Probabilistic cost estimation with @Risk

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ABOUT PALISADE CORPORATION



APALISADE

PRODUCTS

The Decision Tools Suite 7.6:

• @RISK

•

•

•

Top Rank

Evolver

- Montecarlo Simulation
- Deterministic Sensitivity Analysis

Neural Network Predictive Analysis

- Deterministic Optimization
- Risk Optimizer* Probabilistic Optimization *Only available in @Risk Industrial

Statistical Analysis

Mind mapping

- Precision Tree Decision Tree Analysis
- Stat Tools
- Neural Tools
- Big Picture
- @Risk for Project^{**}

Project Risk Assessment **Requires Microsoft Project



















THE STATE OF RISK OVERSIGHT

The flaw of averages



Plans based on average assumptions are incorrect in average



THE STATE OF RISK OVERSIGHT

2018

THE STATE OF RISK OVERSIGHT

AN OVERVIEW OF ENTERPRISE RISK MANAGEMENT PRACTICES

9TH EDITION | MARCH 2018



- 47% of projects exceed their original Budget due to an incorrect estimation of costs and resources.
- Almost 50% of all projects were changed throughout their life cycle due to changes in required tasks.
- 48% of projects have shown losses of different types which create a sense of failure. This situation makes organizations' plans less productive and more expensive.
- In average, organizations waste 10% for each dollar being invested in projects due to a non-sufficient performance of projects.
- Probabilities of achieiving succesful projects are highly discouraging, with a rate as low as 50%. Therefore, there is an urgent need of a culture shift towards **Project Management**.



TRADITIONAL QUALITATIVE RISK ANALYSIS

| Ocurrence | Score | | | | | | | | | _ |
|-------------|-------|---|-------|-----|---|----------|-----------|-----------|---|---|
| Not likely | 1 | | | 2J | | | | | | |
| low | | | роос | 4 | | | | | | L |
| probability | 2 | | ikeli | S | | | | | | |
| Likely | 3 | | | 2 | | | | | | |
| Very likely | 4 | | | · · | | | | | | F |
| Certain | 5 | | | | 1 | 2 Con | 3 sequ | 4 ence | 5 | |
| | | • | | | | | | | 1 | |

| Priority | Description | Impact | Mitigation / Responsibility |
|----------|-------------|--------|--------------------------------|
| 1 | | | |
| | | | |
| n | | | |

Risk Register

| Impact in Time | Impact in cost | Technical impact | Score |
|--|-----------------------|--|-------|
| Minimum or No Impact | Minimum or no impact | Minimum or No Impact | 1 |
| Additional activities are required / Deadlines will be fulfilled | Increase Budget < 1% | Reduction in project's performance with small impact. | 2 |
| Minor deviation in current plan schedule | Increase Budget < 5% | Reduction in project's performance with médium impact. However, there are alternatives to meet expectations. | 3 |
| It affects the critical path of the project | Increase Budget < 10% | Not acceptable but there are available alternatives | 4 |
| A project's milestone won't be accomplished | Increase Budget > 10% | Not acceptable. There are no available alternatives. | 5 |



TRADITIONAL QUALITATIVE RISK ANALYSIS

Risk Index = Probability x Impact







Risk Analysis

- Qualitative Risk Analysis Risk analysis used to screen risks wherein risk probabilities of occurrence and impacts are expressed narratively or in ranked categories of severity
- Quantitative Risk Analysis Risk analysis used to estimate a numerical value (usually probabilistic) on risk outcomes wherein risk probabilities of occurrence and impact values are used directly rather than expressing severity narratively or by ranking as in qualitative methods
 - Assessing the range of possible outcomes, their probabilities or likelihoods, causal factors, and their interrelationships.



DETERMINISTIC VS PROBABILISTIC RISK ANALYSIS





WHAT DOES @RISK DO?

- » @Risk helps to make a transition from Deterministic models into Probabilistic models
 - It can include one or several variables
 - It provides additional information to the "single number approach"
- » @Risk generates results that are important for Risk Analysis
 - It provides a statistical distribution of results by using Montecarlo Simulation





» It is not a single method

» It is a set of procedures that ...

