Risk Analysis for Design-Build Construction Projects: A Simplified Approach

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Construction Projects are being implemented under different contract systems in the Midwest. Negotiated design-build has been a popular contract system in recent years. It provides various advantages through entailing the contractor to be responsible for the whole project. However, design-build turns out to be risky system for both owners and contractors unless the risks are identified, quantified and analyzed through the project execution. This paper proposes a simplified schedule and risk analysis model to help construction estimators. A hypothetical case study was used to demonstrate the applicability of this simplified model. The developed model showed a promising enhancement to be used by estimators in analyzing the risk of project schedule and cost overruns.

Keywords: risk analysis; Design-build; Construction; Simplified approach

Introduction

In a negotiated contract, decisions on pricing strategies are based on the contractor's experience, intuition, and personal bias. There is a lack of practical models that could quantify risks on construction projects. Xu et al. (2001) proposed an approach to the risk assessment of the contractor's pricing strategies while Tummala et al. (1999) formulated a risk management process (RMP) model to evaluate the risks associated with project cost in different phases of the project life cycle. Songer et al. (1997) suggest risk analysis tools like Monte Carlo simulation for evaluating uncertainties on construction projects that are procured by design-build, construction management, or built-operate-and-transfer methods. Dawood (1998) developed a simulation model using risk management techniques to estimate activity and project durations. Mak et al. (2000) conducted a survey on the usage of risk analysis techniques in determining the contingency allowance in project cost estimating but included no special consideration of risks on DB type construction projects.

The number of studies related to the design-build contract system is increasing as the application of this project delivery method expands. Rowings et al. (2000) surveyed electrical contractors regarding many different aspects of design-build and how those factors impact their business. The survey revealed several important trends and preferences among electrical contractors. One area identified in the survey worthy of note was that many of the electrical contractors felt ill prepared to embark on design-build with their current understanding of the issues.

Chan et al. (2001) identified a set of project success factors for design-build projects and examined the relative importance of these factors on the project outcome. One of the factors he found to be important was risk assessment in design-build projects. However, the numbers of studies that combine the risk analysis/management and design–build subjects are still scarce.

Based on the author's personal experience with Midwestern Construction Company, this paper proposes a simplified schedule and risk analysis model to help construction estimators to perform a risk analysis process, as a step of project risk management systems, for design-build projects. A hypothetical case study was used to demonstrate the applicability of this simplified model. The developed model showed marked enhancement in analyzing the risk of project schedule and cost overruns.

Risk Management and Analysis

The definition for risk is elusive and its measurement is controversial (Lifson and Shaifer 1982). There is no consistent or uniform usage of the term risk. Often times, risk is interpreted in association with uncertainty. In this sense, risk implies that there is more than one possible outcome for the event, where the uncertainty of outcomes is expressed by probability (Al-Bahar 1988). In project management, risks are typically associated with cost, schedule, safety and technical performance (Rao et al. 1994). For the purpose of this study, risk is defined as *the exposure to the chance of occurrences of cost or schedule growth as a consequence of uncertainty.*

Risk management is a quantitative systematic approach used to manage risks faced by project participants. It deals with both foreseeable as well as unforeseeable risks and the choice of the appropriate techniques(s) for treating those risks. The process of risk management includes three phases: risk identification, risk quantification, and risk control. The process is a continuous cycle that consists of risk analysis, strategy implementation, and monitoring (Minato and Ashley 1998).

Risk Analysis

Risk analysis is needed to determine the potential impact of the risk. Risk analysis techniques are grouped into two main categories: quantitative and qualitative (Flanagan & Norman, 1993; Vaughan, 1997). They both benefit from the data produced by risk identification but the qualitative approach consumes the gathered information through direct judgment, comparing options, and descriptive analysis. In contrast, some of the quantitative risk analysis techniques incorporate uncertainty in a quantitative manner to evaluate the potential impact of risk. In this process, an analyst integrates information from numerous sources through quantitative and/or qualitative modeling, while preserving the uncertainty and the complex relationships between the elements of information (Rao et al. 1994).

Research Methodology

The project begins with identifying the main features, major application deficiencies and summarization of the encountered risks. Afterwards, schedule risk analysis and cost risk analysis are subsequently performed for these risks. A stochastic risk analysis technique, similar to Monte

Carlo simulation, was utilized in both schedule risk and cost risk analysis steps. Microsoft Excel was used to simulate the data and perform the required analysis.

