Software Cost Estimation Meets Software Diversity

Barry Boehm, USC

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Outline

- Sources of Software Diversity
  - A Short History of Software Estimation Accuracy
  - Process, Product, Property, and People Drivers
- Options for Software Cost Estimation
  - Expert Judgement/Consensus; Size-Based; Productivity-Based; Component-Based; Process-Based; Composites
- Best Fits of Estimation-Types to Diversity-Types
  - Extensions of ICSM Common Cases
- Charting Your Path to Improved Estimates

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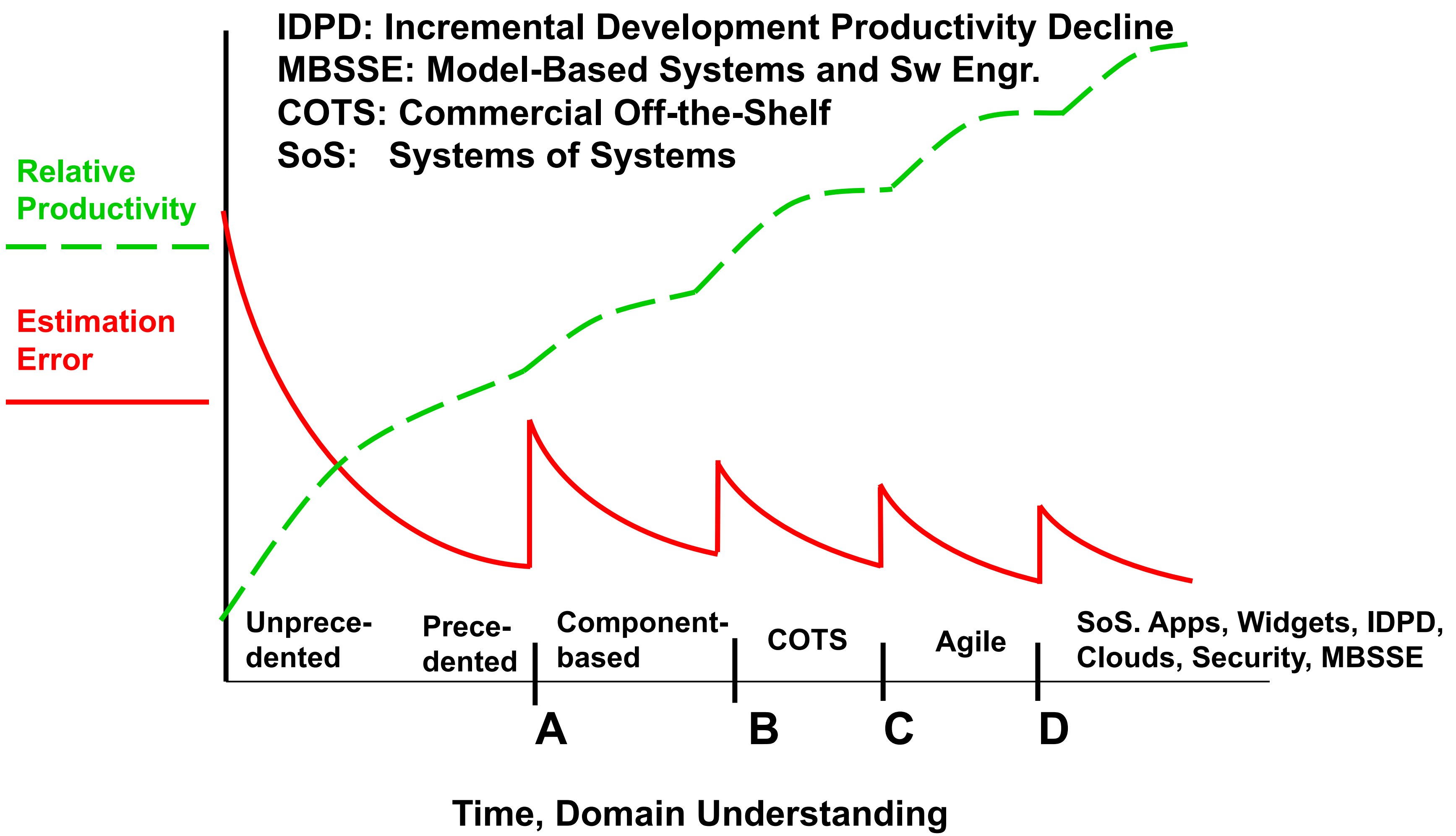
A Short History of Software Estimation Accuracy



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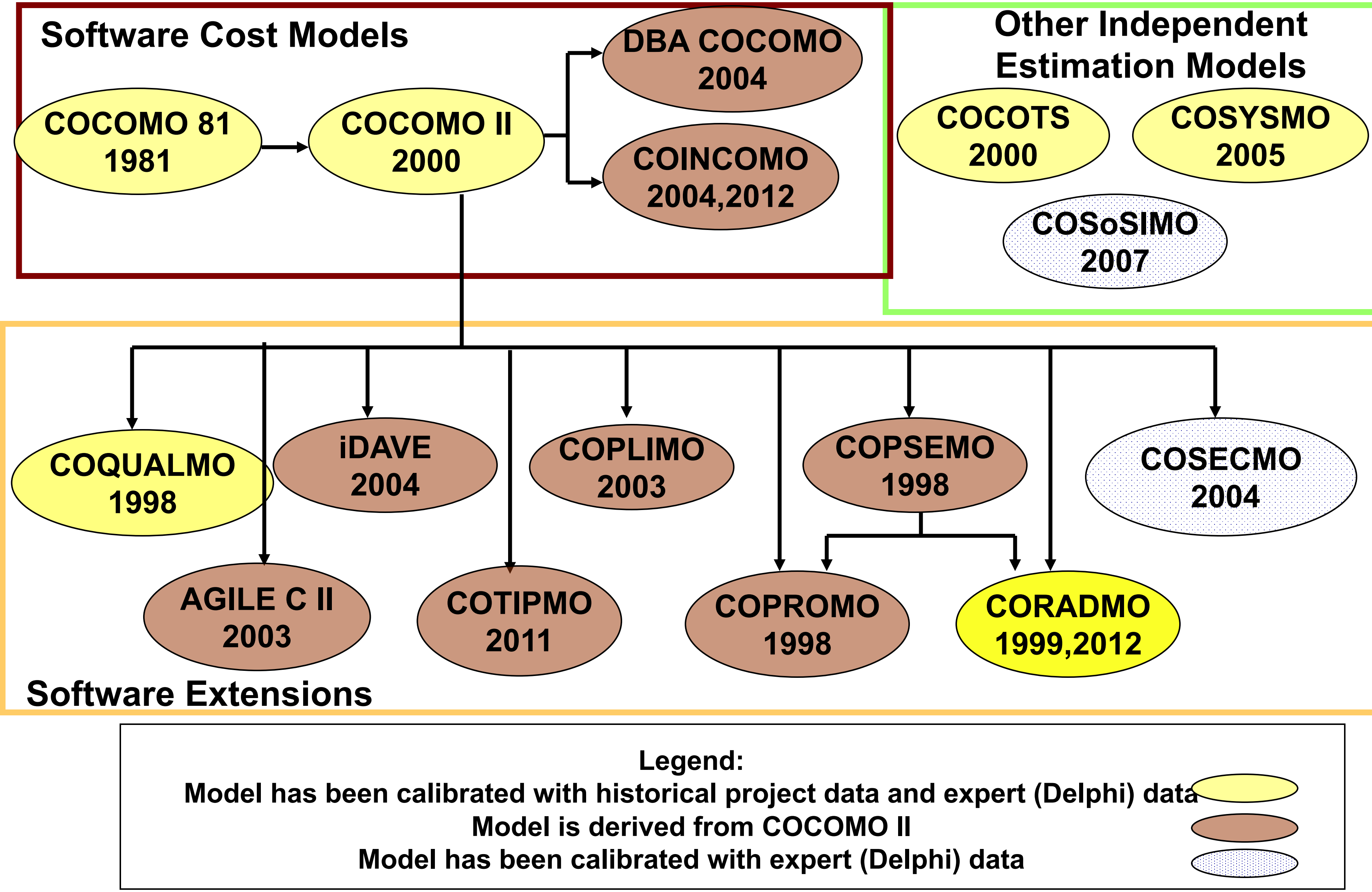
COCOMO Family of Cost Models



