Perform Quantitative Risk Analysis

Introduction

- Quantitative Risk Analysis refers to the thorough and complete numeric analysis of the overall effect of the total quantifiable amount of risks involved in the project objectives.

Purpose and Objectives

- Numeric estimation of overall effect of risk on project objectives based on current plans and information.

- Results evaluate the likelihood of success and estimate contingency reserves for time and cost that are appropriate to both risks and project stakeholders.

- Monte Carlo, a quantitative technique, provides realistic estimation of project cost.

- It is inappropriate if the qualitative risk analysis provides enough information especially in the case of smaller projects.

- The Plan Risk Management process should ensure the application of quantitative risk analysis in projects.

- Calculating estimates of overall project risk is the focus of the Perform Quantitative Risk Analysis process.

- An overall risk analysis, such as one that uses quantitative technique, estimates the implication of all quantified risks on project objectives.

- The implementation of overall risk analysis using quantitative methods requires:

    - Complete and accurate representation of the project objectives built up from individual project elements. e.g., Project schedule or cost estimate.
    - Identifying risks on individual project elements such as schedule activities or line-item costs at a level of detail that lends itself to a specific assessment of individual risks.
    - Including generic risks that have a broader effect than individual project elements.
    - Applying a quantitative method (such as Monte Carlo simulation or decision tree analysis) that incorporates multiple risks simultaneously in determining overall impact on the overall project objectives.

- Results of the quantitative risk analysis compared to the project plan gives the overall estimate of the project risk and answers the following questions:

    - What is the probability of meeting the project's objectives?
    - How much contingency reserve is needed to provide the organization with the level certainty it requires based upon its risk tolerance?
    - What are those parts of project which contribute most risk when all risks are considered simultaneously?
    - Which individual risk contributes the most to overall project risk?

- Estimation of overall project risk using quantitative methods helps to distinguish projects where quantified risks threaten objectives beyond the tolerance of the stakeholders.

Critical Success Factors for the Perform Quantitative Risk Analysis Process

The critical success factors for the Perform Quantitative Risk Analysis process are:

- Prior Risk Identification and Quantitative Risk Analysis
- Appropriate Project Model
- Commitment to Collecting High-Quality Risk Data
- Unbiased Data
- Overall Project Risk Derived from Individual Risks
- Interrelationships between the Risks in Quantitative Risk Analysis

1. Prior Risk Identification and Quantitative Risk Analysis

- Perform Quantitative Risk Analysis Process happens after the Identify Risks and Perform Qualitative Risk Analysis Processes.

- Reference to a prioritized list of identified risks ensures that Perform Quantitative Risk Analysis Process will consider all the significant risks while analyzing.

2. Appropriate Project Model

- Frequently used project models include the project schedule, line-item cost estimates, decision tree and other total-project models.

- Sensitive to the completeness and correctness of the model of the project that is used.

3. Unbiased Data

Successful gathering of data about risks should be done by interviews, workshops, and expert judgment.

4. Overall Project Risk Derived from Individual Risks

The Perform Quantitative Risk Analysis process is based on a methodology that correctly derives the overall project risk from the individual risks. E.g., Monte Carlo simulation for risk analysis of cost and schedule, decision tree for making decisions when the future is uncertain.

5. Interrelationships between the Risks in Quantitative Risk Analysis

- Common root cause risks likely to occur together are addressed by correlating the risks that are related.

- Using a risk register to list risks or root cause risks and attaching it to several project elements.

Tools and Techniques for the Perform Quantitative Risk Analysis Process

The characteristics of tools and techniques used for quantitative risk analysis are as follows:

1. Comprehensive Risk Representation

- Risk models permit representation of any, if not all, of the risks, opportunities, and threats that have impact on an objective simultaneously.

2. Risk Impact Calculation

- Facilitates the correct calculation of the effect of many risks and are described at the level of total project.

3. Quantitative Method Appropriate to Analyzing Uncertainty

- The methods should be able to handle the way uncertainty is represented, be it the probability of occurrence or probability of distributions for a range of outcomes. E.g. Monte Carlo simulation permitting the combination of probability distributions of line-item costs or schedule activity durations.

4. Data Gathering Tools

They include:

- Assessment of historical data and workshops
- Interviews or questionnaires

5. Effective Presentation of Quantitative Analysis Results

- Results from quantitative tools are not available in standard project management methods such as project scheduling or cost estimating. E.g. Probability distribution of project completion dates or cost estimation.

