استراتژی مدیریت ریسک در طول چرخه حیات پروژه

(بر اساس سند مهمی از CMAA)

بخش سوم: تحلیل ریسک (Risk Analysis) در پروژه‌های صنعت ساخت

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What we will learn?

- Introduction
- Risk Assessment (AACE TCM)
- Qualitative Risk Analysis (AACE TCM)
- Qualitative Risk Analysis (CMAA)
- Advanced Qualitative Risk Analysis (CMAA)
- Quantitative Risk Analysis (AACE TCM)
- Quantitative Risk Analysis (CMAA)
- Risks vs. Issues

Introduction

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Introduction

- **After identifying** threats and opportunities,

  the team **must analyze** each risk to measure the **potential** severity and likelihood.

  - This analysis helps a team **prioritize** the risks so that

    they can see **which risks** could have the greatest impact and are the most likely to occur.

Introduction

- The **team** then **uses** this information to
  1. create a status or
  2. score for each risk and
  3. adds the results

     to the risk register.

Project Name **Project Risk Register**			Rev: 0 (Initial risk meeting) Date: December 15, 2023	
Risk ID	**RBS**	**Risk Name**	**Risk Description**	**Threat/ Opportunity**
ID-4	Political/Approvals	Senior stakeholder support	The state's governor and several legislators are highly-engaged and want to show the project is a success, so these officials could help expedite the approval process and allow design and construction to begin sooner	Opportunity
ID-5	Real Estate/ Acquisition	Purchase available adjoining lot	An empty lot next to the jobsite is for sale below the market rate and purchasing it would improve site access and staging, which could also shorten the construction schedule	Opportunity
ID-6	Construction	Certificate of occupancy	An administrative delay could delay the certificate of occupancy's signoff at the end of the project, which would delay substantial completion and move-in	Threat

Figure 5 *– Partial Risk Register with Risk Identification*

Recall that some parts of the industry **use** the term **"risk assessment"** instead, but the process is the same.

Introduction

- **During** risk analysis, the **team must consider**

  how large of an **impact (positive or negative)** that each risk event would have **on delivery.**

  - The **team members** must **not allow** their **perceptions** of **how likely** the risk is to **affect** the severity assessment.
    - When **assessing** a **risk's severity**,

      the team **must**

      1. **Assume** the threat or opportunity will occur and
      2. **Try** to gauge **how it might change** the project's or program's scope, schedule, budget, or quality.

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Introduction

- **Separately**, the team **must** also consider how likely each risk is to **occur**.
  - When **assessing** a **risk's likelihood**, the team must **not allow** their **perceptions** of the **risk's severity** to change **their analysis**.

- The team members must only consider the **chances** that the **risk event** will **happen**.

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- **Recall** that there are **two general types** of risk analysis: qualitative and quantitative.
  1. Qualitative risk analysis categorizes risks based on the **team's judgment** about each risk's **severity** and **likelihood**.
     - Note that qualitative analysis may still **involve mathematical calculations**.
  2. Quantitative risk analysis uses **advanced statistical formulas and programs** to **further refine** this analysis based on **measurable data**.
     - However, quantitative risk analysis is not always cost effective and may not be necessary

Risk Assessment

(AACE TCM)

Process map for risk management

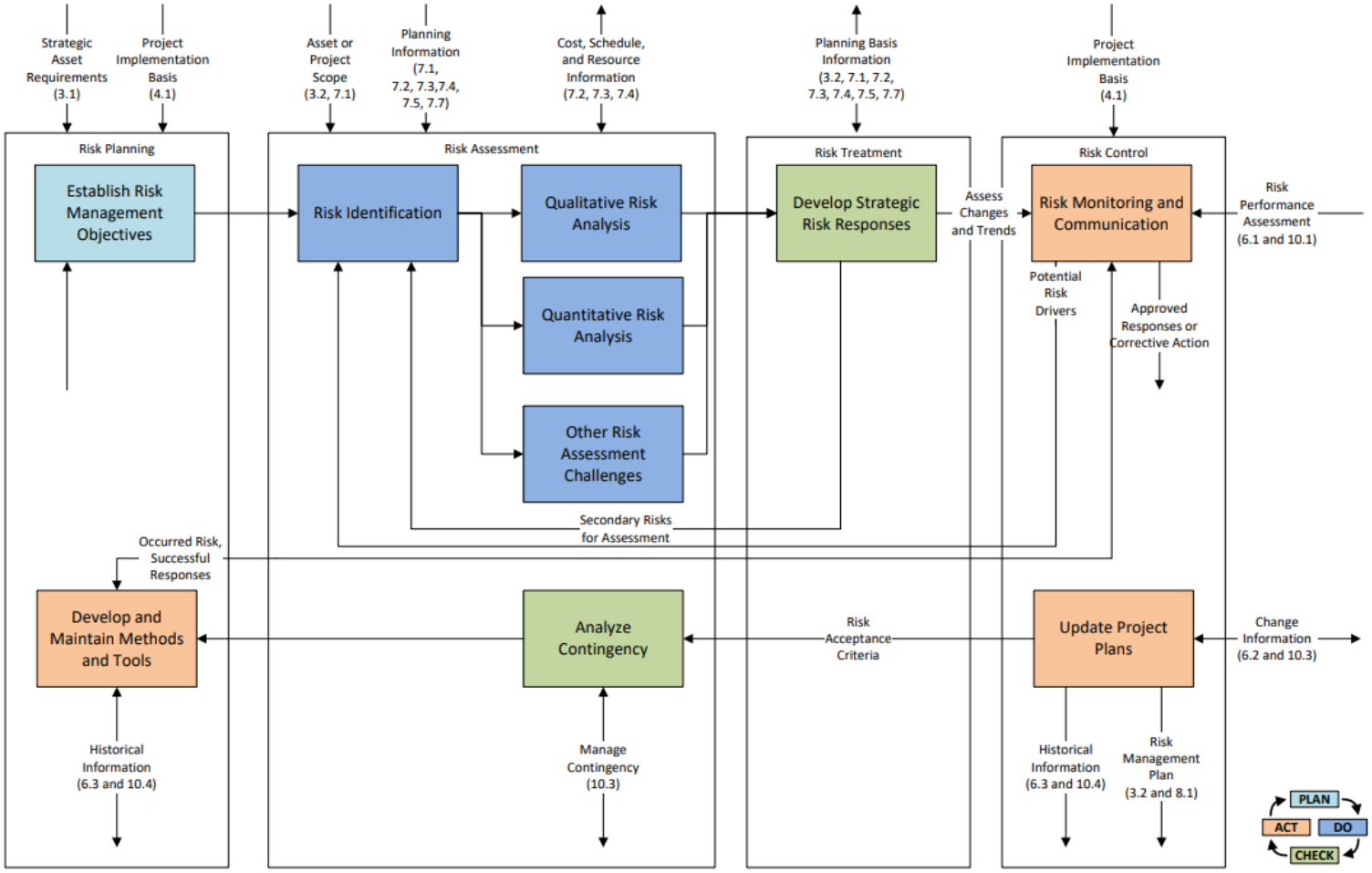

Figure 7.6-1 Process Map for Risk Management

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Risk assessment

- Once the risk management process has been planned and informal agreement or formal approval obtained from all stakeholders, the **team can start** working through the **next step** of risk assessment.

- Risk assessment is typically comprised of **three distinct tasks**:
  1. Risk identification.
  2. Qualitative risk analysis.
  3. Quantitative risk analysis.

Qualitative Risk Analysis

(AACE TCM)

Qualitative risk analysis

- **Entries** in the **risk register** are typically **classified** by their source using the **RBS**.

- The **team** may **further** categorize or organize their risk data **using qualitative methods** that

  help rank risks in terms of

  1. criticality and
  2. significance

     to the enterprise objectives.

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Figure 5 – Partial Risk Register with Risk Identification

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Qualitative risk analysis

- These **qualitative methods** are subjective in nature and assign, for example, a **score** from **one** to **five** to
  1. reflect probability and
  2. each identified effect, consequence or impact.

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Qualitative risk analysis

- A **five point scale** is generally **preferred**.
  - Although a **three point scale** is **common**,

    it can **sometimes prevent** the desired level of analysis.
    - Conversely, **anything beyond** a five point **qualitative scale** (or attempting to provide more quantitative values at this stage)

      can **lead** to what is affectionately **termed analysis paralysis**.

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Qualitative risk analysis

- **Risks are dynamic.**
  - **What may** appear to be a **significant risk** at one point in time **could later evolve** to become one that is **critical**.
    - ✓ Additionally, what may **pose** a schedule risk at the **start** of the project may, for example, **manifest itself** as a safety risk at a **later time**.