Dates indicate the time that the first paper was published for the model

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Future Software Process Diversity

- Sequential Phases
  - Waterfall, V-Model
- Sequential Increments
  - Most agile methods: XP, Scrum, Crystal , SAFE
  - Pre-Planned Product Improvement (P3I)
- Continuous reprioritization
  - Kanban, DevOps
- Evolutionary Definition and Development
  - Incremental Commitment Spiral, Rational Unified Process
- Fully concurrent: Open Source

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ICSM Common Case Examples

Accounting Application	Simple Customer Business App
Size/Complexity: Small/low **Typical Change Rate/Month:** Low **Criticality:** High **NDI Support:** NDI-driven architecture **Organizational Personnel Capability:** NDI-experienced, medium to high **Software Strategy: COTS**	**Size/Complexity:** Small/low **Typical Change Rate/Month:** Medium to high **Criticality:** Medium **NDI Support:** No COTS, development and target environment well-defined **Organizational Personnel Capability:** Agile-ready, domain experience high **Software Strategy: Architected agile**
Cellphone Feature	**Security Kernel**
Size/Complexity: Medium/medium **Typical Change Rate/Month:** Medium to high **Criticality:** Low **NDI Support:** No COTS, development and target environment well-defined **Organizational Personnel Capability:** Agile-ready, domain experience high **Software Strategy: Agile**	**Size/Complexity:** Small/low **Typical Change Rate/Month:** Low **Criticality:** Extra high **NDI Support:** No COTS, development and target environment well-defined **Organizational Personnel Capability:** Strong formal methods experience **Software Strategy: Formal methods**

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Incremental Development Productivity Decline (IDPD)

- Example: Site Defense BMD Software
  - 5 builds, 7 years, $100M; operational and support software
  - Build 1 productivity over 300 LOC/person month
  - Build 5 productivity under 150 LOC/PM
    - Including Build 1-4 breakage, integration, rework
    - 318% change in requirements across all builds
    - IDPD factor = 20% productivity decrease per build
  - Similar trends in later unprecedented systems
  - Not unique to DoD: key source of Windows Vista delays
- Maintenance of full non-COTS SLOC, not ESLOC
  - Build 1: 200 KSLOC new; 200K reused@20% = 240K ESLOC
  - Build 2: 400 KSLOC of Build 1 software to maintain, integrate

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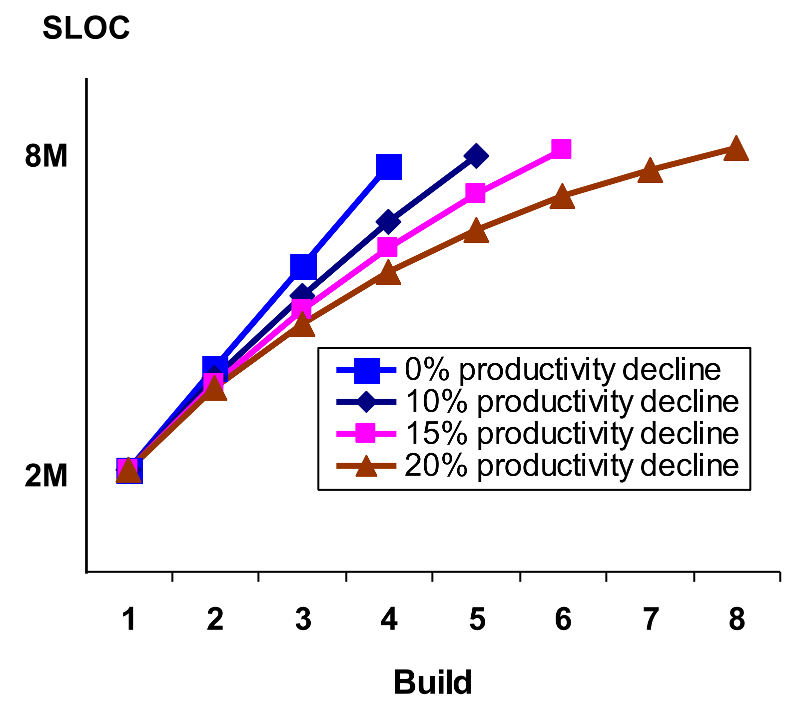
Effects of IDPD on Number of Increments

- Model relating productivity decline to number of builds needed to reach 8M SLOC Full Operational Capability
- Assumes Build 1 production of 2M SLOC @ 100 SLOC/PM
  - 20000 PM/ 24 mo. = 833 developers
  - Constant staff size for all builds
- Analysis varies the productivity decline per build
  - Extremely important to determine the incremental development productivity decline (IDPD) factor per build



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Future Software Product Diversity

- Developed, Reused, Generated Software
  - Source Lines of Code (SLOC), Function Points (FP)
  - Reused: Equivalent SLOC
  - Generated: Model Directives
- Product Line Definition and Development
  - Reused, Modified, Generated SLOC or FP
- Non-Developmental Items (NDI), Cloud Services
  - NDI: Commercial Off-the-Shelf (COTS), Open Source
  - Costing: Assessment, Tailoring, Glue Code, New-Release Adaptation
- Domain Languages: Business, Supply Chain, Space
- Datasource-Driven: Selection Criteria

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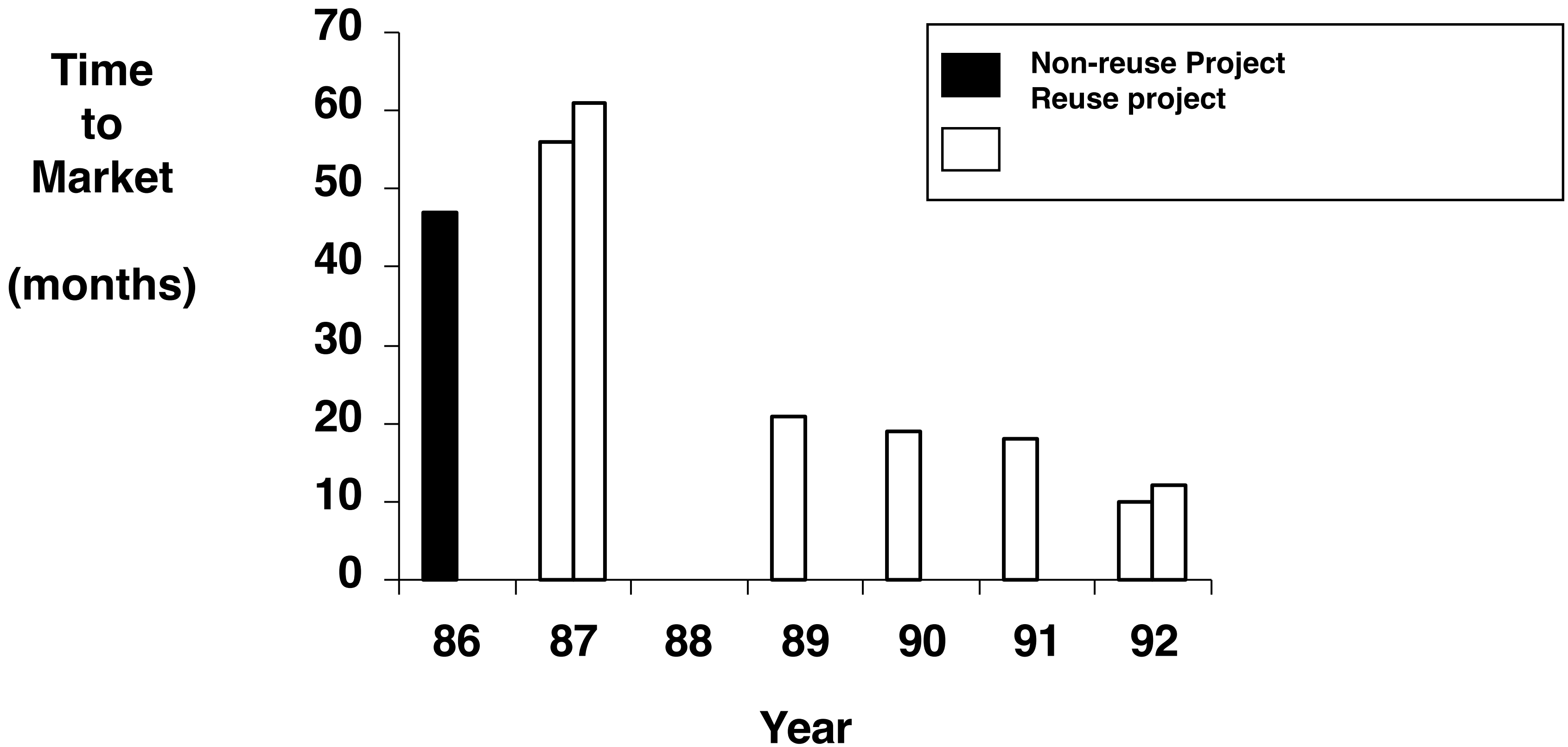
Reuse at HP's Queensferry Telecommunication Division



