

COQUALMO

(COnstructive QUALity MOdel):

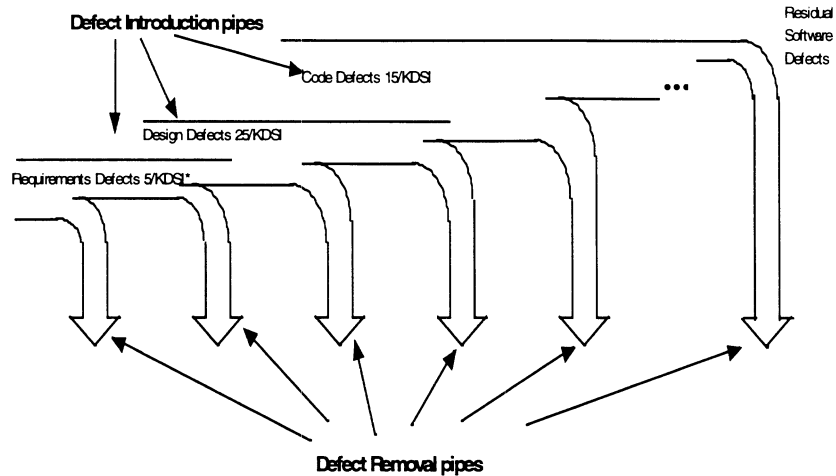
Quality Model Extension to COCOMO II

Sunita Chulani
Research Assistant
University of Southern California
Center for Software Engineering

Outline

- **Model Framework**
 - **The Defect Introduction Sub-Model**
 - **Initial Data Results**
 - **The Defect Removal Sub-Model**
 - **COQUALMO Integrated with COCOMO II**
 - **Calibration Plans**

Model Framework



*Baseline rates of the late 1970s based on studies done by Jones, Thayer et al and Boehm

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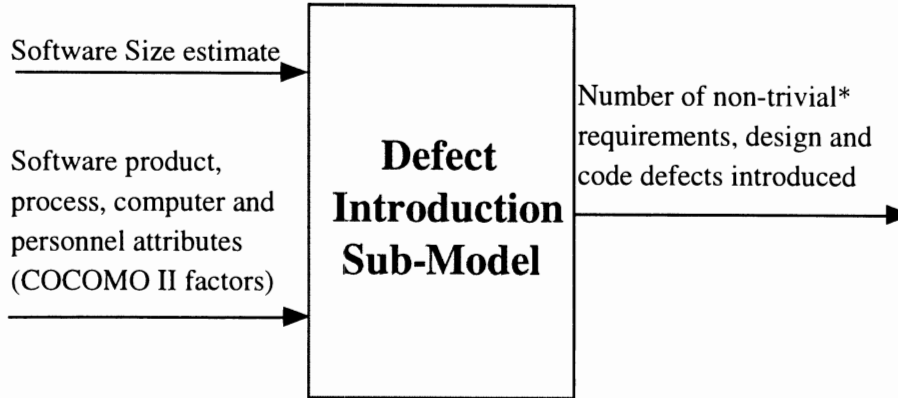
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The Defect Introduction (DI) Sub-Model



*Non-trivial defects include

- Critical** (causes a system crash or unrecoverable data loss or jeopardizes personnel)
- High** (causes impairment of critical system functions and no workaround solution exists)
- Medium** (causes impairment of critical system function, though a workaround solution does exist).

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Modeling Effects of COCOMO II Cost Drivers on DI

Defects Inserted/ KDSI or 10FPS	Requirements	Design	Code
Baseline	5	25	15

Now,

If ACAP is VH & RELY is VH How does baseline change? As compared to ACAP-VL & RELY-VL

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An Example DI Rate Driver

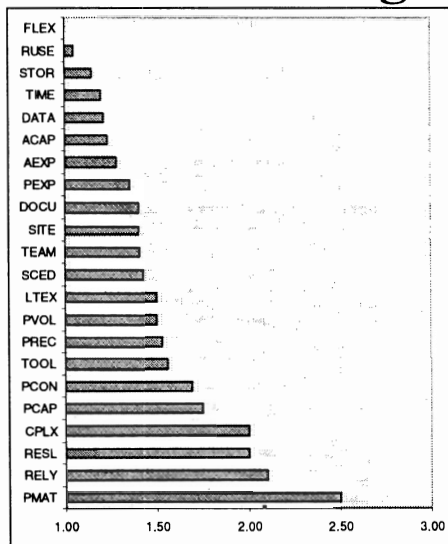
A EXP (Applications Experience) level	Requirements	Design	Code	
VH	Fewer Requirements defects due to less learning and fewer false starts Fewer Requirements understanding defects 0.81	Fewer Design defects due to less learning and fewer false starts Fewer Requirements traceability defects Fewer defects introduced in fixing requirements, preliminary design fixes 0.82	Fewer Coding defects due to less learning Fewer Coding defects due to requirements, design shortfalls 0.88	
Nominal	Nominal level of defect introduction 1.0			
VL	More Requirements defects due to extensive learning and more false starts More Requirements understanding defects 1.24	More Design defects due to less learning and fewer false starts More Requirements traceability defects More defects introduced in fixing requirements, preliminary design fixes 1.22	More Coding defects due to extensive learning More Coding defects due to requirements, design shortfalls 1.13	
Behavioural analysis; relative significance	1.56	1.56	1.32	
Expert-judgment	Range	1.4-1.65	1.3-1.56	1.05-1.4
Delphi Round 1	Median	1.5	1.5	1.26
Expert-judgment	Range	1.5-1.6	1.4-1.56	1.2-1.32
Delphi Round 2	Median	1.53	1.5	1.28