- Combine a set of inputs
- Generates random samples according to one or several probability distributions
- Calculates a set of scenarios for a final output

» History

- Enrico Fermi (1930)
- Stanislaw Ulam (1946) Solitaire
- John Von Neumann





A typical Deterministic Model



Every input variable is located inside of an Excel cell without any type of uncertainty. Generally speaking, input variables are obtained from AVERAGE historical data.



A typical Motecarlo Model (Probabilistic approach)



Each input variable is associated to a probability distribution. It is possible to include correlations among these variables.

The model gets to be recalculated thousands of times by using sample data from input variables. Therefore, new distributions are generated for each of the output variables that were previously defined by the user.



Deterministic vs Probabilistic Approach





Case : Project cost estimation model

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| Dist | Image: Construction of the construc | 1000 2 2 Start Simulation tion | ixcel Browse Results | Advanced RISK Time Analyses * Optimizer * Series * Tools | Project Library • • • • • • • • • • • • • • • • • • • | Vtilities • Color Cells • Thumbnails • • Utilities | |
| A11 | - : × ✓ fr | | | | | | |
| | А | В | С | D | E | F | G |
| 1 | Project Data | Sta | rt together | Requires Tasks 1 & 2 | Requires task 3 | Start togerther | & Require Task 4 |
| 2 | | Task 1 | Task 2 | Task 3 | Task 4 | Task 5 | Task 6 |
| 3 | Monthly Cost | \$ 2,800.0 | 0 \$ 3,000.00 | \$ 1,400.00 | \$ 2,900.00 | \$ 2,500.00 | \$ 2,100.00 |
| 4 | | | | First Milestone | | Second I | Vilestone |
| 5 | | | | | | | |
| 6 | Deadline for Milestone 1 | 13 | Months | | | | |
| 7 | Deadline for Milestone 2 | 27 | Months | | | | |
| 8 | Additional Bonus 1 (Based on Milestone 1 Completion) | \$ 20,000.0 | 0 | | | | |
| 9 | Additional Bonus 2 (Based on Milestone 2 Completion) | \$ 30,000.0 | 0 | | | | |
| 10 | Additional Bonus 3 (Based on completion of both milestones) | \$ 15,000,0 | n | | | | |

Net project Cost = Gross project cost + Bonuses (if applicable)



Case : Project cost estimation model

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| B42 | • : × ✓ fr | | | | | | |
| | А | В | С | D | E | F | G |
| 12 | Variability parameters for unkown duration tim | es Task 1 | Task 2 | Task 3 | Task 4 | Task 5 | Task 6 |
| 13 | Historical data | NO | NO | NO | NO | NO | YES |
| 14 | Minimum number of months | 6.0 | 6.00 | 5.00 | | | |
| 15 | Lower percentile | | | | 8% | | |
| 16 | Limit for lower percentile | | | | 4.50 | | |
| 17 | Intermediate percentile | | | | 50% | | |
| 18 | Limit for intermediate percentile | | | | 5.40 | | |
| 19 | Most Likely value | | 6.90 | 5.90 | | 6.9 | 6.0 |
| 20 | Upper percentile | | | | 92% | | |
| 21 | Limt for upper percentile | | | | 6.30 | | |
| 22 | Maximum number of months | 9.0 | 8.50 | 7.50 | | | |
| 23 | Standard deviation | | | | | | 0.5 |
| 24 | Absolute deviation with respect to Most Likely Value | | | | | 0.9 | |
| 25 | Simmetry | | | | | | |
| 26 | Low Probability of extreme values | NO | NO | YES | NO | YES | |
| 27 | · · · · · · · · · · · · · · · · · · · | | | | | | |
| 28 | Uncertain inputs | | | | | | |
| 29 | Months to complete | 7.50 | 6.90 | 5.90 | 5.40 | 6.90 | 6.00 |