Spreadsheet Modeling

The simplified spreadsheet solutions developed by Hegazy and Ayed (1999) were used as a platform for developing the risk analysis model after performing the required schedule calculations. These spreadsheet models provide opportunity to achieve the project duration and total project cost range in percentiles at the end of simulation with taking into account the identified risks and their effects on activity durations and costs. They have also the following basic characteristics: ***Schedule risk model:*** The model consists of all project activities, their relationships, and their minimum, likely, and maximum durations (Figure 1). ***Cost risk model:*** The model consists of all price items with their units that constitute the total price. It leads the user to enter the minimum, maximum, and likely production amount and unit price of every price item (Figure 2).

Case Study

A hypothetical case study was used to demonstrate the applicability of this simplified model. This hypothetical project includes the design and construction of a 12,000 square foot commercial property that will be used as a fast food retail restaurant. It was a negotiated job and the owner wanted his bid after 10 days. According to the CPM calculations and the parametric estimation of the project, the estimator can submit his bid for $1,273,300 that can be executed in 131 days.

This case study will help the author to illustrate the negative effects of the lack of risk identification and risk analysis of design-build construction projects. It should be emphasized that there are some deficiencies in the application of design-build contract systems for this specific project due to the short time allowed for preparing an estimate for this project. In order to clarify the scope of the study, the major risks that have to be taken into consideration along the risk analysis are summarized in Table 1:

Table 1: Risk Identification/Classification Table

Risk No.	**Risk description**	**Consequence**
1	Changes in quantity/ scope of work	Duration & cost
2	Design changes	Duration
3	Delay in design	Duration
4	Subcontractor or Vendor delays or default	Duration
5	Weather conditions	Duration
6	Owner Financial problems	Duration & cost
7	Inadequate quality of work and re-work delay	Duration & cost
8	Sub-soil Stability conditions	Duration & cost
9	Safety	Duration & cost

	Duration =	146.9				Predec-cessors				Succ-essors								
ID	Activity Name	Min. Duration	Likely Duration	Max. Duration	Simulated Activity Duration	P1	P2	P3	P4	S1	S2	S3	S4	ES	EF	LS	LF	TF
1	Design	20.0	30.0	60.0	39.0					3				0.0	39.0	0.0	39.0	0.0
2	Site prep	1.0	2.0	2.0	1.6					3				0.0	1.6	37.4	39.0	37.4
3	Site Excavation	2.0	5.0	20.0	3.3	1	2			4				39.0	42.3	39.0	42.3	0.0
4	Deep Foundation	1.0	2.0	7.0	4.7	3				5				42.3	47.0	42.3	47.0	0.0
5	Foundations	7.0	8.0	10.0	7.0	4				6	8			47.0	54.0	47.0	54.0	0.0
6	Wall foundation	2.0	3.0	5.0	2.7	5				7	9	27		54.0	56.6	55.4	58.1	1.5
7	Underground Insulation	1.0	1.0	1.0	1.0	6								56.6	57.6	145.9	146.9	89.2
8	Site Utilities	3.0	5.0	10.0	4.1	5				9				54.0	58.1	54.0	58.1	0.0
9	ground Floor Slab	1.0	2.0	3.0	1.7	8	6			10	11			58.1	59.8	58.1	59.8	0.0
10	Backfill	1.0	1.0	1.0	1.0	9				12				59.8	60.8	74.7	75.7	14.8
11	Structural Steel	10.0	14.0	20.0	15.8	9				12				59.8	75.7	59.8	75.7	0.0
12	Internal and External walls	13.0	16.0	21.0	15.1	10	11			13	14	16		75.7	90.8	75.7	90.8	0.0
13	Doors and Window frames	2.0	2.0	2.0	2.0	12								90.8	92.8	144.9	146.9	54.1
14	Plumbing	8.0	10.0	14.0	13.3	12				15	19	22		90.8	104.1	90.8	104.1	0.0
15	Electrical Conduits	6.0	8.0	11.0	7.9	14				17	18	20		104.1	112.0	104.1	112.0	0.0
16	Roof work	8.0	10.0	15.0	12.4	12				23				90.8	103.2	118.8	131.2	28.0
17	Wall Tiles	8.0	10.0	14.0	8.5	15				21				112.0	120.6	115.5	124.1	3.5
18	Floor Tiles	8.0	10.0	15.0	12.1	15				21				112.0	124.1	112.0	124.1	0.0
19	Doors & Windows	8.0	10.0	15.0	9.0	14				21	22			104.1	113.1	115.1	124.1	10.9
20	Electricl Wiring	5.0	7.0	10.0	5.7	15								112.0	117.7	141.2	146.9	29.2
21	Internal Painting	8.0	10.0	15.0	9.8	17	18	19		24	26			124.1	133.9	124.1	133.9	0.0
22	Sanitary fittings	5.0	6.0	8.0	7.9	14	18							124.1	132.0	139.0	146.9	14.9
23	HVAC units	5.0	6.0	8.0	5.9	16				24				103.2	109.1	131.2	137.0	28.0
24	Electrical devices and armatures	4.0	5.0	6.0	6.0	23	21			25				133.9	139.8	137.0	143.0	3.2
25	Furnature	1.0	5.0	7.0	3.9	24								139.8	143.7	143.0	146.9	3.2
26	External painting	5.0	6.0	8.0	5.6	21				28	29			133.9	139.5	133.9	139.5	0.0
27	Signange	1.0	1.0	3.0	1.0	6				30				56.6	57.6	115.6	116.6	59.0
28	Paving and curbs	3.0	4.0	6.0	3.9	26								139.5	143.4	143.0	146.9	3.5
29	External tiles	4.0	5.0	8.0	7.4	26								139.5	146.9	139.5	146.9	0.0
30	Site Concrete	3.0	4.0	6.0	3.6	27				31				57.6	61.2	116.6	120.2	59.0
31	Asphalt	7.0	10.0	14.0	7.2	30				32				61.2	68.4	120.2	127.4	59.0
32	Landscaping	10.0	14.0	20.0	13.4	31				33				68.4	81.8	127.4	140.8	59.0
33	Main service connections	6.0	8.0	12.0	6.1	32								81.8	87.9	140.8	146.9	59.0

