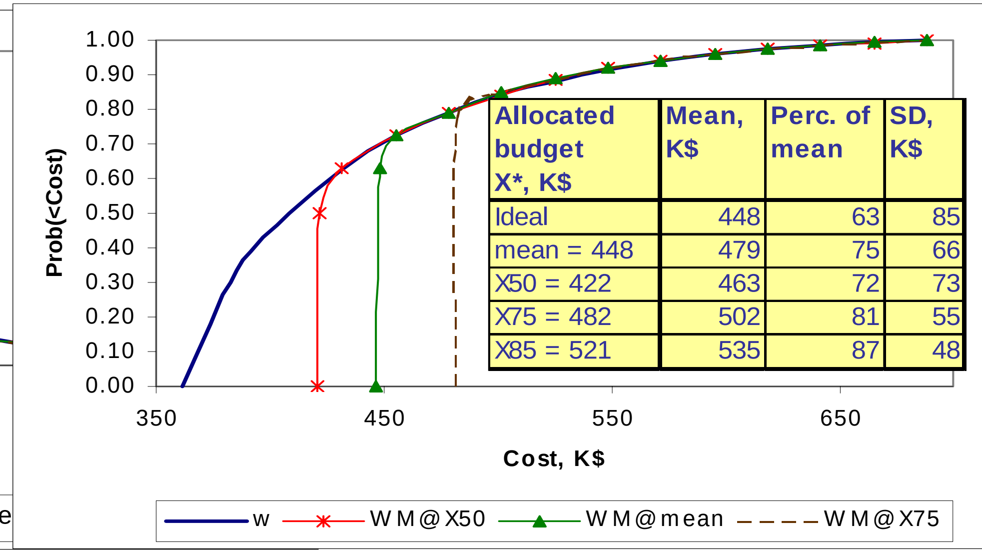
- **Overconfidence**
  - **R&D folks are intrinsically optimistic about new technologies.**
  - ***"For heaven's sake, Spread Those Fractiles! Be honest with yourselves! Admit what you don't know!"*** Alpert and Raiffa, 1982
- **Negative human behavior – MAIMS Principle**
  - ***"Money Allocated Is Money Spent."*** C. Gordon, 1997
    - ☞ **Task underruns are rarely available to protect against tasks overruns. Task overruns are passed on to the total project cost.**
- **Mistakes of reason**
  - ***"Too many details tend to cloud the big picture."***
    - ☞ **Total project cost is not simply the sum of the individual cost elements. Project characteristics and risks are likely to affect multiple elements.**
  - ***"Implicitly trusting the most readily available information or anchoring too much on convenient facts."*** Russo and Schoemaker, 1990 - Decision trap # 5
    - ☞ **Realistic cost analysis requires a systems engineering approach.**

A credible cost analysis needs to integrate psychological findings with mathematically valid models and sound management techniques.

MAIMS significantly impacts PCA cost elements

❑ **Illustration- Cost element with 3-parameter Weibull distribution**





Allocated budget X*, K$	Mean, K$	Perc. of mean	SD, K$
Ideal	448	63	85
mean = 448	479	75	66
X50 = 422	463	72	73
X75 = 482	502	81	55
X85 = 521	535	87	48

◆ **Properties of MAIMS-Modified distributions**

- Proper PDFs
- Minimum value: allocated budget, x*
- Modified Dirac delta function at x*
- Identical to original cost element for values > x*

✋ **Not the same as Crystal Ball and @Risk truncated PDFs**

MAIMS has a significant impact on PCA.
Impact increases with increased budget allocation.

A correlation model for dependencies at the subsystem and system levels

- **There are multiple dependencies among cost elements**
  - **Within a given subsystem due to technical complexity and common staff**
  - **Among different subsystems due to common organizational and programmatic considerations**

☞ **Consider cost elements $C_{m.j}$**

- 1st and 2nd integers refer to WBS level 2 and level 3, respectively

» **We model cost correlations based on Markowitz's multi-factor model**

$$C_{m.j} = R_{m.j} + \alpha_{m.j} * F_m$$

– $\alpha_{m.j}$ are constants; $R_{m.j}$ are independent random variables; F_m are correlated random variables; $R_{m.j}$ and F_n are independent

✍ **It can be shown** $\quad Corr(C_{m.j}, C_{n.k}) = Corr(F_n, F_m) * \alpha_{m.j} * \alpha_{n.k}$

- **Given the lack of data, we make the following assumptions**
  1. $Corr(C_{m.j}, C_{m.k}) = \rho_{int}$ **for cost elements in the same subsystem**
  2. $Corr(C_{m.j}, C_{n.k}) = \rho_{ext}$ **for cost elements in different subsystems**
  3. $\rho_{int} > \rho_{ext}$

Neglecting correlations gives the illusion that higher WBS levels have lower risk than lower ones.