- The results include:
    - Probability of achieving a project objective such as finishing on time or within budget.
    - Amount of contingency reserve needed to provide a required level of confidence.
    - Identity or location within the project model of the important risks.

The elements of the quantitative risk analysis are illustrated in **Figure 7.1.**

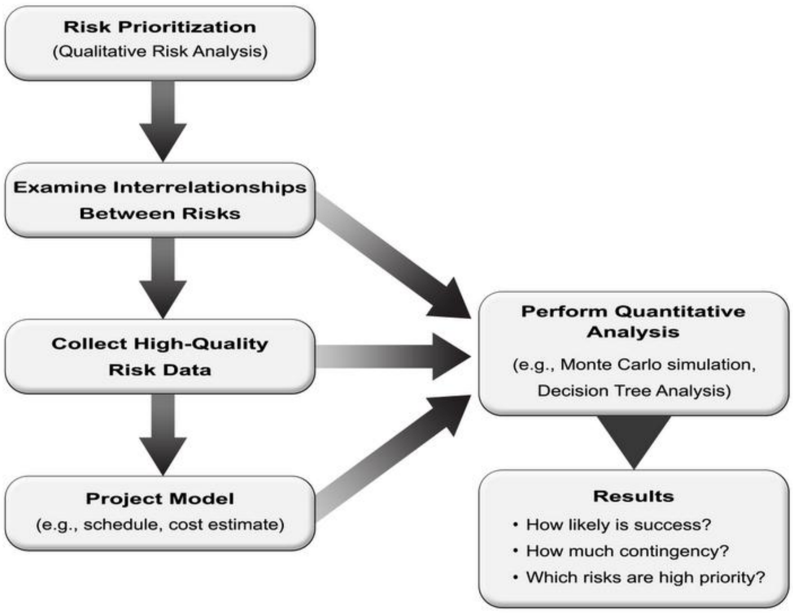


Figure 7.1 Structure of Quantitative Risk Analysis

6. Iterative Quantitative Risk Analysis

- Periodical analysis of individual risks of project enhances the success of quantitative risk analysis.
- The frequency of analysis is planned in the Plan Risk Management process, and events within the project also influence it.

7. Information for Response Planning

Overall project contingency reserve in time and cost should be reflecting in the project schedule and budget.

Quantitative Risk Analysis provides information to modify the project.

Documenting the Results of Quantitative Risk Analysis Process

- The contingency reserves calculated are incorporated into the cost estimates and the schedule to establish a prudent target and a realistic project.
- If the contingency reserves required exceeds the time or resources, changes in the project scope and plan may result.
- The results of the quantitative risk analysis are recorded and passed on to the personnel/ group for any further action required to make full use of the results.

TECHNIQUES

The Perform Quantitative Risk Analysis seeks to determine the overall risks to project objectives when all risks potentially operate simultaneously on the project.

- It provides answers to several questions regarding the project. They are as follows:
  - How likely is the project to complete on the scheduled date or earlier?
  - How likely is the project actual cost to be the budgeted cost and less?
  - How reliable will the product be that the project produces?
  - What is the best decision to make in the face of uncertain results?
  - How much contingency in time and cost is needed to provide the organization with its desired degree of confidence in the results?
  - How should the design of the product or system be changed most economically to increase its reliability?
  - What are the individual risks that seem to be the most important in determining the overall project risk?

1. Decision Tree Analysis:

- Causes the organization to structure the costs and benefits of decisions when the results are determined in part by uncertainty and risk.

- Solution of the decision tree helps select the decision that provides the highest Expected Monetary Value or expected utility to the organization.

- Critical success factors:
  - Careful structuring of the decision tree; all alternative decisions that are materially different should be considered; decision trees should be specified completely
  - Access to high-quality data about probability, cost, and reward for the decisions and events specified using historical information or judgment of experts.
  - Use of a utility function that has been validated with the organization's decision makers.
  - Availability and understanding of the specialized software needed to structure and solve the decision tree.

- Weaknesses:
  - Sometimes difficult to create the decision structure.
  - Probabilities of occurrences can be difficult to quantify in the absence of historical data.
  - The best decision may change with relatively plausible changes on the input data, meaning that the answer may not be stable.
  - The organization may not make decisions based on a linear Expected Monetary Value basis, but rather on a non-linear utility function; these functions are difficult to specify.
  - Analysis of complicated situations requires specialized (through available) software.
  - There may be some resistance to using technical approaches to decision making.

- Specialized and widely available software used specifies the structure of the decision with decision nodes, chance nodes, costs, benefits, and probabilities
- User can evaluate the different decisions using functions based on Expected Monetary Value or non-linear utility functions of various shapes.

