# **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: <u>Schedule risk model:</u> The model consists of all project activities, their relationships, and their minimum, likely, and maximum durations (Figure 1). <u>Cost risk model:</u> The model consists of all 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
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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					Prec	iec- sors			Su ess	cc-	;					
ID	Activity Name	Min. Duration	Likely Duration	Maz. Duratio n	Simulated Activity Duration	P1	P2	P3	P4	S1	<b>S</b> 2	53	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	Vall 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	Vall 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 & Vindows	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.

I         Allypoth etical Illstrated Project         vol         Unit Price         Simulated         Simulated <th></th> <th>A</th> <th>в</th> <th>С</th> <th>D</th> <th>E</th> <th>F</th> <th>G</th> <th>н</th> <th></th> <th>J</th> <th>К</th> <th>L</th> <th>M</th>		A	в	С	D	E	F	G	н		J	К	L	M
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48       Site Concrete       3680.025       43,147.00       6143.75       0.66       53102.3071       53102.3071         91       Asphalt       9680.25       46,700.00       13340       0.38       95108.857         92       Rebar Fabrication       34177       4,543.00       5686.25       0.57       4697.65919       4457.65934         92       Rebar Install       32.85.764       3758.00       14462.288       103423.08       10343.28       10343.28       10343.08       1034	47	Site Utilities					31913.25	42,551.00	53188.75			0.26	37520.7161	37520.71612
49       Asphalt       68088       90,784.00       10340       0.38       85180.8577       85180.8577         50       Landscaping       0       28757       0.11       1426.2881       141281.2881       14128.2881       <	48	Site Concrete				_	36860.25	49,147.00	61433.75			0.66	53102.9071	53102.90711
50         Landscaping         150         Landscaping         157         16, 177         16, 454 00         5666 2.5         0.57         10.19         14122.2801         14122.2801         14122.2805         1457, 65189         1457, 65189         1457, 65189         1457, 65189         1457, 65189         1457, 65189         1457, 65189         1457, 65189         1457, 65189         1457, 65189         1457, 65189         1452, 255, 5984         1455, 5984         1455, 5984         1455, 5984         1455, 5984         1455, 5984         1455, 5984         1452, 2081         10342, 008         1034, 208, 01, 01, 038, 5618, 563, 568         3560, 653, 3568,	49	Asphalt					68088	90,784.00	113480			0.38	85180.8557	85180.8557
51       Rebar Install       341173       4,549.00       5582.55       0.57       4597.65819       4497.658193         52       Rebar Install       32663465       4,355.00       6147.5775       0.46       4255.59944       4255.59944         53       Masonry       68812.5       Tiv/Kolo       14487.5       0.23       5980.2872       5980.2872         54       Steel Fabrication       47580       63,440.00       59735       0.40       4228.1488       4228.1488         55       Finish Carpentry Furnish       33441       44,588.00       55735       0.40       4228.1488       4228.1488         67       Doors, Frames & Hardware Furnish       3213.75       4,285.00       5562.5       0.00       3633.65198       9633.451986         68       Aluminun, Glass & Glasing       9385.5       12,514.00       15642.5       0.05       9289.3557       12,245.00       528.25       0.37       527.447769       527.447769         69       MLI: Stds, Glay, Tape & ACT       9013       120,180.00       1502.25       0.05       9289.3557       12,340.5134         62       Ceramic Tile Fal       28312.5       37.700.00       2987.5       0.37       1565.06887       1350.6887       1530.68894 <td>50</td> <td>Landscaping</td> <td></td> <td></td> <td></td> <td></td> <td>12525</td> <td>16,700.00</td> <td>20875</td> <td></td> <td></td> <td>0.19</td> <td>14126.2881</td> <td>14126.28807</td>	50	Landscaping					12525	16,700.00	20875			0.19	14126.2881	14126.28807
52       Rebar Install       3286 3965       3.4358,00       9447.5775       0.45       4255.59844       4255.59844       4255.59844       4255.59844       4255.59844       4255.59844       4225.08       103423060       103423060       103423060       0.33       5980.2872       5981.486.428       4020.4884       4225.4484       4225.484       4281.4894       4282.4484       4281.4890.4480.48983.4868       4980.4780.287       10	51	Rebar Fabrication					3411.75	4,549.00	5686.25			0.57	4697.66919	4697.669189
