



**ARAB ACADEMY FOR SCIENCE, TECHNOLOGY
AND MARITIME TRANSPORT**

College of Engineering and Technology

Construction and Building Engineering Department

**CONDITION ASSESSMENT FOR
INFRASTRUCTURE ASSETS USING BLOCKCHAIN**

4.0

By

Ahmed Ahmed Mousad Hassan Handouka

**A thesis submitted to AASTMT in partial
fulfillment of the requirements for the award of the degree of
MASTER OF SCIENCE**

in

CONSTRUCTION AND BUILDING ENGINEERING

Supervisors

Prof. Mohamed Ihab Elmasry

*Construction and Building Engineering
Department*

*Arab Academy for Science, Technology
and Maritime Transport, Alexandria*

Prof. Ahmed Abdelmoty Elhakeem

*Construction and Building Engineering
Department*

*Arab Academy for Science, Technology
and Maritime Transport, Cairo*

DECLARATION

I certify that all the material in this thesis that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this thesis reflect my own personal views, and are not necessarily endorsed by the University.

Name

Signature

Date

Dedication

I dedicate this thesis to my *Parents*.

Acknowledgments

First and foremost, I would like to thank God, whose guidance has led me this far. My thanks also go to several people whose support helped me bring forth this work. I would first like to express my sincere thanks and gratitude to my professors and supervisors, Prof. *Mohamed Ihab Elmasry* and Prof. *Ahmed Abdelmoty Elhakeem* for their keen interest, extensive assistance, guidance, motivation, generous support, and close supervision throughout working on this thesis. It has been a great honor to work with them and to learn from their experience.

Also, I would like to thank my family for their emotional support and encouragement that helped me overcome any challenge. I would like to thank my father, *Ahmed Handouka* for his unconditional support, my mother for her love and continuous prayers that enlightened my path; and my siblings, Alaa, and Mohamed of whom I will always be proud.

Thank you,

Ahmed M. Handouka

Abstract

Infrastructure networks like roads, bridges, and buildings have considerable value in the nations' economies. Infrastructure networks have been modernized and gained complexity over time, putting owning organizations worldwide under pressure to ensure their proper functionality and sustainability. Infrastructure Asset Management is the key solution to this challenge. It is the process of maintaining, upgrading, and operating infrastructure assets cost-effectively through a set of functions. The main function is to determine the assets conditions in the network, whether the current ones or the projected future conditions. Such function as such is the key for making optimum decisions and developing priority plans over the planning horizon. Both current and future conditions are highly dependent on information and data management. This data management may be an obstacle confronts seeking rational repair strategies.

Blockchain technology gained fame with the introduction of the Bitcoin cryptocurrency in 2009. It is used as a data management mechanism to distribute and circulate Bitcoin transactions safely. Later, researchers extended the use of blockchain to other areas. Blockchain technology is rapidly evolving and as 2022 the latest generation of Blockchain, Blockchain 4.0 was introduced. It integrates Blockchain with AI, adding a robust computation and decision analysis dimension to its original data management capabilities.

This research introduces blockchain-based AI condition assessment framework, for monitoring and assessing the current condition and predicting the future condition of building infrastructure assets. The framework follows a four-step methodology, as such: (1) developing a permissioned blockchain network to manage and exchange asset information while boosting collaboration and coordination between relevant stakeholders; (2) incorporating chain-codes to regulate the Blockchain's behavior; (3) incorporating a trained, tested, and validated ANN model to the prediction chain code to perform analytics and predict asset conditions; and (4) validating the system's workability and performance using two case studies and a created frontend interface. The system's performance is technically evaluated in terms of transfer latency, privacy & security, storage size, and system scalability. The average latency for the writing and reading was less than 5000 and 2000 milliseconds, respectively. Also, the system has the capability to be upscaled at any time to accommodate the use case under consideration without the need to rebuild the whole system.

The two case studies for validation are a minor one of 134 doors and a major global one of 35 buildings' structural system. The machine learning models were developed using NeuroSolutions Software Version 6.0. The ANNs included in the chain codes of the two case studies showed a promising result with R^2 values of 0.99, 0.98, and 0.99 for training, cross-validation, and testing sets, respectively, for doors ANN. While R^2 values of 0.98, 0.99, and 0.93 for training, cross-validation, and testing sets, respectively, for the structural system ANN. Which proves the reliability of the system.