Illustrative Analysis

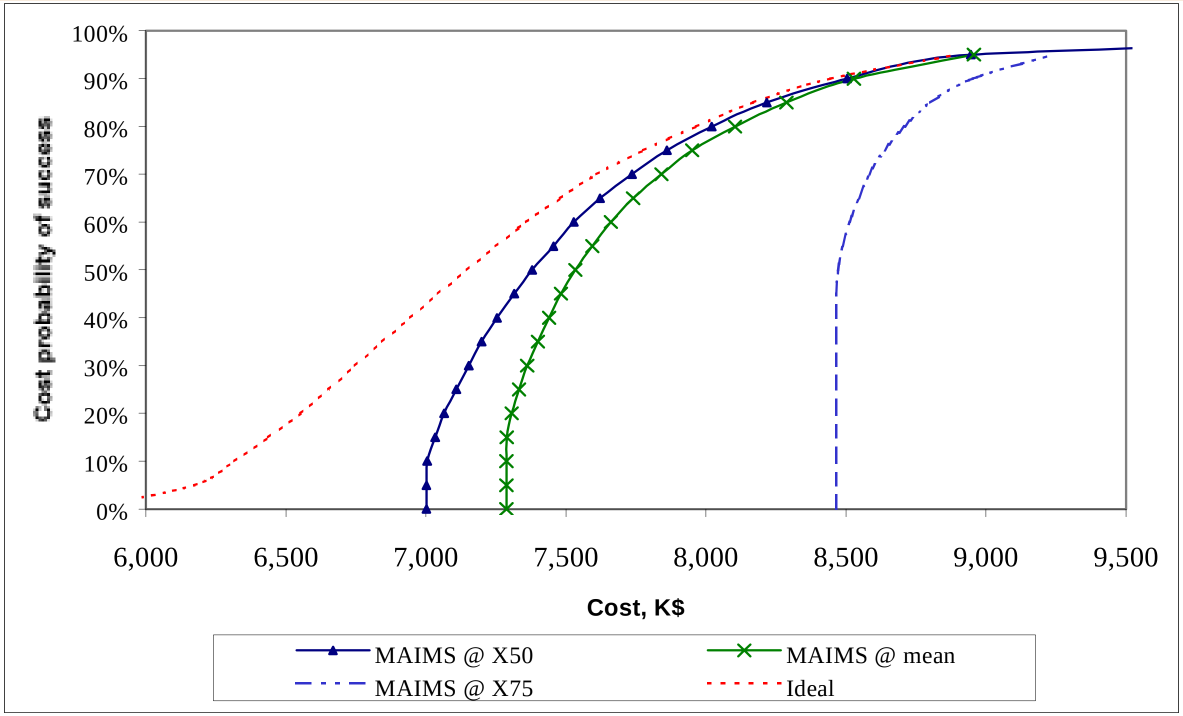
Sample design/engineering project

WBS Cost Elements	Estimated Percentiles K$		
	X_{10}	X_{50}	X_{90}
1.0 Total project/system, C_T			
1.1 Project/system-level, C_1			
1.1.1 Project management, $C_{1.1}$	382	421	499
1.1.2 Systems engineering, $C_{1.2}$	220	232	257
1.1.3 Integration & test, $C_{1.3}$	887	1,010	1,256
1.2 Subsystem X, C_2			
1.2.1 Mechanical components, $C_{2.1}$	970	1088	1,323
1.2.2 Electrical components, $C_{2.2}$	742	846	1,054
1.2.3 Integration & test, $C_{2.3}$	596	724	980
1.3 Subsystem Y, C_3			
1.3.1 Software development, $C_{3.1}$	1,069	1,282	1,708
1.3.2 Firmware, $C_{3.2}$	634	743	961
1.3.3 Integration & test, $C_{3.3}$	541	656	886

