Project Management Institute. Romania

#MARATHONPM2021

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#ReinventingPM

Monte Carlo Simulation – a Practical Approach

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Why Projects are at risk?

All projects are risky since they are unique undertakings with varying degrees of complexity that aim to deliver benefits. They do this in a context of constraints and assumptions, while responding to stakeholder expectations that may be conflicting and changing.

How do we manage Project's risks?

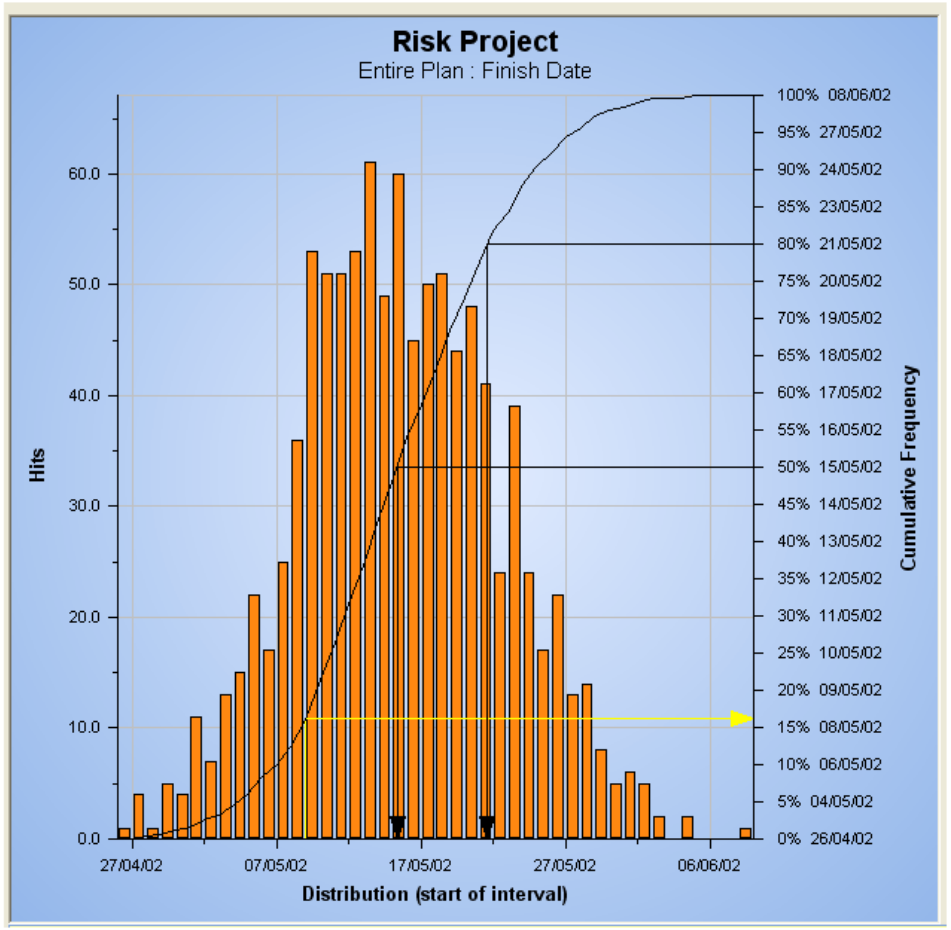
Project Risk Management aims to identify and manage risks that are not addressed by the other project management processes. Its processes will:

- Plan the strategy for dealing with risks.
- Identify as many risks as possible.
- Assess risks from a qualitative perspective.
- **Numerically quantify all high importance risks.**
- Plan risk responses at the action level.
- Implement the risk responses.
- Monitor the risk and continuously improve the Project Risk Management.

Quantitative Risk Analysis

Quantitative Risk Analysis is the process of numerically analyzing the combined effect of identified individual project risks and other sources of uncertainty on overall project objectives.

The key benefit of this process is that it quantifies overall project risk exposure, and it can also provide additional quantitative risk information to support risk response planning.



Representation of uncertainty

Where the duration, cost, or resource requirement for a planned activity is uncertain, the range of possible values can be represented in the model as a probability distribution. This may take several forms:

- Discrete distribution
- Continuous distribution

Discrete distribution

A discrete probability distribution describes the probability of the occurrence of each value of a discrete random variable. A discrete random variable is a random variable that has countable values. The variable is said to be random if the sum of the probabilities is one.