Case : Project cost estimation model

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| | Model Sir | mulation | Results | Tools | | Utilities | |
| A28 | \cdot : \times \checkmark f_x Uncertain inputs | | | | | | |
| | А | В | С | D | E | F | G |
| 28 | Uncertain inputs | | | | | | |
| 29 | Months to complete | 7.50 | 6.90 | 5.90 | 5.40 | 6.90 | 6.00 |
| 30 | | | | | | | |
| 31 | Outputs | | | | | | |
| 32 | | Task 1 | Task 2 | Task 3 | Task 4 | Task 5 | Task 6 |
| 33 | Part of critical path (1=Yes, 0=No) | 1 | 0 | 1 | 1 | 1 | 0 |
| 34 | | | | | | | |
| 35 | Time to complete milestone 1 (Months) | 13.40 | | | | | |
| 36 | Time to complete milestone 2 (Months) | 25.70 | Project FINISHED | | | | |
| 37 | Bonus for achieving Milestone 1 on time | \$- | | | | | |
| 38 | Bonus for achieving Milestone 2 on time | \$ 30,000.00 | | | | | |
| 39 | Bonus for archieving both milestones | \$- | | | | | |
| 40 | Gross project cost | \$ 95,470.00 | | | | | |
| 41 | Net project cost | \$ 65,470.00 | | | | | |



Uniform Distribution (RISKUNIFORM)

Description

- All values occur within a range with the same probability
- It is also known as "Rectangular Distribution"

Examples

- Random number generation (needed to generate other type of variables)
- Time samples taken at random intervals



- Minimum expected value
- Maximum expected value



Triangular Distribution (RISKTRIANG)

Description

- It is used whenever there is information about minimum, maximum and most likely values
- It is recommended when we have little information about the reality we need to model
- Easy to calculate and generate

Examples

- Product pricing
- Manufacturing costs



- Most likely value (mode)
- Minimum and Maximum values



Pert Distribution (RISKPERT)

Description

- The best alternative to the Triangular Distribution
- Smoothing approach
- Extreme values are less likely to occur

Examples

- Product pricing
- Manufacturing costs
- Sales volume
- Raw materials prices



- Most likely value (mode)
- Minimum and máximum values



Triangular vs Pert



% of cases for Upper Tail in Triang Function (greater than Pert Distribution)



ALT functions in @Risk

RiskTriangAlt



RiskPertAlt



- % associated to lower percentiles
- Lower percentile value
- % associated to second percentile
- Second percentile
- % associated to upper percentile
- Upper percentile



Normal Distribution (RISKNORMAL)

Description

- It is the most popular distribution of all as it describes many natural phenomena suchas people's IQ and heights.
- It is being used in several scientific applications where variability is explained by a single cause.
- It has Infinite Limits Watch out !

Examples

- Process variation
- Inflation rates
- Price of goods
- Measurement errors
- Population sampling
- Volume forecasts



Input variables

- Mean
- Standard Deviation



Distribution Fitting

Description

- Highly Effective to compare a hypothetical distribution against historical sample data
- It combines the effect of multiple assumptions
- It is important to remove any trends or stationary behaviour of data



Example

Historical price data

Input parameters

Data source



The Risk Register

| | 5 ¢ | Ŧ | | | Project Cost I | Estimation Model (I | nitial).xlsx - Excel | | | | |
|---------------|------------------------------|------------------------------------|----------------------------------|------------------------------|---|-------------------------------|----------------------------------|-------------|--------------|-------------------|---|
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| | | Model | Simulation | | Results | | | Tools | | Ut | ilities |
| A2 | - | × ✓ fx Risk # | | | | | | | | | |
| | А | В | C | | D | E | F | G | Н | Ι | J |
| 1 | | Addit | ional Risks | | | | | | | | |
| 2 | Risk # | Description | Task unde | r impact Pi | robability of Ocurrence | Minimum Impact (Months) | Maximu m Impact (Months) | | | | |
| 3 | 1 | Government Labor issues | Task 1 & | Task 2 | 60% | 1 | 5 | | | | |
| 4 | 2 | Bad weather | Task 3 & | Task 4 | 30% | 1 | 2 | | | | |
| 5 | 3 | Delivery's delay from suppliers | Task | : 6 | 45% | 1 | 8 | | | | |



