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ORIGINAL RESEARCH ARTICLE

Integrating blockchain in the healthcare sector: Adoption and challenges for sustainable waste management

Supplementary Files

Table S1. Expert panel background information

Area of expertise	Relevant experience (years)	Industry domain
Academia	13	Energy sector and sustainability consulting
Academia	5	Waste management
Academia	9	Blockchain consultant
Academia	12	Healthcare industry and hospitals
Academia	4	Environmental impact and sustainability
Industry	11	Medical professional
Industry	16	Logistics & supply chain
Industry	9	Logistics & supply chain
Industry	6	Private hospital administration
Industry	16	Public hospital administration

Table S2. Best and worst factors identified by each expert

Expert	Best factor (most critical)	Worst factor (least critical)
1	Lack of organizational vision and support	Interoperability and coordination issues
2	Data access and integrity issues	Health and environmental risks
3	Lack of organizational vision and support	Regulatory ambiguity and stakeholder trust issues
4	Lack of organizational vision and support	Lack of technical expertise
5	Data privacy and security concerns	Interoperability and coordination issues
6	Data privacy and security concerns	Scalability challenges
7	Resistance and lack of awareness	Infrastructure and design limitations
8	Infrastructure and design limitations	Lack of organizational vision and support
9	Data privacy and security concerns	Lack of technical expertise
10	Interoperability and coordination issues	Data access and integrity issues

Table S3. Triangular fuzzy number scale for linguistic judgments

Linguistic term	TFN
Very low (VL)	(1, 1, 2)
Low (L)	(1, 2, 3)
Medium (M)	(2, 3, 4)
High (H)	(3, 4, 5)
Very high (VH)	(4, 5, 6)
Extremely high (EH)	(5, 6, 7)

Table S4. Aggregated fuzzy values and defuzzified crisp values

Challenges	B2O		O2W	
	Fuzzy numbers	Crisp values	Fuzzy numbers	Crisp values
E1: Lack of organizational vision and support	(2.3,2.7,3.4)	2.75	(2.8,3.6,4.5)	3.62
E2: Resistance and lack of awareness	(3.3,4.1,5)	4.12	(2.5,3.2,4.2)	3.25
E3: Financial barriers	(2.5,3.1,4.1)	3.17	(2.1,2.9,3.9)	2.93
E4: Uncertain return on investment	(2, 2.8, 3.8)	2.83	(2.1,2.9,3.9)	2.93
E5: Infrastructure and design limitations	(2.4,3.2,4.1)	3.22	(2.6,3.2,4.1)	3.25
E6: Scalability challenges	(3.5,4.4,5.4)	4.42	(3.2,4,4.9)	4.02
E7: Data privacy and security concerns	(2.4,3.1,3.8)	3.10	(1.7,2.5,3.5)	2.53
E8: Lack of technical expertise	(2.9,3.9,4.9)	3.90	(2.6,3.3,4.1)	3.32
E9: Interoperability and coordination issues	(2.2,3,3.9)	3.02	(2.1,2.8,3.6)	2.82
E10: Lifecycle management gaps	(3.6,4.5,5.5)	4.52	(2.4,3.3,4.3)	3.32
E11: Regulatory ambiguity and stakeholder trust issues	(2.3,3.1,4.1)	3.13	(2.5,3.3,4.2)	3.32
E12: Health and environmental risks	(2.4,3.2,4.2)	3.23	(2.7,3.6,4.5)	3.60
E13: Data access and integrity issues	(2,2.7,3.6)	2.73	(2.2,3,3.9)	3.02

Notes: B_2O is better compared to other factors; O_2W means other factors are better compared to the worst factor.

Table S5. Aggregated structural self-interaction matrix

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
E1	0.8	0.6	0.4	0.4	0.5	0.6	0.6	0.5	0.5	0.5	0.2	0.6	0.5
E2	0.6	1	0.4	0.3	0.4	0.5	0.4	0.4	0.7	0.5	0.4	0.6	0.5
E3	0.7	0.8	0.9	0.7	0.5	0.9	0.3	0.4	0.5	0.5	0.4	0.4	0.4
E4	0.5	0.8	0.2	0.9	0.6	0.6	0.5	0.6	0.5	0.5	0.4	0.2	0.5
E5	0.5	0.6	0.4	0.7	0.9	0.6	0.6	0.3	0.6	0.7	0.7	0.3	0.5
E6	0.6	0.6	0.8	0.5	0.9	0.8	0.5	0.7	0.5	0.3	0.6	0.7	0.6
E7	0.4	0.4	0.6	0.7	0.2	0.6	0.9	0.7	0.7	0.4	0.5	0.3	0.6
E8	0.5	0.5	0.4	0.4	0.6	0.6	0.6	0.9	0.8	0.7	0.6	0.4	0.4
E9	0.6	0.6	0.6	0.3	0.2	0.4	0.3	0.7	0.9	0.6	0.5	0.2	0.7
E10	0.6	0.7	0.2	0.3	0.5	0.1	0.6	0.6	0.5	0.9	0.8	0.5	0.3
E11	0.5	0.6	0.4	0.7	0.6	0.5	0.5	0.4	0.4	0.5	0.8	0.5	0.7
E12	0.5	0.2	0.5	0.6	0.6	0.4	0.4	0.6	0.6	0.7	0.5	0.8	0.5
E13	0.6	0.6	0.2	0.4	0.6	0.4	0.5	0.3	0.4	0.5	0.4	0.6	0.8

Note: Expert-evaluated influence relationships among adoption challenges before thresholding.

Table S6. Initial reachability matrix

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
E1	1	0	0	0	0	0	0	0	0	0	0	0	0
E2	0	1	0	0	0	0	0	0	1	0	0	0	0
E3	1	1	1	1	0	1	0	0	0	0	0	0	0
E4	0	1	0	1	0	0	0	0	0	0	0	0	0
E5	0	0	0	1	1	0	0	0	0	1	1	0	0
E6	0	0	1	0	1	1	0	1	0	0	0	1	0
E7	0	0	0	1	0	0	1	1	1	0	0	0	0
E8	0	0	0	0	0	0	0	1	1	1	0	0	0
E9	0	0	0	0	0	0	0	1	1	0	0	0	1
E10	0	1	0	0	0	0	0	0	0	1	1	0	0
E11	0	0	0	1	0	0	0	0	0	0	1	0	1
E12	0	0	0	0	0	0	0	0	0	1	0	1	0
E13	0	0	0	0	0	0	0	0	0	0	0	0	1

Note: Binary matrix derived from the structural self-interaction matrix using a 0.7 threshold value.