Table of Contents

Declaration.....	ii
Dedication.....	iv
Acknowledgments.....	v
Abstract.....	vi
Table of Contents.....	vii
List of Tables.....	x
List of Figures.....	xi
Nomenclatures.....	xiii
1 Introduction.....	2
1.1 Infrastructural assets and the economy growth.....	2
1.2 Blockchains as an information management solution.....	3
1.3 Artificial neural networks as a reliable prediction technique.....	4
1.4 Research motivation.....	4
1.5 Research Objectives, Methodology and Scope.....	5
1.6 Thesis Organization.....	8
2 Literature Review.....	10
2.1 The Need for Asset Management.....	10
2.2 Asset Management Systems.....	10
2.3 Blockchain as a distributed ledger technology.....	14
2.3.1 Chain-codes.....	15
2.3.2 Evolution of Blockchain.....	16
2.3.3 Main blockchain platforms.....	17
2.3.4 Blockchain: An emerging trend.....	18
2.3.5 Blockchain potential applications in AECO industry.....	19
2.4 Artificial Neural Network (ANN).....	22
2.4.1 Neuron as a processing element.....	22
2.4.2 Neural Networks Structure.....	23
2.4.3 Activation Function.....	24
2.4.4 Backpropagation.....	24
2.4.5 Popular software.....	25
2.4.6 ANNs application in civil domains.....	25
2.5 Ordinary least square regression method (OLS).....	26

2.6	Blockchain and AI collaboration	26
2.6.1	Research gap	27
3	Research Methodology	30
3.1	Information management module	31
3.2	Condition assessment module	35
3.2.1	Decomposition of Educational Facility	35
3.2.2	Simplified Rolling-Up Approach	35
3.3	Condition prediction module	36
4	System development.....	38
4.1	Blockchain development	38
4.1.1	The Intelligent Chain-code Layer	40
4.1.2	Blockchain network layer	42
4.1.3	The frontend access layer	46
4.2	Case study 1	48
4.3	Defect/impact matrix	51
4.4	Neural Network Model	52
4.4.1	Identification of input and output parameters.....	52
4.4.2	Neural Network Topology	52
4.5	Case study 2	53
4.5.1	Subsystem/impact matrix	53
4.5.2	Neural Network Topology	57
5	System Assessment	59
5.1	BC Performance Evaluation	59
5.1.1	Transfer Latency	59
5.1.2	Privacy & Security	60
5.1.3	Storage Size	60
5.1.4	Scalability	61
5.2	ANNs performance evaluation.....	61
5.3	Doors model results.....	61
5.3.1	ANN and OLS performance comparison	66
5.4	Structure system model results	66
6	Conclusions, Limitations and Recommendations	72
6.1	Conclusions.....	72
6.2	Research Limitations	74
6.3	Recommendations for future work.....	75

Bibliography.....	77
Publications.....	83

List of Tables

Table 2.1 References of different condition scales	12
Table 2.2: Comparison between Ethereum and Hyperledger Fabric	17
Table 2.3: Hyperledger fabric elements with the corresponding description	18
Table 2.4 Recent BC Studies in the CEM Field.....	22
Table 3.1 Data Exchange’s Relationships.	31
Table 4.1 Inspection guide summary.....	49
Table 4.2 snapshot of doors data tables on MS Excel	51
Table 4.3 Defects/Impact Matrix	51
Table 4.4 Neural network input/output parameters of doors	52
Table 4.5. Subsystem/Impact matrix for the civil system	53
Table 4.6 overall Systems’ CI of building A.	54
Table 4.7 Snapshot of the structure system collected data for various sub systems.	55
Table 4.8 Different condition states with corresponding ratings.	56
Table 4.9 condition index (CI) according to the inspection committee’s decision.	56
Table 4.10 Neural network input/output parameters of the structural system.	57
Table 5.1. Summary of interior doors model results	62
Table 5.2 Summary of all results.	66
Table 5.3 Comparison of measurements between ANN & OLS.	66
Table 5.4. Summary of the structure system ANN model results.....	67