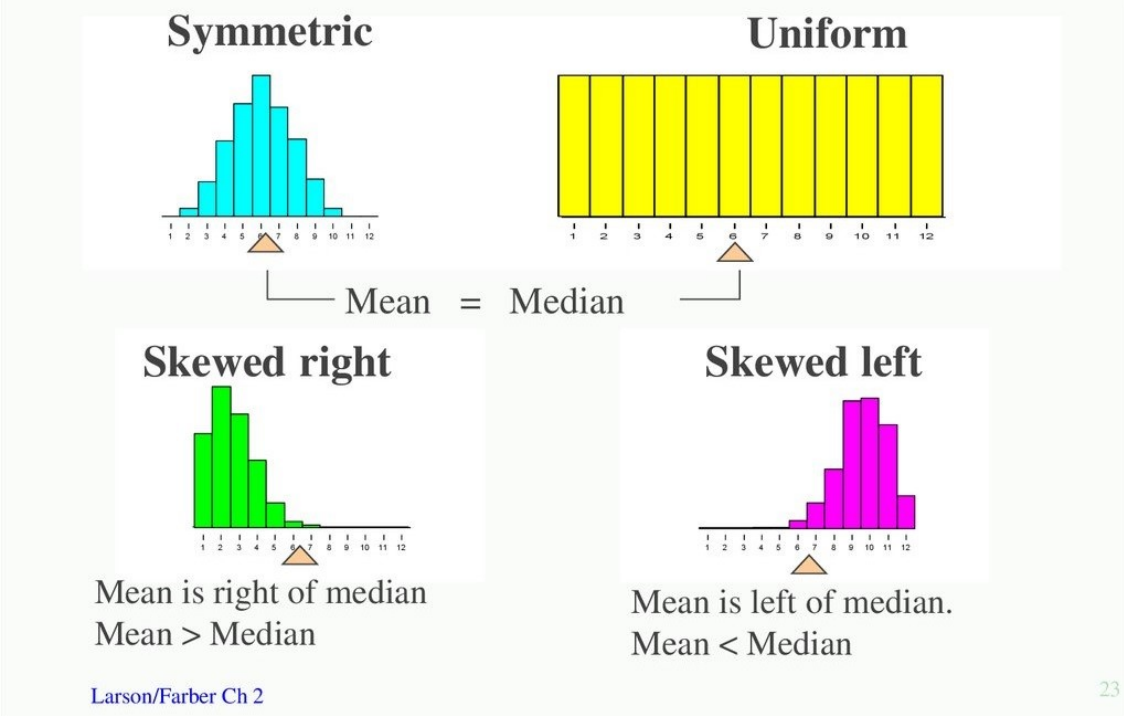
For example, if a coin is tossed three times, then the number of heads obtained can be 0, 1, 2 or 3. In other words, the number of heads can only take 4 values: 0, 1, 2, and 3 and so the variable is discrete.

Continuous distribution

A random variable whose value may fall anywhere in a range of values is a continuous random variable and will be associated with some **continuous distribution**.

Examples of continuous distribution types:

- Beta distribution
- Triangular distribution
- Uniform distribution
- Normal distribution
- Lognormal distribution