For this reason, it is recommended that …

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Qualitative risk analysis

- For this reason, it is recommended that the team
  1. **Establish** a baseline for each risk,
  2. **Scoring** them before any responses have been implemented,
  3. Then **periodically** **reviewing** and **updating** their qualitative risk analysis if necessary,
  4. **Enabling** them to monitor for any adverse trends.

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Qualitative risk analysis

- The **content** of the **scoring matrix** used for this exercise should have been agreed with **all stakeholders** during **risk planning**.

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Qualitative risk analysis

- The **output** of the qualitative risk analysis is typically reported using a **matrix** where

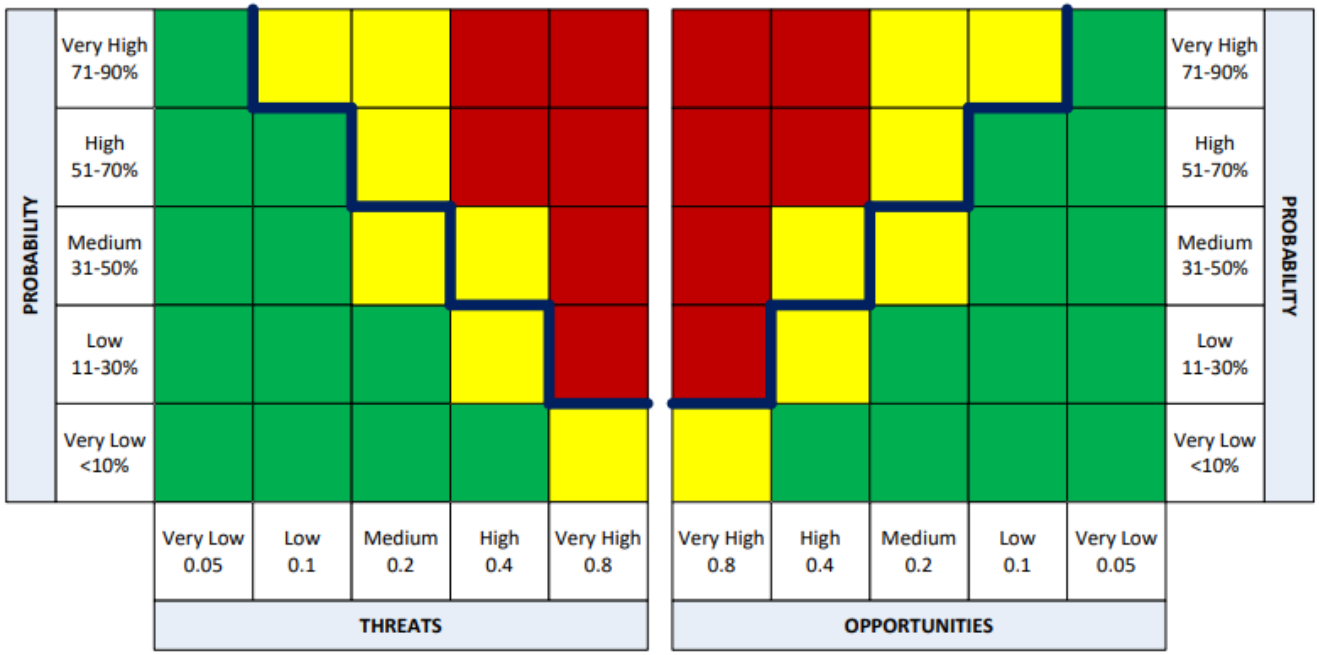
  Risk impact or **consequence** is

  Plotted **against** **probability**.

  - An **indicative example** of a **five by five matrix** is provided in next Figure.
  - An **organization** that has a **mature risk** aware culture would, for example, use **two matrices** to report on both threats and opportunities.
    - The **majority** of organizations, however, typically **focus solely** on threats and

      the **left hand matrix** is commonly used in **isolation**.

Qualitative risk analysis



Double Probability vs. Impact Matrix

Qualitative Risk Analysis

(CMAA)

Qualitative risk analysis

- Risk management is a **continuous process** that continues throughout the project/program lifecycle,

  so **qualitative analysis** must accompany risk identification **throughout all phases**.

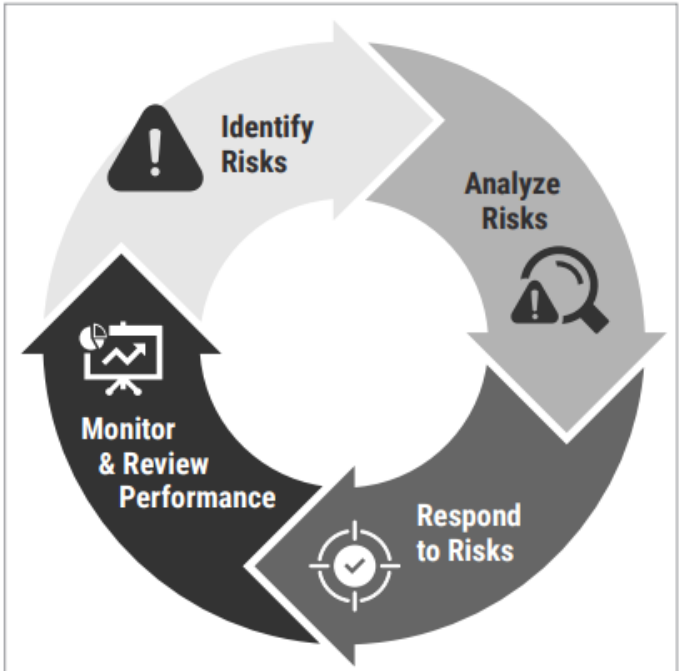


Figure 1 – Continuous Risk Management

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Qualitative risk analysis

- At certain schedule milestones or phases, it may also be necessary to **revisit risks** on the risk register that

  the **team already** qualitatively analyzed in case any conditions have **changed**.

- **Qualitative analysis** may be the **only analysis** that is possible in

  the pre-design phase and early in the design phase

  because at those stages the team may have little or no data about the project/program.

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Qualitative risk analysis

- As **part** of a qualitative risk analysis, the team
  1. **Evaluates** the probability and impact of each risk in the risk register and
  2. **Prioritizes** those risks.
- The team uses **their expertise** to consider
  1. **Odds** of each risk on the risk register and
  2. **Severity** of each risk if it should occur.

  Then, the team **assigns** a **qualitative impact** to the risk.

- The qualitative impact status helps the team **quickly identify** which risk events could have the **greatest impact** on **productivity**.

Qualitative risk analysis

- The exact steps and owner's requirements for a qualitative risk analysis **may vary**, so the **RMP** should **explain** the team's specific procedure.
  - However, the **team** should **attempt** to remain as objective as possible.

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Qualitative risk analysis

- Generally, **after** the team **identifies** new risks and **adds** them to the **risk register**, the **risk manager (CM or risk specialist)** will **facilitate** a **discussion** among the team members who are **knowledgeable** about the potential severity and likelihood of that risk event.

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Qualitative risk analysis

- The **team** then **votes** on
  1. How likely each risk event is and
  2. How severely it would **impact** the project/program.

- The **averages** of **these votes** determine the **status** of the risk's impact.

- The **RMP defines** if the team will use the mean, median, or some other method to determine the **average**.

Qualitative risk analysis

- The **RMP** should **also define** the range(s) that the team members **use** to **determine** the risk impact.
- **Some teams** may use **descriptions** such as “Minor” or “Critical” to **assess** likelihood and severity.
- **Others** may **prefer** numerical values, such as “0 to 5” or “1 to 10,” or a **combination** of numbers and descriptions.
  - **Whatever** range(s) the team uses,

    the likelihood and severity form a **matrix**.
    - ✓ **Figure 6** shows an **example** of a **risk event impact matrix** based on descriptive values.

Qualitative risk analysis

Risk Event Status

SEVERITY	LIKELIHOOD				
	Minor	Unlikely	Possible	Likely	Almost Certain
Critical	Serious	Major	Major	Critical	Critical
Major	Moderate	Serious	Major	Major	Critical
Serious	Moderate	Moderate	Serious	Serious	Major
Moderate	Moderate	Moderate	Moderate	Serious	Serious
Minor	Minor	Minor	Moderate	Moderate	Serious

Figure 6 – Sample Qualitative Risk Matrix

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Qualitative risk analysis

- As **Figure 6** demonstrates, the severity and likelihood form a **matrix** that the team uses to **determine** a risk's impact.

- A **risk matrix** helps the team **quickly see** which risks are the **highest priority**.