List of Figures

Figure 1.1 ASCE 2021 report card (Adapted from (ASCE, 2021)).....	2
Figure 1.2 Schools rating in USA	3
Figure 1.3 Illustration of research methodology	7
Figure 2.1 Rating Scales and Linguistic Representations (adapted from (Mohamed and Marzouk, 2021))	11
Figure 2.2. An aging model with different maintenance strategies (Adapted from (Elhakeem, 2005)).	13
Figure 2.3 After repair deterioration (Adapted from (Elhakeem, 2005)).	13
Figure 2.4 Illustration of blockchain concept.	15
Figure 2.5 Blockchain generations key-features	16
Figure 2.6 Bibliometric map of the co-occurrence of the top-30 keywords of documents including blockchain in the civil engineering and the construction industry in Scopus..	19
Figure 2.7 Summary of artificial neural network structure.....	23
Figure 2.8. Summary of activation functions.....	24
Figure 2.9. The connection between a neuron and its predecessor high weights neurons.	25
Figure 3.1 Methodology illustration.....	30
Figure 3.2 Blockchain architecture adopted from (Adel et al., 2022).....	33
Figure 3.3 Data flow in the system.....	34
Figure 3.4 AASTMT Portsaid branch breakdown.	35
Figure 3.5. CI Rolling up approach (Adapted from (Ali and Hegazy, 2013)).....	36
Figure 4.1 IBM platform components (Adapted from www.ibm.com).	39
Figure 4.2: IBM cloud console Interface.....	39
Figure 4.3 Snapshot of BC smart contract using Visual Studio Code.....	42
Figure 4.4 Kubernetes Cluster for Operating BBN.....	43
Figure 4.5 IBM cloud console launch interface	43
Figure 4.6: BBN Certificate Authorities.....	44
Figure 4.7 BCN Peer Nodes.....	44
Figure 4.8 Snapshot of IBM cloud Blockchain.....	45
Figure 4.9 Snapshot of Serverless Action - (Frontend Access)	47
Figure 4.10: Samples of functions that are used by the front-end interface.	48
Figure 4.11 Elements Coding System	49
Figure 4.12 The architecture of the neural network model.....	53
Figure 5.1 Latency test for different functions	60
Figure 5.2 Channel activation log	60
Figure 5.3 Training & cross-validation loss vs Epochs.....	63
Figure 5.4 Target & output data for various sets. (a) Target/output data for training set; (b) Target/output data for cross-validation set; (c) Target/output data for testing set.	64
Figure 5.5 Target and output data for all samples.	64
Figure 5.6 Percentage error distribution of all door samples.	65
Figure 5.7 coefficient of determination plots of ANN for various datasets. (a) R2 value for training dataset; (b) R2 value for cross-validation dataset; (c) R2 value for testing dataset; (d) R2 value for all datasets.	65

Figure 5.8 Training & cross-validation loss vs Epochs.....	67
Figure 5.9 Target & output data for various sets. (a) Target/output data for training set; (b) Target/output data for cross-validation set; (c) Target/output data for testing set.	69
Figure 5.10 Target and output data for all samples.	69
Figure 5.11 Percentage error distribution of all building samples	70
Figure 5.12 coefficient of determination plots of ANN for various datasets. (a) R2 value for training dataset; (b) R2 value for cross-validation dataset; (c) R2 value for testing dataset; (d) R2 value for all datasets.....	70

Nomenclatures

AEC: Architecture, Engineering, and Construction	10
AI: Artificial Intelligence.....	73
AMIS: Asset Management Information System	3
AMS: Asset Management Systems	2
ANNs: Artificial Neural Networks.....	2
API: Application Programming Interface.....	43
BaaS: Blockchain-as-a-Service	39
BCN: Blockchain Network	14
BCT: Blockchain Technology	2
CAPMAS:Central Agency for Public Mobilization and Statistics	10
CAs: Certificate Authorities.....	39
CI: Condition Index	5
CLI: Command Line Interface	33
GAs: Genetic Algorithms	11
HTTP: Hypertext Transfer Protocol.....	33
MAE: Mean Absolute Error.....	62
MAEP: Mean Absolute Error Percentage.....	62
ML: Machine Learning.....	31
MSE: Mean Squared Error.....	62
MSPs: Membership Service Providers	39
PTP: Peer-to-Peer	15
R ² : Coefficient of Determination	62
RMSE: Root Mean Squared Error.....	62
VSCoDe: Visual Studio Code.....	8

