A SunCam online continuing education course

Managing Project Risk

By

James N. Salapatas, PE, PMP

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INTRODUCTION

This course is about managing project risk in an organization whether you are an engineer, senior manager or professional project manager. In the project world, managing risk is critical because every decision, every action taken contains some element of risk. Risk cannot be eliminated. Risk can only be controlled and accepted if the decision or action needs to be made. Understanding this concept becomes important when considering that practically everyone in an organization is involved in some kind of project work and makes decisions involving risk.

In the ideal project world, project managers are trained in project risk management.[1] In the real project world, many projects are small and assigned to engineers and managers with less than formal risk management training. Managing risks become critical to achieving project cost and schedule targets. This course presents three basic principles for managing project risk, namely, identify, quantify, and control. However, managing project risk still depends on experience and skill of the engineer or manager to identify, quantify and control the risk in order to manage it.

Figure 1

[1] Project Management Institute, *PMBOK® GUIDE Fifth Edition 2013 Project Risk Management, Chapter 11*

COURSE MAP

The course map below presents the key topics of the course with a page number.

INTRODUCTION

Risk management formally began after World War II in the financial world.[2] The original context of risk covered loss. Loss of possessions, property, and health were considered insurable. This type of risk was called pure risk. Risk connected to a company's profit or loss was not insurable. This type of risk was called business risk. In parallel, engineers were developing operating process models and technology advancements that involved risk. That risk was also connected to a company's profit or loss and was considered a business risk and not insurable. Projects can have components of pure risk and business risk. Managing project risk begins first by identifying the various components of risk and separating pure risk, which is insurable, and business risk which is not.

Business Risk

Figure 2

Making a decision or taking action for a project will cause an event to occur that may involve risk. These are classified as business risks and can be identified, quantified and controlled. The ability of organizations to forecast the future has always been a challenge. The future is unknown. There are future events that could happen in projects that are unexpected and we know nothing about. Unexpected events that happen in projects are defined as uncertainty. Uncertainty is unknown. Uncertainty cannot be identified, quantified or controlled.

UNCERTAINTY VS RISK

Uncertainty

In the project world uncertainty is defined as double unknown event or condition, or an unknown. The first unknown means that the event or condition has never happened before in this type of project, and if it did, it would not be expected. The second unknown means that there is no practical way to anticipate and measure the impact of that unknown event or condition until it happens.

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[2] Dionne, G. (March 2013), *Risk Management: History, Definition and Critique,* CIRRELT, Universite de Montreal

For example, an over-size transport vehicle waiting to deliver 50 tons of structural steel for cellular towers to a construction site falls into a sink hole outside the construction gate. This is an unexpected, unanticipated event and is classified as uncertainty, an unknown. Uncertainty in contract law is covered by a legal term called an "act of God" that implies impossibility or impracticability.[3] The event or condition is outside human control such as natural disasters. No one can be held responsible for natural disasters.

Figure 3

Risk

In the project, world risk is classified as a known unknown. The known part means that the event or condition typically happens in most projects. It has happened before and data exists on how the event or condition was managed. The unknown aspect of risk means that the event or condition may never happen, or if it does, it is difficult to predict when it may happen.

For example, the over-size transport vehicle delivering the 50 tons of structural steel for cellular towers to a construction site must follow a specific highway itinerary. This is necessary due to the over-size condition of the transport vehicle. The route and delivery date are planned and scheduled by contract. The route involves coordination between several state highways. This means that permits and clearances must be obtained in a timely fashion to connect the route to the construction site without any delays.

However, experience has shown that some problems seem to happen in route that delays the delivery schedule. Data records show when and where these problems have occurred in the past. Accordingly, the delivery contractor can be prepared to take action if and when these problems occur. The risks have been identified, the potential delivery schedule impact can be quantified and a control plan can be put in place.

[3] *Webster's II New College Dictionary*, *Third Edition 2005: Law*- An unforeseeable or inevitable event, as an earthquake or flood, caused by nature. Also found in legal and financial reference documents

PLANNING FOR MANAGING PROJECT RISK

A discussion describing the basic principles for managing project risk would not be complete without a brief overview of the project management process.

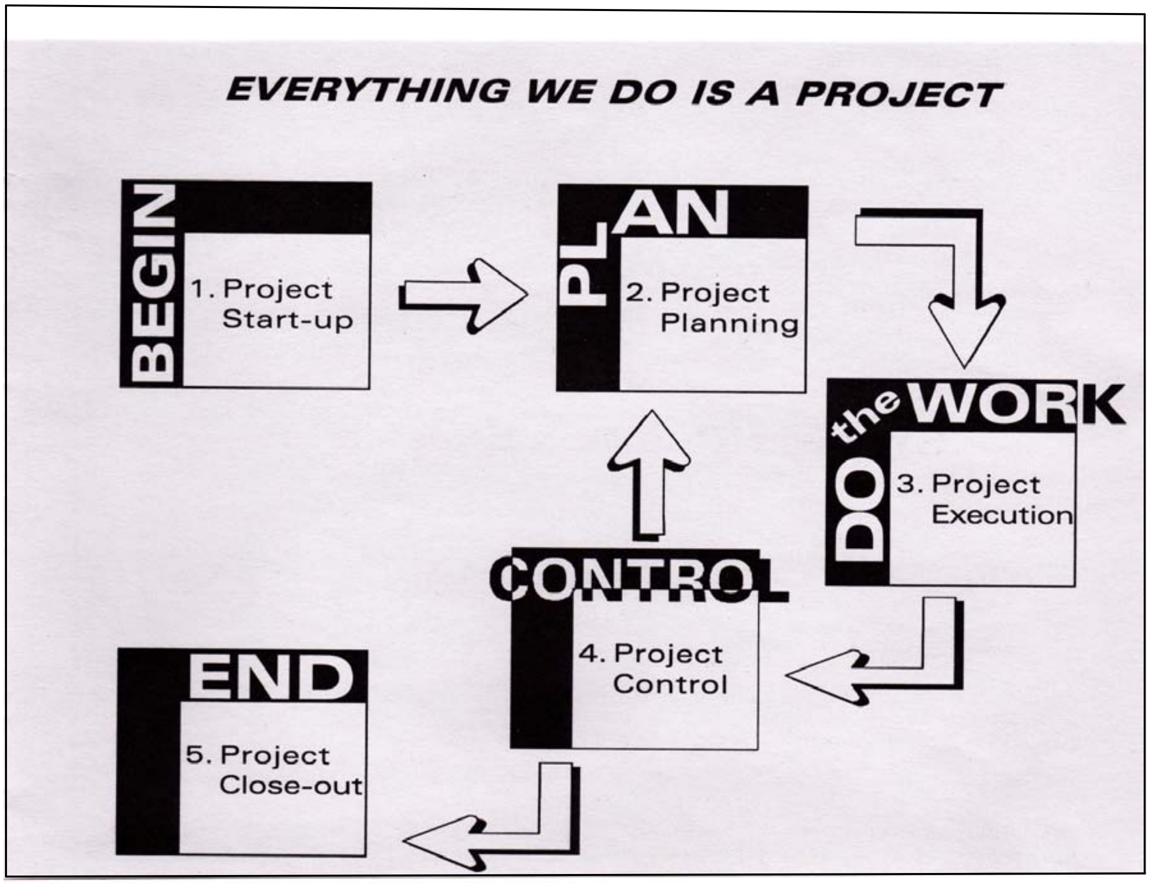

Figure 4

Project Management is the application of knowledge, skills, tools and techniques to project activities to meet project requirements.[4] Figure 1 is an illustration that represents Project Management's five Process Groups. All projects, regardless of size, follow the process groups. The more complex and larger the project, the more formal documentation is required.

