Supplementary material

MODELING RISKS IN REAL ESTATE DEVELOPMENT PROJECTS: A CASE FOR EGYPT

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Table S1. Example Boolean matrix representation

Gate event ID	Gate type	Basic events					OR (GE)		AND (GE)	
		A	B	C	D	E	TE	GE2	GE1	GE3
TE	OR	0	0	0	0	0	0	1	1	1
GE2	OR	1	0	1	1	0	0	0	0	0
GE1	AND	1	1	0	0	0	0	0	0	0
GE3	AND	1	1	0	0	1	0	0	0	0

Table S2. Qualitative fault tree analysis iterations

Iteration (methodology steps)	Basic events					OR (GE)		AND (GE)	
	A	B	C	D	E	TE	GE2	GE1	GE3
1	0	0	0	0	0	0	1	0	0
	0	0	0	0	0	0	0	1	0
	0	0	0	0	0	0	0	0	1
2	0	0	1	1	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	1	0
	0	0	0	0		0	0	0	1
3	0	0	1	0	0	0	0	0	0
	0	0	0	1	0	0	0	0	0
	1	1	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	1
4	0	0	1	0	0	0	0	0	0
	0	0	0	1	0	0	0	0	0
	1	1	0	0	0	0	0	0	0
	1	1	0	0	1	0	0	0	0

Table S3. Working Boolean matrix of mitigation strategies failure

Mitigation strategy 1						Mitigation strategy 2						
Basic events		OR (GE)		AND (GE)		Basic events			OR (GE)		AND (GE)	
A	B	TE	GE2	GE1	GE3	C	D	E	TE	GE2	GE1	GE3
1	0	0	0	0	0	1	0	0	0	0	0	0
0	1	0	0	0	0	0	1	0	0	0	0	0
						0	0	1	0	0	0	0

Table S4. Fuzzy probability of failure for mitigation strategies using α–**c**ut principle

∝	Mitigation strategy 1		Mitigation strategy 2	
	Lower bound	Upper bound	Lower bound	Upper bound
0	37	88	43	95
0.05	38	87	45	95
0.1	39	87	47	94
0.15	40	86	48	94
0.2	42	85	50	93
0.25	42	84	51	93
0.3	44	83	53	92
0.35	44	83	54	92
0.4	46	82	56	91
0.45	47	81	57	91
0.5	48	80	58	90
0.55	49	79	59	89
0.6	50	78	61	89
0.65	51	77	62	88
0.7	52	76	64	87
0.75	53	75	65	86
0.8	54	74	66	86
0.85	55	73	67	85
0.9	56	72	68	84
0.95	57	71	69	83
1	58	70	71	82

Table S5. Fuzzy importance analysis of failure for mitigation strategies

Mitigation strategy	Event ID	(TE1)	(TE2)	FIM	Rank
1	A	64	55	14.06	3
	B	64	65	1.56	4
2	C	76.5	64	16.34	1
	D	76.5	64	16.34	1
	E	76.5	57.5	14.84	2

Table S6. Description of real estate development projects

Project No.	Project description	Project price (million EGP.)	Project location
1	Constructing 30 villas and 10 residential buildings	145	6 October City
2	Constructing 70 residential buildings	350	6 October City
3	Constructing 30 residential buildings	210	6 October City
4	Constructing 20 residential buildings	100	6 October City
5	Construction 50 town houses and 100 residential building	650	El-Sheikh Zayed City
6	Construction 120 residential buildings	600	6 October City
7	Construction 35 residential buildings	175	6 October City
8	Interior and exterior Finishes of 20 residential buildings	25	6 October City
9	Interior and exterior Finishing of 10 residential buildings	14	6 October City
10	Interior and exterior Finishing of 15 Villas	13	El-Sheikh Zayed City
11	Constructing 15 residential buildings	55	6 October City
12	Interior and exterior finishing of 10 residential buildings	10	El-Sheikh Zayed City
13	Interior and exterior finishing of five villas	6	El-Sheikh Zayed City
14	Construction and finishing of one commercial mall and 100 residential apartments	75	6 October City
15	Constructing 20 villas and 35 residential buildings	210	El-Sheikh Zayed City