BIBLIOGRAPHY

Bibliography

- [1] ASCE. 2021. *Report card for America's infrastructure* [Online]. Available: <https://infrastructurereportcard.org/> [Accessed 20 February 2022].
- [2] Elhakeem, A. A., 2005. *An asset management framework for educational buildings with life-cycle cost analysis*, Waterloo: University of Waterloo
- [3] Robjent, L., Clark, P., Marti, M., Freese, R., Johnson, A. & County, C. 2019. *Asset Management Guide for Local Agencies*. Minnesota. Department of Transportation. Office of Research & Innovation.
- [4] Wu, L., Lu, W., Peng, Z. & Webster, C., 2023, A blockchain non-fungible token-enabled 'passport' for construction waste material cross-jurisdictional trading. *Automation in Construction*, 149 104783.
- [5] Wang, Z., Wang, T., Hu, H., Gong, J., Ren, X. & Xiao, Q., 2020, Blockchain-based framework for improving supply chain traceability and information sharing in precast construction. *Automation in Construction*, 111 103063.
- [6] Elghaish, F., Abrishami, S. & Hosseini, M. R., 2020, Integrated project delivery with blockchain: An automated financial system. *Automation in construction*, 114 103182.
- [7] Yin, W. & Ran, W., 2021, Theoretical Exploration of Supply Chain Viability Utilizing Blockchain Technology. *Sustainability*, 13 (15), 8231.
- [8] Turk, Ž. & Klinc, R., 2017, Potentials of blockchain technology for construction management. *Procedia engineering*, 196 638-645.
- [9] Hewavitharana, T., Nanayakkara, S. & Perera, S., 2019, Blockchain as a project management platform.
- [10] Kuhle, P., Arroyo, D. & Schuster, E., 2021, Building A blockchain-based decentralized digital asset management system for commercial aircraft leasing. *Computers in Industry*, 126 103393.
- [11] Penzes, B., KirNup, A., Gage, C., Dravai, T. & Colmer, M. Blockchain technology in the construction industry: Digital transformation for high productivity. Institution of civil engineers (ICE), 2018.
- [12] Ye, Z., Yin, M., Tang, L. & Jiang, H. Cup-of-Water theory: A review on the interaction of BIM, IoT and blockchain during the whole building lifecycle. ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction, 2018. IAARC Publications, 1-9.
- [13] Lokshina, I. V., Greguš, M. & Thomas, W. L., 2019, Application of integrated building information modeling, IoT and blockchain technologies in system design of a smart building. *Procedia computer science*, 160 497-502.
- [14] Yang, R., Wakefield, R., Lyu, S., Jayasuriya, S., Han, F., Yi, X., Yang, X., Amarasinghe, G. & Chen, S., 2020, Public and private blockchain in construction business process and information integration. *Automation in construction*, 118 103276.
- [15] Bartram, S. M., Branke, J. & Motahari, M., 2020. *Artificial intelligence in asset management*, CFA Institute Research Foundation.
- [16] Sun, H., Burton, H. V. & Huang, H., 2021, Machine learning applications for building structural design and performance assessment: State-of-the-art review. *Journal of Building Engineering*, 33 101816.
- [17] Fan, C., Sun, Y., Zhao, Y., Song, M. & Wang, J., 2019, Deep learning-based feature engineering methods for improved building energy prediction. *Applied energy*, 240 35-45.

- [18] Kecman, V., 2001. *Learning and soft computing: support vector machines, neural networks, and fuzzy logic models*, MIT press.
- [19] Matel, E., Vahdatikhaki, F., Hosseinyalamdary, S., Evers, T. & Voordijk, H., 2022, An artificial neural network approach for cost estimation of engineering services. *International journal of construction management*, 22 (7), 1274-1287.
- [20] Brandín, R. & Abrishami, S., 2021, Information traceability platforms for asset data lifecycle: blockchain-based technologies. *Smart Sustainable Built Environment*, 10 (3), 364-386.
- [21] Raslan, A., Kapogiannis, G., Cheshmehzangi, A., Tizani, W. & Towey, D. A framework for assembling Asset Information Models (AIMs) through permissioned blockchain. 2020 IEEE 44th Annual Computers, Software, and Applications Conference (COMPSAC), 2020a. IEEE, 529-534.
- [22] Adel, K., Elhakeem, A. & Marzouk, M., 2022, Decentralizing Construction AI Applications Using Blockchain Technology. *Expert Systems with Applications*, 194 116548.
- [23] Peraka, N. S. P. & Biligiri, K. P., 2020, Pavement asset management systems and technologies: A review. *Automation in Construction*, 119 103336.
- [24] Li, D., Cong, A. & Guo, S., 2019, Sewer damage detection from imbalanced CCTV inspection data using deep convolutional neural networks with hierarchical classification. *Automation in Construction*, 101 199-208.
- [25] Edirisinghe, R., Setunge, S. & Zhang, G., 2015, Markov model—based building deterioration prediction and ISO factor analysis for building management. *Journal of Management in Engineering*, 31 (6), 04015009.
- [26] Mohseni, H., Setunge, S., Zhang, G. & Wakefield, R., 2017, Markov process for deterioration modeling and asset management of community buildings. *Journal of Construction Engineering Management*, 143 (6), 04017003.
- [27] Dais, D., Bal, I. E., Smyrou, E. & Sarhosis, V., 2021, Automatic crack classification and segmentation on masonry surfaces using convolutional neural networks and transfer learning. *Automation in Construction*, 125 103606.
- [28] Rao, A. S., Nguyen, T., Palaniswami, M. & Ngo, T., 2021, Vision-based automated crack detection using convolutional neural networks for condition assessment of infrastructure. *Structural Health Monitoring*, 20 (4), 2124-2142.
- [29] Badger, W. W. & Garvin, M. J. Facilities asset management: a new career field for construction management graduates. Proceedings of the Associated Schools of Construction 43rd Annual International Conference, Flagstaff, AZ, USA, April, 2007. Citeseer, 12-14.
- [30] Bureau, U. S. C. 2022. *Value of Construction Put in Place in the United States* [Online]. Available: <https://www.census.gov/construction/c30/prpdf.html> [Accessed 1 February 2022].
- [31] Vanier, D. J., 2001, Why industry needs asset management tools. *J. Comput. Civ. Eng.*, 15 (1), 35-43.
- [32] CAPMAS. 2017a. "Distribution of buildings according to building type in 2017" [Online]. Available: https://www.capmas.gov.eg/Pages/StatisticsOracle.aspx?Oracle_id=1962&page_id=5109&YearID=23345 [Accessed 9 April 2022].
- [33] CAPMAS. 2017b. "Distribution of regular buildings according to the building's need for renovation in 2017" [Online]. Available: https://www.capmas.gov.eg/Pages/StatisticsOracle.aspx?Oracle_id=1962&page_id=5109&YearID=23345 [Accessed 9 April 2022].