[4] Project Management Institute, *PMBOK® GUIDE Fifth Edition 2013 Introduction, Chapter 1*

Using the Project Management Process to Manage Risk

The **PLAN** process, Project Planning, is the starting point for identifying project risks. Where do project risks come from? One needs only to look at the organization and the project plan to recognize them. The following list identifies the type of risks that could affect a project.

External Environment

- **Technical**
- **Political**
- **Laws/Regulations**

Internal Environment

- **Operations**
- **Finance**
- **Stakeholders**

Project Environment

- **Scope of Work**
- **Work Breakdown Structure**
- **Schedule Delivery**
- **Cost & Budget**
- **Quality**

This course will focus on the ***project environment***. The project environment is where projects, small and medium in size and complexity, are assigned to engineers and managers with less than formal risk management training. This is where the engineers and managers can use the basic principles effectively to manage project risk. The following project example was selected to demonstrate the application of the principles for managing project risk.

Project Title: The Hermes Tower
Project Description: The increased demands in wireless service has provided Towerbuild Communications, Inc, (TCI) with a successful business to design and build relay towers and control centers and lease them to communications companies nation-wide. Because of TCI's success and their expertise in project management, the largest of these communications companies, Global Technologies Corporation (GTC), has contracted with TCI to deliver a new prototype cellular relay tower with advanced digital technology and increased relaying capacity. This project involves new technology to design and build a new cellular relay tower that would improve the quality of GTC's global wireless system. The prototype tower called 'Hermes' was named after the Greek god 'messenger.' GTC has advertised that the Hermes Tower will dramatically improve their wireless system next year. They expect a substantial increase in revenue and an increase in market share. For TCI, a successful design, build and acceptance test of the Hermes tower would result in an exclusive 7 year contract for more Hermes towers. The contract was awarded to TCI in July at the beginning GTC's fiscal year. The contract stipulates that the project must be completed in the summer of the following year.

Hermes Tower

Figure 5

IDENTIFYING PROJECT RISK

The principle of indentifying risks involves the process of determining which risks may affect the project and documenting their characteristics. The factors that characterize risk are:

- **RISK EVENT**
- **PROBABILITY OF OCCURRENCE *(SHOWN IN PERCENT)***
- **AMOUNT AT STAKE *(SHOWN IN DOLLARS)***

RISK EVENT

The definition of risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives.[5]A tool for identifying a risk event is the "What if, Then" rule. This rule can be used for data gathering and is important because it specifies the elements of a *RISK EVENT* in more detail. Some examples are:

- "**What if** a coil spring was stretched beyond its prescribed length limit, **then** the coil spring would not return to its original working length and need to be replaced.

- **What if** a 1000 pound load was put on a factory weighing scale calibrated at a maximum of 500 pound, **Then** the scale would break and need to be replaced

- **What if** a cellular tower was designed to withstand a 250 MPH wind velocity and a wind gust was measured that exceeded that velocity, **then** the tower would collapse and need to be rebuilt.

RISK EVENT when combined with the *PROBABILITY OF OCCURRENCE* and *AMOUNT AT STAKE* is used for quantifying and controlling risk. The *PROBABILITY OF OCCURRENCE* and *AMOUNT AT STAKE* will be defined later in the discussion.

[5] Project Management Institute, *PMBOK® GUIDE Fifth Edition 2013, Glossary*

Managing Risk in the Project Environment

In this course the **project environment** will be the focus of project risk. In the introduction, it was stated that managing project risk depended on the experience and skill of the engineer or manager to identify and quantify the risk in order to manage it. While this is still important to managing risk, company data of project miscues and how they were solved and records of project lessons learned are vital resources for risk identification.

Companies who work on projects typically compile this information into a formal comprehensive record called a Risk Register.[6] In any case, what is important is to record in a document and/or computer file the history of risks that have occurred in company projects and how they were managed. This **risk history** becomes one source to identify project risks. Other sources that involve **data gathering** are listed below:

DATA GATHERING TECHNIQUES

- Brainstorming
- Delphi Technique
- Interviewing
- Root Cause Analysis
- SWOT Analysis

Brainstorming is a creative data gathering method in a group setting of team members and subject matter experts who present ideas, problems and solutions to problems without initial justification or analysis. A time limit is set for the session.

Delphi Technique is an iterative process of gathering consensus on an idea, problem or solution to a problem from a group of subject matter experts (SME). A facilitator uses a questionnaire to poll the SME's and summarizes the results.

Interviewing is an approach to data gathering by a face to face meeting to solicit ideas, problems or solutions to problems from SME's and stakeholders. A predesigned questionnaire with specific questions is used for the interview with responses recorded.

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[6] ibid

Root Cause Analysis is an analytical technique to uncover a basic underlying reason that causes a problem or a risk. A root cause may underlie more than one problem or risk.

SWOT Analysis is an analytical approach to identify a company's **S**trengths, **W**eaknesses, **O**pportunities, and **T**hreats. The analysis involves executive level participation and with a focus on the organization's mission and strategic objectives.

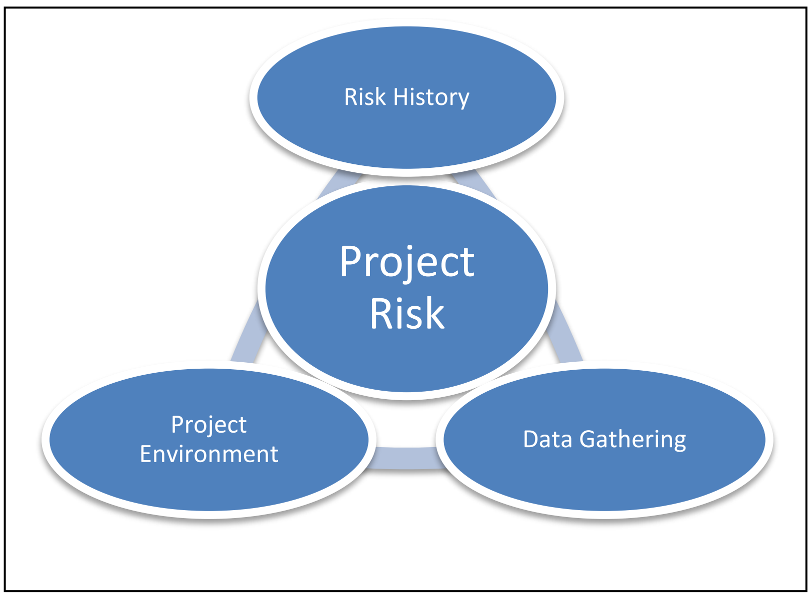


Figure 6

Figure 6 show the three main sources for identifying project risk, namely, Risk History, Project Environment, and Data Gathering. All three are combined in an iterative process until the project team comes to consensus on a list of risks.

Data Gathering in a Project Environment

Experience has shown that the project environment, specifically the Work Breakdown Structure (WBS) is a common starting point in most projects for identifying risks. The WBS represents the scope of the work to be done and describes the deliverables of the project. If risks were to be found, they would impact the deliverables. Figure 7 below is an example of a LEVEL 3 WBS for TCI's Hermes Tower project.