An example is shown below here:

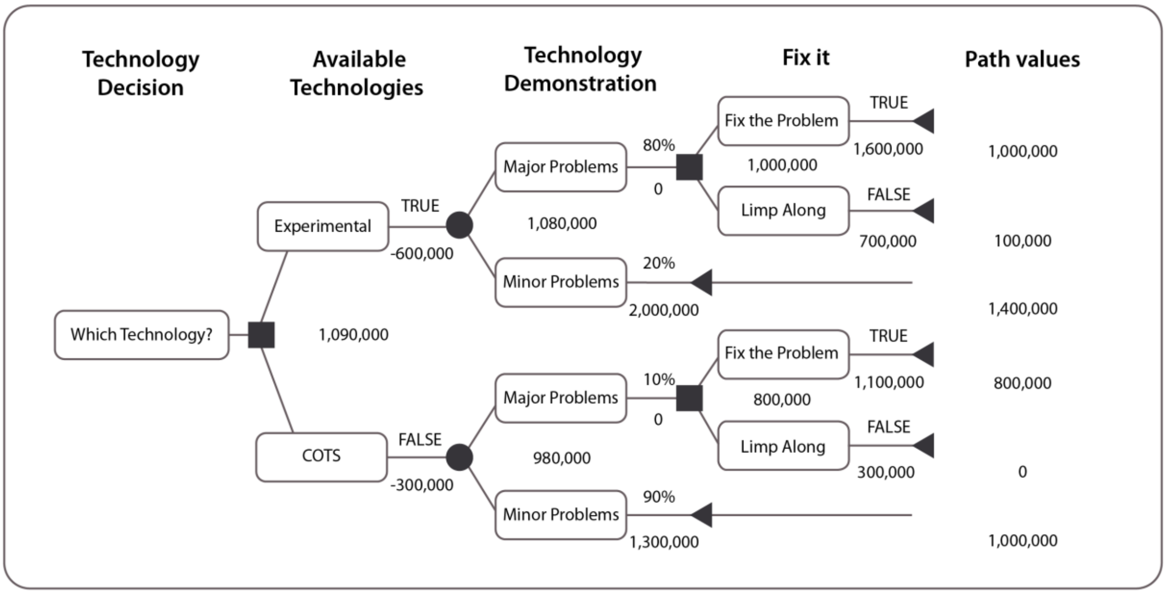


Figure 7.2: Example of Decision Tree for Choosing between an Experimental Technology vs. Commercial Off the Sheet (COTS) Technology.
Source: Precision Tree from Palisade Corporation

- The negative numbers represent outflows or investments (e.g. COTS)
- The percentage represents probabilities of the event occurring (e.g. Major Problems)
- The positive numbers represent rewards or values (e.g., after "Fix the problem")
- "True" indicates the decision option taken from the square decision node, whereas "false" indicates the decision option not taken.

2. Expected Monetary Value (EMV):

- Allows the user to calculate the weighted average (expected) value of an event that includes uncertain outcomes.
- It is well-suited to Decision Tree Analysis.
- Incorporates both the probability and impact of the uncertain events.
- Simple calculation that does not require special software.
- Critical success factors include:

- Identification of all possible events that need to be included in the EMV calculation.
- Access to historical data or expert opinions on the values of probability and impact that are needed for the calculation of EMV.
- Understanding of the difference between EMV and the output of simulation tools such as Monte Carlo analysis.

- Weaknesses are:

  - Assessment of probability of risky events' occurring and of their impact can be difficult to make.
  - EMV provides only the expected value of uncertain events; risk decisions often require more information than EMV can provide.
  - Sometimes used in situations where Monte Carlo simulation would be more appropriate and provide additional information about risk.

The EMV calculation for an event by weighting the individual possible outcomes by their probabilities of occurring is shown in **Figure 7.3** below**.**

Example of an Expected Monetary Value (EMV) Calculation for a Business Strategy that Depends on Uncertain Market Demand			
Uncertain Outcome	**Reward ($000)**	**Probability**	**Contribution to EMV**
High Market Demand	800	30%	240.0
Moderate Market Demand	450	45%	202.5
Low Market Demand	250	25%	62.5
Total EMV			**505.0**

3. Fault Tree Analysis (FMEA):

- A Fault Tree Analysis is the analysis of a structured diagram which identifies elements that can cause system failure.
- This technique is based on deductive logic and can be adapted to risk identification to analyze how risk impacts arise. The effective application of this technique requires a detailed description of the area being discussed.
- The undesired outcome is first identified and then all possible conditions/failures which lead to that event are identified. This reveals potentially dangerous elements at each phase of the project.
- Disadvantage:

  - Opportunities may be missed in this step as emphasis is laid on threats. The tools required in this technique are generally available only to experts.

