CENG 6108 Construction Economics

Risk Assessment

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Contingency (AACE)

- “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”; included in the estimate and expected to be expended (but uncertain as to where).
- Accounts for factors that are apparent and inherent in the estimate, e.g.:
  - Uncertainty in productivity, quantities, unit rates (variation within a small margin)
  - Planning and estimating errors and omissions
  - Minor price fluctuations
  - Design developments and changes within the scope

Risk Allowance (AACE)

- Risk is "the degree of dispersion or variability around the expected or "best" value, which is estimated to exist for the economic variable in question (e.g., a quantitative measure of the upper and lower limits, which are considered reasonable for the factor being estimated)"; accounts for factors that are more managerial in nature.
- Risk Allowance: may or may not be spent (based on probability of undesirable outcome); **expected** value of risk allowance will be spent, if correctly estimated.
- Example: Uncertainty in material unit rate based on length of project and market conditions (demand); major scope changes; natural disasters, escalation.

Expected Cost of Risk

- Risk allowance and contingency are amounts of money used to provide for project risks, uncertainties, and unforeseen costs that are associated with a construction project
- In the construction industry, contractors are required to accept a certain level of risk due to the unforeseen costs that are incurred during construction
- A reasonable value (combination of risk allowance and contingency) should be included in the bid to cover for the risks involved in construction
- The objective is to ensure that the estimated project cost is realistic and sufficient to contain any costs incurred due to risks and uncertainties

Expected Cost of Risk

- Underestimating risk allowance and contingency could result in severe losses to the contractor
- Cost Estimators generally tend to be conservative and overestimate risk and contingency which might lead to:
  - Contractors losing bids
  - Public sector funding being misallocated, which might delay other projects
- Traditionally risk allowance and contingency are estimated to be a fixed percentage of the contract price (usually 5%-10%). This technique, though widely used for its simplicity, might deviate significantly from the actual numbers. This is due to the different levels of risk encountered in the different projects. The risk allowance and contingency for each project should be derived separately.

Expected Cost of Risk

- There are many methods to derive project risk allowance and cost contingency, of which we can mention:
  - Estimating Using Risk Analysis (ERA):

    Using Risk Analysis to Determine Construction Project Contingencies, Mak and Picken (2000)
  - Probabilistic Risk Models (e.g., Monte Carlo simulation models)
- Deals with risk due to unforeseen expenditure not known at planning stage
- Accounts for elements of both contingency and risk allowance by identifying and costing risk events
- Useful for cost consultants (feasibility, planning stage estimates) and for owner

Estimating Using Risk Allowance

- ERA makes planning stage budget more realistic; does not reduce total project cost/budget, but makes it less uncertain & quantifies uncertainty
- Goal is not to overestimate or underestimate
- Unknown contingency transferred to bidders: provisional sums
- The first step is the identification of the project risks by the project team, which are categorized as either Fixed or Variable

Estimating Using Risk Allowance

- Fixed Risk Items: These events either happen in total or do not happen; an example is the need for an additional access road to the project
- Variable Risk Items: Are events that will occur but the extent is unknown; an example is the depth and type of piles to be driven

1. Identify base estimate = known scope, risk "free"
2. Identify risks by project team:

- Fixed = event will either happen (maximum cost) or not at all (no cost)
- Variable = event will occur, but extent is uncertain (variable cost)

Estimating Using Risk Allowance

3. For each risk event, determine:

- Average risk allowance
- Maximum risk allowance

TABLE 1. Relationship between Risk Allowance and Risk Category in ERA

Type of risk (1)	Average risk allowance (2)	Maximum risk allowance (3)
Fixed risk	Probability × maximum cost	Maximum cost
Variable risk	Estimated separately	Estimated separately
Assumption	50% chance of being exceeded	10% chance of being exceeded

Fixed risk:

- Maximum = maximum cost if occurs
- Average = probability of risk occurring * maximum risk allowance

Estimating Using Risk Allowance

Variable risk:

- Maximum = based on experience for most expensive scenario (10% chance of being exceeded)
- Average = 50% chance of being exceeded
- Total Average Risk Allowance/Cost Contingency = Summation of the average risk allowance of all events
- It should be noted that the contingency derived value at different project phases will most likely be different
- As the project develops, some uncertain events will get deleted from the list or be included in the base estimate as certain events, thus reducing the total risk allowance/contingency of the project

ERA Calculation

Project: Construction of the Central Library
Client: Urban Council

Date: 2 March 1995
ERA Run: 1

(1) Risk	(2) Type	(3) Probability (Fixed Risks Only)	(4) Average Risk Allowance $	(5) Max. Risk Allowance $	(6) Spread (5) - (4) $ M	(7) Spread square d $ M
Design Development	V		8,400,000	12,600,000	4.2	17.64
Additional Space	F	.70	11,760,000	16,800,000	5.04	25.4016
Site Conditions	V		525,000	1,000,000	.475	0.2256
Market Conditions	V		4,000,000	8,500,000	4.5	20.25
A/C Cooling Source	V		250,000	1,250,000	1	1
Access Road	F	.50	250,000	500,000	.25	0.0625
Additional Client Requirements	V		1,680,000	4,200,000	2.52	6.3504
Contract Variations	V		8,400,000	12,600,000	4.2	17.64
Project Co-ordination	V		500,000	1,500,000	1	1
Contract Period	F	.60	1,000,000	1,750,000	.75	0.5625
			36,765,000			90.1326
					Sq Root	9.494

Maximum Likely Addition = $9,494,000

Base Estimate = $168,000,000

Average Risk Estimate = Base Estimate + *Total* Average Risk Allowance
= $204,765,000 (21.88% on base)

Maximum Likely Estimate = Base Estimate + Average Risk Allowance + Maximum Likely Addition
= $214,259,000 (27.54% on base)

Note: The Maximum Likely Addition is the figure (the additional amount) which would flow from a situation where every identified risk identified by the project group occurs in total with maximum financial consequences. This is seen as a catastrophic set of circumstances. The mathematical expression of the combined effect of the maximum risk allowances is that they do not add together by simple addition. This situation is dealt with by the Central Limit Theorem - that is the various maximum risk allowances for each risk add together by the sum of their squares.

FIG. 1. Example of ERA Worksheet at Sketch Design Stage

ERA Calculation

Project: Construction of the Central Library
Client: Urban Council

Date: 11 September 1995
ERA Run: 2

(1) Risk	(2) Type	(3) Probability (Fixed Risks Only)	(4) Average Risk Allowance $	(5) Max. Risk Allowance $	(6) Spread (5) - (4) $ M	(7) Spread square d $ M
Design Development	V		5,400,000	9,000,000	3.6	12.96
Additional Space	F	No longer a risk			-	-
Site Conditions	V		250,000	750,000	.5	.25
Market Conditions	V		0	4,250,000	4.25	18.0625
A/C Cooling Source	V	No longer a risk			-	-
Access Road	F	No longer a risk			-	-
External Cladding	V		3,150,000	4,500,000	1.35	1.8225
Redesign	F	.75	2,275,000	3,030,000	.755	.5700
Additional Client Requirements	V		1,800,000	3,600,000	1.8	3.24
Contract Variations	V		9,000,000	13,500,000	4.5	17.64
Project Co-ordination	V		0	500,000	.5	.25
Contract Period	F	.90	1,800,000	2,000,000	.2	.04
			23,675,000			54.835
					Sq Root	7.405

Maximum Likely Addition = $7,405,00

Base Estimate = $180,000,000
Average Risk Estimate = Base Estimate + *Total* Average Risk Allowance
= $203,675,000 (13.15% on base)

Maximum Likely Estimate = Base Estimate + Average Risk Allowance + Maximum Likely Addition
= $211,080,000 (17.27% on base)