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A-Priori Expert-Judgment Based Code DI Ranges



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DI Model Equations

- **Baseline Defect Introduction Rate - 1970s**

Type of Artifact	DIR _{Baseline}
Requirements Defects	5/KDSI
Design Defects	25/KDSI
Coding Defects	15/KDSI

- **Nominal Defect Introduction (DI) (like Basic COCOMO)**

$$DI_{Nom\ j} = DIR_{Baseline\ j} \times (Size)^B$$

- **Estimated Defect Introduction Rate (like Intermediate COCOMO)**

$$DI_{Est\ j} = A_j \times \frac{DI_{Nom\ j}}{22} \times QAF_j$$

$$QAF_j = \prod_{i=1}^{ij} DIR\text{-}driver_{ij}$$

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Initial Data Analysis on the DI Model

Type of Artifact	1970's Baseline DIRs	Quality Adjustment Factor	Predicted DIR	Actual DIR	Calibrated Constant (A)	1990's Baseline DIRs
Requirements	5	0.5	2.5	4.5	1.8	9
Design	25	0.44	11	8.4	0.77	19
Code	15	0.5	7.5	16.6	2.21	33

DIR = Defect Introduction Rate

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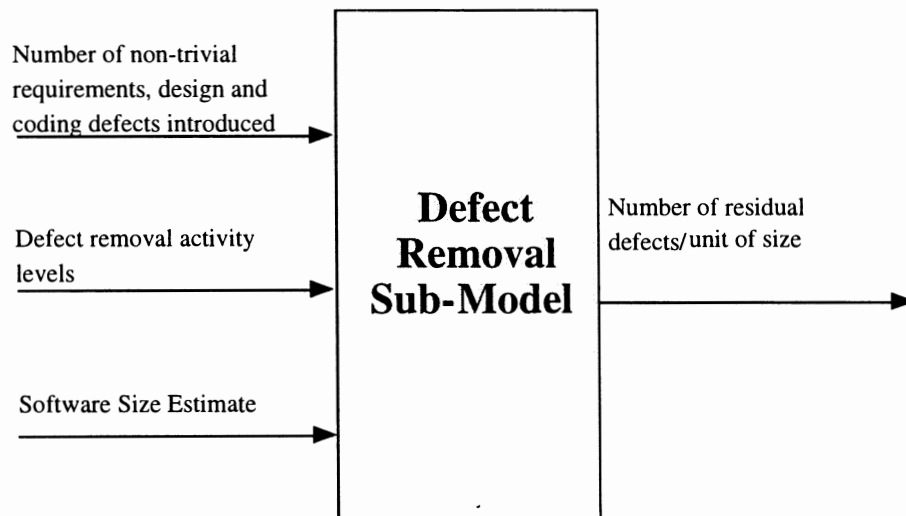
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The Defect Removal (DR) Sub-Model



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DR Activity Profiles

- **3 relatively orthogonal profiles**
 - Automated Analysis
 - People Reviews
 - Execution Testing and Tools
- **Each profile has 5 levels**
 - Very Low, Low, Nominal, High, Very High
 - Very Low level -- removes the least number of defects
 - Very High level -- removes the most number of defects

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Automated Analysis

	Very Low	Low	Nominal	High	Very High
Rating Scale	Simple compiler extensions for static module-level code analysis, syntax, type-checking.	Simple compiler extensions for static module-level code analysis, syntax, type-checking. Basic requirements and design consistency, traceability checking	Intermediate-level code syntax and semantic analysis. Simple requirements /design view consistency checking	More elaborate requirements/design view consistency checking. Basic distributed-processing and temporal analysis, model checking, symbolic execution	Formal specification and verification. Advanced distributed processing and temporal analysis, model checking, symbolic execution
Fraction of Reqts. Defects removed	0	0.40	0.60	0.70	0.80
Fraction of Design Defects removed	0	0.40	0.60	0.70	0.80
Fraction of Code Defects removed	0	0	0.40	0.60	0.80

- Need to refine DRF (Defect Removal Fractions) percentages
 - Will conduct Delphi at breakout group at the 'COCOMO II and Its Extensions' workshop
 - Delphi instrument sent out to affiliates in late-August