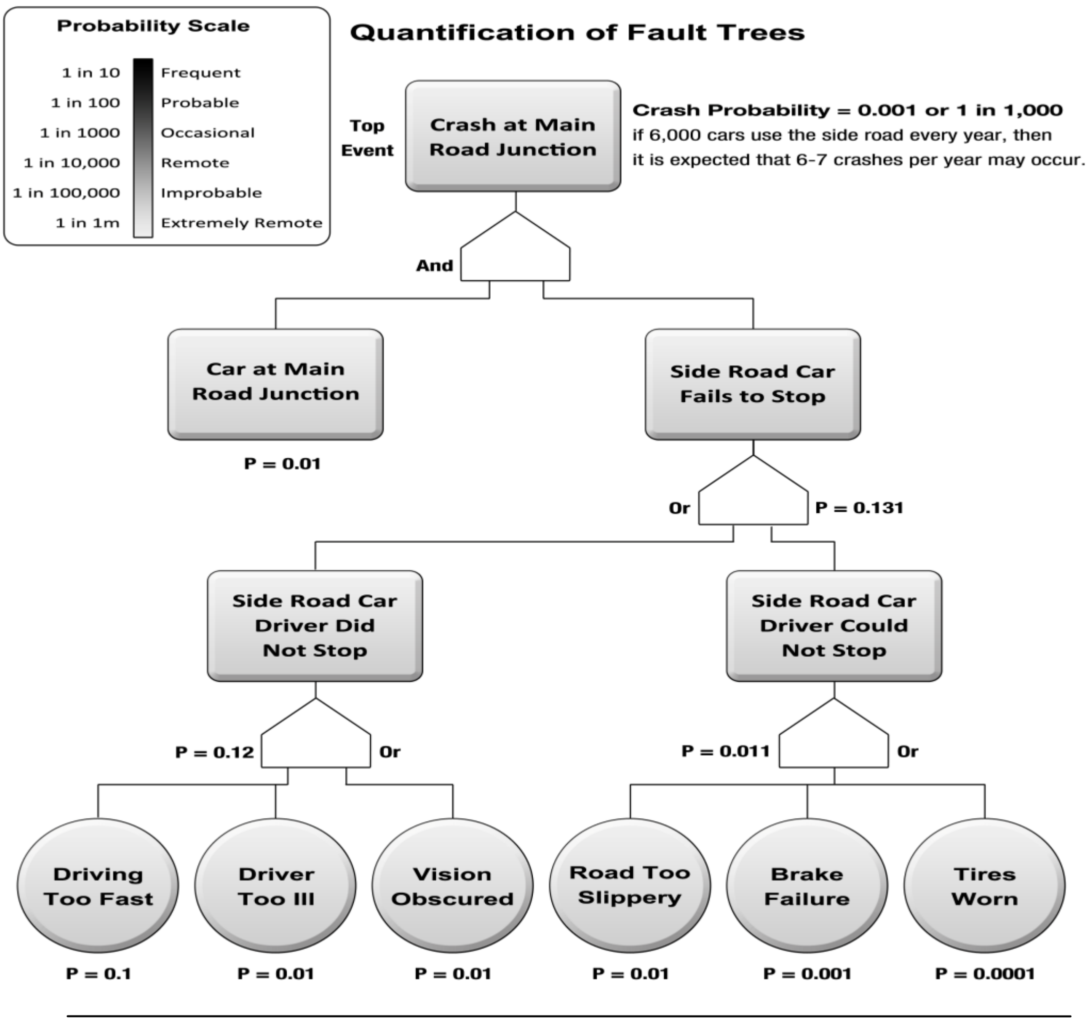


Figure 7.4 Fault Tree Analysis of the Possible Causes of a Crash at the Main Road Junction

4. Monte Carlo Simulation:

- Used primarily for project schedule and cost risk analysis in strategic decisions.
- Allows all specified risks to vary simultaneously.
- Calculates quantitative estimates of overall project risk; reflects the reality that several risks may occur together on the project.
- Provides answers to questions such as:
    - How likely the base plan to be successful?
    - How much contingency in time and cost do we need to achieve our desired level of confidence?
    - Which activities are important in determining the overall project risk?

