Building Process Improvement Business Cases Using Bayesian Belief Networks and Monte Carlo Simulation

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Quality Factors

Validate

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Problem Statement

Introduction

Quality improvement needed in many organizations

Business case

- Identification of problem areas
- Selected improvement
- Decision

Quantified

- Costs & benefits
- Lead time to result

Quantification problems

Introduction

Much time needed to gather data

Difficult to measure things

Hard to keep management commitment

Expensive

Required: Business case, with limited but sufficient measurement effort, to gain management commitment and funding

Affiliate Collaboration

Introduction

Ericsson Netherlands: Market Unit Northern Europe & Main R&D Center

R&D: Value Added Services

- Strategic Product Management
- Product marketing & technical sales support
- Provisioning & total project management
- Development & maintenance
- Customization
- Supply & support

SEI Pittsburgh, PA: Software Engineering Measurement & Analysis

Modern Measurement Methods

- Goal Driven Measurement
- Analyzing Project management Indicators
- Improving Process Performance using Six Sigma, Designing Products and Processes using Six Sigma
- Understanding CMMI High Maturity Practices
- Client Support & Research
- Training Development & Delivery

Solution

Introduction

Technologies

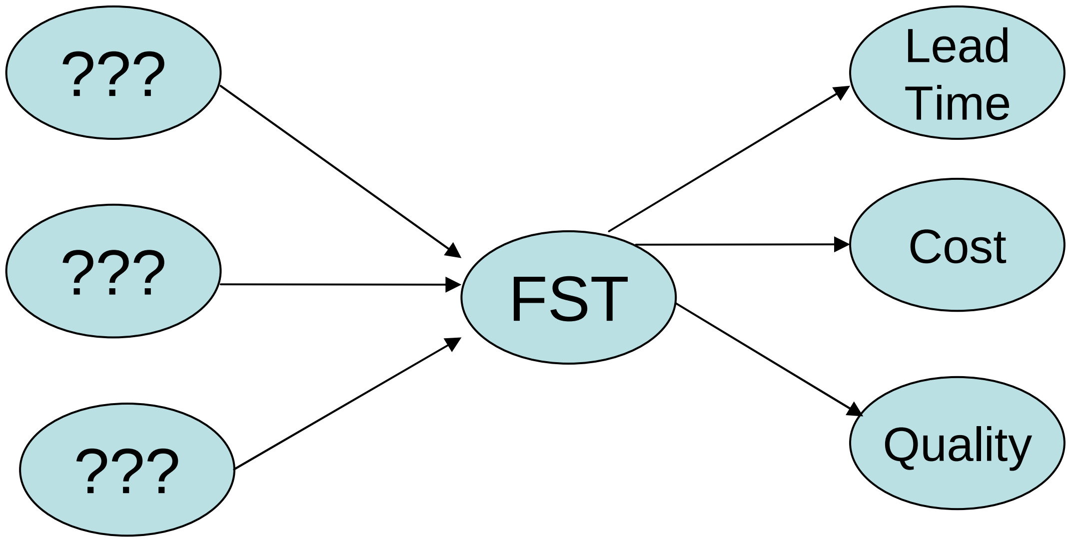
- Bayesian Belief Networks (BBN)
- Monte Carlo Simulation
- Root Cause Analysis
- Cost of Quality, Defect Slippage

Six Sigma DMAIC Approach

- Modeling Business Cases
- Research Quality Factors & quantify Quality Improvement
- Validate “Business Case for Quality”

Fault Slip Through

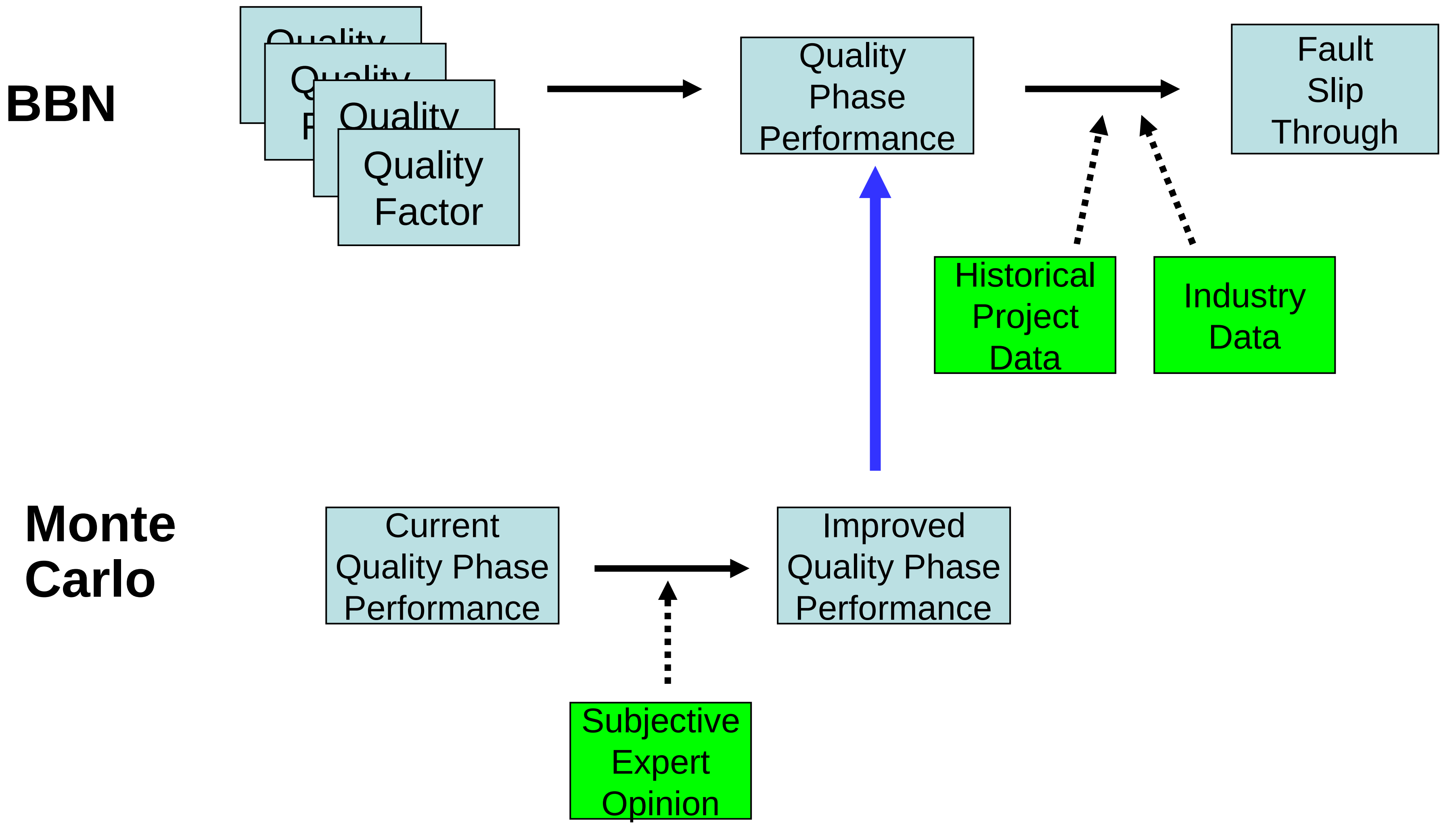
Business Cases



Fault Slip Through = Number of defects detected in integration & customer test that should have been detected earlier

"Should" implies that the defect is more cost effective to find earlier.

