

Supplementary material for the article “Alpha-cut based fuzzy cognitive maps with applications in decision-making”

DATA AND RESULTS RELATED TO:

ERP MAINTENANCE RISK MODEL

Table S.1 Strengths of causal relationships in ERP risk model

Causal connection	Sign	Strength of causal relationship		
		Crisp	T1 fuzzy	IT2 fuzzy
C ₁ →C ₂	+	0.220	(0,0.06,0.6)	((0,0.06,0.6;1),(0.005,0.06,0.595;0.8))
C ₁ →C ₅	+	0.257	(0,0.07,0.7)	((0,0.07,0.7;1),(0.005,0.07,0.695;0.8))
C ₁ →C ₉	+	0.273	(0,0.12,0.7)	((0,0.12,0.7;1),(0.005,0.12,0.695;0.8))
C ₁ →C ₁₀	+	0.147	(0,0.04,0.4)	((0,0.04,0.4;1),(0.005,0.04,0.395;0.8))
C ₁ →C ₁₃	-	0.086	(0,0.05,0.208)	((0,0.05,0.208;1),(0.005,0.05,0.203;0.8))
C ₂ →C ₆	+	0.110	(0,0.03,0.3)	((0,0.03,0.3;1),(0.005,0.03,0.295;0.8))
C ₂ →C ₁₁	+	0.337	(0,0.01,1)	((0,0.01,1;1),(0.005,0.01,0.995;0.8))
C ₂ →C ₁₃	-	0.150	(0,0.108,0.342)	((0,0.108,0.342;1),(0.005,0.108,0.337;0.8))
C ₃ →C ₄	+	0.418	(0,0.255,1)	((0,0.255,1;1),(0.005,0.255,0.995;0.8))
C ₃ →C ₅	+	0.408	(0,0.325,0.9)	((0,0.325,0.9;1),(0.005,0.325,0.895;0.8))
C ₃ →C ₆	+	0.395	(0,0.185,1)	((0,0.185,1;1),(0.005,0.185,0.995;0.8))
C ₃ →C ₇	+	0.183	(0,0.05,0.5)	((0,0.05,0.5;1),(0.005,0.05,0.495;0.8))
C ₄ →C ₃	+	0.300	(0,0.15,0.75)	((0,0.15,0.75;1),(0.005,0.15,0.745;0.8))
C ₄ →C ₅	+	0.268	(0,0.105,0.7)	((0,0.105,0.7;1),(0.005,0.105,0.695;0.8))
C ₅ →C ₄	+	0.147	(0,0.04,0.4)	((0,0.04,0.4;1),(0.005,0.04,0.395;0.8))
C ₅ →C ₆	+	0.542	(0,0.625,1)	((0,0.625,1;1),(0.005,0.625,0.995;0.8))
C ₅ →C ₈	+	0.390	(0,0.17,1)	((0,0.17,1;1),(0.005,0.17,0.995;0.8))
C ₅ →C ₁₃	-	0.050	(0,0.018,0.133)	((0,0.018,0.133;1),(0.005,0.018,0.128;0.8))
C ₆ →C ₈	+	0.220	(0,0.06,0.6)	((0,0.06,0.6;1),(0.005,0.06,0.595;0.8))
C ₆ →C ₁₃	-	0.103	(0,0.109,0.2)	((0,0.109,0.2;1),(0.005,0.109,0.195;0.8))
C ₇ →C ₆	+	0.240	(0,0.12,0.6)	((0,0.12,0.6;1),(0.005,0.12,0.595;0.8))
C ₇ →C ₈	+	0.293	(0,0.08,0.8)	((0,0.08,0.8;1),(0.005,0.08,0.795;0.8))
C ₇ →C ₁₃	-	0.068	(0,0.038,0.167)	((0,0.038,0.167;1),(0.005,0.038,0.162;0.8))
C ₈ →C ₆	+	0.203	(0,0.11,0.5)	((0,0.11,0.5;1),(0.005,0.11,0.495;0.8))
C ₈ →C ₁₁	+	0.293	(0,0.08,0.8)	((0,0.08,0.8;1),(0.005,0.08,0.795;0.8))
C ₈ →C ₁₃	-	0.065	(0,0.029,0.167)	((0,0.029,0.167;1),(0.005,0.029,0.162;0.8))
C ₁₀ →C ₁₃	-	0.036	(0,0.025,0.083)	((0,0.025,0.083;1),(0.005,0.025,0.078;0.8))
C ₁₁ →C ₁₃	-	0.094	(0,0.032,0.25)	((0,0.032,0.25;1),(0.005,0.032,0.245;0.8))
C ₁₂ →C ₂	+	0.347	(0,0.14,0.9)	((0,0.14,0.9;1),(0.005,0.14,0.895;0.8))
C ₁₂ →C ₆	+	0.360	(0,0.28,0.8)	((0,0.28,0.8;1),(0.005,0.28,0.795;0.8))
C ₁₂ →C ₇	+	0.272	(0,0.315,0.5)	((0,0.315,0.5;1),(0.005,0.315,0.495;0.8))
C ₁₂ →C ₈	+	0.128	(0,0.035,0.35)	((0,0.035,0.35;1),(0.005,0.035,0.345;0.8))
C ₁₂ →C ₁₀	+	0.073	(0,0.02,0.2)	((0,0.02,0.2;1),(0.005,0.02,0.195;0.8))
C ₁₂ →C ₁₁	+	0.073	(0,0.02,0.2)	((0,0.02,0.2;1),(0.005,0.02,0.195;0.8))
C ₁₂ →C ₁₃	-	0.189	(0,0.134,0.433)	((0,0.134,0.433;1),(0.005,0.134,0.428;0.8))

