ACEMI

نحوه برآورد ذخیره احتیاطی (Contingency) در پروژه

الزامات + اصول کلی + نکات حیاتی

(بر اساس اسنادی از AACE)

ارائه دهنده:

سید محمدرضا علوی‌پور

(PhD, PMP, CMIT)

CMAA Authorized Trainer

دانشگاه Illinois Tech آمریکا

ACEMI

What we will learn?

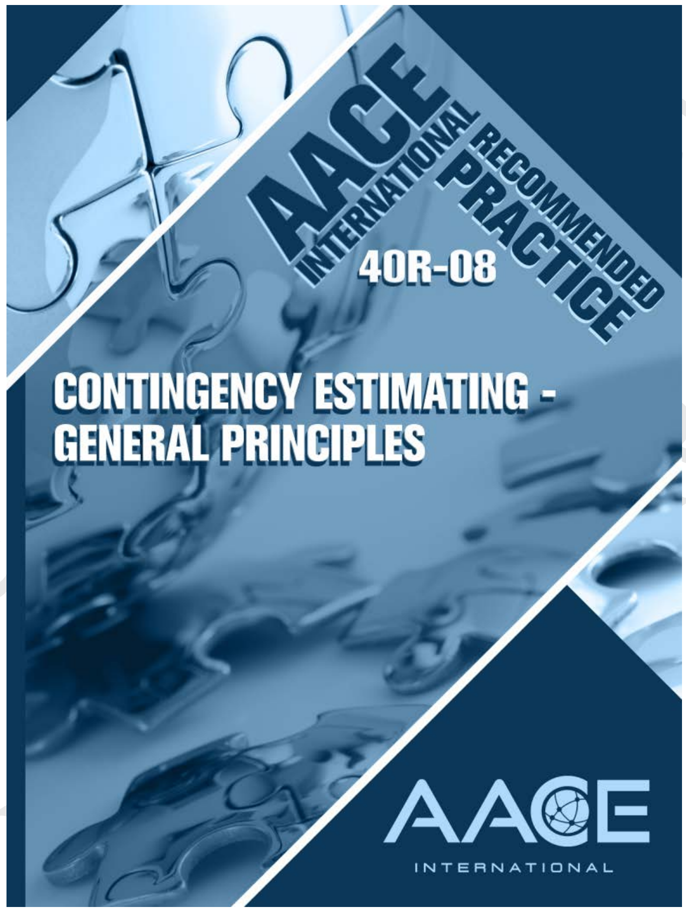
- ❑ Introduction
- ❑ Recommended practice
- ❑ General principles of estimating quantitative risk impact
  - ❖ Objectives, expectations and requirements
  - ❖ Decision or risk management process
  - ❖ Fit-for-use
  - ❖ Identifying risk drivers
  - ❖ Linking risk drivers and outputs
  - ❖ Avoid iatrogenic (self-inflicted) risks
  - ❖ Empiricism
  - ❖ Experience/competency
  - ❖ Probabilistic

What we will learn?

- ❑ General categories and characteristics of methods in practice
  - ❖ Expert judgment
  - ❖ Predetermined guidelines
  - ❖ Simulation analysis
  - ❖ Parametric modeling
  - ❖ Hybrid methods
- ❑ Principles and methods at a glance
- ❑ Contingency determination tools & software
- ❑ Contingency allocation and control

Reference

Primary reference



Other references

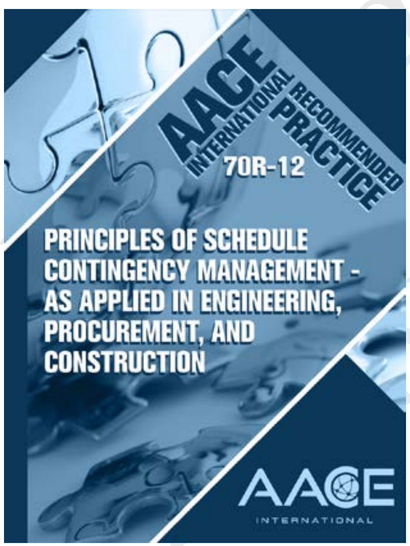
Estimating Project Cost
March 5, 2021

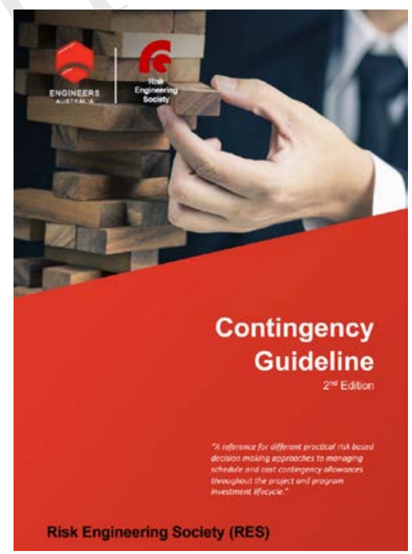
NAC Executive Insights

Contingency

Key Points

- Five levels of cost estimate classification are described.
- Building and process projects are compared.
- Tendency of complex projects to behave more consistent with process projects is noted.
- Elements of cost are described at a macro level and attention is called to the inclusion of allowances in the base cost estimate.
- Elements of contingency are described.
- Tendency of contingency analysis to underestimate variability of outcomes is flagged.
- Management reserve is described as not being a part of contingency.
- Unique features of public projects as they relate to contingency are highlighted.
- An example of sharing contingency for result is provided.





Introduction

Risk tolerance

- **Owner risk tolerance** is a necessary discussion as an **integral part of planning** a project or program.
- Understanding the **level of tolerance** is vital to several of the tasks in the planning effort.
- Risk can and should be **addressed** in
  - The scope definition,
  - The contract type,
  - The contractual language,
  - The choice of project delivery method,
  - The change management process,
  - Quality and experience of the management staff,
  - Procurement process,
  - The integrated risk/schedule and in the implementation of the plan.

ACEMI

Contingency determination importance

- This Executive Insight focuses on contingency in **capital construction projects**.

- It seeks to address questions often raised by owners as to

  what are **appropriate contingency** levels to include in project and budget estimates.

AACE 40R-08

- This recommended practice (RP) of AACE International defines
  - Expectations,
  - Requirements, and
  - General principles of practice for estimating contingency,
  - Reserves and similar risk funds (as defined in RP 10S-90) and
  - Time allowances for project cost and schedule

  as part of the overall risk management process (as defined in TCM Framework Section 7.6).

The RP provides a **categorization framework** and provides a **foundation** for,

but does **not define** specific contingency estimating methods

that will be **covered by other RPs.**

ACEMI

AACE 40R-08

- This RP is intended to provide **guidelines** (i.e., not a standard) for contingency estimating

  that most practitioners would consider to be **good practices** that can be relied on and that they would **recommend be considered** for use where applicable.

- There is a **broad range** of contingency estimating **methodologies**;

  this RP will help **guide practitioners** in developing or selecting **appropriate methods** for their **situation**.

- There is **no one best way** to quantify risks or to estimate contingency;

  each method has its advocates.

  - However, there is **general agreement** that any recommended practice should be in accordance with first principles of decision and risk management as described here.

Recommended Practice

Contingency versus risk impact

- This RP covers **more than** just the estimation of traditional "contingency" for cost or schedule.

- It also refers to the **estimation of risk values** in general (excluding escalation, currency, and other primarily monetary or financial risks).

Framework of this RP

1. General Principles of Estimating Quantitative Risk Impact
2. General Categories and Characteristics of Methods in Practice

General Principles of Estimating Quantitative Risk Impact

General principles of estimating quantitative risk impact

- Any methodology developed or selected for quantifying risk impact should address these general principles:
  - Meet client objectives, expectations and requirements
  - Part of and facilitates an effective decision or risk management process (e.g., TCM)
  - Fit-for-use
  - Starts with identifying the risk drivers with input from all appropriate parties
  - Methods clearly link risk drivers and cost/schedule outcomes
  - Avoids iatrogenic (self-inflicted) risks
  - Employs empiricism
  - Employs experience/competency
  - Provides probabilistic estimating results in a way the supports effective decision making and risk management

These principles are further described below.

General Principles of Estimating Quantitative Risk Impact

(Objectives, Expectations and Requirements)

ACEMI

Objectives, expectations and requirements

- Management (or other customer of the estimate) may require traditional contingency or float values, reserves, ranges, and other information.
- This determination includes **agreeing on the meaning** of the terms “risk” and “contingency”;

  definitions **may vary somewhat** among organizations and applications (e.g., does risk include both opportunities and threats?).

  - During this discussion, the **client’s level of risk tolerance** should be **gauged**.
    - For example, is it the **client’s desire** that the budget or schedule represent the most likely result, or a more conservative or aggressive outcome?

Contingency definition

- AACE defines Contingency, in the Cost Engineering Terminology RP, as

  "An amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs."

- Contingency does not include
  - Major scope changes,
  - Force majeure events,
  - Management reserves,
  - Escalation and currency changes.

ACEMI

Contingency definition

- Contingency can be
  1. Carried in the original budget, and during the stage-gate process of project controls,
  2. Subdivided into specific categories such as design contingency, estimating contingency, procurement contingency, construction contingency.

Contingency definition

- Note that **not all contingency funding** is due to specific risk events,

  some is needed for accommodating the **standard of care** in the construction process, from design to estimating to construction.

- There is **some level** of design errors and omissions that falls **outside the industry standard of care** which recognizes that scope definition in the way of plans and specifications cannot be perfect.

  - This is part of the purpose of Contingency.

Management reserves definition

- AACE defines Management Reserves, in the Cost Engineering Terminology RP, as

  *"An amount added to an estimate to allow for **discretionary management purposes** outside of the defined scope of the project, as otherwise estimated."*

- This is where an Owner would normally fund the items **not included in Contingency**,

  such as **scope change**.

- Management Reserves would typically be carried **outside the project**, and

  managed by the **Program Manager or Owner**,

  not the Project CM team.

- The **better the definition** of these terms,

  the **easier it is to manage** and account for change orders.

Management reserves definition

- **Estimating Management Reserves** is more difficult than Contingency because this fund is designed to **cover unknowns** such as
  - **improvements in technology** that might interest the **end user** to upgrade equipment
    - that was **specified in the original scope** definition, is still sufficient, but **not the most desired technology**.

Contingency and management reserves definitions

- Use of a **robust Change Management** effort during construction ensures that **original contract scope** is provided, that **Contingency** is drawn down appropriately and according to the relief of risks, and **Management Reserves** are used appropriately.

ACEMI

Schedule contingency

(1) Duration added to a **schedule activity** to allow for the probability of possible or unforeseen events.

- ❖ Use in this manner is **not recommended** as the contingency is hidden and may be misused.

(2) A **unique activity** used to model specific float available to a project phase.

- ❖ Used in this manner gives **ownership of float** to those activities and or **responsibility entity**.

(3) The amount of **time added to specific activities** of a project (or program) schedule to mitigate (dampen/buffer) the effects of risks or uncertainties identified or **associated with specific elements** of that schedule.

Syn.: SCHEDULE BUFFER. See also: SCHEDULE MARGIN. (October 2013)

Schedule contingency

- When applying this definition, the generally accepted attributes of schedule contingency are as follows:
  - Schedule contingency must be visible in the schedule.
  - Schedule contingency is time only and does not contain scope, resources or costs.
  - Schedule contingency is only established based upon an analysis of schedule risk.
  - Schedule contingency is not float (i.e. neither project float nor total float).
  - Schedule contingency is not lag/lead (relationship durations).
  - Schedule contingency is not hidden artificial lengthening of schedule activities.
  - Schedule contingency is not the improper use of what some term as **"preferential logic".**
  - Schedule contingency is not a non-work period in the software calendar.
  - Schedule contingency is not management reserve.

Schedule management reserve

- Schedule management reserve (SMR) is a designated amount of time to
  1. Account for risks that **cannot be quantified and/or managed** with contingency; or
  2. Allow time for **management purposes** and

     the use of management reserve generally requires a **formal baseline change.**

A matter of perspective

- **Schedule contingency** usually **cannot** be managed successfully from only one participant's perspective.
- Schedule contingency should be developed from a total project perspective and needs to be managed from the top (project owner) down.
- **Project contract (terms and conditions)** will determine whether or not schedule contingency can be **jointly established and managed** in the project schedule.
- **Scheduling specifications** require modification to include the definitions and guidelines for the management and use of schedule contingency.
- Successful use of contingency/buffers requires a **significant investment of time** at the beginning of the project to

  educate the project participants to understand the contingency management process.