Building a business case



Bayes Belief Network (BBN)

Business Cases

- Probabilistic graphical model, to model uncertainty
- Diagnose and explain why an outcome happened
- Predict outcomes based on insight to one or more factors

Used:

- Modeling Quality Factors
- Predicting Quality Phase Performance
- What if Scenario

Monte Carlo Simulation

Business Cases

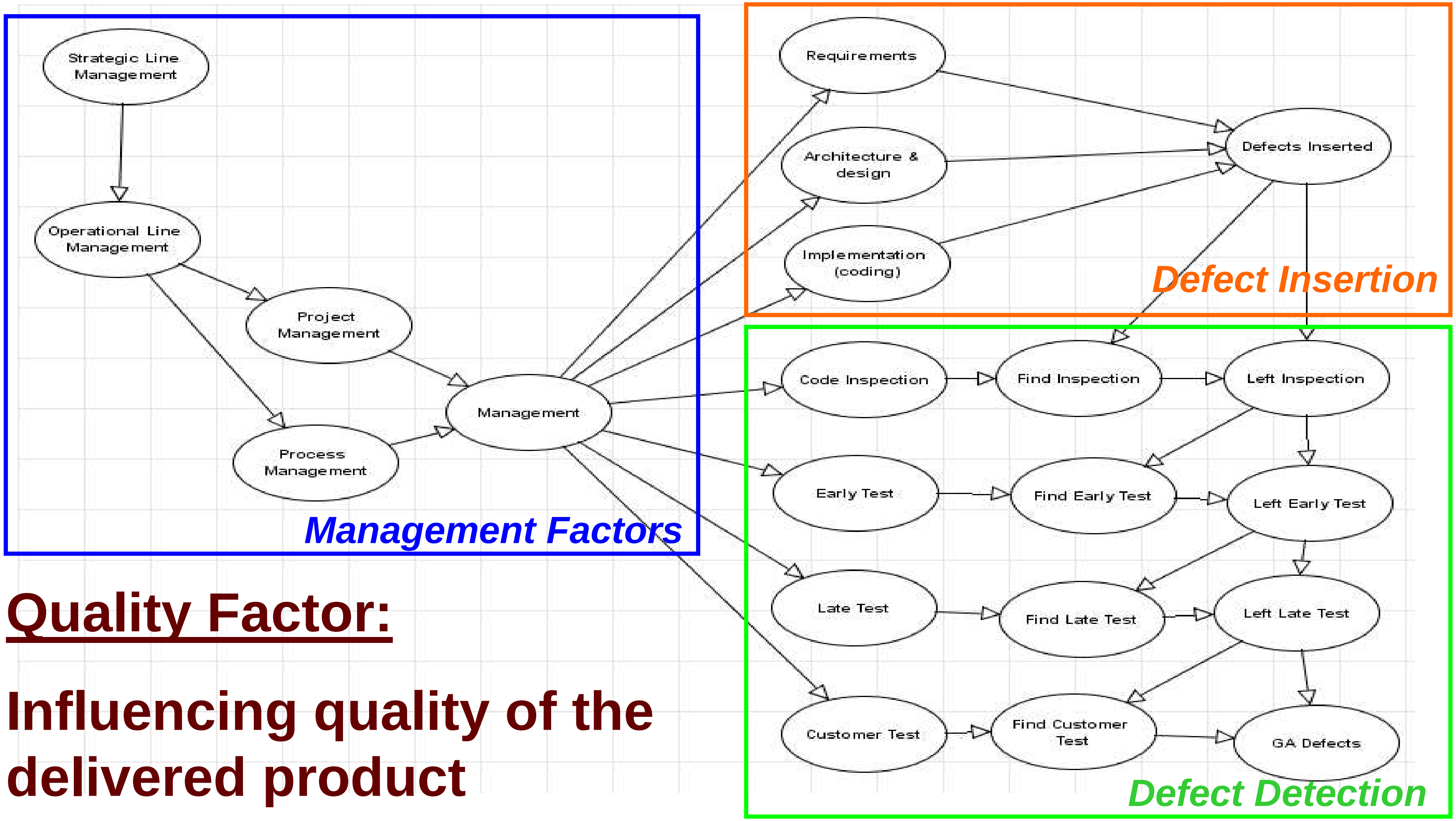
- Compute a result based on random sampling
- Modeling distributions of data
- Can make uncertainty visible

Used:

- Calculate value of process changes

Quality Phase Performance

Quality Factors



Quality Factor:

Influencing quality of the delivered product

Management Factors

Quality Factors

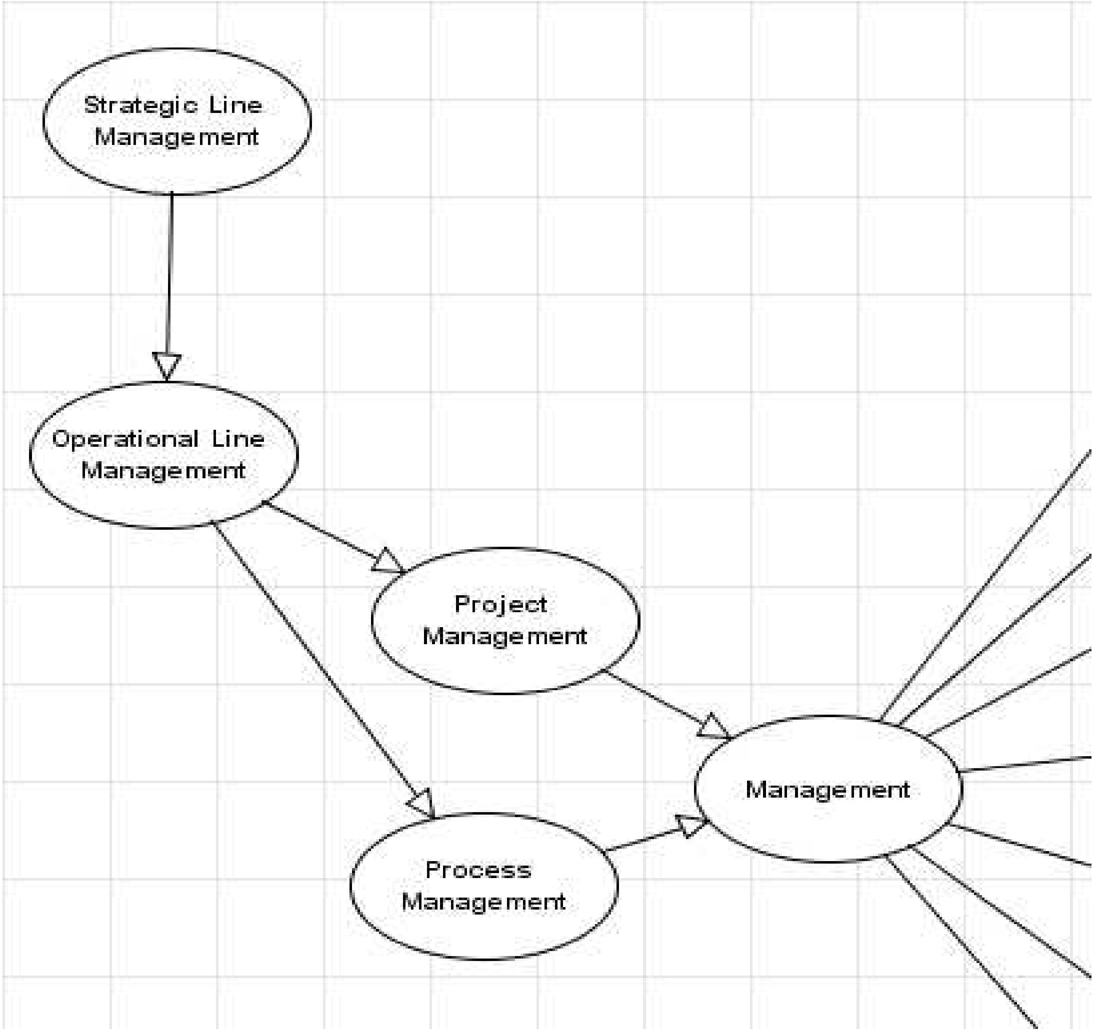
Management Context for Technical Activities

