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IMPLEMENTING MONTE CARLO SIMULATION MODEL FOR REVENUE FORECASTING UNDER THE IMPACT OF RISK AND UNCERTAINTY

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Abstract
In the existent world of continuous production systems, strong attention has been waged to anonymous risk that probably generates significant apprehension. The forecast for net present value is extremely important for any production plant. The objective of this paper is to implement Monte Carlo simulation technique for perceiving the impact of risk and uncertainty in prediction and forecasting company's profitability. The production unit under study is interested to make the initial investment by installing an additional spray dryer plant. The expressive values acquied from the Monte Carlo technique established a range of certain results. The expected net present value of the cash flow is $14,605, hence the frequency chart outcomes confirmed that there is the highest level of certainty that the company will achieve its target. To forecast the net present value for the next period, the results confirmed that there are 50.73% chances of achieving the outcomes. Considering the minimum and maximum values at 80% certainty level, it was observed that 80% chances exist that expected outcomes will be between $5,830 and $22,587. The model's sensitivity results validated that cash inflows had a greater sensitivity level of 21.1% and the cash inflows for the next year as 19.7%. Cumulative frequency distribution confirmed that the probability to achieve a maximum value of $23,520 is 90 % and for the value of $6,244 it is about 10 %. These validations suggested that controlling the expenditures, the company's outflows can also be controlled definitely.

Keywords
Risk analysis, management, Monte Carlo simulation model, crystal ball package software, production uncertainty.

Introduction

All the projects are initiated on the basis of certain problems that need to be completed for creating returns. The reduction of costs of a project is associated with uncertainty and risk [1]. The basic extents of risk and uncertainty as illustrated in Fig. 1 which shows the duration of the project with cash flows, the benefits from the outputs and the uncertainty regarding unexpected results due to the unanticipated implications [2]. The product completion time, process duration, resources allocations and budget are always uncertain especially in the early stage when not much work has been carried out. This is the point when there is a considerable degree of uncertainty [3]. However, these uncertainties may be diminished by implementing proper efforts and using some technological approaches. Making initial assumption regarding the application of risk analysis is to take probability distributions of required values which illustrate the relevant parameters along with variables related to the decisions making [4].

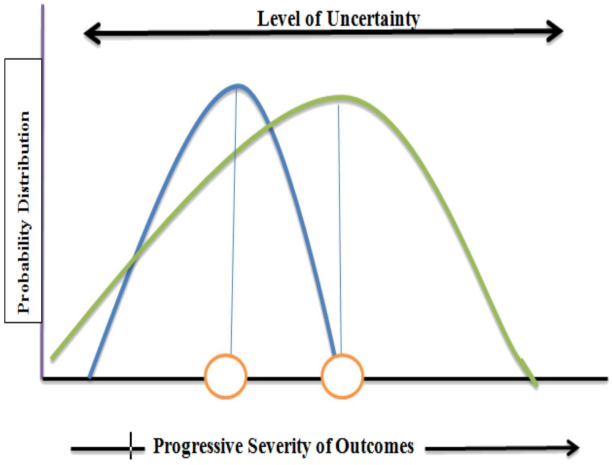

Fig. 1. Level of risk and uncertainty.

Monte Carlo simulation model

Monte Carlo simulation identifies the risk factors associated with the probability of occurrence of those aspects that cause to lower down the production rate [5]. It successfully demonstrates the intense possibilities for nearly all the risky situations and the most conformist decisions. Its work is based on substituting an assortment of input values, probability distribution for any given factor that has intrinsic uncertainty [6]. During the model simulation, the values are selected randomly from the input ranges while the final results are recomputed again and again [7]. Mathematically, an approximation of Monte Carlo is based on the possible expectation of random variables which may be defined using expression (1). The right side of expression only gives just approximation of what the random variable x expectation $E(x)$ is

