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Use of Decision Tree and Risk Analysis as Aid of Decision Making(Case Study)

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Abstract: *Decision Tree (DT) is used successfully in many various areas such as big companies, institutes, industrial sectors and Governments with professional consultants to take a right hard decision among several true ones. The most important feature of DT is their capability to break down a complex decision-making process into a collection of simpler decisions, thus providing a solution which is easier to take. This paper presents a case study that using DT structure design, feature selection at each internal node, and decision making using expected monetary value (EMV). However, two analysis methods would be carried to assist decision making which they are the risk profile strategy and sensitivity analysis.*

Keywords -*Decision Tree (DT), Expected Monetary Value (EMV), Risk Profile, Sensitivity analysis*

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I. Introduction

Life is a sequence of decisions, some of them are important and others are not, but each one of them has some impacts on our future career. So decisions need to be fully examined and evaluated before decide them. Usually, investigations, experiments, asking experts or looking at similar issues give us clear view to make the right decision, but nowadays there is a big developing in taking decisions mechanism [1].

Nevertheless, science has been involved in taking more reliable and efficient decisions. Thus, making hard decision became one of the most important scientific fields. It has been used by big companies, institutes, industrial sectors and Governments with professional consultants to take a right hard decision among several true ones [2].

An important method in making a hard decision is the Decision Tree (DT). It starts with a decision that you need to make by drawing a small square to represent this towards the left. From this box lines towards the right for each possible solution would be drawn, and write that solution along the line. The lines should be kept apart as far as possible so that thoughts could be expanded. Squares represent decisions, and circles represent uncertain outcomes [3-5].

Probability estimation is considered as a calculation of the summary measure (the mode, the average, or just a conservative estimate). The assumption then has to be made that the selected value is certain to occur (assigning a probability of 1 to the chosen single-value best estimate). However, Probability is used to express quantitatively the beliefs and expectations of experts regarding the outcome of a particular event. People who have this expertise are usually in a position to judge which one of these choices best express their knowledge about the subject [6, 7].

Risk profile is a Graph that shows probabilities for each of the possible outcomes given a particular decision strategy. Others consider it as a probability mass function for the discrete random variable representing the outcomes for the given decision strategy. In addition, there is the cumulative risk profile which isa graph shows cumulative probabilities associated with a risk profile [8].

Sensitivity analysis is the study of how the uncertainty in the output of a model (numerical or otherwise) can be apportioned to different sources of uncertainty in the model input. However, if the model is wrong or if it is a poor representation of reality, determining the sensitivity of an individual parameter in the model is a meaningless pursuit [9].

However, in our case we are going to use making hard decisions' strategies which they are; Decision Tree, Probability estimation, Risk profile and Sensitivity analysis for deciding which decision is better to the factory's manager who is looking whether to continue with his old main product or to make a brave jump by introducing a new product. In regard to this issue, factory consultants make a good effort by looking at profits' table for old product and its probabilities for success or fail, as well as, distributing a good questionnaire among the target area (city and towns around) to know the probability of success or fail for the expected new product before taking any serious decision toward it.

II. Case Definition

Existing Food Factory which is considered as one of the good medium factories in Libya. Its products are well distributed among the city and towns around. The mean product in this factory gives alone (without considering other sub-products) annually profit as follow:

Table1.Factory annual profit for 4 years

Year	2010	2011	2012	2013
Total Sale (boxes)	280800	Closed	218400	156000
Total profit (in millions)	13.5	---------	10.5	7.5