Direct:

- Project Management
- Process Management

Indirect:

- Strategic & Operational Line Management

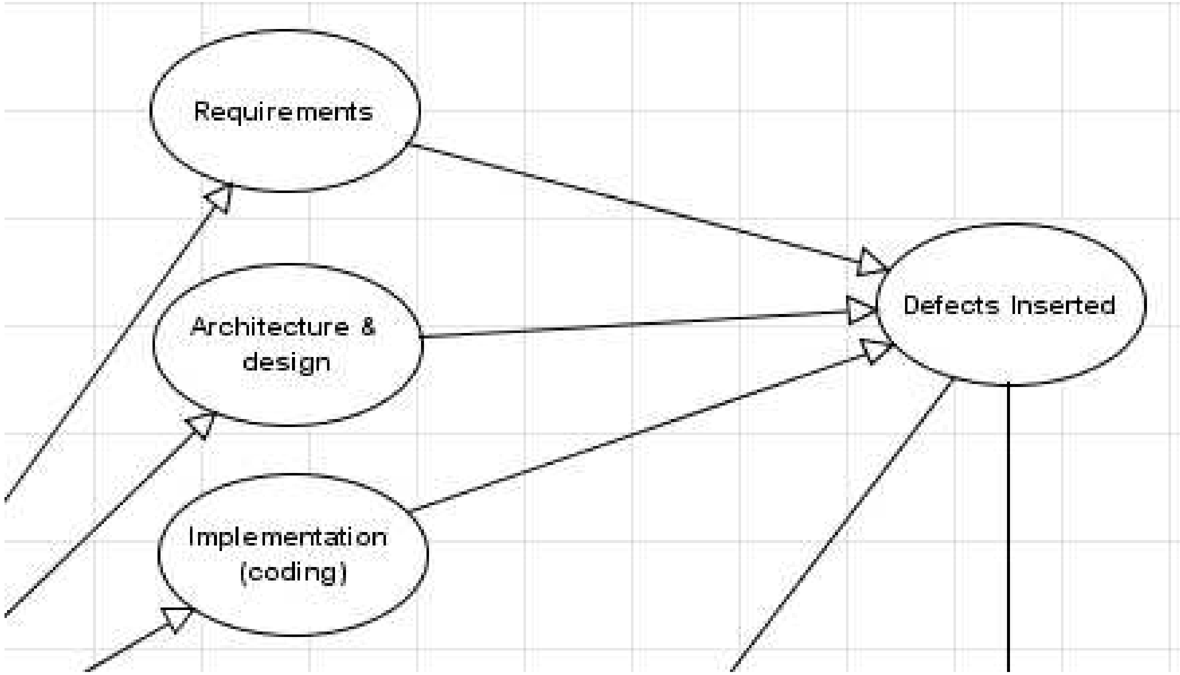


Defect Insertion

Quality Factors

Technical Activities where defects inserted

- Root Cause Analysis
- Defect Prevention



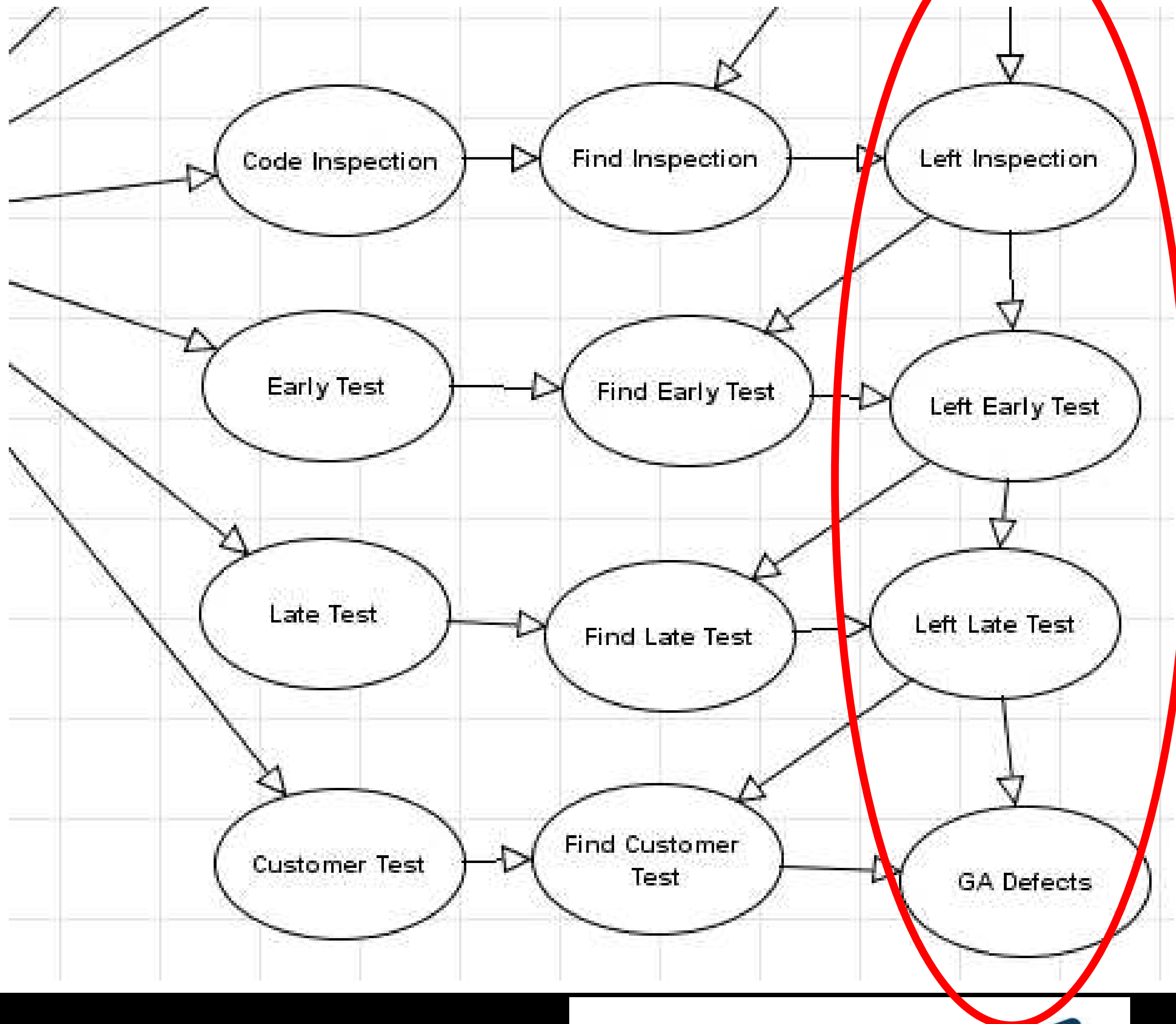
Defect Detection

Quality Factors

Technical Activities where defects detected

- Early Detection
- Economy of Test
- Release Quality

Reduce Defect Slippage

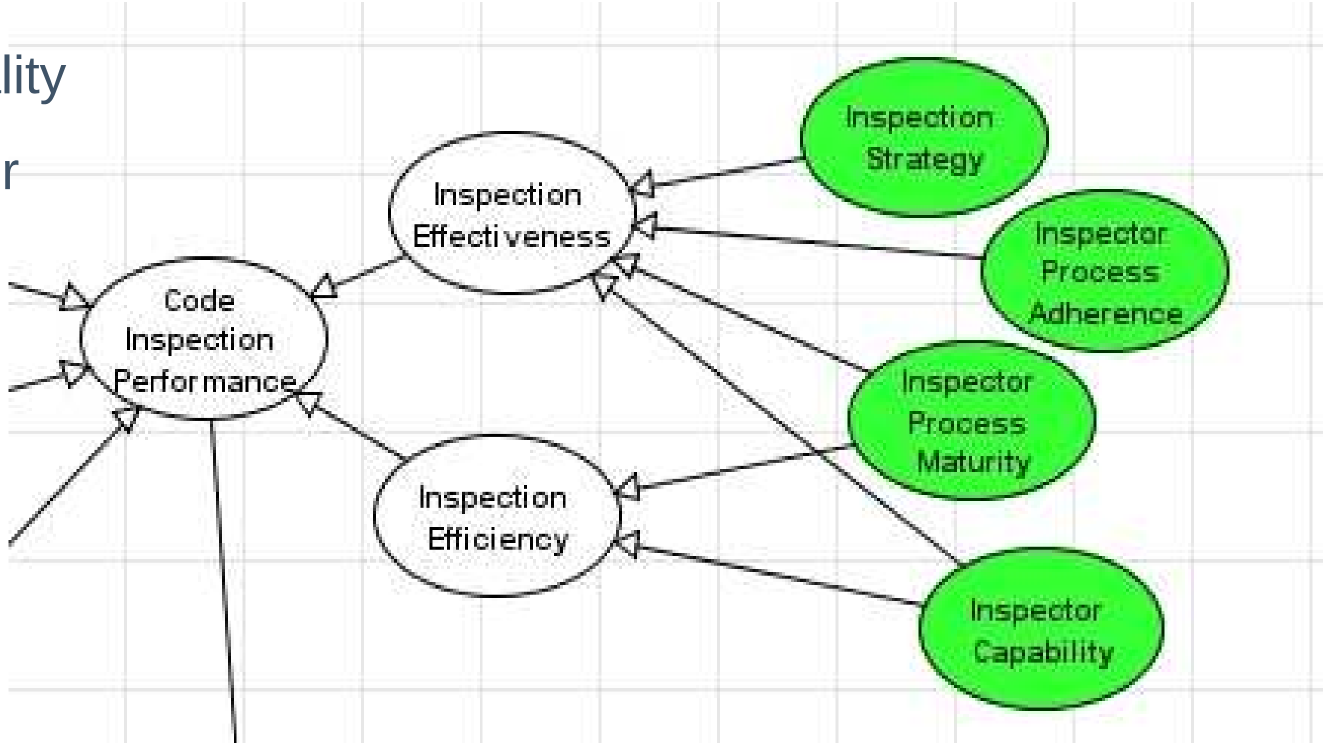


Quality Factors

Quality Factors

Purpose

- Predictor of Quality
- Leading indicator



Sources

- Research
- Expert opinion
- Experience

Quantify Quality Improvement

Quality Factors

Connect defect data with Quality performance