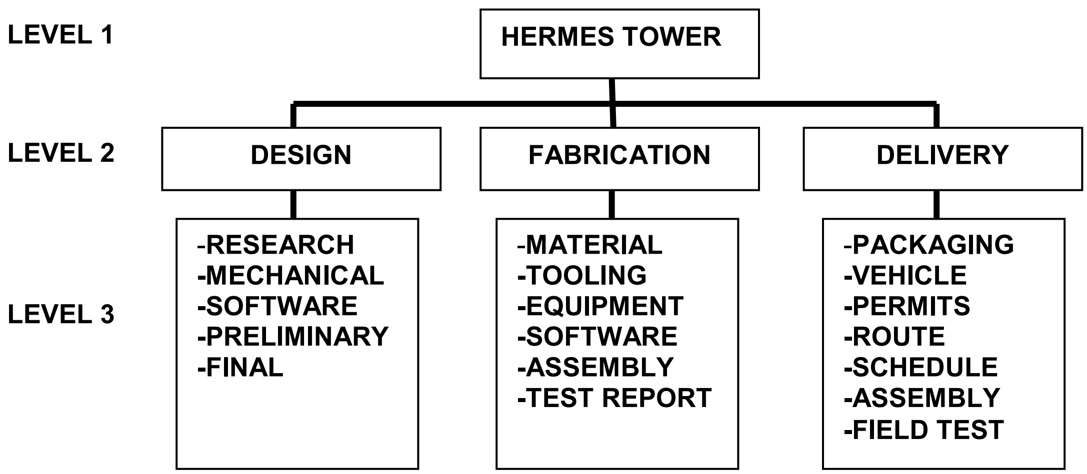


Figure 7

Identifying Project Risk for the Hermes Project

Before awarding the contract to Towerbuild Communications, Inc. (TCI) to deliver a new prototype cellular relay tower with advanced digital technology and increased relaying capacity, Global Technologies Corporation (GTC) had checked TCI's references cited in the proposal response. The proposal response described how TCI had successfully tested the technology using a smaller model of the Hermes.

The proposal stated that their factory layout would need to be changed to accommodate fabrication of the large prototype. New fabricating equipment and tools would be made and a new factory control system would be implemented to insure fabrication deadlines would be met. TCI's proposal included a detailed project schedule and a cost breakdown with a contingency. The contract was Cost plus Incentive Fee (CPIF) with bonus/penalty for delivery schedule completion.

Given TCI's project management expertise, the team met to begin identifying project risks. The Hermes Tower was a prototype using new technology. Since there was no risk history, there could be technical risks in the tower design and the communications software. These technical risks in the tower design could affect the delivery schedule. More importantly, TCI needed to build new fabricating equipment and tools and change their factory layout to accommodate the fabrication of the Hermes. The project included plans to install a new factory control system.

A miscue in any of these planned situations might cause a delay to the delivery beyond the target GTC had set and advertized to its clients. Instead of a bonus, TCI might end up with a penalty for missing the scheduled delivery target and jeopardize any future contract with GTC. The TCI team decided that further data gathering was necessary to indentify the risks.

Two of the most reliable risk data gathering techniques are Brainstorming and Root Cause analysis performed in unison. Brainstorming creates the list of risks. What can be done about a risk depends a great deal on its causes. For each identified risk that is assessed as significant, a cause must be determined for the type of risk that it represents.[7] The Cause-Effect Diagram provides an effective tool to identify causes that might result in risk. The Cause-Effect Diagram method organizes the risks and assigns them into categories for quantifying.

The Cause-Effect Diagram originated during the Japanese quality movement by Dr. Kaoru Ishikawa, a quality guru, and has been called a fishbone diagram because of its configuration. Along with flow diagrams, it is used widely in the quality management field to solve process problems. The benefit of the Cause-Effect Diagram is that it presents a visual display of root causes that allows a deeper understanding of the sources and likelihood of potential problems.[8]

A Cause-Effect Diagram will have several main branches as shown in Figure 8, with multiple potential sources attached to the main branches. Note that the problem, the *effect*, is Product Delivery. Customers complain that the product is rarely delivered as promised. The diagram has four main branches, each of which have sources of

[7] Tom Kendrick, PMP, *Identifying and Managing Project Risk*(Second Edition, AMACOM,2009)
[8] ibid

potential problems. A significant cause that appears in both Process and Equipment is Low MTBF which means low Mean Time Between Failure. The low reliability of process and equipment could be a significant cause for delivery problems.

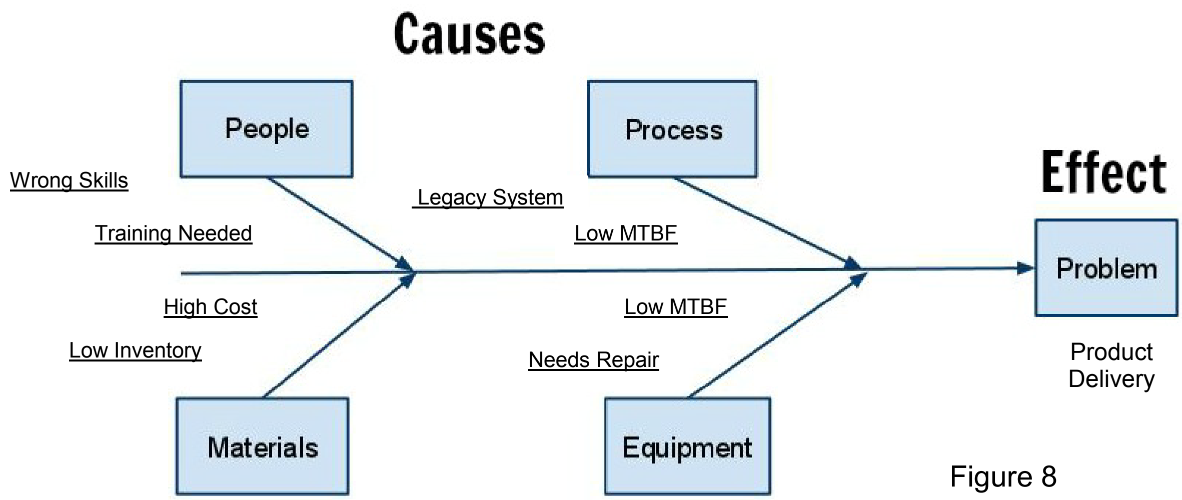


Figure 8

Identifying Risk for the Hermes Tower

Identifying risks for the Hermes Tower started by looking at new technology. Other questions were raised. What if fabrication work was delayed? What if the new factory control system had problems? All these questions seemed to affect the delivery target. Given that the delivery risk was significant for the Hermes Project, the project team, in a brainstorming session, came up with a list of causes for this risk and selected their respective categories. The significant risks were then posted in each branch on the following Cause-Effect Diagram, Figure 9.

Some of the team questions used the "What If, Then" rule. See examples below.

- **What if** the new factory equipment installation has operating problems, **Then** the target delivery of the Hermes Tower could be delayed.

- **What if** the current factory could not accommodate the new layout and fabrication had to be moved to another site, **Then** the target delivery of the Hermes Tower would be missed.

- **What if** there is a route delay during Hermes Tower delivery, **Then** the target delivery of the Hermes would be missed.

Review of the Hermes Tower Cause-Effect Diagram revealed that the 15 risk items posted would be enough for the first round of quantifying risks for evaluation.