Table S.2 Simulation results of ERP risk model with hyperbolic tangent function

λ	Concept	Scenario 1			Scenario 2		
		Crisp	T1 fuzzy	IT2 fuzzy	Crisp	T1 fuzzy	IT2 fuzzy
1.0	C1	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))
	C2	0.265	(0,0.198,0.346)	((0,0.198,0.346;1), (0.063,0.198,0.345;0.8))	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))
	C3	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))	0.777	(0.031,0.625,0.931)	((0.031,0.625,0.931;1), (0.135,0.625,0.93;0.8))
	C4	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))	0.868	(0.031,0.723,0.98)	((0.031,0.723,0.98;1), (0.164,0.723,0.98;0.8))
	C5	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))	0.895	(0.031,0.789,0.987)	((0.031,0.789,0.987;1), (0.164,0.789,0.987;0.8))
	C6	0.770	(0,0.612,0.935)	((0,0.612,0.935;1), (0.164,0.612,0.933;0.8))	0.971	(0,0.932,0.999)	((0,0.932,0.999;1), (0.208,0.932,0.999;0.8))
	C7	0.245	(0,0.258,0.287)	((0,0.258,0.287;1), (0.063,0.258,0.286;0.8))	0.672	(0,0.436,0.871)	((0,0.436,0.871;1), (0.126,0.436,0.869;0.8))
	C8	0.765	(0,0.524,0.94)	((0,0.524,0.94;1), (0.153,0.524,0.939;0.8))	0.935	(0,0.751,0.997)	((0,0.751,0.997;1), (0.194,0.751,0.997;0.8))
	C9	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))
	C10	0.160	(0,0.104,0.213)	((0,0.104,0.213;1), (0.063,0.104,0.211;0.8))	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))
	C11	0.809	(0,0.484,0.969)	((0,0.484,0.969;1), (0.151,0.484,0.968;0.8))	0.786	(0,0.53,0.94)	((0,0.53,0.94;1), (0.142,0.53,0.939;0.8))
	C12	0.019	(0.017,0.018,0.019)	((0.017,0.018,0.019;1), (0.017,0.018,0.019;0.8))	0.000	(0,0,0)	((0,0,0;1), (0,0,0;0.8))
	C13	-0.784	(-0.937,-0.661,0)	((-0.937,-0.661,0;1), (-0.934,-0.661,-0.214;0.8))	-0.815	(-0.95,-0.704,0)	((-0.95,-0.704,0;1), (-0.947,-0.704,-0.23;0.8))
3.0	C1	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))
	C2	0.999	(0,0.998,1)	((0,0.998,1;1), (0.995,0.998,1;0.8))	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))
	C3	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))	0.999	(0.995,0.998,1)	((0.995,0.998,1;1), (0.995,0.998,1;0.8))
	C4	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))	1.000	(0.995,0.999,1)	((0.995,0.999,1;1), (0.995,0.999,1;0.8))
