Software Quality Engineering:

Testing, Quality Assurance, and Quantifiable Improvement

Jeff Tian, tian@engr.smu.edu
www.engr.smu.edu/~tian/SQEbook

Chapter 19. Quality Models and Measurements

- Types of Quality Assessment Models.
- Comparing Quality Assessment Models.
- Data Requirements and Measurement
- Measurement and Model Selection.

QA Data and Analysis

- Generic testing process:
  - ▷ Test planning and preparation.
  - ▷ Execution and measurement.
  - ▷ Test data analysis and followup.
  - ▷ Related data ⇒ quality ⇒ decisions
- Other QA activities:
  - ▷ Similar general process.
  - ▷ Data from QA/other sources (Ch.18).
  - ▷ Models used in analysis and followup:
    - – provide timely feedback/assessment
    - – prediction, anticipating/planning
    - – corrective actions ⇒ improvement

QA Models and Measures

- General approach
  - ▷ Adapt GQM-paradigm.
  - ▷ Quality: basic concept and ideas.
  - ▷ Compare models ⇒ taxonomy.
  - ▷ Data requirements ⇒ measurements.
  - ▷ Practical selection steps.
  - ▷ Illustrative examples.

- Quality attributes and definitions:
  - ▷ Q models: data ⇒ quality
  - ▷ Correctness vs. other attributes
  - ▷ Our definition/restriction:
    being defect-free or of low-defect
  - ▷ Examples: reliability, safety,
    defect count/density/distribution/etc.

Quality Analysis

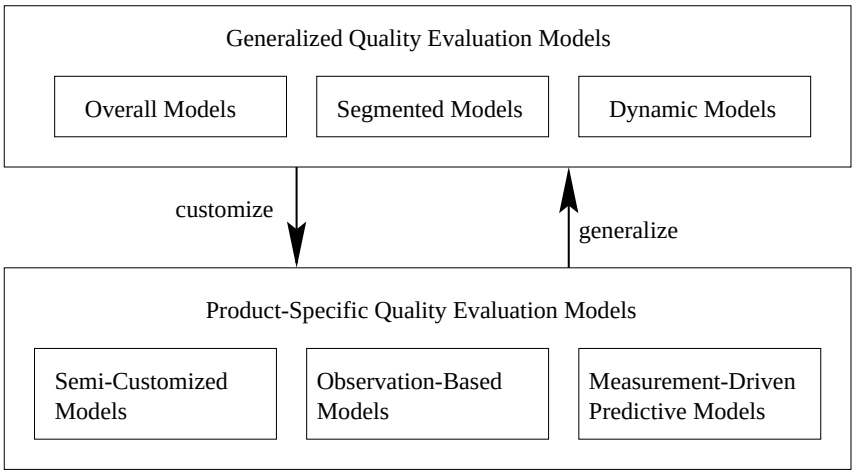
- Analysis and modeling:
  - ▷ Quality models: data ⇒ quality
    - – a.k.a. quality assessment models or quality evaluation models
  - ▷ Various models needed
  - ▷ Assessment, prediction, control
  - ▷ Management decisions
  - ▷ Problematic areas for actions
  - ▷ Process improvement

- Measurement data needed
  - ▷ Direct quality measurements: success/failure (& defect info)
  - ▷ Indirect quality measurements:
    - – activities/internal/environmental.
  - ▷ Indirect but early quality indicators.
  - ▷ All described in Chapter 18.

Quality Models

- Practical issues:
  - ▷ Applicability vs. appl. environment
  - ▷ Goal/Usefulness: information/results?
  - ▷ Data: measurement data required
  - ▷ Cost of models and related data
- Type of quality models
  - ▷ Generalized: averages or trends
  - ▷ Product-specific: more customized
  - ▷ Relating to issues above

Generalized Models: Overall



- Model taxonomy: Fig 19.1 (p.324).
  - ▷ Generalized:
    - – overall, segmented, and dynamic
  - ▷ Product-specific:
    - – semi-customized: product history
    - – observation-based: observations
    - – measurement-driven: predictive

Generalized Models: Overall

- Key characteristics
  - ▷ Industrial averages/patterns
    $\Rightarrow$ (single) rough estimate.
  - ▷ Most widely applicable.
  - ▷ Low cost of use.

- Examples: Defect density.
  - ▷ Estimate total defect with sizing model.
  - ▷ Variation: QI in IBM
    (counting in-field unique defect only)

- Non-quantitative overall models:
  - ▷ As extension to quantitative models.
  - ▷ Examples: 80:20 rule, and other general observations.