HERMES TOWER CAUSE - EFFECT DIAGRAM

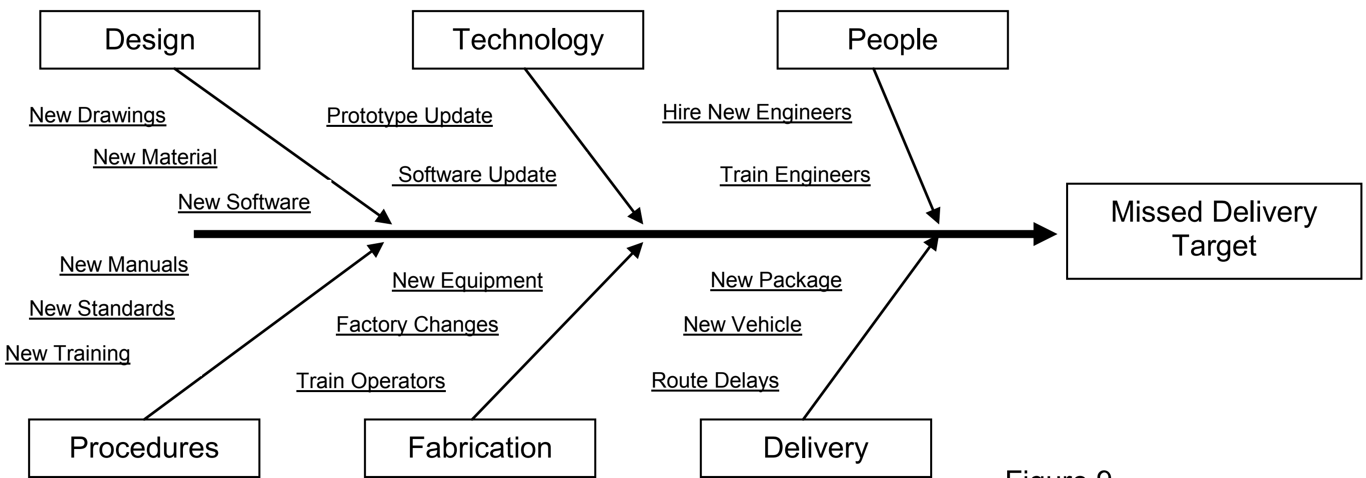


Figure 9

QUANTIFYING PROJECT RISK

The principle of quantifying risk involves the process of assigning probability and impact to the identified risks, prioritizing them and adding monetary value according to the impact and consequences on project performance. The first step in quantifying risk involves a qualitative approach.[9] Risk is analyzed based on the quality or character of the risk as opposed to its size or quantity. Before expending time and effort to perform more detailed analyses and adding size or quantity values to all of the identified risks, a simple method using probability of occurrence and impact will often yield an initial priority list of risks to analyze.

Figure 10 illustrates a Risk Matrix that compares the probability of a risk occurring and compares that risk to its impact on a project objective. Impact is the vertical scale and Probability is the horizontal scale.

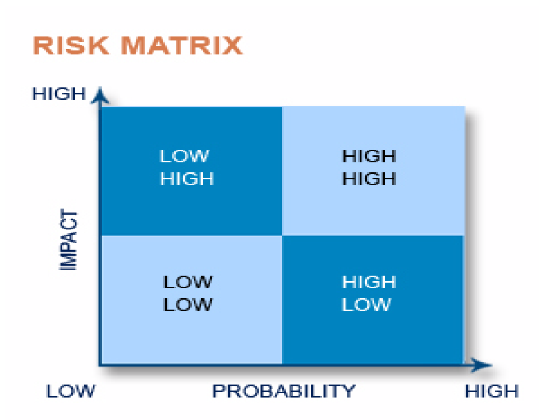


Figure 10

IMPACT represents the effect a risk has on a project objective. It is typically a consensus of opinions, using a scale of high to low in team meetings from subject matter experts, project manager and/or team members. Later, that impact consensus will be assigned a numerical value to aid in prioritizing the list of risks.

[9] Project Management Institute, *PMBOK® GUIDE Fifth Edition 2013, Chapter 11.3 Project Qualitative Risk Analysis*

PROBABILITY represents the likelihood that the risk will occur. It is typically a consensus of opinions, using a scale of high to low in team meetings from subject matter experts, project manager and/or team members. Later, that probability consensus will be assigned numerical values to aid in prioritizing the list of risks.

Hermes Tower Risk Matrix

The Hermes Tower Risk Matrix below, Figure 11, was the result from a team meeting where impact and probability of the risks were estimated by subject matter experts, the project manager and team members. This is the qualitative approach using terms of high-low for each cell in the matrix. The following calculation was used to prioritize the risks. Each high-low term was assigned a **numerical value (1 to 5)** multiplied with each other (Impact times Probability). The Priority Value Table, Figure 12, shows the 15 risks, from the Risk Matrix with their respective impact and probability value and calculates their priority value.

HERMES TOWER RISK MATRIX

IMPACT	PROBABILITY				
	VERY LOW (1)	LOW (2)	MODERATE (3)	HIGH (4)	VERY HIGH (5)
VERY HIGH (5)		Delivery -Route Delays		Fabrication -New Equipment	
HIGH (4)		Technology -Prototype Update	People -Hire New Engineers	Fabrication -Factory Changes	
MODERATE (3)		Design -New Drawings	Design -New Software People -Train Engineers		
LOW (2)		Design -New Material	Fabrication -Train Operators	Technology -Software Update	
VERY LOW (1)	Procedures -New Standards	Procedures -New Manuals -New Training	Delivery -New Vehicle	Delivery -New Package	

Figure 11

Hermes Tower – Priority Value Table

No.	Risk	Impact	Probability	Priority Value	Priority
1	Fabrication -New Equipment	Very High (5)	High (4)	5x4=20	1
2	Fabrication -Factory Changes	High (4)	Very High (4)	4x4=16	2
3	People -Hire New Engineers	High (4)	Moderate (3)	4x3=12	3
4	Delivery -Route Delays	Very High (5)	Low (2)	5x2=10	4
5	People -Train Engineers	Moderate (3)	Moderate (3)	3x3=9	5
6	Design -New Software	Moderate (3)	Moderate (3)	3x3=9	5
7	Technology -Software Update	High (4)	Low (2)	4x2=8	6
8	Design -New Drawings	Moderate (3)	Low (2)	3x2=6	7
9	Fabrication -Train Operators	Low (2)	Moderate (3)	2x3=6	7
10	Design -New Material	Low (2)	Low (2)	2x2=4	8
11	Delivery -New Package	Very Low (1)	High (4)	1x4=4	8
12	Delivery -Vehicle	Very Low (1)	Moderate (3)	1x3=3	9
13	Procedures New Manuals	Very Low (1)	Low (2)	1x2=2	10
14	Procedures New Training	Very Low (1)	Low (2)	1x2=2	10
15	Procedures New Standards	Very Low (1)	Very Low (1)	1x1=1	11

Figure 12

QUANTIFYING PROJECT RISK - Using the Risk Factors

The factors that characterize risk were presented in an earlier discussion. They are:

- **RISK EVENT**
- **PROBABILITY OF OCCURRENCE *(SHOWN IN PERCENT)***
- **AMOUNT AT STAKE *(SHOWN IN DOLLARS)***

RISK EVENT

The definition of risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives.[10] A Risk Event is different than the definition of risk because its description must include the other factors namely, the Probability of Occurrence and Amount at Stake. A tool for identifying a risk event is the "What if, Then" rule.

PROBABILITY OF OCCURRENCE

The *PROBABILITY OF OCCURRENCE* is the likelihood that a specific RISK *EVENT* will occur. The *RISK EVENT* must contain a full description of the event and a full description of the outcome. The *PROBABILITY OF OCCURRENCE* is expressed as a percentage.

AMOUNT AT STAKE

The *AMOUNT AT STAKE* is the value of the investment of the decision to be made whether it is an increase (+) or a loss (-). The *AMOUNT AT STAKE* is expressed in dollars. If the decision is made will it result in an increase in the cost? If the decision is made will the loss be greater?

