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Applications of Risk Management Using Monte Carlo Simulation

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“Fortune favors the prepared mind.”

- Louis Pasteur

“Hope is not an effective risk mitigation strategy.”

- Unknown

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Agenda

- Objectives
- What is risk?
- How should you plan for risk?
- What are good ways to manage risk?
- Summary

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Objectives

After this session, you should understand how to:

- **Identify projects that implement effective risk management plans in order to avoid them**
- **Sabotage effective risk management by not evaluating risks and opportunities on a regular basis**
- **Stay in fire-fighting mode in order to be recognized and promoted for heroic efforts**

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Learning Outcomes

- When you leave this presentation you will understand how you can
  - Define categories and sources of risk
  - Evaluate risks against pre-defined criteria
  - Use Monte Carlo simulation to evaluate project risk
  - Tailor the project's defined process based on this risk assessment
  - Implement effective risk management activities

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What Is a Risk?

- **Risk**
  - **Potential change—with consequence!**
- **Consequence**
  - **Affect of a realized change on the ability of the project team to meet defined cost, schedule, and quality goals**
  - **Perturbs the ability of the team to meet their commitments**
  - **May be positive or negative**
    - **Negative = traditional view of risk**
    - **Positive = non-traditional view i.e., <u>opportunity</u>**

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Common Risk Matrix

Risk	Probability of Occurrence {Low, Medium, or High}	Impact {Low, Medium, or High}	Exposure Combine Probability and Impact
Team members pulled away to other tasks	Low	High	Moderate
Poor estimation	Low	Medium	Nominal
Lost funding	Medium	High	Significant
Change in scope	Low	Low	Low

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How Should You Plan for Risk?

- Establish a strategy for risk management
  - Identify sources of risk
  - Categorize risks
  - Evaluate risks according to defined parameters
- Continuous feedback loop
  - Risks drive project planning, monitoring, & control
  - Project planning identifies risks

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Effective Strategy for Risk Management

- Identify sources of risk
  - People
  - Processes
  - Products
- Categorize risks
  - Individually
  - In aggregate for the project or organization
- Build and update a Risk Taxonomy

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People Risks

- **Capability**
  - **Analysis (problem domain)**
  - **Implementation (solution domain)**
  - **Ability to translate between the two**
- **Continuity**
  - **Turnover rate**
  - **Ratio of senior/junior personnel**
- **Communication**
  - **Interpersonal issues**
  - **Co-located vs. globally-dispersed team**

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Process Risks

- **Maturity**
  - **Organizational maturity vis-à-vis CMMI®**
  - **Project-specific maturity**
- **Mentality**
  - **“Thrash & burn”**
  - **“We’re different”**
- **Monitoring—analysis paralysis?**
  - **Risk chaos**
  - **Funding**

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Product Risks

- Comfort
  - Familiar problem?
  - Same tool set as last time?
- Complexity
  - Product-specific
  - Reuse
- Constraints
  - Customer
  - Schedule
  - ‘Ilities…

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Project Risk Taxonomy Example

- What drives risk evaluation early in a project?
  - Factors influencing success/failure
  - Consequences of failure
- Multiple brainstorming & discussion sessions
  - Project managers
  - Quality manager
  - Senior technical staff
  - Process improvement lead

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Project Risk Taxonomy - 2

- **Key topics identified**
  - **Contract characteristics**
    - **Type**
    - **Value**
    - **Liability**
  - **The work itself**
    - **Have we done this before?**
    - **How well defined is the architecture?**
    - **How complex is the proposed solution?**
    - **Are there constraints on execution time?**
    - **How much flexibility do we have for trade-off decisions?**

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Project Risk Taxonomy - 3

- **Key topics identified (continued)**
  - **The project team**
    - **Cohesion**
    - **Continuity**
    - **Experience**
      - **Language/Tools**
      - **Platform**
      - **Application**
    - **Skill levels**
      - **Analysts**
      - **Developers**

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Project Risk Taxonomy - 4

- **Ramifications of risk … consequences of failure**
  - **Technical**
  - **Cost**
  - **Schedule**

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Categorize Risks

- At the individual level
  - Probability * Consequences
  - Pareto analysis
  - Probability * Consequences * Weighting Factor
- At the project or organizational level
  - Aggregation of individual risks
  - Historical data & checklists
  - Monte Carlo simulation

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Evaluate According to Defined Parameters

- At the individual risk level
  - Document the boundary conditions & rational for
    - Probability of occurrence
    - Consequences
    - Weighting factor
  - COCOMO II.2000 example