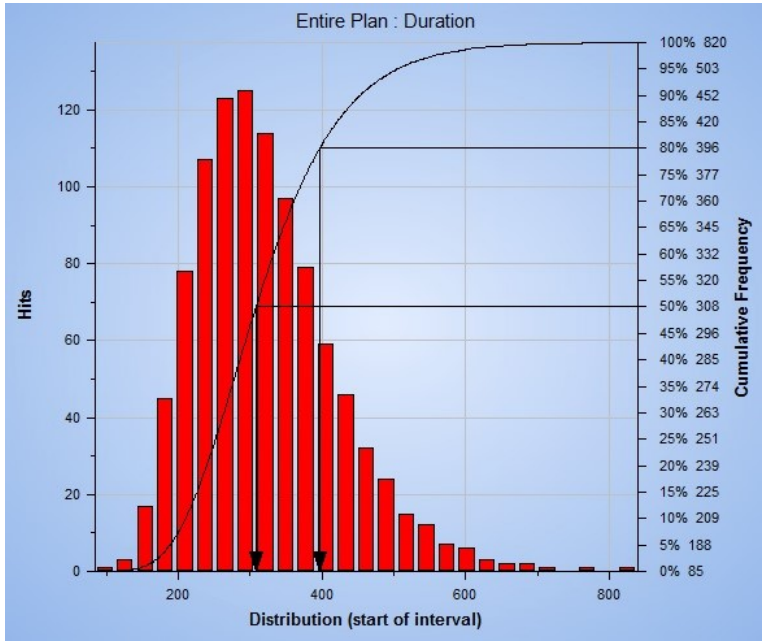


Monte Carlo Analysis - Definition

The Monte Carlo simulation is a quantitative risk analysis technique used in identifying the risk level of achieving objectives.

This technique was invented by an atomic nuclear scientist named Stanislaw Ulam in 1940, it was named Monte Carlo after the city in Monaco that is famous for casinos.

Monte Carlo Simulation is a mathematical technique that allows you to account for risks in decision-making. It helps you determine the impact of the identified risks by running multiple simulations and finding a range of outcomes.

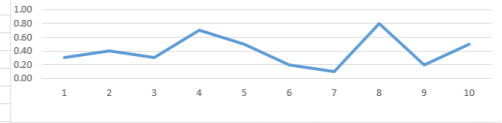


Monte Carlo Analysis - Definition

Monte Carlo simulations try to model the probability of different outcomes in a process that cannot easily be predicted due to the intervention of random variables. It is a technique used to understand the impact of risk and uncertainty in prediction and forecasting models. It is also referred to as a **multiple probability simulation**.

The basis of a Monte Carlo simulation involves assigning multiple values to an uncertain variable to achieve multiple results and then to average the results to obtain an estimate

10 Iterations										
Min value	9282.787	5691.686	5692.906	6224.032	7374.304	6410.124	3907.764	12130.98	6024.011	8096.763
Max value	19217.65	19428.94	23914.32	20173.94	18617.28	17526.02	21639.24	23386.93	19196.22	22501.2
Average	13117.07	12930.3	13824.58	15087.03	14350.45	11982.68	12066.38	18102.3	12302.4	14726.65
Prob > 15000	0.30	0.40	0.30	0.70	0.50	0.20	0.10	0.80	0.20	0.50



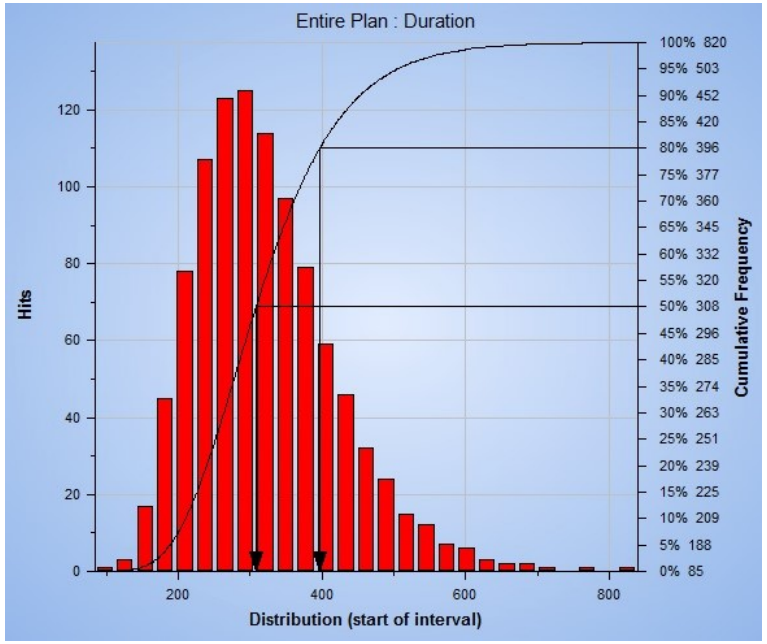
100 Iterations										
Min value	4005.265	5370.361	4621.028	4444.751	4938.007	5099.819	3557.353	2681.093	4655.151	5970.928
Max value	24239.33	24937.3	24565.79	21731.95	23935.79	21510.08	25089.13	20918.18	23783.11	24455.22
Average	13154.46	13882.74	13591.5	14015.49	12692.9	12699.19	13661.78	12178.74	13821.01	13464.13
Prob > 15000	0.35	0.41	0.39	0.42	0.28	0.26	0.4	0.23	0.42	0.36

