ISBN 978-989-9121-49-2
60th ISTANBUL International Conference on Advances in "Science, Engineering & Technology" (IASET-25)
Istanbul (Turkiye) May. 22-23, 2025

Knowledge Management System Design for Industrial Technology Management with Ontology

Choat Inthawongse[1] and Noppadol Amdee[2]

[1,2]Industrial Technology Management Program, Faculty of Industrial Technology,
Muban Chom Bueng Rajabhat University, Ratchaburi Province, Thailand

***Abstract*:** *This research addresses the critical challenge of effective knowledge management within the complex domain of industrial technology, leveraging ontology to facilitate both explicit and tacit knowledge integration. It presents a novel approach to structuring and utilizing knowledge for enhanced efficiency and innovation in industrial settings. The objectives are: 1) to design a domain-specific ontology optimized for tacit knowledge representation and management, and 2) to develop a knowledge management system for industrial technology based on this ontology. The knowledge elicitation process yielded an ontology structured with 11 core classes (Technology, Organization, Process, Innovation Process, Project, Resource, Market Factor, Skill, Knowledge, Regulation, Performance Indicator, and Innovation Process) and their interrelationships, which offers a robust framework for knowledge representation. System evaluation, conducted across multiple trials, demonstrates high accuracy, consistently achieving results between 80% and 100%. Specifically, the mean accuracy across trials ranged from 83% to 87%, with limited outliers, indicating strong reliability. Furthermore, the ontology's completeness across 6 dimensions (Production Technology, Information Systems, Innovation, etc.) was evaluated, revealing distinct distribution patterns and a high degree of coverage in key areas. This research contributes a valuable and validated framework and system prototype for advanced knowledge management in industrial technology, with potential applications in areas such as Industry 4.0, digital transformation, and smart manufacturing, offering a pathway to improved decision-making, process optimization, and accelerated innovation cycles.*

Keywords: *Industrial Technology Management, Knowledge Management, Ontology Engineering*

1. Introduction

In today's rapidly evolving industrial landscape, effective knowledge management is crucial. However, the complexity of industrial technology presents unique challenges. The complexity of industrial technology presents unique challenges, particularly in capturing, structuring, and utilizing both explicit and tacit knowledge to drive innovation and efficiency. This question is central to this research. This research addresses the critical need for enhanced knowledge management in the field of Industrial Technology Management (ITM).

Industrial technology is inherently complex [1], with knowledge derived from diverse backgrounds, encompassing both explicit knowledge (theory) and tacit knowledge (experience) [6]. Traditional approaches often fall short in capturing the nuanced, experience-based knowledge that is vital for problem-solving and innovation. This gap hinders our ability to fully leverage valuable insights. This is where ontologies offer a powerful solution to bridge this gap.

Ontologies provide a structured framework for representing knowledge, enabling the integration of explicit knowledge (documents, procedures) and tacit knowledge (individual know-how). By establishing a shared

https://doi.org/10.17758/HEAIG17.DiR0525141

understanding of key concepts and their relationships, ontologies facilitate more effective knowledge sharing, retrieval, and application, paving the way for enhanced collaboration and decision-making. By creating a shared understanding of key concepts and their relationships, ontologies facilitate knowledge sharing, retrieval, and application.

This research holds the potential to transform knowledge management practices in industrial technology, offering a pathway to improved decision-making, process optimization, and accelerated innovation cycles. Our research aims to: 1) design a domain-specific ontology tailored for industrial technology, and 2) develop a knowledge management system leveraging this ontology. We employed a rigorous methodology, including knowledge acquisition, ontology design, development, and evaluation, to create a practical and effective solution. This systematic approach ensures the robustness and applicability of our findings.

In the following presentation, we will delve into the specifics of our ontology design, system architecture, and evaluation results, demonstrating its potential to transform knowledge management practices in industrial technology.

2. Theoretical Foundations

2.1. Knowledge Management (KM) Foundation

Knowledge Management (KM) is a strategic and systematic approach to managing an organization's knowledge assets. It encompasses the processes, tools, and techniques that facilitate the creation, organization, storage, sharing, and application of knowledge. The goal of KM is to enhance organizational effectiveness, improve decision-making, and foster innovation by ensuring that the right knowledge is available to the right people at the right time. In essence, Table I summarizes the key components of Knowledge Management, KM seeks to transform individual and collective knowledge into a valuable organizational resource.

TABLE I: Key Components of Knowledge Management

Component	Description	Details
People	Creators, holders, and users of knowledge	Considerations: Culture, Collaboration, Trust, Motivation
Processes	Framework for managing knowledge lifecycle	Specific processes: Knowledge Identification, Knowledge Creation and Acquisition, Knowledge Organization and Storage, Knowledge Sharing and Dissemination, Knowledge Application and Use
Technology	Tools and platforms supporting KM processes	Examples: Knowledge repositories, Collaboration tools, Content management systems, Search engines, Artificial intelligence

- The SECI Model

One of the most influential frameworks for understanding how knowledge is created and shared within organizations is the SECI model, developed by Nonaka and Takeuchi (1995):

1) **Socialization:** This involves the sharing of tacit knowledge through direct interaction, observation, and shared experiences, such as on-the-job training, mentoring, and communities of practice.
2) **Externalization:** This is the process of articulating tacit knowledge and converting it into explicit forms, such as documents, manuals, and databases.
3) **Combination:** This involves integrating different forms of explicit knowledge to create new knowledge, such as through synthesis, analysis, and conceptualization.
4) **Internalization:** This is the process of converting explicit knowledge into tacit knowledge as individuals internalize and apply it in their work.