EXAMPLE RISK EVENT: 'missing target delivery'

*For e*xample, If the delivery of a product misses the target delivery by 5 days, then there will be a loss of sales revenue of approximately $5,000 per day. The *PROBABILITY OF OCCURRENCE* was estimated at 50%. The *AMOUNT AT STAKE* is $5,000.It is important to note that the *PROBABILITY OF OCCURRENCE is connected to the specific risk event.*

[10] Project Management Institute, *PMBOK® GUIDE Fifth Edition 2013, Glossary*

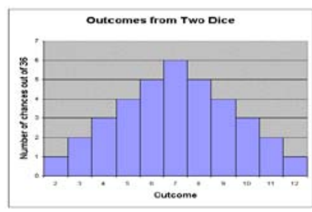
A different *RISK EVENT;* i.e. If the delivery of a product misses the target delivery by a different number of days, both the *PROBABILITY OF OCCURRENCE* and the *AMOUNT AT STAKE* could change.

Determining the Probability of Occurrence

Probability of occurrence may be objective or subjective. Objective probability means that there are a finite number of outcomes. The outcomes of a coin flip and tossing dice are considered objective. For a coin flip there are two sides, heads or tails.

The probability of getting a head or a tail is 50 % (1÷2) *Formula = 1outcome divided by a total of two possible outcomes*

For a pair of dice, there are six sides with dots in each side from one to six.



There are 36 combinations for summarizing the dots of a pair of dice. The probability of getting a 7 is 17 % (6÷36) There are 6 combinations: #1 (1+6, 2+5, 3+4) #2 (6+1, 5+2, 4+3). *Formula = 6 outcomes divided by a total of thirty six possible outcomes*

Subjective probability, on the other hand, may have an infinite number of outcomes. Forecasting weather or predicting population health issues for insurance are considered subjective probability. The conventional wisdom is that subjective probability contains no formal calculations and reflects only opinions and past recorded experience. Over the years vast data has been accumulated for forecasting weather and predicting health issues. Forecasting and insurance models have been developed to aid in determining subjective probability.

The world of project management has many cost and schedule outcomes. Project management falls under the category of subjective probability. Similarly, project risk history, lessons learned, and trends have been accumulated and used to develop models and techniques to determine project subjective probability. Some computer models, such as Monte Carlo Simulation and PERT[11] are used by the government and industry for very large projects. Decision Trees can be used when there are a small number of outcomes.

PERT (Program Evaluation Review Technique): is a technique using a Beta Curve, Figure 11, to predict cost and schedule outcomes. PERT was developed by the Navy in 1950 for their Polaris Missile Program and later the NASA space program. It was released to the public and has been a workhorse cost and scheduling tool for projects in education and private industry.[12]

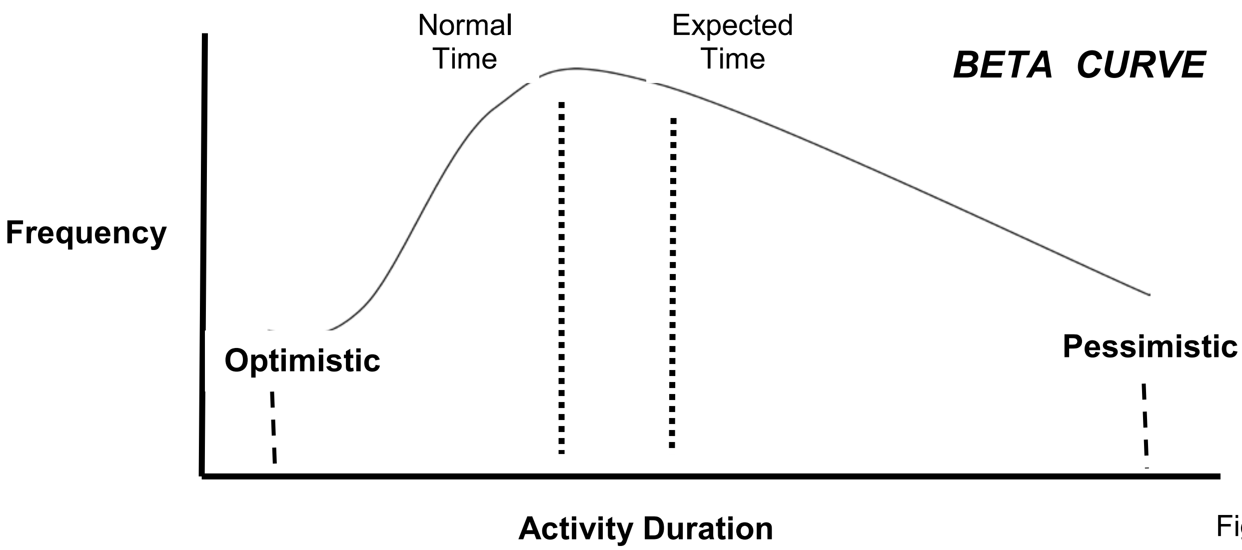


Figure 13

The PERT technique uses three time values, Optimistic, Normal, and Pessimistic. Expected Time is calculated to provide input to the probability of occurrence. The formula is given below.

$$\text{Expected Time} = \frac{\text{Optimistic time} + 4 \times \text{Normal time} + \text{Pessimistic time}}{6}$$

Expected values are calculated for the critical activities of a project schedule and follow a 3 STEP process that results in determining the probability of meeting the project schedule. The Hermes Tower project is scheduled to be completed in 45 weeks and has the following critical project activities as listed in Figure 14 below.

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[11] Program Evaluation Review Technique (PERT) is a technique using a Beta curve model to predict cost and schedule outcomes. PERT was developed by the Navy in 1950 for their Polaris Missile Program.
[12] Microsoft Office Project Profession 2010 has PERT

STEP 1 Hermes Critical Activities (Activity Data Bank)

Critical Activities	Optimistic weeks	Normal weeks	Pessimistic weeks	Expected weeks	Standard Deviation	Variance
Design System	3	5	7	5.00	0.667	0.444
Purchase Equip.	5	9	11	8.67	1.000	1.000
Code Software	5	7	9	7.00	0.667	0.444
Fabricate Tower	10	13	15	12.83	0.833	0.694
Deliver to Site	2	3	5	3.17	0.500	0.250
Assemble & Test	4	6	9	6.17	0.833	0.694
Total	29	43	56	42.84		3.526
				Square	Root	1.878

Figure 14

STEP 2

Using the formula below calculate **Z** to use on the Standard Normal Distribution Table.

$$\frac{\text{Project Schedule} - \text{Expected Schedule}}{\text{Standard Deviation}} = Z$$

$$\frac{45 \text{ weeks} - 42.84 \text{ weeks}}{1.878} = 1.154$$

STEP 3

Locating the Z of [1.154] on the Standard Normal Distribution Table shows a value of [0.8749]. The probability of meeting a 45 week schedule is 87%.

RISK HISTORY determining probability was based on TCI's Risk History as shown in Figure 13 below.

Risk Matrix Description	***Probability Percent***
Very high	**50 % +**
High	**40% to 50%**
Moderate	**30% to 40%**
Low	**20% to 30%**
Very Low	**10% to 20%**

Figure 15

EXPECTED MONETARY VALUE is a number expressed in dollars that is a result of a statistical technique that presents the outcome when a risk may or may not happen. It is used first to prioritize risk and second determine the minimum cost to manage the risk. The formula for Expected Monetary Value (EMV) is:

Probability of Occurrence x Amount at Stake = Expected Monetary Value

The concept of EMV was adapted from the actuarial profession. An actuary is a business professional who analyzes the financial consequences of risk. Actuarial tables are used to determine premium costs for health insurance, home and automobile insurance and a host of other tangible assets. While there are different models for determining premium costs, the credibility theory[13] applies to EMV because it is used when one has very few data. Accordingly, EMV represents the 'insurance premium', so to speak, for the risk event; the minimum amount that should be spent to offset the risk.