$$E(x) \approx \frac{1}{n} \sum_{n=1}^{N} X_n. \tag{1}$$

The probability distribution functions for the simulation model define the relative probability of the expectations [8]. As shown in expression (2), the uniform distribution with a range from Y to Z, where $Y < Z$ are real numbers and gives equal probability to every number in its range

$$P(x) = \frac{1}{Z - Y}, \qquad Z \leq x \leq Y. \tag{2}$$

Usually, the cumulative distribution function is used for sampling purposes which are defined as an integral of the probability distribution function for the uniform distribution [9]. The expression (3) tells about the probability that a number sampled randomly from the probability distribution function will always be less than or equal to any number x

$$P(x) = \int_{Y}^{X} p(x) = \frac{x - Y}{Z - Y}, \qquad Y \leq x \leq Z. \tag{3}$$

Based on the number of uncertainty levels and ranges, a Monte Carlo simulation model may simulate a large number of recalculations before displaying the results [10]. It can successfully consign manufacturers in pose to constructively influence the general bottom line which offers a true picture that highlight the decisions that could be taken or avoided [7]. Any production firm that gets the benefit of this model will always possess a much better knowledge of how they are forced by risks explicit to their exceptional production models [11]. Some time Monte Carlo simulation discloses such risk factors that would have taken decision-makers by disclosure, or exposes such opportunities that might left ignored [12]. In this work, the Monte Carlo Simulation model has been presented for revenue forecasting that posses a great impact on the progress of production tasks related to Frontier Ceramics Company which is dealing with the production of ceramic wall tiles.

Research scheme and data sources

Determining the financial competence of investments in ceramics based production units is very complex due to the high setup of the initial expenses [13]. Current techniques that analyze the costs based on one financial business year does not deliver enough accurateness and consistency [14]. The equipment for the ceramic production units continues for several years. It is also conceivable that the commercial effect may not be similar in all years. Therefore, it is suggested to discount the income of each year for the desired period [15]. In this study, an applied approach for calculating the net present value, cash inflows, cash outflows and the payback period is implemented. The output values are obtained using software like MS Excel and Crystal Ball. Since probabilistic approaches for computing net present value may cover some constraints that vary with time, hence considering the uncertainty in the results using the Monte Carlo technique provides conceivable information for decision-making [16]. The current operating costs of the company include costs of raw material inputs, fuel, energy, maintenance system and the costs of the fixed assets. These are the independent variables and the key parameters which distress the indicators selected for the investigation of the company [17]. The company is interested to install

an additional spray dryer plant. The methodological approach is shown in Fig. 2 that describes the general steps flow chart of the simulation-based relationship among the input assumptions and net present value forecasting. More attention is focused on the construction work of the plant, price, assembly, and testing of the equipment. The foremost challenges in the dried powders are the reduction of production costs [18]. Through this way, the output of the newly installed plant is proposed to be maximized while the process conditions are supposed to be minimal concerning the product losses due to poor separation efficiencies of the cyclone, lower tangential particle speed at the radius of the leaving duct, decreasing slurry feed flow rate and increasing atomizing air flow rate which has a detrimental effect on the powder yield [19].

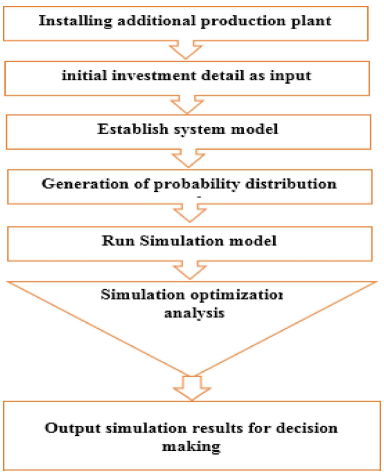

Fig. 2. General steps flow chart of simulation.

