Reliability & Risk Division

The Global Voice of Quality®

ASQ RRD Webinar Series:

Risk-Based Decision-Making

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Risk

- Risk is anything that can affect our ability to achieve the organization's objectives. (ISO9001:2015)*
- A course of action or inaction taken under conditions of uncertainty which exposes the **risk taker** to possible loss (or gain) to reach a desired outcome.
- An undesirable situation or circumstance that is likely to cause a harm or a loss.

* Risk management could be the single most significant addition to ISO 9001:2015. It requires a complete change of focus in implementing a quality management system (QMS).

What does Risk Mean to Business?

- If I cut the staff on this project to save money; what doesn't get done; and how will it affect the product?
  (think aircraft, pacemakers, Cell phone batteries, Microsoft software development……)
- NRC says a few pumps need to be replaced; we can take our time, we have lots of redundancy, right?
  (think Nuclear power plants –e.g. Three Mile Island)
- Can we change the electrical system in our vehicle to run 440V?
  (Didn't seem like a big deal, at the time, but guess what?)
- We need to develop the next product in half the time, what can we do to accomplish this?
  (And not have our warranty costs increase, or our customers become unhappy, or….?)
- We have never assembled a Compressor bladed disk incorrectly, so let's drop the Quality inspection to save time?

I know what I'm doing, I've been doing it for 20 years (30 years, 40 years)

I don't need any tests or redundant inspections or pilot lot or…….

Classically, Risk is a function of

- Event
- Probability
- Impact

Then, a “Risk Event” = Probability of Risk,
given the Cause has occurred
(some industries call this a Reliability event)

NOTE: A Safety event =
“Risk Event” x Safety Factor

Risk Worry items- The Project Team's 1st meeting*

- Sources of risk
- Amount of information available
- Personal risk (if the team isn't successful!)
- Business Risk-Company reputation-Safety Risk
- Ability to control Risk
- Constraints

* Remember: Project Management is RISK Management

Risk Management processes

1. Risk Management planning

2. Risk identification

3. Qualitative risk analysis

4. Quantitative risk analysis

5. Risk Response planning

6. Risk Monitoring and Control

Qualitative Risk Analysis

Performing analysis of risk and condition(s) to prioritize those that have major impact(s) on the project.

Quantitative Risk Analysis

- Evaluating risks and risk interaction to assess the range of possible project outcomes.
- Measuring the probability and the consequence of risk and estimating its impact on the project objectives

Qualitative Tools for Risk Analysis

1. Failure Modes and Effects Analysis(FMEA)
2. Multi Attribute Utility
3. Delphi Technique

Multi-Attribute Utility

- Many decisions require us to pay attention to multiple criteria.
  - Buying a home
  - What you decide to wear each day!
  - However, in business consequences are important, MAU helps organize the information in order to make a decision (most often in a team environment).
- Sometimes called Multi-attribute Value Analysis(MAVA) or Multi-criteria Decision Analysis (MCDA).