FIG. 2. Example of ERA Worksheet at Pretender Stage

Risk Allowance/Contingency vs. Project Phase

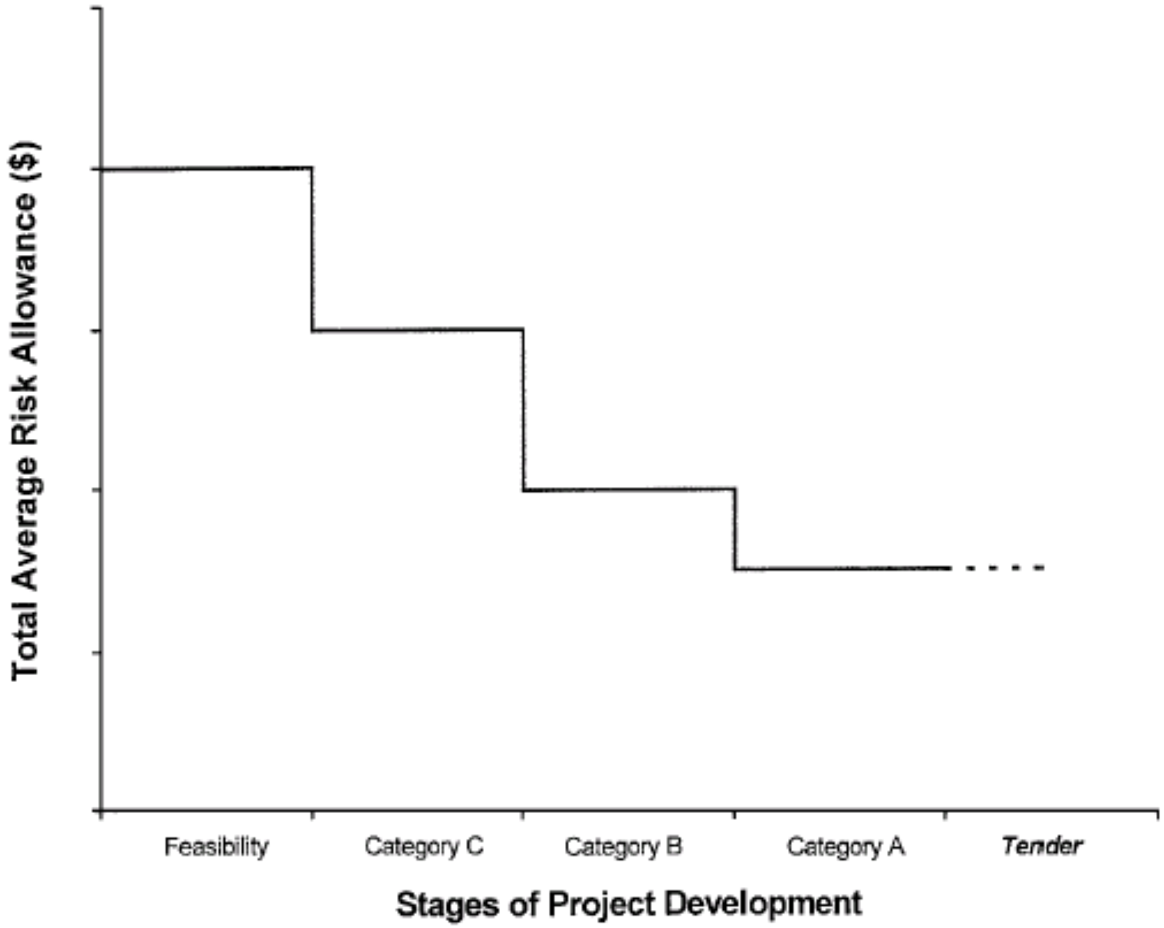

FIG. 3. Total Risk Allowance versus Stages of Project Development

Proportion of Risk Allowance/ Contingency vs. Project Phase

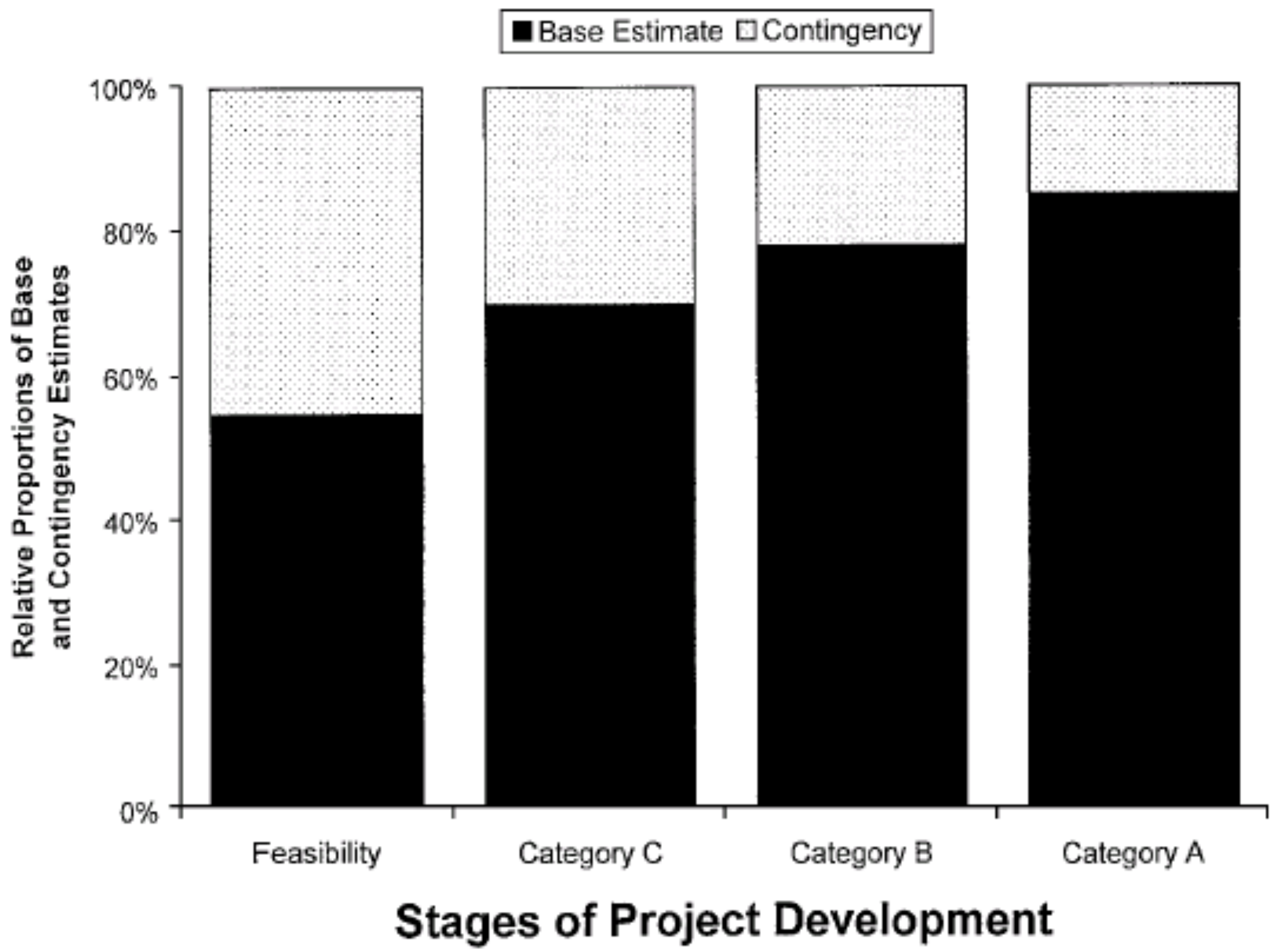

FIG. 4. Proportion of Total Risk Allowance versus Stages of Project Development

Monte Carlo Simulation

An Approach For Contingency Estimation

Background

- Contingency estimation techniques
  - Gut feeling
  - Traditional 5%-10% contingency rule
- Affects competitive edge of companies (especially on massive projects)
- Simulation – a numeric approach to decision support in contingency estimation