For this purpose, online product quality control using computational fluid dynamics (CFD) is proposed to be implemented in which the use of the prognostic computerized system will be very helpful. It will help to diminish the formation of coarse accumulation of large blocks as shown in Fig. 3. The reason for this composite interface is the process variables like hot airflow velocity and the impact of particles, the circulation of spray and the atomization process [20]. This phenomenon during the process of spray drying is referred to as the black box and is functioned by trial and error method. It is anticipated that installing the new system regarding current production level and marketing issues through which the company can get more benefits by facilitating more opportunities with truthful sales evidence [21]. However, the company has initiated necessary steps regarding installation works, installation of mechanical systems and auxiliary equipment, which all of them make the initial costs. The required initial investment is as follows: To upgrade the current system, the initial investment of $145,000 is reserved for purchasing and $120,000 is projected for installation.

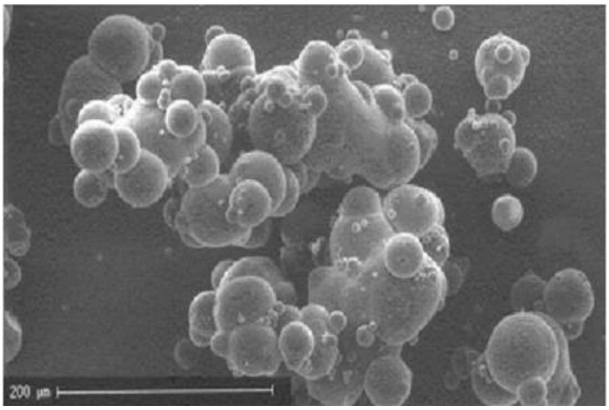

Fig. 3. Black box formation of spray-dried powder (source: X-ray powder diffraction (XRD)).

To integrate the new system into the current system interference another amount of $80,000 is required. Expected time for operating and installation is 1 year while another 1 year will be required for system integration. The updates for controlling system software are mandatory hence a considerable amount of outflows about $35,000 based on each 2nd year will be needed and that will begin in the early stage of the 4th year till the last year of its productive life. The expected outcomes with income seem to be generated in the third year, with a speedy and positive manner. These benefits will raise with a better probabilistic approach showing that estimated outcomes of $70,000 in the 1st financial year, $140,000 in the 2nd year followed by the gradual decline outline as described in Table 1. In the end, the software may be retailed out with a salvage value of $55,000. Establishing a hurdle frequency of 0.12 (12%) for all capital investments with an expected inflation rate of 3% about 3 percent for the project life. According to the table data since all the remaining expenses become apparent at the end of the year as lump sums, therefore, the Net Present Value of production unit is observed to be positive and thus the decision is to upgrade the system. For reviewing the payback period, the total cash inflows are $93,900 per annum based on an average of 10 years while the amount of investment needed is $345,000. Based on average for 10 years a straight forward depreciation amounting to $34,500, the Payback Period is computed using expression (4)

$$P.B.P \frac{\text{Investmentneed}}{\text{cash inflows} + \text{depriciation amount}}. \quad (4)$$

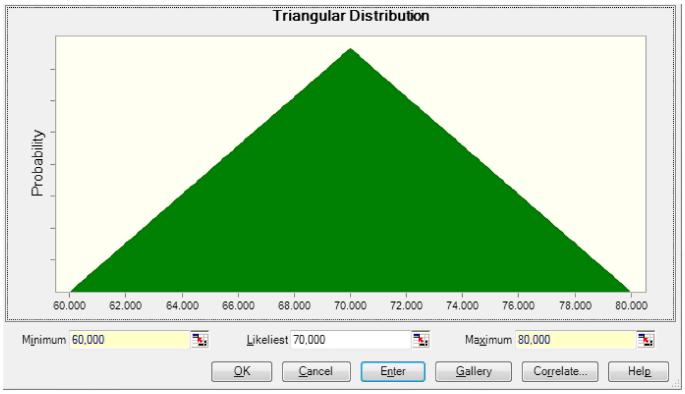

Fig. 4. Triangular probability distribution.

A Payback Period of 2.7 years shows that the unit would likely be well-thought-out and quite appropriate.