Procedure

1. Establish CWBS
2. Assess cost elements
   - » Direct fractile assessment method
   - 3 percentiles
   - engineering judgment, experience, & available data
3. Calibrate estimates
4. Fit estimates
   - » Three-parameter Weibull
5. Allocate budget to each cost element
6. Modify each cost element for MAIMS
7. Model correlation among cost elements
   - » Two-level correlation model
8. Perform Monte Carlo Simulation
9. Establish PoS
10. Determine total cost & contingency

Budget allocation impacts project cost and probability of success



◆ **Ideal Project**

- **"100% rational" team**
- **Each cost manager spends money only as necessary to satisfy requirements**
- **Savings are available to support other cost elements on an as-needed basis**

Actual costs may be less than budgeted costs

◆ **Real Projects**

- **Human behavior and organizational considerations**
- **MAIMS principle**
- **Budget and contingency management are important confounding factors**

➢ **Effects increase with higher allocated budgets and are substantial**

A story of a project cost overrun

① **Agency X issues a RFP**
- Requests cost at 50% CL
- Illustrative R&D project

② **Contractor A prepares bid**
☞ possesses limited sophistication; but not cognizant of MAIMS principle
- Develops CWBS
- Performs today's typical PCA
    - P50: 7,348 K$
    - Min: 5,633 K$

③ **Contractor A submits bid of 7,348 K$**
☺ Confident he will succeed. Thinks cost estimate has a 30% margin.

④ **Contractor A is winner**

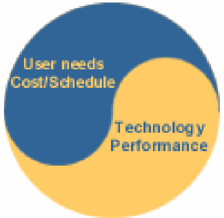
⑤ **The project starts & budgets are allocated**
- The practice is to baseline the WBS level-3 elements at mean values
    - Baseline cost: 7,665 K$
    - ☹ But this impossible!

⑥ **Much time is spent reallocating and prorating budgets**
- Budget cost elements at 50% CL
    - Baseline cost: 7,002 K$
    - Management reserve: ~ 5%

⑦ **The outcome**
☹ Everybody works very hard. But the project runs out of budget and is cancelled.

Epilogue
✓ Another project has succumbed to the MAIMS principle.
✓ Today's typical PCA models a mythical project.
✓ Future RFPs: contracting agencies & contractors use proposed approach.

It's NOT your textbook contingency anymore!



- **Cost contingency depends on desired probability of success and cost management strategy**