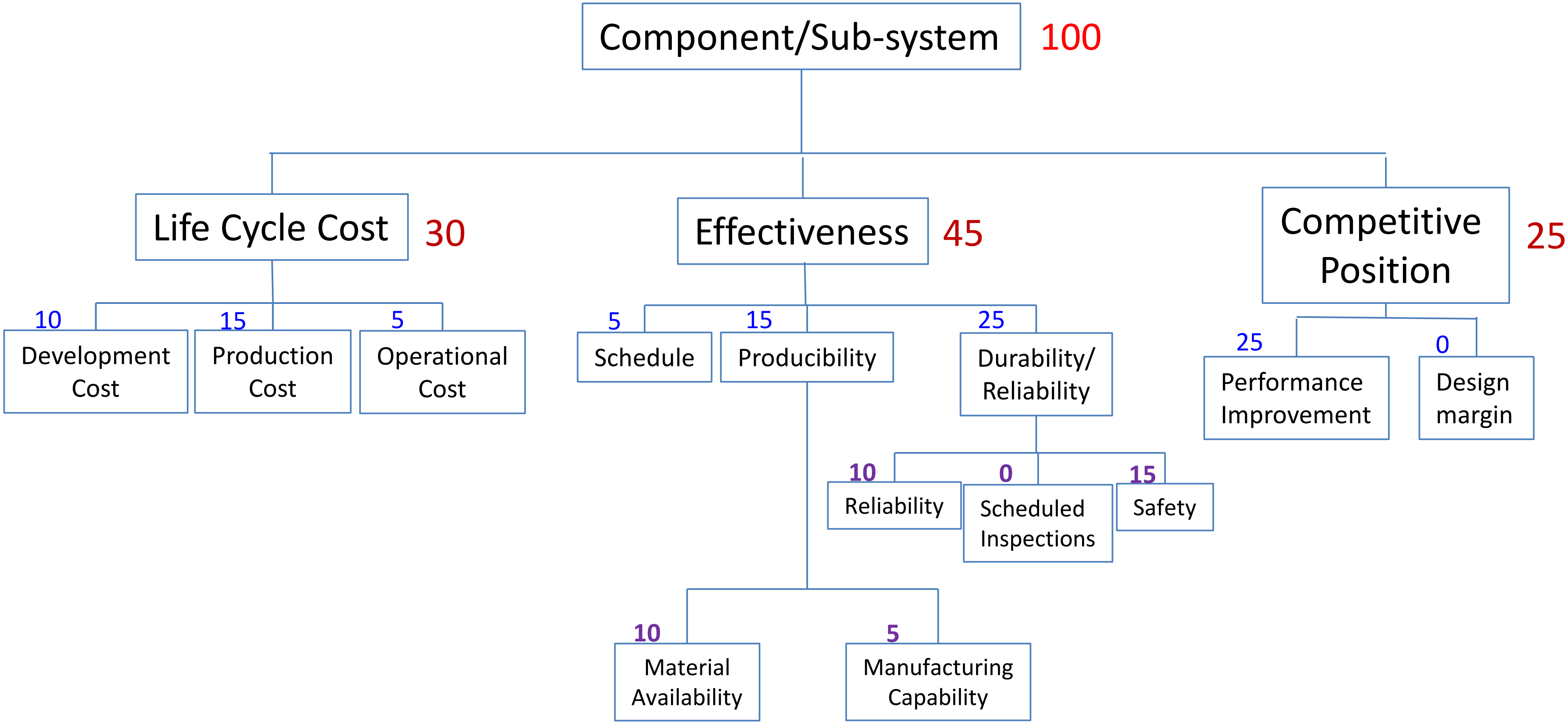
MAU used in Engineering

- Where should the new test facility be built?
  - Domestic? Europe? Asia?
- What's the best design for a new jet engine for the fighter plane of 2035?
- What's the best combination of new technologies for the follow-on to the 787?