	C5	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))	1.000	(0.995,1,1)	((0.995,1,1;1), (0.995,1,1;0.8))
	C6	1.000	(0,1,1)	((0,1,1;1),(0.995,1,1;0.8))	1.000	(0,1,1)	((0,1,1;1), (0.995,1,1;0.8))
	C7	0.999	(0,0.999,1)	((0,0.999,1;1), (0.995,0.999,1;0.8))	0.998	(0,0.996,1)	((0,0.996,1;1), (0.995,0.996,1;0.8))
	C8	1.000	(0,0.998,1)	((0,0.998,1;1), (0.995,0.998,1;0.8))	1.000	(0,0.999,1)	((0,0.999,1;1), (0.995,0.999,1;0.8))
	C9	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))
	C10	0.997	(0,0.995,0.998)	((0,0.995,0.998;1), (0.995,0.995,0.998;0.8))	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))
	C11	1.000	(0,0.997,1)	((0,0.997,1;1), (0.995,0.997,1;0.8))	0.999	(0,0.997,1)	((0,0.997,1;1), (0.995,0.997,1;0.8))
	C12	0.995	(0.995,0.995,0.995)	((0.995,0.995,0.995;1), (0.995,0.995,0.995;0.8))	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))
	C13	-1.000	(-1,-1,0)	((-1,-1,0;1), (-1,-1,-0.996;0.8))	-0.999	(-1,-0.999,0)	((-1,-0.999,0;1), (-1,-0.999,-0.996;0.8))
5.0	C1	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))
	C2	1.000	(0,1,1)	((0,1,1;1),(1,1,1;0.8))	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))
	C3	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))	1.000	(1,1,1)	((1,1,1;1),(1,1,1;0.8))
	C4	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))	1.000	(1,1,1)	((1,1,1;1),(1,1,1;0.8))
	C5	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))	1.000	(1,1,1)	((1,1,1;1),(1,1,1;0.8))
	C6	1.000	(0,1,1)	((0,1,1;1),(1,1,1;0.8))	1.000	(0,1,1)	((0,1,1;1),(1,1,1;0.8))
	C7	1.000	(0,1,1)	((0,1,1;1),(1,1,1;0.8))	1.000	(0,1,1)	((0,1,1;1),(1,1,1;0.8))
	C8	1.000	(0,1,1)	((0,1,1;1),(1,1,1;0.8))	1.000	(0,1,1)	((0,1,1;1),(1,1,1;0.8))
	C9	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))
	C10	1.000	(0,1,1)	((0,1,1;1),(1,1,1;0.8))	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))
	C11	1.000	(0,1,1)	((0,1,1;1),(1,1,1;0.8))	1.000	(0,1,1)	((0,1,1;1),(1,1,1;0.8))
	C12	1.000	(1,1,1)	((1,1,1;1),(1,1,1;0.8))	0.000	(0,0,0)	((0,0,0;1),(0,0,0;0.8))
	C13	-1.000	(-1,-1,0)	((-1,-1,0;1),(-1,-1,-1;0.8))	-1.000	(-1,-1,0)	((-1,-1,0;1),(-1,-1,-1;0.8))