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Criteria for Evaluation

- Several sources & categories of risks identified correlated well with specific COCOMO II.2000 scale factors and effort multipliers, e.g.
  - Precedentedness
  - Complexity
  - Platform factors
  - Personnel factors
    - Analyst/Developer capability
- This correlation drove development of an interview tool to build on the Likert scale inherent in COCOMO II

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Sample COCOMO II.2000 Post-Architecture Cost Drivers & Scale Factors

Driver/ Factor	Very Low	Low	Nominal	High	Very High	Extra High
Reliability (reverse scored)	Slight Inconven-ience	Low, easily recover-able losses	Moderate, easily recoverable losses	High financial loss	Risk to human life	N/A
Programmer Capability (percentile)	15th	35th	55th	75th	90th	N/A
Schedule (% of nominal)	75%	85%	100%	130%	160%	N/A
Precedent	Thorough-ly unprece-dented	Largely unprece-dented	Somewhat unprece-dented	Generally familiar	Largely familiar	Thorough-ly familiar
Process Maturity	CMMI CL 0	CMMI CL 1	CMMI CL 2	CMMI CL3	CMMI CL 4	CMMI CL5

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Risk Weighting Example

Risk	Weight	Low (1)	Nominal (3)	High (5)	Insane (7)
Computa-tional complexity	40%	Data table lookups	Standard math & statistical routines	Multivariate analysis; differential equations	Rocket science
Funding instability	30%	Incrementally-funded multi-year contract	Current-year funding obligated	Can pay this month's bills	Overhead
Schedule compression	20%	Accepted team estimate + 25% margin	Accepted team estimate	Slashed team estimate by 30%	Wanted it yesterday
Analyst Capability	10%	Smartest guys in the room	Average Jane & Joe	Can e-mail questions to Ted	What analyst?
Total	100%				

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Sample Risks: Probability, Consequences, & Weighting

Risk	Weight	Low (1)	Nominal (3)	High (5)	Insane (7)
Computa-tional complexity (1.8)	40%	Data table lookups	Standard math & statistical routines (0.5)	Multivariate analysis; differential eqations (0.25)	Rocket science (0.25)
Funding instability (1.7)	30%	Incrementally -funded multi-year contract	Current-year funding obligated	Can pay this month's bills (0.7)	Overhead (0.3)
Schedule compressio n (1.4)	20%	Accepted team estimate + 25% margin	Accepted team estimate	Slashed team estimate by 30%	Wanted it yesterday (1.0)
Analyst Capability (0.6)	10%	Smartest guys in the room	Average Jane & Joe	Can e-mail questions to Ted (0.5)	What analyst? (0.5)
Total = 5.5	100%		0.6	0.5+1.05+.25 = 1.8	0.7+0.6+1.4+ 0.4 = 3.1

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Sample Risks: Probability, Consequences, & Weighting

Risk	Weight	Low (1)	Nominal (3)	High (5)	Insane (7)
Computa-tional complexity (0.4*3=1.2)	40%	Data table lookups	Standard math & statistical routines	Multivariate analysis; differential equations	Rocket science
Funding instability (0.3*5=1.5)	30%	Incrementally -funded multi-year contract	Current-year funding obligated	Can pay this month's bills	Overhead
Schedule compressio n (0.2*7=1.4)	20%	Accepted team estimate + 25% margin	Accepted team estimate	Slashed team estimate by 30%	Wanted it yesterday
Analyst Capability (0.1*5=0.5)	10%	Smartest guys in the room	Average Jane & Joe	Can e-mail questions to Ted	What analyst?
Total = 4.6	100%		3*0.4=1.2	5*(0.3+0.1)=2.0	7*0.2=1.4

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Evaluate According to Defined Parameters

- At the project level
  - Aggregate individual risks to determine project risk
    - Total = 5.5?
    - Total = 4.6?
  - Collect & analyze data to establish organizational norms
    - High, medium, low
    - Low, nominal, high
  - Monte Carlo analysis
    - Drive tailoring of the organization's standard processes
- Ensure action thresholds clearly specified

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Criteria for Evaluation

- **Sample COCOMO II.2000 factors**

	Extra Low	Very Low	Low	Nominal	High	Very High	Extra High
Preceden-tedness*	N/A	Thoroughly unprece-dented	Largely unprece-dented	Somewhat unprece-dented	Generally familiar	Largely familiar	Thoroughly familiar
Value*	N/A	6.20	4.96	3.72	2.48	1.24	0.00
*Analyst Capability	N/A	15th %	35th %	55th %	75th %	90th %	N/A
*Value	N/A	1.42	1.19	1.00	0.85	0.71	N/A