ACEMI

A matter of perspective

- Schedule contingency may be **established by either** the owner of the project or the contractor performing the work (or both) based upon an analysis of schedule risk.
- The owner and the contractor have **different perspectives**.
  - For example, an engineering or design error may be considered a scope change to the **construction contractor** which would not be addressed with **contingency**.
  - But to the owner, unless the basic premise of the project changes (i.e., capacity, size, location, etc.) very little is a scope change because the **owner's contingency** must **address all risks**, including errors and omissions.

Contingency and management reserves definitions

Level/Type of Cost	Terms Used in EIA-748/Capital Programming Guide Reference	Terms Used in Common Commercial Practice
Owner Cost Contingency	Contingency	Management Reserve
Owner Schedule Contingency	Contingency	Schedule Contingency
Contractor Cost Contingency	Management Reserve	Cost Contingency
Contractor Schedule Contingency	Schedule Margin	Schedule Contingency

Table 1 - Comparisons of terms for schedule and budget reserves created and managed on the contractor and owner level for project uncertainties (this may vary by Industry)

General Principles of Estimating Quantitative Risk Impact

(Decision or Risk Management Process)

Risk management process

- Estimating **quantitative risk** impacts is **not an end** in itself;

  it should be **part of some process**.

  - Therefore, the practitioner must identify the **decision or risk management process.**

- If there is **no such process in place,** the practitioner should **recommend that one** be established as appropriate for the objectives and requirements of the customer.

Risk management process

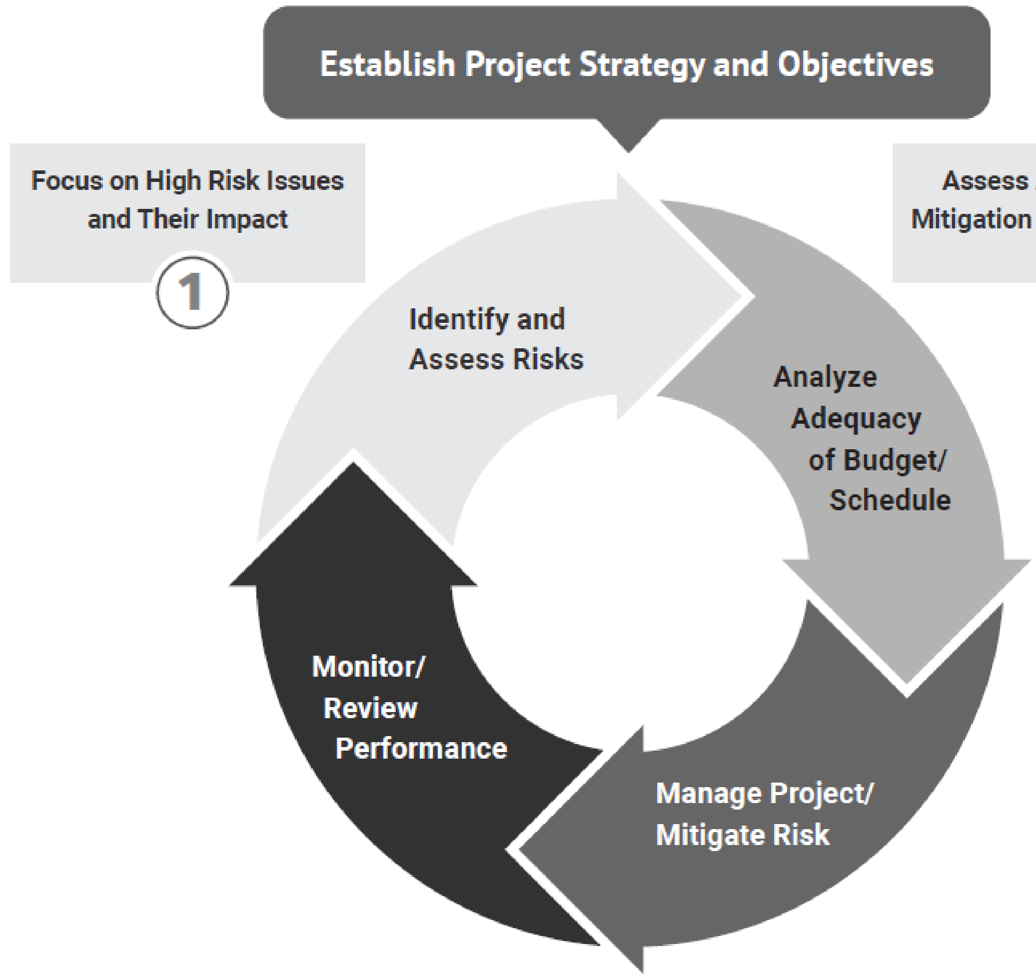
- While **few academic programs** include knowledge of risk management as a prerequisite for a professional degree, there are professional certifications that support understanding of risk.
- At the construction/project management level, the Project Management Institute (PMI) includes risk management as one of the knowledge areas, so a Project Management Professional (PMP) certification would indicate exposure to risk on project work, not specifically construction projects, but still project risk.
- The Construction Management Association of America (CMAA) offers the Certified Construction Manager (CCM) certification and the CMAA Standards of Practice as taught for the CCM fully integrate risk into the CM processes, and these are specifically for construction projects.

ACEMI

Risk management process

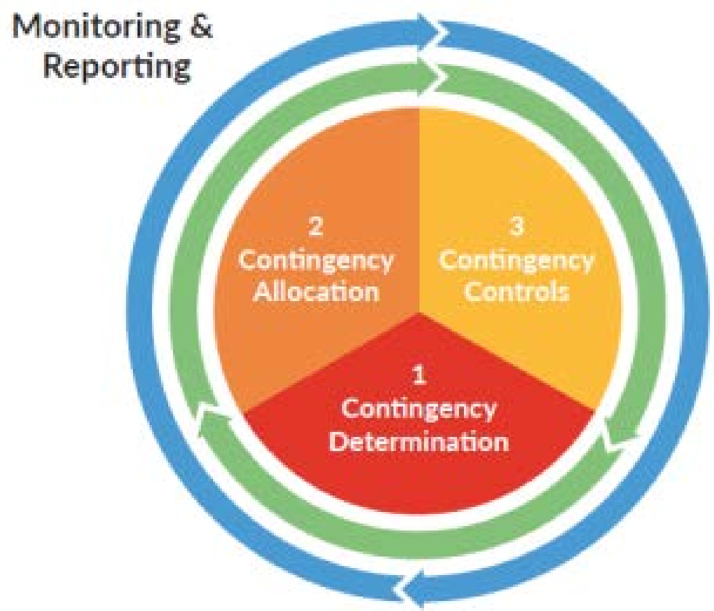
- When it comes to specialization in risk management, there are **two primary industry** risk certifications; the Risk Management Professional (PMI-RMP) by PMI and the Decision and Risk Management Professional (DRMP) by AACE International.
  - Once again, the PMI-RMP is not specifically designed for construction as is the DRMP but the general risk processes are the same regardless of industry.

Risk management process



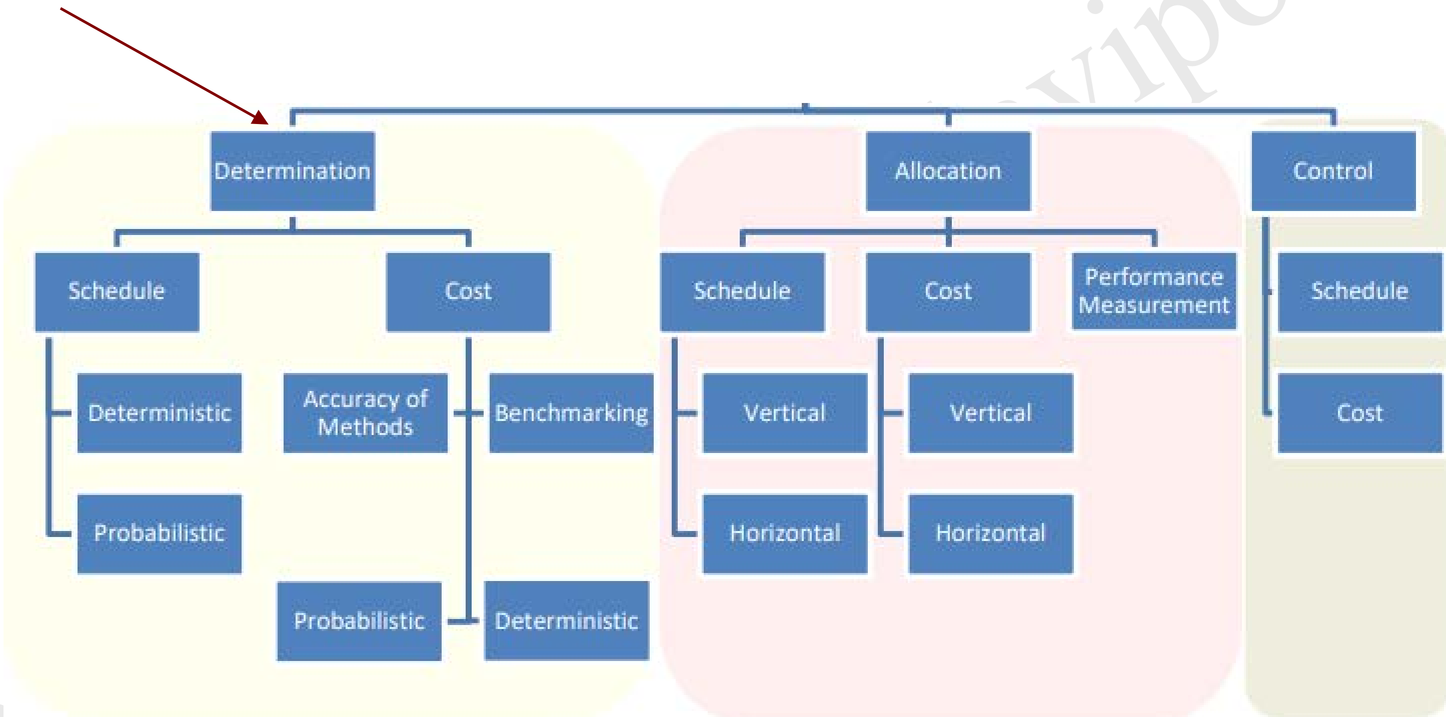
An iterative and continuous process for managing risk as it changes and shifts.