- Maximum quality factor => Industry best in class
  Published industry data from various sources
- Distribution: Linear (keep it simple)

Extend BBN to calculate remaining defects after each phase

Result: Model for “what if scenario’s”

- Calculate defects in release products, when quality performance improves
- Cost of Quality data to calculate savings

Validate “Business Case for Quality”

Validate

- Quality Performance Assessment
  - Determine areas for Improvement

- Pilot: Agile for Requirements
  - Calculate value of process change
  - Run the pilot
  - Evaluate the result

Quality performance assessment

Validate

Survey based upon Quality Factors

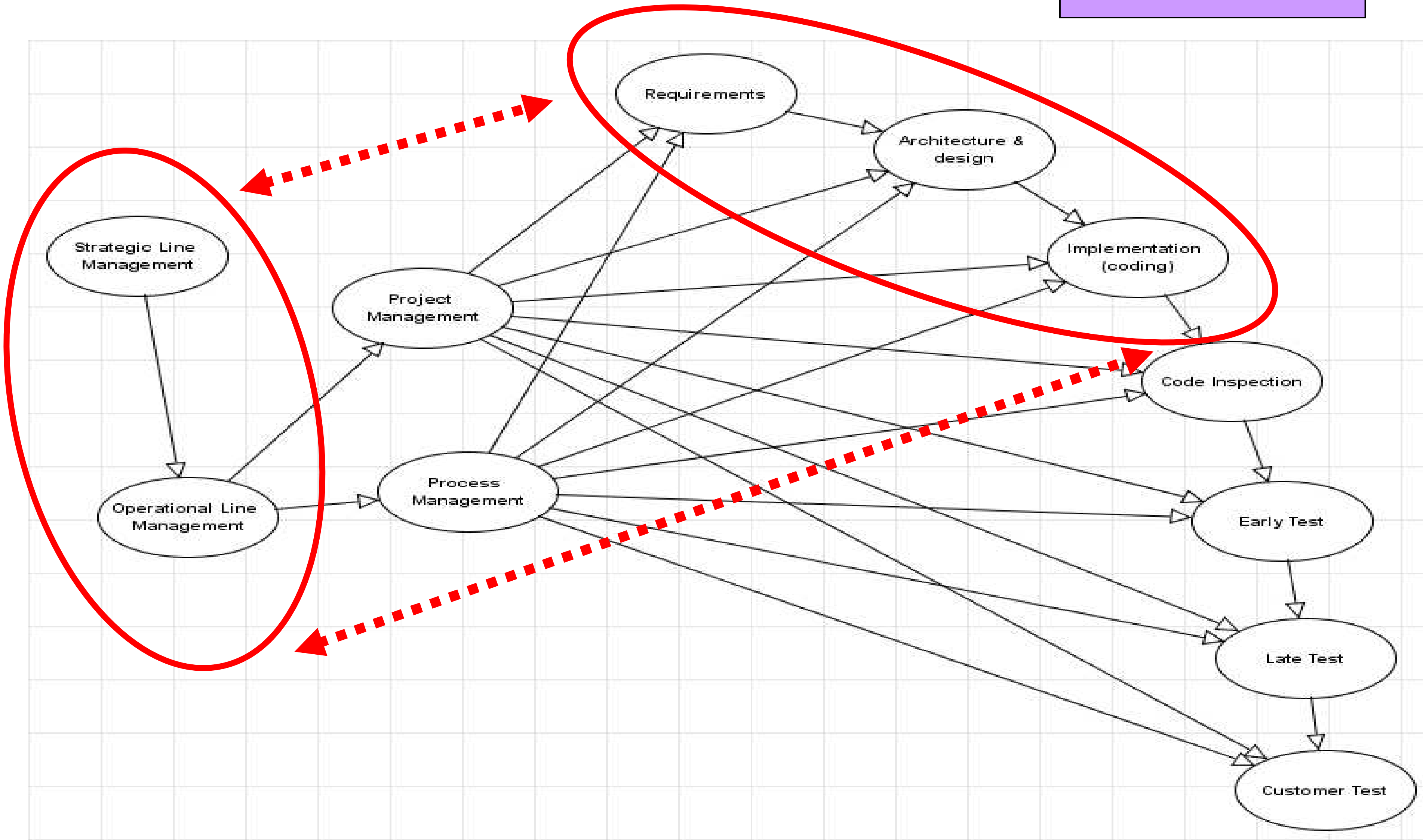
- 34 respondents from management & technical roles
- 4 management areas & 7 technical areas