- The **values** that the team uses **may vary**,

  but generally the **risks with higher** likelihoods and severities should be **higher priorities**

Qualitative risk analysis

- In the scenario in Figure 6, the **team would vote**
  1. on each risk's severity using a **range** from "Minor" to "Critical" and then
  2. for the likelihood on a **similar range** from "Minor" to "Almost Certain."

- When the team **combines** the severity and likelihood ratings in this example, they **determine** the risk impact with a range from "**Minor" to "Critical**."
  - For example, the team would give a risk event with a **"Serious" severity** and **"Unlikely" likelihood** a "Moderate" status.
    - ✓ However, again **recall** that these **values may vary** from project to project.

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Qualitative risk analysis

- After the **team** determines a **risk's qualitative** severity and likelihood, the **CM or risk specialist adds this information** to the risk register.
  - The risk manager should also add a **legend** for the **matrix values** to the risk register.
    - ✓ Figure 7 shows the **partial risk register** from Section 2 with this information based on a hypothetical qualitative analysis.

Qualitative risk analysis

SEVERITY	LIKELIHOOD				
	Minor	Unlikely	Possible	Likely	Almost Certain
Critical	Serious	Major	Major	Critical	Critical
Major	Moderate	Serious	Major	Major	Critical
Serious	Moderate	Moderate	Serious	Serious	Major
Moderate	Moderate	Moderate	Moderate	Serious	Serious
Minor	Minor	Minor	Moderate	Moderate	Serious

Project Name
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ID-1	Procurement/ Market Conditions	Pre-purchase curtain wall	Long lead of the curtain wall system could delay the curtain wall's arrival, which could delay the critical path and the completion date	Threat	Critical
ID-2	Construction/Scope	Construction scope change	The owner is unfamiliar with construction, which could lead to scope changes during the construction phase that could create delays, cost overruns, and quality issues	Threat	Critical
ID-3	Design/Schedule	Deficient drawings	Due to the tight design schedule, the drawings could be deficient, resulting in more change orders/ RFIs/claims	Threat	Major

Qualitative risk analysis

SEVERITY	LIKELIHOOD				
	Minor	Unlikely	Possible	Likely	Almost Certain
Critical	Serious	Major	Major	Critical	Critical
Major	Moderate	Serious	Major	Major	Critical
Serious	Moderate	Moderate	Serious	Serious	Major
Moderate	Moderate	Moderate	Moderate	Serious	Serious
Minor	Minor	Minor	Moderate	Moderate	Serious

Project Name
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ID-4	Political/Approvals	Senior stakeholder support	The state's governor and several legislators are highly-engaged and want to show the project is a success, so these officials could help expedite the approval process and allow design and construction to begin sooner	Opportunity	Major
ID-5	Real Estate/ Acquisition	Purchase available adjoining lot	An empty lot next to the jobsite is for sale below the market rate and purchasing it would improve site access and staging, which could also shorten the construction schedule	Opportunity	Serious
ID-6	Construction	Certificate of occupancy	An administrative delay could delay the certificate of occupancy's signoff at the end of the project, which would delay substantial completion and move-in	Threat	Minor

***Figure 7** – Partial Risk Register with Qualitative Analysis*

Advanced Qualitative Risk Analysis

Advanced qualitative risk analysis

- During advanced qualitative risk analysis,

  the **risk manager (CM or risk specialist)** **facilitates** conversations with the team members who are **knowledgeable** about each risk to determine **more specific estimates** than a **basic** qualitative analysis.

- **Instead of using** generic values ("minor," "moderate," "severe," etc.), the team **adds** advanced fields to the risk register.

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Advanced qualitative risk analysis

- Advanced fields include (but are not limited to):
  1. Probability score;
  2. Cost, schedule, and quality impacts; and
  3. Overall risk score.

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Advanced qualitative risk analysis

- **These fields** involve **calculations** based on the team's qualitative estimates.
- Note that **complex relationships** often **exist** among cost, time, and quality.
- During advanced qualitative risk analysis, the team

  must be objective, use their judgment, make realistic assumptions, and understand each risk.
- Also note, **risk registers** often **list** threat scores as **positive values** and **opportunity scores** as negative values to

  indicate the degree of the potential harm or benefit to the project/program.

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Advanced qualitative risk analysis

- A **significant advantage** of advanced qualitative analysis is that the information it produces **helps the team** perform quantitative analysis.

- **Regardless**, advanced qualitative analysis is based on the **team's input** and is **separate** from quantitative analysis.

For more on quantitative analysis, see the next section.

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Probability

- As part of an **advanced qualitative analysis**, the team should **estimate** the probability that each risk will occur.
- A **best practice** at this stage is to
  1. **Express this estimate** as a range **(e.g., 40%-60%)** based on the team's expertise, and
  2. Then determine a corresponding probability score.
- The **RMP** should **define** the **steps** in this process.
- Generally, the **risk manager facilitates** the **discussion** to help the team determine a **range**.
- For **simplicity** and **uniformity**,

  the **probability score** may use the **same range** as the cost, schedule, and quality impact scores (e.g., "0 to 5").

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Probability

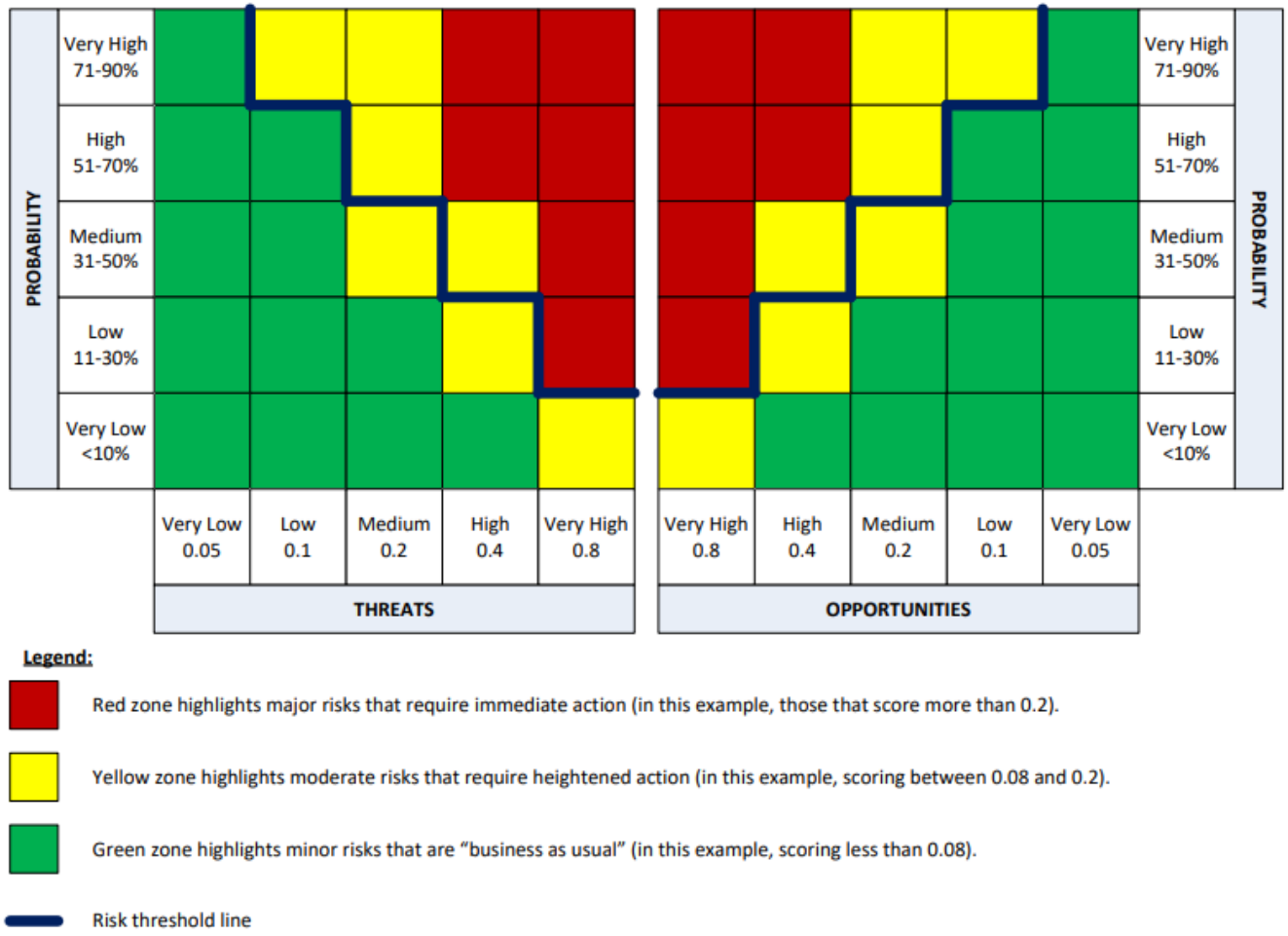

Figure 7.6-2. Double Probability vs. Impact Matrix

Cost impact

- During cost impact analysis, the **team discusses** if each opportunity or threat will affect cost.
  - If the team believes there will be an **impact**, the team
    1. **Estimates a possible range** from the least to most impact that the risk will have on the budget and then
    2. **Indicates** where on that range they believe is the **most likely**.
- The team should **refer** to the best available data for these estimates (e.g., material availability, market prices, labor costs, equipment fees, overhead, delay impact costs, etc.).