Figure 1: Schedule Risk Model of the Project

In order to build up the schedule risk analysis model of the project, the simplified spreadsheet solutions developed by Hegazy and Ayed (1999) were used as a platform to develop the deterministic CPM calculations. Extra columns with a simulation-like algorithm were coded in the spreadsheet to add the ability to run different cycles of simulation on the model. The triangular probability distributions, with likely-minimum- maximum activity durations, were represented.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**A Hypothetical Illstrated Project**												
2	**Base Bid**		**QTY**			**Unit Price**				**Simulated Amount**		**Simulated Unit Price**	
3	**Work Description**	**Unit**	**Min.**	**Likely**	**Max.**	**Min.**	**Likely**	**Max.**					**Item Price**
4	Design					30,000.00	52,500.00	75,000.00			0.33	44703.1337	44703.1337
5													
6	**Division 1**												
7	Supervision	hrs	430	480	530	47	53	65	0.42	471.8073493	0.08	47.9685776	22631.92744
8	Site Layout	hrs	14	16	18	90	100	120	0.91	17.63664782	0.39	97.7224666	1723.496728
9	Clean Up	hrs	180	200	225	50	56	70	0.02	180.6004117	0.04	50.4635946	9113.745963
10	Safety	hrs	7	8	9	42	47	60	0.96	8.914084067	0.52	47.5527332	423.8890613
11	Temp Facilities	mo	3	4	5	960	1075	1300	0.88	4.757599836	0.25	1016.54921	4836.334369
12	Dewatering	hrs	7	8	9	40	45	55	0.28	7.559901721	0.31	43.073843	325.6340198
13													
14	**Division 3**												
15	Sign Footing	cy	1	1	2	360	400	500	0.05	1	0.68	435.555677	435.5556774
16	Sign Foundation Wall	cy	2.5	3	4	540	600	730	0.23	2.731854146	0.01	541.664636	1479.748783
20	Foundation Walls	cy	55	62	69	450	500	600	0.99	68.80532877	0.66	532.995326	36672.91861
21	Piers	cy	5	6	7	550	600	750	0.49	5.97156574	0.30	580.036388	3463.725426
22	SOG	cy	104	116	130	175	195	240	0.22	109.2624782	0.97	237.108225	25907.03232
23													
41													
42	**Division 12**												
43	Owner Furnished Items	ea	13	15	17	180	200	240	0.28	14.11793213	0.90	232.286211	3279.400958
44													
45	**Subcontractors**												
46	Site Excavation					23025	30,700.00	38375			0.24	26689.2017	26689.20165
47	Site Utilities					31913.25	42,551.00	53188.75			0.26	37520.7161	37520.71612
48	Site Concrete					36860.25	49,147.00	61433.75			0.66	53102.9071	53102.90711
49	Asphalt					68088	90,784.00	113480			0.38	85180.8557	85180.8557
50	Landscaping					12525	16,700.00	20875			0.19	14126.2881	14126.28807
51	Rebar Fabrication					3411.75	4,549.00	5686.25			0.57	4697.66919	4697.669189
52	Rebar Install					3268.5465	4,358.06	5447.5775			0.45	4255.59984	4255.599842
53	Masonry					86812.5	115,750.00	144687.5			0.29	103429.08	103429.0801
54	Steel Fabrication					47580	63,440.00	79300			0.39	59880.2872	59880.28723
55	Finish Carpentry Furnish					30465	40,620.00	50775			0.26	35660.6553	35660.65525
56	Roofing					33441	44,588.00	55735			0.40	42282.1488	42282.14884
57	Doors, Frames & Hardware Furnish					3213.75	4,285.00	5356.25			0.20	3639.56199	3639.561986
58	Aluminum, Glass & Glazing					9385.5	12,514.00	15642.5			0.05	9694.41599	9694.415989
59	Roof Hatch Furnish					450	600.00	750			0.26	527.447769	527.4477694
60	Mtl. Stds, Gyp, Tape & ACT					90135	120,180.00	150225			0.05	92896.3558	92896.35577
61	Painting					12525	16,700.00	20875			0.37	15653.0689	15653.06887
62	Ceramic Tile F&I					28312.5	37,750.00	47187.5			0.87	44802.9699	44802.96994
63	Carpet & Wood Flooring F&I					14175	18,900.00	23625			0.98	23410.5135	23410.51346
64	Toilet Accessory Furnish					684.75	913.00	1141.25			0.11	735.878877	735.8788767
65	Toilet Partition Furnish					1590.75	2,121.00	2651.25			0.04	1631.0685	1631.068504
66	Fire Extinguisher Furnish					337.5	450.00	562.5			0.76	508.772952	508.7729517
67	Knox Box Furnish					262.5	350.00	437.5			0.52	354.036517	354.0365169
68	Awning F&I					8277.75	11,037.00	13796.25			0.02	8384.70834	8384.708336
69	Fire Protection					11250	15,000.00	18750			0.74	16794.1069	16794.10692
70	Plumbing					54447	72,596.00	90745			0.30	65345.049	65345.04903
71	HVAC					61337.25	81,783.00	102228.75			0.99	101813.433	101813.4333
72	Electrical					98983.5	131,978.00	164972.5			0.56	135697.869	135697.8689
73													
74	**Total of Above**												**1,238,251**
75	**General Liability**	**1**	**ls**									**1,242,326**	**4074**
76	**Building Permit**	**1**	**ls**									**1,245,772**	**3446**
77	**Additional Insurance**	**1**	**ls**									**1,245,772**	
78	**Payment & Performance Bo**	**1**	**ls**									**1,245,772**	
79	**Fees**	**1**	**ls**									**4.00%**	**49831**
80	**Total Cost**												**1,295,602**