- [34] Bureau, U. S. C. 2008. "Expenditures for Maintenance and Repairs and Improvements" [Online]. Available: <https://www.census.gov/construction/c50/c50index.html> [Accessed 1 February 2022].
- [35] Abbott, G. R., McDuling, J. J., Parsons, S. A. & Schoeman, J. C. Building condition assessment: a performance evaluation tool towards sustainable asset management. 2007-05 2007.
- [36] Mohamed, A. G. & Marzouk, M., 2021, Building condition assessment using artificial neural network and structural equations. *Expert Systems with Applications*, 186 115743.
- [37] Aktan, A. E., Farhey, D. N., Helmicki, A. J., Brown, D. L., Hunt, V. J., Lee, K.-L. & Levi, A., 1997, Structural identification for condition assessment: experimental arts. *Journal of structural engineering*, 123 (12), 1674-1684.
- [38] Elhakeem, A. & Hegazy, T. Improving deterioration modeling using optimized transition probability matrices for Markov chains. Proceedings of the 84th Transportation Research Board Annual Meeting, TRB, Washington, DC, USA, 2005.
- [39] Lounis, Z., Vanier, D. & Lacasse, M. A discrete stochastic model for performance prediction of roofing systems. Proc. CIB World Congress, 1998. Citeseer, 203-313.
- [40] Piaia, E., Maietti, F., Di Giulio, R., Schippers-Trifan, O., Van Delft, A., Bruinenberg, S. & Olivadese, R., 2021, BIM-based cultural heritage asset management tool. Innovative solution to orient the preservation and valorization of historic buildings. *International Journal of Architectural Heritage*, 15 (6), 897-920.
- [41] Schneider, J., Gaul, A. J., Neumann, C., Hogräfer, J., Wellßow, W., Schwan, M. & Schnettler, A., 2006, Asset management techniques. *International Journal of Electrical Power Energy Systems*, 28 (9), 643-654.
- [42] Nakamoto, S., 2008, Bitcoin: A peer-to-peer electronic cash system. *Decentralized Business Review*, 21260.
- [43] Tapscott, D. & Tapscott, A., 2016. *Blockchain revolution: how the technology behind bitcoin is changing money, business, and the world*, Penguin.
- [44] Hamledari, H. & Fischer, M., 2021, Role of blockchain-enabled smart contracts in automating construction progress payments. *Journal of legal affairs dispute resolution in engineering construction*, 13 (1), 04520038.
- [45] Lin, Y.-H., Ho, S. P., Wang, H.-K. & Hsu, W.-C. Application of Blockchain in Construction Inspection Activities. The 2nd international conference on computing and data science, 2021. 1-5.
- [46] Pilkington, M. 2016. Blockchain technology: principles and applications. *Research handbook on digital transformations*. Edward Elgar Publishing.
- [47] Tezel, A., Papadonikolaki, E., Yitmen, I. & Hilletoft, P., 2020, Preparing construction supply chains for blockchain technology: An investigation of its potential and future directions. *Frontiers of Engineering Management*, 7 (4), 547-563.
- [48] Mason, J. & Escott, H. Smart contracts in construction: Views and perceptions of stakeholders. Proceedings of FIG Conference, Istanbul May 2018, 2018. FIG.
- [49] Lu, W., Wu, L., Zhao, R., Li, X. & Xue, F., 2021a, Blockchain technology for governmental supervision of construction work: Learning from digital currency electronic payment systems. *Journal of construction engineering management*, 147 (10), 04021122.