2 sub questions for each quality factor:

- How relevant is the factor when we want to improve quality?
  “little if any,” “moderate,” “substantial,” or “extensive,”
- How well are we doing currently?
  “poor,” “fair,” “good,” and “excellent.”

Improvement Areas

Validate



Agile for Requirements

Validate

Problem areas

- Requirements Stability
- Scope Stability
- Requirement Definition Capability

Agile solution

- Planning Game
- Stand-up meetings
- Architecture team
- Iterations
- Risk Based Testing

Pilot: Prevent Requirement Defects

Validate

Monte Carlo Simulation

- Simulate Current Performance on Defect Insertion & Detection
- Estimate Agile improvement (expert opinion)

Bayes Belief Network

- Ericsson data to calibrate current performance
- Predict savings due to less defects inserted

Current

Phase	Quality Factor	Detected defects	Defects left	Detection %
Req	4,4			
Arch	5,1			
Impl	5,1			
Total development			49	
Inspection	5,3	12	37	24%
Early Test	5,0	12	25	32%
Late Test	6,2	11	14	44%
Customer Test	5,0	5	9	36%
Total development				
Maint				
Total				

Improved

Phase	Quality Factor	Detected defects	Defects left	Savings
Req	4,7			
Arch	5,1			
Impl	5,1			
Total development			45	
Inspection	5,3	11	34	
Early Test	5,0	11	23	
Late Test	6,2	10	13	
Customer Test	5,0	5	8	
Total development				4%
Maint				
Total				9%

Results Agile

Validate

- **Very low number of requirement defects**
- **Previous projects also had a low number**
- **Based upon the data no conclusion could be drawn**

Root Cause Analysis:

- understanding requirements increased: planning game & stand-up meetings.
- Improvements from retrospectives increased cooperation between development team and product owner.

<u>Requirements quality performance increased!</u>

Evaluation Business Case

Conclusions

Bayesian Belief Networks were successful:

- High level graphical overview
- Focus on improving requirements quality
- Positive results from the pilot
- Limited investment needed for the business case
- We do not know for sure if improvements in an other area would have been more beneficial

Monte Carlo Simulation of potential results has had less value:

- Limited data available on requirements
- Used Root Cause Analysis to confirm improvements

Conclusions

Conclusions

Quicker Business Cases with BBN:

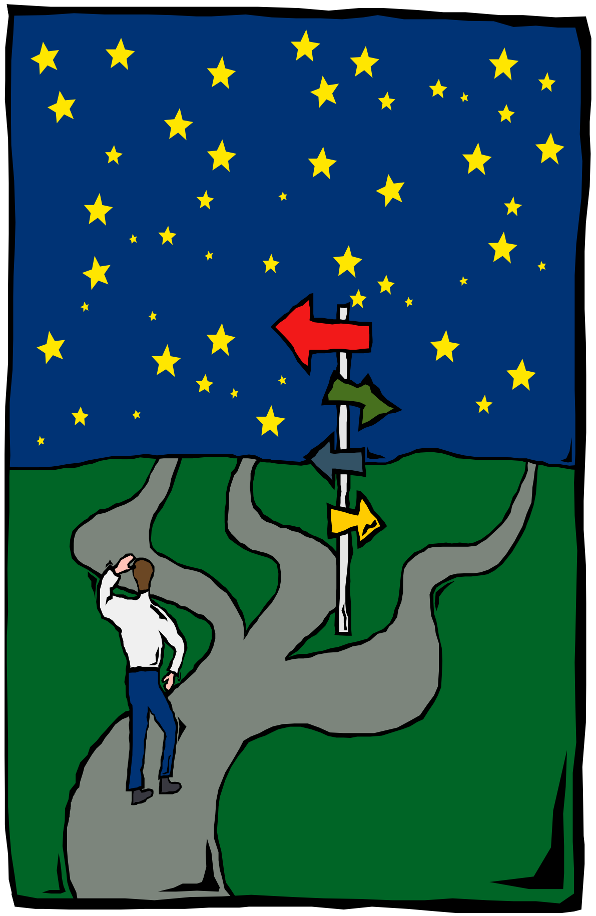
- Quality Factors/Performance
- Fault Slip Through

Monte Carlo value Simulation:

- Distribution of cost savings

Benefits

- Quick Improvement Scope
- Better Business Case: Value for Business
- Agile increased requirements quality
- Value based measurement approach



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Software Engineering Economics