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Multi-Mission Support Systems Costing

- Product Line Engineering
  - Identify multi-mission commonalities and variabilities
  - Identify fully, partially sharable commonalities
  - Develop plug-compatible interfaces for variabilities
- Product Line Costing (COPLIMO) Parameters
  - Fractions of system fully reusable, partially reusable and cost of developing them for reuse
  - Fraction of system variabilities and cost of development
  - System lifetime and rates of change
- Product Line Life Cycle Challenges
  - Layered services vs. functional hierarchy
  - Modularization around sources of change
  - Version control, COTS refresh, and change prioritization
  - Balancing agilty, assurance, and affordability

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The Basic COPLIMO Model
- Constructive Product Line Investment Model

- Based on COCOMO II software cost model
  - Statistically calibrated to 161 projects, representing 18 diverse organizations
- Based on standard software reuse economic terms
  - RCR: Relative cost of reuse
  - RCWR: Relative cost of writing for reuse
- Avoids overestimation
  - Avoids RCWR for non-reused components
- Provides experience-based default parameter values
- Simple Excel spreadsheet model
  - Easy to modify, extend, interoperate

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Basic COPLIMO Output Summary

Summary of Inputs:

AVPROD	300	
AVSIZE	50000	(SLOC)
UNIQ%	40	(%)
ADAP%	30	(%)
RUSE%	30	(%)
RCR-UNIQ	100	(%)
RCR-ADAP	40	(%)
RCR-RUSE	5	(%)
RCWR	1.7	

(Note: Do not change above values!)
(Change from "Input" sheet.)

7 year Product Line Effort Savings:

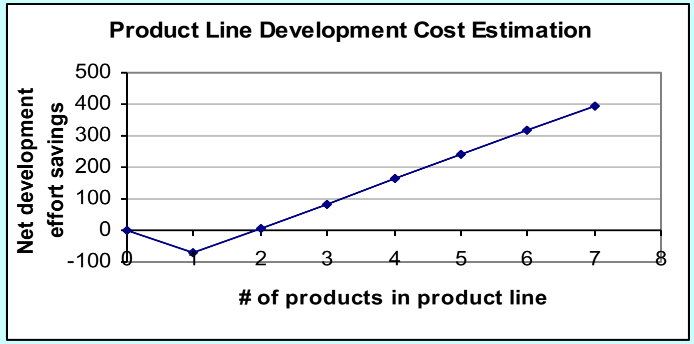

Table of Results:

# of Products	0	1	2	3	4	5	6	7
Unique SLOC	0	20000	40000	60000	80000	100000	120000	140000
Adapted SLOC	0	15000	30000	45000	60000	75000	90000	105000
Reused SLOC	0	15000	30000	45000	60000	75000	90000	105000
Total Non-PL SLOC	0	50000	100000	150000	200000	250000	300000	350000
Non-PL Effort (PM)	0	166.667	333.333	500	666.667	833.333	1000	1166.667
1-Product Equiv. SLOC	0	71000	26750	26750	26750	26750	26750	26750
1-Product Equiv. Effort	0	236.667	89.1667	89.1667	89.1667	89.1667	89.1667	89.16667
Cum. Equiv. PL SLOC	0	71000	97750	124500	151250	178000	204750	231500
Cum. PL Effort	0	236.667	325.833	415	504.167	593.333	682.5	771.6667
PL Effort Savings	0	-70	7.5	85	162.5	240	317.5	395
PL Reuse Investment	0	70						
Return on Investment	N/A	-1	0.10714	1.21429	2.32143	3.42857	4.53571	5.642857

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Persistence of Legacy Systems

- Before establishing new-system increments
  - Determine how to undo legacy system

1939's Science Fiction World of 2000

Actual World of 2000

Failed Greenfield Corporate Financial System

- Used waterfall approach
  - Gathered requirements
  - Chose best-fit ERP system
  - Provided remaining enhancements
- Needed to ensure continuity of service
  - Planned incremental phase-in of new services
- Failed due to inability to selectively phase out legacy services
  - Dropped after 2 failed tries at cost of $40M

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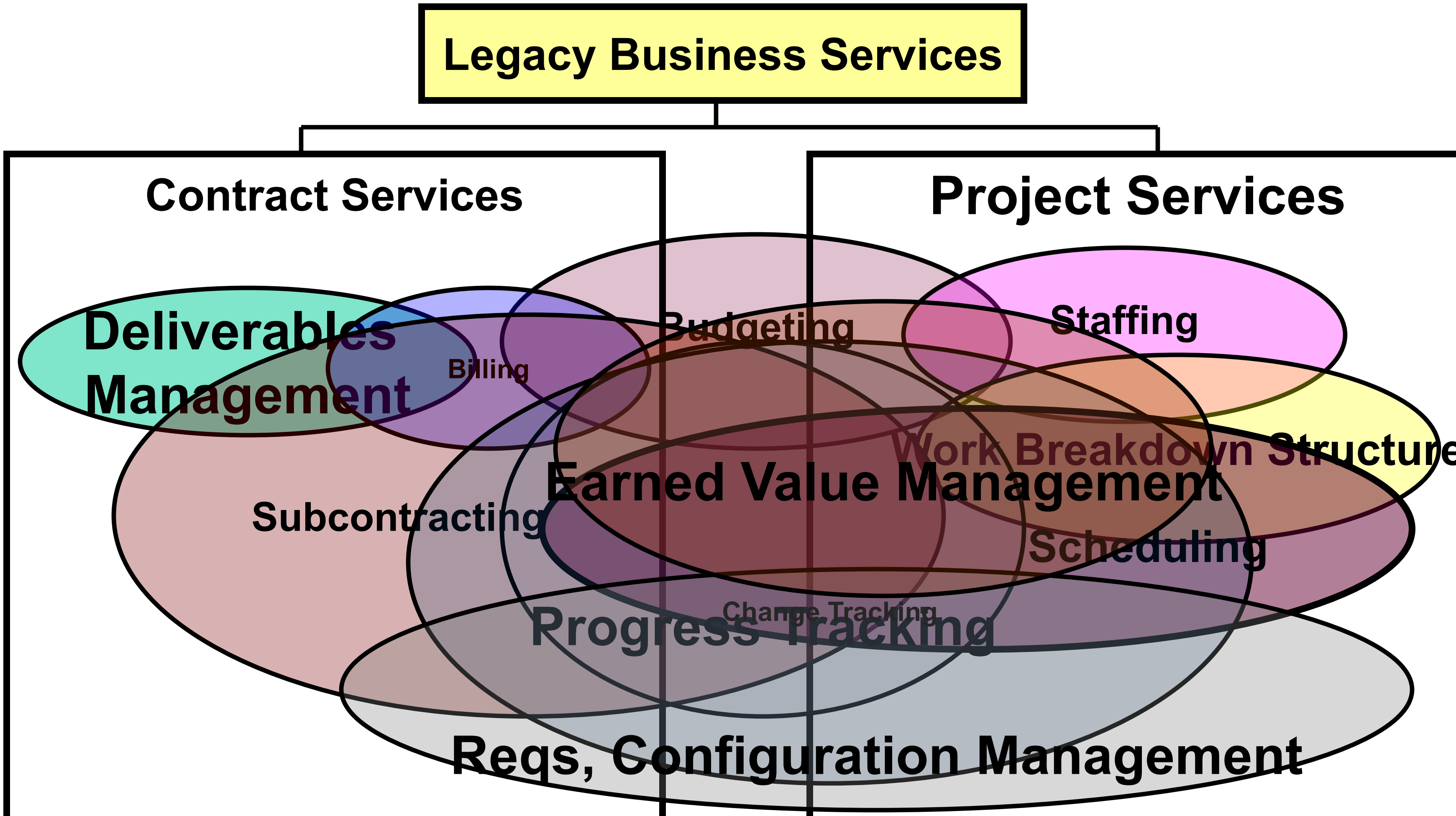
Legacy Systems Patched, Highly Coupled Financial and Non-Financial Services