Contingency management process overview

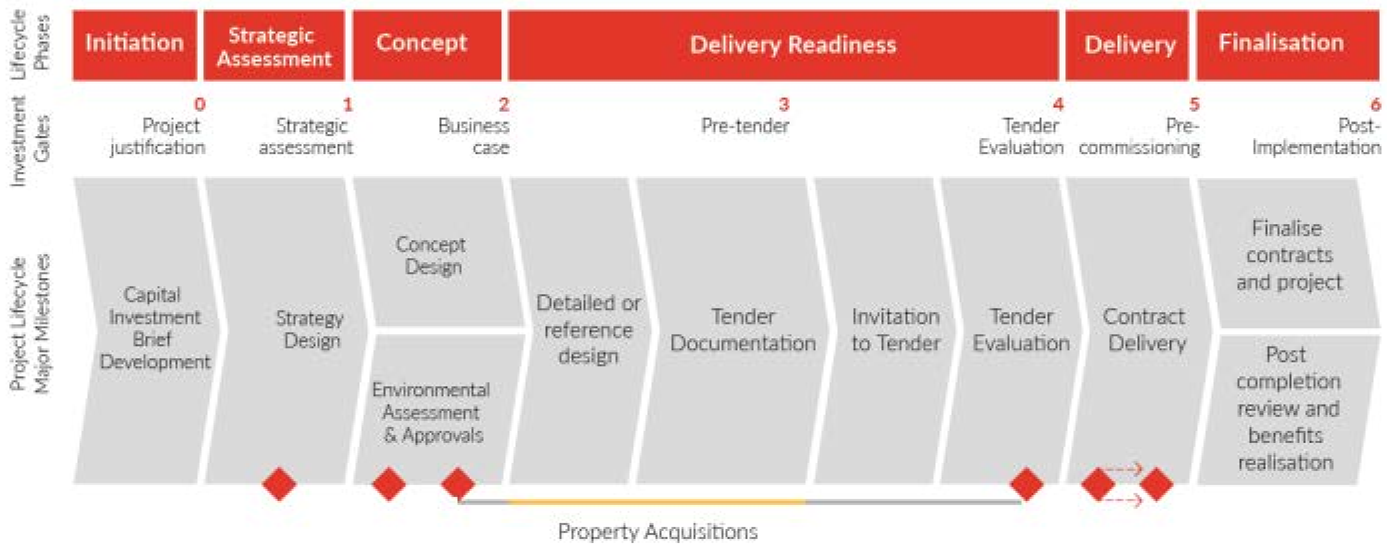


The overall process of the contingency management framework

Contingency management process overview

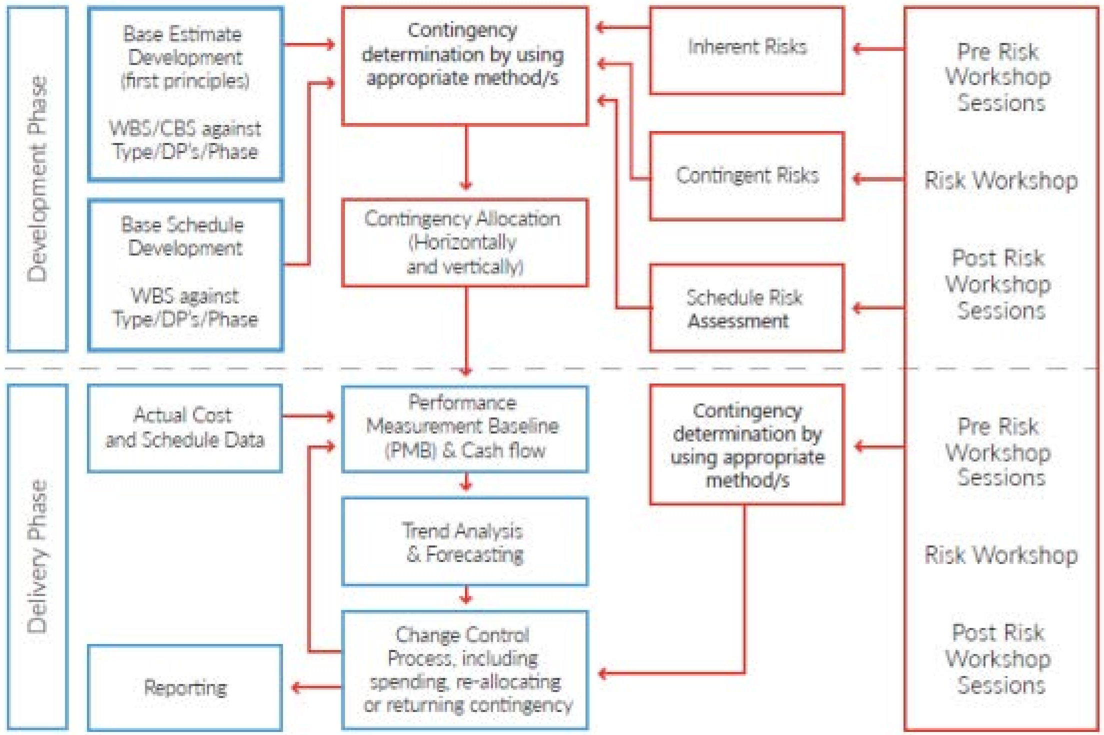


Contingency management process overview



A typical project lifecycle and its key phases and milestones

Contingency management process overview



A typical high level contingency management process

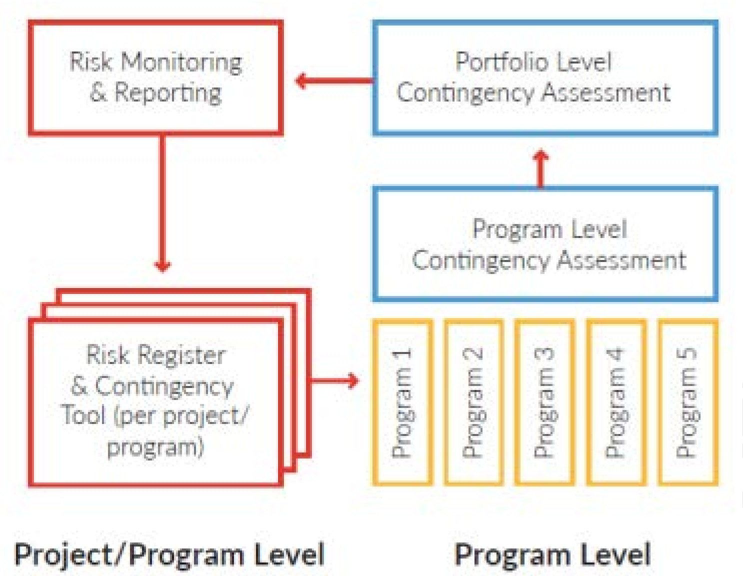
General Principles of Estimating Quantitative Risk Impact

(Fit-for-Use)

Fit for use

- In **addition to** considering the general requirements of the client and the process, the practitioner must also consider the following:
  - **Portfolio, Program or Project Type:** Scope, size, complexity, level of technology
  - **Risk Type:** Strategic versus tactical, systemic versus project-specific.
  - **Project Phase:** Estimate/Schedule Class
  - **Base Estimate/Schedule Methodologies:** Methods, tools, and data used to develop the estimate or schedule (without risk cost/time included)
  - **Skills and Knowledge:** Of both the practitioner and other participants

Contingency at program & portfolio level



Scope definition

- This is the **first decision** that should be made by any **Owner** but is **routinely ignored or minimized**, partly because it is driven by the **investment in design services**.

- The **level of scope definition** directly affects the **level of risk** for any given project.
  - Therefore, professional and experienced **estimators** <u>recommend contingencies</u> that can be **reduced as the maturity** of the scope definition is **improved**.

Scope definition

- The **AACE**,
  1. Notes the **maturity** of scope definition is aligned with the level of accuracy of the cost estimate,
  2. As well as the **appropriate usage of the schedule** based on the degree of project definition.

Scope definition

- The **accuracy range** speaks directly to the **risk associated** with the cost estimate;

  the **tighter** the accuracy range,

  the **lower** the risk of meeting that cost.

Scope definition

	Primary Characteristic	*Secondary Characteristic*			
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical +/- range relative to index of 1 (i.e. Class 1 estimate) [a]	**PREPARATION EFFORT** Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Screening or feasibility	Stochastic (factors and/or models) or judgment	4 to 20	1
Class 4	1% to 15%	Concept study or feasibility	Primarily stochastic	3 to 12	2 to 4
Class 3	10% to 40%	Budget authorization or control	Mixed but primarily stochastic	2 to 6	3 to 10
Class 2	30% to 75%	Control or bid/tender	Primarily deterministic	1 to 3	5 to 20
Class 1	65% to 100%	Check estimate or bid/tender	Deterministic	1	10 to 100

Notes: [a] If the range index value of "1" represents +10/-5%, then an index value of 10 represents +100/-50%.
[b] If the cost index value of "1" represents 0.005% of project costs, then an index value of 100 represents 0.5%.

Figure 1 - Cost Estimate Classification Matrix for Construction from AACE RP No. 17R-03[ii]

Scope definition

	Primary Characteristic	Secondary Characteristic		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Figure 2 - Cost Estimate Classification Matrix for Process Industries from AACE RP No. 18R-97[iii]

ACEMI

Scope definition

- AACE Recommended Practice No. 27R-03, **“Schedule Classification System”,** provides these **schedule classes designations** and shows how they align with project scope definition maturity.
- From this RP, Figure 3 addresses **how the scheduling methods** achieve reasonable project duration and planning dates while **covering scope definition maturity**.

Scope definition

	Primary Characteristic	Secondary Characteristic	
SCHEDULE CLASS	DEGREE OF PROJECT DEFINITION (Expressed as % of complete definition) [1]	END USAGE	SCHEDULING METHODS USED
Class 5	0% to 2%	Concept screening	Top down planning using high level milestones and key project events.
Class 4	1% to 15%	Feasibility study	Top down planning using high level milestones and key project events. Semi-detailed.
Class 3	10% to 40%	Budget, authorization, or control	"Package" top down planning using key events. Semi-detailed.
Class 2	30% to 70%	Control or bid/tender	Bottom up planning. Detailed.
Class 1	70% to 100%	Bid/tender	Bottom up planning. Detailed.

Figure 3 - Schedule Classification Matrix - From AACE RP No. 27R-03[iv]

Scope definition

Class 5 Schedule	
Description: Class 5 schedules are generally prepared based on very limited information, and subsequently have wide accuracy ranges. The Class 5 schedule is considered a preliminary document, usually presented in either Gantt (bar chart) or table form. The class 5 schedule should have, as a minimum, a single summary bar per stage with major project milestones identified. **Degree of Project Definition Required:** 0% to 2%	**End Usage:** Class 5 schedules are prepared for any number of strategic business planning purposes, such as but not limited to: market studies, assessment of initial viability, evaluation of alternative schemes, project screening, project location studies, evaluation of resource needs and budgeting, long range capital planning, etc. **Scheduling Methods Used:** Gantt, bar chart, milestone / activity table Top down planning using high level milestones and key project events.

Table 2a – Class 5 Schedule

ACEMI

Scope definition

Class 1 Schedule	
Description: Class 1 schedules are generally prepared for discrete parts or sections of the total project rather than generating this amount of detail for the entire project. The updated schedule is often referred to as the current control schedule and becomes the new baseline for the cost/schedule control of the project. The Class 1 schedule may be a detailed, resource loaded, logic-driven schedule and is considered a "production schedule" used for establishing daily or weekly work requirements. **Degree of Project Definition Required:** 65% to 100%	**End Usage:** Class 1 schedules are typically prepared to form the current control schedule to be used as the final control baseline against which all actual start and completion dates and resources will now be monitored for variations to the schedule, and form a part of the change/variation control program. They may be used to evaluate bid-schedule checking, to support vendor/contractor negotiations, or claim evaluations and dispute resolution. It is recommended that the Class 1 schedule be reconciled to the Class 2 schedule to reflect the changes or variations identified as a result of more project definition and design. **Scheduling Methods Used:** Gantt / bar charts, PDM, PERT Bottom up planning. Detailed.

Table 2e – Class 1 Schedule

Contract type

- Allocation of risk is determined by the type of contract, with **fixed price contracts** shifting performance risk to the Contractor and **cost reimbursable** contracts accepting risk by the Owner.

ACEMI

Contract type

- One of the places where Owners assume **unintended risk** is in the change management process during design and construction.
- The **goal of change management** should be to place the Owner and Contractor back in the same risk profile as the original contract dictated,

  however, when change management is **not handled in a timely and effective** way,

  the **Owner** often assumes additional risk.

Contract type

- The **solution** to this is to prepare accurate estimates and time impact analysis that can be used to **negotiate change orders**, including,
  legitimate time extensions, as early as possible.

- This timely approach to change management
  1. **Reduces the owner assumption** of performance risk,
  2. **Avoids claims** such as constructive acceleration, and
  3. **Keeps the schedule** as a good model of project status, capable of use in analysis of delays.

Contractual language

- There are a variety of approaches to limit or shift risk in the contract, regardless of the project **delivery method or contract type**.

- These approaches are defined in the **contractual language** and can affect risk for **time** and **costs**.

Contractual language

- When the **contract is silent** with respect to float ownership, in most states the float is owned by the project and shared by Owner and Contractor.

- The Owner must manage this issue by **protecting against a Contractor** using up all available float for an Owner to discover that there is a **change order needed** which would then be compensable.
- **Careful schedule review and monitoring** to ensure that

  float is accurately calculated and reported is essential in protecting against this risk.