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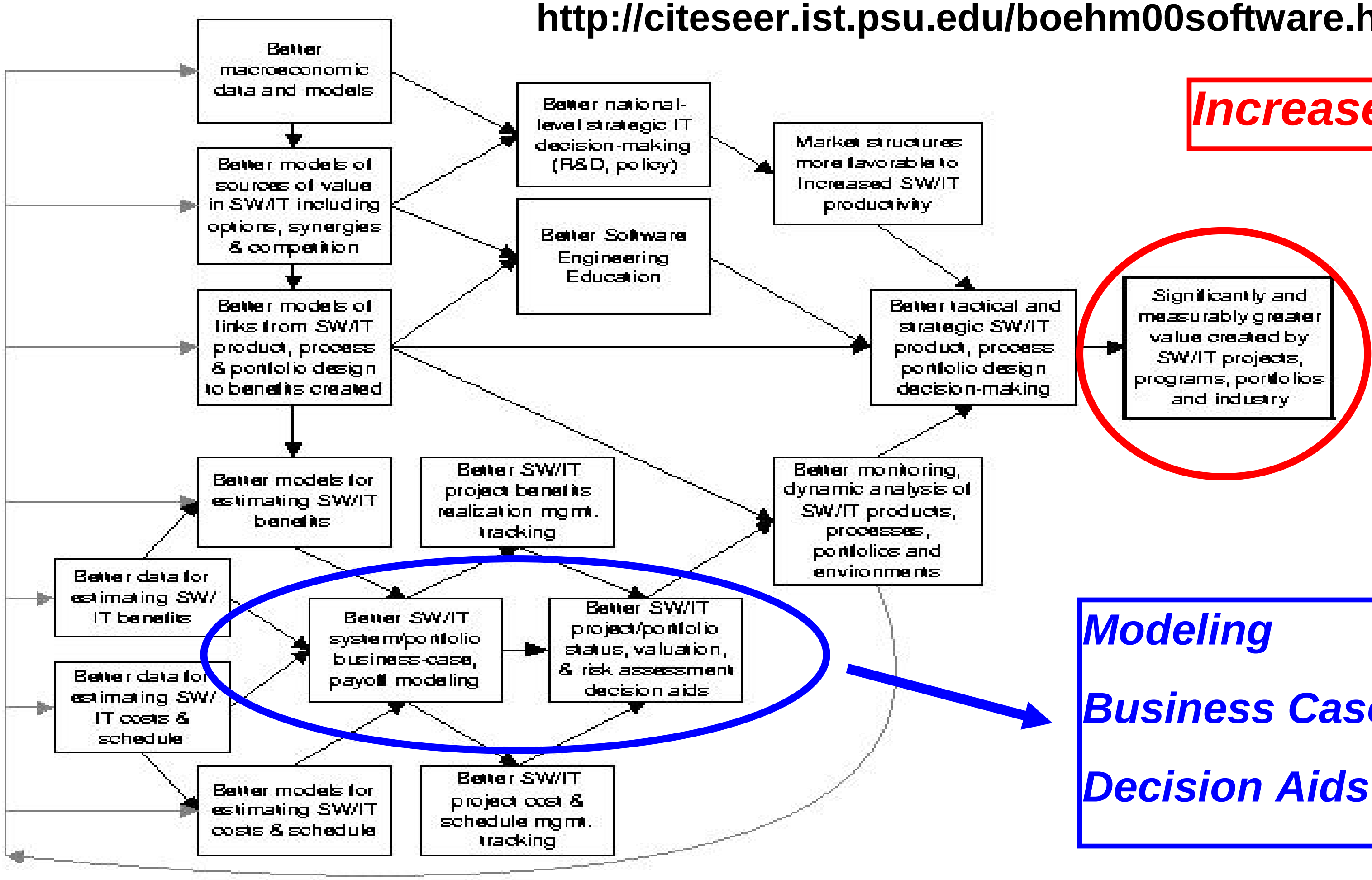


Figure 1: Roadmap for research in software engineering economics.

Increased Value

Modeling

Business Cases

Decision Aids

Affiliate Assignment

Joint effort: Ericsson (Ben Linders) and SEI (Bob Stoddard)

- Time, money, materials
- Knowledge & experience

Deliverables Ericsson

- Defect data & benchmarks
- Improved decisions skills
- Business case & Strategy 2007:
  - Early phases: **Improvements**
  - Late test phases: **Reduction**

Research contribution

- Apply Six Sigma business cases
- Verify technology (CoQ, RBT, FST, etc)

Six Sigma DMAIC mapping

2006: **DMA** Project “Improved Test Decisions”:

Identify current data used

Potential areas for Quality Improvement

Define required data & set baseline

Propose improvement for 2007

2007/2008: **IC** Six Sigma based Strategic Improvement program

Pilots: Agile, Modeling, Quality Culture

Measure benefits

Institutionalize improvements

Define

Project Scope

- Problem Statement
- Baseline data
- Goal
- Voice of Customer/Business
- SIPOC
- Quality Roadmap

Establish Project

- Initial Business Case
- Scope & Excluded
- Research Areas
- Assignment roles, costs, planning

Measure

Identify needed data

- Process Model
- GQIM
- Hypothesis & Predictions
- Required data

Obtain Data Set

- Prediction model
- Available data

Evaluate Data Quality

Summarize & Baseline Data

- Benchmarking

Ben Linders, Ericsson

Analyze

Explore data

Characterize process & problem

Update improvement project scope & scale

Improve

Pilot Agile Requirements

Measure impact on slipped through defects

Root Cause Analysis

Control

Establish measurements on Balanced Scorecard

- Fault Slip Through
  Root Cause Analysis for continuous improvement
- Defects after Release
  Both predicted (handshake with product owner) and actual

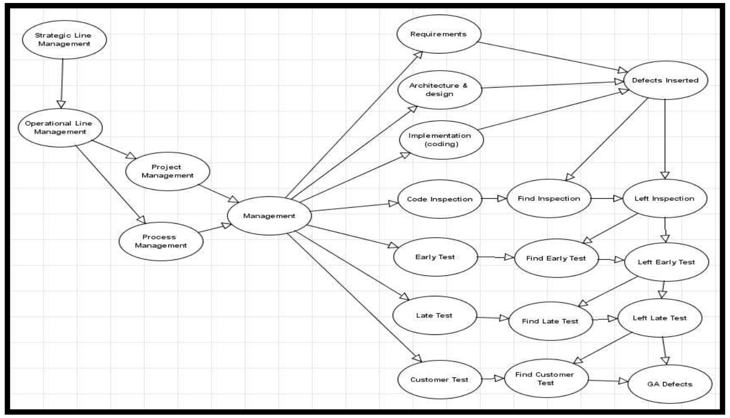
Quality Steering on all levels

- Inside Project: Planning game, Root Cause Analysis
- Programs: Monthly Project Steering Group
- R&D: Monthly quality meeting with MT members

Two step approach

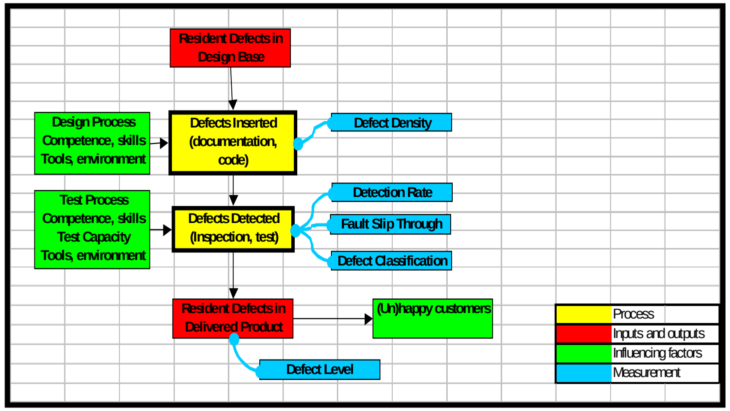
Quality Factor Model

- Expert opinion, extended with data
- Quick Quality Scan
- Rough Prediction Fault Slip Through
- Improvement Areas