Generalized Models: Segmented

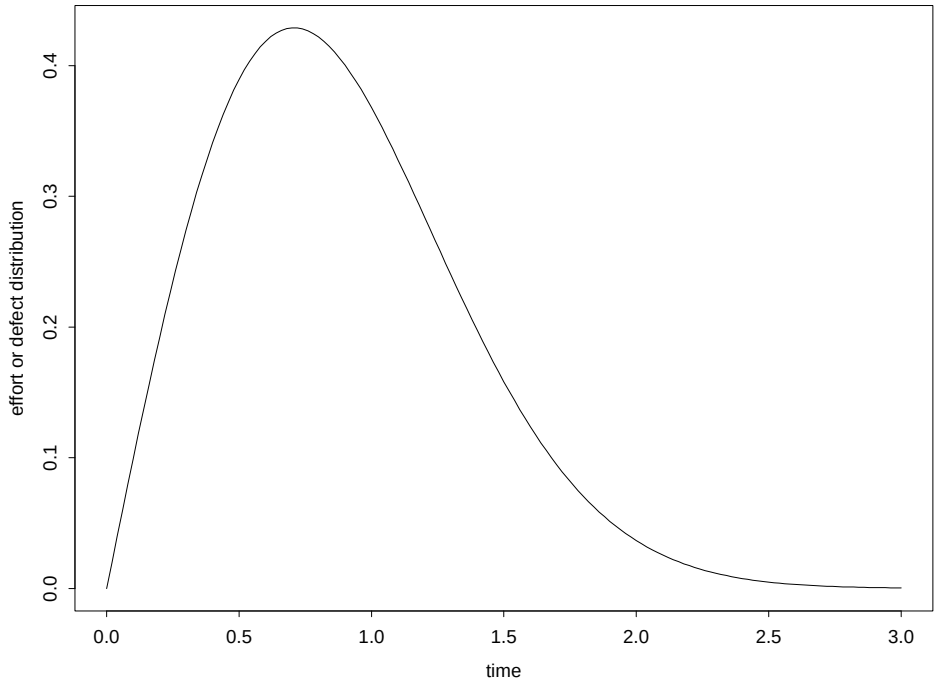
- Key characteristics:
  - ▷ Estimates via product segmentation.
  - ▷ Model: segment $\rightarrow$ quality.
  - ▷ Multiple estimates provided.

- Example: Table 19.1 (p.326)

Product Type	Failure rate (per hour)	Reliability Level
safety-critical	$< 10^{-7}$	ultra-high
commercial	10^{-3} to 10^{-7}	moderate
auxiliary	$> 10^{-3}$	low

- Other applications.
  - ▷ Commonly used in software estimation.
  - ▷ Example: COCOMO models.

Generalized Models: Dynamic



- Example: Putnam model Fig 19.2 (p.326)
  Rayleigh curve for failure rate: $r = 2Bate^{-at^2}$

- Overall/average trend over time.
  - ▷ Often expressed as a mathematical function or an empirical curve.
  - ▷ Combined models possible, e.g., segmented dynamic models.

Product-Specific Models (PSM)

- Product-specific models (PSMs):
  - ▷ Product-specific info. used (vs. none used in generalized models)
  - ▷ Better accuracy/usefulness at cost ↑
  - ▷ Three types:
    - semi-customized
    - observation-based
    - measurement-driven predictive

- Connection to generalized models (GMs):
  - ▷ Customize GMs to PSMs with new/refined models and additional data.
  - ▷ Generalize PSMs to GMs with empirical evidence and general patterns.
  - ▷ Illustrated in Fig 19.1 (p.324).

PSM: Semi-Customized

- Semi-customized models:
  - ▷ Project level model based on history.
  - ▷ Data captured by phase.
  - ▷ Both projections and actual.
  - ▷ Linear extrapolation.

- Example: DRM in Table 19.2 (p.327)

Requirement	Design	Coding	Testing	Support
5%	10%	35%	40%	10%

- Related extensions to DRMs:
  - ▷ Defect dynamics model in Ch.20,
  - ▷ ODC defect analyses in Ch.20:
    - 1-way distribution/trend analysis
    - 2-way analysis of interaction.