Simulation experiment and analytics

After setting the initial variables in the research scheme, the next stage is to analyze the simulation model using the Crystal Ball software package. The attention here is to forecast the company's net present value by predictive modeling, simulation, and optimization techniques. It requires two assumption cells, the cash inflows, and the inflation rate. The Forecast represents the outcomes of the model. For instance, from a common list of 21 different probability distribution gallery list, the triangular probability distribution is selected. This type of probability distribution is based on a continuous distribution with lower bound an upper bound b and mode c. The sequence is shown in expression (5)

$$a < b \quad \text{and} \quad a \leq c \leq b. \tag{5}$$

In this case minimum, likeliest and maximum parameters are considered that show \$60,000, \$70,000 and \$80,000. After the first run, the model automatically creates random values that fall from minimum to maximum and the cash inflow of \$70,000 changes to mean of the triangular probability distribution as shown in Fig. 4. Repeating the necessary steps will show the leftover cash flow assumption cells as tabulated in Table 2 and further, the estimated cash inflows are illustrated in Table 3 with most likely, minimum and maximum respectively. Through this, it is quite simple to analyze the future outcomes in the form of net present value because the unit has successfully passed all the possible hurdles of 12%. The projected net flows over its life is \$489,000 with discounted and the hurdle rates along 3% per year inflation while the net present value of the cash flow becomes equal to \$14,605. Being an uncertain risk-based variable the inflation rate is presented at the last column of the table. All the related expenses are fixed therefore no uncertainty regarding cash outflows does exist. However, there exists uncertainty about cash inflows. Moreover, the rate of the hurdle is taken as fixed therefore to investigate the required discount factor, the rate of inflation of 3% with the application of normal distribution and a tolerance of 1 % is considered that represents three standard deviations.

The next strategy is to analyze those assumption cells which are related to the inflation rate for a 4% rate. This time selecting normal distribution with bell-shaped in such a way that the values mean of the data distribution falls in the center. The normal distribution is the best suitable for describing future inflation. The mean is provided with three standard deviations that show 99% of the given database while this is assumed to be 0.04 (4%) followed by the standard deviation of 0.0033 (1/3 of 1% percent). Figure 5 shows the data associated with normal distribution mean along with the deviation curve. It is noticeable that the curve just exhibits two decimals of standard deviation but the definite standard deviation of .0033 is operated by the program interference. The distribution highlights a mean of 4% from a range starting from 3% to 5% respectively. There are two numbers of cash out flows in the year 2003, however, the first ones start at the start of the year while the other ends at the end of the year 2003. Working with the inflation rate at a fixed rate of 4%, no issue creates however when creating inflation rate using based on random variable then this issue arises and should be fixed by doing such that: $= 1/(1 + 0.12 + G14)\text{^}(A15 - 2002)$ that shows that the same typical rate of inflation is applied for both 2013 years respectively. Finally, the company's revenue forecast or net present value is analyzed by selecting fit a probability distribution to the forecast from the forecast window.

Table 1
Distinct point estimates of cash inflows.

Year (X)	Inflows (Y) (in 000)	Cash Inflows (Z) (in 000)	Net cash flows $NF = (Y - Z)$	Discount factor $1/(1+k+p)^t$	$NPV(NF * DF)$ (in 000)
2019*	$	$(145)	1.00	1.00	$ (145)
2019	–	(120)	0.86	0.86	103.448
2020	–	(80)	0.74	0.74	59.453
2021	70	70	0.64	0.64	44.84
2022	140	105	0.55	0.55	57.99
2023	135	135	0.47	0.47	64.27
2024	125	90	0.41	0.41	36.94
2025	117	117	0.35	0.35	41.39
2026	110	75	0.30	0.30	22.87
2027	102	102	0.26	0.26	26.82
2028	85	85	0.19	0.19	16.61
2029	55	55	0.19	0.19	10.74

* t is considered as 0 at the start of the year 2003.

Table 2
Distinct point estimates of cash inflows for frontier ceramics Ltd.