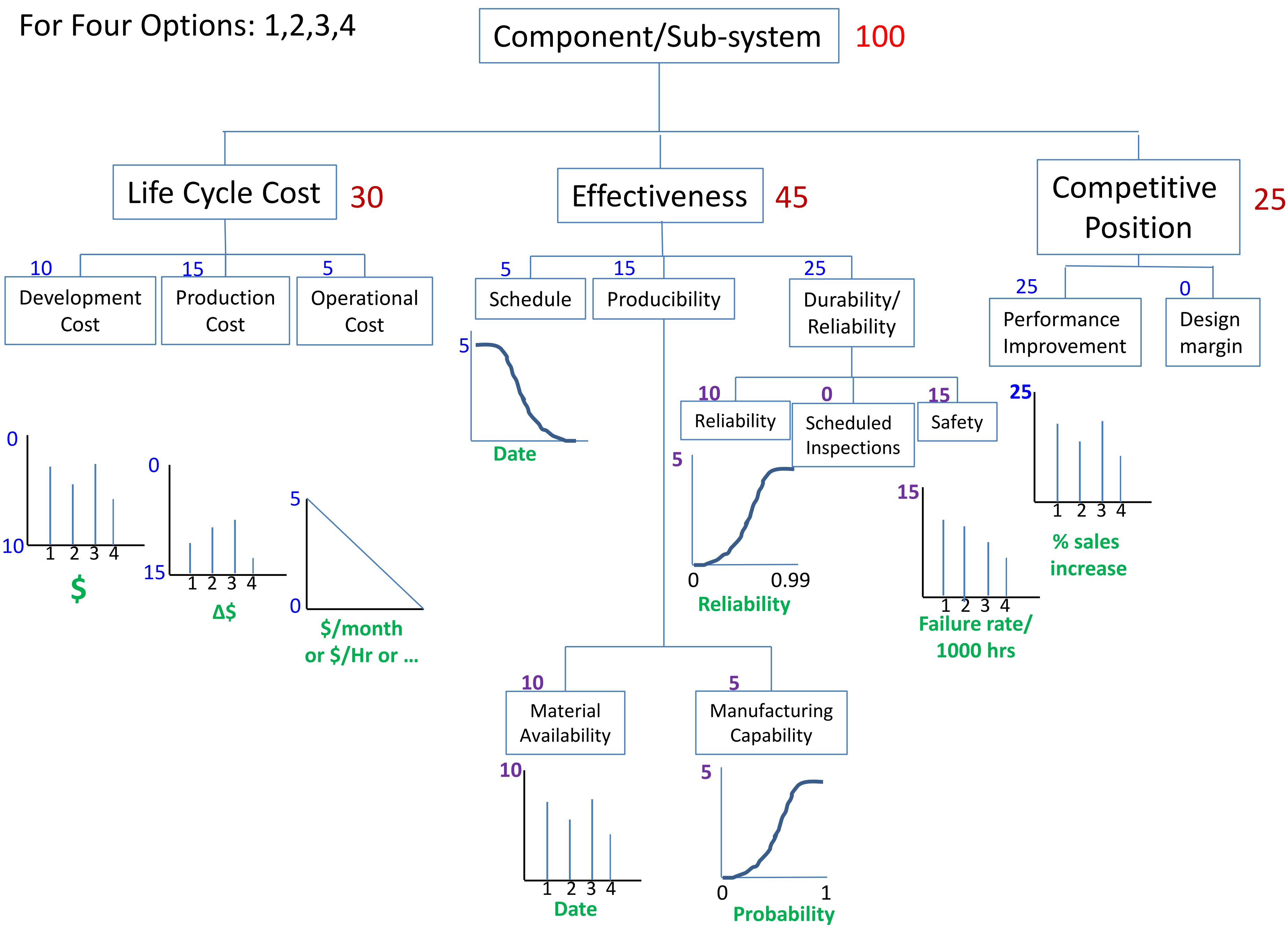
Multi-Attribute Utility Process

A Multi-Attribute Utility decision analysis is developed in the following steps:

1. define the improvement item (e.g. Component/Sub-system design).
2. assign an arbitrary number of weighting points to this improvement item.
3. define each item that affects this major System or Sub-system (e.g. LCC, Effectiveness, Competitive Position) and apportion the total number of points according to importance.
4. breakdown each of these objects and continue until measurable parameters are reached (e.g. Reliability, Safety).
5. at this time, evaluate each option through each measurable parameter.
6. combine this break through the tree for each option.



1. Set the weighting Factor (overall) – (say) 100
2. Set the next level of weighting factors (based on importance)-Sums to Overall
3. Continue setting the next level of weights
4. **And the Next**


For Four Options: 1,2,3,4
Component/Sub-system 100
Life Cycle Cost 30
Effectiveness 45
Competitive Position 25
10 Development Cost
15 Production Cost
5 Operational Cost
5 Schedule
15 Producibility
25 Durability/ Reliability
25 Performance Improvement
0 Design margin
10 Reliability
0 Scheduled Inspections
15 Safety
10 Material Availability
5 Manufacturing Capability
$
Δ$
$/month or $/Hr or …
Date
Reliability
0.99
Failure rate/ 1000 hrs
% sales increase
Date
Probability

Quantitative Tools for Risk Analysis

1. Statistical tools (e.g. Probability, ANOVA, DOE, Logistic Regression)
2. Weibull analysis
3. Monte Carlo Simulation
   - Safety Risk Analysis
   - Tolerancing
   - Calculating Max stress/Load
   - Forecasting spare parts needs/modules to depot

What is Logistic Regression?

Variable type	Number of categories	Characteristics	Examples
Binary	2	two levels	success, failure yes, no
Ordinal	3 or more	natural ordering of the levels	none, mild, severe fine, medium, coarse
Nominal	3 or more	no natural ordering of the levels	blue, black, red, yellow sunny, rainy, cloudy

What is Logistic Regression?

- Binary Logistic regression is a technique for making predictions when the dependent variable is a dichotomy(0 or 1), and the independent variables are continuous and/or discrete.
- Data are transformed so that predictions are restricted to be between 0 and 1.
- Let *p* = probability of response, and consider the model

$$\ln\left(\frac{p}{1-p}\right) = \alpha + \beta_1 x_1 + \beta_2 x_2$$

$$p = \frac{\exp(\alpha + \beta_1 x_1 + \beta_2 x_2)}{1 + \exp(\alpha + \beta_1 x_1 + \beta_2 x_2)}$$

- (Simple) Binary logistic regression has a single predictor. If you have more than one predictor, it's called (Multiple) Binary logistic regression.

Challenger O-Ring example

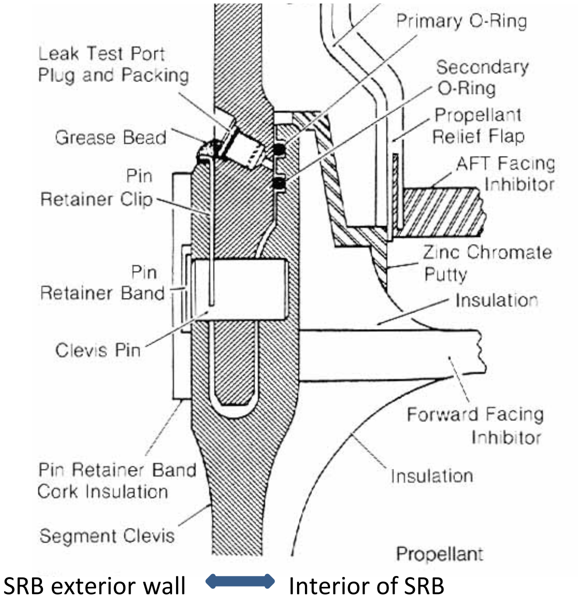
The following data will be used to study the performance of the O-ring seals on the Space Shuttle Challenger:

Number of O-rings at risk on a given flight	Flght	Launch temperature (° F)	Primary o-ring erosion	Primary o-ring Blow-by	Erosion or blow-by	Damage Index	Date of flight
6	51-C	53	3	2	5	11	1/24/1985
6	41-B	57	1		1	4	2/3/1984
6	61-C	58	1		1	4	1/12/1986
6	41-C	63	1		1	2	4/6/1984
6	1	66			0	0	4/12/1981
6	6	67			0	0	4/4/1983
6	51-A	67			0	0	11/8/1984
6	51-D	67			0	0	4/12/1985
6	5	68			0	0	11/11/1982
6	3	69			0	0	3/22/1982
6	2	70	1		1	4	11/12/1981
6	9	70			0	0	11/28/1983
6	41-D	70	1		1	4	8/30/1984
6	51-G	70			0	0	6/17/1985
6	7	72			0	0	6/18/1983
6	8	73			0	0	8/30/1983
6	51-B	75			0	0	4/29/1985
6	61-A	75		2	2	4	10/30/1985
6	51-I	76			0	0	8/27/1985
6	61-B	76			0	0	11/26/1985
6	41-G	78			0	0	10/5/1984
6	51-J	79			0	0	10/3/1985
6	51-F	81			0	0	7/29/1985

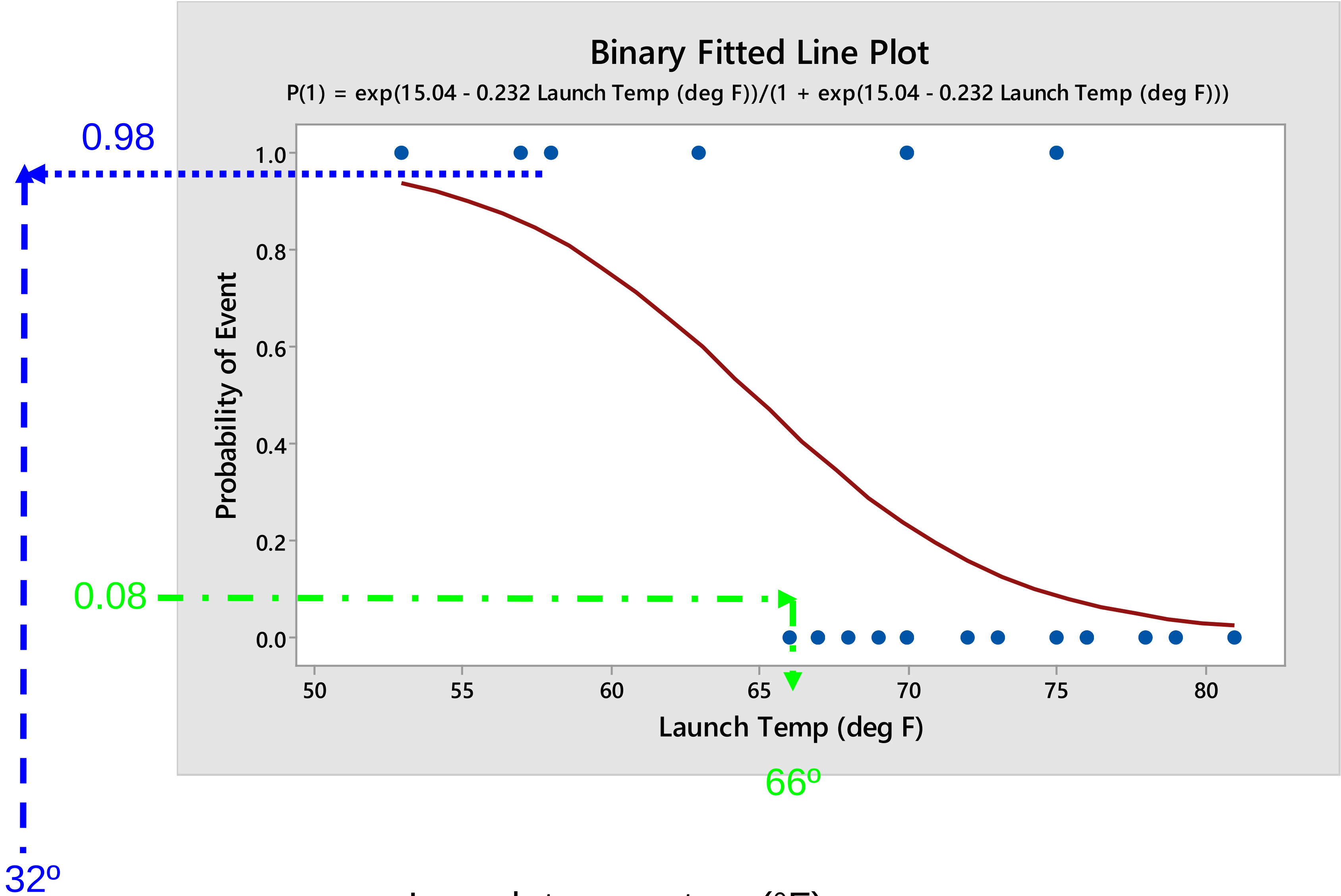
Table taken from *Presidential Commission on the Space Shuttle Challenger Accident (PCSSCA) , volume II, pp H1-H3 & volume IV p.664.*