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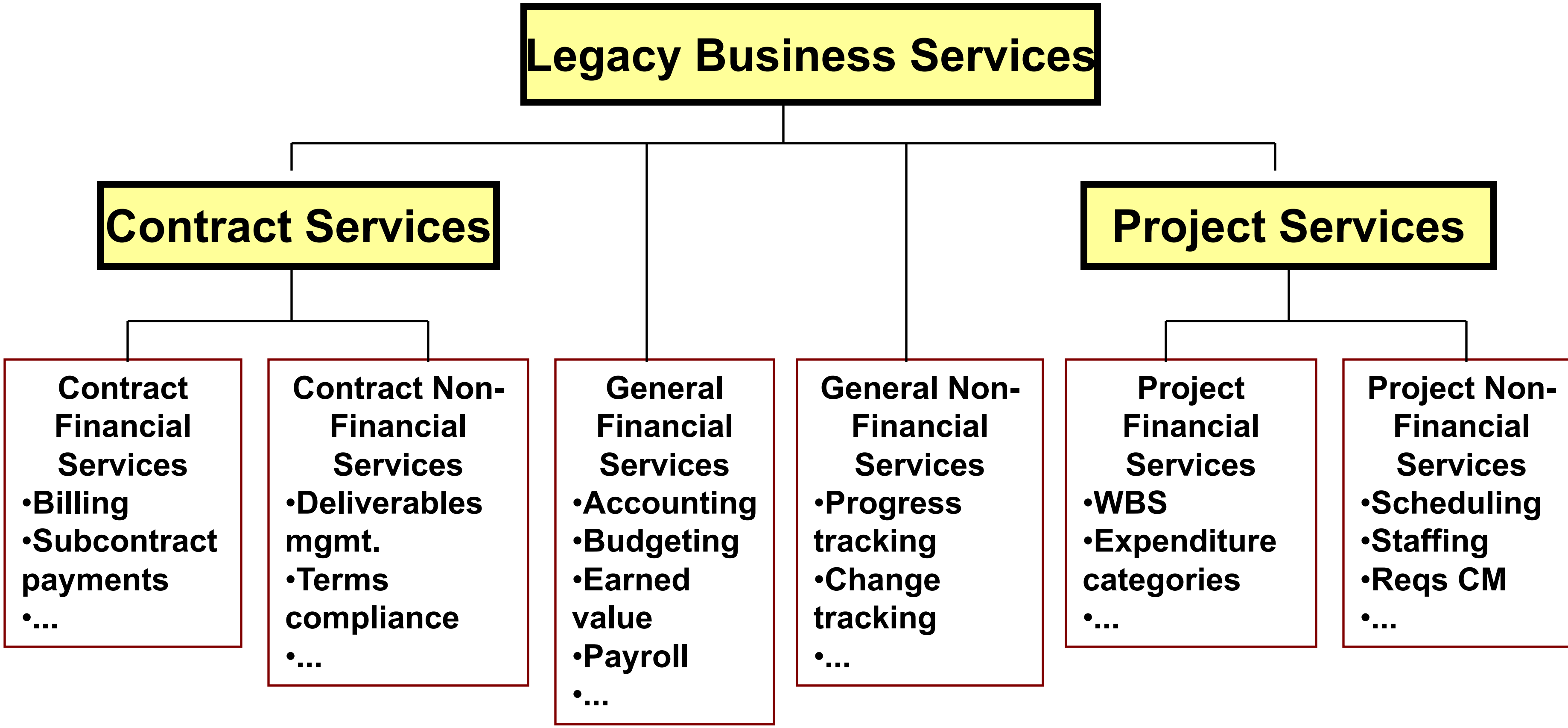
Result of Legacy Re-engineering



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Future Software Properties Diversity

- Dependability
  - Reliability, Availability, Safety, Security
- Changeability
  - Adaptability, Maintainability, Modifiability, Repairability
- Mission Effectiveness
  - Response Time, Throughput, Accuracy, Usability, Scalability, Interoperability
- Life Cycle Efficiency (Cost-Effectiveness)
  - Development and Maintenance Cost, Schedule; Reusability

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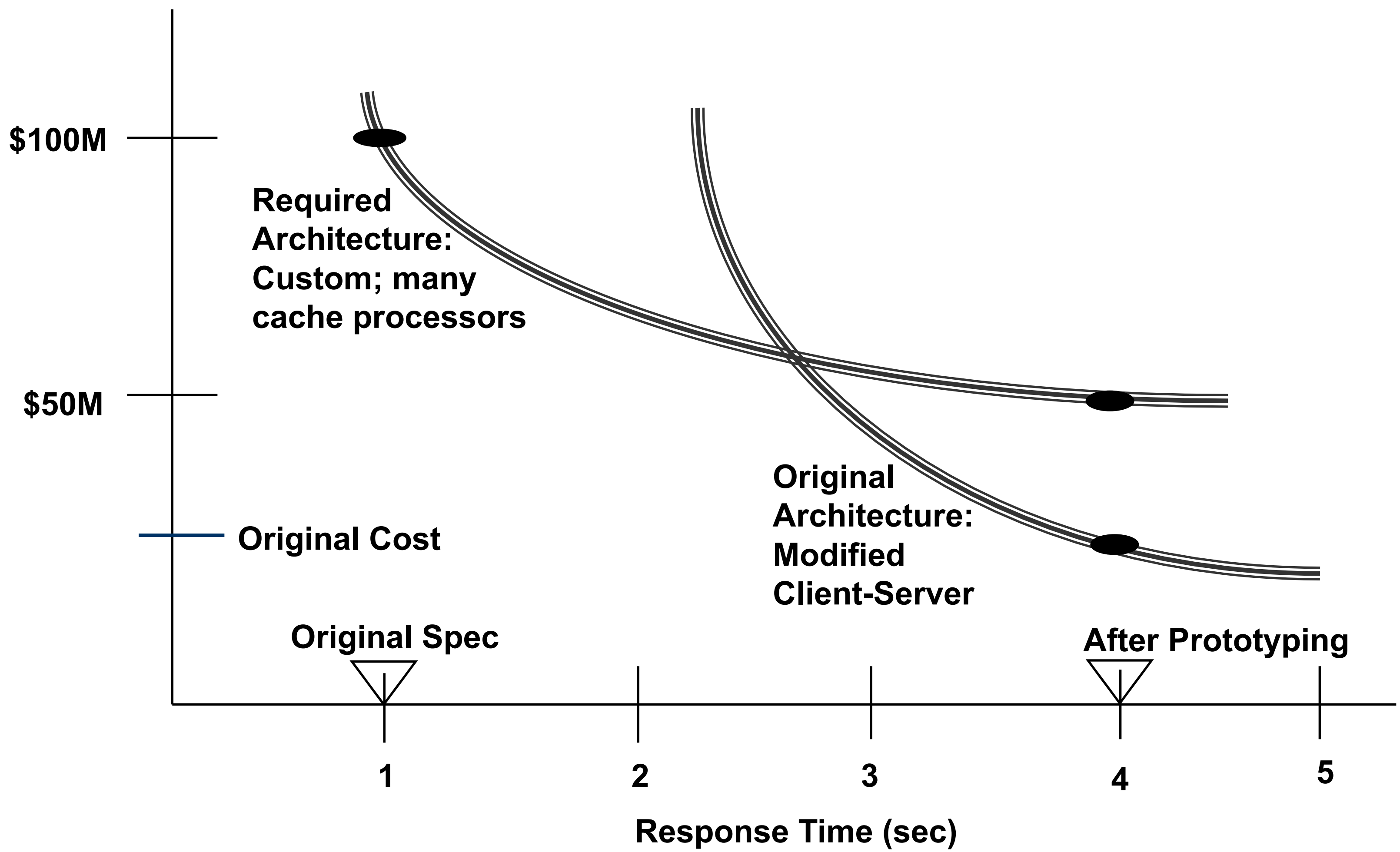
Response Time Rqt. Impact on Cost