Year X	Cash Inflow Y	Cash Outflow Z	Net Flow $NF = (B - C)$	Discount Factor $1/(1+K+p) \wedge t$	Net Present Value $NF \times$ (Disc. Factor)	Inflation rate
2019	$ –	$ 145,000	$ (145,000)	1.0000	$ (145,000)	0.04
2019	–	120,000	$ (120,000)	0.8621	$ (103,448.28)	0.04
2020	–	80,000	$ (80,000)	0.7432	$ (59,453.03)	0.04
2021	70,000	–	$ 70,000	0.6407	$ 44,846	0.04
2022	140,000	35,000	$ 105,000	0.5523	$ 57,991	0.04
2023	135,000	–	$ 135,000	0.4761	$ 64,275	0.04
2024	125,000	35,000	$ 90,000	0.4104	$ 36,940	0.04
2025	117,000	–	$ 117,000	0.3538	$ 41,398	0.04
2026	110,000	35,000	$ 75,000	0.3050	$ 22,877	0.04
2027	102,000	–	$ 102,000	0.2630	$ 26,821	0.04
2028	85,000	–	$ 85,000	0.1954	$ 16,609	0.04
2029	55,000		$ 55,000	0.1954	$ 10,748	
Total	**$ 939,000**	**$ 450,000**	**$ 489,000**		**$ 14,605**	

Table 3
Estimates of cash flows.

Year	Minimum ($)	Likeliest ($)	Maximum ($)
2021	60,000	70,000	80,000
2022	126,000	140,000	154,000
2023	121,500	135,000	148,500
2024	112,500	125,000	137,500
2025	105,300	117,000	128,700
2026	99,000	110,000	121,000
2027	91,800	102,000	112,200
2028	76,500	85,000	93,500
2029	49,500	55,000	60,500
Total	**$ 842,100**	**$ 939,000**	**$ 1,035,900**

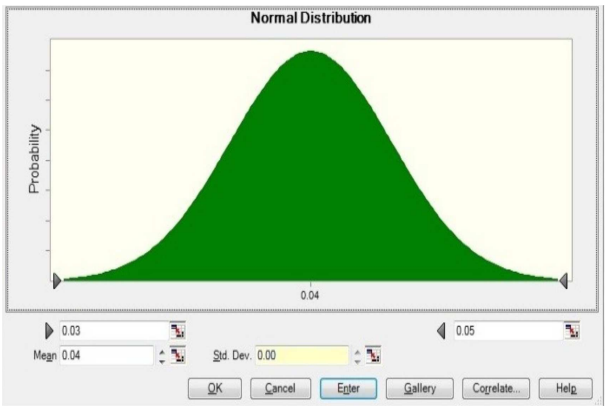

Fig. 5. Normal distribution of inflation rate – 2002 with mean and standard deviation.

Preparation of simulation run

The next step is to run the program and observe the simulation process. During the simulation, the program simply chooses all the random variables from each assumption cell. Using a probabilistic approach, the net present value of the company is analyzed. To get the possible distribution of the outcomes the process of simulation repetition is allowed for 1000 run after that the results of the model are analyzed.

Verification and validation of model

Net present value statistics showed both the mean and median outcomes and courteously positive values at a 12% hurdle rate. Figure 6 displays the frequency view of the values generated during the 1000 iterations. The certainty range falls between negative and positive infinity while the certainty level is 100%. Crystal Ball forecasts the entire range of results for the company by taking the initial certainty range which includes all possible values. Confirming the highest level of the certainty grabbers in the middle of the chart, it predicted that the company will be able to successfully achieve the net present value of $14,605.