In this case use "Event/Trial" format For input in MINITAB's Binomial Logistic Regression:

Probability (Erosion or blow-by)= f(Launch temp)



Challenger O-Ring example

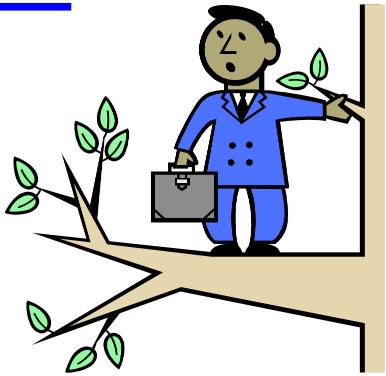


Launch temperature (°F)

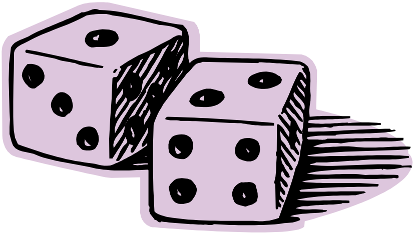
Quantitative Tools for Risk Analysis

1. Statistical tools (e.g. Probability, ANOVA, DOE, Logistic Regression)
2. Weibull analysis
3. Monte Carlo Simulation
   - Safety Risk Analysis
   - Tolerancing
   - Financial Forecasting
   - What's a good design?
   - Project Risk

Project Risk Analysis

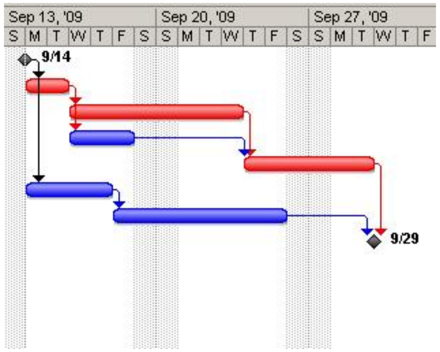


- Projects are full of risks
  - Technical approach
  - Resource availability
  - Missed requirements
  - Too many defects
  - Late subcontract deliverable
  - …



Project Risk Analysis

- Major concern – Improving confidence in schedule and budget projections

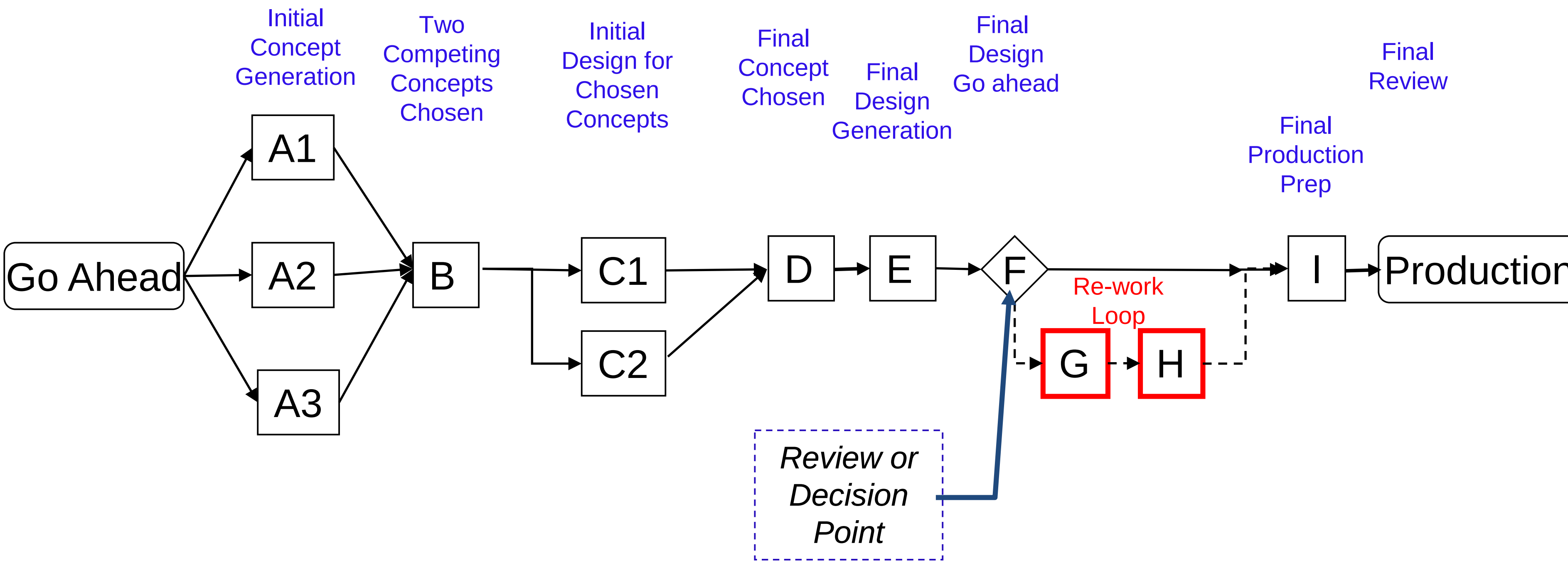


- Key challenges
  - Uncertainty in time or cost estimates
  - Translating uncertainty into reserve or buffer
  - Applying models and simulation techniques