53         Masonry         96812.5         TWWF0.00         144887.5         0.29         103423.08         103423.08           54         Steel Fabrication         47580         63,440.00         73300         0.39         59880.2872         59880.2872           55         Finish Carpentry Furnish         30445         40,620.00         50775         0.28         35660.6552         35660.6552           56         Roofing         33441         44,588.00         55735         0.40         42282.1483         42282.1483           57         Doors, Frames & Hardware Furnish         3213.75         4,285.00         5564.25         0.02         3639.41539         9694.41593           58         Aurinium, Glass & Glazing         33451         12,514.00         15642.5         0.05         3289.5518         527.447768         527.447768         527.447768         527.447768         527.447768         527.447768         527.447768         528.5558         3289.3557         63         538         1653.0688         1653.0688         1653.0688         1653.0688         1653.0688         1653.0688         1653.06887         1631.06850         1631.06850         1631.06850         1631.06850         1631.06850         1631.06850         1631.06850         1631.06850	52	Rebar Install					3268.5465	4,358.06	5447.5775			0.45	4255.59984	4255.599842
54       Steel Fabrication       47580       63,440.00       73300       0.33       59880.2872       59880.585       9604.41598       563.41598       563.41598       563.41598       3669.441598       3663.441598       3663.441698       3678.57       0.37       15653.06887       3678.357       368.341698       36555.30.67	53	Masonry					86812.5	115,750.00	144687.5			0.29	103429.08	103429.0801
55       Finish Carpenty Furnish       30465       40,620,00       50775       0.26       3560,6553       33560,6552         56       Roofing       33414       44,588.00       55735       0.40       42282,1488       42282,1488         57       Doors, Frames & Hardware Furnish       3213.75       4,285.00       5356.25       0.20       3633,56139       3639,365189         58       Atomirum, Glass & Glazing       9335.5       12,514.00       15642.5       0.005       9694,41593       9694,415939         59       Roof Hatch Furnish       450       600.00       750       0.26       527,447769       527,447769         60       Mtl.Stds, Gyp, Tape & ACT       90155       120,180.00       150225       0.037       15653,0883	54	Steel Fabrication					47580	63,440.00	79300			0.39	59880.2872	59880.28723
66       Roofing       33441       44,88.00       55735       0.40       42282,1483       42282,14834         57       Doors, Frames & Hardware Furnish       3213.75       4,285.00       55356.25       0.20       3633,56139       3633,56139         68       Aluminum, Glass & Glazing       9385.5       12,514.00       15642.5       0.005       9594,41539       9634,41598         59       Roof Hatch Furnish       450       600,00       750       0.26       527,447769       527,447769         60       Mtl. Stds, Gyp, Tape & ACT       90135       120,180.00       150225       0.05       9286,35575       9286,35577         61       Paining       1252.5       16,700.00       20875       0.37       15653.0689       165653.0689         62       Carant Tile F&I       28312.5       37,750.00       47187.5       0.87       44802.9693       44802.9693         63       Carpet & Wood Flooring F&I       14175       18,90.00       23825       0.98       23410.1515       23410.5134         64       Toilet Accessorg Furnish       1590.75       2,121.00       2651.25       0.04       1631.06851       1631.068504         66       Fire Extinguisher Furnish       2827.75       10.03	55	Finish Carpentry Furnish					30465	40,620.00	50775			0.26	35660.6553	35660.65525
57       Doors, Frames & Hardware Purnish       3213.75       4,281.00       5582.5       0.20       3633.56139       3633.56139         58       Aluminum, Glass & Glazing       9385.5       12,514.00       15642.5       0.05       9634.41539       9634.41539         59       Roof Hatch Furnish       450       600.00       750       0.22       527.447763       527.447763         60       Mtl. Stds, Gigp, Tape & ACT       90135       120.180.00       150225       0.05       92896.3558       92896.3557         51       Painting       12525       67.00.00       20875       0.37       15653.0689       14602.98994         52       Caramic Tile Fel       28312.5       37.750.00       47187.5       0.87       44802.98994         64       Toilet Accessory Furnish       684.75       913.00       1141.25       0.11       735.878877       735.878877         65       Toilet Partition Furnish       1590.75       2,121.00       2562.5       0.06       1631.068504         66       File Erunish       262.5       350.00       437.5       0.52       354.036517       354.036517         67       Knox Box Furnish       262.5       350.00       437.5       0.52       354.036517 <td>56</td> <td>Roofing</td> <td></td> <td></td> <td></td> <td></td> <td>33441</td> <td>44,588.00</td> <td>55735</td> <td></td> <td></td> <td>0.40</td> <td>42282.1488</td> <td>42282.14884</td>	56	Roofing					33441	44,588.00	55735			0.40	42282.1488	42282.14884