******Software Cost Estimation with COCOMO II*, Boehm, et al, p. 32

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Criteria for Evaluation

- **Sample of other factors considered**

	Extra Low	Very Low	Low	Nominal	High	Very High	Extra High
Contract Type	N/A	Cost Plus	N/A	T&M	N/A	Fixed Price	N/A
Value	N/A	0.5	N/A	1.5	N/A	4.5	N/A
Contract Value	N/A	< $50K	$50K≤ <$500K	$500k≤ <$5M	$5M≤ <$50M	≤$50M	N/A
Value	N/A	0.1	0.3	0.5	0.7	0.9	N/A

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Criteria for Evaluation

- Converted all factors to common scale
  - Highest Risk ←→ Lowest Risk
  - Eliminated problem with reverse scoring
  - Tailored descriptions to fit organization
- Normalized all rating scales
  - 0 – 1
- Weighted individual factors
  - Probability Factors: 0.05, 0.10, 0.15
  - Consequence Factors: 0.30, 0.40
- All feed into the Risk Factor calculation
  RF = PF + CF – PF * CF

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Monte Carlo Simulation

- Define a domain of possible inputs
- Generate inputs randomly from the domain
- Perform a deterministic computation on them
- Aggregate the results of the individual computations into the final result
- Easy to do in excel!

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Monte Carlo Simulation

Probability Risk Factor	Highest Risk					Lowest Risk
Precedentedness	0.33	0.27	0.20	0.13	0.07	
Development Flexibility	0.33	0.27	0.20	0.13	0.07	
Architecture/Risk Resolution	0.33	0.27	0.20	0.13	0.07	
Team Cohesion	0.33	0.27	0.20	0.13	0.07	
Product Complexity	0.25	0.20	0.17	0.15	0.13	0.11
Execution Time Constraints	0.32	0.26	0.22	0.20		
Personnel Factors	0.53	0.25	0.12	0.06	0.03	
Contract Type		0.69			0.23	0.08
Contract Value		0.36	0.28	0.20	0.12	0.04

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Monte Carlo Simulation

Consequences Risk Factor	Highest Impact				Lowest Impact
Cost	0.9	0.7	0.5	0.3	0.1
Schedule	0.9	0.7	0.5	0.3	0.1
Technical	0.9	0.7	0.5	0.3	0.1

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Monte Carlo Simulation

Personnel Fac tors	Prob.
0.53	0.2
0.26	0.2
0.12	0.2
0.06	0.2
0.03	0.2
PF1	0.53
PF2	0.26
PF3	0.06
…	…
PF10,000	0.12

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Monte Carlo Simulation

CT	IPF	PC	P	ARR	DF	TC	PPC	LI	CV	**PF**	C	S	T	**CF**	**RF**
0.53	0.26	0.24	0.07	0.07	0.07	0.27	0.12	0.36	0.04	**0.2285**	0.7	0.5	0.5	**0.58**	**0.67597**
0.26	0.12	0.19	0.27	0.27	0.27	0.2	0.36	0.28	0.36	**0.2365**	0.3	0.3	0.5	**0.36**	**0.51136**
0.06	0.03	0.3	0.2	0.07	0.33	0.33	0.12	0.04	0.2	**0.1695**	0.3	0.3	0.5	**0.36**	**0.46848**
0.12	0.53	0.11	0.33	0.27	0.2	0.13	0.12	0.36	0.12	**0.237**	0.3	0.9	0.9	**0.66**	**0.74058**
0.53	0.12	0.19	0.07	0.33	0.07	0.2	0.12	0.28	0.2	**0.223**	0.9	0.3	0.5	**0.6**	**0.6892**
0.03	0.12	0.3	0.33	0.13	0.33	0.33	0.12	0.2	0.2	**0.2055**	0.9	0.9	0.7	**0.84**	**0.87288**
0.06	0.03	0.3	0.2	0.33	0.2	0.33	0.2	0.36	0.12	**0.1985**	0.7	0.3	0.3	**0.46**	**0.56719**
0.03	0.53	0.19	0.27	0.2	0.27	0.27	0.04	0.36	0.28	**0.2475**	0.5	0.1	0.3	**0.32**	**0.4883**
0.26	0.26	0.19	0.07	0.07	0.33	0.07	0.04	0.12	0.04	**0.1705**	0.7	0.7	0.7	**0.7**	**0.75115**

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Monte Carlo Simulation

Bin	*Frequency*	median	average	standard deviation
0.1	0	0.602	0.601	0.134
0.2	0			
0.3	91			
0.4	643	0.47	+/- 1 sigma	0.74
0.5	1592	0.33	+/- 2 sigma	0.87
0.6	2623	0.20	+/- 3 sigma	1.00
0.7	2592			
0.8	1728			
0.9	661			
1	70			
More	0			

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Process Tailoring

- 3 risk categories based on Monte Carlo Analysis
  - High, RF ≥ 87
  - Nominal, 33 < RF < 87
  - Low, RF ≤ 33
- Examples of process factors subject to tailoring based on risk factor
  - Frequency of mandatory management reviews
  - Frequency and content of QA audits
  - Use of formal peer reviews
  - Always possible to do things not required!