- One such modeling technique: Monte Carlo Simulation

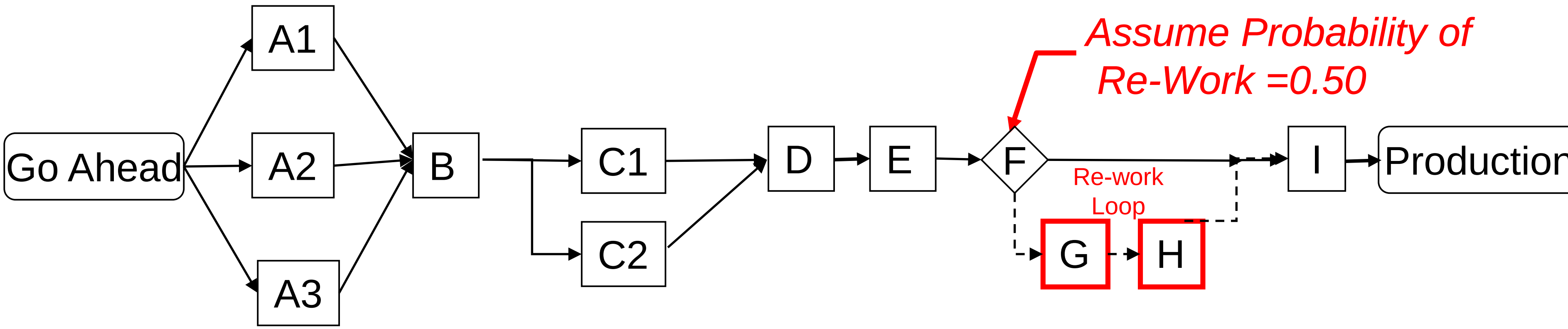
Project Estimation; With & Without a Re-Work Loop

- The Estimated Duration for this Process is 56-72 Weeks



Task	A	B	C	D	E	F	G	H	I	Sum
Most Likely (weeks)	8	2	12	1	24	1	6	10	8	= 72

Three-Point Estimation to Create Input for Monte-Carlo Simulation

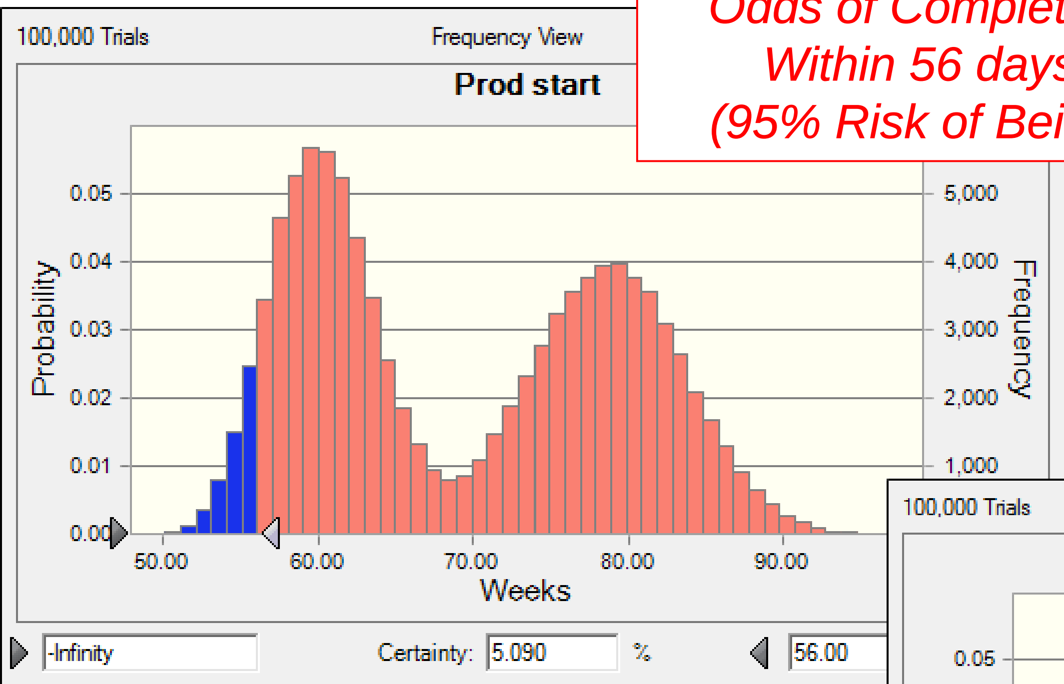


				Amt of					Amt of									
			Max ofA's	decision time					decision time									
	A1	8	8	B	2	C1	12	12	D	1	E	24	F	1	I	8	Prod start	56
Opt	4			0.5		10			0.5		20		0	1	6		Opt	9
MostLikely	8			2		12			1		24				8		MostLikely	16
Pess	12			3		16			2		30		0.5		12		Pess	29
													1					
	A2	8				C2	12						2	one for				
Opt	4					10								decision time				
MostLikely	8					12												
Pess	16					12												
	A3	8																
Opt	4													G	6	H	10	
MostLikely	8												Opt	4		6		
Pess	8												MostLikely	6		10		
													Pess	12		15		

