Coping With Uncertainty Using Monte Carlo Simulation Technique in a Casting Foundry

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Abstract— **It is very difficult for any factory to accomplish its target of maximum productivity with increased market demand and to satisfy consumer expectations. We need material planning to produce a product with a lot of small modules and we need to ensure that the flow of material on the manufacturing line is uninterrupted. In this article, the Monte Carlo simulation technique was used to calculate the profit or loss that a casting foundry may incur on the basis of random numbers produced using Microsoft Excel.**

Index Terms— **Monte Carlo Simulation, Break-Even point, Probabilities, Expected profit or loss incurred by a Casting Foundry**

I. INTRODUCTION

The Monte Carlo simulation, developed in the 1940's is a form of simulation that relies on repetitive random sampling and statistical analysis to establish the results. This simulation method relates to random experiments, experiments about which the precise outcome is not specified in advance. Monte Carlo simulations are employed to model the probability of multiple events in a mechanism that cannot be readily determined due to the intervention of random variables. It is a methodology used to consider the effect of risk and instability on prediction and forecasting models. This technique is limited to the use of random numbers to solve deterministic and stochastic problems. [1, 2]
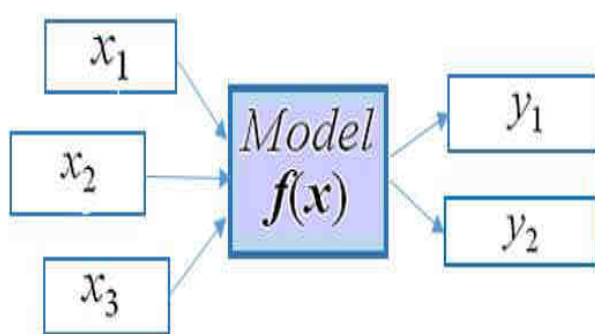

Figure 1- Mathematical Model

II. TERMINOLOGIES

1) Statistical distributions:
Statistical distributions or probability distributions identify the outcomes of various random variables and the

probabilities of these outcomes happening. If the random variable involves only discrete values, the subsequent probability distributions are called discrete probability distributions. Examples of this category include binomial distribution, Poisson distribution, and hyper-geometric distribution. From the other dimension, if the random variable takes continuous values, the resulting probability distributions are termed continuous probability distributions. Instances of this category are the normal, exponential, and gamma distributions.

2) Random sampling:
In statistics, a finite subset of individuals in a population is considered a sample. In random sampling, samples were obtained randomly from the population, which ensures that each population unit has an equal probability of being included in the survey. A randomly selected sample is supposed to be an impartial representative of the entire population. [3]

3) Random number generator:
A random number generator is a computational or physical tool designed to produce a series of numbers that tend to be independent from a population and that almost always pass a series of statistical tests. They are also named the Pseudo-random number generators. This figures are between 0 and 1 (0 and 100 percent) because the random numbers generated by this approach are not real but simulated. Random numbers can be created on a computer. The Random Number Generator is a technology designed to obtain a sequence that has no pattern and thus appears to be random. [4]

4) Software random generators (PRNG):
Software RNGs use mathematical algorithms to acquire random numbers, initialize an algorithm with a "seed" value obtained from a certain repetitive operation on the software, such as keystrokes, running operations, computer clocks, or mouse movements. However it is remarkably difficult to produce an absolutely random seed value, as most of these operations only serve seeds with a limited set of values. [5]

5) Hardware random generators (TRNG):
Hardware RNGs do not demand seeds since hardware random numbers are not computed values; they are not obtained from a repeatable algorithm. Instead, hardware-generated random numbers are digitized snapshots of naturally existing noise. As there is no algorithm and no repeated sets of numbers, even though a hacker might determine a number, he would not be able to use it to predict numbers. For this function, RNG hardware is known as Truly Random Number Generators, or TRNGs.

III. STEPS FOR MONTE CARLO SIMULATION

Usually, the following steps are conducted for the simulation of the Monte Carlo physical process.
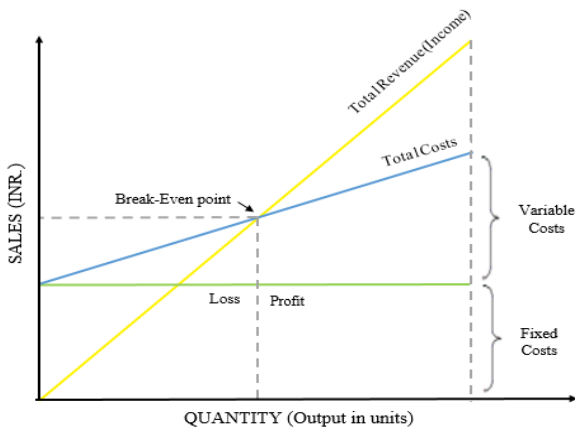

Figure 2- Break-Even Chart

1. Static Model Generation:

Any simulation of Monte Carlo begins with the creation of a deterministic model that closely resembles a real scenario. In this deterministic model, the most probable value (or base case) of the input parameters is used. We implement mathematical relationships that use input variable values and convert them to the desired output.