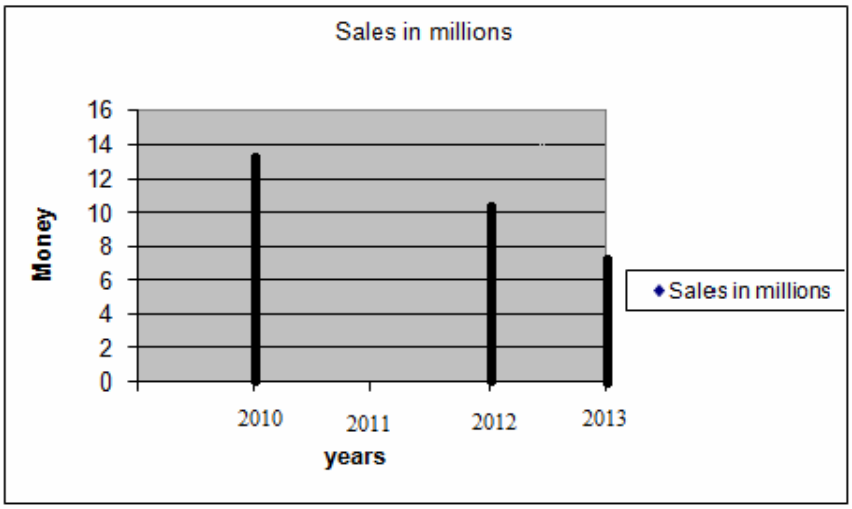

Figure 1. Graph of annual profit for 4 years

The year 2011 was considered as the worst year in Libya due to revolution war, therefore, it was excluded from our counting. However, it still indicated that the indicator for sales was going down in 2012 and worse in 2013, which led us to the probability of recession.

The manager of the factory made a meeting with owners to discuss the options that available, whether they continue with the risk in existing product which considered as a mean production in the factory, with a probability of 45% to success and 55% to fail according to factory consultants' team experience, or to produce a new product instead to avoid recession. Hence, they would be the first producer of it in the target area. But also there were probabilities of success and fail need to be investigated. Moreover, the manager was thinking in case of success of the new product to increase product lines from 3 lines to 4 line for maximizing his expected profit.

However, in case of success of new product and increase of product lines, the probability of success and failure would be equal. Consultants indicated that the total expected profits in success and fail when increasing the product lines (depending on feedback from similar factories in other city)would be:

Table 2. The total expected profits in success and fail when increasing the product lines

Status	Fail	Success
3 Line production	0 millions	12 millions
4 Line production	3 millions	16 millions

The factory consultants made a survey among city and towns around to determine the percentage of success of the new product. Depending on this information they have to decide which decision is better for the factory manager to take (to maximize profit and minimize the risk of fail).

2.1 Uncertain Events and Objectives

It is noticeable that our uncertain events are the success and failure, whether with the old product or with the new product, as well as, with increasing new product lines. However, it is clear that our objectives to avoid recession and continue in the market with favorable product, thus, they can increase their profit and keep good reputation around. Therefore the value here will be money.

2.2 Consequences and Decisions

Continuing with the old product will result in getting 7.5 million in success or loss of 0.5 million from the revenue. Whereas going risky with new product results in 12 million in success and 0 million in fail, as well as, when increasing production lines profit jump to 16 million in case of success or, in contrast, decrease to 3 million in case of fail.

Depending on what has been mentioned above, decisions are:

- ✓ Decide to continue with the old product or move to the new one.
- ✓ In case of success, they may decide to increase production line.

III. Decision Tree of theCase Study

Decisions and uncertainty should be taken carefully to represent the case correctly. Every brunch of the DT should represent a logical strategy with its possibility. Starting with Decisionswhether to continue with old product (which give in successful and failure case 7.5 million and -0.5 million respectively) orto introducethe new product. Then two line of possibilities of success or fail (0 million) would be drawn toward the left for the choosing of the new product to expend the tree. After that, there is another possibilities whether to stay with same level of productivity with 3 lines, or to increase product lines in case of success of the new product. However, increasing product lines to 4 lines give in successful situation around 16 million but in failure situation the profit will drop to only 3 million.