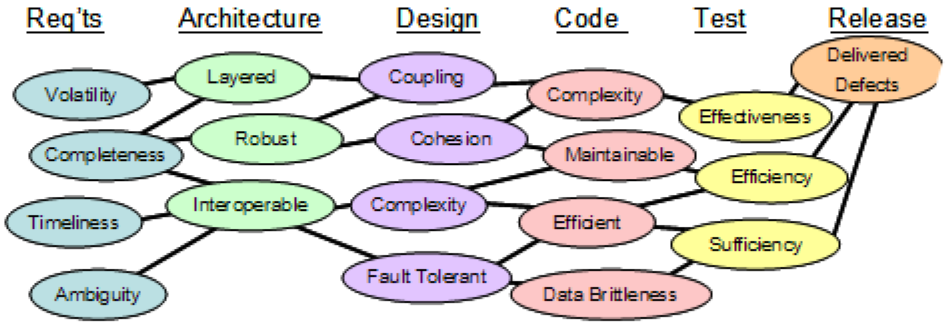


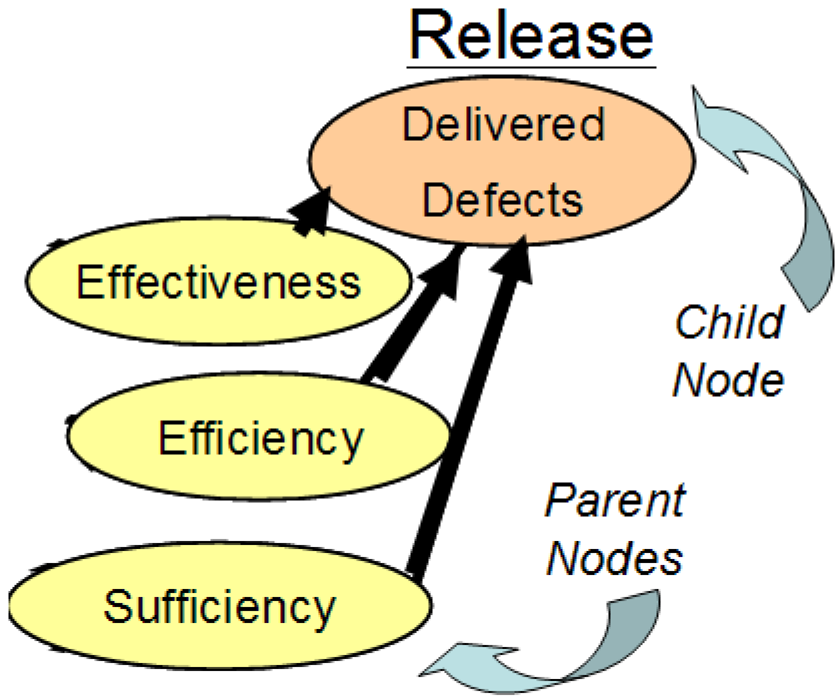
Defect Prediction Model

- Data, tuned with expert opinion
- Detailed Prediction Fault Slip Through
- Improvement Business Case



Example of Bayesian Belief Model





STEP 1:

Develop a model that depicts leading indicator nodes and/or root cause nodes for each node to be predicted. In this diagram, the flow is from left to right and thus, each child node (nodes with incoming lines) may be predicted with the parent nodes (nodes sending a line to a child node)

STEP 2:

Model the relationship between each “child” node and the associated “parent” nodes for the child using:

Regression & ANOVA with Objective Data
Design of Experiments with Subjective Data

Economic Model

Understand costs of defects

Process & project performance

Dialog managers & developers

Use operational data

Manage under uncertainty & incomplete data

Technologies

- Cost of Quality
- Bayesian Belief Networks
- Real Options
- Lean Six Sigma

Quality Prediction

Current Model: Estimation

- Extrapolate past performance
- Based on inserted/detected defects
- Plan & track

Wanted: Prediction

- Causes of defects
- What if Scenarios
- Decision taking

All models are wrong

Some models are useful

Deming

History Defect Modeling

2001

- Defect Model defined, pilot in first project

2002/2003

- Improved based on project feedback
- First release quality estimates
- Industrialize model/tool, use in all major projects

2004/2005

- Targets: Project portfolio management
- Process Performance & Cost of Quality

2006/2007

- Process Improvement Business Cases
  SW Engineering Economics, Six Sigma
- Defect Prediction

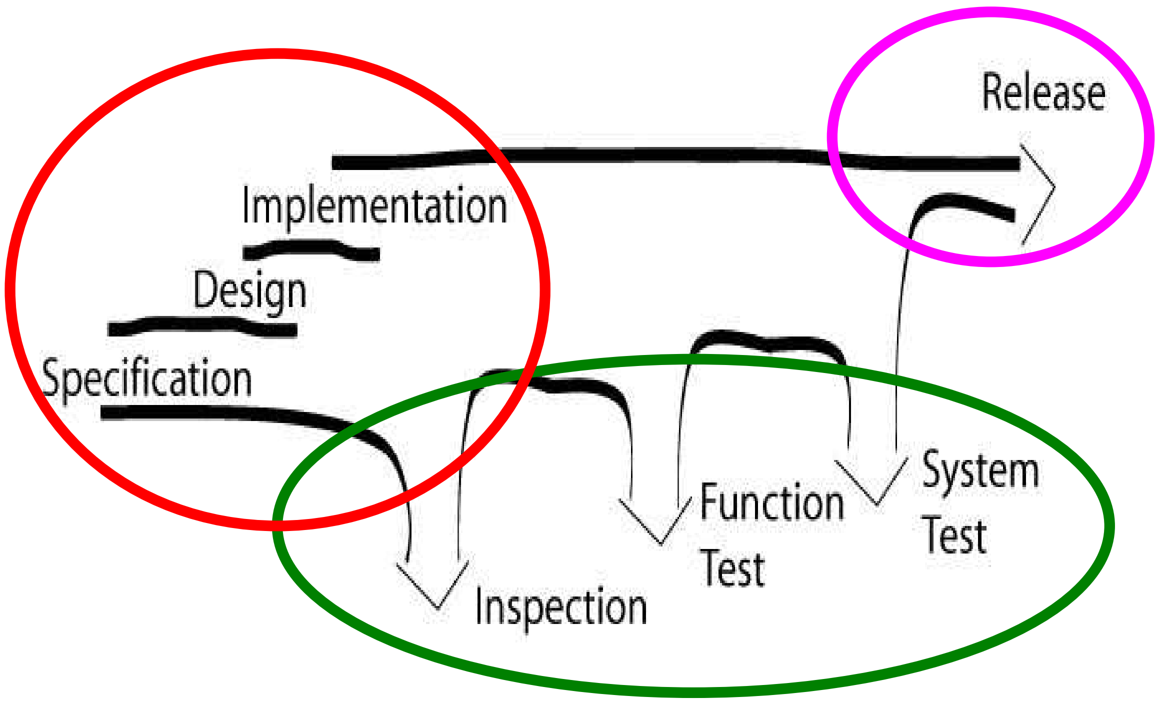
Project Defect Model

Why?