2. Input Distribution Identification:

If we are satisfied with the deterministic model, we introduce the risk components to the methodology. As mentioned earlier, since the risks derive from the stochastic nature of the input variables, we try to classify the underlying distributions, if any, that regulate the input variables. This step requires historical data for input variables. Standard statistical procedures are in place to define input distributions

3. Random Variable Generation:

Once we have established the underlying distributions of input variables, we create a set of random numbers (also called random variables or random samples) from such distributions. A set of random numbers, consisting about one value for each of the input variables, will be utilized in the deterministic model to provide one set of output values. Then we replicate this step by producing more sets of random numbers, one for each input distribution, and collecting various sets of potential output values. This section is at the core of the Monte Carlo simulation.

4. Analysis and Decision Making:

After we have retrieved a sample of the output values from the simulation, we can perform a statistical analysis of those values. This step gives us statistical consistency in the decisions that we could make after we run the simulation.

IV. BREAK EVEN ANALYSIS METHOD

Break-even analysis is a financial tool that allows a business to assess the point at which the company or a potential service or product would be profitable. In other terms, a financial calculation is used to calculate the amount of goods or services that a business can sell or deliver to cover its expenses. Break-even is a scenario where a company does not make money or lose revenue, but all expenses have been covered. Break-even analysis is useful in analyzing the relationship between variable costs, fixed costs and sales. [5]

1. Components of Break Even Analysis:

* Fixed costs:

Fixed costs are also referred to as overhead costs. They are expenses that do not change with varying outputs. Such overhead costs arise after the decision to pursue an economic activity has been taken and these costs are explicitly related to the level of production, but not to the quantity of production. Fixed costs include (but are not limited to) interest, taxes, wages, leasing, depreciation, labor costs, energy costs, etc. This costs are set in relation to demand. The costs must therefore be incurred in the event of no output.

* Variable costs:

Variable costs are costs that enhance or reduce directly in relation to the volume of production. These encompass the cost of raw materials, the cost of packaging, the cost of fuel and other costs directly related to production.

* Sales costs:

The breakeven selling price informs users the minimum price for which you can market your products and still cover your costs. Computing the sale price breakeven for your product is a significant calculation when establishing your sale price. It should be calculated over a range of production and sales quantities. [6, 7]

2. Calculation of Break-Even Analysis:

The basic formula for the break-even analysis is derived by dividing the overall fixed cost of production by the contribution per unit, as follows:

$$Break\ even\ point\ in\ quantity\ (BEP) = \frac{FC}{Contribution\ per\ unit}\ or\ \frac{FC}{(P-VC)}$$

$$*FC = [Total\ Fixed\ Costs]$$
$$VC = [Variable\ costs\ per\ unit]$$
$$P = [Average\ price\ per\ unit]$$

The other formulas include:

$$Contribution\ per\ unit = selling\ price\ per\ unit - variable\ costs\ per\ unit$$

$$Contribution\ Margin = Price\ of\ Product - Variable\ Costs$$

3. Applications of Break-Even Analysis:

* Starting a new business:

A break-even analysis is a prerequisite to start a new business. Not only does it help to decide whether the idea of starting a new business is sustainable, but it will compel the start-up to be cost-effective and provide the basis for the pricing strategy. [8, 9]

* Creating a new product:

In the case of an existing business, the company should continue to conduct a break-even analysis prior to the introduction of a new product, especially if such a product contributes significant expenditure.

- Changing the business model:

When the firm is heading to change the business model, such as shifting from wholesale to retail, so a break-even review must be carried out. Costs could change considerably and the breakeven analysis would help to set the sale price.

- It helps to evaluate the remaining/unused potential of the organization after the breakeven has been achieved. This will help demonstrate the full benefit on a given product/service that can be produced.
- It helps to analyze the effect on profit on manual automation switch (a fixed cost replaces a variable cost).
- It helps to evaluate the change in earnings if the value of a stock is changed.
- Helps determine the proportion of damages that may be suffered if there is a decline in revenue. In addition, a break-even analysis is very advantageous to know the total potential of a company to earn profit. In the case of a company whose breakeven point is similar to the highest cost of revenue, this means that it is almost impractical for a company to make a profit except in the best of situations. It is also the management's duty to continuously track the breakeven stage. Of necessity, this tracking decreases the breakeven point wherever possible.

4. Ways to monitor Break-even point:
- Pricing analysis:

Minimize or eliminate the use of discounts or other price cutting incentives, as such promotional strategies raise the breakeven point.

- Technology analysis:

Implement any technologies that can increase market performance, thus increasing efficiency at no extra expense.

- Cost analysis:

The continuous analysis of all fixed costs to check if any can be eliminated can definitely benefit. Often, study the total variable cost to see if they can be excluded. This study would raise the margin and reduce the breakeven point.

- Margin analysis:

Push sales of the maximum margin (high contribution earnings) products and pay meticulous attention to product margins, thus decreasing the breakeven point.