1000 Iterations										
Min value	4193.612	3105.86	4083.344	2891.012	3644.405	3098.477	2929.791	3238.457	3020.828	3675.929
Max value	25735.44	26042.92	25695.79	25029.5	25376.43	24547.73	26760.03	25500.5	25658.94	24678.86
Average	13514.99	13579.81	13330.98	13661.41	13588.78	13391.09	13435.66	13413.2	13334.96	13406.44
Prob > 15000	0.38	0.38	0.36	0.38	0.38	0.37	0.36	0.38	0.36	0.35

Monte Carlo Analysis – How it works?

Unlike a normal forecasting model, Monte Carlo Simulation predicts a set of outcomes based on an estimated range of values versus a set of fixed input values. A Monte Carlo Simulation builds a model of possible results by leveraging a probability distribution, such as a uniform or normal distribution, for any variable that has inherent uncertainty.

It, then, recalculates the results over and over, each time using a different set of random numbers between the minimum and maximum values. In a typical Monte Carlo experiment, this exercise can be repeated thousands of times



Monte Carlo Analysis – Example 1

Let's discuss the Monte Carlo Simulation's use in determining the project schedule.

Suppose that you have three activities with the following estimates (in months):

Activity	Optimistic	Most Likely	Pessimistic	PERT Estimate
A	5	4	6	4.5
B	5	6	7	6
C	6	7	8	7
Total	16	17	21	17.5

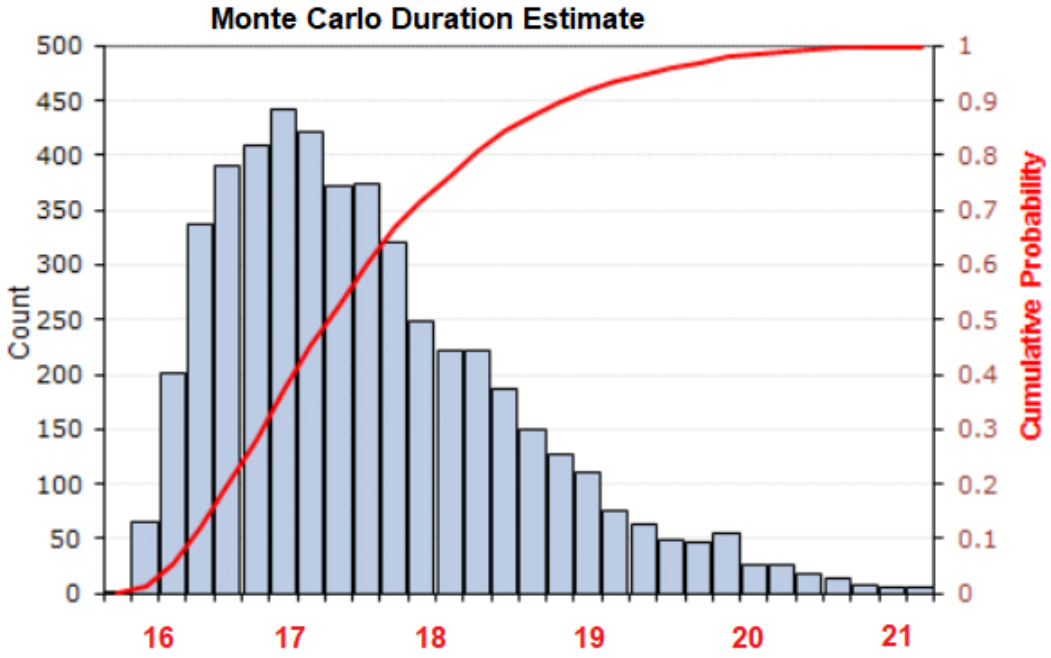
From the above table you can see that, according to the PERT estimate, you can complete these activities in 17.5 months.