- Critical success factors include:
  - Creation of a good project model and typical models include the cost estimate and the schedule.
  - Use summary-level models such as project schedules and cost estimates.
  - Access to high-quality data on risks including the risks impact on project elements, uncertain activity durations and uncertain cost elements; the credibility depends on the quality of the data collected
  - Use of correct simulation tools.

- Weaknesses include:
  - Schedules are not simple and often cannot be used in simulation without significant de-bugging by an expert scheduler.
  - The quality of the input data depends heavily on the expert judgment and the effort and expertise of the risk analyst.
  - Simulation is sometimes resisted by management as being unnecessary or too sophisticated compared to traditional project management tools.
  - Requires specialized software which must be acquired and learned, causing a barrier to its use.
  - Produces unrealistic results unless input data include both threats and opportunities.

Examples of the output of schedule and cost risk results are shown in **Figures 7.5 and 7.6.**

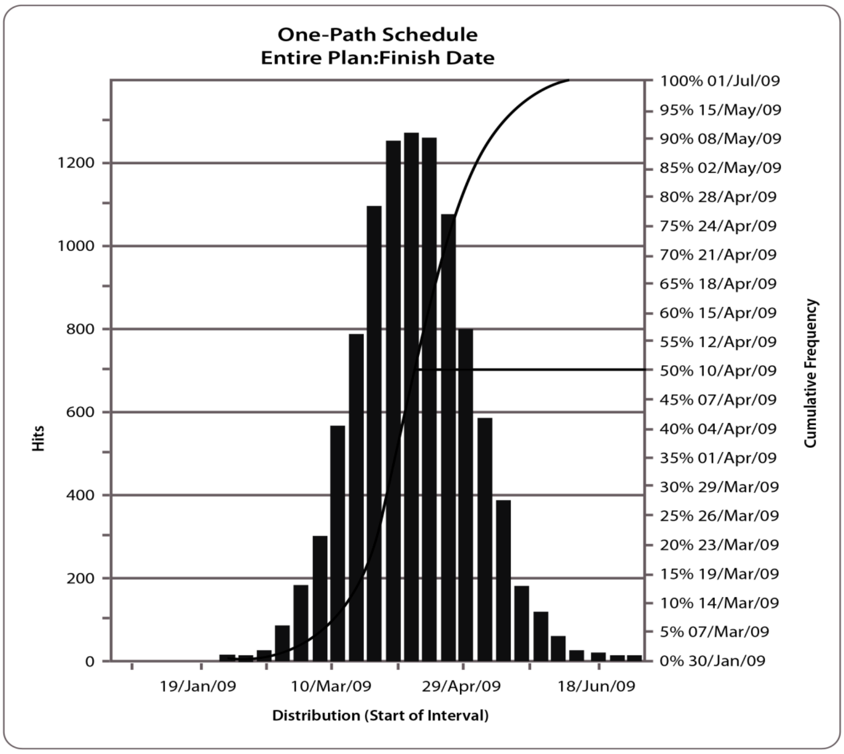
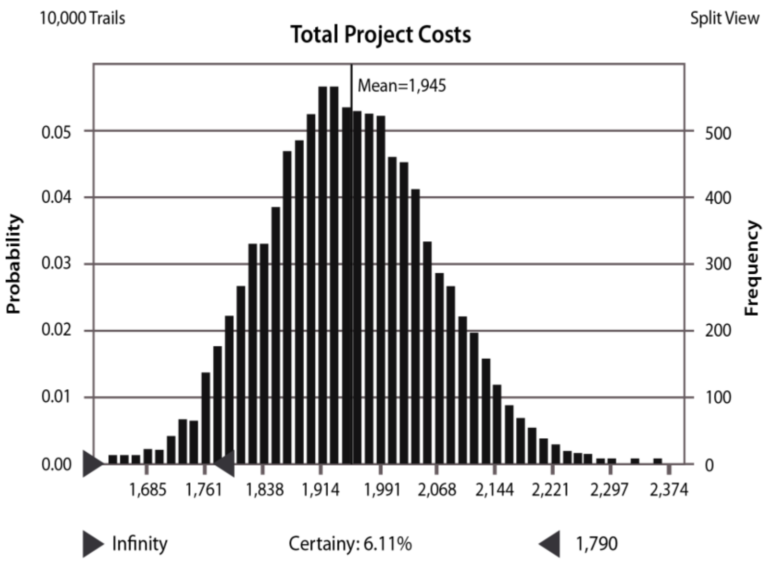