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Cost impact

- **When determining** the cost impact of schedule leads and delays,

  the team should consider **risks**

  1. **before** construction begins separately from
  2. risks **after** construction begins.

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Cost impact

- **Many risks** could have cost impacts, but the **greatest cost impacts** before construction begins are usually **threats** that would **delay** the start of construction.
  - These **delays** may cause costly design schedule lags (i.e., time that an activity is delayed from the start or finish of its predecessor(s)).
  - Meanwhile, **leads** may result in **opportunities** for cost savings, but this will **vary depending** on the project/program and the contract documents.

- **Leads** are the **opposite of lags**.
  - A **lead is time** that a schedule activity's **start or finish precedes** the start or finish of its successor(s).

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Cost impact

- **Scope changes** may also have **cost impacts**, but these are unique to each project/program and will **also vary**.
- **Teams** should use cost escalation rates for all project/program costs to **measure** the **impact** before construction.
- Note that a **team member** may have an **economist** within their organization who can **help** the team estimate escalation rates.

[2] *If an economist is unavailable, some government agencies such as the U.S. Bureau of Labor Statistics provide publicly-available, reliable economic data to help calculate escalations. More information is available at* ***https://www.bls.gov/***.

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Cost impact

- For a **lead or lag** which occurs **after** construction begins, the team should **calculate** a daily cost impact.
  - If a lead, there may be a **cost savings** but note that the **builder may still** be entitled to **compensation** depending on the unique circumstances and contract documents.
  - If a delay occurs which a builder is **not responsible** for (such as an owner-directed scope change),

    this **cost impact estimates** the time-related costs that are compensable to the builder.

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Cost impact

- The **sum** of all the **individual risks' costs** helps the team develop the project's/program's **cost contingency**.
- **Recall** that this method expresses the **value of each risk**

  as a **range** from the **lowest to highest** potential impact.
- The **team** adds these **values together** to develop an **overall range** for the **entire** project or program.
- This method is **more manageable** for owners because it allows them to
  1. see the range of possible total costs and
  2. set their cost contingency

     based on their own risk tolerance.

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Cost impact

- As a **final step**, the team may **assign** a cost impact score to each risk on the **risk register.**
  - For **uniformity**, the **cost impact score** should use the **same range** as the schedule impact and quality impact scores.
    - ✓ For example, "0 to 5," but the **exact range may vary**.
- This **simplified score** makes it easier for the team to **compare different types** of impacts and calculate an overall risk score.

For more, see CMAA Cost Management Guidelines.

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Probability

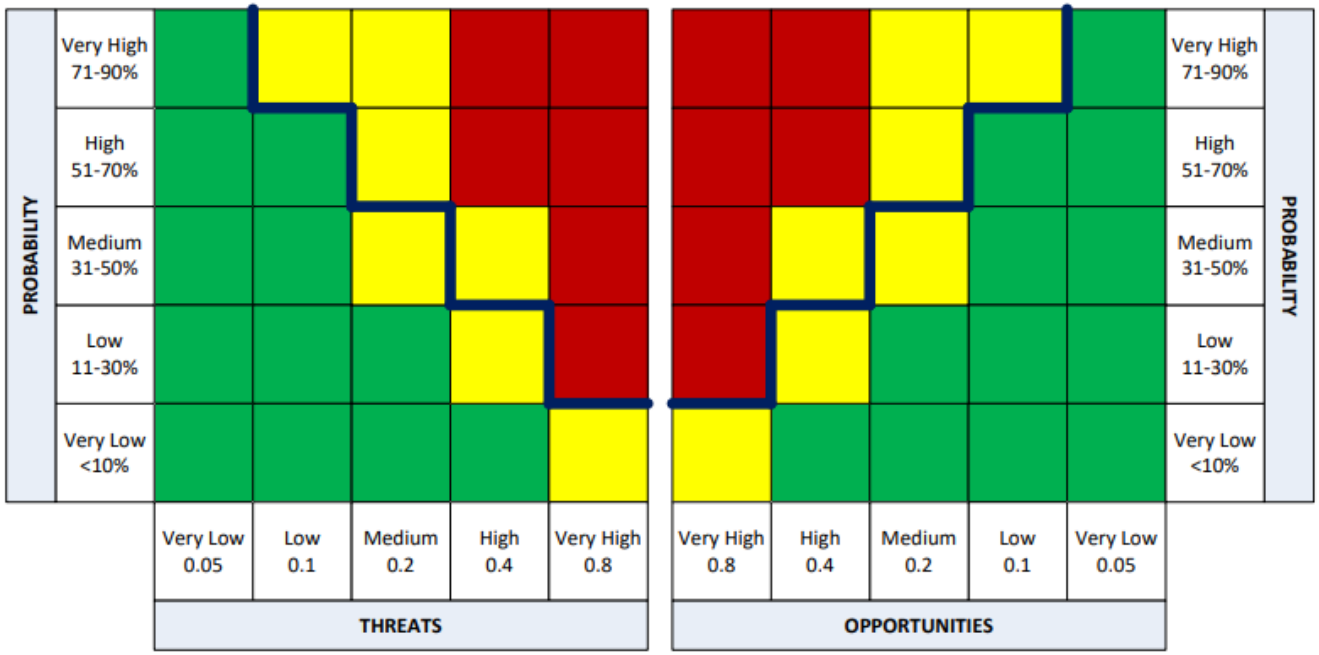

Figure 7.6-2. Double Probability vs. Impact Matrix

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Schedule impact

- To determine **schedule impacts**, the team **evaluates each risk** based on the current schedule.
- The **team members** who are knowledgeable **about each risk** discuss if each **opportunity or threat** will affect the schedule.
- This analysis should include the **person(s) who developed** the schedule.
- If the team identifies an impact, the team **estimates**
  1. **a range** of possible schedule impacts and
  2. where on the range is the **most likely**.
- Teams typically **measure impacts** in months,

  but more detailed estimates in **weeks or days** are also possible.

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Schedule impact

- **Similar to cost impact analysis**,

  the team

  1. calculates a schedule impact **score for each risk** using a **consistent range (e.g., "0 to 5")** and
  2. develops an **overall range** of possible schedule impacts.