58       Aluminum, Glass & Glazing       9385.5       1,514.00       15642.5       0.05       9694.41593       9694.41593         59       Roof Hatch Furnish       4505       600.00       750       0.26       527.447769       527.4477694         60       Mtk. Stds, Gup, Tape & ACT       90135       120,180.00       150225       0.05       92886.3568       92296.3568       92396.3568       92396.3568       92396.3568       92896.3568       92396.3568       92396.3568       92896.3568       92396.3568       92896.3568       92340.5136       92340.5136       92340.5136       92340.5136       92340.5136       92340.5136       92340.5136       92340.5136       92340.5136       92340.5136       92340.5136       92340.5136       92340.5136       92340.5136       92340.5136       92340.5136       92340.5136       92340.5136 </th <td>57</td> <td>Doors, Frames &amp; Hardware Furnish</td> <td>า</td> <td></td> <td></td> <td></td> <td>3213.75</td> <td>4,285.00</td> <td>5356.25</td> <td></td> <td></td> <td>0.20</td> <td>3639.56199</td> <td>3639.561986</td>	57	Doors, Frames & Hardware Furnish	า				3213.75	4,285.00	5356.25			0.20	3639.56199	3639.561986
59       Hoof Hatch Furnish       460       600.00       750       0.25       527.447763       527.4477634         60       Mtl. Stds, Gup, Tape & ACT       90135       120,180.00       150225       0.05       9286.3558       9286.3558       9286.3558       9289.3588       92893.5888       928935       93890.00       23825       0.87       44802.9699       44802.9698       44802.9698       44802.9698       44802.9698	58	Aluminum, Glass & Glazing					9385.5	12,514.00	15642.5			0.05	9694.41599	9694.415989
800       Mtt. Stds, Gap, Tape & ACT       30135       120,180.00       150225       0.05       92885.3568       7358.7877       735.878777       735.878777       735.878777       735.878777       735.878777       9384.70834       8384.70836       8384.70836       8384.70836       8384.70836       8384.70836       8384.70836       8384.70836       8384.70836       8384.70836       8384.70836       8384.70836       8384.70836       8384.70836       8384.70836       8384.70836	59	Roof Hatch Furnish					450	600.00	750			0.26	527.447769	527.4477694
61       Painting       1225       16,700.00       20875       0.37       15653.0689       15653.0689         62       Ceramic Tile F&I       28312.5       37,750.00       47187.5       0.87       44802.9693       44802.9694         63       Carpet & Wood Flooring F&I       14175       18,900.00       23825       0.98       23410.5136       23410.5136         64       Toilet Accessory Furnish       684.75       913.00       114125       0.11       735.878877       735.8788767         65       Toilet Partition Furnish       1590.75       2,121.00       265125       0.04       16310685       163106850         66       Fire Extinguisher Furnish       2262.5       350.00       562.5       0.76       508.772952       508.7729517         68       Awning F&I       2262.5       350.00       1376.25       0.02       8384.70834       8384.70836         69       Fire Protection       11250       15,000.00       18750       0.74       16794.10692       16794.10692         70       Plumbing       544447       72,596.00       90745       0.30       65345.049       65345.04903         71       HVAC       61337.25       81,783.00       102228.75       0.99	60	Mtl. Stds, Gyp, Tape & ACT					90135	120,180.00	150225			0.05	92896.3558	92896.35577
bc       28312.5       37,750.00       4787.5       0.87       448023633       448023633         63       Carpet & Wood Flooring F&l       14175       18,900.00       23625       0.98       23410.5135       23410.51346         64       Toilet Accessory Furnish       1590.75       2,121.00       2651.25       0.04       1631.0685       1631.06850         65       Toilet Partition Furnish       1590.75       2,121.00       2651.25       0.04       1631.0685       1631.068504         66       Fire Extinguisher Furnish       2362.5       350.00       437.5       0.52       354.036517       354.036518         68       Awning F&l       2827.75       11,037.00       13796.25       0.02       8384.70834       8384.73410832       737       767	61	Painting					12525	16,700.00	20875			0.37	15653.0689	15653.06887