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People Reviews

	Very Low	Low	Nominal	High	Very High
Rating Scale	Ad-hoc informal walkthroughs Minimal preparation, follow-up	Well-defined sequence of preparation, review, follow-up. Informal review roles and procedures	Formal review roles and procedures applied to detailed design and code reviews	Formal review roles and procedures applied to specification, design code, test, documentation artifacts. Basic review checklists, root cause analysis	Formal review roles and procedures for fixes, change control. Extensive review checklists, root cause analysis Continuous review process improvement
Fraction of Reqts. Defects removed	0.25	0.40	0.60	0.55	0.70
Fraction of Design Defects removed	0.30	0.50	0.65	0.75	0.80
Fraction of Code Defects removed	0.35	0.50	0.65	0.75	0.85

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Execution Testing and Tools

	Very Low	Low	Nominal	High	Very High
Rating Scale	Ad-hoc testing and debugging. Basic text-based debugger	Basic unit test, integration test, system test process Basic test data management, problem tracking support	In Well-defined test sequence tailored to organization (acceptance / alpha / beta / flight / etc.) test Basic test coverage tools, test support system Basic test process management	More advanced test tools, test data preparation, basic test oracle support, distributed monitoring and analysis, assertion checking Metrics-based test process management	Highly advanced tools for test oracles, distributed monitoring and analysis, assertion checking Integration of automated analysis and test tools Model-based test process management
Fraction of Reqts. Defects removed	0.50	0.75	0.90	0.97	0.99
Fraction of Design Defects removed	0.60	0.80	0.93	0.98	0.992
Fraction of Code Defects removed	0.70	0.90	0.96	0.99	0.995

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Residual Defects Equation

- Estimated Number of Residual Defects

$$DRes_{Est,j} = B_j \times DI_{Est,j} \times \prod_i (1 - DRF_{ij})$$

$DRes_{Est,j}$ = Estimated No. of Residual Defects for the j^{th} artifact

B_j = Calibration Constant for the j^{th} artifact

$DI_{Est,j}$ = Estimated No. of Defects Introduced for the j^{th} artifact
(output of DI Sub-Model)

i = Defect Removal profile

DRF_{ij} = Defect Removal Fraction

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Defect Densities from Initial DRF Values

	Automated Analysis DRF	People Reviews DRF	Execution Testing and Tools DRF	Product (1-DRF _{ij})	DI/KSLOC	DRes/KSLOC
Very Low	0	0.25	0.50	0.38	10	3.8
	0	0.30	0.60	0.28	20	5.6
	0	0.35	0.70	0.195	30	5.8
	Total:					15.2
Low	0.40	0.40	0.75	0.09	10	0.9
	0.40	0.50	0.80	0.06	20	1.2
	0	0.50	0.90	0.05	30	1.5
	Total:					3.6
Nom	0.60	0.60	0.90	0.016	10	0.16
	0.60	0.65	0.93	0.0098	20	0.20
	0.40	0.65	0.96	0.0084	30	0.25
	Total:					0.61
High	0.70	0.55	0.97	0.004	10	0.04
	0.70	0.75	0.98	0.0015	20	0.03
	0.60	0.75	0.99	0.001	30	0.03
	Total:					0.1
Very High	0.80	0.70	0.99	0.0006	10	0.006
	0.80	0.80	0.992	0.00032	20	0.0064
	0.80	0.85	0.995	0.00015	30	0.0045
	Total:					0.017

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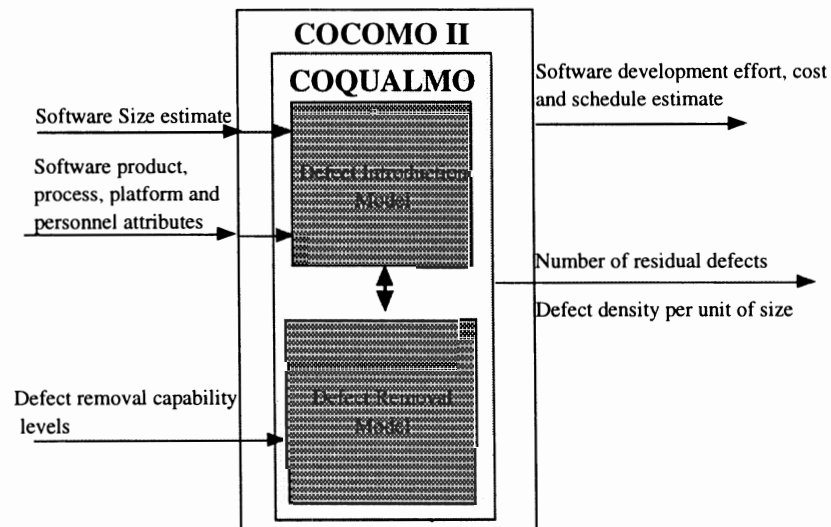
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Integrated COQUALMO



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Calibration Plans

- **A-Priori COQUALMO**
 - **DI Sub-Model A-Priori Model defined**
 - **DR Sub-Model A-Priori Model will be refined at breakout group**
- **Collect data on actual completed projects**
- **Adjust a-priori values based on the data-determined results using the Bayesian framework**

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