Table S.3 Simulation results of ERP risk model with sigmoid function

λ	Concept	Scenario 1				Scenario 2		
		Crisp	T1 fuzzy	IT2 fuzzy	Crisp	T1 fuzzy	IT2 fuzzy	
1.0	C1	0.659	(0.659,0.659,0.659)	((0.659,0.659,0.659;1), (0.659,0.659,0.659;0.8))	0.659	(0.659,0.659,0.659)	((0.659,0.659,0.659;1), (0.659,0.659,0.659;0.8))	
	C2	0.756	(0.659,0.696,0.864)	((0.659,0.696,0.864;1), (0.661,0.696,0.864;0.8))	0.756	(0.659,0.696,0.864)	((0.659,0.696,0.864;1), (0.661,0.696,0.864;0.8))	
	C3	0.721	(0.659,0.689,0.815)	((0.659,0.689,0.815;1), (0.66,0.689,0.814;0.8))	0.721	(0.659,0.689,0.815)	((0.659,0.689,0.815;1), (0.66,0.689,0.814;0.8))	
	C4	0.766	(0.659,0.715,0.889)	((0.659,0.715,0.889;1), (0.661,0.715,0.888;0.8))	0.766	(0.659,0.715,0.889)	((0.659,0.715,0.889;1), (0.661,0.715,0.888;0.8))	
	C5	0.815	(0.659,0.749,0.94)	((0.659,0.749,0.94;1), (0.662,0.749,0.94;0.8))	0.815	(0.659,0.749,0.94)	((0.659,0.749,0.94;1), (0.662,0.749,0.94;0.8))	
	C6	0.909	(0.659,0.862,0.989)	((0.659,0.862,0.989;1), (0.665,0.862,0.989;0.8))	0.909	(0.659,0.862,0.989)	((0.659,0.862,0.989;1), (0.665,0.862,0.989;0.8))	
	C7	0.741	(0.659,0.724,0.827)	((0.659,0.724,0.827;1), (0.661,0.724,0.826;0.8))	0.741	(0.659,0.724,0.827)	((0.659,0.724,0.827;1), (0.661,0.724,0.826;0.8))	
	C8	0.840	(0.659,0.729,0.968)	((0.659,0.729,0.968;1), (0.663,0.729,0.967;0.8))	0.840	(0.659,0.729,0.968)	((0.659,0.729,0.968;1), (0.663,0.729,0.967;0.8))	
	C9	0.709	(0.659,0.681,0.775)	((0.659,0.681,0.775;1), (0.66,0.681,0.774;0.8))	0.709	(0.659,0.681,0.775)	((0.659,0.681,0.775;1), (0.66,0.681,0.774;0.8))	
	C10	0.699	(0.659,0.67,0.761)	((0.659,0.67,0.761;1), (0.661,0.67,0.759;0.8))	0.699	(0.659,0.67,0.761)	((0.659,0.67,0.761;1), (0.661,0.67,0.759;0.8))	
	C11	0.793	(0.659,0.681,0.937)	((0.659,0.681,0.937;1), (0.662,0.681,0.937;0.8))	0.793	(0.659,0.681,0.937)	((0.659,0.681,0.937;1), (0.662,0.681,0.937;0.8))	
	C12	0.659	(0.659,0.659,0.659)	((0.659,0.659,0.659;1), (0.659,0.659,0.659;0.8))	0.659	(0.659,0.659,0.659)	((0.659,0.659,0.659;1), (0.659,0.659,0.659;0.8))	
	C13	0.455	(0.19,0.536,0.659)	((0.19,0.536,0.659;1), (0.198,0.536,0.65;0.8))	0.455	(0.19,0.536,0.659)	((0.19,0.536,0.659;1), (0.198,0.536,0.65;0.8))	
3.0	C1	0.944	(0.944,0.944,0.944)	((0.944,0.944,0.944;1), (0.944,0.944,0.944;0.8))	0.944	(0.944,0.944,0.944)	((0.944,0.944,0.944;1), (0.944,0.944,0.944;0.8))	
	C2	0.990	(0.944,0.97,0.999)	((0.944,0.97,0.999;1), (0.946,0.97,0.999;0.8))	0.990	(0.944,0.97,0.999)	((0.944,0.97,0.999;1), (0.946,0.97,0.999;0.8))	
	C3	0.979	(0.944,0.966,0.995)	((0.944,0.966,0.995;1), (0.945,0.966,0.995;0.8))	0.979	(0.944,0.966,0.995)	((0.944,0.966,0.995;1), (0.945,0.966,0.995;0.8))	
	C4	0.990	(0.944,0.978,0.999)	((0.944,0.978,0.999;1), (0.946,0.978,0.999;0.8))	0.990	(0.944,0.978,0.999)	((0.944,0.978,0.999;1), (0.946,0.978,0.999;0.8))	
	C5	0.997	(0.944,0.988,1)	((0.944,0.988,1;1), (0.947,0.988,1;0.8))	0.997	(0.944,0.988,1)	((0.944,0.988,1;1), (0.947,0.988,1;0.8))	