- [50] Christidis, K. & Devetsikiotis, M., 2016, Blockchains and smart contracts for the internet of things. *Ieee Access*, 4 2292-2303.
- [51] Andoni, M., Robu, V., Flynn, D., Abram, S., Geach, D., Jenkins, D., McCallum, P. & Peacock, A., 2019, Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Renewable Sustainable Energy Reviews*, 100 143-174.
- [52] Dakhli, Z., Lafhaj, Z. & Mossman, A., 2019, The potential of blockchain in building construction. *Buildings*, 9 (4), 77.
- [53] Nawari, N. O. & Ravindran, S., 2019a, Blockchain technology and BIM process: review and potential applications. *Information Technology in Construction*, 24 (12), 209-238.
- [54] Mason, J., 2017, Intelligent contracts and the construction industry. *Journal of Legal Affairs Dispute Resolution in Engineering Construction*, 9 (3), 04517012.
- [55] Crosby, M., Pattanayak, P., Verma, S. & Kalyanaraman, V., 2016, Blockchain technology: Beyond bitcoin. *Applied Innovation*, 2 (6-10), 71.
- [56] Angelis, J. & da Silva, E. R., 2019, Blockchain adoption: A value driver perspective. *Business Horizons*, 62 (3), 307-314.
- [57] Plevris, V., Lagaros, N. D. & Zeytinci, A., 2022, Blockchain in civil engineering, architecture and construction industry: State of the art, evolution, challenges and opportunities. *Frontiers in Built Environment*, 49.
- [58] Qian, X. A. & Papadonikolaki, E., 2020, Shifting trust in construction supply chains through blockchain technology. *Engineering, Construction Architectural Management*,
- [59] Lu, W., Li, X., Xue, F., Zhao, R., Wu, L. & Yeh, A. G., 2021b, Exploring smart construction objects as blockchain oracles in construction supply chain management. *Automation in construction*, 129 103816.
- [60] Nawari, N. O. & Ravindran, S., 2019b, Blockchain and building information modeling (BIM): Review and applications in post-disaster recovery. *Buildings*, 9 (6), 149.
- [61] Xu, Y., Chong, H.-Y. & Chi, M., 2022, Blockchain in the AECO industry: Current status, key topics, and future research agenda. *Automation in Construction*, 134 104101.
- [62] Shojaei, A. J. E. b. D. O., Hossein Ataei, Mehdi Modares, Asli Pelin Gurgun, Siamak Yazdani, & Singh, A., 2019, Exploring applications of blockchain technology in the construction industry. *Proceedings of International Structural Engineering Construction*, 6
- [63] Raslan, A., Kapogiannis, G., Cheshmehzangi, A., Tizani, W. & Towey, D. Blockchain: future facilitator of asset information modelling and management? 2020 IEEE 44th Annual Computers, Software, and Applications Conference (COMPSAC), 2020b. IEEE, 523-528.
- [64] Luo, H., Das, M., Wang, J. & Cheng, J. C. Construction payment automation through smart contract-based blockchain framework. ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction, 2019. IAARC Publications, 1254-1260.
- [65] Das, M., Luo, H. & Cheng, J. C., 2020, Securing interim payments in construction projects through a blockchain-based framework. *Automation in construction*, 118 103284.
- [66] Pattini, G., Di Giuda, G. M. & Tagliabue, L. C. 2020. Blockchain application for contract schemes in the construction industry. *Proceedings of International*