- This range helps the **owner**

  1. See the **possible lengths** of the schedule and
  2. Determine an **appropriate contingency**.

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Probability

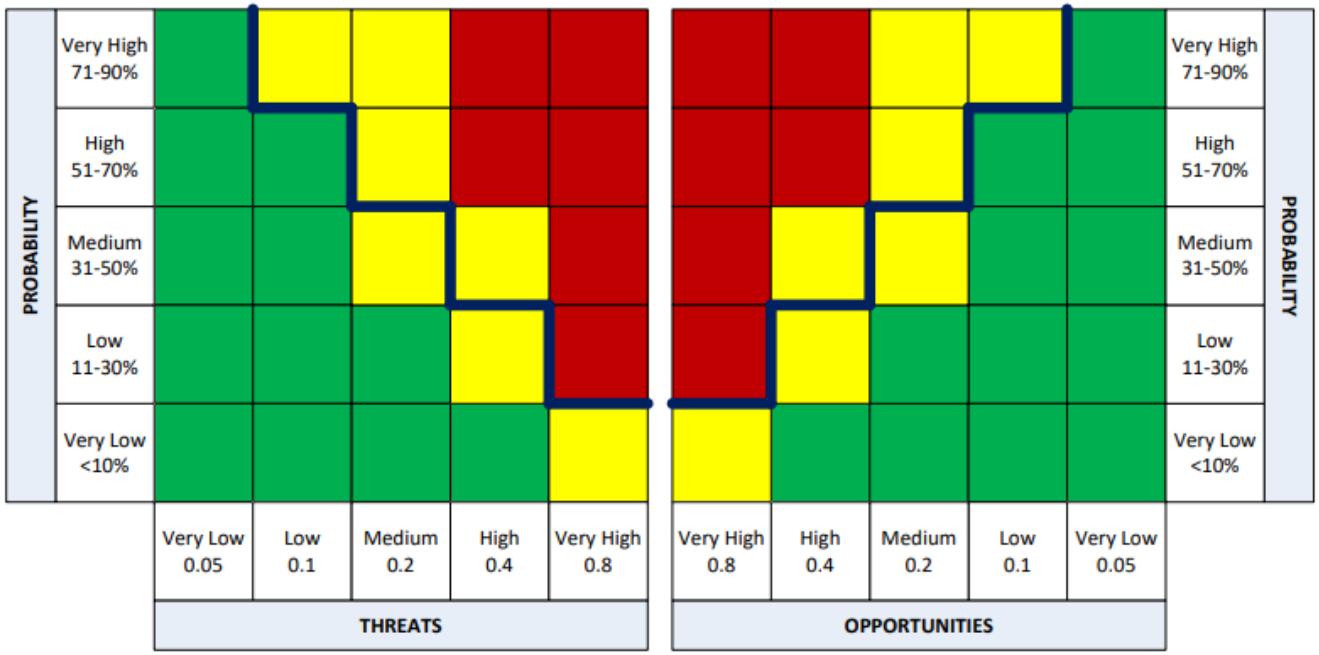

Figure 7.6-2. Double Probability vs. Impact Matrix

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Schedule impact

- The team should analyze leads and delays.
- **Before** the team has a **detailed schedule** (i.e., in pre-design and early in the design phase),

  the team may **analyze** the **schedule impacts** by phase.

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Schedule impact

- However, when **determining** an **overall range** the team must understand if any leads or lags will **happen concurrently** so as not to **"double-count"** a **concurrent** threat or opportunity's impact.
- If **two risk events** occur **simultaneously**, the team should **not count** the time that they **overlap twice**.
  - For example, if **two threats** may occur at the **same time** and b**oth would delay** the schedule by **one to three weeks**, the potential schedule impact is **one to three weeks**.

Schedule impact

For more, see CMAA Time Management Guidelines.

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Quality impact

- The team uses their **expertise** in design and construction to evaluate the **quality impact** of each risk.
- The team members who are **knowledgeable** about **each risk** should participate.
- **Quality** can be **subjective**, so it is **wise** to also include an **owner's representative**.
- The **risk manager (CM or risk specialist)** must understand that **quality** is the degree to which a project/program and its components **meet** the **owner's requirements**.

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Quality impact

- For **each quality impact**, the team develops
  1. a possible range,
  2. a most likely impact, and
  3. a quality impact score.

- The **risk manager** then adds the **quality impact score** to the risk register.

- As a **best practice**, this range should be consistent (e.g., “0 to 5” based on how severely the quality risk impacts the team).

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Quality impact

- Achieving quality avoids rework, so **rework** is **one way** the team may **evaluate** each **risk's quality impact**.

1. **Quality opportunities** are risk events that
   help the team meet or exceed the owner's requirements,
   which **prevent rework** (and may create leads or cost savings).
2. **Quality threats** are risk events that may cause the team to fail to meet the owner's requirements, which may **require rework** (and may create delays or cost overruns).

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Quality impact

- For more, see CMAA Quality Management Guidelines.

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Overall risk

- **After** the team **calculates**
  1. probability and
  2. cost,
  3. schedule, and
  4. quality

  impact scores, the risk manager may develop an **overall risk score** for each risk.

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Overall risk

- A common way to develop an overall risk score for a risk is to **multiply** the probability score by

  the **average (mean)** of the cost, schedule, and quality **impact scores**.

$$\text{Overall Risk Score} = \text{Probability} \times [(\text{Cost} + \text{Time} + \text{Quality}) \div 3]$$

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Probability

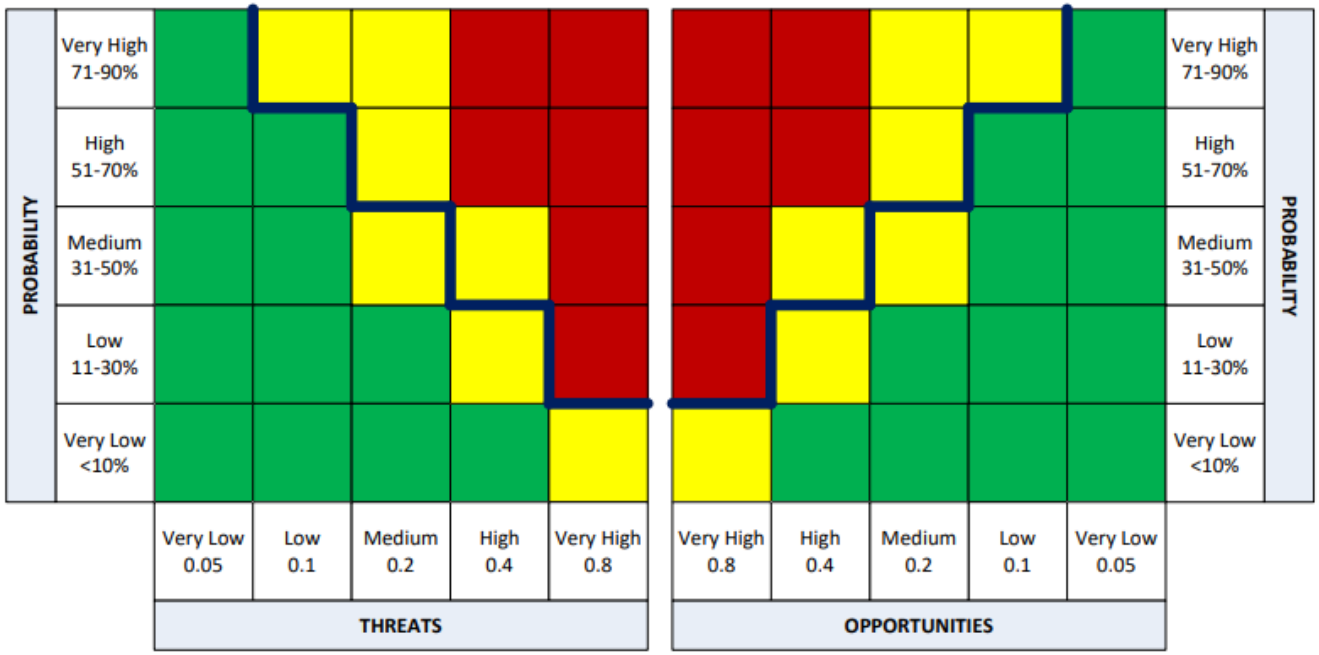

Figure 7.6-2. Double Probability vs. Impact Matrix

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Overall risk

- For example, a project team may be **analyzing a risk** that **long lead time** for the curtain wall system may delay the project (risk ID-1 from the risk register in Figure 7).

Qualitative risk analysis

SEVERITY	LIKELIHOOD				
	Minor	Unlikely	Possible	Likely	Almost Certain
Critical	Serious	Major	Major	Critical	Critical
Major	Moderate	Serious	Major	Major	Critical
Serious	Moderate	Moderate	Serious	Serious	Major
Moderate	Moderate	Moderate	Moderate	Serious	Serious
Minor	Minor	Minor	Moderate	Moderate	Serious

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ID-3	Design/Schedule	Deficient drawings	Due to the tight design schedule, the drawings could be deficient, resulting in more change orders/ RFIs/claims	Threat	Major

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Overall risk

- The team is using a **range** of 1 to 5 for risk impact scores.
- The team **estimates ranges** for this threat and calculates impact scores as:

Probability is 75%-90% (Probability = 4)

Cost impact is $1-1.5 million (Cost = 5)

Time impact is a delay of 1-2 months (Time = 3)

Quality impact is no or minimal rework (Quality = 1)

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Overall risk

- In this example, one way to calculate the overall risk score would be:

$$\text{Overall Risk Score} = \text{Probability} \times [(\text{Cost} + \text{Time} + \text{Quality}) \div 3]$$

$$12 = 4 \times [(5 + 3 + 1) \div 3]$$

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Overall risk

- When the team uses **advanced fields**,

  the risk manager should **reorder the risks** in the **risk register**

  from **highest to lowest** based on the overall risk score.

  - This **new order** would **not change** each risk's risk ID.

- Figure 8 shows the same **partial risk register** from Figure 7 with **advanced fields** and the **risks in order** based on their overall risk scores.