EXAMPLE: The risk event below concerns a full truck load for delivery of a product to a computer retail store. The store has advertized in the media that this product will be on sale over a holiday weekend and the following week. They expect a crowd of buyers. The manufacturer is shipping the product by ground transportation which has 80% reliability. The product can also be shipped by air.

RISK EVENT is specific description of an occurrence using the "If Then, Rule."
Example: If the delivery of the product misses the target delivery of a product by 5 days, then there will be a loss of sales revenue of approximately $5,000 per day.

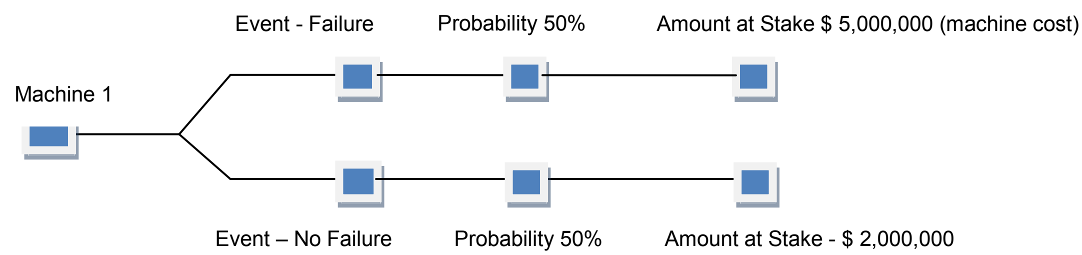
PROBABILITY OF OCCURRENCE is a specific number in percent that the risk event is expected to happen. ***Example:*** *100% - 80% = 20%*

AMOUNT AT STAKE expressed in dollars is an estimate of the cost of missing the target delivery of the product by 5 days. ***Example:*** *Cost per day representing loss of revenue without a product @$5,000/day.*

Probability of Occurrence (.20) x Amount at Stake ($5,000) = EMV ($1,000)

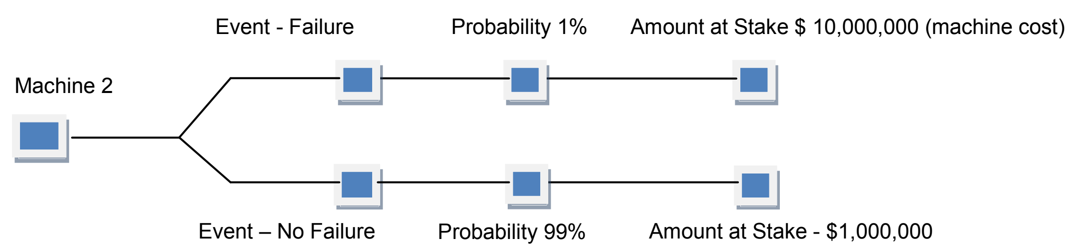
[13] Rob Kass, Marc Goovaerts, Jan Dhaene, Michel Denuit, *Modern Actuarial Risk Theory, Using R* (Springer 2nd Edition 2008)

DECISION TREE: a decision support tool that uses a tree-like graph or model of decisions and their possible consequences, including chance event outcomes and resource costs. Any decision, no matter how complex, can be analyzed with a decision tree analysis. Decision tree analysis is especially suited for everyday problems when one needs to pick the best alternative quickly and proceed.[14] A decision tree diagram has three annotations: 1) Event, 2) Probability, 3) Amount at Stake. The lowest Expected Monetary Value (EMV) is used to determine the decision.



Machine 1 Failure: 50% x +$5,000,000 = +$2,500,000 EMV
Machine 1 No Failure: <u>50%</u> x - $2,000,000 = <u>- $1,000,000 EMV</u>
100% + $1,500,000 EMV

Figure 16 A



Machine 2 Failure: 1% x + $10,000,000 = +$ 100,000 EMV
Machine 2 No Failure: <u>99%</u> x - $ 1,000,000 = <u>- $ 990,000 EMV</u>
100% + $ 890,000 EMV

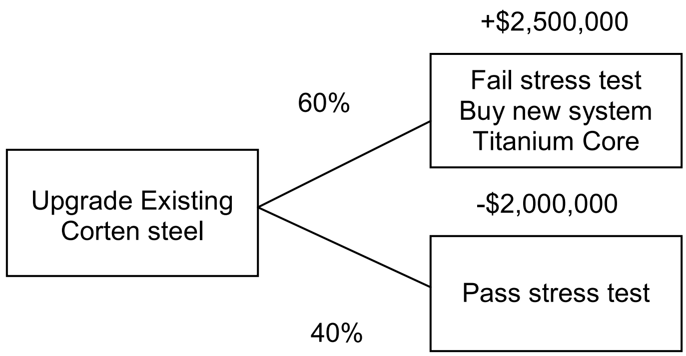
Figure 16 B

Machine 1 vs. Machine 2 illustrated in Figure 13 A and Figure 13 B are examples using two path decision trees. The decision is to determine which of two machines should be purchased and installed for the company's manufacturing factory. Machine 1 cost is estimated at $ 5,000,000. Machine 2 cost is estimated at $10,000,000. Both machines are rated equally on output. The probability and failure data was obtained from the machines specifications and numerous tests. Machine 1 has an EMV of + $ 1,500,000. Machine 2 has an EMV of + $ 890,000. Machine 2 is the preferred decision based on the lowest EMV.

[14] Tom Kendrick, *Identifying and Managing Project Risk, Second Edition*(AMACOM 2009)

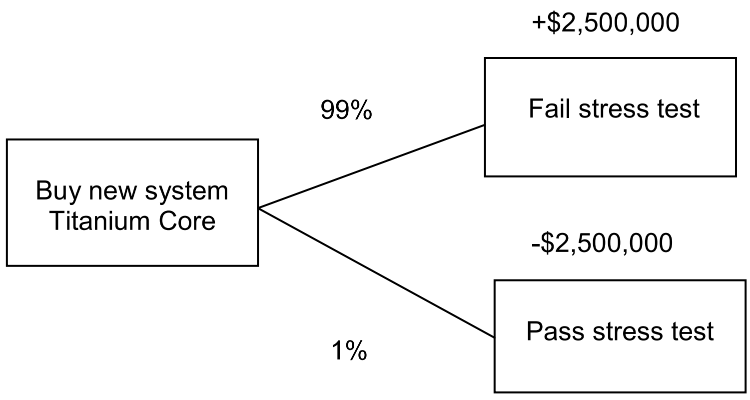
Hermes Tower Design

The Hermes tower design called for new material. This was based on the structural specifications developed from the prototype design. Corten steel has been the dominant structural component for TCI's towers. The new material under consideration was a Corten Upgrade and a composite Titanium Core structure. Before making a final decision on the new material, the team collected steel manufactures specifications and conducted live testing on Corten Steel and Titanium Core. Using a decision tree process (Figures 13A & B), they produced the following results:



Corten Failure: 60% x + $2,500,000 = + $1,500,000 EMV
Corten No Failure: 40% x - $2,000,000 = - $ 800,000 EMV
100 % + $ 700,000 EMV

Figure 17 A



Titanium Failure: 99% x + $2,500,000 = +$2,475,000 EMV
Titanium No Failure: 1% x - $2,500,000 = - $ 250,000 EMV
100 % + $2,225,000 EMV

Figure 17 B

The decision tree results (the lowest EMV) show that Upgrade Corten Steel should be used for the Hermes Tower construction.