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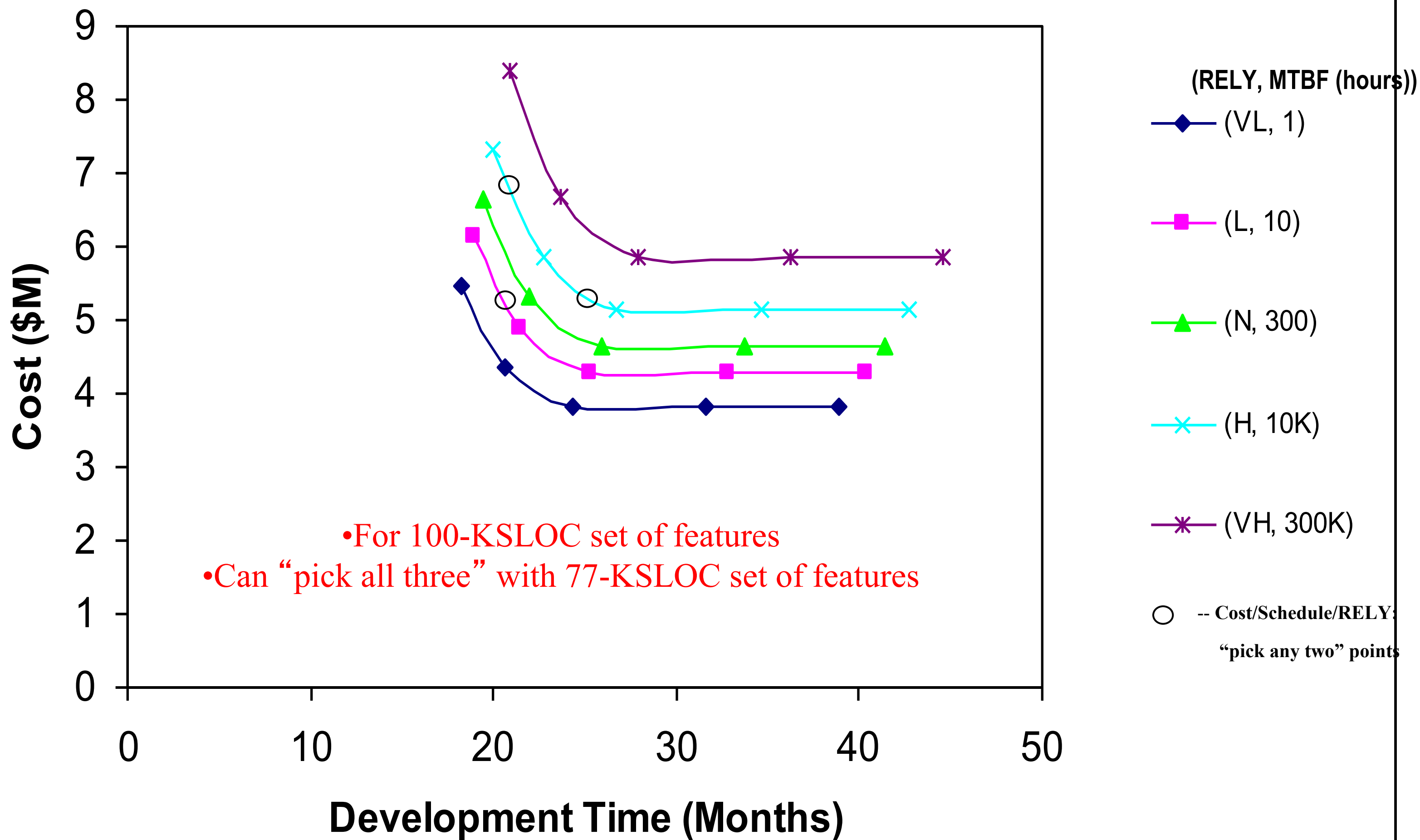
Better, Cheaper, Faster: Pick Any Two
COCOMO II Model Results



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Future Software People Diversity

- Desired Software People Capabilities
  - Software System Analysis
  - Software System Development
  - Application Domain Experience
  - Software Languages and Tools Experience
  - Software Process Maturity
  - Team Cohesion
  - Low Personnel Turnover
  - Familiarity with Apps, Widgets, Social Media, Data Analytics, Multimedia, Virtual Reality

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Estimation-Type Options

- Expert-Judgement; Stakeholder Consensus
  - Planning Poker, Wideband Delphi, Bottom-Up
- Analogy: Previous Projects; Yesterday's Weather
  - Agile COCOMO II, Case-Based Reasoning, Causal Modeling
- Parametric Models
  - COCOMO/COSTAR, Knowledge Plan, SEER, SLIM, True-S
- Resource-Limited
  - Cost or Schedule as Independent Variable (CAIV, SAIV)
- Reuse-Driven: Equivalent Size
  - Adjusted for %Design,Code,Test Modified, Understandability
- Product Line
  - % Development for Reuse; % Development with Reuse

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Best Fits of Estimation-Types to Diversity-Types

- Pure Agile: Planning Poker, Agile COCOMO II
- Architected Agile
  - COSYSMO for architecting; Planning Poker, CAIV-SAIV for sprints, releases; IDPD for large systems
- Formal Methods: $/SLOC by Evaluated Assurance Level
- NDI/Services-Intensive: Oracle, SAP, other ERP
  - RICE Objects: (R)eports, (I)nterfaces, (C)onversions, (E)nhancements
  - COCOTS, Value-Added Function Points, Agile for portions
- Hybrid Agile/Plan-Driven
  - Expert Delphi, Parametric Models, Agile for portions; IDPD
- Systems of Systems
  - COSYSMO for Integrator; Hybrid Agile/Plan-Driven for component systems
- Family of Systems: COPLIMO
- Brownfield: Experiment for refactoring; above for rebuilding

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Proliferation of Estimation Types