Therefore, after drawing and connecting events together and putting squares (which represent decision) and circles (which represent uncertainty), the initial DT will be as follow:

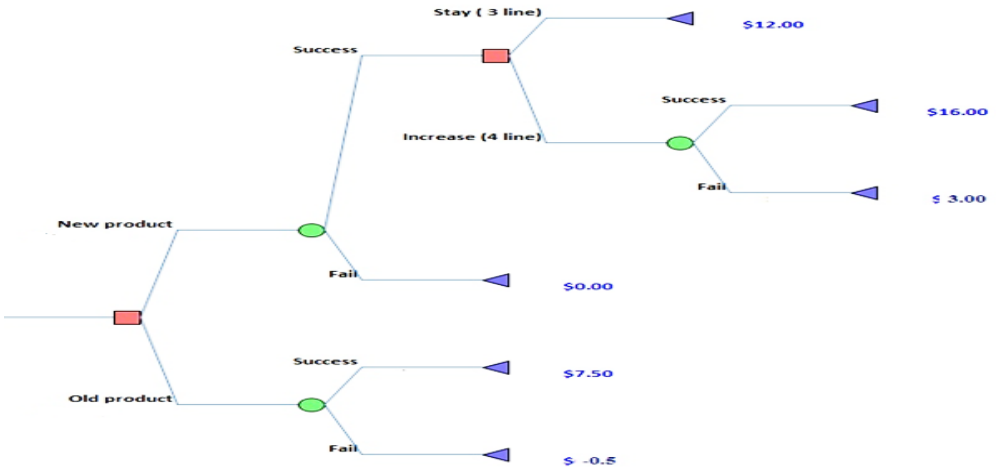

Figure 2. The relations between certain & uncertain events in decision tree sketch

3.1 Probability estimation on DT

Regarding the probability of success or failure for the new product, a well-designed questionnaire was distributed in the target area and it returned this result:

Table 3. Survey results

Targets	City		Town1		Town2		Town3	
	Agree	Don't agree	Agree	Don't agree	Agree	Don't agree	Agree	Don't agree
People	17	39	10	8	4	11	5	5
Retailers	6	4	3	6	1	7	4	5
	∑23	∑43	∑13	∑14	∑5	∑18	∑9	∑10
Sum∑	All=66		All=27		All=23		All=19	

(Yes for New product) =50/135=37% =➔ it has been taken 35% to be in safe side
(No for New product) =85/135=63% =➔ it has been taken 65% to be in safe side
It should be noted that survey was distributed among people and retailers, and results with (yes) and (no) for new product were collected. Therefore, relying on this result, it can be said that:

Pr. (New product success) =0.35
Pr. (New product fail) =0.65
Pr. (New product success/increase lines success) =0.5
Pr. (New product success/increase lines fail) =0.5

Thus, the DT with probability would be as follows:

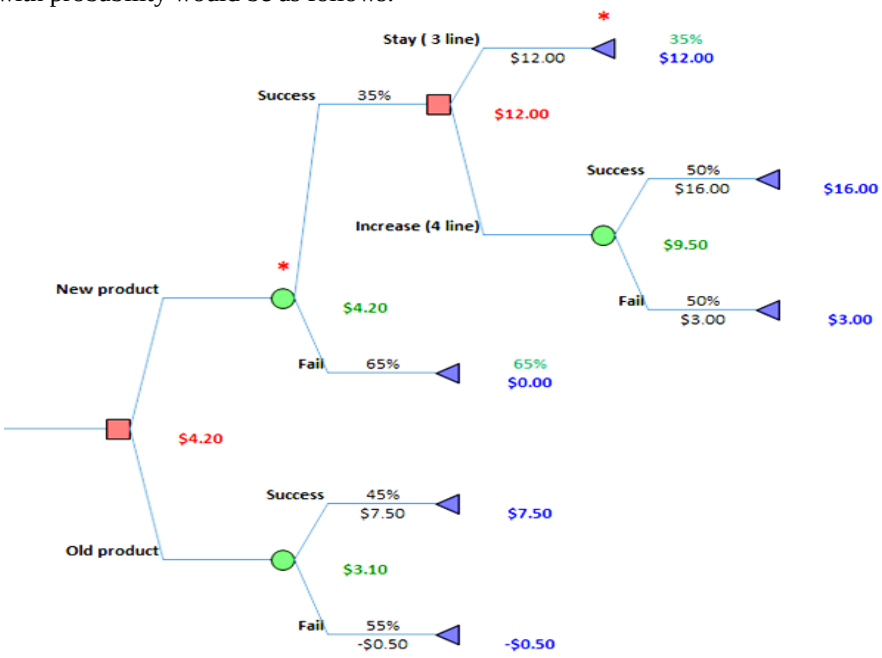

Figure 3. The final decision tree

Noticeably, Increasing 4 line bring 9.5 million as total profit which resulting from the sum of multiplying 16 million and 3 million in their percentages. On the other hand, there is 12 million come from the upper brunch which represents the staying with 3 line. Because of 12 million > 9.5 million, we chose it and multiply it in 0.35 to get 4.2 million which considered the highest Expected monetary value (EMV)when comparing with 3.1 million that come from down branchwhich has been resulted fromsimilarcalculated process that was done in upper brunch.So when we could easily conclude that our EMV is 4.2 millionthat came from 3 product line for the new product.

IV. Possible Strategies and Risk Profiles

Our DT has 3 possible strategies which could be extracted into:

- **Strategy 1**

Pr. (Profit=$-0.5) =0.55 Pr. (Profit<$-0.5) =0.55
Pr. (Profit=$7.5) =0.45 Pr. (Profit<$7.5) =0.45

Figure 4. Graph shows Risk profile for strategy1

- **Strategy 2**

Pr. (Profit=$0) =0.65 Pr. (Profit<$0) =0.65
Pr. (Profit=$12) =0.35 Pr. (Profit<$7.5) =0.35

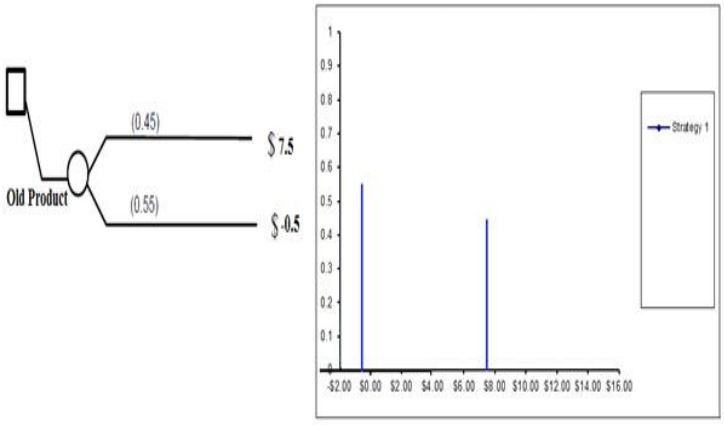

Figure 5. Graph shows Risk profile for strategy2

- **Strategy 3**

Pr. (Profit=$0) =0.65 Pr. (Profit<$0) =0.65
Pr. (Profit=$16) =0.35*0.5=0.175 Pr. (Profit<$16) =0.175
Pr. (Profit=$3) =0.35*0.5=0.175 Pr. (Profit<$3) =0.175