The SECI model highlights the dynamic interplay between tacit and explicit knowledge and emphasizes the importance of both in the knowledge creation process.

2.2. Ontology Engineering (OE) Foundation

Ontology engineering is a field that applies ontological theories to the design and implementation of knowledge-based systems. It provides a set of principles and methodologies for building ontologies, which are formal representations of knowledge within a specific domain.

Key Aspects of Ontology Engineering

- Ontology Development Process: This process involves several stages, including:
- Determining the scope of the ontology
- Reusing existing ontologies
- Enumerating important terms
- Defining classes and class hierarchy
- Defining properties of classes
- Defining facets of the properties
- Creating instances

Ontology Languages: Ontology languages provide a formal syntax and semantics for representing ontologies. Examples include:

1) OWL (Web Ontology Language): A standard language for building ontologies, allowing for rich knowledge representation and reasoning.
2) RDF (Resource Description Framework): A language for representing metadata and relationships between resources.
3) XML (Extensible Markup Language): A markup language used for structuring and encoding documents.

Ontology Tools: Various tools support the development, management, and application of ontologies. For example, Protégé is a popular open-source ontology editor that provides a user-friendly interface for creating and editing ontologies.

2.3. Ontologies in Knowledge Management

Ontologies are playing an increasingly important role in knowledge management (KM) by providing a structured framework for representing and organizing knowledge. Traditional KM approaches often struggle with the complexity and heterogeneity of knowledge, particularly in domains like industrial technology. Ontologies offer a solution by enabling the integration of both explicit and tacit knowledge, thus facilitating more effective knowledge sharing, retrieval, and application.

Key Benefits of Ontologies for KM

1) Enhanced Knowledge Representation: Ontologies provide a formal and explicit representation of concepts within a domain, along with their relationships. This structured approach allows for a more precise and unambiguous representation of knowledge compared to traditional methods like keywords or unstructured text.
2) Improved Knowledge Sharing: By providing a shared vocabulary and understanding of a domain, ontologies facilitate communication and knowledge exchange among individuals, teams, and systems. This is particularly valuable in complex domains where different stakeholders may use different terms or have varying interpretations of concepts [4].

3) Effective Knowledge Retrieval: Ontologies enable more intelligent and context-aware knowledge retrieval. Semantic search techniques, powered by ontologies, allow users to find relevant information based on the meaning of their queries, rather than just matching keywords.
4) Knowledge Integration: Ontologies can be used to integrate knowledge from diverse and heterogeneous sources. By mapping different data sources to a common ontology, organizations can create a unified view of their knowledge assets.
5) Support for Reasoning and Inference: Ontologies, especially those based on Description Logics, support automated reasoning and inference. This allows systems to deduce new knowledge from existing knowledge, which can be valuable for tasks such as decision support and problem-solving.

Ontology-Based KM Systems

Ontology-based KM systems leverage ontologies to provide a range of knowledge management functionalities, including:

- Knowledge capture and creation
- Knowledge storage and organization
- Knowledge retrieval and search
- Knowledge sharing and collaboration
- Knowledge application and reuse

By providing a structured and semantic-rich foundation for knowledge [6], ontologies enhance the effectiveness of KM initiatives and enable organizations to better leverage their intellectual capital.

3. Ontology Development

The development of ontology for linking the knowledge base of those involved in industrial technology management will be carried out by domain experts, ontology engineers, and instructors. This will ensure that ontology represents complete knowledge. The developed ontology will support the reuse of knowledge that is separate from operational knowledge. The general steps are as follows [2]:

1. **Determine the Domain and Scope of the Ontology**: In this step, the framework and domain of the knowledge source to be studied are identified, along with the goals and scope of the ontology to be developed.
2. **Consider Reusing Existing Ontologies**: The concepts from other ontologies are used, checking whether they can be improved or applied. The knowledge scope is created by determining the target group. An understanding is developed regarding the needs of the target user group. The user group is analyzed to create concepts or classes of related knowledge scopes.
3. **Enumerate Terms in the Ontology**: The details are considered, and the importance of each term in the ontology of interest is listed. This involves explaining to developers and users by writing possible terms about the subject of study, along with detailed term properties.
4. **Define Classes and the Class Hierarchy**: The classes and structure of the classes are identified.
5. **Define the Properties of Classes (Slots)**: The number of values, types of values, and possible values of the class properties are defined.
6. **Define the Facets of the Slots**: The conditions and constraints, which are the properties of the class, are defined, such as defining the number of values of the slots (slot cardinality), slot-value type, and the domain and range of the slots.
7. **Create Instances**: This involves defining examples of data in that class.