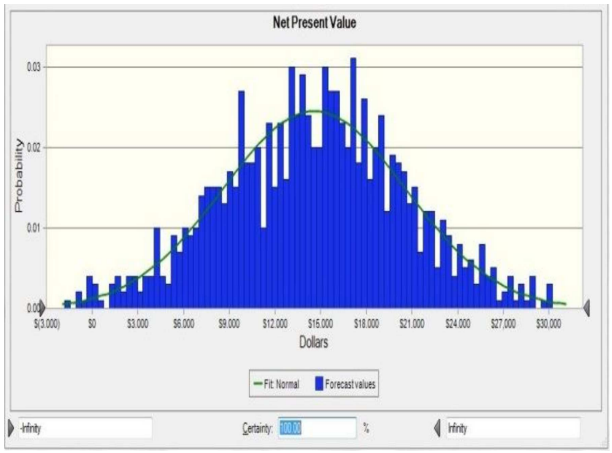

Fig. 6. Frequency chart output value.

If it is desired to forecast for the next period, then perhaps there exists uncertainty regarding the output of the project associated with risk. Therefore, some assumptions needed to be defined that the expected outcomes may be between minimum to a maximum level. At this stage, the question arises such as how to ensure what is the likelihood that the desired outcome will be exactly as calculated before.

For this purpose, the model shows the interactive forecast chart by analyzing the target value and immediately the chart shows the certainty of achieving the estimated value of $14,606. In this case, the chart moves the left certainty grabber (the triangle at the base of the graphic view) to the value and predicts that chances of achieving the goal. Figure 7 clearly shows that the certainty is only about 50.73% which means that there are almost 50% chances of achieving the outcomes. Certainly, there are times when the company can have positive cash flow while reporting negative net income or predicting what is the probability of not making any profit. In this case, the net profit forecast chart as shown in Fig. 8 displays the certainty level of 0.88 % which confirms that there are pretty worthless chances that the unit may lose money (shown as blue line at the start with $0) on this project. Also looking through the minimum and maximum values in a range of 80% certainty level, it

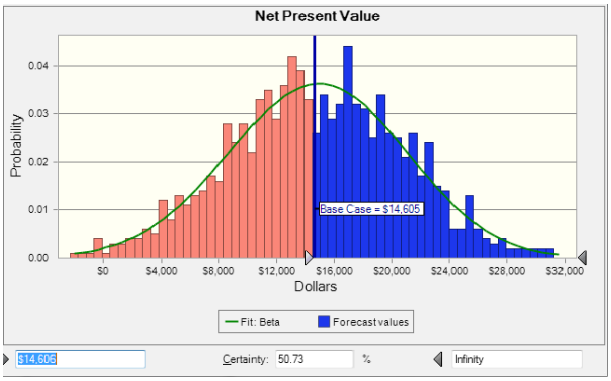

Fig. 7. Net present value certainty results with $14,606.

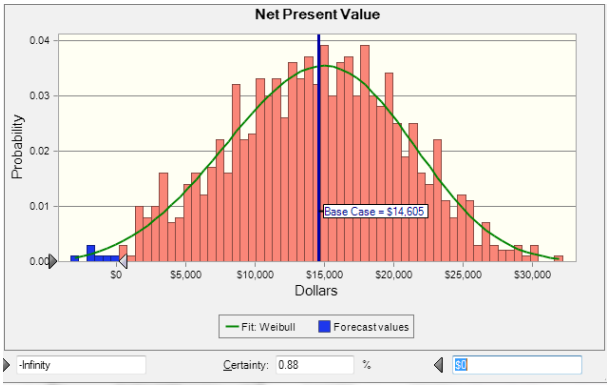

Fig. 8. Net present value certainty results with $0.00.