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Overall risk

Figure 8 – Partial Risk Register with Impacts and Overall Risk Scores

Score	±1	±2	±3	±4	±5
Probability	< 10%	10%-49%	50%-74%	75%-90%	> 90%
Cost	< $30k	$30k - $99k	$100k - $299k	$300k - $1m	> $1m
Time	< 2 weeks	2-4 weeks	1-2 months	2-4 months	> 4 months
Quality	Minimal rework	< 5% rework	5%-14% rework	15%-30% rework	> %30 rework

Overall Score	< |±3| (low)	|±3| - |±9.5| (medium)	> |±9.5| (high)

Project Name
Project Risk Register
Rev: 5 (Advanced qualitative analysis)
Date: April 9, 2024

Risk ID	RBS	Risk Name	Risk Description	Threat/ Opportunity	Probability Score	Cost Impact	Schedule Impact	Quality Impact	Overall Risk Score
ID-2	Construction/Scope	Construction scope change	The owner is unfamiliar with construction, which could lead to scope changes during the construction phase that could create delays, cost overruns, and quality issues	Threat	5	5	4	3	20
ID-1	Procurement/Market Conditions	Pre-purchase curtain wall	Long lead of the curtain wall system could delay the curtain wall's arrival, which could delay the critical path and the completion date	Threat	4	5	3	1	12
ID-4	Political/Approvals	Senior stakeholder support	The state's governor and several legislators are highly-engaged and want to show the project is a success, so these officials could help expedite the approval process and allow design and construction to begin sooner	Opportunity	(-5)	(-3)	(-3)	(-1)	(-12)
ID-3	Design/Schedule	Deficient drawings	Due to the tight design schedule, the drawings could be deficient, resulting in more change orders/RFIs/claims	Threat	3	4	4	3	11
ID-5	Real Estate/ Acquisition	Purchase available adjoining lot	An empty lot next to the jobsite is for sale below the market rate and purchasing it would improve site access and staging, which could also shorten the construction schedule	Opportunity	(-3)	(-3)	(-2)	(-1)	(-6)
ID-6	Construction	Certificate of occupancy	An administrative delay could delay the certificate of occupancy's signoff at the end of the project, which would delay substantial completion and move-in	Threat	2	1	1	1	2

Overall risk

- With this **new order**, the team can **more easily see** which threats and opportunities are the highest and lowest priorities.

- Again, note that opportunity scores often have **negative values**.

- The **RMP** may **also allow** the team to **round overall risk scores** to the nearest whole number.

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Overall risk

- Remember that **qualitative** risk analysis scores are based on **range estimates** (**not exact values**).

- **Advanced qualitative** risk scores help the team **differentiate** the risks **more precisely** than **general categories** like “minor,” “moderate,” or “severe,”
  but they are **still based** on **ranges**. **See the legend in Figure 8.**

- The team on an actual project/program **may use different ranges** to score risk impacts.

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Overall risk

- Note that **qualitative analysis** may help the team develop an overall **range of possible impacts.**

- The results from the **advanced qualitative analysis** can help the owner
  1. evaluate their overall requirements and
  2. make **adjustments** based on the owner's risk tolerance.
     - For example, when the **risk manager adds** together the **impact analysis results** from all the known risks,
       it may provide an **overall range** that can help the owner understand
       if the budget and schedule are **realistic** for the quality requirements.

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Overall risk

- However, **qualitative** analysis has **limitations**.
- A qualitative risk analysis is **subjective**, so the risk manager **must use** the team's **expertise** and **common sense** to recognize if any risks are **prioritized incorrectly**.

A **misprioritization** is **more common** with risks that have

1. **low probability** but extremely **high impact(s)**, and
2. **risks with low impact(s)** but extremely **high probability**.

❖ For example, an earthquake with an **8.0 Richter scale magnitude** may have a **low probability** but could have an **extremely high impact** on a project,

so the **risk manager** may need to **prioritize** the risk higher than the qualitative analysis originally indicated.

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Overall risk

- A **qualitative** risk score is also **not the same** as a quantitative risk analysis.
- Although the team may use numbers to perform qualitative analysis, a quantitative analysis requires **more effort** and is **usually more precise**.
- **Qualitative** analysis can help the team **better understand** the project's/program's risk profile and is **necessary before** the team can perform **quantitative analysis**.

Quantitative Risk Analysis

(AACE TCM)

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Quantitative risk analysis

- **Once** the risks have been identified and ranked,

  their **quantitative impact** on the asset or project plans can, with the support of the project team, be **analyzed** in an **objective** way by a professional risk practitioner.

  - This may be
    1. A **person** that is **already** among the risk management leadership team,
    2. Someone **working** from within **organization's specialist** support services pool or
    3. **External consultant** contracted in especially for this effort.

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Quantitative risk analysis

- **For each risk** selected by the team for quantitative risk analysis,

  a **probabilistic estimate** of its impact will be prepared.

- The **chosen methodology** will have been **specified** during **the risk planning phase**.

- One of the following three methods or a **hybrid** of the three is commonly employed:

  1. expected value,
  2. range estimating, or
  3. parametric modeling.

Quantitative risk analysis

- When using the **expected value method**, estimates of
  1. The probability of occurrence and
  2. Potential impact of the risks are prepared.
     - These probability and impact ranges typically
       1. Take the form of **"three point estimates"** and
       2. Portray the team's **optimistic** and **pessimistic** view,

          where the **most likely value** frequently, but not always, **aligns with** the **estimated value.**

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Quantitative risk analysis

- With **range estimating**, the impacts (usually three points) are estimated while risks and their probabilities are **addressed by the team** based upon their experience and knowledge as appropriate when determining impact ranges.

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Quantitative risk analysis

- With **parametric methods**,

  the **risk-to-impact** estimating relationship is implicit and the probabilistic outcomes are **inherent** to the algorithm.

Quantitative risk analysis

- Expected value and parametric values are sometimes called **risk driver approaches** because they **start with** and **focus directly** on the risk drivers.

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Quantitative risk analysis

- The estimated value is referred to as
  1. Base estimate,
  2. Point estimate or
  3. Deterministic value.
- In **expected value** and **range estimating methods**,

  computer simulations using Monte Carlo, or

  similar statistical sampling processes,

  compute thousands of different outcomes or probabilistic values.
- **These probabilistic values** can be used for **sensitivity analysis** (i.e. identifying which variables are most influential) and also to **produce** a **probability distribution** for

  total cost, completion date or other measure of interest.

Quantitative risk analysis

- **Parametric models** can output **distributions directly**.

- The **probability distribution** is commonly used to derive the **confidence level percentage values**

  that **support** estimation of the **appropriate contingency** depending on management's risk appetite or tolerance.

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Quantitative risk analysis

- **Any** qualifications, assumptions, or exclusions used in the quantitative risk analysis need to be **clearly stated and accepted** by **all key stakeholders**.

- Done properly, the risk analysis will address cost and schedule risks in an **integrated manner.**

- At a minimum, the cost and schedule impacts must reflect **consistent assumptions** that appropriately account for **residual risk**.

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Quantitative risk analysis

- The **first quantitative** risk analysis is typically performed to help set an **appropriate level of contingency.**
- For the risk management process to be most effective, and resources permitting,

  it is good practice to **repeat this exercise** at

  1. periodic intervals and/or
  2. milestones

  as agreed in the risk management plan.

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Contingency

- **Contingency** is an amount added to an **estimate** (of cost, time, or other planned resource) to allow for items, conditions, or events for which
  the state, occurrence, and/or effect is **uncertain** and
  that experience shows will likely result, in aggregate, in additional cost.

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Contingency

- **Contingency analysis**, a sub-step of risk assessment,

  quantifies the risk impacts after **all treatment efforts** are **complete**, also known as residual risk.

  - The team should **guard against assumptions** that the treatment efforts will be entirely successful, or not successful at all.
  - Following treatment, more often than not, **risk cannot** be completely **eliminated** and there will be some **degree of residual risk**.
    - ✓ In addition, **many treatment efforts** can introduce,

      inadvertently or knowingly,

      subsequent variation or secondary risks.

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Contingency

- **Successful contingency analysis** will account for all
  1. Residual risk and
  2. Secondary risk

  that **cannot be treated** in some way.

- In this sense, it should be **appreciated** that appropriate **contingency analysis** is **mutually dependent** on the **other two iterative process steps**:
  1. Risk treatment and
  2. Risk control.

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Contingency

- The **amount** of contingency depends in part on
  1. An organization's risk **appetite** or
  2. Willingness to **accept** risk or **avoid** risk.

- The **greater the appetite**, the **more risk** the organization is willing to accept that the project may either
  1. exceed or
  2. under achieve

  its objectives.

Contingency

- **Contingency** is normally controlled by the project manager or equivalent team leader because experience shows that contingency will likely be **required by the project**.
  - However, the **organization may decide** that additional funds, time or other values at risk be considered for risks that are **beyond the control** of the project team.
    - ✓ These amounts, typically **controlled** by senior management, are known as the funded liability or management reserves.