- Structural Engineering and Construction-Holistic Overview of Structural Design and Construction.*
- [67] Daniels, J., Sargolzaei, S., Sargolzaei, A., Ahram, T., Laplante, P. A. & Amaba, B., 2018, The internet of things, artificial intelligence, blockchain, and professionalism. *IT Professional*, 20 (6), 15-19.
- [68] Banotra, A., Gupta, S., Gupta, S. K. & Rashid, M. 2021. Asset security in data of Internet of Things using blockchain technology. *Multimedia Security*. Springer.
- [69] Ni, Y., Sun, B. & Wang, Y., 2021, Blockchain-Based BIM Digital Project Management Mechanism Research. *IEEE Access*, 9 161342-161351.
- [70] Xu, J., Liu, H. & Han, Q., 2021, Blockchain technology and smart contract for civil structural health monitoring system. *Computer-Aided Civil Infrastructure Engineering*, 36 (10), 1288-1305.
- [71] Das, M., Tao, X., Liu, Y. & Cheng, J. C., 2022, A blockchain-based integrated document management framework for construction applications. *Automation in Construction*, 133 104001.
- [72] Karsoliya, S., 2012, Approximating number of hidden layer neurons in multiple hidden layer BPNN architecture. *International Journal of Engineering Trends Technology*, 3 (6), 714-717.
- [73] Hagan, M. T., Demuth, H. B. & Beale, M., 1997. *Neural network design*, PWS Publishing Co.
- [74] Gurney, K., 2018. *An introduction to neural networks*, CRC press.
- [75] Günaydın, H. M. & Doğan, S. Z., 2004, A neural network approach for early cost estimation of structural systems of buildings. *International journal of project management*, 22 (7), 595-602.
- [76] Chollet, F., 2021. *Deep learning with Python*, Simon and Schuster.
- [77] Field, A., 2013. *Discovering statistics using IBM SPSS statistics*, sage.
- [78] Adeli, H., 2001, Neural networks in civil engineering: 1989–2000. *Computer-Aided Civil Infrastructure Engineering*, 16 (2), 126-142.
- [79] Angulo, A., Vega-Fernández, J. A., Aguilar-Lobo, L. M., Natraj, S. & Ochoa-Ruiz, G. Road damage detection acquisition system based on deep neural networks for physical asset management. Mexican International Conference on Artificial Intelligence, 2019. Springer, 3-14.
- [80] Assaad, R. & El-adaway, I. H., 2020, Bridge infrastructure asset management system: Comparative computational machine learning approach for evaluating and predicting deck deterioration conditions. *Journal of Infrastructure Systems*, 26 (3), 04020032.
- [81] Tijanić, K., Car-Pušić, D. & Šperac, M., 2020, Cost estimation in road construction using artificial neural network. *Neural Computing Applications*, 32 (13), 9343-9355.
- [82] Perez, H., Tah, J. H. & Mosavi, A., 2019, Deep learning for detecting building defects using convolutional neural networks. *Sensors*, 19 (16), 3556.
- [83] Zhang, H., Feng, H., Hewage, K. & Arashpour, M., 2022, Artificial Neural Network for Predicting Building Energy Performance: A Surrogate Energy Retrofits Decision Support Framework. *Buildings*, 12 (6), 829.
- [84] Kim, G.-H., An, S.-H. & Kang, K.-I., 2004, Comparison of construction cost estimating models based on regression analysis, neural networks, and case-based reasoning. *Building and environment*, 39 (10), 1235-1242.
- [85] Hong, J., Choi, H. & Kim, W.-s., 2020, A house price valuation based on the random forest approach: the mass appraisal of residential property in South Korea. *International Journal of Strategic Property Management*, 24 (3), 140-152.

- [86] Zheng, Z., Xie, S., Dai, H.-N., Chen, X. & Wang, H., 2018, Blockchain challenges and opportunities: A survey. *International Journal of Web Grid Services*, 14 (4), 352-375.
- [87] Lei, X., Xia, Y., Komarizadehasl, S. & Sun, L. Condition level deteriorations modeling of RC beam bridges with U-Net convolutional neural networks. *Structures*, 2022. Elsevier, 333-342.
- [88] Mohseni, H. 2012. *Deterioration prediction of community buildings in Australia*. RMIT University.
- [89] Ekici, B. B. & Aksoy, U. T., 2009, Prediction of building energy consumption by using artificial neural networks. *Advances in Engineering Software*, 40 (5), 356-362.
- [90] Ali, A. & Hegazy, T. Performance assessment framework for healthcare facilities. 4th Specialty Conference on Coastal, Estuary and Offshore Engineering, Montreal, QC, 2013.

المستخلص

شبكات البنية التحتية مثل الطرق والجسور والمباني لها قيمة كبيرة في اقتصادات الدول. تم تحديث شبكات البنية التحتية واكتسبت تعقيداً بمرور الوقت ، مما وضع المنظمات المالكة في جميع أنحاء العالم تحت ضغط لضمان وظائفها المناسبة واستدامتها. إدارة أصول البنية التحتية هي الحل الرئيسي لهذا التحدي. إنها عملية صيانة أصول البنية التحتية وتحديثها وتشغيلها بطريقة فعالة من حيث التكلفة من خلال مجموعة من الوظائف. وتتمثل الوظيفة الرئيسية في تحديد حالة هذه الأصول في الشبكة ، سواء كانت الحالة الحالية أو المستقبلية المتوقعة. هذه الوظيفة على هذا النحو هي المفتاح لاتخاذ القرارات المثلى وتطوير خطط الأولوية على مدى أفق التخطيط. تعتمد كل من الحالات الحالية والمستقبلية بشكل كبير على إدارة المعلومات والبيانات. قد تكون إدارة البيانات هذه عقبة تواجه البحث عن استراتيجيات إصلاح عقلانية.