PSM: Observation-Based

- Observation-based models:
  - ▷ Detailed observations and modeling
  - ▷ Software reliability growth models
  - ▷ Other reliability/safety models

- Model characteristics
  - ▷ Focus on the effect/observations
  - ▷ Assumptions about the causes
  - ▷ Assessment-centric
  - ▷ Example: Goel-Okumoto NHPP SRGM
    - functional relation: $m(t) = N(1-e^{-bt})$
    - observed failures over time
    - curve fitting
    - reliability assessment/prediction
    - management decisions: exit criteria

PSM: Predictive

- Measurement-driven predictive models
  - ▷ Establish predictive relations
  - ▷ Modeling techniques: regression, TBM, NN, OSR etc.
  - ▷ Risk assessment and management
- Model characteristics:
  - ▷ Response: chief concern
  - ▷ Predictors: observable/controllable
  - ▷ Linkage quantification

PSM: Predictive Model Example

Product	Subset	#Modules	Mean-DF
LS	lrrr	16	9.81
	rlr	53	10.74
	rr	17	22.18
	whole product	1296	1.8
NS	rlll	8	55.0
	rr	5	77.0
	whole product	995	7.9

- Example: Table 19.3 (p.329)
  - ▷ tree-based defect modeling
  - ▷ substantially different high-risk areas
  - ▷ identification and remedial actions

Model Summary

Model Type	Sub-Type	Primary Result	Applicability
generalized quality models		rough quality estimates	all or by industry
	overall	overall product quality	across industries
	segmented	industry-specific quality	within an industry
	dynamic	quality trend over time	trend in all
product-specific quality models		better quality estimates	specific product
	semi-customized	quality extrapolation	prev→cur release
	observation-based	quality assessments	current product
	measurement-driven	quality predictions	both above

- Summary: Table 19.4 (p.329)

Model Applications

- Applications:
  - ▷ ¬ data ⇒ GMs as early choices.
  - ▷ Data arrival ⇒ phase in PSMs:
    - special case: historical data
      ⇒ semi-customized models.
  - ▷ Model customization within application.

- Model customization (from generalized to product-specific) in connection with model applications.

- Model generalization:
  - ▷ data/results accumulation
  - ▷ generalized model possible?
  - ▷ mathematical function/empirical trend

Relating Models to Measurements

- Data (Ch. 18) required by quality models:
  - ▷ Direct quality measurements
    – to be assessed/predicted/controlled
  - ▷ Indirect quality measurements
    – means to achieve the goal
    – environmental, activity, product-internal
  - ▷ Data requirement by models:
    summarized in Table 19.5 (p.331)

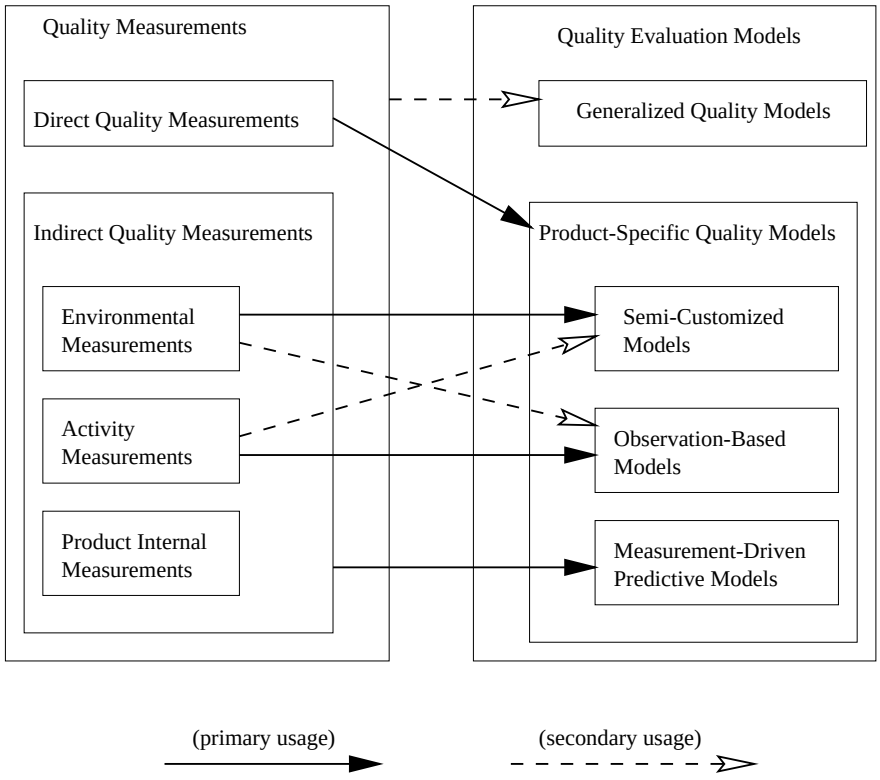
Model Type	Sub-Type	Measurement Data
generalized		industrial averages
	overall	average: all industries
	segmented	average: own industry
	dynamic	trend: all industries
product-specific		product-specific data
	semi-customized	rough historical data
	obser.-based	current observations
	meas.-driven	current & historical data