Next, TCI's project team selected the first three risks from the Hermes Tower Priority Value Table, Figure 12, to quantifying risks for the risk control process. Below are examples:

1 **<u>Fabrication</u>**

-New Equipment

RISK EVENT: *If the new fabricating equipment has operating problems that could not be resolved in 14 days, then there could be a delay in delivery of the Hermes Tower by 14 days that would result in contract penalty of $10,000 per day.*
PROBABILITY OF OCCURRENCE: *estimated at 30 %*
AMOUNT AT STAKE*: Cost per day representing contract penalty of $10,000/day*

Probability of Occurrence (.30) x Amount at Stake ($140,000) = EMV ($56,000)

2 **<u>Fabrication</u>**
-Factory Changes

RISK EVENT: if the current factory could not accommodate the new layout, fabrication would be moved to another site, and then time to fabricate could increase by a minimum of 30 days which would also affect the delivery of the Hermes Tower and would incur a *contract penalty of $10,000 per day.*
PROBABILITY OF OCCURRENCE is estimated at 30 %
AMOUNT AT STAKE*: Cost per day representing contract penalty of $10,000/day*

Probability of Occurrence (.30) x Amount at Stake ($300,000) = EMV ($90,000)

3 **<u>People</u>**
-Hire New Engineers

RISK EVENT: if human resources cannot hire the needed new mechanical and electrical engineers to design the Hermes Tower according to present schedule, then this could delay the design effort by minimum of 10 days which would also affect the delivery of the Hermes Tower and would incur a *contract penalty of $10,000 per day.*
PROBABILITY OF OCCURRENCE is estimated at 15 %
AMOUNT AT STAKE*: Cost per day representing contract penalty of $10,000/day*

Probability of Occurrence (.30) x Amount at Stake ($100,000) = EMV ($30,000)

CONTROLLING PROJECT RISK

The principle of controlling risk involves the process of developing options and actions to enhance opportunities and minimize adverse consequences to project performance. There are three parts to controlling risk. Part one is developing options. Part two is developing actions. Part three is monitoring the action taken to see if it is working.

Developing options for controlling risks depends on the results from quantifying the risks. But, it also depends on the culture of the organization and the risk propensity of executive management. In business and industry today, engineering and construction firms are very safety conscious and tend to be risk averse. Entrepreneurs and venture capitalists tend to be risk prone. Before selecting risk options and actions, it is important for project managers and team members responsible for managing risk to check with executive management.

RISK OPTIONS
Ignore Risk
Accept Risk
Prevent Risk
Lessen Risk
Transfer Risk

Ignore Risk is to decide that the risk is so insignificant that it will not adversely affect the project objectives.

Accept Risk is to decide that the risk is significant but after a cost benefit analysis the benefit is greater than the cost so accepting the risk is worthwhile.

Prevent Risk is connected to reducing the probability of occurrence. The options listed below can be considered to reduce the probability of occurrence:

Lessen Risk is connected to minimizing the consequences of risk. The options listed below can be considered for minimizing the consequences.

Transfer Risk is to decide to share the risk or to transfer risk to others. The options listed below can be considered when transferring risk.

PREVENT RISK OPTIONS	LESSEN RISK OPTIONS
More detail planning	Contingency planning
Improved design	Structural barriers
Procedural changes	Quality assurance process
Preventative maintenance	Contract terms & conditions
Formal quality control	Regular inspection & audits
Regular inspection & audits	Crisis recovery plans

TRANSFER RISK OPTIONS
Joint venture
Subcontract
Licensing

EXAMPLE: 'missing target delivery'
A risk event example, 'missing target delivery' was presented on page 20. In the Example, the risk event stated; if the delivery of the product misses the target delivery of a product by 5 days, then there will be a loss of sales revenue of approximately $5,000 per day to the seller of the product. The probability of occurrence was estimated at 50%. This falls under the option of prevent risk, namely, reduce the probability of occurrence. The Expected Monetary Value (EMV) of the risk is 5 days times $5,000 per day times 50% which equals $12,500. The method of delivery by the vendor was ground transportation at a contract price of $3,500. Air delivery guaranteed to arrive on time has a cost of $7,000. By spending an additional $7,000 the seller can be guaranteed arrival of the product on time and $25,000 revenue less the cost of air delivery. Otherwise, there is a 50% chance that the seller could lose $25,000.

So, what was the value of calculating the EMV? The EMV is statistical number that is used to determine the measurable extent of risk to be taken. In this case, the measurable risk limit to be taken was $12,000. Spending over that amount is not cost effective. Part two, the action taken for this risk was to change the delivery method from ground transportation to air freight. Part three was to monitor the delivery by using a tracking system. It is important to note that the action to spend the addition $7,000 was based on a management decision to object to the 50% probability. It could have gone a different way. Take no action and accept the consequences of a missed delivery target. Each decision reflects the culture of the organization and the risk propensity of executive management.

EXAMPLE: 'missing target delivery'
In another example, from page 24 concerns a full truck load for delivery of a product to a computer retail store. The store has advertized in the media that this product will be on sale over a holiday weekend and the following week. They expect a crowd of buyers. If the delivery of the product misses the target delivery of a product by 5 days, then there will be a loss of sales revenue of approximately $5,000 per day. The manufacturer is shipping the product by ground transportation which has 80% reliability. The product can also be shipped by air. The Expected Monetary Value was calculated at $1,000.[15] Shipping the product by air freight was estimated to cost $ 11,000. In this case the decision was take no action and accept the consequences of a missed delivery target.

The examples above demonstrate the use of Expected Monetary Value (EMV) to make risk control decisions. As described previously, EMV is also used to prioritize risk options when making the control decisions. Below are the first three risks from the Hermes Tower Priority Value Table, Figure 12, from page 26 that were used by TCI's project team to begin the control process.

[15] Probability of Occurrence .20 x Amount at Stake $5,000 = $1,000 EMV

1 **Fabrication**

-New Equipment

RISK EVENT: *If the new fabricating equipment has operating problems that could not be resolved in 14 days, then there could be a delay in delivery of the Hermes Tower by 14 days that would result in contract penalty of $10,000 per day.*
PROBABILITY OF OCCURRENCE: *estimated at 30 %*
AMOUNT AT STAKE*: Cost per day representing contract penalty of $10,000/day*

Probability of Occurrence (.30) x Amount at Stake ($140,000) = EMV ($56,000)

2 **Fabrication**
-Factory Changes

RISK EVENT: if the current factory could not accommodate the new layout, fabrication would be moved to another site, and then time to fabricate could increase by a minimum of 30 days which would also affect the delivery of the Hermes Tower and would incur a *contract penalty of $10,000 per day.*
PROBABILITY OF OCCURRENCE is estimated at 30 %
AMOUNT AT STAKE*: Cost per day representing contract penalty of $10,000/day*

Probability of Occurrence (.30) x Amount at Stake ($300,000) = EMV ($90,000)

3 **People**
-Hire New Engineers

RISK EVENT: if human resources cannot hire the needed new mechanical and electrical engineers to design the Hermes Tower according to present schedule, then this could delay the design effort by minimum of 10 days which would also affect the delivery of the Hermes Tower and would incur a *contract penalty of $10,000 per day.*
PROBABILITY OF OCCURRENCE is estimated at 30 %
AMOUNT AT STAKE*: Cost per day representing contract penalty of $10,000/day*

Probability of Occurrence (.30) x Amount at Stake ($100,000) = EMV ($30,000)

The original priority ranking of the top three risk events was:

Rank No.	Risk Event	Probability of Occurrence	Amount at Stake	Expected Monetary Value
1	**Fabrication** **-New Equipment**	**30%**	**$140,000**	**$56,000**
2	**Fabrication** **-Factory Change**	**30%**	**$300,000**	**$90,000**
3	**People** **-Hire New Engineers**	**30%**	**$100,000**	**$30,000**

The priority rank of the top three showed that the EMV of the factory change risk event was greater than the others. This is a change in priority. The project team needs to focus on the factory change risk event first. The options selected for this risk was a combination of preventing and lessening the consequences of the risk by detailed planning that included regular inspections of the fabrication process. The actions taken were: (1) the fabrication process was planned in stages, (2) As a contingency plan a temporary building was erected in vacant area near TCI's main plant in case additional space was needed to accommodate the various stages of the Hermes, (3) A contract was let with an engineering consulting firm to monitor the fabrication process. The costs to perform these actions were kept to under $90,000.