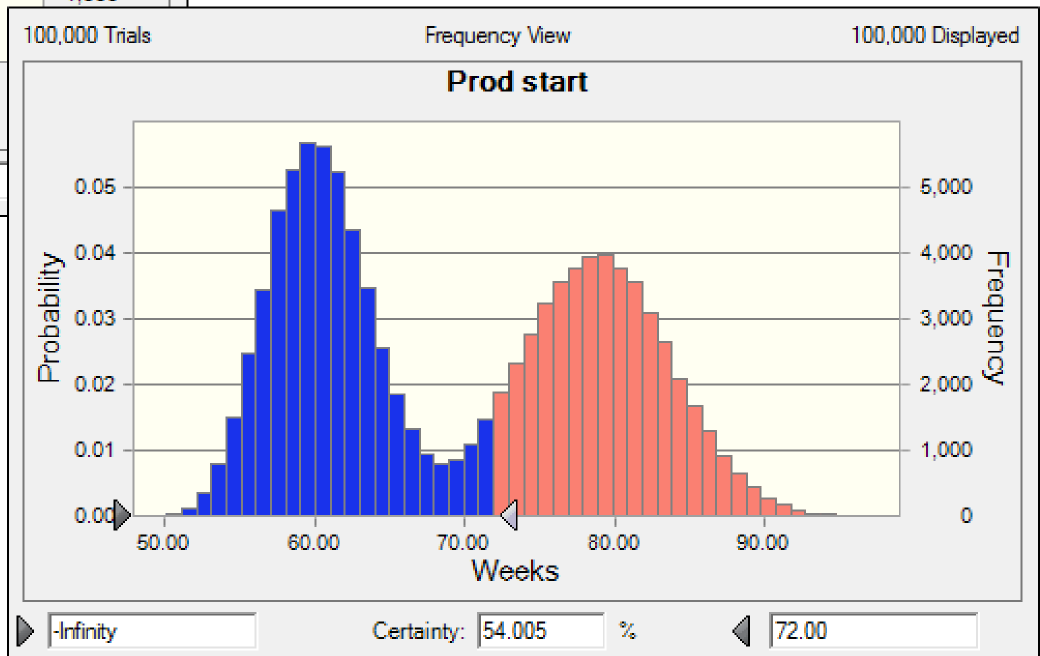
Above EXCEL™ file is using Crystal Ball™ (Monte Carlo Simulation add-on the EXCEL™)

Crystal Ball(CB)™ Output – Quantifies Probability of Missing Deadline

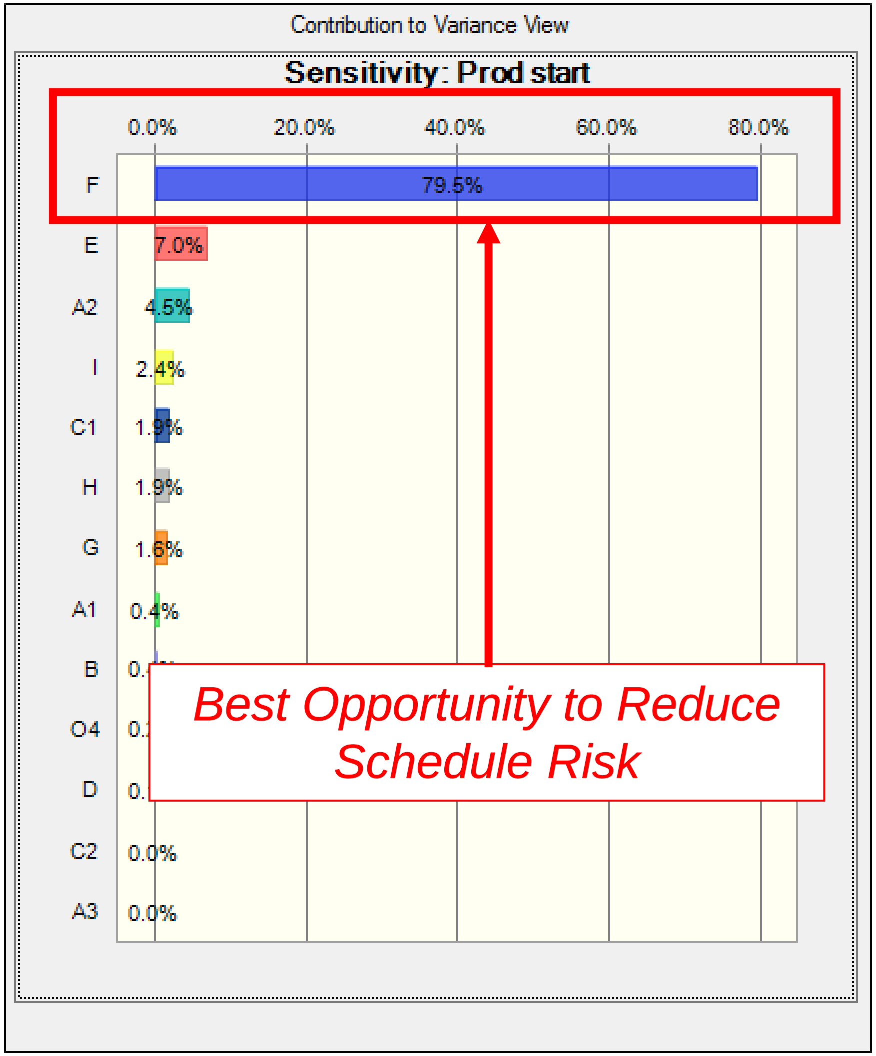
Odds of Completing Plan
Within 56 days: 5 %
(95% Risk of Being Late)