- Outsourcing:

If the task consists of a fixed cost, aim to outsource the activity (whenever feasible), which lowers the breakeven point.

5. Benefits of Break-even analysis:
- Catch missing expenses:

When you consider regarding a new business, it's very probable that you could forget about a few expenditures. A break-even analysis will also allow you to evaluate all financial commitments in order to identify your break-even point. This analysis definitely limits the amount of challenges on the way or at least prepares a business for them.

- Set revenue targets:

Once the break-even analysis is done, you will get to see how much you need to sell to make a profit.

- Make smarter decisions:

Entrepreneurs often take emotion-based decisions about their companies. Emotion is essential, that is, how you feel, even if it's not enough. To be a good entrepreneur, choices should be based on facts.

- Fund your business:

This study is a core component of every business strategy. Usually, this is a prerequisite if you want outsiders to finance your company. You need to show that your strategy is feasible in order to finance your company. In addition, if the report looks good, you would be confident enough to take on the burden of different forms of funding.

- Better Pricing:

Finding a break-even point would help to appropriately price the items. This tool is commonly used to provide the best price on a commodity that will make the most profit without increasing the same price.

- Cover fixed costs:

Break-even analysis targets to cover the fixed costs.

V. SIMULATION OF THE CASTING FOUNDRY USING THE MONTE CARLO METHOD FOR A SPECIFIC PRODUCT AT A CERTAIN LOCATION

DEMAND	PROBABILITY	SALES PRICE	PROBABILITY	VARIABLE COST	PROBABILITY
1,000	0.05	100	0.1	5	0.25
5,000	0.2	250	0.4	10	0.2
10,000	0.35	500	0.25	15	0.1
25,000	0.3	750	0.15	20	0.3
50,000	0.1	1,000	0.1	25	0.15

Table 1-Probability of Uncertain Elements

1) *Introducing Uncertainty Elements:*
Assuming,

Fixed costs = Rs. 10,00,000

(Variable cost is uncertain, it can increase or decrease depending on the surrounding conditions)

(Sale Price is also uncertain, we do not know what market will sustain the sales price so it depends on the environment)

2) *Generating and Assigning Random Numbers:*
I. To generate a simulation event in an impartial manner, we allocate random numbers to events in the same proportion as their probability of occurrence.
II. Suppose we have 100 random numbers from 0-99

III. The assigning of random numbers follows the cumulative distribution of probability of demand

IV. Random variables are generated using the excel algorithm (=randbetween (0,99))

V. After random numbers are obtained, the material will be assigned.

RANDOM NUMBERS		
DEMAND	*SALES PRICE*	*VARIABLE COST*
79	5	33
7	78	11
53	55	63
10	16	46
0	76	1
27	86	47
8	17	22
62	16	27
7	36	10
75	51	70
60	39	65
34	90	45
75	31	58
49	57	56
27	29	31

Table 3- Generation of Random Numbers using Microsoft Excel

3) Establishing Cumulative Probability Distribution Table and Setting Random Number Intervals:

VARIABLE COST	PROBABILITY	CUMULATIVE PROBABILITY	RANGE	
			MINIMUM	MAXIMUM
5	0.25	0.25	0	24
10	0.2	0.45	25	44
15	0.1	0.55	45	54
20	0.3	0.85	55	84
25	0.15	1	85	99

DEMAND	PROBABILITY	CUMULATIVE PROBABILITY	RANGE	
			MINIMUM	MAXIMUM
1,000	0.05	0.05	0	4
5,000	0.2	0.25	5	24
10,000	0.35	0.6	25	59
25,000	0.3	0.9	60	89
50,000	0.1	1	90	99

SALES PRICE	PROBABILITY	CUMULATIVE PROBABILITY	RANGE	
			MINIMUM	MAXIMUM
100	0.1	0.1	0	9
250	0.4	0.5	10	49
500	0.25	0.75	50	74
750	0.15	0.9	75	89
1,000	0.1	1	90	99

4) Simulation:

Sr. No.	DEMAND	SALES PRICE	VARIABLE COST
1	25,000	100	10
2	5,000	750	5
3	10,000	500	20
4	5,000	250	15
5	1,000	750	5
6	10,000	750	15
7	5,000	250	5
8	25,000	250	10
9	5,000	250	5
10	25,000	500	20
11	25,0000	250	20
12	10,000	1,000	15
13	25,000	250	20
14	10,000	500	20
15	10,000	250	10

VI. RESULTS

This stimulation can help to find the following:

- Probability that the company can break even
- The Business shall make a profit of at least 50,000.
- The probability that the organization may incur losses of INR 50,000 or more

CONCLUSION

This analysis is informative in deciding whether a Casting Foundry will incur benefit or loss with the aid of random numbers generated using Microsoft Excel, using Monte Carlo simulation technique. It helps to assess the manager implication for the company. The Break-Even point is also evaluated, which is useful in the interpretation. It was concluded that the profit or loss incurred by the company can be determined by this methodology

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