

Expert-Judgment Calibrated Quality Model Extension to COCOMO II: COQUALMO (COConstructive QUALity MOdel)

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Outline

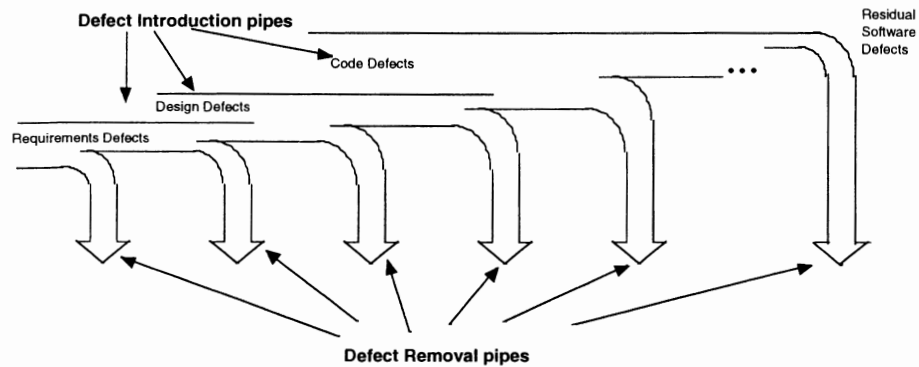
- **COQUALMO Framework**
- **The Defect Introduction Sub-Model**
 - Expert-Judgment Model + Some Initial Data Results
- **The Defect Removal Sub-Model**
 - Expert-Judgment Model (Result of COQUALMO Workshop)
- **COQUALMO Integrated with COCOMO II**
- **Future Plans**
 - Call for Data

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Model Framework



Classification of Defects - I

- **Based on origin**
 - **Requirements Defect Example: leaving out a Cancel option in an Input screen**
 - **Design Defect Example: Error in algorithm**
 - **Code Defect Example: Looping nine instead of ten times**

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Classification of Defects - II

- **Based on severity (COQUALMO accounts for only non-trivial defects)**
 - **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 functions although a workaround solution exists
 - **Low:** Causes inconvenience or annoyance
 - **None:** None of the above; or concerns an enhancement rather than a defect

Trivial defects

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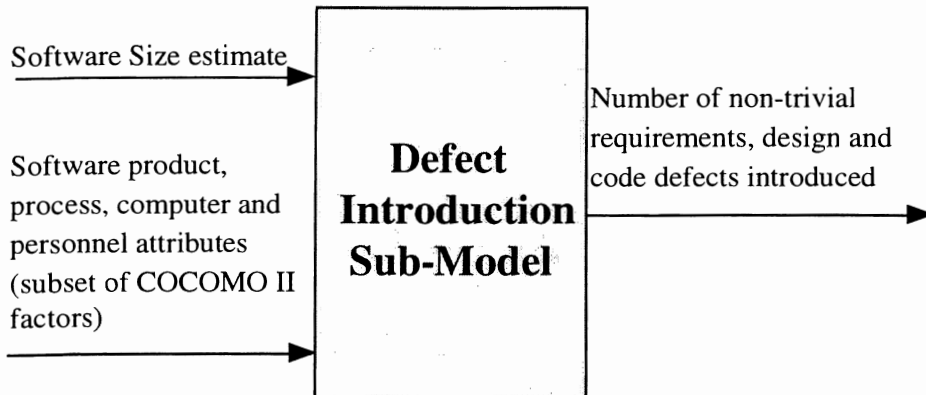
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The Defect Introduction (DI) Sub-Model



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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 AEXP is VH

**How does baseline
change?**

**As compared
to AEXP being
VL**

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An Example DI Rate Driver

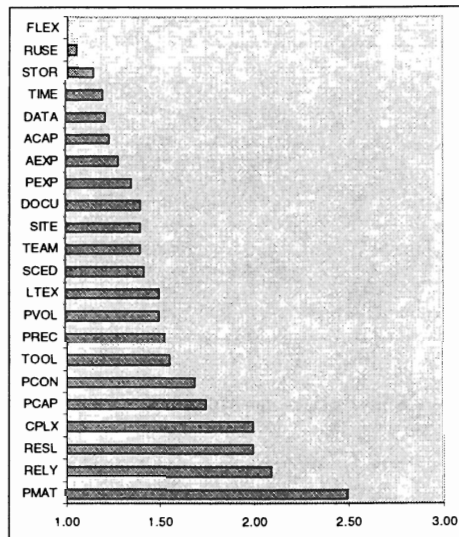
A EXP (Applications Experience) level	Requirements	Design	Code
VH	Fewer Requirements defects due to less learning and fewer false starts Fewer Requirements understanding defects 0.81	Fewer Design defects due to less learning and fewer false starts Fewer Requirements traceability defects Fewer defects 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
Delphi Round 1	Median	1.5	1.5
Expert-judgment	Range	1.5-1.6	1.4-1.56
Delphi Round 2	Median	1.53	1.5