Bernoulli Distribution (RISKBERNOULLI)

Description

It only allows integer values

- 0 = Failure, 1 = Success
- p : Probability of success in a single trial
- RiskBernoulli(p) = Result for a trial



Example

- Flipping a coin
- Ocurrence of a single event

Input parameters

p = Probability of ocurrence of a Success



@RISK for MS Project

- » Allows simulation of project schedules using @RISK for Excel
- » Modeling is done in Excel vs. earlier versions of @RISK for Project where all modeling was done in Microsoft Project
- » All scheduling calculations are still done in Project
- » How does this happen?





Excel is a New "View" of a Project

- » A new communication layer between Excel and Project was built
 - This allows live updating of schedules in Project when changes are made in Excel
 - Combines the best of two worlds Excel formulas, functions, graphs and the Microsoft Project scheduling engine

Project takes the Values are sent to All schedule This ensures that values sampled in Project and schedule is Results go back to calculations during results are calculated @RISK for Excel or recalculated using @RISK for Excel simulations are done just as an add-in to calculated with Excel those values in Project Project would do formulas



Risk Approach Traditional vs Integration Approach



Gantt

Chart

(Project)

Cash

Schedule Risk Analysis

Risk

Register

Traditional

- » Use Excel for CostRisk Management
- » Use MS Project for Duration Cost Management
 - CPM, Slack time, etc.

Integration

- » Excel + MS Project
- » Run analysis simultaneously
 - Cost + Duration
- » Components linked
 - Gantt Chart
 - Risk Register



What does a User Need?

- » An installed copy of Excel and the new version of @RISK for Excel that supports project schedules
- » An installed copy of Microsoft Project 2003 or higher
- » Project schedules in MPP format that they want to analyze for risk



@RISK for Project Interface





Import MPP File



| Import Settings: Correlations | × |
|--|--------------------|
| Import Project to | |
| New Workbook | |
| C Active Workbook | |
| Project Tables to Import | |
| Task Table | @RISK 💌 |
| Resource Table | @RISK 💌 |
| @RISK 4.x Data to Import | |
| Imported Table - Data is Located in <none></none> | Field(s): |
| O All Text Fields in Project - Data is Lo <none></none> | cated in Field(s): |
| | OK Cancel |



New Risk for Project Interface

| | १ र २ र <u>द</u> े। र | _ | Book | 1 - Microsoft E | ixcel | - | _ | _ | _ | _ | • X |
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| | E15 • (* f* | | | | | | | | | | * |
| A | В | С | D | E | I | J | К | L | М | N | 0 |
| 1 | Name | Duration | Start | Finish | Sep-2010 | Oct-2010 | Nov-2010 | Dec-2010 | Jan-2011 | Feb-2011 | Mar-2011 |
| 2 1 | Database Training | 178 days | 9/9/2010 | 5/16/2011 | | | | | | | |
| 3 2 | Move to new database system | 5 days | 9/9/2010 | 9/15/2010 | | | | | | | |
| 4 3 | Install software | 3 days | 9/16/2010 | 9/20/2010 | 1 | | | | | | |
| 5 4 | Install test drive | 20 days | 9/21/2010 | 10/18/2010 | | | $\langle \rangle$ | | | | = |
| 6 5 | Set up terminals | 10 days | 10/19/2010 | 11/1/2010 | | | | $\langle \rangle$ | | | |
| 7 6 | Work software tutorials | 30 days | 11/2/2010 | 12/13/2010 | | 1 | | | | | |
| 8 7 | Develop training class program | 30 days | 12/14/2010 | 1/24/2011 | | | | | | | |
| 9 8 | Group I training | 20 days | 1/25/2011 | 2/21/2011 | | | | A | \checkmark | | |
| 10 9 | Group II training | 20 days | 2/22/2011 | 3/21/2011 | | | | | | | |
| 11 10 | Group III training | 20 days | 3/22/2011 | 4/18/2011 | | | | | | \sim | |
| 12 11 | Group IV training | 20 days | 4/19/2011 | 5/16/2011 | | | | | | | |
| 13 | | | | | | | | | | | |
| 15 | | | | | | | | | | | • |
| Ready | I asks Kesources Sneeti Ka | | | | | | | | 100% (| | + |
| | | | | | | | | | | | ,i |