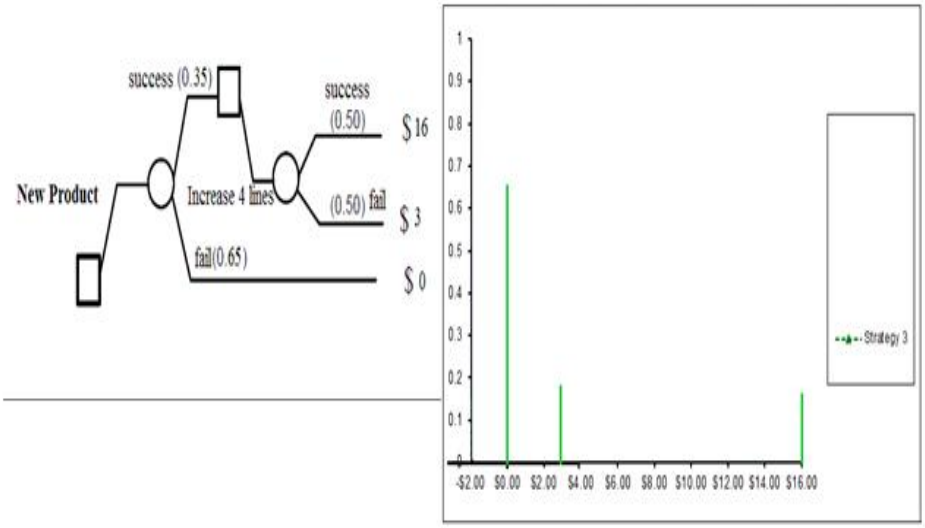

Figure 6. Graph shows Risk profile for strategy3

Finally, our Cumulative Risk Profile (CRP) for all strategies will be as shown below:

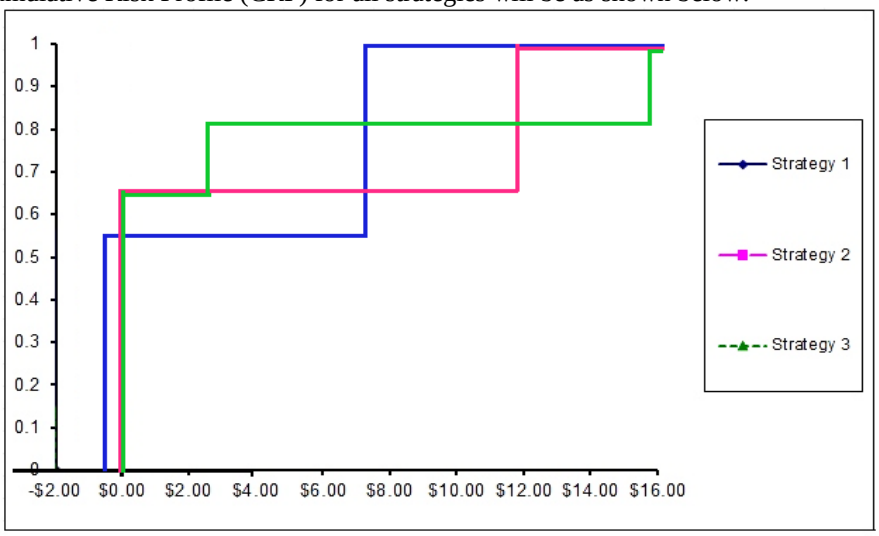

Figure: 7 Graph shows Cumulative Risk profile for all strategies (1, 2 & 3)

Cumulative Risk Profiles' lines are crossed with each other which mean that we cannot get a clear view which strategy is better in our case. In addition, if we want to maximize the profit we should choose the most line that leans on the right side, in contrast, if we want to reduce the cost we should choose the most line that leans on the left side. Thus, in our case, the comparison will be between strategy 2 and 3. With the second review of the graph, the strategy 2 line is better because it is going deeper toward the down-right, as well as, has higher EMV.

V. Sensitivity Analysis

To work with sensitivity we should first ask our self; how many important variables that we have. For example in our decision tree we consider the number of product lines as the most important variable because it has extremely effect on the profit (in term of success or fail), as well as, it controls the highest EMV.

Therefore, the best choice to work with sensitivity is One-way sensitivity analysis. Although, if we consider success in new product as an important variable because it leads us to the first variable (increase in product lines), then Two-way sensitivity analysis may become applicable.