In the best case, you can complete them in 16 months, and in the worst case, 21 months.

Monte Carlo Analysis – Example 1

Now, if we run the Monte Carlo Simulation for these tasks, one thousand times, it will show us the following results:

- 10% chance of completing the project in 16 months
- 35% chance of completing the project in 17 months
- 69% chance of completing the project in 18 months
- 70% chance of completing the project in 19 months
- 92% chance of completing the project in 20 months
- 100% chance of completing the project in 21 months



This technique provides you with a more in-depth analysis of your data, and you can make a better-informed decision.

Monte Carlo Analysis – The why?

The Monte Carlo simulation will help the Project Management Team with:

- **Probabilistic analysis of the project**. Estimates are made of potential project schedule and cost outcomes listing the possible completion dates and costs with their associated confidence levels. This output, often expressed as a cumulative frequency distribution, is used with stakeholder risk tolerances to permit quantification of the cost and time contingency reserves. Such contingency reserves are needed to bring the risk of overrunning stated project objectives to a level acceptable to the organization.
- **Probability of achieving cost and time objectives.** With the risks facing the project, the probability of achieving project objectives under the current plan can be estimated using quantitative risk analysis results, before and after corrective or preventive actions.

Monte Carlo Analysis – Limitations

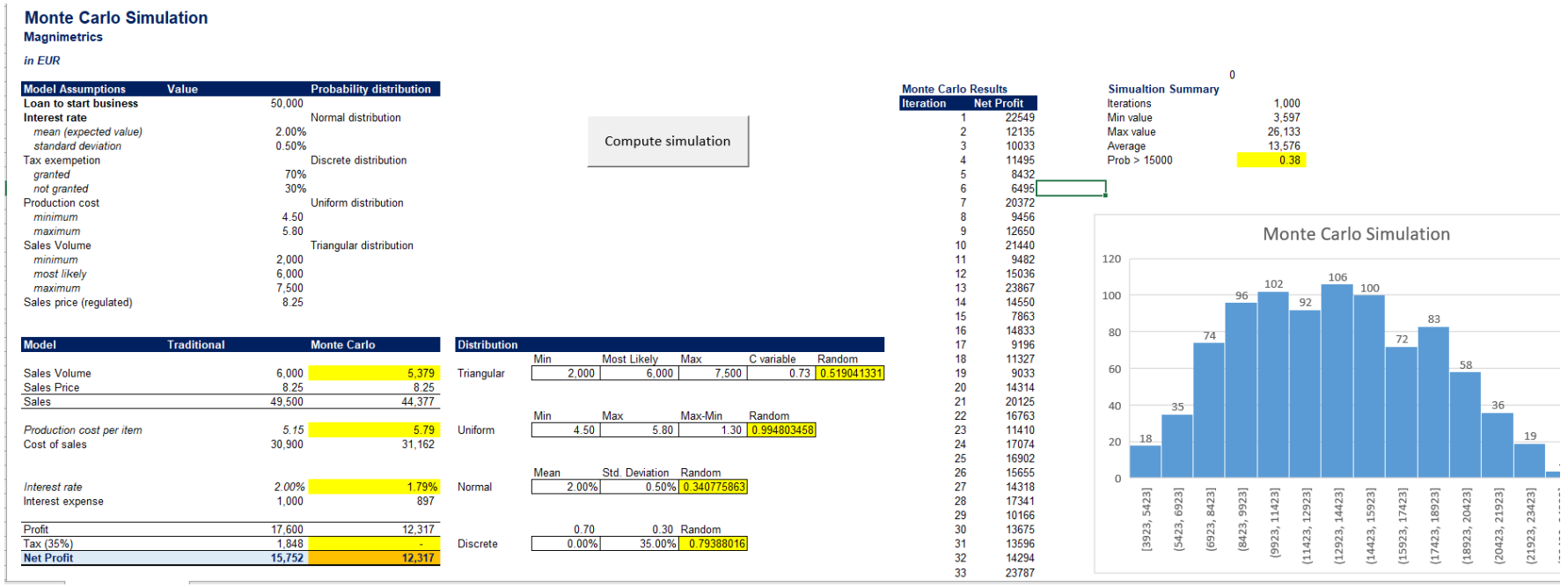
The Monte Carlo simulation has a few limitations, for example:

- The results depend on the quality of your estimates, so if the data are biased, the simulation will give a false result.
- The Monte Carlo Simulation shows the probability of completing the tasks, not the actual time to complete.
- This technique is not useful for a single activity; you need to have many activities with risk assessments completed.
- You will need to buy an add-on or a software program to run the Monte Carlo simulation

Monte Carlo Analysis – Example 2

Scenario

We are in the pre-project phase, and we are trying to determine the probability of achieving a certain objective of a potential project.



Monte Carlo Simulation
Magnimetrics

in EUR

Model Assumptions	Value	Probability distribution
Loan to start business	50,000	
Interest rate		Normal distribution
mean (expected value)	2.00%	
standard deviation	0.50%	
Tax exempetion		Discrete distribution
granted	70%	
not granted	30%	
Production cost		Uniform distribution
minimum	4.50	
maximum	5.80	
Sales Volume		Triangular distribution
minimum	2,000	
most likely	6,000	
maximum	7,500	
Sales price (regulated)	8.25	

Compute simulation

Model	Traditional	Monte Carlo
Sales Volume	6,000	5,379
Sales Price	8.25	8.25
Sales	49,500	44,377
Production cost per item	*5.15*	5.79
Cost of sales	30,900	31,162
Interest rate	*2.00%*	1.79%
Interest expense	1,000	897
Profit	17,600	12,317
Tax (35%)	1,848	-
Net Profit	**15,752**	**12,317**

Distribution	Min	Most Likely	Max	C variable	Random
Triangular	2,000	6,000	7,500	0.73	0.519041331
	Min	**Max**	**Max-Min**	**Random**	
Uniform	4.50	5.80	1.30	0.994803458	
	Mean	**Std. Deviation**	**Random**		
Normal	2.00%	0.50%	0.340775863		
	0.70	**0.30**	**Random**		
Discrete	0.00%	35.00%	0.79388016		

0

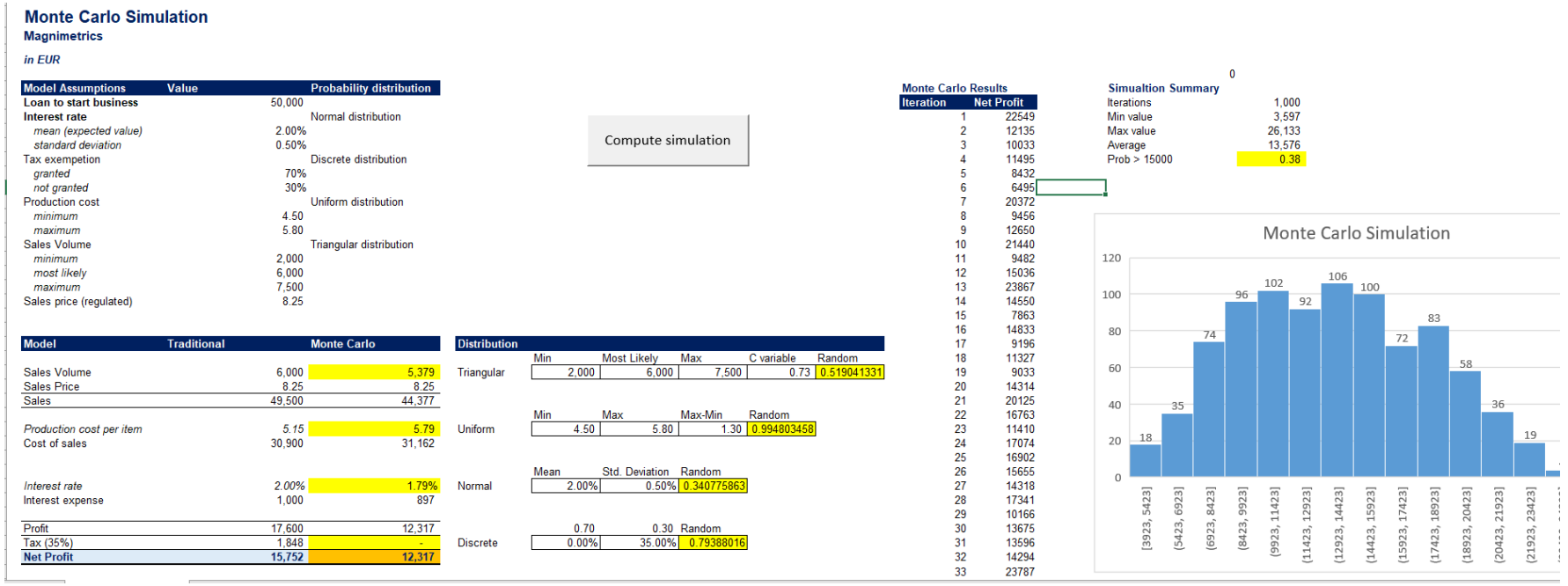
Monte Carlo Results	
Iteration	**Net Profit**
1	22549
2	12135
3	10033
4	11495
5	8432
6	6495
7	20372
8	9456
9	12650
10	21440
11	9482
12	15036
13	23867
14	14550
15	7863
16	14833
17	9196
18	11327
19	9033
20	14314
21	20125
22	16763
23	11410
24	17074
25	16902
26	15655
27	14318
28	17341
29	10166
30	13675
31	13596
32	14294
33	23787