Thanks to Capers Jones

- Source Lines of Code (SLOC)
  - Physical/Logical; Executable/nonexecutable; New/reused; Programmmed/generated/translated; Added/modified/deleted
- Function points (FP)
  - Original IBM; IFPUG 2,3,4; Fast; COSMIC; Mark II, FISMA, NESMA; Unadjusted/adjusted; RICE Objects
- SLOC/FP backfire ratios
  - SPR, QSM, DAVIDS, Gartner Group
- Agile sizing
  - Story points (Planning Poker, T-shirt size); ideal person-weeks
- Risky: high variability
  - Number of requirements/shalls; nonfunctional requirements (SNAP points); UML diagram counts

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Charting Your Path to Improved Estimates

- Identify your most critical future improvement areas
- Identify, experiment with best candidate estimation methods in most critical areas
- Experiment with available methods for others; evaluate further improvement needs
- Build up, analyze experience base, use to steer path

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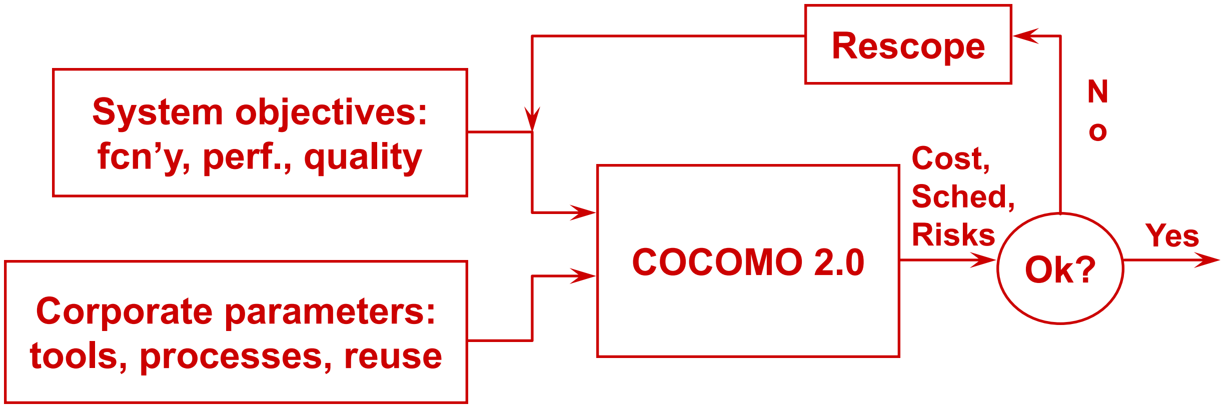
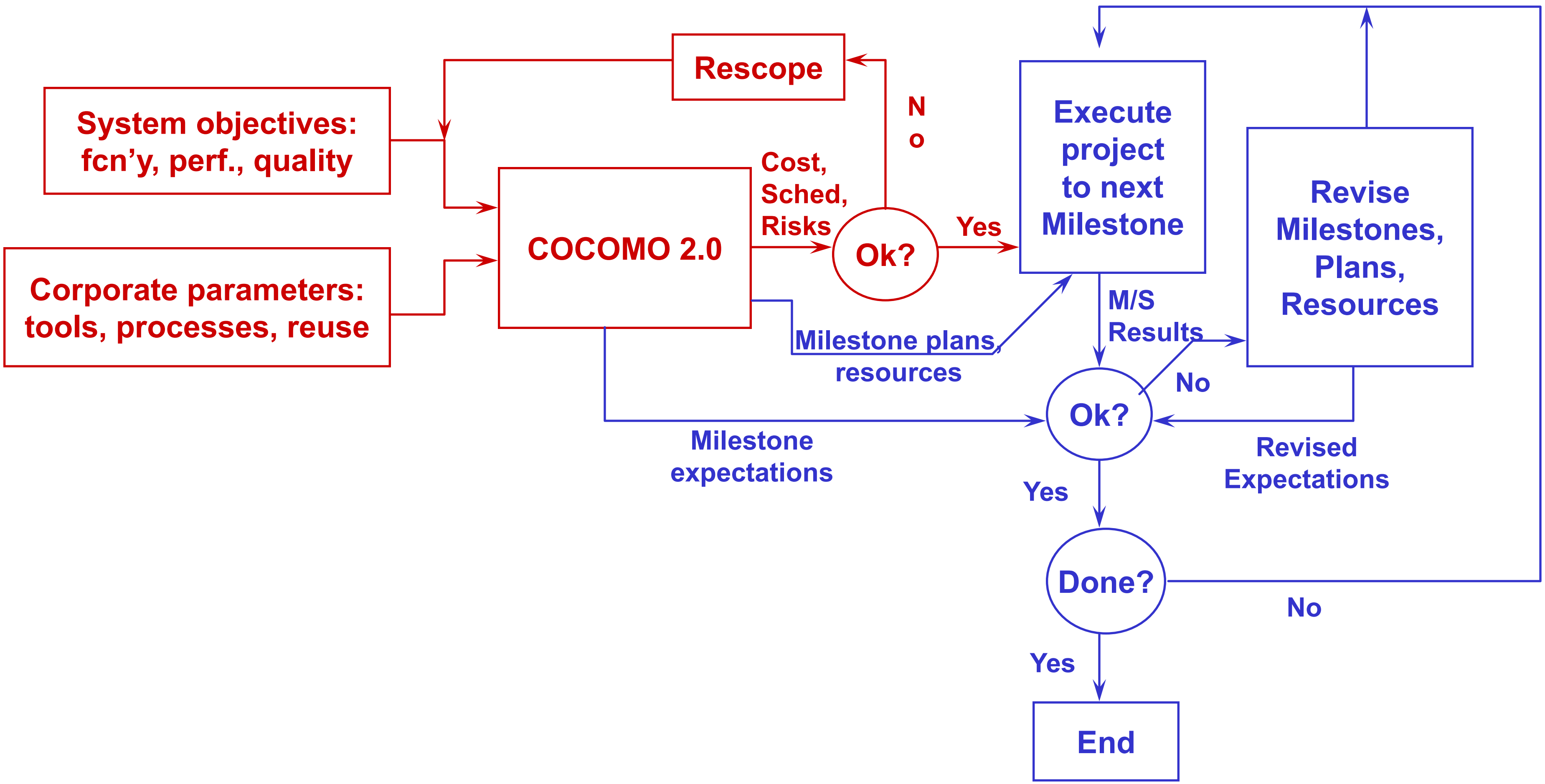
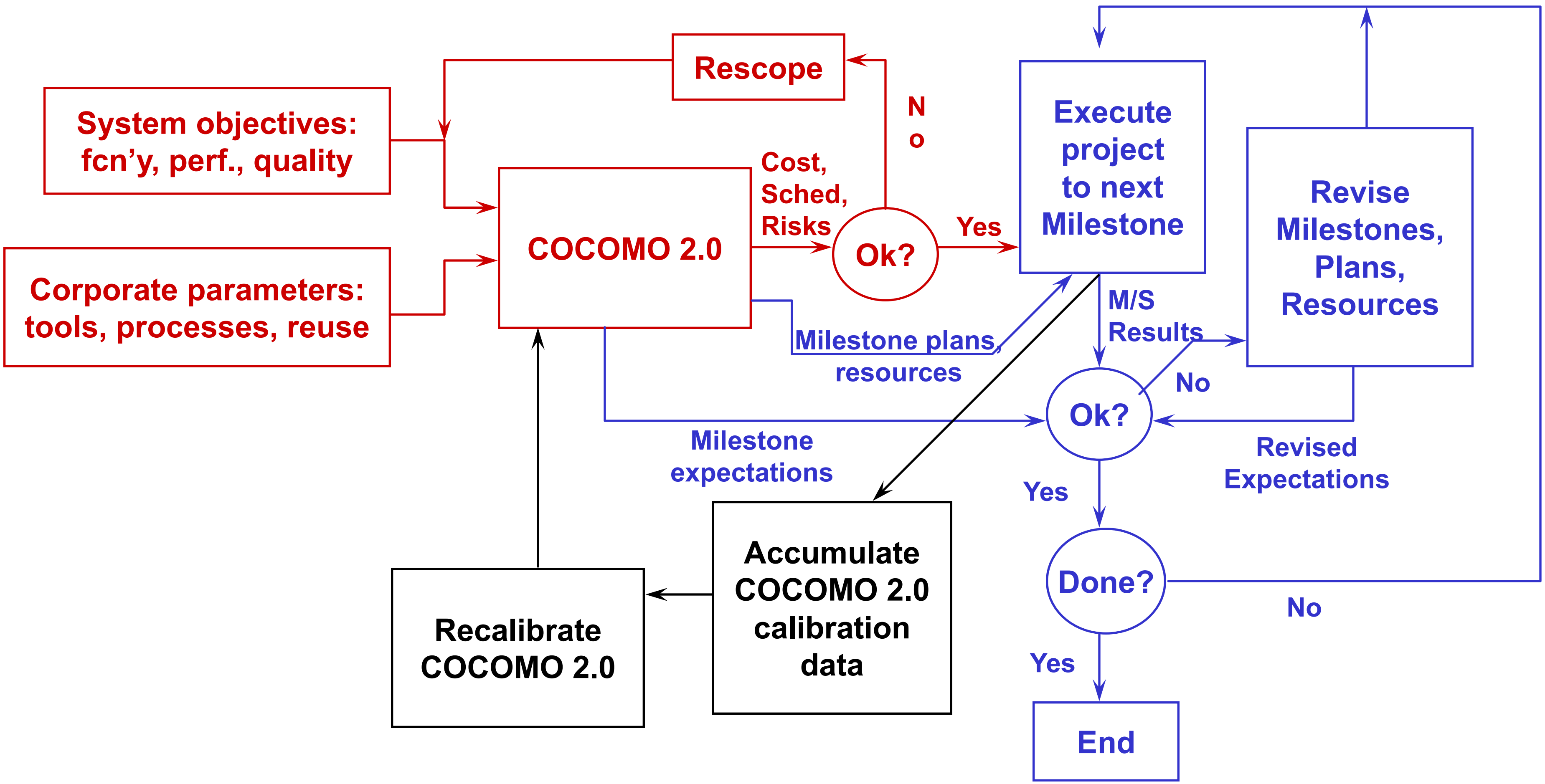
COCOMO II Experience Factory: I