@Risk & MS Project in Action !

| 6 | 1 5 ¢ + | | | | | | Risk Model | with Registers.xl | sx - Excel | | | | | | | | Sign in | Œ |
|-------|--|--------------------------|--|-------------------------------|---------------------|---------------------------------|------------------------|-------------------|---------------------------|---|-----------|------------|------------------|---|-------------|----------|----------|----------|
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| 4 | A D | E | F | G | Н | 1 | Resource | K | 1 | U | V | vv | X | Ŷ | Z | AA | AB | AC |
| 1 | ID Task Name | Duration | Start | Finish | Predecessor | rs Cost | Names | Text11 | jul-2017 | ago-2017 | sep-2017 | oct-2017 | nov-2017 | dic-2017 | ene-2018 | feb-2018 | mar-2018 | abr-2018 |
| 2 | 1 SW Architecture Optimization | 167 days | 17/07/17 | 06/03/18 | | \$593,232.00 | | | | | | | | | | | | |
| 3 | 2 SW Modules Implementation | 71.2331302 | days 13/11/17 | 20/02/18 | | \$113,968.00 | 1 | -1 | | | | | | | | | | |
| 4 | 3 Legacy Code Refactoring | 63.997542 0 | lays 07/12/17 | 06/03/18 | | \$102,400.00 | 2 | -2 | | | | | | | | | | |
| 5 | 4 Performance Optimization | 15.9603228 | days 22/01/18 | 12/02/18 | | \$25,536.00 | 3 | RSK-4, RSK-5 | | | | | | | | | | |
| 6 | 5 Validation and Stabilization | | K - Output: I2 | 05/52/18 | | \$112,176.00 | | | | | 22 | | | | | | | |
| 7 | 6 System Integration Testing | 29.8 | | Drain at C | ant (Mitha | ut Diels Desister | -) | | Statistics G | rid | - | | | | | | | |
| 8 | 7 Quality Stabilization | 40.2 | \$566,88 | | ost (witho | | 508,656 | | P | roject Cost | <u> </u> | | | | | | | |
| 9 | 8 Packaging | 149 4.5 | 5.0% | | 90.0% | | | 5.0% | | Without Risk egister) | | | | | | | | |
| 10 | 9 CS - Milestone | 40 | | | | | | | Cell | Tasks!I2 | 2 | | | | | | * | |
| 11 | | 4.0 | | | | | | | Maximum | \$622,736.00 | 0 | | | | | | | |
| 12 | | 3.5 | - | | | | | | Mean | \$587,011.98 | 8 | | | | | | | |
| 14 | | 30 | | | | | | | 90% CI Mode | ± \$1,453.50 \$566,016.00 | 0 | | | | | | | |
| 15 | | 5.0 | | | | | | | Median | \$585,888.00 | 0 | | | | | | | |
| 16 | | <u></u> 2.5 | - | | | | | | Std Dev | \$12,840.54 | 4 | | | | | | | |
| 18 | | , se a | | | | | | | Kurtosis | 2.7812 | 2 | | | | | | | |
| 19 | | All 2.0 | | | | | | | Values | 213 | 3 | | | | | | | |
| 20 | | 1.5 | - | | | | | | Errors | (| 0 | | | | | | | |
| 21 | | _ | | | | | | | Left X | \$566,880 | | | | | | | | |
| 23 | | 1.0 | | | | | | | Left P | 5.0% | 6 | | | | | | | |
| 24 | | 0.5 | - | | | | | | Right X | \$608,656 | 6 | | | | | | | |
| 25 | | _ | | | | | | | Dif. X | \$41,776.00 | 0 | | | | | | | |
| 27 | | 0.0 | 8 8 | 8 8 | ġ | 00 | ģ | 8 | Dif. P | 90.0% | 6 | | | | | | | |
| 28 | | _ | 550,1 | 550,0 | 0'065 | 900 Y | ;610,С | 620,(| 0.000 5% | \$566,880.00 | 0 | | | | | | | |
| @RIS | K Simulating | | | vr v | • | •• • | | | 10% | 10 63A 9322 | | | | | | | | |
| | 8% | | | '] (₹ * ▲ | | | ~ | | 1 | Close | | | | | | | | |
| Itera | tion: 225 of 1000 | | | | | | | | | | | | | | | | | |
| Simu | lation: 1 of 3 | | | | | | | | | | | | | | | | | |
| Runt | ime: 00:00:25 of 00:06:03 | | | | | | | | | | | | | | | | | |
| Iters | Per Sec: 8.22 | | | | | | | | | | | | | | | | | |
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@Risk & MS Project in Action !