Simualtion Summary	
Iterations	1,000
Min value	3,597
Max value	26,133
Average	13,576
Prob > 15000	0.38

Monte Carlo Analysis – Example 2

Scenario

Let's evaluate the feasibility of a project business case, which involve creating a new product. Variables like interest rate of the initial funding, production cost, sales volume, sale price and tax exemption must be assessed when all of them change simultaneous.



Monte Carlo Simulation
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Simualtion Summary

Iterations	1,000
Min value	3,597
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Monte Carlo Analysis – Example 2

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Conclusions

- Heavy business decisions can be better supported by Monte Carlo simulations, especially when more variable are involved in decision.
- More probability distribution types can be involved in the same model for the Monte Carlo simulation.
- The simulation allow all the variables to have different values on each iteration simulation, allowing to understand the real distribution of the possible outcomes.
- It is very important to generate simulations with as many iterations as possible, in order to have an as narrow as possible domain of results. The more iterations are calculated, the more reliable the results are.

Monte Carlo Analysis benefits

The Monte Carlo simulation method has many benefits in project management, such as:

- It helps you evaluate the risk of the project.
- It helps you predict the chances of failure, and schedule and cost overrun.
- It converts risks into numbers to assess the risk impact on the project objectives.
- It helps you build a realistic budget and schedule.
- It helps you gain management support for risk management.
- It helps you in decision making with objective evidence.
- It helps you to find the chances of achieving project milestones or intermediate goals.

References

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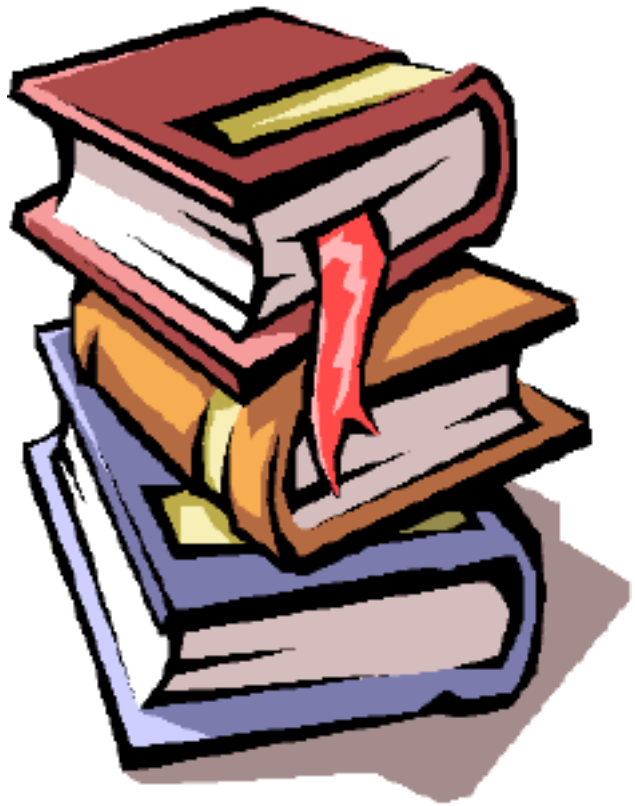