is observed that 80% chances exist that expected outcomes will be between $5,830 and $22,587 respectively. Therefore, the company decides to go ahead with installing additional production plant and proceed to develop and market their revolutionary products. To determine the sensitivity of the forecast to each assumption, the sensitivity chart displayed a quickly and easily judged forecast cell. Figure 9 shows the sensitivity analysis chart of net present value. In this case, the cash inflows have a much larger sense of 21.1% showing a higher impact on the variance of the outcomes of the profit, followed closely by the cash inflows of the next year's assumption of 19.7%. The remaining six assumptions have a lesser degree of impact on profit uncertainty. These validations helped in terms that if the company controls the expenses then the outflows can also be controlled definitely. So if it is intended to reduce the variability around the inflation rate then the risk for the variance around profit may also be reduced. The results obtained from the net present value forecast graph as a cumulative frequency distribution as shown in Fig. 10 describes the amount (percentage) of desired values less than or equal to the desired given values. Looking through the distribution making baseline value of $14,606 confirms that the probability to achieve an outcome for maximum value of $23,520 is approximately 90% however the probability for the minimum value of $6,244 is about 10% which is also logical in this sense since the probability of NPV concerning these two values is 0.80 $(0.90 - 0.10 = 0.80)$ or level of certainty = 80%.

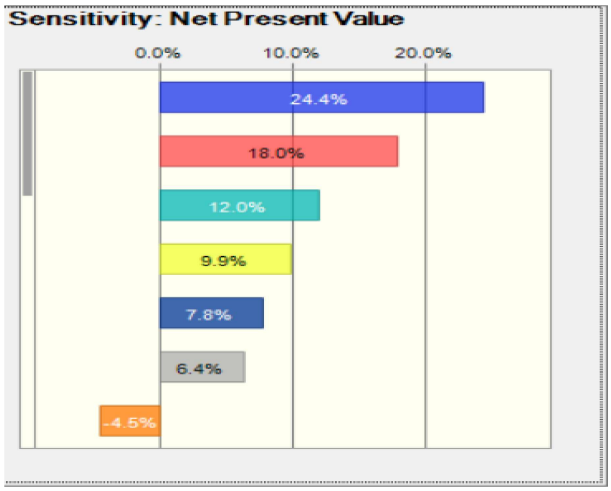

Fig. 9. Sensitivity analysis chart of net present value.

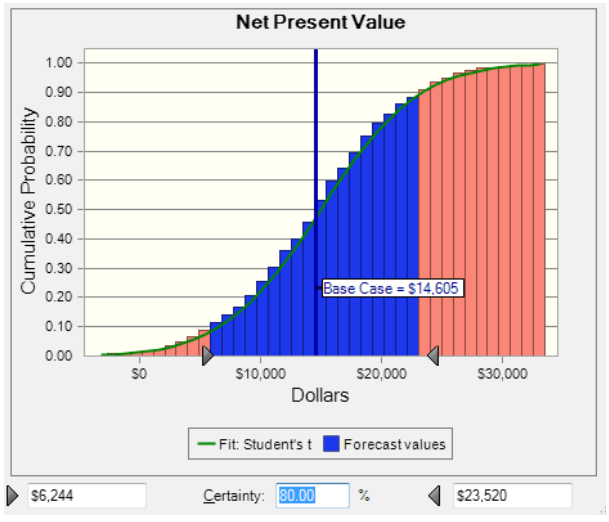

Fig. 10. Net present value cumulative frequency distribution.

Finally, the results obtained from the net present value forecast graph as a reverse cumulative frequency distribution as shown in Fig. 11 describes the number or proportion (percentage) of values greater than or equal to the desired given values.

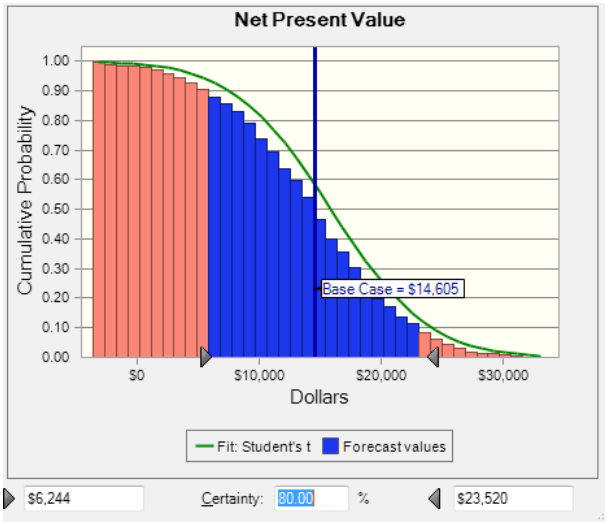

Fig. 11. Net present value reverse cumulative frequency distribution.