| | რ ძ | | | | | | | Risk Model with Registers | xlsx - Excel | |
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| A9 | × 1 | × | √ <i>f</i> x RS | K-1 | | | | | Advanced Analyses | |
| A | | В | | E | F | G | н | K L M N | Performs an advanced analysis | X Y Z AA AB |

Quantitative Risk Analysis of Program Schedule and Budget

Program Risk Register

| 5 | | Qualita | tive Anal | ysis | | | Quantitative Analysis | | | | | | | | | | |
|----------|---------|--|--|-----------------|-----------|---|---------------------------|-------------------|-------------|-----------------------------|------------------|--|-----------|-------------|--|--|--|
| 6 | Ris | ks Identification | Deten | ministic Analys | sis | Р | robabilistic Pre-Mitig | Analysis ation | | | Proba Po | bilistic Analy st-Mitigatior | ysis 1 | | | | |
| 8 | Risk ID | Risk Name | Severity in Days (Most Likely) | Probability | Risk Rank | Severity in Days | Probability | Occurs? | Risk Impact | Mitigation Cost(in days) | Severity in Days | Probability | Occurs? | Risk Impact | | | |
| 9 | RSK-1 | New features feasibility research might not have been sufficient | 15 | 0.35 | 5.25 | 21.33 | 0.35 | | 0.00 | 5 | 7.17 | 0.2 | | 5 | | | |
| 10 | RSK-2 | The scope of Legacy Code Refactoring effort can be much bigger than expected | 20 | 0.36 | 7.2 | 28.83 | 0.36 | | 0.00 | 10 | 15.83 | 0.2 | | 10 | | | |
| 11 | RSK-3 | Not all interdependencies between the subsystems were considered | 15 | 0.35 | 5.25 | 17.17 | 0.35 | | 0.00 | 5 | 13.00 | 0.1 | | 5 | | | |
| 12 | RSK-4 | Code Refactoring affects Performance and Quality | 15 | 0.35 | 5.25 | 17.17 | 0.35 | | 0.00 | 4 | 9.67 | 0.1 | | 4 | | | |
| 13 | RSK-5 | Performance not meeting specification | | | | 25.17 | 0.52 | | 25.17 | 10 | 11.83 | 0.1 | | 10 | | | |
| 14 | RSK-6 | Change can cause stability lavel to fall below acceptable level | 25 | 0.72 | 18 | 28.33 | 0.72 | 1 | 28.33 | 15 | 11.67 | 0.3 | 0 | 15 | | | |
| 15 | | | | | Over | all Risk | Imp | act d | ue to | o exte | ernal ris | sks | | | | | |
| 18 | Risk li | Risk Impact | t Deterministic (Total Expected Risk) 53.95 | | | Pre-Mitigation (Simulated Risks) 53.50 | | | | Post-Mitig (Simulated | gation Risks) | | 49 | | | | |
| 19 20 | | | | | | | | | | | | *Post-Mitigation Impact Plus Cost of Mitigation) | | | | | |



Any questions?







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