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Other risk assessment challenges

- There are **two additional key challenges** for risk analysis.
  1. First, the **impacts** of **some risks** are difficult to imagine or estimate, even for the **most experienced project teams**.
  2. Second, even if **individual risk drivers are understood**, it is difficult to understand the **interaction of risks**.
     - For example, does the occurrence of one risk influence the occurrence or consequence of others? Are the impacts of associated risks added or compounded?

Other risk assessment challenges

- Parametric modeling is **one method** that helps address interaction and complexity challenges.
- Parametric models are typically **multi-variable regressions** of historical, quantified risk drivers versus actual project outcomes.
- **Regression** empirically **quantifies** the impact while **allowing** the **dependency** of risks to be examined.
  - **Regression models** also provide useful probabilistic outputs, and results are replicable.

There are also proprietary **commercial project risk analysis systems** available that help address these risk analysis challenges.

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Other risk assessment challenges

- **Sensitivity analysis** is another way to address risk complexity and interaction.
- Sensitivity analysis **examines risk drivers** (or cost or schedule drivers) by
  1. **Developing** a model relating the drivers to impacts (can be a parametric or another model type), and
  2. Then **changing** the **driver variable values** to examine the impact of each driver or combination of drivers on the impact.

This helps prioritize the risk drivers for later risk treatment.

Quantitative Risk Analysis

(CMAA)

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Quantitative risk analysis

- A **quantitative risk analysis** uses statistical formulas and software to **refine** the **calculations** for the likelihood and range of potential impact of each risk in the **risk register.**
  - This process relies on the **team's expert judgment** to make realistic assumptions and use accurate data.

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Quantitative risk analysis

- A quantitative analysis
  1. requires **detailed information** about the project/program (such as the team's advanced qualitative analysis) and
  2. may involve **predetermined standards** (empirical guidelines defined in the RMP), parametric models, and **other statistical simulations**.
- The team **may use data** from the project/program (e.g., actual costs, activity durations, procurement data, etc.).

Quantitative risk analysis

- **Parametric models** can use statistical algorithms that **attempt to estimate** the values of specific variables based on **multiple other independent data** points.
- For example, a team could attempt to determine a risk's schedule impact based on data from related activities.

[3]*Parametric modeling commonly uses a statistical method known as multiple linear regression. For more on multiple linear regression, see: "The Multiple Linear Regression Model." The Pennsylvania State University, Eberly College of Science.* **https://online.stat.psu.edu/stat501/lesson/5/5.3**

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Quantitative risk analysis

- If the **team** performs **quantitative risk analysis**,

  the **risk manager (CM or risk specialist)**

  1. Facilitates this process and
  2. Updates the risk register

     with the results.

  - If the **CM is not the risk manager**,

    the CM should still **generally**

    understand this process and

    be able to **manage it**, if necessary.

Quantitative risk analysis

- If the **team performs** quantitative risk analysis,

  the **results** may inform the team's decision about **how to respond** to a **certain risk.**

  - The **risk responses** are **separate fields** in the risk register.

For more on risk responses, see Section 4.

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Quantitative risk analysis

- However, note that **some owners** may **not require** a **quantitative analysis**.
  - A quantitative analysis is **less likely** on **smaller projects** and in situations where the **risks** are already **well-known.**

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Monte Carlo simulations

- The **industry standard** for performing a quantitative risk analysis is a **Monte Carlo simulation.**
  - A Monte Carlo simulation is a **software-based statistical method** that relies on **repeated random sampling** to obtain
    1. a range of possible outcomes and
    2. the probabilities that they will occur.
- The **CM** does **not necessarily** need to be **an expert on Monte Carlo simulations**, but the **CM must understand** the process well enough to **manage it.**
  - If the **CM is the risk manager**, the CM should **lead Monte Carlo simulations**.

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Monte Carlo simulations

- When applied to construction risk analysis, the team simulates the same schedule or cost model hundreds (or even thousands) of times.
  - A **single Monte Carlo iteration** should produce a **logically-possible scenario** and outcome based on **reliable input**.
    - ✓ Therefore, the team should analyze the simulation to ensure that the **input is realistic** and that **each of the hundreds** (or thousands) of iterations is at **least logically possible**.

A realistic simulation helps the team see the **range of possible outcomes**.

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Monte Carlo simulations – Inputs

- In other words, simulations are based on the **risks** that the team **identified in the risk register,** including a risk event's probability and severity (potential impact on cost, schedule, quality, etc.).
- These variables can be **subjective**, so the team must **carefully review them**.
- Additionally, the **Monte Carlo simulation** should use actual data (design, cost, schedule, etc.) to **refine** the analysis.
- Even **slight variations** may have **significant impacts** on the simulation results.
- The project's or program's **unique risks** and **unforeseeable risk events** can also affect the outcome.

Monte Carlo simulations – Inputs

- To perform an **accurate Monte Carlo simulation**, the team must analyze **which risks** are **related to each other**.
  - If the **team believes** that a relationship exists between **two or more risk events**, the team should develop a statistical correlation to determine **how strongly one risk** may impact the other.
  - A **mutually-inclusive risk event** is an event that **can only occur** if another specific risk event **occurs first**.
    - ✓ Meanwhile, a **mutually-exclusive** risk event is an event that **can only occur if another** specific risk event does **not occur**.

A Monte Carlo simulation should model this relationship.

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Monte Carlo simulations – Inputs

- For example, the **risk of changes** in the design and budget may **impact procurement**.
  - If the **owner switches** the design from **materials with short lead times** to **materials with long lead times**,

    then the **threat of a procurement delay** would be a mutually-inclusive risk.
- In other words, in this example a **procurement delay** might depend on w**hether or not a design change** occurs.
  - However, if a **procurement delay** is more **likely after a design change**, it may be **less likely** that the **owner would change** the design.

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Monte Carlo simulations – Outputs

- **Monte Carlo simulations** essentially produce a **range** of **possible** project/program **contingencies** which the team can pick from based on the **owner's risk tolerance**.
- A Monte Carlo simulation typically provides
  1. A range of potential completion dates and
  2. Final costs,

  so a best practice is to express Monte Carlo estimates in ranges instead of absolute values.
- These results provide a **range of probabilities** that **each estimate** will be correct.
- **Range estimates** are necessary because it is usually **impossible to remove** all **uncertainty**.

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Monte Carlo simulations – Outputs

- For example, the **simulation in Figure 9** shows that the **project's baseline** estimated budget is **$29 million**, but when accounting for risk there is **only** a **5% confidence level (P5)** that the project costs will be **within that baseline**.
  - In other words, when the team ran the Monte Carlo simulation, only 5% of the results were $29 million or less.
    - ✓ The range of potential costs could be between **$26 million and $41 million**.
- In this example, the team can set an **appropriate budget (and contingency)** within that range based on the owner's risk tolerance.