Next in order of priority the team addressed the new equipment risk. The option selected was to transfer the risk using a subcontractor. In the project management world of small and medium projects, contracting is the most prevalent option. Joint ventures and licensing options are left to senior executives and business owners. The process of obtaining goods and services for projects is called procurement management.[16] Contracting is a part of the procurement process. While project managers need to have knowledge and understanding of contracts, it is best to let the

[16] Charles L. Huston, *Management of Project Procurement* (The McGraw-Hill Companies, 2001)

procurement department take the lead in the contracting process. Below is some of the information about contracts that a project manager needs to know to do an effective job.

Contract Definition:

A contract is a mutually binding agreement that obligates the *seller* to provide the specified *product* or *service* or *result* and obligates the *buyer* to pay for it.[17] There are three types of contracts. They are:

- Fixed-price or lump-sum contracts
- Cost-reimbursable contracts
- Time & Material contracts

Contract type	Advantage	Disadvantage
Fixed-price or lump-sum contracts • Fixed-Price (FP) • Fixed-Price + Incentive (FPI)	Buyer has less work to manage contract Seller has a strong incentive to control costs Buyer knows the total price at project start	Seller may under-price the work to make up profits on change orders Seller may not complete some of the contract if they begin to lose money
Cost-reimbursable contracts • Cost-Plus (CP) • Cost-Plus-Incentive-Fee (CPIF) • Cost-Plus-%-of Cost CPPC) • Cost-Plus-Fixed-Fee (CPFF)	The fixed price contract statement of work is more simple to prepare The fixed price contract requires less work to write the scope The fixed price contract has lower cost because the seller does not have to add as much for risk	Buyer is required to audit seller's invoices Buyer is required to do more work to manage the contract Buyer does not know the total price of the contract
Time & Material Contracts (T&M)	Contract is quick to create Contract duration is brief Contract is a good choice when hiring "bodies" or people to augment staff	Profit is in every hour billed Seller has no incentive to control costs Buyer is required to perform day to day oversight

[17] Ibid

Contracts are the main source for companies to obtain goods and services to conduct business. If a company has the capacity, technology, and skills to conduct business by themselves, they are considered vertically integrated.[18] However, most companies use contractors and vendors to conduct business. In cases where the company has the capacity, technology, and skills to conduct business, they still have the option to add contractors to increase their capacity, technology, and skills. Using this option is typically based on an economic analysis called '*make or buy*.' Make means using the company's resources to perform the work. Buy means using a contractor to perform the work. Transferring risk is an integral part of the business process. The figure below illustrates the comparison of risk sharing between the buyer and the seller. The seller has the highest risk for a fixed price contract, while the buyer has the highest risk for a fixed fee type contract. Note that risk is equal between the buyer and the seller for a time and material contract.

RISK SHARING COMPARISON

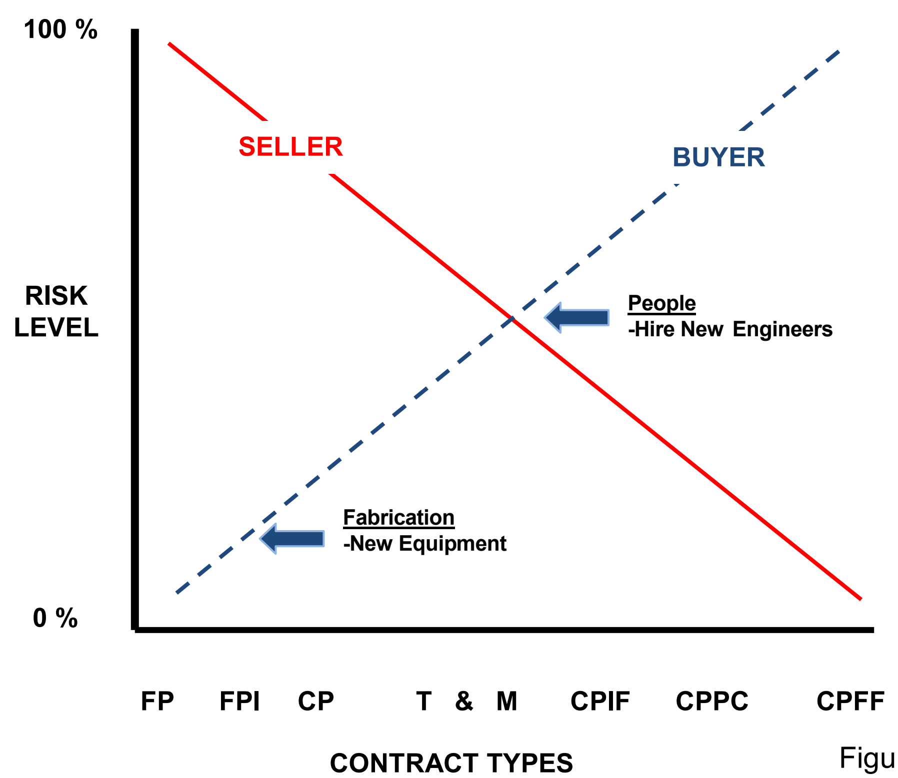


Figure 18

[18] Kathryn R. Harrigan, *Vertical Integration, Outsourcing, and Corporate Strategy*(Beard Books ,Inc. 2003)

Controlling the equipment risk for TCI was a buy decision to transfer the risk to a contractor for making the fabrication equipment and tools. TCI's purchasing department selected a Fixed-Price + Incentive contract. TCI had in-house technology and skills to build the fabrication equipment and tools so the contract was easier to write. With their in-house knowledge the project manager and purchasing would be able to monitor the contract very closely. Thus, most of the risk was transferred to the seller as shown in Figure 18 with the incentive giving the contractor and opportunity to meet or better the schedule.

The third risk priority was the possibility of human resources being unable to hire the needed new mechanical and electrical engineers in time to meet the design schedule for the Hermes Tower. TCI's purchasing department selected a Time and Material contract to control this risk. This is a good choice when hiring bodies to augment staff; quick to create contract and easy to monitor. The risk did not change as shown in Figure 18, but human resources could use their normal recruiting and hiring process without having to be concerned about hurrying to meet a schedule. The remaining risks from the Priority Value Table were assigned appropriate options, actions and monitoring.

In summary, the three parts to controlling risk; part one developing options, part two developing actions, and part three monitoring the action all depend on the experience and skill of the project manager to interpret the risk's characteristics, namely, priority values and EMV. Given this information the engineer, senior manager or project manager responsible for the project needs to solicit guidance from executive management and procurement to facilitate successful risk control.