	C6	1.000	(0.944,0.999,1)	((0.944,0.999,1;1), (0.949,0.999,1;0.8))	1.000	(0.944,0.999,1)	((0.944,0.999,1;1), (0.949,0.999,1;0.8))	
	C7	0.986	(0.944,0.982,0.997)	((0.944,0.982,0.997;1), (0.946,0.982,0.997;0.8))	0.986	(0.944,0.982,0.997)	((0.944,0.982,0.997;1), (0.946,0.982,0.997;0.8))	
	C8	0.998	(0.944,0.981,1)	((0.944,0.981,1;1), (0.948,0.981,1;0.8))	0.998	(0.944,0.981,1)	((0.944,0.981,1;1), (0.948,0.981,1;0.8))	
	C9	0.976	(0.944,0.962,0.993)	((0.944,0.962,0.993;1), (0.945,0.962,0.993;0.8))	0.976	(0.944,0.962,0.993)	((0.944,0.962,0.993;1), (0.945,0.962,0.993;0.8))	
	C10	0.972	(0.944,0.954,0.991)	((0.944,0.954,0.991;1), (0.946,0.954,0.99;0.8))	0.972	(0.944,0.954,0.991)	((0.944,0.954,0.991;1), (0.946,0.954,0.99;0.8))	
	C11	0.994	(0.944,0.961,1)	((0.944,0.961,1;1), (0.947,0.961,1;0.8))	0.994	(0.944,0.961,1)	((0.944,0.961,1;1), (0.947,0.961,1;0.8))	
	C12	0.944	(0.944,0.944,0.944)	((0.944,0.944,0.944;1), (0.944,0.944,0.944;0.8))	0.944	(0.944,0.944,0.944)	((0.944,0.944,0.944;1), (0.944,0.944,0.944;0.8))	
	C13	0.104	(0.003,0.426,0.944)	((0.003,0.426,0.944;1), (0.003,0.426,0.936;0.8))	0.104	(0.003,0.426,0.944)	((0.003,0.426,0.944;1), (0.003,0.426,0.936;0.8))	
5.0	C1	0.993	(0.993,0.993,0.993)	((0.993,0.993,0.993;1), (0.993,0.993,0.993;0.8))	0.993	(0.993,0.993,0.993)	((0.993,0.993,0.993;1), (0.993,0.993,0.993;0.8))	
	C2	1.000	(0.993,0.997,1)	((0.993,0.997,1;1), (0.993,0.997,1;0.8))	1.000	(0.993,0.997,1)	((0.993,0.997,1;1), (0.993,0.997,1;0.8))	
	C3	0.998	(0.993,0.997,1)	((0.993,0.997,1;1), (0.993,0.997,1;0.8))	0.998	(0.993,0.997,1)	((0.993,0.997,1;1), (0.993,0.997,1;0.8))	
	C4	1.000	(0.993,0.998,1)	((0.993,0.998,1;1), (0.993,0.998,1;0.8))	1.000	(0.993,0.998,1)	((0.993,0.998,1;1), (0.993,0.998,1;0.8))	
	C5	1.000	(0.993,0.999,1)	((0.993,0.999,1;1), (0.994,0.999,1;0.8))	1.000	(0.993,0.999,1)	((0.993,0.999,1;1), (0.994,0.999,1;0.8))	
	C6	1.000	(0.993,1,1)	((0.993,1,1;1), (0.994,1,1;0.8))	1.000	(0.993,1,1)	((0.993,1,1;1), (0.994,1,1;0.8))	
	C7	0.999	(0.993,0.999,1)	((0.993,0.999,1;1), (0.993,0.999,1;0.8))	0.999	(0.993,0.999,1)	((0.993,0.999,1;1), (0.993,0.999,1;0.8))	
	C8	1.000	(0.993,0.999,1)	((0.993,0.999,1;1), (0.994,0.999,1;0.8))	1.000	(0.993,0.999,1)	((0.993,0.999,1;1), (0.994,0.999,1;0.8))	
	C9	0.998	(0.993,0.996,1)	((0.993,0.996,1;1), (0.993,0.996,1;0.8))	0.998	(0.993,0.996,1)	((0.993,0.996,1;1), (0.993,0.996,1;0.8))	
	C10	0.998	(0.993,0.995,1)	((0.993,0.995,1;1), (0.993,0.995,1;0.8))	0.998	(0.993,0.995,1)	((0.993,0.995,1;1), (0.993,0.995,1;0.8))	
	C11	1.000	(0.993,0.996,1)	((0.993,0.996,1;1), (0.994,0.996,1;0.8))	1.000	(0.993,0.996,1)	((0.993,0.996,1;1), (0.994,0.996,1;0.8))	
	C12	0.993	(0.993,0.993,0.993)	((0.993,0.993,0.993;1), (0.993,0.993,0.993;0.8))	0.993	(0.993,0.993,0.993)	((0.993,0.993,0.993;1), (0.993,0.993,0.993;0.8))	
	C13	0.016	(0.0,0.099,0.993)	((0.0,0.099,0.993;1), (0.0,0.099,0.991;0.8))	0.016	(0.0,0.099,0.993)	((0.0,0.099,0.993;1), (0.0,0.099,0.991;0.8))	