Monte Carlo simulations – Outputs

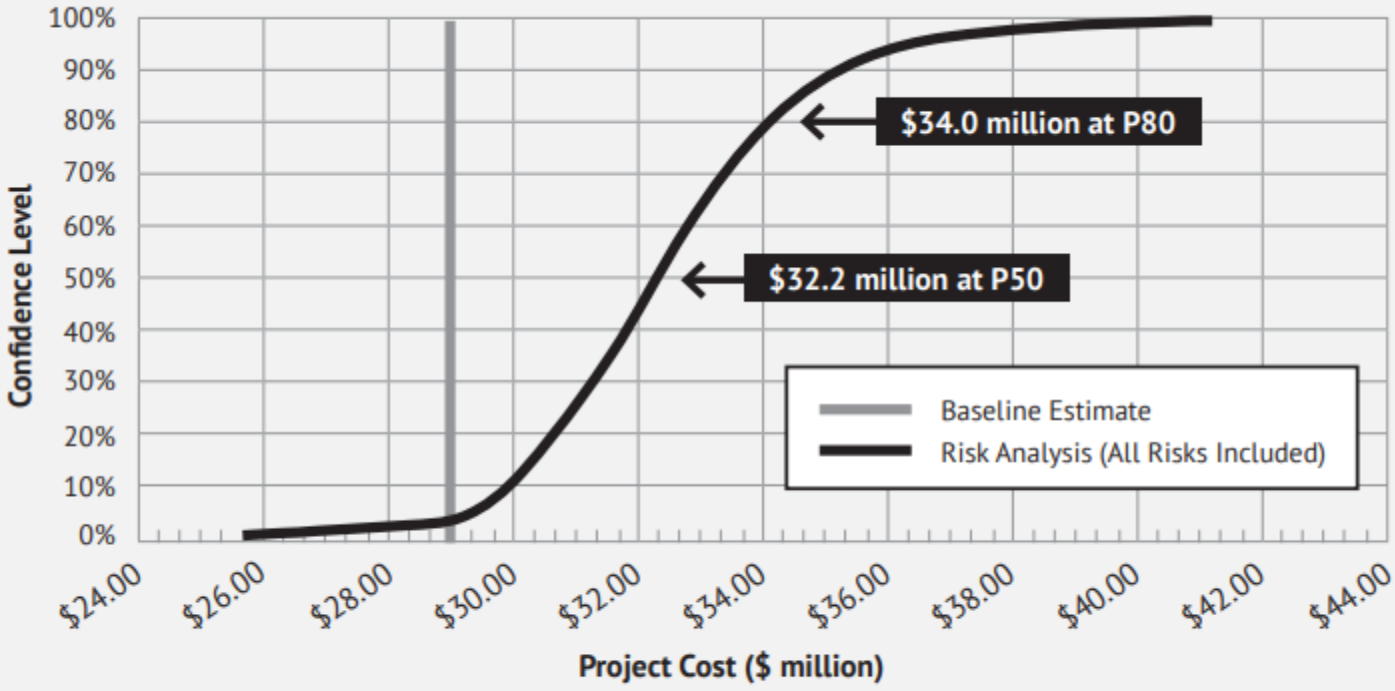

Figure 9 *– Example of Total Project Cost Output from a Monte Carlo Simulation*

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Monte Carlo simulations – Outputs

- In another example, **Figure 10** shows that the baseline schedule **completion date** is March 24, 2026,

  but the **Monte Carlo analysis** shows that the project has **only a 41% confidence level (P41)** that the project will **finish by then**.

  - In other words, when the team factored the **risks only 41%** of the iterations had a **completion date** on or **before March 24**.
    - ✓ The possible completion date could be between August 19, 2025 and November 27, 2026.
    - ✓ The team can set an **appropriate schedule (and contingency)** within that range based on the owner's risk tolerance.

Monte Carlo simulations – Outputs

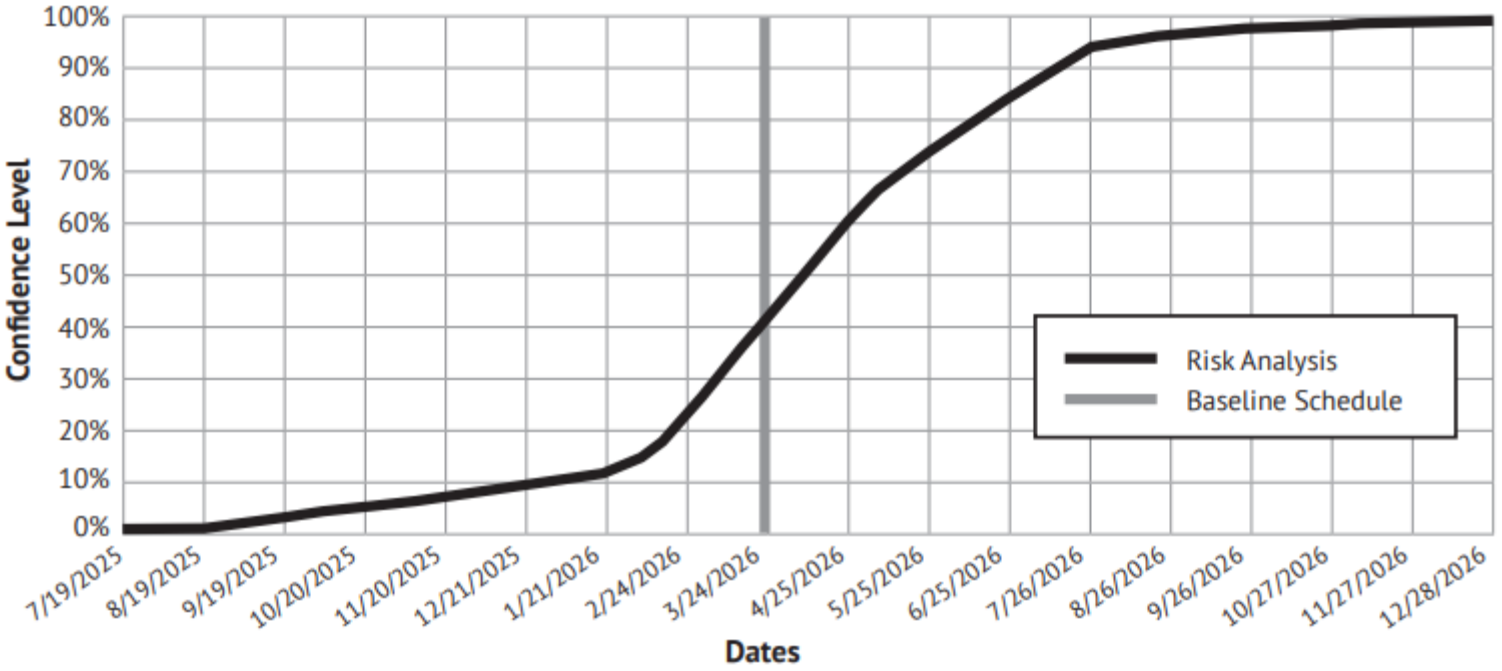

Figure 10 *– Example of Project Completion Date Output from a Monte Carlo Simulation*

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Monte Carlo simulations – Convergence

- **Simulation convergence** is the point when **additional iterations** do **not significantly change** the shape of the output distribution.
  - The simulation results display in a distribution that covers **all possible outcomes** from the model.
  - In **most cases**, the team will reach simulation **convergence with 1,000 iterations**,

    but **larger or more complex** projects and programs may **require additional iterations.**

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Monte Carlo simulations – Convergence

- The **major disadvantages** of Monte Carlo analysis are that it requires
  1. Reliable data inputs and
  2. Many iterations to reach convergence

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Other methods

- **Alternatives** to Monte Carlo analysis exist but are **less common** for quantitative risk analysis in design and construction.
  - **Teams may see more useful results** when **combining** these methods with Monte Carlo analysis.
- The CM does **not necessarily** need to be an expert in these alternative methods, but the CM should **understand them well enough to** manage them, if the owner requires.

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Other methods

- **Separately**, employing an **artificial intelligence** tool is **another method** to analyze and refine the project's/program's analysis.
- AI applies **computer algorithms** to **replicate actions** that humans perform.
- **AI software "learns"** from the data it receives to attempt to **make more accurate** decisions and predictions about cost, schedule, etc.
- An AI tool could use a **library of statistical methods** to analyze all the available information and estimate risk impacts.

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Other methods

- For example, the team may use **AI scheduling software** to analyze leads and delays.
  - While it is **possible** to measure **schedule impacts without software**, **scheduling software** is generally **more objective** than a human and provides a **more reliable range** of impacts if the team **inputs realistic information.**
- The software uses **what-if analysis** to determine how each risk impacts the schedule.

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Other methods

- However, AI is only as good as
  1. The data it receives and
  2. The risk manager interpreting the results.
- **Insufficient** or **inaccurate data** with AI will **not produce reliable** risk analysis.
- **Data collection** in construction usually **lags other industries**, so **historical information** may be necessary to use AI best.
- AI tools can also **miss things** that would be obvious to a human (e.g., weather or worker fatigue).
- If the **owner requires quantitative risk** analysis with AI, the team must evaluate the results carefully.

Risks vs. Issues

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Risks vs. Issues

- Recall from **Section 1** that a risk involves **uncertainty**.
- Whether a **threat** or an **opportunity**, a risk will always meet at least one of the following criteria:

1. A risk has a probability greater than 0% but less than 100%.
2. A risk's impact on the project/program will not be fully known until it occurs.

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Risks vs. Issues

- During risk analysis, if the **team realizes** that
  1. a risk event will definitely occur **and**
  2. the team already knows the risk's full effects on the project/program,

  then the item is an issue, not a risk.
- An issue is a **certain event** or **condition** that will have a **known negative or positive** impact on a construction project or program.
  - For example, the **team might identify** a **cash flow issue** that will delay the project for two months.
    - ✓ If the team knows for **certain** that the event will happen and the impact, then it is an issue.

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Risks vs. Issues

- The team **should** have **separate processes** for managing issues.
- The RMP, PMP, or PgMP should **define how** the team removes issues from the **risk register.**
- Typically, the **CM or risk specialist** moves an issue to an **issue log.**
- All the items on an **issue log** will definitely occur and the **team knows exactly how** they will impact the project/program.
- The **team manages** the items on the **issue log** with **separate processes** that are beyond the **scope of risk management**.
- The **contract documents** should also specify which **team member(s)** is/are **responsible for each issue**

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