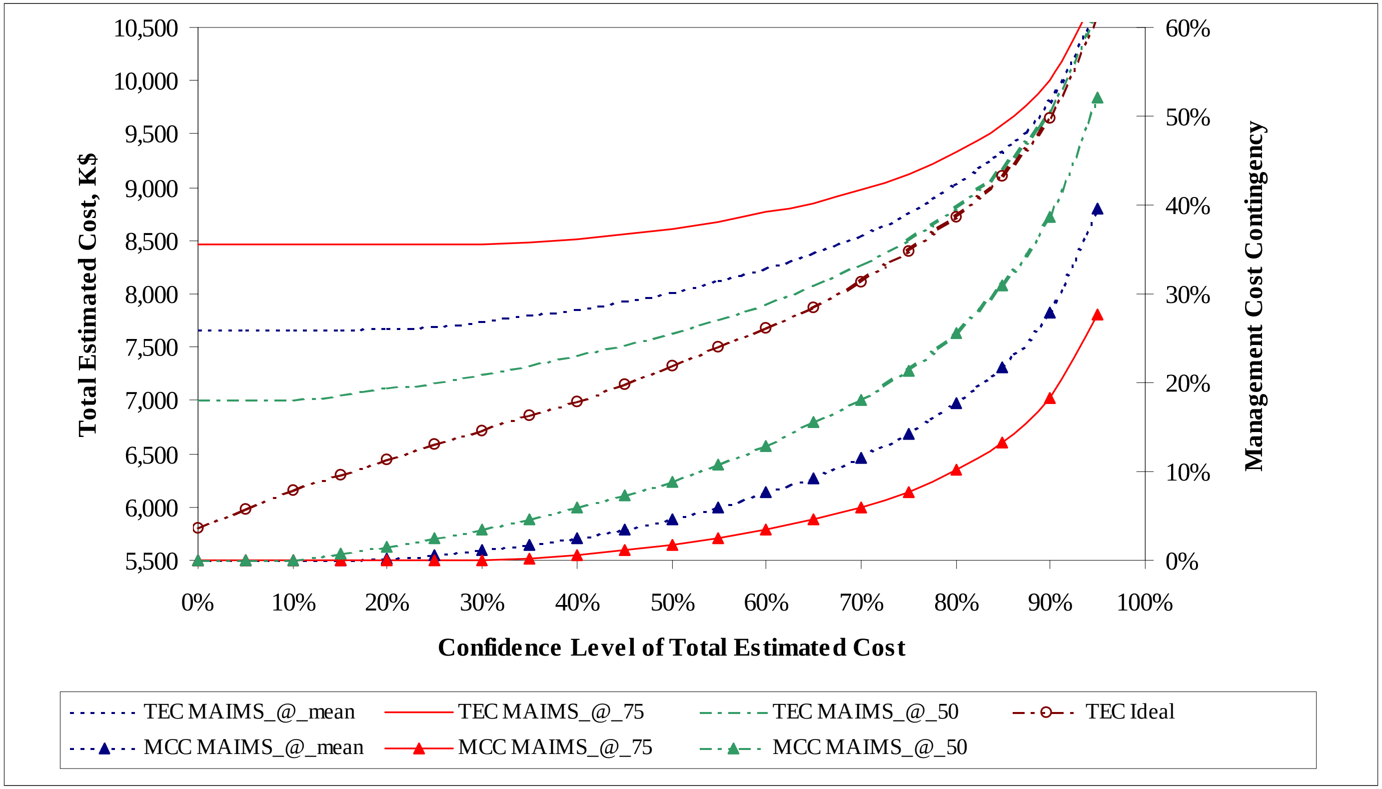
  – $MCC(PoS, PBC_1,\ldots,PBC_n) = TEC(PoS, PBC_1,\ldots,PBC_n) - PBC.$

  - MCC: Management Cost Contingency
  - TEC: Total Estimated Cost
  - PoS: Probability of Success
  - PBC_i: Baseline Budget for Cost element C_i
  - PBC: sum over all cost elements.

  » **Management strategies and desired probabilities of success vary across business categories**

- **Major differences with both deterministic practice and today's typical PCA**
  - » **MCC is NOT a fixed percentage of PBC**
  - » **MCC incorporates MAIMS principle and depends on the management strategy**
  - » **Interactive and iterative process: system analysts, engineers, management**