Problem Definition

Item Number	Description	Unit	Estimated Quantity	Unit Price ($)	Estimated Amount ($)
1	Column C7	m^3	40.72	1,824.74	74,303.41
2	Slab	m^3	209.00	544.93	113,890.37
3	Footings	m^3	15.20	646.67	9,829.38
4	Beams	m^3	81.10	1,023.11	82,974.22
5	Balcony Railings	m^3	128.19	408.76	52,398.94
6	Exterior Wall 1 (EW1)	m	410.19	763.56	313,204.68
7	Exterior Wall 2 (EW2)	m	224.75	1,322.60	297,254.35
8	W1 Window	pcs	27.00	3,543.56	95,676.12
9	W2 Window	pcs	37.00	4,883.05	180,672.85
10	Basement Wall	m^3	73.90	1,288.58	95,226.06
11	Roof Wall	m^3	31.20	965.69	30,129.53
12	Main Floor Slab	pcs	6.00	198,357.06	1,190,142.36
13	Appliances	L.S.	1.00	5,830.39	5,830.39
14	Bath tub	pcs	1.00	4,520.42	4,520.42
15	Cabinents	pcs	1.00	2,507.85	2,507.85
16	Counter Top	pcs	1.00	1,783.15	1,783.15
17	Sink	pcs	1.00	1,329.44	1,329.44
18	Partition WT1	m	125.69	206.42	25,944.93
19	Partition WT2	m	246.23	336.86	82,945.04
20	Partition WT3	m	185.32	3,183.85	590,031.08
21	Partition WT9	m	445.41	338.33	150,695.57
22	D1 Door	pcs	73.00	413.77	30,205.21
23	D2 Door	pcs	30.00	413.77	12,413.10
24	Elevator Walls	m^3	68.10	1,214.23	82,689.06
25	Stairs	m^3	17.60	3,091.34	54,407.58
26	Carpet Flooring	m^2	2,143.70	89.83	192,568.57
27	Ceramic Tile Flooring	m^2	503.51	227.04	114,316.91
28	Wood Flooring	m^2	1,230.97	196.72	242,156.42
29	False Ceiling - Gypsum	m^2	1,074.68	166.77	179,224.38
	TOTAL BID PRICE				**4,309,271.38**

Problem Definition

EXPERT OPINION OF UNIT PRICES

Critical Element	Low Value ($)	Most Likely Value ($)	High Value ($)
Footings	614.34	652.35	690.78
Balcony Railings	188,439.21	200,357.06	210,274.91
Appliances	5,238.87	5,952.39	6,976.91

Contingency Estimation using Simulation

$$Mean = \frac{Low\ Value + 4 * Most\ Likely\ value + High\ Value}{6}$$

$$Standard\ Deviation = \frac{High\ Value - Low\ Value}{6}$$

DISTRIBUTIONS FOR UNIT PRICES

Critical Element	Mean Value ($)	Standard Deviation Value ($)
Footings	652.42	12.74
Main Floor Slab	200,023.73	3,639.28
Appliances	6,004.22	289.67

Using MS Excel

- Random number generation [=RAND()]
- Fixing the Random number [=F9RAND()]
- Sampling values [=NormInv(probability, mean, StdDev)] --> probability = Random number
- Percentiles [=Percentile(Array, k)]