COCOMO II Experience Factory: II



COCOMO II Experience Factory: III



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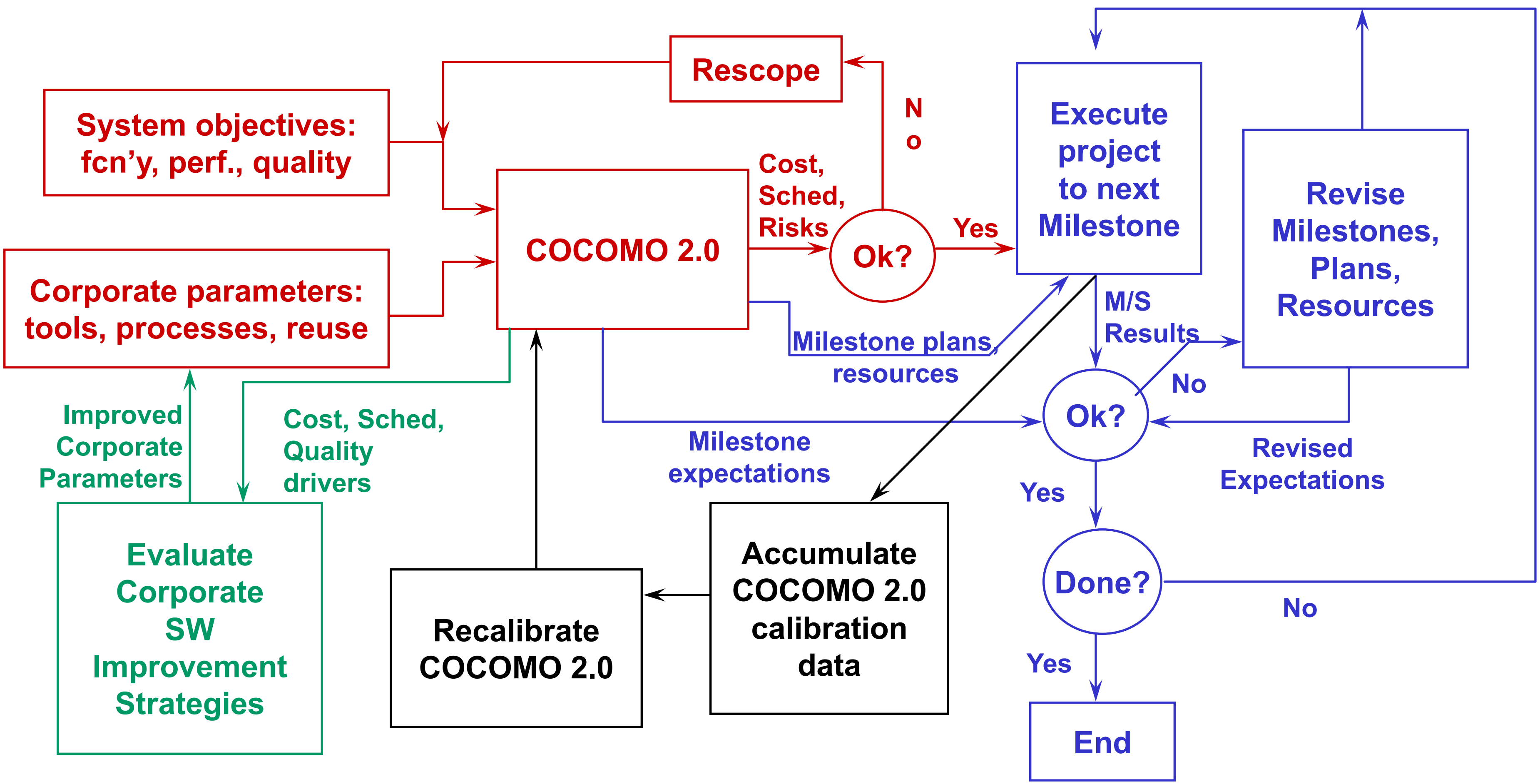
COCOMO II Experience Factory: IV