bit         Carper & Wood Problem Period         19173         18,300.00         23825         0.38         23410.5136         22410.5136           64         Toilet Accessory Furnish         684.75         913.00         1141.25         0.11         735.878877         735.878877         735.878877         735.878877         735.878876         735.87876         735.878767         735.878876         735.87876         735.87876         735.878767         735.878767         735.878767         735.878767         735.878767         735.878767         735.878767         735.878767         735.80876         735.80876         735.80876         735.80876         735.80876         735.80876         736.8384.708336         65345.04986         65345.04986         65345.04986         65345.04986         65345.04986         6534	62	Ceramic Tile Fox					28312.5	37,750.00	4/187.5			0.87	99802.3639	44802.96994
For Fore Accessing Furnish         664,79         913.00         114.25         0.11         738.87897         738.878877           65         Toilet Partition Furnish         1590.75         2,121.00         2651.25         0.04         1631.06850         1650.068504           66         Fire Extinguisher Furnish         337.5         450.00         562.5         0.76         508.772952         508.794.10632         56345.049         65345.049         101813.433         101813.433         101813.433<	63	Carpet α wood Flooring Fαl					141/5	18,300.00	23625			0.98	23910.5135	23410.51346
Construction Funition         1930.73         Z_1CL00         2931.23         0.04         1831.0883         1831.0833         1831.0833         1831.0833         1831.0833         1831.0833         1831.0833         1831.0833         1831.0833         1831.0833         1831.0833         1831.0833         1831.0833         <	09	Toilet Accessory Fumish					684.75 1590.75	313.00	2651.25			0.04	100.078877	100.0700767
Open Language Frank         335         400.00         302.5         0.76         306.7723017           67         Knox Box Funish         262.5         350.00         437.5         0.52         354.036517         305.0725017           68         Awning F&I         88.470832         354.036517         305.01725017         8384.70832           69         Fire Protection         11250         15,000.00         13796.25         0.02         8384.70833         85345.04933           69         Fire Protection         11250         15,000.00         18750         0.74         16794.1063         16794.10632           70         Plumbing         54447         72,596.00         90745         0.30         65345.049         65345.04903           71         HVAC         61337.25         81,783.00         102228.75         0.39         101813.433         101813.4333           72         Electrical         98983.5         131,978.00         164972.5         0.56         135697.863         135697.8639           73         Face         1         15         1         1,248,251         1,248,251           73         General Liability         1         Is         1         1,245,772         34466	60	Fire Extinguisher Euroish					1030.75 227 K	450.00	2001.20			0.04	509 772952	631.066304 509 7729517
68       Awing Fål       1       207.75       11,037.00       13796.25       0.02       394.058017       3984.70836         68       Awing Fål       8277.75       11,037.00       13796.25       0.02       8384.70836       8187.70536         68       File Protection       11250       15,000.00       18750       0.74       16734.1063       16734.1063         70       Plumbing       54447       72,596.00       90745       0.30       65345.049       65345.04903         71       HVAC       61337.25       81,783.00       102228.75       0.39       101813.433       101813.4333         72       Electrical       98983.5       131,978.00       164972.5       0.56       135697.863       135697.8683         73       General Liability       1       Is       -       -       1,238,251         74       Total of Above       -       -       -       1,248,252       4074         76       Building Permit       1       Is       -       -       1,245,772       34466         77       Additional Insurance       1       Is       -       -       1,245,772       34466         78       Payment & Performance Bo       1	67	Knov Bov Furnish					001.0 000 E	250.00	427.5			0.70	354 026517	354 0265109
Number of the protection         002111:0         00210         0020	68	Auping F&l					202.0 8277 75	11 037 00	407.0 13796.25			0.02	9394 70924	8384 709226
Interference         Interference<	69	Fire Protection					11250	15,000,00	19750			0.02	16794 1069	16794 10692
101     101     101     101     101     100     000     00	70	Plumbing					54447	72 596 00	90745			0.14	65345.049	65245 04902
11     <	71	HVAC					61337.25	81783.00	102228 75			0.99	101813 433	101813 4333