Simulation Results

Range Estimates – Bid Price

Simulation Run (Iteration #)	Cost of Static Elements	Cost of Footings	Cost of Main Floor Slab	Cost of Appliancies	Total Bid Price ($)
1	3,103,469.25	10,111.59	1,190,934.31	6,035.27	4,310,550.41
2	3,103,469.25	9,687.79	1,227,246.09	5,960.60	4,346,363.73
3	3,103,469.25	10,233.98	1,203,368.54	6,177.89	4,323,249.67
4	3,103,469.25	10,279.44	1,222,704.49	6,361.67	4,342,814.86
5	3,103,469.25	9,836.74	1,215,137.21	5,976.23	4,334,419.43
6	3,103,469.25	9,930.69	1,242,323.12	6,033.48	4,361,756.54
7	3,103,469.25	10,150.23	1,189,745.54	6,024.79	4,309,389.80
8	3,103,469.25	9,702.76	1,203,420.15	6,034.63	4,322,626.78
9	3,103,469.25	10,021.26	1,194,296.92	6,031.65	4,313,819.08
10	3,103,469.25	10,007.79	1,203,076.38	6,040.73	4,322,594.16
11	3,103,469.25	10,066.92	1,187,568.08	5,719.28	4,306,823.53
12	3,103,469.25	10,033.82	1,169,004.06	5,480.58	4,287,987.71
13	3,103,469.25	9,441.49	1,213,357.21	5,855.82	4,332,123.77
14	3,103,469.25	10,357.86	1,171,145.38	6,052.99	4,291,025.48
15	3,103,469.25	9,928.56	1,179,704.63	6,556.16	4,299,658.60
16	3,103,469.25	10,275.47	1,191,558.58	5,405.58	4,310,708.88
17	3,103,469.25	10,025.32	1,231,619.38	5,851.78	4,350,965.73
18	3,103,469.25	10,156.07	1,219,253.32	6,031.82	4,338,910.47
19	3,103,469.25	9,646.28	1,148,530.01	5,533.25	4,267,178.79
20	3,103,469.25	10,186.62	1,183,876.81	5,548.51	4,303,081.18
21	3,103,469.25	9,888.58	1,246,194.85	6,194.66	4,365,747.34
22	3,103,469.25	10,224.29	1,215,963.67	6,266.48	4,335,923.69
23	3,103,469.25	9,694.87	1,206,497.91	6,348.43	4,326,010.46
24	3,103,469.25	10,153.48	1,195,809.13	5,335.95	4,314,767.82
25	3,103,469.25	9,849.45	1,167,380.30	6,285.51	4,286,984.50
26	3,103,469.25	9,907.72	1,206,109.96	6,241.05	4,325,727.98
27	3,103,469.25	9,932.18	1,232,170.68	6,345.97	4,351,918.08
28	3,103,469.25	9,884.45	1,169,232.23	5,742.33	4,288,328.26
29	3,103,469.25	9,873.33	1,239,644.41	5,886.43	4,358,873.42
30	3,103,469.25	9,804.00	1,220,637.61	5,634.58	4,339,545.45

Percentiles

PERCENTILES	VALUES ($)
0.1	4,288,294.21
0.15	4,292,752.11
0.2	4,301,027.63
0.25	4,304,952.35
0.3	4,308,106.67
0.35	4,309,917.43
0.4	4,311,330.92
0.45	4,314,672.95
0.5	4,318,680.99
0.55	4,325,727.98
0.6	4,328,455.78
0.65	4,334,783.72
0.7	4,338,611.79
0.75	4,339,545.45
0.8	4,350,965.73
0.85	4,351,822.85
0.9	4,356,786.82
0.95	4,361,622.99
1	4,365,747.34

Contingency Determination

$$Contingency(\%) = \frac{\{Kth\ Percentile\ -\ Base\ Estimate\ (with\ 0\%\ contingency)\}}{Base\ Estimate\ (with\ 0\%\ contingency)} \times 100$$

PARAMETER	VALUE
Base Cost (0% Contigency)	4,309,271.38
85th Percentile	4,351,251.43
Proposed Contingency (%)	0.97

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- *CIV E 406: Range Estimation, Lecture Notes,* Lu, M. University of Alberta, 2012.
- *CIV E 601: Project Management, Lecture Notes,* Fayek, A. R. University of Alberta, 2013.
- Mak, S. and Picken, D. (2000). Using Risk Analysis to Determine Construction Project Contingencies. Journal of Construction Engineering and Management, 126(2): 130-136.