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A-Priori Expert-Judgment Based Code DI Ranges



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DI Model Equations

• **Estimated Number of Reqts. Defects Introduced =**

$$A_{req} * (Size)^{B_{req}} * \prod_{i=1}^{21} (DI_driver)_{i;req}$$

- A_{req} is the baseline DIR Adjustment Factor.
- B_{req} is initially set to 1
- $(DI_driver)_{i;req}$ is the Defect Introduction driver for requirements defects and the i^{th} rate driver.

where:

$$QAF_{req} = \prod_{i=1}^{21} DIR_driver_{i;req}$$

• **Estimated Number of Defects Introduced =**

$$\sum_{j=1}^3 A_j * (Size)^{B_j} * QAF_j$$

where j is type of artifact i.e. requirements, design and code

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Initial Data Analysis on the DI Model

Type of Artifact	1970's Baseline DIRs	Quality Adjustment Factor (QAF _j)	Predicted DIRs	Actual DIRs, 1990s project	Baseline DIR Adjustment Factors (A _j)	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
j = type of artifact

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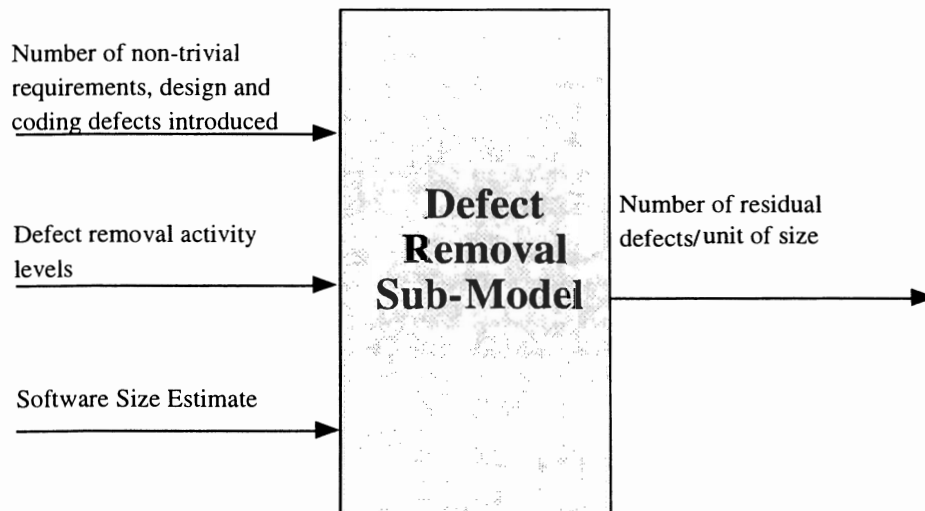
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The Defect Removal (DR) Sub-Model



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Defect Removal Profiles

- **3 relatively orthogonal profiles**
 - Automated Analysis
 - Peer Reviews
 - Execution Testing and Tools
- **Each profile has 6 levels => Note: this has been modified since the COCOMO forum in Oct '98**
 - **Very Low, Low, Nominal, High, Very High, Extra High**
 - **Very Low level -- removes the least number of defects**
 - **Extra High level -- removes the most number of defects**

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Automated Analysis

Rating	Automated Analysis
Very Low	Simple compiler syntax checking.
Low	Basic compiler capabilities for static module-level code analysis, syntax, type-checking.
Nominal	Some compiler extensions for static module and inter-module level code analysis, syntax, type-checking. Basic requirements and design consistency, traceability checking.
High	Intermediate-level module and inter-module code syntax and semantic analysis. Simple requirements/design view consistency checking.
Very High	More elaborate requirements/design view consistency checking. Basic distributed-processing and temporal analysis, model checking, symbolic execution.
Extra High	Formalized* specification and verification. Advanced distributed processing and temporal analysis, model checking, symbolic execution. *Consistency-checkable pre-conditions and post-conditions, but not mathematical theorems.

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Peer Reviews

Rating	Peer Reviews
Very Low	No peer reviews.
Low	Ad-hoc informal walkthroughs Minimal preparation, no follow-up.
Nominal	Well-defined sequence of preparation, review, minimal follow-up. Informal review roles and procedures.
High	Formal review roles and procedures applied to all products using basic checklists, follow up.
Very High	Formal review roles and procedures applied to all product artifacts & changes (formal change control boards). Basic review checklists, root cause analysis. Use of historical data on inspection rate, preparation rate, fault density.
Extra High	Formal review roles and procedures for fixes, change control. Extensive review checklists, root cause analysis. Continuous review process improvement. User/Customer involvement, Statistical Process Control.