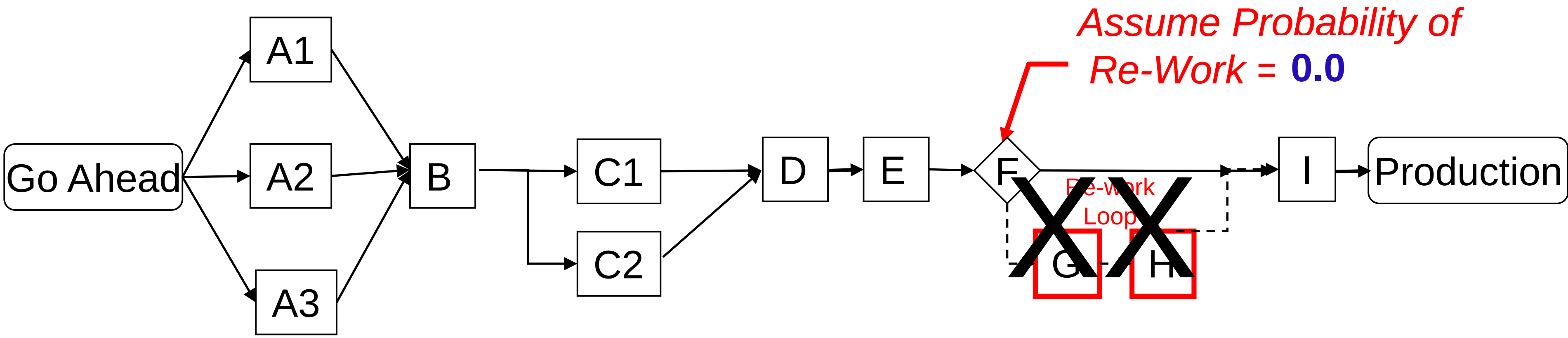
Odds of Completing Plan
Within 72 days: 54 %
(46% Risk of being late)

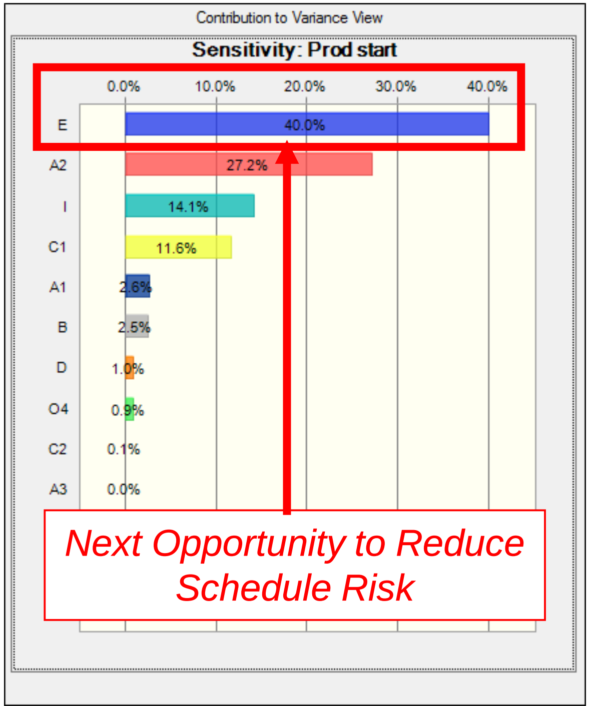


CB Output – Sensitivity of Total Process Time to each Task



Eliminate the re-Work Loop….





Probability of Completing Plan Within 72 days: 0.99 (~0 Risk of Being Late)