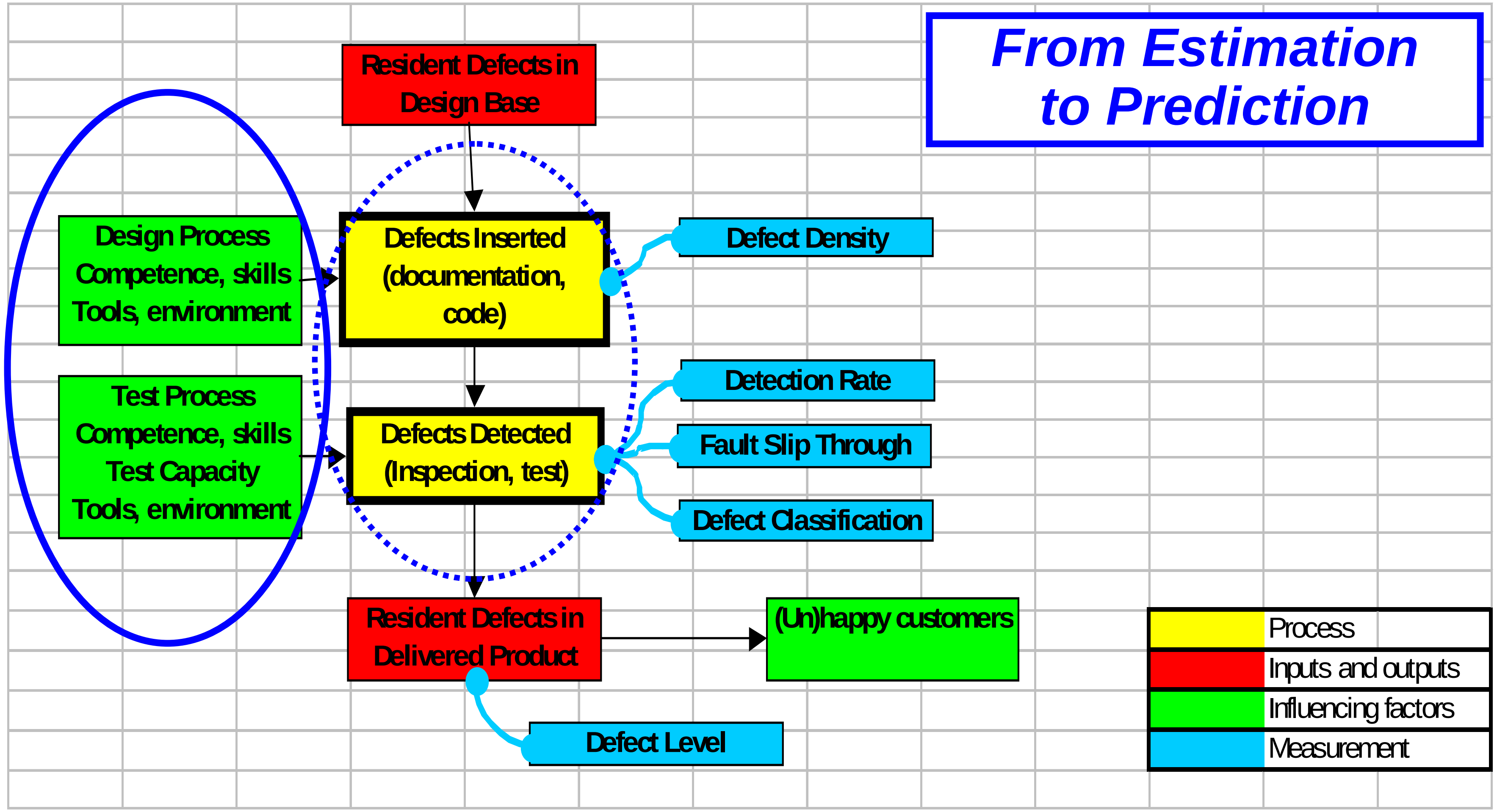
- to control quality of the product during development
- improve development/inspection/test processes

Business Value:

- Improved Quality
- Early risks signals
- Better plans & tracking
- Lower maintenance
- Save time and costs
- Happy customers!



Step 2: Defect Causes & Effect



Step 2: Defect Prediction

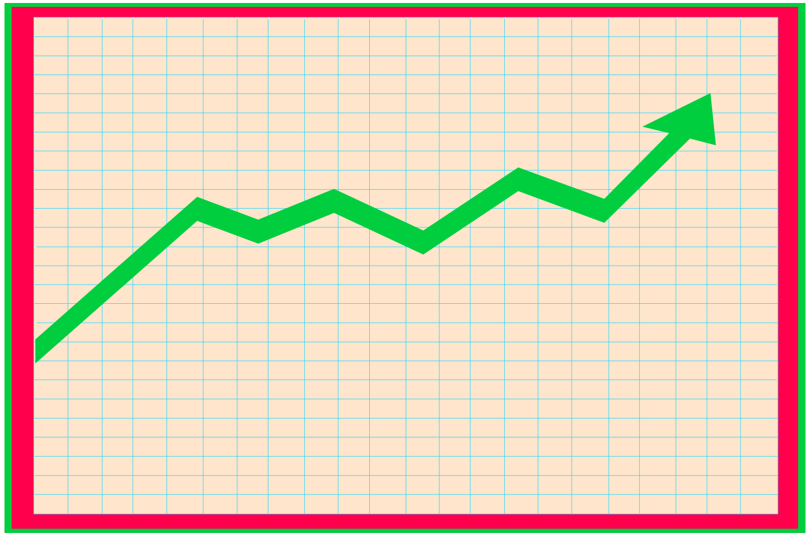
Fault Slip Through

Defect found in a (later) test phase that should have been found earlier

"Should": More Cost effective (economical)

Predict Defect Reduction

- Determine process impact
- Simulate quality change
- Predict savings



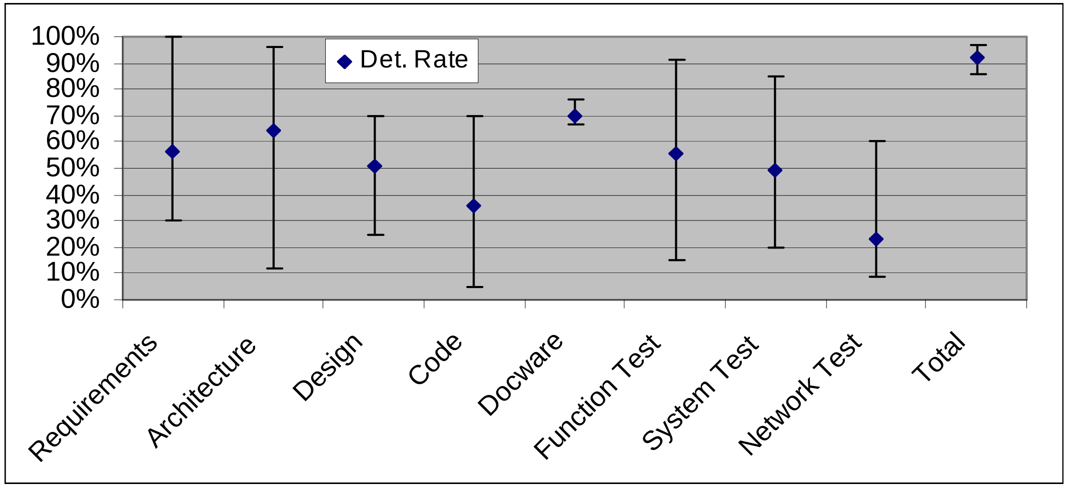
Pilots

- Agile
- Model Driven Development

Process Performance

Project Data

- Insertion Rates
- Detection Rates
- Defect Distribution
- Fault Slip Through
- Post Release Defects



Process View

- Performance of design & test processes
- Benchmarking
- Best Practices & Improvement Areas

Steering Agile Quality

- Estimate amount of latent defects after demo in the planning game.
- Collect all defects during the test phases (after the demo).
- Classify defects:
  - “introduction phase“
  - “should have been detected phase”
- Root cause analysis on defects that should have been found before demo.
- Decide on improvement actions and present to the project team.
- Re-estimate remaining defects and predict release quality.

Monte Carlo: Quality performance

Monte Carlo simulation

- Input from 5 experts
- Estimated chance of occurrence and impact on FST (1-5 scale)
- Simulation done to calculate impact on quality factors
- Result used in BBN model to calculate effect on defect slippage

Expected result:

- Reduced number of requirement defects introduced
- Increased effectiveness of late testing phases
- Less defects in products shipped to customers
- Cost saving:
  - Limited saving in the project
  - Major saving during maintenance

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