73     73     6000 1000 10000     100010000       74     Total of Above     1     1       75     General Liability     1     1       76     Building Permit     1     1       77     Additional Insurance     1     1       78     Payment & Performance Bo     1     1       79     Fees     1     1       70     Point Cost     4.00x     49831       80     Total Cost     1     1,295,602	72	Electrical					98983.5	131,978,00	164972.5			0.56	135697.869	135697.8689
74       Total of Above       1       1       1,238,251         75       General Liability       1       1       1       1         76       Building Permit       1<	73	and a second sec					00000.0	.01,010.00	101012.0			0.00		100001.0000
75     General Liability     1     1s     1,242,326     4074       76     Building Permit     1     1s     1,245,772     3446       77     Additional Insurance     1     1s     1,245,772     3446       77     Additional Insurance     1     1s     1,245,772     3446       78     Payment & Performance Bo     1     1s     1,245,772       78     Fees     1     1s     4.002     49831       80     Total Cost     1,295,602     1,295,602	74	Total of Above												1 238 251
76     Building Permit     1 Is     1,245,772     3446       77     Additional Insurance     1 Is     1,245,772     3446       78     Payment & Performance Bo     1 Is     1,245,772     3446       78     Payment & Performance Bo     1 Is     1,245,772     3446       79     Fees     1 Is     1,245,772     4.00%     49831       80     Total Cost     1,295,602     1,295,602	75	General Liabilits	1	ls									1.242.326	4074
77         Additional Insurance         1         Is         1,245,772           78         Payment & Performance Bo         1         Is         1,245,772           78         Payment & Performance Bo         1         Is         1,245,772           79         Fees         1         Is         4.00%         49831           80         Total Cost         1         1,295,602         1,295,602	76	Building Permit	i	ls									1.245.772	3446
78         Payment & Performance Bo         1 Is         1,245,772           73         Fees         1 Is         4.00%         49831           80         Total Cost         1,295,602         1,295,602	77	Additional Insurance	1	ls									1,245.772	
73         Fees         1 Is         4.00%         49831           80         Total Cost         1,295,602         1,295,602	78	Payment & Performance Bo	1	ls									1,245,772	
1,295,602	79	Fees	1	ls									4.00%	49831
	00	Total Cost												1 295 602
	00													1,200,002

🗰 🔸 🕨 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		Cumulative
Duration	Frequency	%
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.

## References

- Al-Bahar, J. (1988). "Risk management approach for construction projects: a systematic analytical approach for contractors". PhD thesis, Univ. of California, Berkeley, CA.
- Chan A., Ho D., and Tam C. (2001). "Design and build project success factors; multivariate analysis", Journal of Construction Engineering and Management, volume 127, pp.93-100.
- Dawood N. (1998). "Estimating project and activity duration: a risk management approach using network analysis" journal of Construction Management and Economics, volume 16, pp.41-48.
- Flanagan R, Norman G. (1993). "Risk management and construction", Cambridge: Backwell Scientific.
- Hegazy, T., and Ayed, A., (1999) "Simplified Spreadsheet Solutions: Models for CPM and TCT Analyses," Cost Engineering, AACE International, AACE, Vol. 41, No. 7, 26-33.
- Lifson, M. and Shaifer, E. (1982). "Decision and risk analysis for construction management", New York: Wiley-Interscience.
- Mak S, Picken D.(2000). "Using risk analysis to determine construction project contingencies" Journal of Construction Engineering and Management, volume 126, pp.130-136.
- Minato T. and Ashley D., (1998). "Data-Driven Analysis of 'Corporate Risk' Using Historical Cost-Control Data", Journal of Construction Engineering and Management, ASCE, Vol. 124, No. 1, pp. 42-47.
- Rowings J., Federle M., Rusk J.(2000). "Design/build methods for electrical contracting industry", Journal of Construction Engineering and Management, volume 126, pp. 15-21.
- Songer A., Diekmann J, Pecsok R. (1997). "Risk analysis for revenue dependent infrastructure projects", Journal of Construction Management and Economics, volume 15, pp.377-382.
- Tummala V.and Burchett J. (1999). "Applying a risk management process (RMP) to manage cost risk for an EHV transmission line project", International Journal of Project Management, volume 17, pp.223-35.
- Tummala, V., Nkasu, M., Chuah, K. (1994), "A systematic approach to risk management", Journal of Mathematical Modeling and Scientific Computing, Vol. 4. No. 1, pp. 1-38
- Vaughan E.(1997). "Risk management", New York; Wiley.
- Xu T. and Tiong R (2001). "Risk assessment on contractor's pricing strategies" Journal of Construction Management and Economics; Volume 9, p.p.77-84.