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Execution Testing and Tools

Rating	Execution Testing and Tools
Very Low	No testing.
Low	Ad-hoc testing and debugging. Basic text-based debugger
Nominal	Basic unit test, integration test, system test process. Basic test data management, problem tracking support. Test criteria based on checklists.
High	Well-defined test sequence tailored to organization (acceptance / alpha / beta / flight / etc.) test. Basic test coverage tools, test support system. Basic test process management.
Very High	More advanced test tools, test data preparation, basic test oracle support, distributed monitoring and analysis, assertion checking. Metrics-based test process management.
Extra High	Highly advanced tools for test oracles, distributed monitoring and analysis, assertion checking Integration of automated analysis and test tools. Model-based test process management.

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Residual Defects Equation

- Estimated Number of Reqts. Residual Defects

$$DRes_{req} = C_{req} * DI_{req} * \prod_i (1 - DRF_{i;req})$$

$DRes_{req}$ = Estimated No. of Reqts. Residual Defects

C_{req} = Baseline Defect Removal Constant

$DI_{Est,j}$ = 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 Expert- Judgment Calibrated COQUALMO

		Automated Analysis	Peer Reviews	Execution Testing and Tools	Product (1-DRF _i)	DI/kSLOC*	DRes/kSLOC
Very Low	Reqts.	0.00	0.00	0.00	1.00	10	10
	Design	0.00	0.00	0.00	1.00	20	20
	Code	0.00	0.00	0.00	1.00	30	30
	Total:						
Low	Reqts.	0.00	0.25	0.23	0.58	10	5.8
	Design	0.00	0.28	0.23	0.55	20	11
	Code	0.10	0.30	0.38	0.39	30	11.7
	Total:						
Nominal	Reqts.	0.10	0.40	0.40	0.32	10	3.2
	Design	0.13	0.40	0.43	0.3	20	6
	Code	0.20	0.48	0.58	0.17	30	5.1
	Total:						
High	Reqts.	0.27	0.50	0.50	0.18	10	1.8
	Design	0.28	0.54	0.54	0.15	20	3
	Code	0.30	0.60	0.69	0.09	30	2.7
	Total:						
Very High	Reqts.	0.34	0.58	0.57	0.14	10	1.4
	Design	0.44	0.70	0.65	0.06	20	1.2
	Code	0.48	0.73	0.78	0.03	30	0.9
	Total:						
Extra High	Reqts.	0.40	0.70	0.60	0.07	10	0.7
	Design	0.50	0.78	0.70	0.03	20	0.6
	Code	0.55	0.83	0.88	0.009	30	0.27
	Total:						

* 1990's Baseline DIRs, excluding DIR_driver effects.

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Delphi Results: Automated Analysis

Automated Analysis							
		Round 1			Round 2		
		Median	Range (min max)		Median	Range (min max)	
Very Low	Requirements defects	0.00	0.00	0.00	0.00	0.00	0.00
	Design defects	0.00	0.00	0.00	0.00	0.00	0.00
	Code defects	0.00	0.00	0.05	0.00	0.00	0.05
Low	Requirements defects	0.00	0.00	0.15	0.00	0.00	0.15
	Design defects	0.00	0.00	0.20	0.00	0.00	0.20
	Code defects	0.10	0.00	0.25	0.10	0.00	0.25
Nominal	Requirements defects	0.10	0.00	0.40	0.10	0.00	0.40
	Design defects	0.15	0.00	0.45	0.13	0.00	0.45
	Code defects	0.20	0.05	0.45	0.20	0.05	0.45
High	Requirements defects	0.25	0.10	0.60	0.27	0.10	0.60
	Design defects	0.33	0.10	0.65	0.28	0.10	0.65
	Code defects	0.30	0.10	0.60	0.30	0.10	0.60
Very High	Requirements defects	0.33	0.10	0.85	0.34	0.15	0.85
	Design defects	0.50	0.15	0.85	0.44	0.15	0.85
	Code defects	0.48	0.15	0.75	0.48	0.15	0.75
Extra High	Requirements defects	0.40	0.20	0.90	0.40	0.20	0.90
	Design defects	0.58	0.20	0.90	0.50	0.20	0.90
	Code defects	0.55	0.15	0.85	0.55	0.20	0.85

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Delphi Results: Peer Reviews