Cost Risk Analysis Model | Schedule Risk Analysis Model | Simulation Results

Figure 2: Cost Risk Model of the Project

The cost risk analysis spreadsheet model was developed in MS Excel as shown in Figure 2. The estimate was executed based on a simple floor plan that the estimator sketched with the owner in the scope clarification meeting. The likely, minimum, and maximum amount values were decided with the estimator's experience and historical records from other projects. The price items were represented by means of triangular probability distributions.

Results and Comments

Deterministic Schedule analysis has shown that the project can end at 131 days. However, after running the simulation, Table 2 shows that the probability of finishing this project in time is close to 17%. This is a proof that the project is sufficiently risky regards to schedule under the current conditions.

Table 2: Simulation Results of Schedule Risk analysis model

Project Duration	*Frequency*	*Cumulative %*
118.1	1	1.00%
124.93	3	4.00%
131.76	13	17.00%
138.59	24	41.00%
145.42	12	53.00%
152.25	13	66.00%
159.08	14	80.00%
165.91	6	86.00%
172.74	12	98.00%
179.57	0	98.00%
More	2	100.00%

Similarly, Deterministic Cost Analysis has shown that the total project cost is $1,273,300. Figure 3 illustrates the simulation results for the cost risk analysis model. This shows that the bid of that project at $1,273,300 was likely to happen with a probability close to 2%. Such a risky bid value has naturally converted the project from a profitable project to an unprofitable one to the company.

A question may come into mind at this point: How would the estimator select the appropriate project duration and project cost among the various values with different probability percentiles? The answer would be that the decision would be related to the risk attitude, experience, intuition, and risk identification capabilities of the contractor and his staff.