Contractual language

- Another place where Owners can protect themselves against performance risks is by using **language to limit or prevent** the possibility of a Contractor pursuing a compensable extension of time based on an **early completion schedule**.
- Case law suggests that a **Contractor has a right to finish early**, so if he bids a project and reduces the costs by planning to finish in less time than the contractual completion date (CCD),

    he could earn **extended general conditions**

        if the Owner **causes a delay**

            beyond the Contractor's early completion date and the CCD.
- There are a **number of clauses** that protect against the **Contractor's early completion** schedule and leave flexibility in the schedule for Owner needs.

Contractual language

- The **subject of notice** from the Contractor to the Owner about alleged delays is **another place** where risk can be controlled.

- Contract language requiring the Contractor to provide formal, **written notice of any delay**

  will limit the risk of large change orders

  that come as a **surprise to the Owner** with the late discovery

  limiting the ability of the Owner to **participate in mitigation decisions and actions.**

Contractual language

- A **risk shifting approach** that Contractors often use is a **reservation of rights** provided with change orders.

- This is an **attempt to keep options open** for **future claims** of indirect, consequential and/or cumulative disruption costs and time impacts.
  - This approach can **alter change order language** that otherwise notes that the **change order settles** all cost and time claims associated with the issue.

Contractual language

- Another set of risk shifting language is that of **exculpatory contract clauses**, sometimes called **disclaimers**,

  which attempt to **absolve responsibility** for damages from **future or unknown** circumstances.

- This is a way to shift **undetermined risk to the Contractor** from issues like **third-party uncontrolled risks.**
- It also occurs in existing conditions such as geotechnical reports and Owner limitations for information only or **differing site conditions**.
- These can also be **pay when paid** or **indemnity clauses**, all of which require experienced legal support to provide maximum value in the use.

ACEMI

Contractual language

- The last set of risk shifting language is that of the **no damages for delay**, and this **limits delay entitlement** to time only.
  - But no damages for delay clauses shift risk to the **Contractors who do not have the ability** to control that risk,

    so the use of this approach tends to **increase the costs** and **detracts from the collaborative** construction team effort that is most effective.

Choice of project delivery method

Figure 4 - Project Delivery Methods - Risk and Control[vi]

General Principles of Estimating Quantitative Risk Impact

(Identifying Risk Drivers)

Identifying risk drivers

- The risk management process starts with **identifying risks**, and therefore, any **risk estimating method** must begin likewise (e.g., do **not quantify** ranges on a cost or activity, **without first** determining **what is driving** the range).
- This process needs to consider both
  1. Inherent estimate uncertainty (as a result of level of definition available, methodologies employed and other **systemic risks**) and
  2. Risk events (including both project specific and external risks that may impact the project).

INHERENT RISK – A risk that exists (but may or may not be identified) due to the very nature of the asset, project, task, element, or situation being considered. (December 2011)

Risk drivers

- RISK DRIVERS – Events or circumstances that may influence or cause uncertainty in asset or project performance.

  Syn.: RISK FACTORS. See also: CONDITION (RISK CONDITION); EVENT. (December 2011)

ACEMI

Risk drivers and contingency

- **Contingency** is included to **address risks** due to items such as:
  - Incomplete designs
  - Errors & omissions
  - Contract (prime and subcontracts) terms and conditions
  - Project location and environmental factors
  - Availability of skilled labor resources and equipment
  - Capabilities and experience of available subcontractors and suppliers
  - Construction disturbances (accidents or breakdowns)
  - Changes in market conditions
  - Regulatory risk
  - Land acquisition issues
  - Permitting issues
  - Technological changes
  - Abnormal construction and start-up problems
  - Changes in safety requirements

Features of work

- Project labor and material **production/cost** factors for the **various features of work** should be considered.
  - The **various features of work** (civil & earthwork, concrete, structural steel, buildings, machinery & equipment, piping, electrical, instrumentation, painting, insulation and scaffolding)

    will have

    1. **Different crew staffing**
    2. As well as distinctively different **production rates** that will affect risks.

General Principles of Estimating Quantitative Risk Impact

(Linking Risk Drivers and Outputs)

Linking risk drivers and outputs

- A **comprehensive risk management process** requires clear understanding of
  1. Each risk and
  2. Its potential impact.
  - Risks are **continually reassessed** throughout a project's life cycle.
  - If management **cannot explicitly see** the **connection** between a given risk and the potential impact,

    then **management** of the risk during execution will be **difficult**.

    - ✓ Therefore, it should be clear in the estimation practice **how each identified risk** is <u>linked</u> to the estimated impact.

Cost and schedule contingency link

- Schedule contingency **shares certain attributes** with cost contingency.

- **Both** cost and schedule estimates are by definition **uncertain** and there is general agreement that the **uncertainty should be explicitly addressed** in project planning.

Cost and schedule contingency link

- As a **rule of thumb**,

  when there are **contingency costs** added to the project estimate,

  there **most likely** is an element of time contingency.

- Conversely, **most project risks** that affect schedule durations also affect costs.

ACEMI

Cost and schedule contingency link

- Contingency usually excludes major scope changes such as
  - changes in end product specification, capacities, facility sizes and/or the location of the asset or project.

- Contingency time for **construction rework** is not normally included in construction **schedules**.

- Contingency also excludes force majeure (extraordinary events such as major strikes and natural disasters).

Schedule contingency management

- To be successful, **schedule contingency management** must be integrated with the other project control processes and procedures related with
  - Risk management,
  - Forecasting and
  - Change management and documented

  in other AACE recommended practices.

- According to the AACE TCM Framework, **change management** is the preferred process for

  managing contingency during **project execution**.

  Contingency change management requires a disciplined, well-documented and controlled process.

ACEMI

Change management process

- After all, that is the real root of the matter,

  if **legitimate change** happens and there is a **fund set up** to accommodate the change,

  there is **no impact** to the project.

- Once the **categories of change** are established (and many contracts as well as AACE RPs offer definitions),

  it is possible to **plan for how to fund** the changes when they occur.

Change management process

- Looking at **two broad funding approaches**,

  Contingency and Management Reserves,

  the difference in the use is that

  - **Contingency** is **intended to be used** for changes that are expected to happen even if the extent is not known, and
  - **Management Reserves** are intended to **fund scope requests** that are **not included in the original scope description**, and

    hence the budget, from the Owner, End-User, A/E.

Change management process

- When it comes to **change management** for an existing project, providing accurate **AACE Class 2 or Class 1 estimates** for changed conditions is vital to evaluate the costs.
- **Without the ability** to discuss specific quantities and unit costs for changes,
  the Owner is at a **huge disadvantage**.
- In addition, when there is a **time impact** from a changed condition or delay,
  the **costs** for the **extended general conditions** when the project is truly **prolonged** can be a **large part** of the total change order.
- This makes it imperative that a good process to develop independent Time Impact Analyses (TIA) in order to
  evaluate the contractor's TIAs, and **armed** with this independent evaluation, the **negotiations** are quicker and easier.

ACEMI

Change management process

- **Once** a delay or impact event has been **identified**,
  - **prior to absorbing the delay** into the schedule and project,
    - the goal should be to **quickly move the Owner back** to the original risk allocation strategy from the contract,
      - which is usually assigning the **cost and time performance** to the contractor.

ACEMI

Change management process

- This requires **negotiating** any extensions of time (EOT) that the contractor is entitled to received **after careful analysis** to validate the request or need.
  - Issuing the proper EOT in a **timely fashion** fulfills the need to allocate the risk properly and **eliminates** the risk of constructive acceleration to the project.
    - Owners are at risk of **turning non-compensable time extensions** into compensable acceleration efforts **simply by not awarding** legitimate EOTs as they are earned.

General Principles of Estimating Quantitative Risk Impact

(Avoid Iatrogenic (Self-Inflicted) Risks)

ACEMI

Avoid iatrogenic (self-inflicted) risks

- The estimation process itself should **not introduce new risks**.
- For example, if
  - Too many risks are considered, or
  - Too many cost items are included in range estimating,

important risk drivers may not get sufficient attention, and in some cases, the cost analysis may become **corrupted or obscured**.

Avoid iatrogenic (self-inflicted) risks

- If the risk impact estimate is **too low**,

  it will **distort** the project control process

  as **teams** try to work around **inadequate** plans.

- If the risk impact estimate is **too high**,

  history shows the **excess funds or time** will be consumed to the detriment of profitability or **other** project success **measures**.

General Principles of Estimating Quantitative Risk Impact

(Empiricism)

Empiricism

- **Estimation** as a general practice is based on **taking experience** from the past and applying it to the present and future.
  - **Any method** must be informed by **past experience**.

- Empiricism implies objectively **capturing experience** through measurement and analysis of past practices and outcomes.
  - For example, empirical research has shown that there are **systemic risks** that have **fairly predictable impacts**.

Empiricism

- Empiricism can be brought to bear
  1. **Directly** through parametric quantification methods (e.g., Regression based) or
  2. **Less directly** through the use of lessons learned and/or benchmarking, or validating analysis results against historical data.

General Principles of Estimating Quantitative Risk Impact

(Experience/Competency)

ACEMI

Experience/Competency

- Empirically based or not, **no estimating algorithm or routine** will provide reliable estimates **without** the input of an experienced and competent estimator (in this case, a risk analyst).

- The **probability of iatrogenic risks** increases with inexperience and/or incompetence of the practitioners.

- The **less empiricism** incorporated in the methodology itself,

  the **more critical** the experience, skills and knowledge of the analyst and team become.

- **Competency** is best obtained through both training and hands-on practice.

Quality and experience of the construction management team

- While risk is a **common buzzword**, few stakeholders in projects have a strong depth of understanding of risk and the risk processes.

- Risk must be integrated into the construction management processes, and the **CM staff** should be well versed in risk principles and implementation.

Quality and experience of the construction management team

- **Engaging** in forensic schedule and cost analysis requires a **deep understanding** of CPM scheduling, forensic analysis methodologies, negotiations skills, and cost and time legal principles.
- The **experiences of reviewing** schedules and documentation to
  - Determine what happened to cause delays,
  - Determine the quantum of delay,
  - Examine entitlement and liability, and
  - Place responsibility for delays,
  - All contribute to a much better understanding of project risk and how to control it.
- This means that **CM team members** who have forensic analysis and dispute resolution are much **more competent** to manage risk during the project life-cycle.

General Principles of Estimating Quantitative Risk Impact

(Probabilistic)

Probabilistic

- The **quantitative risk impact estimate** is always part of the **basis** of a management **decision**.

- The client
  1. May use the risk estimate values in a **business case simulation** supporting an investment decision, or
  2. They may simply be deciding how much risk impact to include in a project **budget or schedule** (or to insure, or establish as a reserve, etc.).

Probabilistic

- **Probabilistic estimate outputs** (i.e., distributions or ranges)

  help ensure that the client understands the potential consequences of their **decision**;

  point estimate values do not do this.

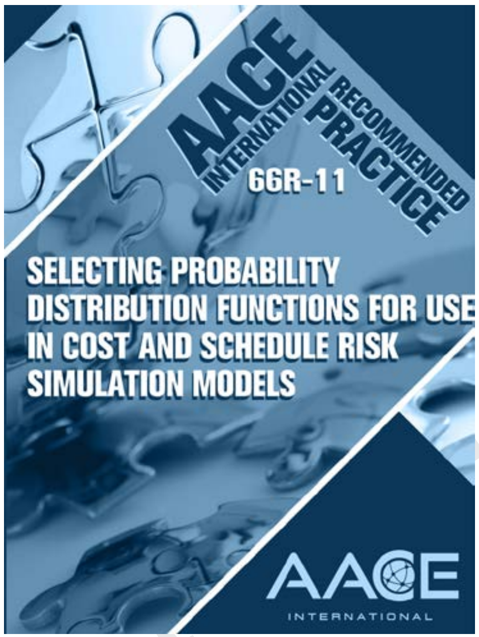
Probabilistic

- **If** the risk impact estimating method does **not directly generate a distribution or range** (e.g., through simulation),

  then the analyst and team is obliged to otherwise **communicate equivalent information** through other means,

  preferably based on empirical data and experience.