Relating Models to Measurements

- Data requirement of GMs:
  - ▷ Quality averages/patterns: $\overline{Q}$
  - ▷ No measurements from current project

- Data requirement of PSMs:
  - ▷ All use direct quality measurements: Q
    - related to other measurements: M
    - as relations: $Q \sim M$
    - or as functions: $Q = f(M)$
  - ▷ Measurement-driven models:
    - M = all measurements
  - ▷ Semi-customized models:
    - M = environmental measurements
  - ▷ Observation-based models:
    - M = activity measurements
  - ▷ Various other secondary uses

Relating Models to Measurements



- Relating models to measurements: Fig 19.3 (p.332) – chapter summarized.

- Can also be examined from the direction of measurements-models forward links.

Model/Measurement Selection

- Customize GQM into 3-steps
- Step 1: Quality goals
  - ▷ Restricted, not general goals
- Step 2: Quality models
  - ▷ Model characteristics/taxonomy
  - ▷ Model applicability/usefulness
  - ▷ Data requirement/affordability
- Step 3: Quality measurements
  - ▷ Model-measurements relations
  - ▷ Detailed model information

Selection Example A

- Goal: rough quality estimates
- Situation 1:
  - ▷ No product specific data
  - ▷ Industrial averages/patterns
  - ▷ Commercial tools: SLIM etc.
  - ▷ Product planning stage
  - ▷ Defect profile in lifecycle
  - ▷ Use generalized models
- Situation 2:
  - ▷ Data from related products
  - ▷ DRM for legacy products
  - ▷ ODC profile for IBM products
  - ▷ Semi-customized models

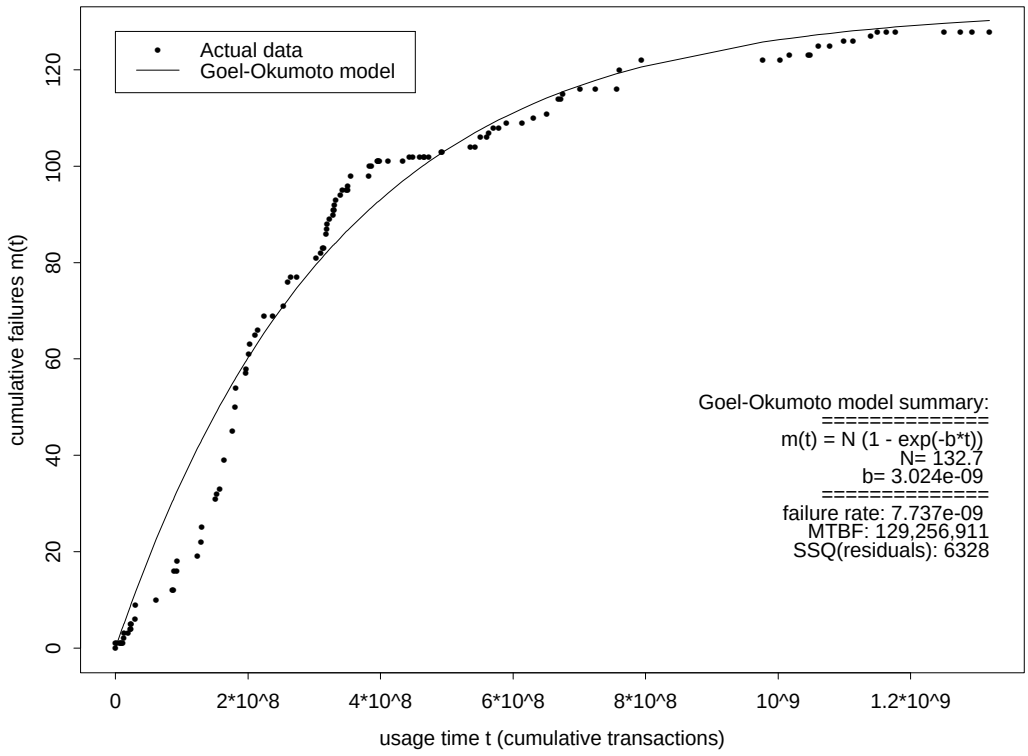
Selection Example B

- Goal: customer-view of quality in system testing

- Quality model:
  - ▷ SRGMs: info. about reliability
  - ▷ Assessment: customer-view
  - ▷ Prediction: project management
  - ▷ Decisions: exit criteria
  - ▷ Affordability: data and modeling