Figure 7.5: Example Histogram from Monte Carlo Simulation of a Project Schedule
Source: Pertmaster v 8.0 Primavera Pertmaster



Percentile	Forecast Values
0%	1,634
10%	1,813
20%	1,856
30%	1,887
40%	1,914
50%	1,942
60%	1969
70%	1,999
80%	2,032
90%	2,081
100%	2,364

Figure 7.6: Example Histogram from Monte Carlo Simulation of a Project Estimate.
Source: Crystal Ball v. 7.3.8 from Oracle Hyperion (Decisioneering)

5. Post-project reviews/ Lessons Learned/Historical Information:

- The review of risk databases of previous projects, such as those that arise from post-project reviews or lessons learned exercises or historical information within an organization or industry can reveal information relevant for a current project.

- This technique leverages previous experience, and prevents the occurrence of the same mistakes or missing the same opportunities again.

- Participation of previous project team members and a well-structured project lessons database increases the effectiveness of this technique.

- Disadvantages: Only those risks that have occurred previously can be identified. The information available may also be incomplete with no details on ineffective strategies, lack of details of successful resolution etc.

6. System Dynamics:

- System Dynamics (SD) is a particular application of Influence Diagrams and identifies risks within a project situation through the representation of information flows and other entities.

- An analysis of the SD model exposes unexpected inter-relations between project elements (feedback and forward loops) which lead to uncertainty. The technique can also show the impact of risk events on overall project results.

- Successful application of this technique depends upon the quality of the model, accuracy of input data collected for the project, understanding of feedback, and competence in applying the tools and understanding their output.

- Disadvantages: The building of the SD model requires specialized expertise and software. The technique focuses on impacts but it is difficult to include the concept of probability.

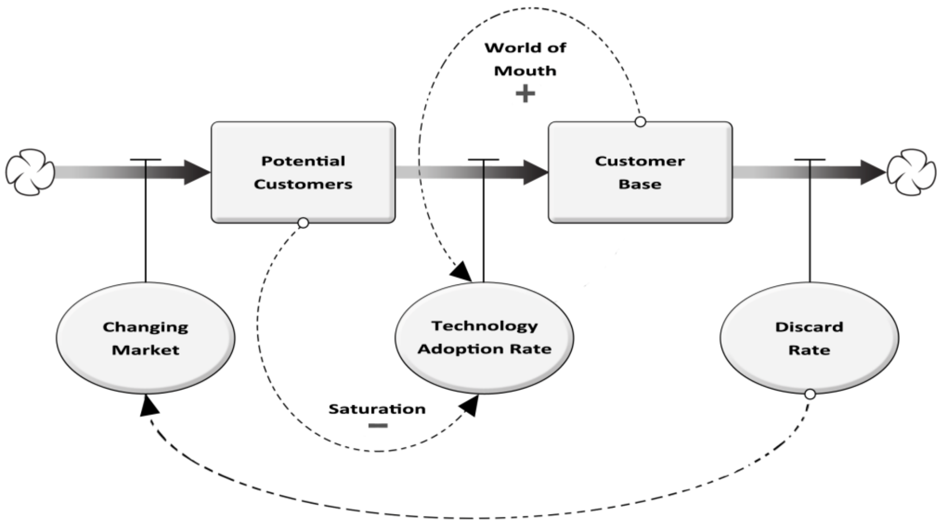


Figure 7.7 Example of a Simple System Dynamics Model with Feedback Loops

Terms and Concepts

1. **Bias**: During information gathering about risk, the source of information exhibits a preference or an inclination that inhibits impartial judgment.

2. **Cause**: Events or circumstances which currently exist and which might give rise to risks.

3. **Decision Tree Analysis:** A diagram that describes a decision under consideration and the implications of choosing one or another of the available alternatives. It is used when some future scenarios or outcomes of actions are uncertain.

4. **Monte Carlo Analysis**: A technique that computers or iterates the project cost or project schedule many times using input values, selected at random from probability distribution of possible costs or durations, to calculate a distribution of possible total project cost or completion of project dates.

5. **Overall Project Risk:** It represents the effects of uncertainty on the project as a whole.

6. **Perform Quantitative Risk Analysis**: The process of numerically analyzing the effect of identified risks on overall project objectives.

7. **Project Management Process Group**: The project management process group refers to specifically the area of logic oriented grouping or arrangement of the numerous projects.

8. **Risk Model**: A representation of the project including data about project elements and risks that can be analyzed by quantitative risk analysis.