1. Introduction

* 70-80% of a facility's costs occur during operations and maintenance phase. A 2018 NIST study found $50B is spent annually on operations and maintenance in the U.S.
* Implementing artificial intelligence (AI) into facility operations and maintenance processes could reduce costs.
* This systematic review investigates how AI can be used with predictive maintenance to reduce operations and maintenance costs in facility operations.

1. Literature background

* Organizations use various maintenance strategies like preventive maintenance (work done at fixed intervals), corrective maintenance (repairs to restore equipment to original state), and predictive maintenance (using monitoring and data to resolve problems before failure).
* AI encompasses techniques like neural networks, machine learning, and expert systems to analyze data and make decisions. AI is expanding rapidly into many industries.

2.1 Research question

* The research question is: How can AI be used with predictive maintenance to reduce operations and maintenance costs in facility operations?
* The theoretical lens is adaptive structuration theory.

1. Theory

* Adaptive structuration theory (AST) examines organizational change from introducing new technology and how people interact with it to create new structures.
* Key concepts are structures (tasks and boundaries), systems (relationships between people and tech), and appropriation (people adapting to new tech).

1. Method

* A rapid evidence assessment (REA) was conducted, an evidence-based management approach to deliver timely recommendations with limited resources.

4.1 Search strategy and inclusion/exclusion criteria

* Searched two databases (ScienceDirect and OneSearch) for peer-reviewed articles published within last 5 years on predictive/proactive maintenance of facility systems using AI.

4.2 Study selection

* 60 articles found initially. Duplicates removed and abstracts screened, resulting in 14 final articles for the REA.

4.3 Critical quality appraisal

* TAPUPAS tool used to appraise articles on 7 criteria. Articles scoring 14+ out of 21 were included. 3 articles eliminated, leaving 14.

4.4 Description of data set and critical appraisal

* Of the 14 articles, 1 was qualitative, 1 mixed methods, 12 quantitative.
* Subjectivity in TAPUPAS scoring is a limitation.

4.5 Coding

* Descriptive coding used in first and second cycle coding to develop themes from the 14 articles.
* Atlas.TI software used to assist coding process.

5.1 Finding 1

* AI enables remote monitoring of facility system conditions in real-time.

5.2 Finding 2

* AI provides unbiased data-backed recommendations for facility system repair, investment, and responses.

5.3 Finding 3

* AI can increase facility system online time by enabling predictive maintenance.

5.4 CERQual

* Confidence in Evidence from Reviews of Qualitative Research (CERQual) framework used to evaluate confidence in the findings.
* All 3 findings assessed as moderate confidence.

6.Discussion

* Current literature shows AI expanding into facility management but focuses on individual systems rather than entire programs.
* AI can provide remote monitoring, unbiased decision-making, and increased uptime, but more research is needed on full implementation.

6.1 Recommendations for practice

1. Start small with targeted AI implementation as research is limited on full program transition.
2. Establish strategic plan to transition from reactive to predictive maintenance using AI.
3. Make AI implementation an organization-wide strategic initiative with executive support.

6.2 Future research

* Cost-benefit analysis of implementing AI in facility management is needed.
* Research common communication standards for facility support systems to enable AI monitoring.
* Checklists for transitioning to AI-enabled predictive maintenance should be developed.

6.3 Limitations

* Research conducted by a student with developing qualitative analysis skills.
* Single reviewer introduced potential bias in article appraisal.
* Researcher's professional experience may have introduced bias but was mitigated by following rapid evidence assessment guidelines strictly.
  1. Conclusion
* This systematic review found evidence that AI combined with predictive maintenance can reduce costs in facility operations.
* AI enables remote monitoring, data-driven decisions, and increased uptime.
* More research is needed on enterprise-wide implementation of AI in facility management.

Regarding datasets and ML techniques:

* The articles reviewed used a variety of datasets, including real-world sensor data from buildings, work order records, equipment inventories, and building information modeling (BIM) data.
* Machine learning techniques employed included artificial neural networks (ANN), support vector machines (SVM), Bayesian networks, and deep learning models.
* Successful implementation involved integrating AI with existing systems like BIM, computerized maintenance management systems (CMMS), and Internet of Things (IoT) networks.
* A phased approach starting with individual critical systems was recommended before attempting full-scale deployment.

DEFINITIONS:

1. MMS (Computerized Maintenance Management System):
   1. A software package that maintains a computer database of information about an organization's maintenance operations. It helps maintenance workers do their jobs more effectively and efficiently by tracking work orders, scheduling preventive maintenance, managing inventory, and providing reports.
2. BIM (Building Information Modeling):
   1. A process supported by various tools and technologies involving the generation and management of digital representations of physical and functional characteristics of buildings. BIM allows for collaboration between different stakeholders at different phases of the building life cycle.
3. IoT (Internet of Things):
   1. A system of interrelated computing devices, mechanical and digital machines, objects, or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.
4. ANN (Artificial Neural Network):
   1. A type of machine learning model inspired by the structure and function of the human brain. It consists of interconnected nodes (neurons) that process and transmit information, learning to recognize patterns and make decisions based on input data.
5. SVM (Support Vector Machine):
   1. A type of machine learning model used for classification, regression, and outlier detection. SVMs find the hyperplane in an N-dimensional space that maximally separates data points of different classes.
6. Bayesian Network:
   1. A probabilistic graphical model that represents a set of variables and their conditional dependencies via a directed acyclic graph. Bayesian networks are used for reasoning under uncertainty and for learning causal relationships.
7. Deep Learning:
   1. A subset of machine learning based on artificial neural networks with multiple layers. Deep learning allows computational models composed of multiple processing layers to learn data representations with multiple levels of abstraction, enabling the discovery of complex patterns in large datasets.
8. RUL (Remaining Useful Life):
   1. The length of time a machine or component is likely to operate before it requires repair or replacement. Estimating RUL is a key goal of predictive maintenance.
9. Digital Twin:
   1. A digital replica of a physical object, process, or system. It acts as a bridge between the physical and digital world, using real-time data to create simulations that can predict how a product will perform.
10. Industry 4.0:
    1. The ongoing automation and data exchange trend in manufacturing technologies, sometimes referred to as the Fourth Industrial Revolution. It includes cyber-physical systems, IoT, cloud computing, and AI.