5.1 One-way Sensitivity Analysis

First, start with the number of product lines as the only most important variable. Taking in mind that, 3 lines is the base value which gives 12 million and leads to the base EMV (4.2 million). On the other hand, 4 lines give 16 million which means increasing by +33 from the base value. Therefore, the lower expectation would be equal to 66% of the base value. This was represented in the Table below:

Table 4. Shows lower, base & upper bound expectation

Variable	Lower bound (2lines)	Base Value(3lines)	Upper bound(4lines)
Number of production lines	(-33%) 8 million	12 million	(+33%) 16 million

- For lower bound: EMV=2.8 million

Figure: 8. Shows one-way sensitivity lower bound

- For base value: EMV=4.2 million

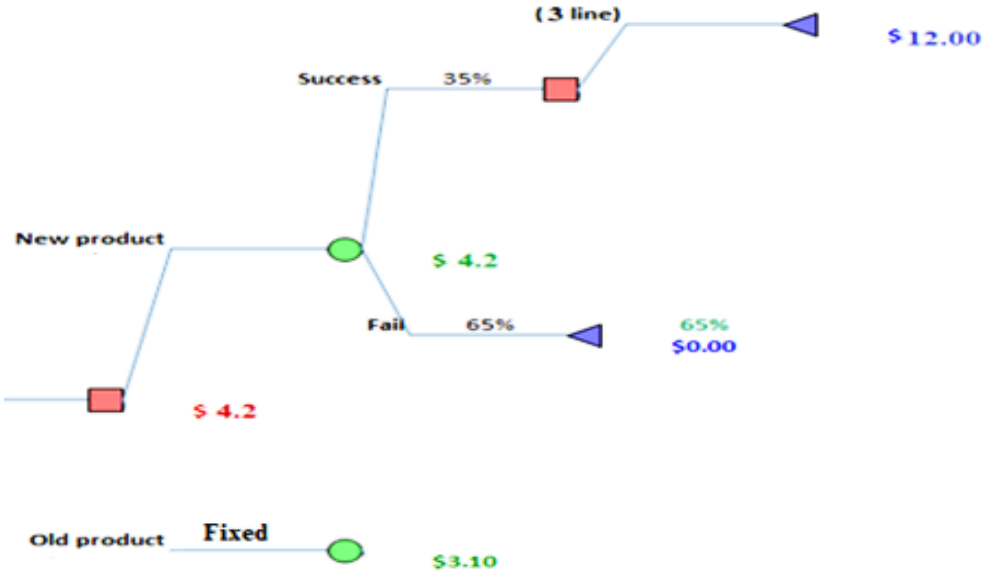

Figure: 9. Shows one-way sensitivity base value

- For upper bound: EMV=5.6 million

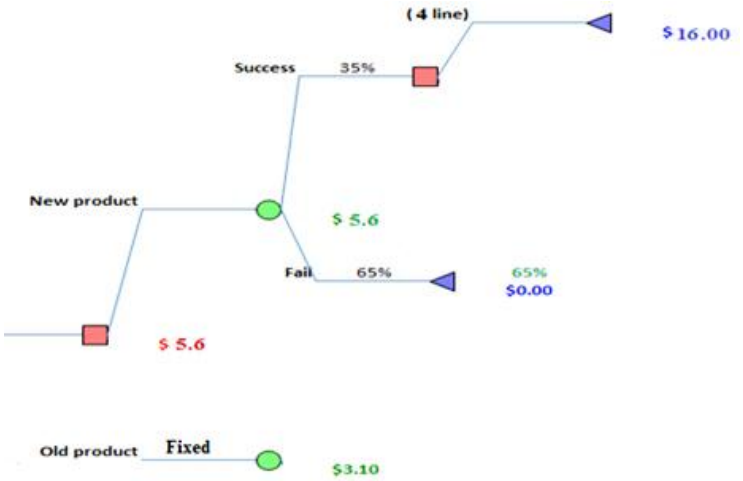

Figure:10 Shows one-way sensitivity upper bound

As a result, our Sensitivity graph, spider diagram, and Tornado Diagram will be:

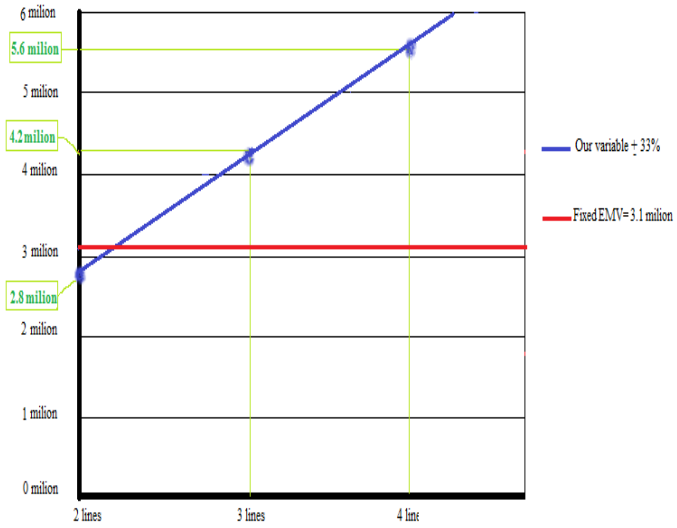

Figure: 11 Shows our Sensitivity Diagram

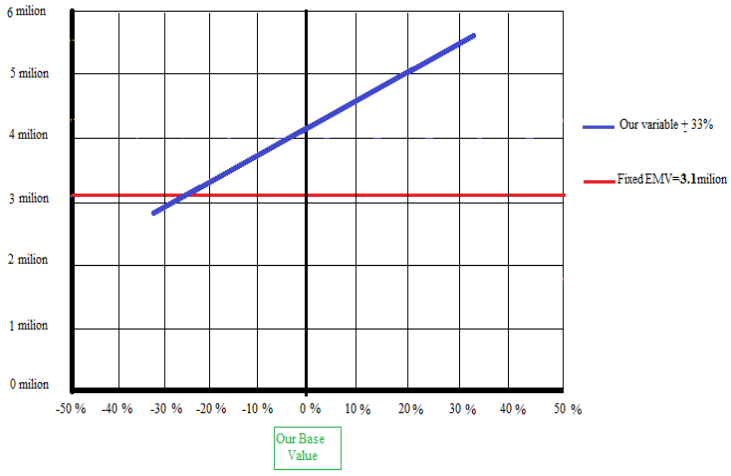

Figure: 12 Shows our Spider Diagram

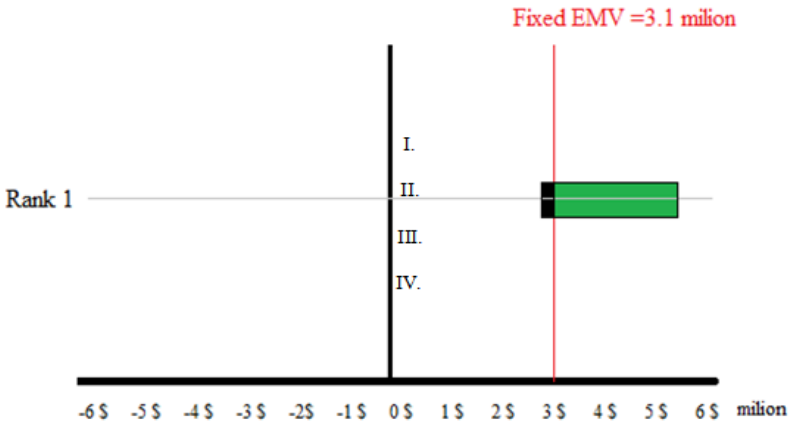

Figure 13. Shows our Tornado Diagram

VI. Making Choice and Conclusion

From the highest expected monetary value EMV and the best line fit the needs in cumulative risk profile, it becomes clear to us that the best choice is to introduce the new product and continuing with 3 production lines.

Going through all investigation that we have made for our case, starting with case analysis then probability estimation, decision tree, risk analysis and sensitivity analysis, we got a deep understandingof our issue. Also, it helps us in choosing the right decision which becomes more clear and confident. Therefore, introducing the new product and continuing with 3 production lines will give the optimal profit with minimum risk of failure.

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