Comparison of commonly used probability distribution functions (PDFs)



PDF Name	Characteristics	Parameters	Typical Application	Advantages	Disadvantages
Discrete	Discrete, Bounded	Discrete values with assigned probabilities.	For variables that have only discrete values	Well known and generally understood. Simple to use.	Estimates of the discrete values may have some uncertainty that is not captured
Uniform (i.e., Rectangular)	Continuous, Bounded	Lowest possible value, Highest possible value.	For variables where a mode does not occur and/or the distribution shape is unknown or disputed.	Well known and generally understood. Simple to use, Can be easy for users to provide parameters.	Can overstate the probability of values at the extremes if the probabilities are indeed lesser in these ranges.
Triangle	Continuous, Bounded	Lowest possible value, Most likely value, Highest possible value.	Broadly used where a most likely value is clearly discerned, but the shape of the distribution is not highly skewed.	Well known and generally understood. Can be easy for users to provide parameters. Its low central tendency can compensate for users that set low/high ranges that are too narrow,	Can overstate the probability of values on the skewed side of ranges when users set extreme low/high values but the actual distribution has a strong central tendency.
Trigen	Continuous, Bounded	Same as Triangle except the user defines what p-value the low and high values represent	Same as Triangle, but used when optimism bias (too narrow of a range) is suspected in the team's input	Well known and generally understood by analysts. Provides a simple way to deal with team input that is biased towards too narrow of a range.	If the team input is not in fact narrowly biased, it will compound the overstatement of the probability of values on the skewed side of ranges
Double Triangle	Continuous (but with an inherent discontinuity of form), Bounded	Lowest possible value, Most likely value, Highest possible value.	Used where a most likely value is clearly discerned, and the shape of the distribution is highly skewed.	Can be easy for users to provide parameters. Allows the estimate to be used as mode value with the flexibility to adjust its probability. Less tendency than Triangle to overweight probability of skewed side ranges.	Less well known; can be difficult to construct and communicate. If the team exhibits optimism bias, may underweight the skewed side.
Normal	Continuous, Unbounded	Mean, Standard deviation	Used to describe values that have symmetrical distributions and there is some empirical basis to define parameters.	Well known and generally understood. Works well for items with unskewed ranges.	Difficult for users to objectively express a standard deviation. Most time and cost estimates are skewed. Being unbounded, can result in inappropriate negative values on the low end
Lognormal	Continuous, Bounded on the low side at zero.	Mean, Standard deviation of the variable's natural logarithm	Used to describe values that have asymmetrical distributions and there is some empirical basis to define parameters.	Well known and generally understood. Works well for items with either skewed or unskewed ranges.	Difficult for users to objectively express a standard deviation.
PERT or BetaPERT	Continuous, Bounded	Lowest possible value, Most likely value, Highest possible value.	Used where a most likely value is clearly discerned, and the shape of the distribution is highly skewed.	Can be easy for users to provide parameters. Less overweighting of skewed ranges than Triangle.	Less well known. If the team exhibits optimism bias, may underweight the skewed sides.
Custom	Varies	Values and probabilities	Primarily used in curve fitting	Can provide better fit if the users have sufficient experience or empirical data to express or define several values and their associated probabilities	Requires more user experience or empirical data. Requires statistical tools to construct or fit to a known distribution
Binomial	Discrete, Bounded	Represented by values of zero and one and probability of it being one	Used to represent the probability of occurrence of a yes/no risk event	Simple to use for yes/no risk event probability. If the yes probability is uncertain, a PDF can be imbedded for that value.	Simple application treats the probability of occurrence as deterministic,
Cumulative	Discrete, Bounded	Replicates known distributions that are entered as the low, high and a series of discrete value/probability pairs	Can be used with historical data or when the output of one probabilistic analysis is used as input to another	Provides a good fit where the data is available	Limited in use to when there is historical or modeling data available

General Categories and Characteristics of Methods in Practice

General categories and characteristics of methods in practice

- The **definition** of contingency and **how to estimate** it are among the most controversial topics in cost engineering.

- While there is **consensus** among cost engineers on **what contingency** is,
  there is **much less consensus** on **how to estimate** it.

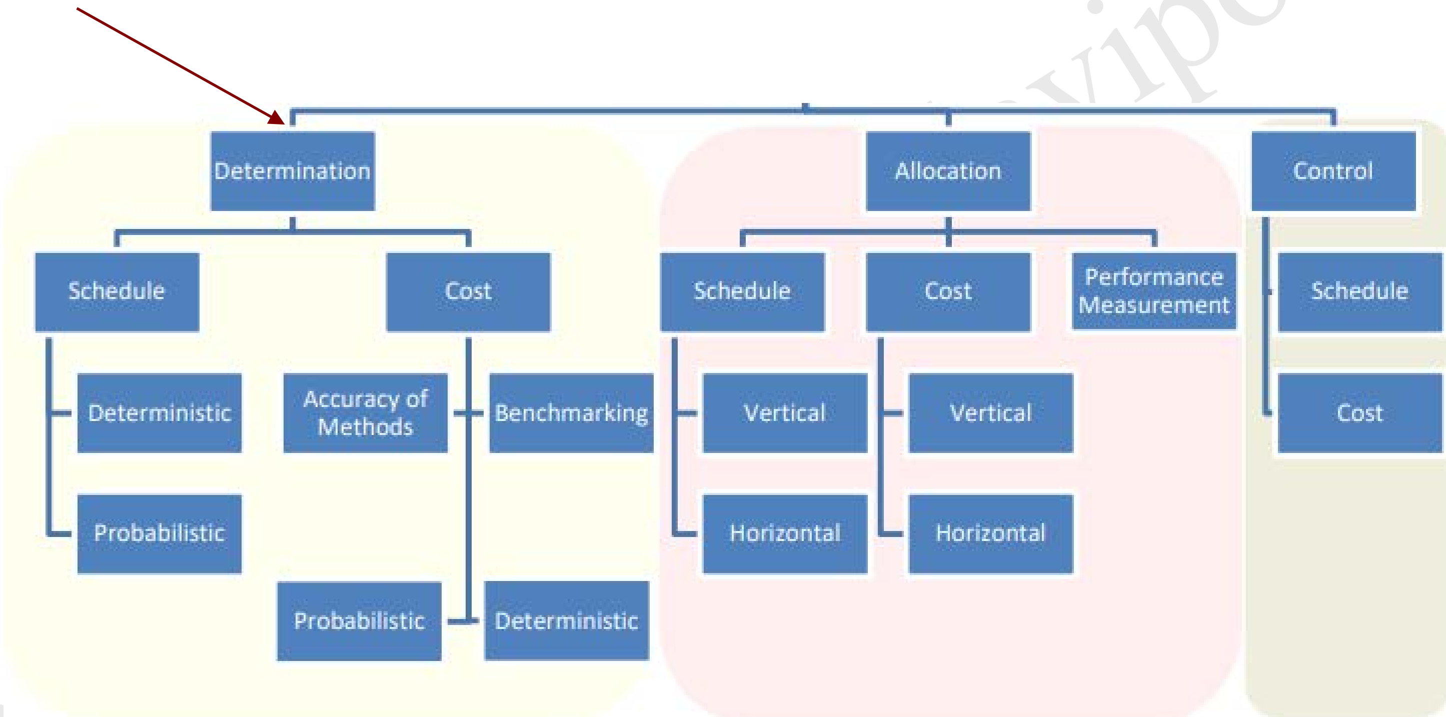
- In general, there are **four classes of methods** used to estimate risk cost/time that can respect the basic principles.

Contingency estimation

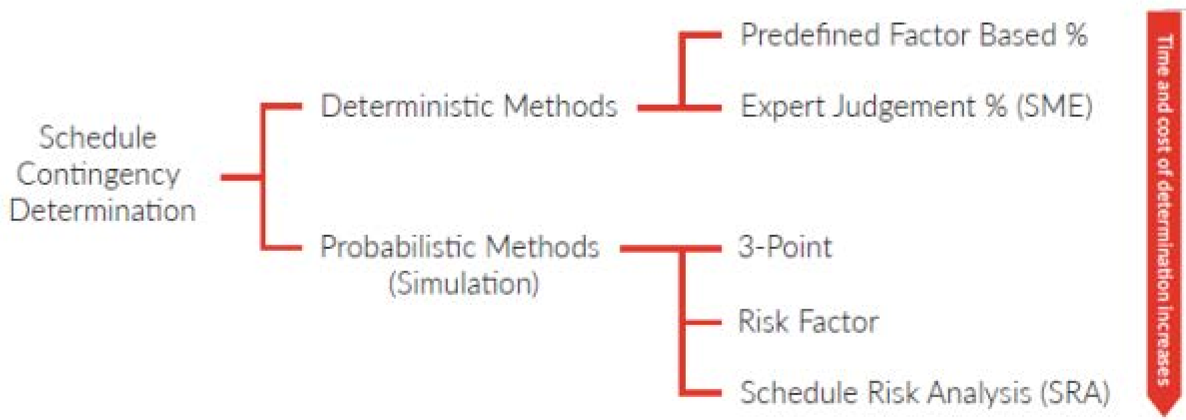
- These include:
  1. Expert Judgment
  2. Predetermined Guidelines (with varying degrees of judgment and empiricism used)
  3. Simulation Analysis (primarily expert judgment incorporated in a simulation)
     - Range Estimating
     - Expected Value
  4. Parametric Modeling (empirically-based algorithm, usually derived through regression analysis, with varying degrees of judgment used)

Hybrid methods that combine several or all of the above classes are also common.

Contingency management process overview

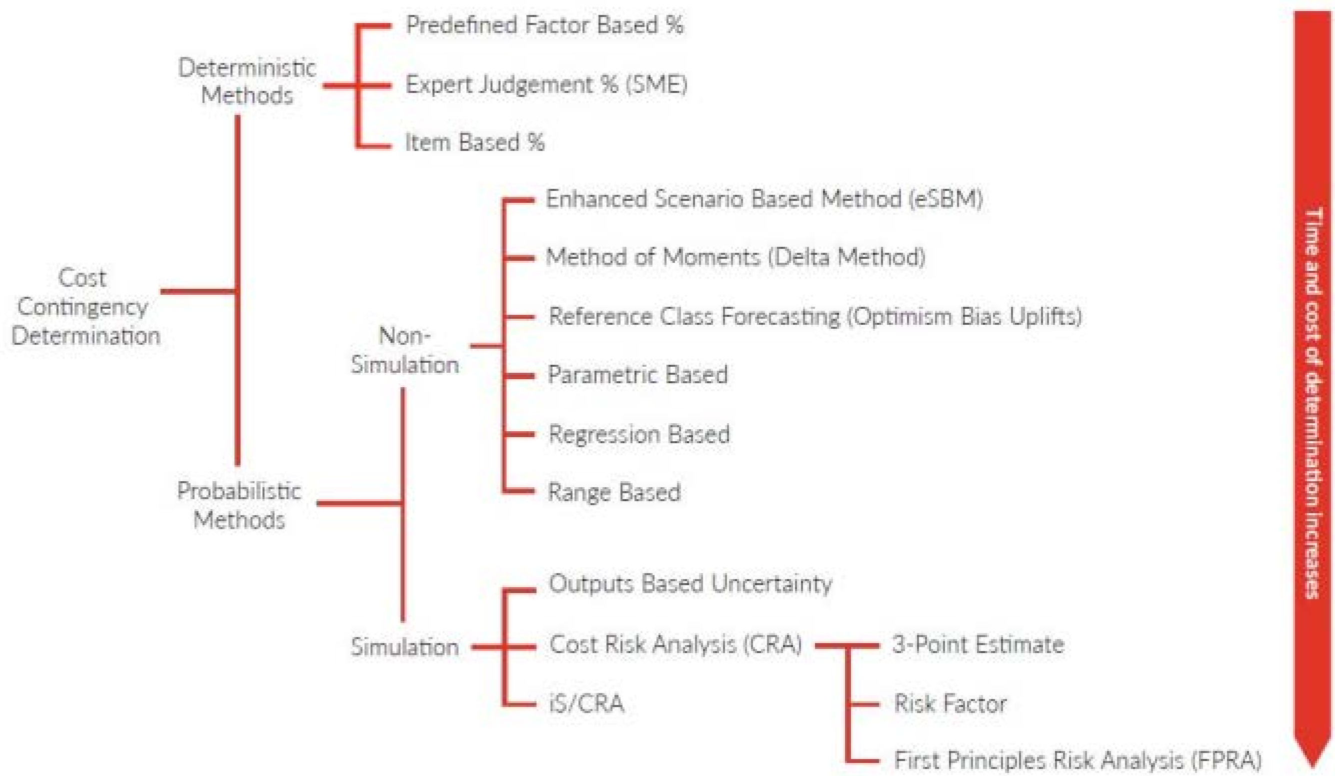


Schedule contingency determination



The most common methods of schedule contingency determination

Cost contingency determination



The common methods of cost Contingency Determination

Contingency estimation

- The following briefly discusses each of the classes of methods provided in AACE; however, **specific methods** are intended to be **described in other** AACE Recommended Practices.