اكتسبت تقنية قواعد البيانات المتسلسلة (Blockchain) شهرة مع ظهور عملة البيتكوين الافتراضية (Bitcoin) عام 2009. حيث تم استخدامها كألية لإدارة البيانات لتوزيع وتداول تحويلات Bitcoin بأمان. في وقت لاحق ، وسع الباحثون استخدام قواعد البيانات المتسلسلة إلى مجالات أخرى. حيث تطورت تقنية قواعد البيانات المتسلسلة بسرعة، وفي عام 2022 تم تقديم أحدث جيل من قواعد البيانات المتسلسلة Blockchain 4.0 بحيث يتم دمج قواعد البيانات المتسلسلة مع الذكاء الاصطناعي ، مضيفاً بُعداً ثورياً قوياً لتحليل البيانات اضافة إلى قدراتها في إدارة البيانات.

يقدم هذا البحث إطار عمل لتقييم الحالة لاصول البنية التحتية باستخدام الذكاء الاصطناعي المستند إلى قواعد البيانات المتسلسلة، من أجل مراقبة وتقييم الحالة الحالية والتنبؤ بالحالة المستقبلية لأصول البنية التحتية للمباني. يتبع إطار العمل منهجية من أربع خطوات ، على النحو التالي: (1) تطوير شبكة blockchain مرخصة لإدارة وتبادل معلومات الأصول مع تعزيز التعاون والتنسيق بين أصحاب المصلحة المعنيين ؛ (2) إنشاء مجموعة من الاكواد لتنظيم عمل blockchain ؛ (3) دمج نماذج تقنية الشبكات العصبية الصناعية (ANN) مدربة ومختبرة في الاكواد شبكة blockchain لإجراء التحليلات والتنبؤ بحالة الأصول؛ و (4) التحقق من قابلية تشغيل النظام وأدائه باستخدام دراستي حالة وواجهة أمامية تم إنشاؤها. يتم تقييم أداء النظام تقنياً من حيث وقت الاستجابة، الخصوصية والأمان، حجم التخزين واخيرا قابلية تطوير النظام. كان متوسط وقت الاستجابة لعمليات الكتابة والقراءة أقل من 5000 و 2000 مللي ثانية ، على التوالي. أيضاً ، يتمتع النظام بإمكانية الارتقاء في أي وقت لاستيعاب حالة الاستخدام قيد النظر دون الحاجة إلى إعادة بناء النظام بأكمله.

دراسا الحالة للتحقق من الصحة عبارة عن دراسة حالة ثانوية لعدد من 134 بابًا ودراسة حالة رئيسية لعدد 35 نظامًا هيكلياً لمباني قائمة. تم تطوير نماذج التعلم الآلي باستخدام الإصدار 6.0 من برنامج Neuro-Solutions. أظهرت نماذج ANN المدرجة في كود السلسلة الخاصة بدراستي الحالة نتائج واعدة بقيم R2 تبلغ 0.99 و 0.98 و 0.99 لمجموعات التدريب والتحقق المتبادل و الاختبار، على التوالي، للأبواب. بينما قيم R2 تبلغ 0.98 و 0.99 و 0.93 لمجموعات التدريب والتحقق المتبادل والاختبار، على التوالي، للنظام الهيكلي. مما يثبت موثوقية النظام.

إقرار الباحث

أقر بأن المادة العلمية الواردة في هذه الرسالة قد تم تحديد مصدرها العلمي وأن محتوى الرسالة غير مقدم للحصول علي أي درجة علمية أخرى، وأن مضمون هذه الرسالة يعكس آراء الباحث الخاصة وهي ليست بالضرورة الآراء التي تتبناها الجهة المانحة.

..... الاسم

..... التوقيع

..... التاريخ



الأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري
كلية الهندسة والتكنولوجيا
قسم هندسة التشييد والبناء

تقييم الحالة لاصول البنية التحتية باستخدام نهج قواعد البيانات المتسلسلة 4.0

إعداد

احمد احمد مسعد حسن حندوقه

رسالة مقدمة للأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري لاستكمال متطلبات نيل درجة

ماجستير العلوم

في

هندسة التشييد والبناء

إشراف

أ.د. احمد عبدالمعطي الحكيم

قسم هندسة التشييد والبناء

كلية الهندسة والتكنولوجيا

الأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري

القاهرة

أ.د. محمد ايهاب المصري

قسم هندسة التشييد والبناء

كلية الهندسة والتكنولوجيا

الأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري

الأسكندرية