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Managing Risks & Opportunities

- Identify
- Prioritize
- Monitor
- Wash, rinse, repeat

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Monitor & Project Risks

- Make someone responsible
  - Project risk manager
  - Team member
- Review & update
  - Weekly team meetings
  - Quarterly management reviews
  - Major project milestones
- Reprioritize regularly
  - 80/20 rule
  - “Top 10” list

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Implementing Corrective & Preventive Actions

- **Choices for dealing with identified, monitored risks**
  - **Accept**
    - **Do nothing**
  - **Avoid**
    - **Redefine the problem**
  - **Transfer**
    - **Make it someone else's problem**
  - **Control**
    - **Manage through mitigation and contingency plans**

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Implementing Corrective & Preventive Actions

- Controlling risks
  - Assigned to a team member
  - Mitigation plan in place
    - Steps to take to prevent risk from being realized
    - Steps to take to enable opportunity to be realized
  - Contingency plan in place
    - Steps to take if risk/opportunity becomes an issue
  - Common features of both types of plan
    - Specific actions identified
    - Target completion dates established
    - Responsible parties named

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Common Risk Matrix

Risk	Probability of Occurrence {Low, Medium, or High}	Impact {Low, Medium, or High}	Exposure Combine Probability and Impact
Team members pulled away to other tasks	Low	High	Moderate
Poor estimation	Low	Medium	Nominal
Lost funding	Medium	High	Significant
Change in scope	Low	Low	Low

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Examples of Documented Risks

Risk	Probability	Consequences	Impact	Mitigation
Computational complexity	50%	2-4 month slip	30-60 day slip	
Funding instability	30%	Work stoppage	Day-for-day slip	Ensure funding remains steady
Schedule compression	80%	Deliver reduced functionality	Overtime; Customer Issues	Overtime
Analyst Capability	10%	See Computational Complexity		

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Exampl

Let's look at this one…

Risk	Probability	Con	ion
Computational complexity		2-4 month slip	
Funding instability	30%	Work stoppage	Day-for-day slip	Ensure funding remains steady
Schedule compression	80%	Deliver reduced functionality	Overtime; Customer Issues	Overtime
Analyst Capability	10%	See Computational Complexity		

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What Do We Need?

- Actionable problem statement
- Priority
- Owner assigned
- Mitigation plan in place
- Contingency plan in place
- Review/update cycle defined

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Example Risk

Statement	**Underestimated complexity of computational algorithms for data mining and regression analysis**		
Rank/Value **Owner** **Updates**	**#7** **1.8**	**Doe, Jane**	**Last: 06 Nov 08** **Next: 20 Nov 08**
Mitigation Plan	**1. Review estimates against historical data from Projects X & Q** **2. Have staff data mining expert John Doe provide independent review of estimate**		
Contingency Plan	**1. Renegotiate functional content of Build 3 with customer** **2. Use up to 2% of Management Reserve budget to hire a consultant who specializes in the problem area**		

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Example Opportunity

Statement	**Underestimated customer plus-up due to year-end fallout money by >50%**		
Rank/Value/ Owner/ Updates	**#7** **1.8**	**Doe, Jane**	**Last: 06 Nov 08** **Next: 20 Nov08**
Mitigation Plan	**1. Inform political liaison of functionality that could be added with sufficient funds** **2. Provide customer with draft implementation plan for additional Build content**		
Contingency Plan	**1. Renegotiate functional content of Build 3 with customer** **2. Replenish Management Reserve account**		

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Summary

- **Be specific with your Top 10!**
  - **Risk statements**
  - **Impact analyses**
  - **Mitigation & contingency plans**
- **Use organizational resources**
  - **Checklists, templates**
  - **Historical data & organizational norms**
  - **Monte Carlo simulation**
- **Regularly Review, Revise, & Reprioritize**

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Learning Outcomes

- When you leave this presentation you will understand how you can
  - Define categories and sources of risk
  - Evaluate risks against pre-defined criteria
  - Use Monte Carlo simulation to evaluate project risk
  - Tailor the project's defined process based on this risk assessment
  - Implement effective risk management activities

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