General Categories and Characteristics of Methods in Practice

(Expert Judgment)

Expert judgment

- This method is largely **self explanatory**.
- The term "expert" explicitly means that the **judgment must have a strong basis** in experience and be backed up by competency in risk management and analysis.
- The **results of all methods** are **improved** to the extent that expertise and good judgment is brought to bear (i.e., most methods are to some extent hybrid combinations employing expert judgment).
  - However, this method is **highly subject** to imposing **iatrogenic** risk when the judgment is inconsistent or biased.
    - ✓ Bias can be **minimized** by obtaining the consensus of multiple experts or an experienced team, provided there is varied, independent opinion (i.e., avoid "group-think").

General Categories and Characteristics of Methods in Practice

(Predetermined Guidelines)

Predetermined guidelines

- This method may be as simple as providing a **single contingency or float value** (e.g., percentage of base cost or duration) for use on **all estimates** or **schedules** of
  - a certain type to complex tables or scoring mechanisms
    - that employ **elements of parametric modeling.**
- A common approach is to establish a **table of contingency values and ranges** for each of AACE's estimate or schedule classes with alternate values and ranges provided for common risks such as the use of new technology.

Predetermined guidelines

- **Advantages** of the method are that it is
  - Simple,
  - Understandable, and
  - Consistent, and as such,
  - It is easy to get management buy-in.
- The **results of guidelines** are improved to the extent that empiricism, expertise and good judgment are brought to bear in development of the guidelines.
  - Because the method is "simple," it is often used by **inexperienced people**; therefore, the guidelines must be clearly **described** and **documented** and supported by training.

Predetermined guidelines

- A **disadvantage** is that it **cannot effectively address** risks
  1. That are **unique** to a specific project, or
  2. That are **common**, but may have inordinate impacts on a given project.

*For that reason it is most useful for **early estimates when systemic** (i.e., non project-specific) risks such as the **level of scope definition** are dominant.*

In all cases, outcomes must be tempered with **expert judgment**.

General Categories and Characteristics of Methods in Practice

(Simulation Analysis)

Simulation analysis

- This method **combines** **expert judgment** with an **analytical model** that is the in used in a simulation routine to provide **probabilistic output**.

Simulation analysis

- An **advantage** of modeling and simulation analysis is that
  1. It facilitates including the analyst's and team's experience and input;
  2. This makes it particularly well suited for project-specific risks.

     It also directly provides **probabilistic output**.

ACEMI

Simulation analysis

- A **disadvantage**

1. Is the **method's complexity** which requires expertise in application (which also makes it subject to manipulation), and
2. Is the outcomes are **not highly consistent** (being highly dependent on the analyst and team input).
3. Also, because the methods are **not empirically-based**, they can sometimes be **more challenging** to apply effectively for

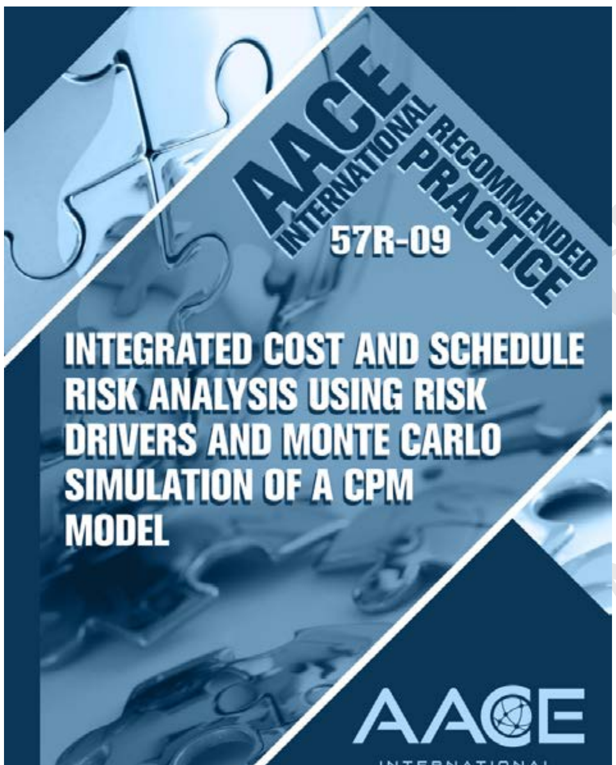
   systemic risks which are predominant for early estimates.
4. Finally, the model requires **consideration** of alternate estimates or schedules (to estimate the impact if a risk happens)

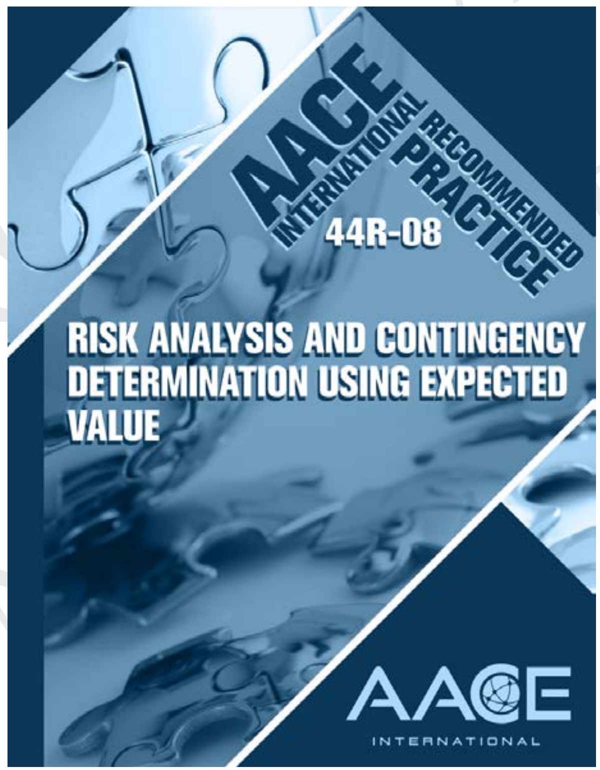
   which requires **estimating and schedule expertise** throughout the exercise.

ACEMI

Simulation analysis

- The most common methods in use are range estimating and expected value; both of which use Monte-Carlo or similar simulation routines.





ACEMI

Range estimating

- In range estimating for a cost estimate, the **cost model** is usually a **summary** of estimated costs at some level of detail.
  - **Simplistic approaches** may use a project's work breakdown and cost account structure as it is (e.g., civil construction costs for process unit X).
  - **More refined approaches** to **avoid iatrogenic risk** may focus on the **cost estimate's critical elements**

    which are identified using a process

    that considers **each cost element's significance** to the total project cost.

Range estimating

- **Each cost element** in the model is
  then **assessed** with a range and distribution
  that is assigned by the team based on their **understanding of the risks**.
- Also, at that time **significant correlations** amongst cost elements are incorporated into the analysis.
- Then a **Monte-Carlo or similar simulation** program is run that uses these cost item ranges and distributions as its input.
- The **simulation's output** is a total cost distribution along with other data designed to support the decision making process.

Range estimating

- For **scheduling**, the model is usually a critical path network schedule.
  - For **each activity**, the duration is replaced by a **duration distribution assigned** by the team.
  - Then a **Monte-Carlo simulation** program is run that uses these duration distributions as its input.
  - The simulation's output is a **total duration distribution**.

Range estimating

- **Medium to large-sized** projects for which the risk analysis is important.
- Suitably **qualified expertise and reviewers** must be used to conduct and verify the us e of such techniques.

ACEMI

Expected value

- The **expected value method** directly estimates the cost or schedule impact of each significant identified risk.
  - The model starts with a **list of risks**.
  - The **probability** of occurrence of each risk is estimated.
  - Then the cost or schedule **impact**, if the risk happens, is estimated.
  - The cost or schedule duration times the probability of occurrence is the **"expected value."**
  - The probability and cost or schedule estimates are **replaced by distributions** that are assigned by the team based on their understanding of the risks.
  - Also, at that time **significant correlations** amongst risks and cost or schedule activities are incorporated into the analysis.
  - Then a **Monte-Carlo** or similar simulation program is run that uses these probability and cost distributions as its input.
  - The **simulation's output** is a total cost or schedule distribution along with other data designed to support the decision making process.

Expected value

- Expected value in its most basic form can be expressed as follows:

$$\textit{Expected Value} = \textit{Probability of Risk Occurring} \times \textit{Impact If It Occurs}$$

Expected value

- The approach of using a bit of each risk (based on probability) suggests that a **risk with extreme impact** (or if it is the only risk) should perhaps be funded using a management reserve;

  i.e., the method **works best for multiple risks** (perhaps 5, 10 or more),

  each with a nominal impact that does not overwhelm the summation.