Contingency, cost, & success are NOT directly related



☞Different representation of data in previous figure

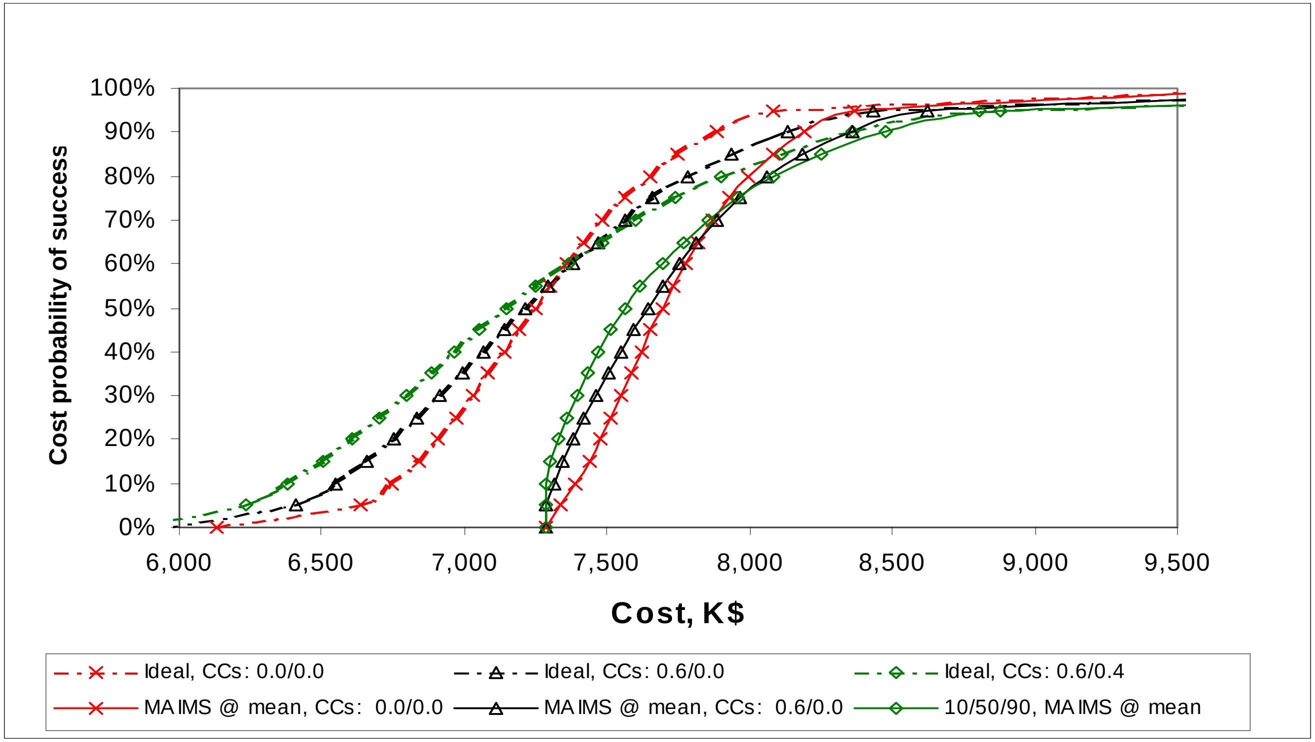
- **High cost NEED NOT provide (1) high PoS or CL and/or (2) high contingency**
- **Low contingency DOES NOT necessarily equate to low cost**
- **High contingency DOES NOT necessarily equate to high cost and/or padding**

Realistic budget allocation, adequate contingency, and dynamic allocation are critical to optimal cost and probability of success

There are many confounding factors to consider

- » Assessment of the cost elements
- » Correlation effects
- » Budget allocation
- » Human behavior
- » Organizational considerations

These are important and confounding factors that should be modeled simultaneously in a PCA.

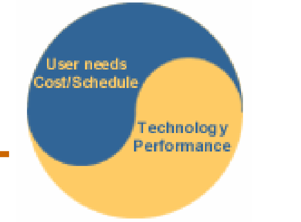


Our approach integrates many key concepts

	Critical Chain[1]	RACM[2]	Today's Typical PCA	Proposed Approach
Parameter	Schedule	Cost	Cost	Cost
Assessment of uncertainty	- "Realistic" task schedule = "Safe" estimate/2	- Gaussian normal PDFs	- Largely ad-hoc - Extensive use of triangular PDFs	- 3 percentiles using DFA method - 3-parameter Weibull
- Human behavior -Organizational influences	- Parkinson' s law - Safe estimates - Multi-tasking	- MAIMS - "Hidden" incentives	"Ideal" project & "100% rational" person	- Calibrate cost elements - Psychological findings - MAIMS principle
Correlations	Basic task dependencies	None	Limited, single parameter model	Two-level correlation model
Calculation method	Deterministic, single-point estimate	- Analytical/ statistical sum	Monte Carlo simulation	Monte Carlo simulation
Project management	- Project buffer - Feeding buffers - Project buffer: 25% of original estimate	- Baseline budget - Management reserve - Statistical cost control	- Cost account level and/or management reserve	- Baseline budget - Management reserve - Dynamic allocation

[1] *Goldratt's basic approach; numerous variations have been proposed*
[2] *Risk Analysis and Cost Management, Lockheed 1990's*

Future directions



- **Presented work focused on cost and macroscopic perspective**
  - it provides a framework for more accurate predictions
  - it results in more realistic expectations
  - benefits are likely to be significant
    - more viable plans, better decisions, reduction in cost overruns.

Most projects are worth the additional effort!

- **Much remains to be done**
  - integrate microscopic and macroscopic approaches
  - simultaneously treat performance/cost/schedule
  - quantitative calibration of data elicitation - single and multiple experts
- ☞ **Greatest challenge- implementation of systems thinking at the personnel, organizational and institutional levels**
  - tool to dynamically adjust budget and modify negative behavior
- ☝ **Hope - More SE research to deal with psychological findings on human behavior and judgment under uncertainty**