Backup Charts

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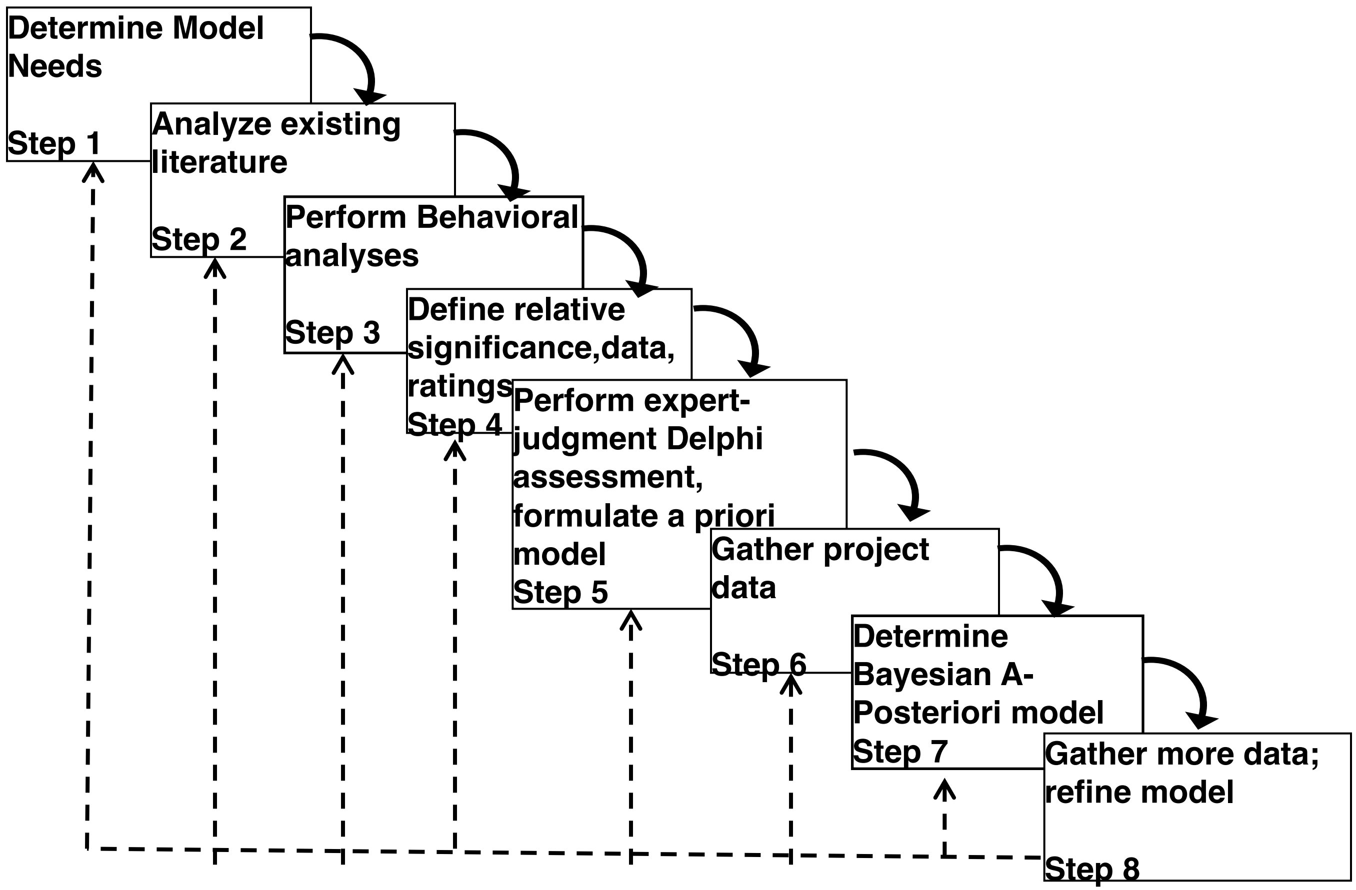
USC-CSSE Modeling Methodology

- concurrency and feedback implied



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Step 6: Gather, Analyze Project Data

- Best to pilot data collection with early adopters
  - Identifies data definition ambiguities
  - Identifies data availability problems
  - Identifies need for data conditioning
- Best to collect initial data via interviews
  - Avoids misinterpretations
    - Endpoint milestones; activities included/excluded; size definitions
  - Uncovers hidden assumptions
    - Schedule vs. cost minimization; overtime effort reported

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Initial Data Analysis May Require Model Revision

- Initial COCOTS model adapted from COCOMO II, with different parameters
  - Effort = A* (Size)^{B*} $\prod$(Effort Multipliers)
- Amount of COTS integration glue code used for Size
- Data analysis showed some projects with no glue code, much effort
  - Effort devoted to COTS assessment, tailoring

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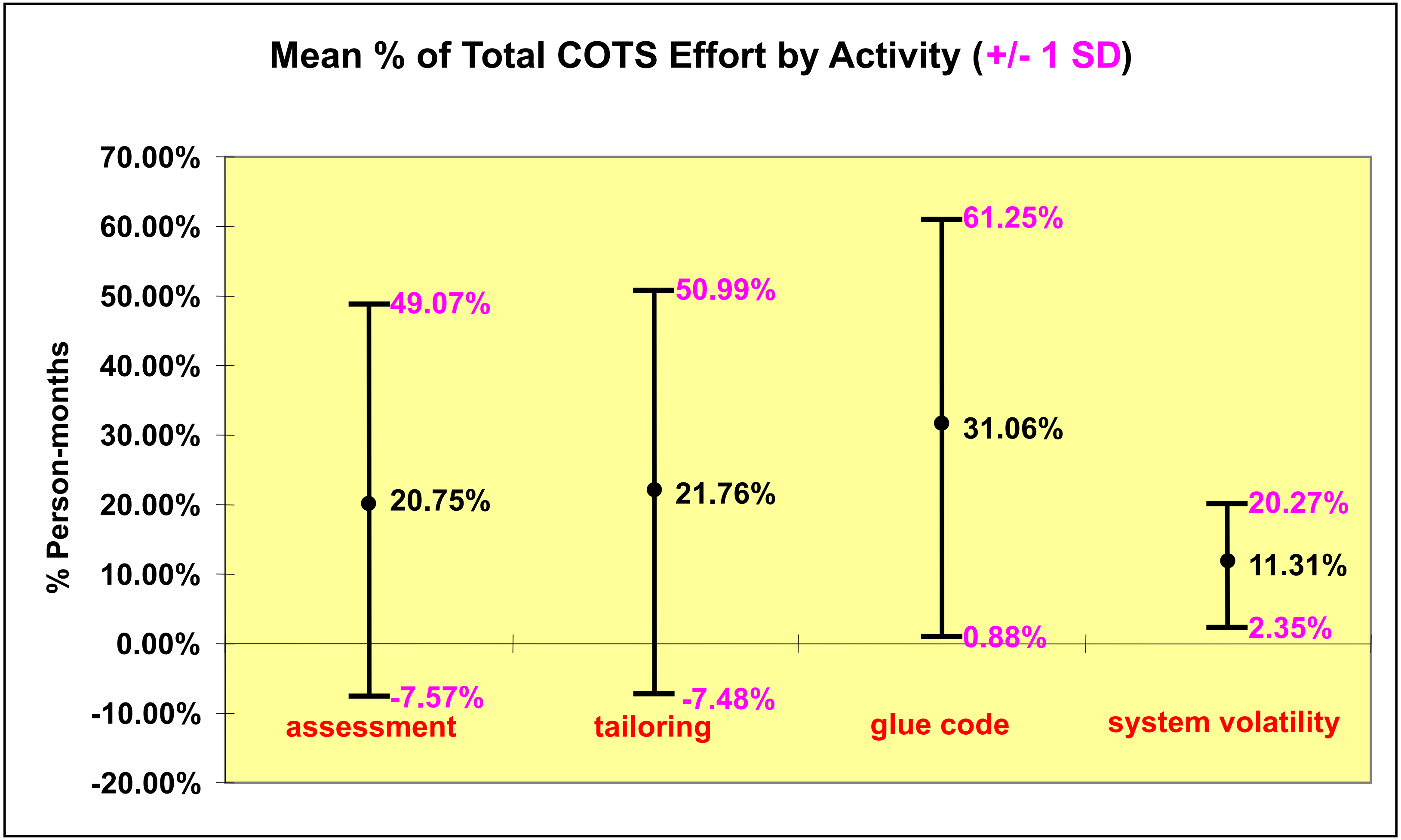
COCOTS Effort Distribution: 20 Projects



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Revised COCOTS Model

- COCOMO-like model for glue code effort
- Unit cost approach for COTS assessment effort
  - Number of COTS products to assess
  - Number of attributes to assess, weighted by complexity
- Activity-based approach for COTS tailoring effort
  - COTS parameters setting, script writing, reports layout, GUI tailoring, protocol definitions

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New Glue Code Submodel Results

- New calibration results
  - Excluding projects with very large, very small amounts of glue code
    - [0.5 - 100 KLOC]: Pred (.30) = 9/17 = 53%
    - [2 - 100 KLOC]: Pred (.30) = 8/13 = 62%
  - Previous calibration results:
    - [0.1 - 390 KLOC]: Pred (.30) = 4/13 = 31%
- Pred(.30) = percent of projects with estimates within 30% of actuals

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