Expected value

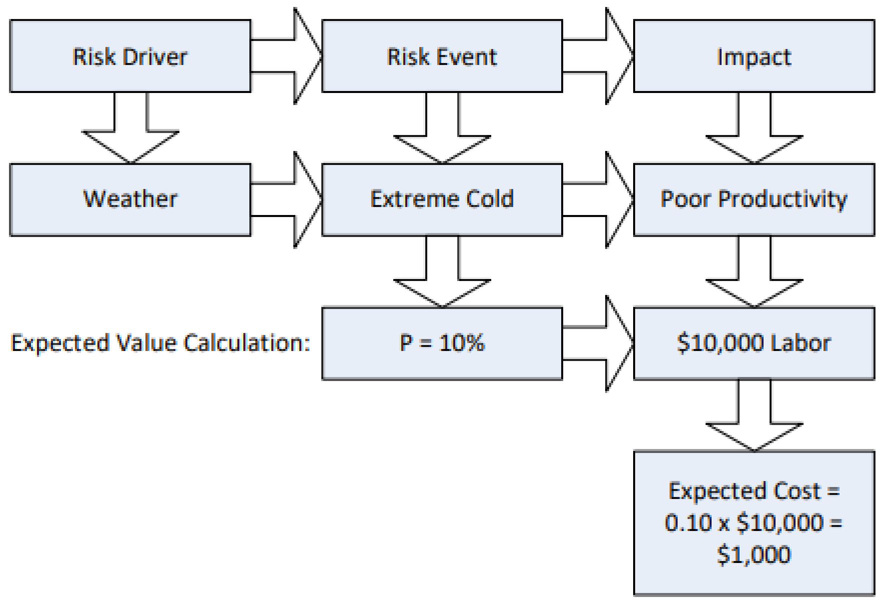
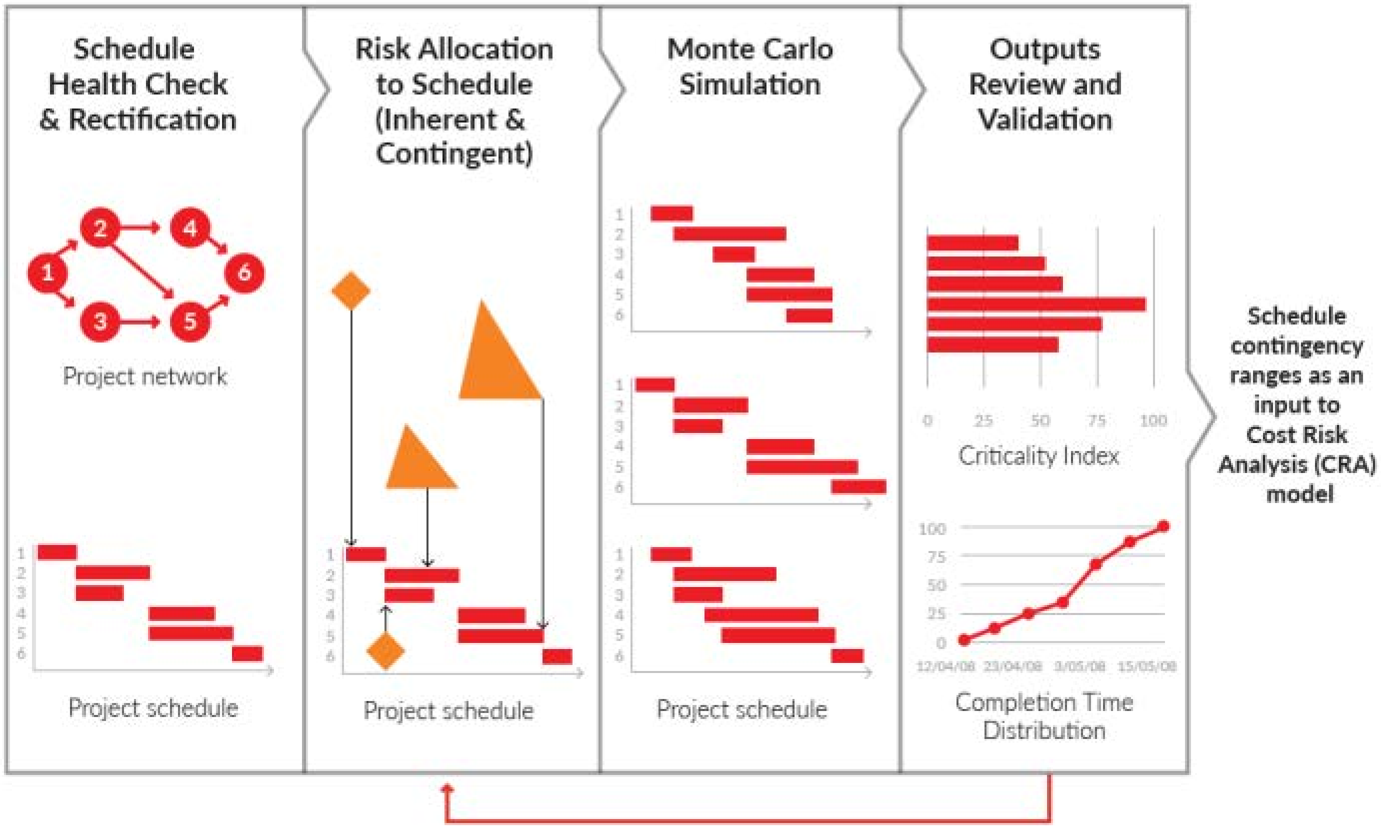
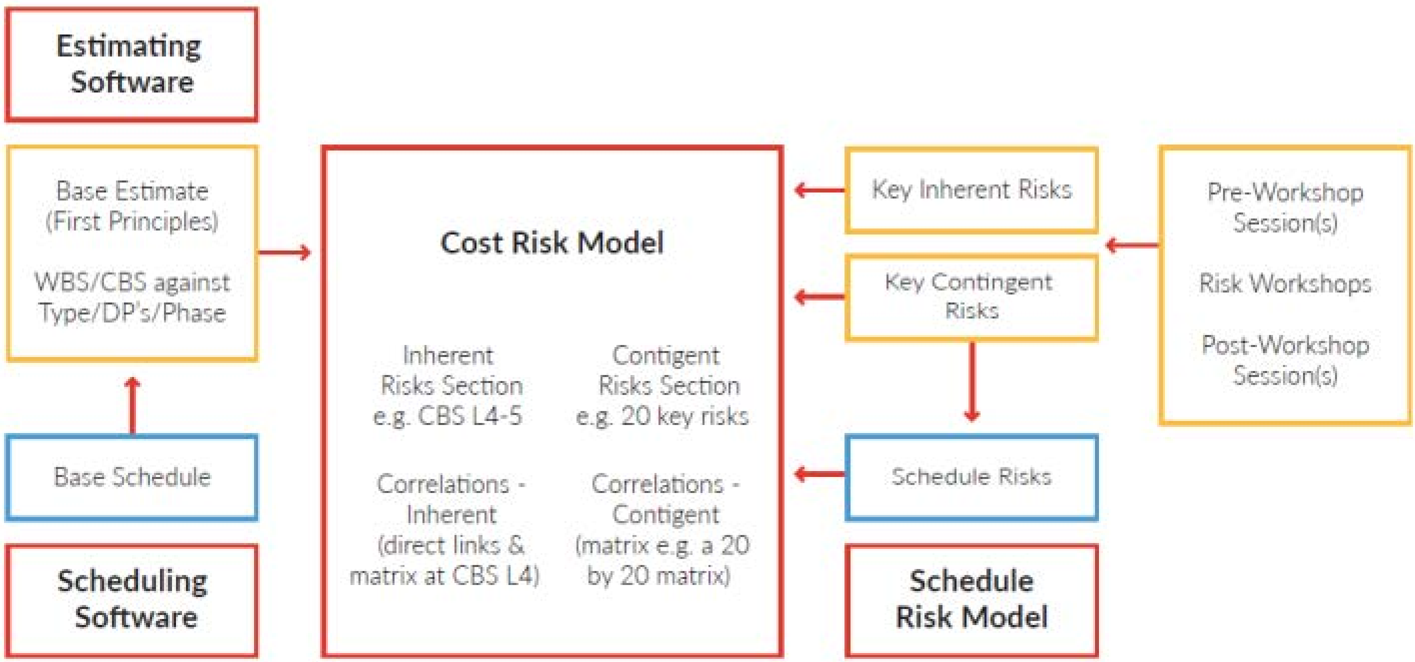


Figure 1 – Example of Expected Value Calculation [5]

- A typical process map for the probabilistic Schedule Risk Analysis (SRA)

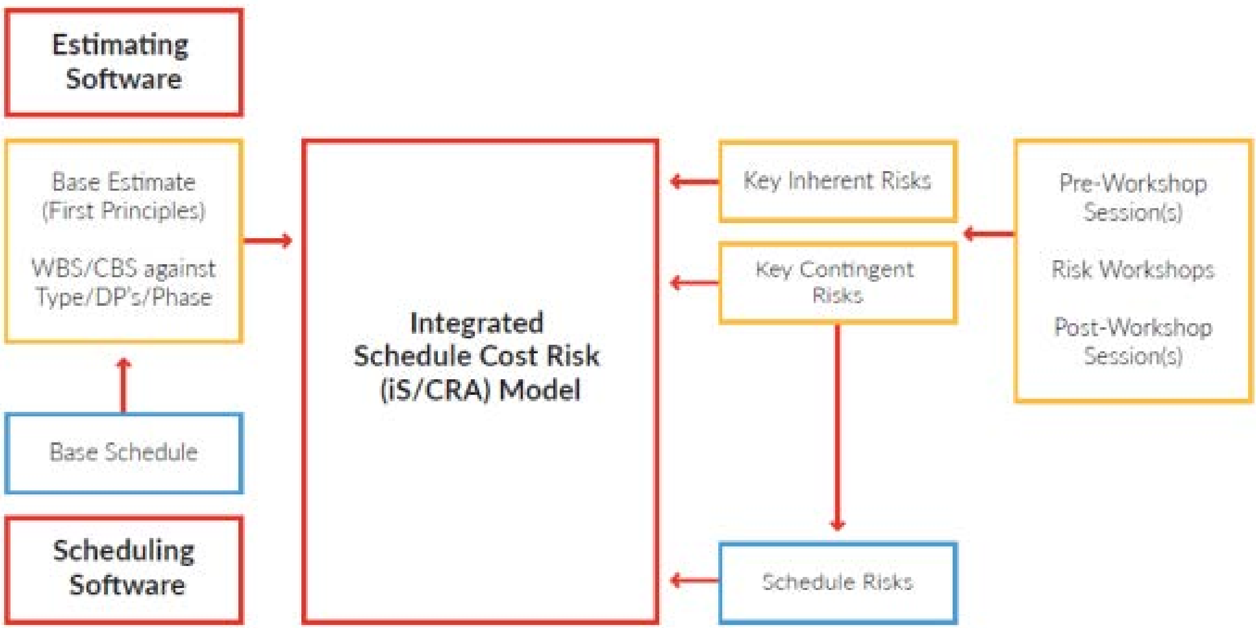


❑ A typical process map for the probabilistic Cost Risk Analysis (CRA) method



iSCRA

❑ A typical process map for the Integrated Cost Schedule Risk Analysis (iSCRA) model



General Categories and Characteristics of Methods in Practice

(Parametric Modeling)

ACEMI

Parametric modeling

- A parametric model is generally an **algorithm** that is derived from **multi-variable regression analysis** of quantified risk drivers

  versus cost growth or schedule slip outcomes for **historical projects.**

  - For example, a **risk driver** such as the level of project scope definition can be given a **score for each project** in a dataset.
    - ✓ This score can be **regressed** against the **actual cost growth** for those projects.
    - ✓ The regression will provide **not only an algorithm**,

      but also **statistical information** about the range.

ACEMI

Parametric modeling

- Generally, the **relationships** of the outcome (e.g., cost growth or schedule slip percentages in this case) and the inputs (e.g., systemic risk drivers) are determined by **studying historical data**,

  typically using **multi-variable linear regression (MLR)** analysis.

- **More advanced analytical methods** such as neural networks, machine learning and ultimately artificial intelligence (supported by improved industry data capture) are not covered by this RP, but are **likely to become the dominant approach** to developing empirically-based risk models in the future.

Parametric modeling

- The following illustrates the **typical form of a simple parametric** estimating algorithm derived from

  MLR: Outcome = Constant + Coefficient 1*(Parameter A) + Coefficient 2*(Parameter B) + …

Parametric modeling

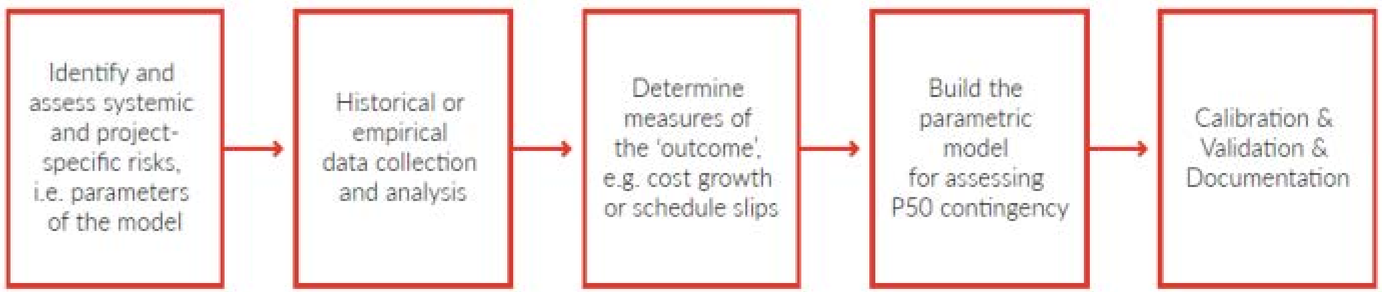
- **Advantages** of parametric modeling include, like predetermined guidelines, being simple to use, understandable, and consistent.
  - Further, it is **empirical by nature**.