Peer Reviews							
		Round 1			Round 2		
		Median	Range (min max)		Median	Range (min max)	
Very Low	Requirements defects	0.00	0.00	0.10	0.00	0.00	0.00
	Design defects	0.00	0.00	0.20	0.00	0.00	0.00
	Code defects	0.00	0.00	0.20	0.00	0.00	0.00
Low	Requirements defects	0.25	0.05	0.30	0.25	0.05	0.30
	Design defects	0.30	0.05	0.40	0.28	0.05	0.40
	Code defects	0.30	0.05	0.40	0.30	0.05	0.40
Nominal	Requirements defects	0.40	0.05	0.65	0.40	0.05	0.65
	Design defects	0.40	0.10	0.70	0.40	0.10	0.70
	Code defects	0.48	0.05	0.70	0.48	0.05	0.70
High	Requirements defects	0.50	0.05	0.75	0.50	0.10	0.75
	Design defects	0.54	0.15	0.75	0.54	0.30	0.75
	Code defects	0.60	0.40	0.80	0.60	0.40	0.80
Very High	Requirements defects	0.54	0.05	0.85	0.58	0.20	0.85
	Design defects	0.68	0.30	0.85	0.70	0.40	0.85
	Code defects	0.73	0.48	0.90	0.73	0.48	0.90
Extra High	Requirements defects	0.63	0.05	0.95	0.70	0.30	0.95
	Design defects	0.75	0.35	0.95	0.78	0.48	0.95
	Code defects	0.83	0.56	0.95	0.83	0.56	0.95

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Delphi Results: Execution Testing and Tools

Execution Testing and Tools							
		Round 1			Round 2		
		Median	Range (min max)		Median	Range (min max)	
Very Low	Requirements defects	0.00	0.00	0.30	0.00	0.00	0.00
	Design defects	0.00	0.00	0.40	0.00	0.00	0.00
	Code defects	0.00	0.00	0.60	0.00	0.00	0.00
Low	Requirements defects	0.23	0.00	0.50	0.23	0.00	0.50
	Design defects	0.28	0.00	0.60	0.23	0.00	0.60
	Code defects	0.40	0.20	0.70	0.38	0.20	0.70
Nominal	Requirements defects	0.40	0.10	0.75	0.40	0.10	0.75
	Design defects	0.45	0.15	0.80	0.43	0.15	0.80
	Code defects	0.60	0.30	0.90	0.58	0.30	0.90
High	Requirements defects	0.50	0.10	0.90	0.50	0.10	0.90
	Design defects	0.55	0.15	0.93	0.54	0.15	0.93
	Code defects	0.73	0.35	0.96	0.69	0.35	0.96
Very High	Requirements defects	0.60	0.10	0.97	0.57	0.10	0.97
	Design defects	0.68	0.15	0.98	0.65	0.15	0.98
	Code defects	0.83	0.45	0.99	0.78	0.45	0.99
Extra High	Requirements defects	0.70	0.10	0.99	0.60	0.10	0.99
	Design defects	0.78	0.20	0.992	0.70	0.15	0.992
	Code defects	0.90	0.50	0.995	0.88	0.50	0.995

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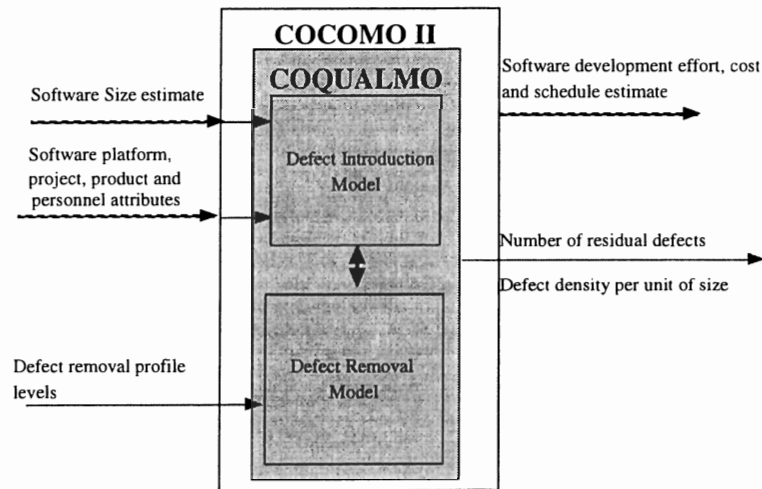
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Integrated COQUALMO



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Future Plans

- **Expert-Judgment Calibrated COQUALMO**
 - Thanks to all the Delphi participants!
- **Collect data on actual completed projects**
 - **Call for Data**
 - Data Collection Form v2.2 available
 - A COQUALMO Mini Questionnaire available (for COCOMO II data previously submitted)
- **Adjust expert-judgment values based on the data-determined results using the Bayesian framework**
 - Successfully used on COCOMO II for 161 datapoints

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