The related frequencies begin from the maximum range and then approach to a decline curve of a reverse cumulative frequency. It is observed that almost 50% of values are less than $14,606 and 50% are greater respectively. It is also noticeable that the graph presents the probability for $27.4 million in about 0.05 (of having a greater value) while the probability for $6,534 is all about 90% (0.9).

Obviously as the probability of NPV concerning between those two values is 0.80 $(0.90 - 0.10 = 0.80)$ or level of certainty = 80%. It may also be noted that this particular chart in which the reverse cumulative frequency distribution given values are supplements of the cumulative frequency distribution values that is $0.90 + 0.10 = 1.00$ (the probability distribution

values regarding \$6,534 and corresponding \$22,645 respectively).

Results and discussion

The initial investment in the plant and machinery is usually known and fixed in existing production plants. However, to expand the current production system, the initial investment and expected outcomes might not be known. The probability to remain within the predicted maximum and minimum value will be a disgrace for the proposed system than the existing. This study presents a probabilistic and dynamic technique to forecast the net present value of a company that is interested to make an initial investment of \$145,000 by installing an additional spray dryer plant. Based on average for 10 years, the Payback Period is 2.7 years. Variability and assessment of expressive values acquired from the Monte Carlo technique using Crystal Ball established a range of certain results. Using different probability distribution approaches and analytical techniques successfully responded to the research questions by deciding which specific input variable has the greatest impact on the required net present value associated with potential levels of uncertainty. The possible results are generally analyzed in the sense of the company's investment associated with its current production schedules which have a level of different cash outflows and inflows. The expected net present value of the cash flow is \$14,605, hence the results of the current model related to the uncertainty based on the frequency chart confirmed that there is the highest level of certainty that the company will successfully achieve its target. To forecast for the next period there exits uncertainty and risk. In this regard, net present value certainty results established that there are 50.73% chances of achieving the outcomes. Looking through the minimum and maximum values in a range of 80% certainty level, it is observed that 80% chances exist that expected outcomes will be between \$5,830 and \$22,587 respectively. For the determination of the sensitivity of input assumption, cash inflows had a much larger sense of 21.1% and the cash inflows related to the next year had 19.7%. These validations suggested that controlling the expenditures, the company's outflows can also be controlled definitely. The results obtained from net present value forecast graph as a cumulative frequency distribution confirmed that the probability to achieve an outcome for maximum value of \$23,520 is approximately 90 % however the probability for the minimum value of \$6,244 is about 10 % which is also logical in this sense since the probability of net present value these two values is 80%.

Conclusions

The stakeholders of a production unit usually unaware regarding the expected benefits of their projects, therefore, every effort should be initiated to ensure the least degree of uncertainty in the production schedule and outcomes may be recognizable. This study has been taken to describe the scenario of the up-gradation of an existing production unit by installing the additional plant. The expected net present value form the new plant was tested by allowing the plant to evaluate under uncertainty and unknown probabilities. The cash flows were uncertain since both incomes and expenses of the company were related to the future. Monte Carlo Simulation technique was implemented for perceiving the impact of risk and uncertainty in prediction and forecasting company's profitability. The results acquied from the Monte Carlo technique confirmed that there is a highest level of certainty that the company will achieve its expected net present value of the cash flow of \$14,605. The new method takes into account the decision maker's attitude towards a given decision problem. The procedure has been implemented with the help of various probability frequency distributions of net cash flows at particular periods since it considers the frequency of each value. Based on the simulation experiments and results discussed it can be concluded that simulation methods such as Monte Carlo using a leading spreadsheet-based application for forecasting may give unparalleled insight into the critical factors affecting risk. These techniques have the capabilities that can make the right tactical decisions to reach the desired objectives and gain a competitive edge under even the most uncertain market conditions.

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