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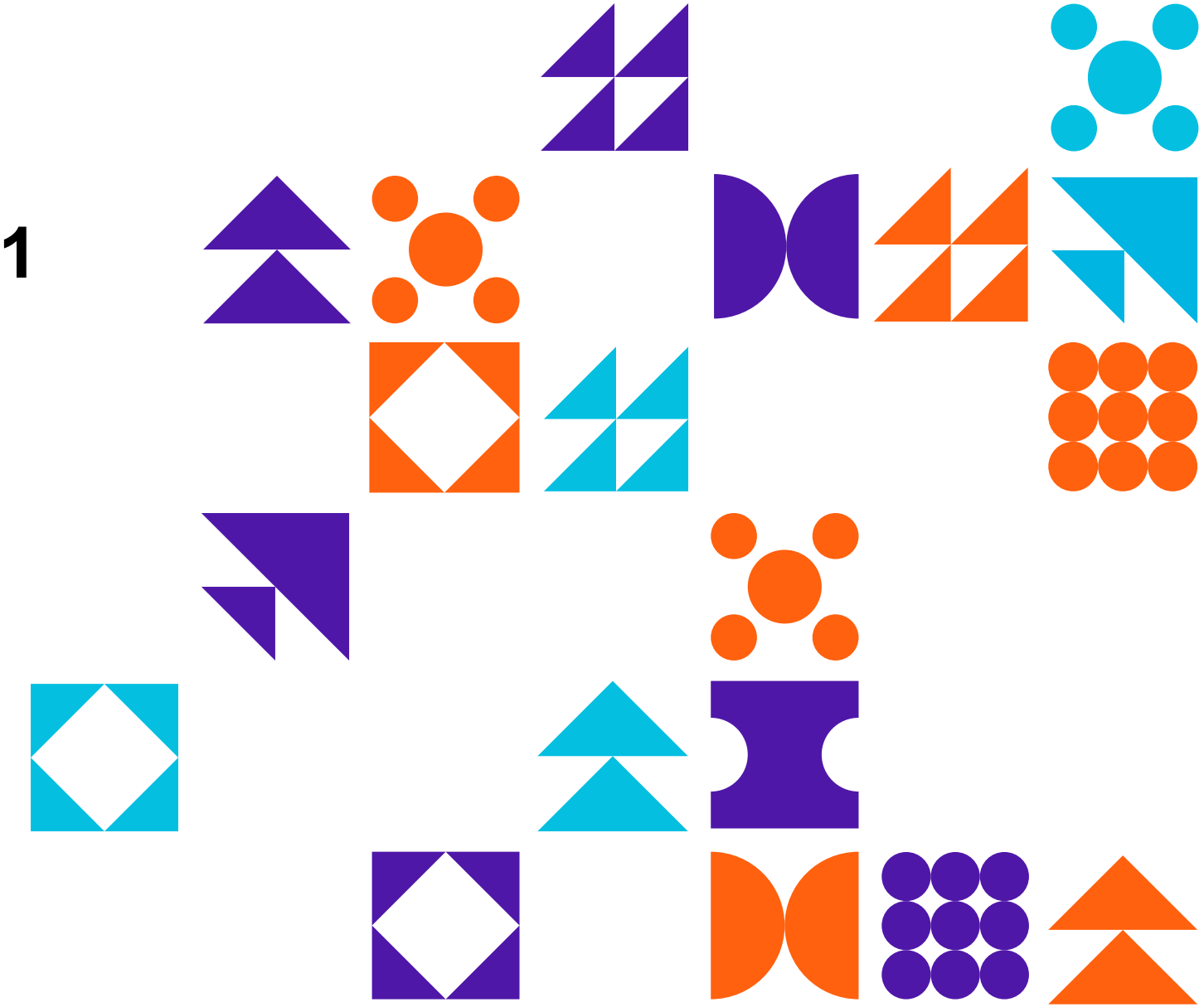

Thank You!

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