Parametric modeling

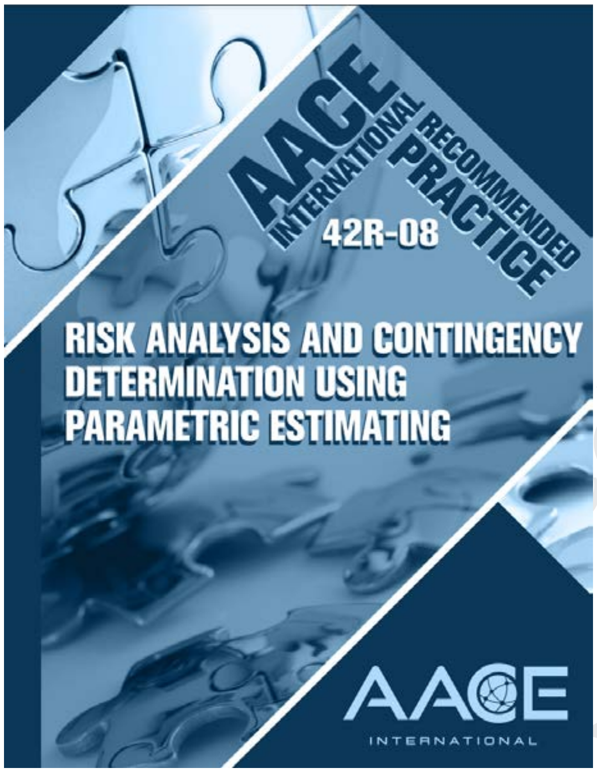
- A **disadvantage** is the **complexity of developing the parametric model** which requires statistical skills and historical data with a range of risks and outcomes.
  - Fortunately, **industry research** of common risks and outcomes is sometimes available for use.
  - The method also **cannot effectively address** risks that are **unique to a specific project**, or risks that are common, but may have **inordinate or unusual impacts** on a given project.

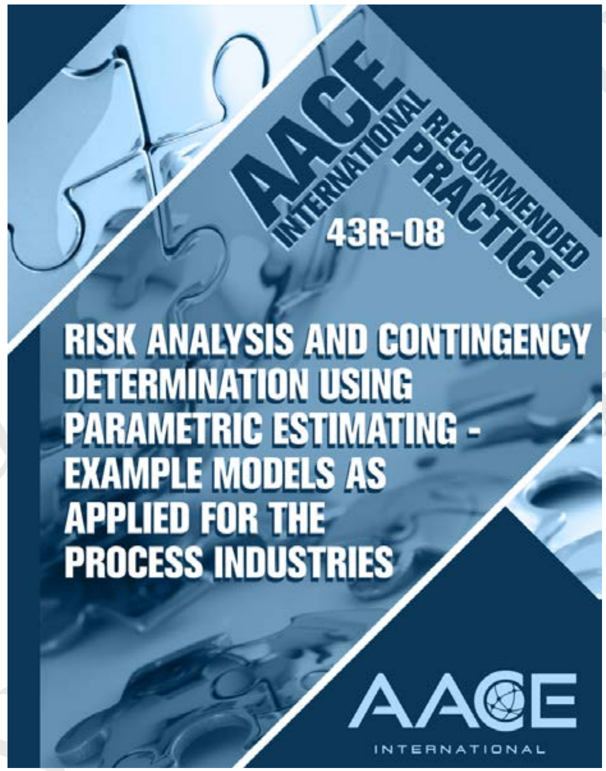
In all cases, outcomes must be tempered with expert judgment.

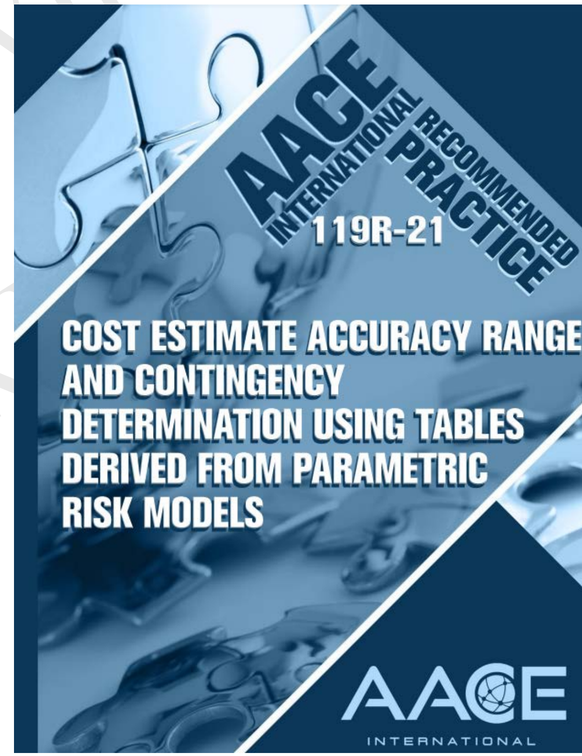
Common process of parametric based methodology



Parametric modeling







General Categories and Characteristics of Methods in Practice

(Hybrid Methods)

Hybrid methods

- Each of the classes of methods described above has **advantages and disadvantages**.
  - Therefore, the **best approach** is sometimes to **use two or more methods** to estimate risk cost/time.
- The most **common combination** is to use expert judgment with any other method.
- **Another combination** is to use a parametric model for systemic risks and simulation analysis for project-specific risks.
  - **Parametric models** may also provide the raw material used to **develop pre-determined guidelines.**

Principles and Methods at a Glance

Principles and methods at a glance

- Table 1 below provides
    1. An overview of the primary classes of risk cost/time estimating methods and
    2. Consideration for each in regards to the general principles.

Practitioners should refer to the AACE RPs describing the specific methods.

Principles and methods at a glance

First Principles	Classes of Contingency Estimating Methods: Expert Judgment	Predetermined Guidelines	Simulation Analysis*	Parametric Modeling
Meets client objectives, expectations and requirements	Whether a given method or combination of methods best meets the clients objectives, expectation or requirements must be determined prior each application			
Part of a risk and decision management process	Any method can potentially be incorporated in a process.			
Fit-for-use	Any method can potentially be made to address a variety of applications, but typically each method has strengths and weakness. Hybrid approaches can take advantage of the strengths of several methods.			
Starts with identifying risk drivers	Any method can potentially be made to start with identifying risk drivers.			
Links risk drivers and cost/schedule outcomes	Requires that expert(s) make and communicate the linkages	Linkages can be directly incorporated in the guidelines	Linkages are directly used in the *expected value* method	Linkage is inherent to this method
Avoids iatrogenic (self-inflicted) risks	Bias must be tempered, often through consensus	Care must be taken with risks not considered in the guidelines	Complexity of the method increases the need for disciplined approach	Care must be taken with risks not considered in the model
Employs empiricism	Generally requires the use of lessons learned, and/or validation or benchmarking using historical information (not an inherent feature of the method)			Explicitly addressed if regression based
Employs experience /competency	Expertise explicitly required	Expertise employed in development	Expertise employed in analysis	Expertise employed in development
Provides probabilistic estimating results	Can provide subjective ranges	Can provide predetermined ranges	Direct output of most simulations	Can be a direct output of algorithm

*Including range estimating and expected value methodologies

Table 1 – Classes of Contingency Methods and General Principle Considerations

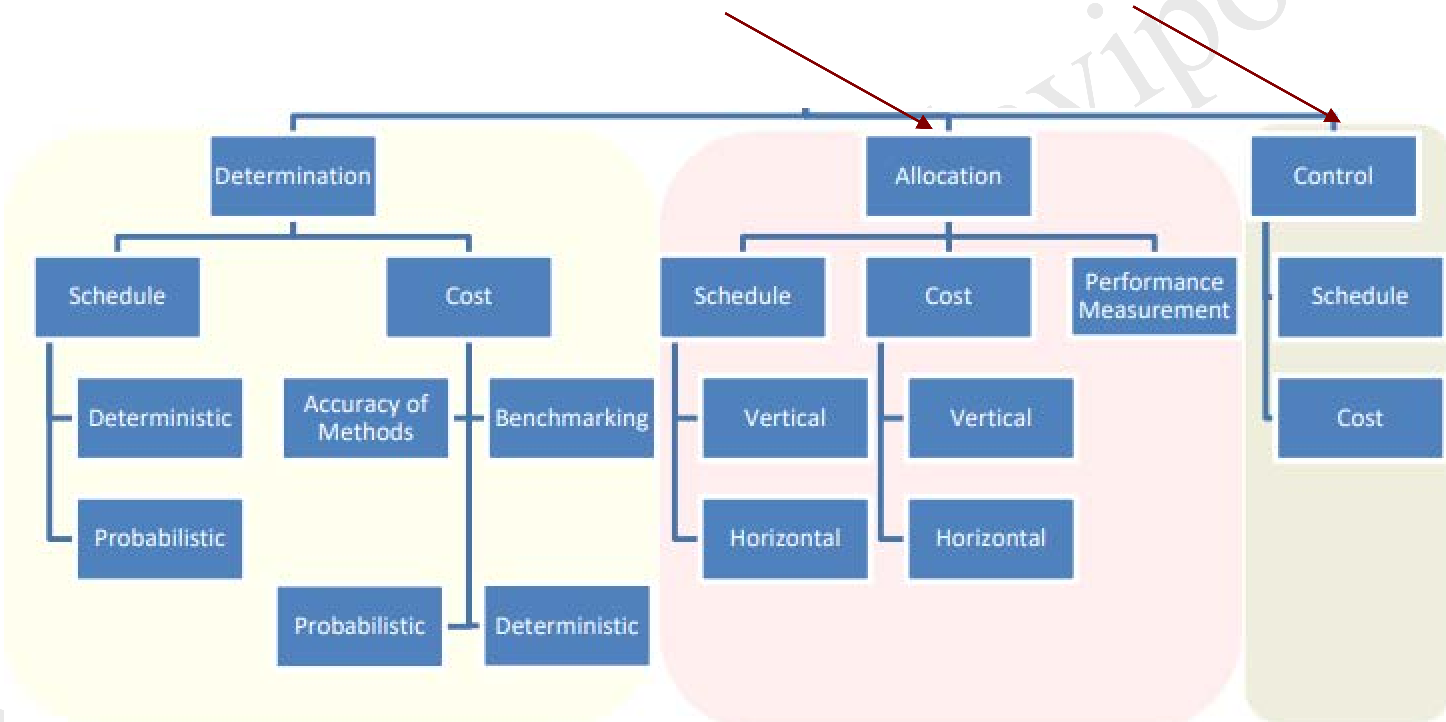
Contingency Determination Tools & Software

Contingency determination tools & software

#	Tools Reference / Software	Reference
1	AACEi - excel versions of The Hackney and the Rand Corp parametric models	<web.aacei.org>
2	ACEIT	<www.aceit.com>
3	Barbecana – Full Monte	<www.barbecana.com>
4	Booz Allen Hamilton – Polaris	<www.boozallen.com/consulting/products/polaris>
5	Crystal Ball	<www.palisade.com>
6	Deltek Acumen	<www.deltek.co.uk/products/ppm/risk/acumen-risk>
7	JACS: Joint Analysis of Cost and Schedule	www.aceit.com
8	John Hollmann – excel versions of parametric cost and schedule models	Project Risk Quantification, Probabilistic Publishing, 2016
9	Microsoft Office Excel	
10	Oracle – Primavera Risk Analysis	<www.oracle.com/applications/primavera/products/risk-analysis.html>
11	Palisade - @Risk and the DecisionTools Suite	<www.palisade.com/risk>
12	PRICE Integrated Models & Standalone Models	<www.pricesystems.com>
13	Project Cost Estimating Capability (PCEC)	<www.oncedata.com>
14	Risk Decisions – Predict! Risk Analysis	<www.riskdecisions.com/predict-risk-management-software>
15	Safran Software Solutions	<www.safran.com/products/safran-risk>
16	SEER	<www.galorath.com>
17	Spider Project	<www.spiderproject.com>
18	Sword Active Risk Manager (ARM)	<www.sword-activerisk.com/products/active-risk-manager-arm>
19	Trigo White – White Box	<www.trigowhite.com/Pages/RiskManagementPages/WhiteBoxRM.aspx>
20	True Planning	<www.pricesystems.com>
21	Vose Software – Pelican, Tamara, ModelRisk, ModelRisk Cloud, StopRisks	<www.vosesoftware.com>

Contingency Allocation and Control

Contingency management process overview



Contingency management process overview

You have learned this in
Construction Cost Accounting and Financial Management
&
Planning and Scheduling Courses

موسسه مهندسی و مدیریت ساخت علوی پور (ACEMI)

دفتر آموزش

تهران، بلوار فردوس شرق، مجتمع آبگینه، طبقه سوم اداری، واحد C42

+۹۸ ۲۱ ۴۶ ۱۰۰ ۴۵۰

+۹۸ ۲۱ ۴۶ ۱۰۰ ۴۴۵

---

www.dralavipour.com

info@dralavipour.com

@acemi_social

@alavipour_pm

@IRANACEMI

@alavipour_pm

ACEMI