Finally, the author has to mention that these results are preliminary and the model needs to be validated and the selection criteria for the minimum, most likely, and maximum values and the selection of the activity or price item distributions should be examined.

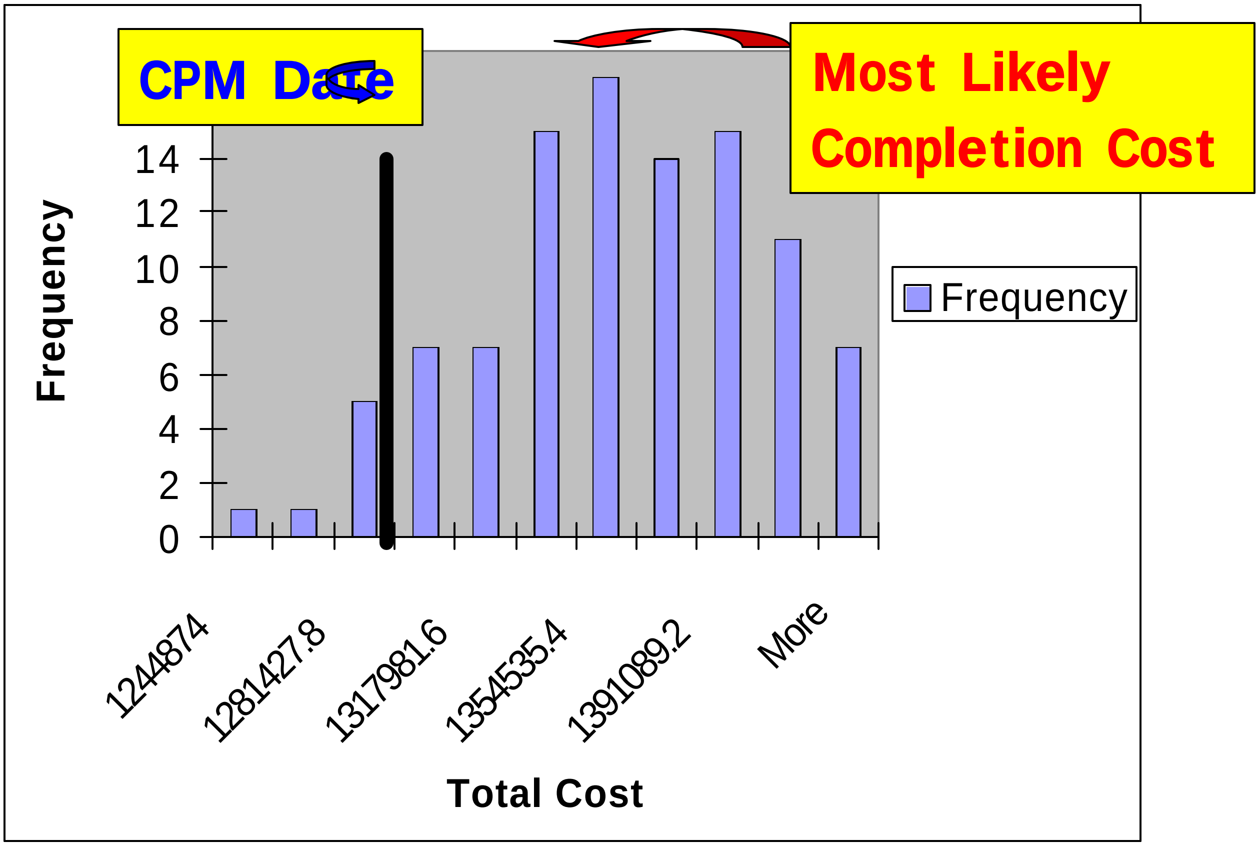

Figure 3: Simulation Results of Cost Risk analysis model

Conclusion

In this study, basic information and relevant literature have been presented related to risk, risk management/ analysis, and design-build construction contract systems. Subsequently, a hypothetical project has been examined from the contractor (design-build firm) point of view. This analysis covers risk identification, schedule risk analysis, and cost risk analysis. Risk analysis was used by developing a spreadsheet model using MS Excel. And the simulation algorithm was simply coded on the spreadsheet.

The results conclude that taking simple methods for estimating bid values or a schedule for a design-build project would be a risky way of doing business. The results from the schedule risk analysis model and the cost risk analysis model indicated that it is necessary to do a risk analysis for design-build projects. As a contractor (design-build firm), in order to be able to prepare and submit a bid for these types of projects, knowledge and experience on design-build systems are required to succeed. In addition, risk management and analysis should be performed during the decision making process to determine the bid price.

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