- Quality measurements:
  - ▷ Reliability: failure-free operation for a given time under a specific environment
  - ▷ Result: success/failure measurement
  - ▷ Time measurement: reflect activity
  - ▷ Environment: implicitly assumed

Selection Example B

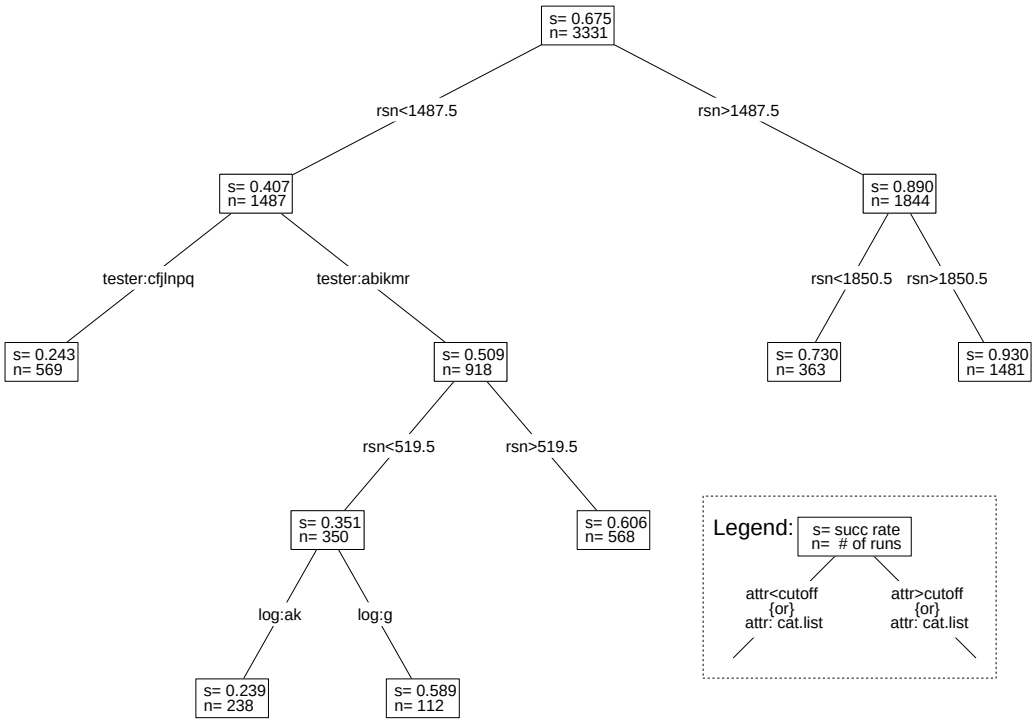


- Fig 19.4 (p.335): SRGM, an observation-based model, selected for Example B
  - ▷ reliability assessed/predicted
  - ▷ time = transactions

Selection Example C

- Goal: testing process/quality improvement, but SRGMs inadequate

- Selecting TBRM in Fig 19.5 (p.336) to focus on reliability improvement



Selection Example C

- TBRM: improvement focus
  - what's wrong: risk identification
  - what to do: remedial actions

- Data attributes: Table 19.6 (p.336)
  - ▷ Result: success/failure measurement
  - ▷ Timing info.: time-domain analysis
  - ▷ Input state: input-domain analysis

Timing: calendar date (*year, month, day*), *tday* (cumulative testing days since the start of testing), and *rsn* (run sequence number, uniquely identifies a run in the execution sequence).

Input state: *SC* (scenario class), *SN* (scenario number), *log* (corresponding to a sub-product with a separate test log) and *tester*.

Result: *result* indicator of the test run, with 1 indicating success and 0 indicating failure.

Summary and Perspectives

- Practical need for quality measurement and model selection

- Viable approach
  - ▷ Model characteristics ⇒ taxonomy
  - ▷ Model data requirement: different types of quality measurements
  - ▷ Selection steps: customized GQM
  - ▷ Viability: examples

- Perspective and future work:
  - ▷ Refined taxonomy
  - ▷ Relating models to measurements: – more details and specific info.
  - ▷ Lifecycle activities and support
  - ▷ Automation?