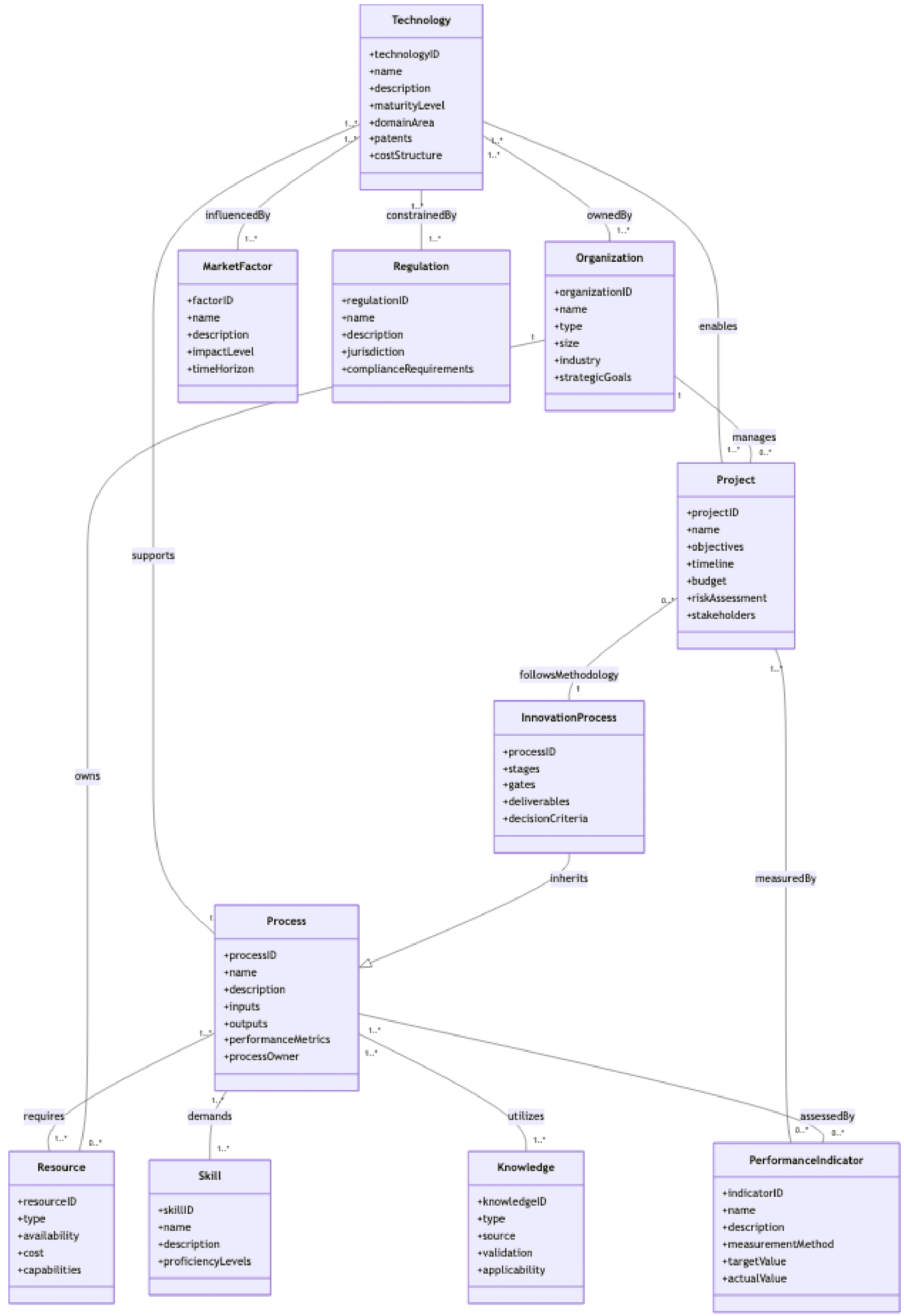

Fig. 1: Main Components of the Designed Ontology

4. Results and Discussions

The research findings demonstrate that ontology is a valuable tool for knowledge management and the development of learning systems in industrial technology management. The ontology development process is systematic, and various tools are available to support the creation of a clearly structured knowledge base that can be efficiently utilized as shown in Fig. 1. The results of the analysis are presented in three parts: 1) Ontology Design, 2) System Development and Testing, and 3) System Evaluation.

4.1. Ontology Design

The ontology design process involved a thorough analysis [3], including Conceptual Framework Analysis, Semantic Relationship Structure Analysis, Knowledge Representation Structure Analysis, and Application Analysis. This resulted in a robust framework with 11 core classes: Technology, Organization, Process, Project, Resource, Market Factor, Skill, Knowledge, Regulation, Performance Indicator, and Innovation Process.

4.2. System Development and Testing:

A system was developed based on the designed ontology, considering the complexity of knowledge in the industrial technology domain, including the types of production processes, machinery, and personnel involved. The development process also emphasized the importance of clearly defining the scope of the ontology, such as focusing on specific areas like supply chain management, preventive maintenance, or quality control.

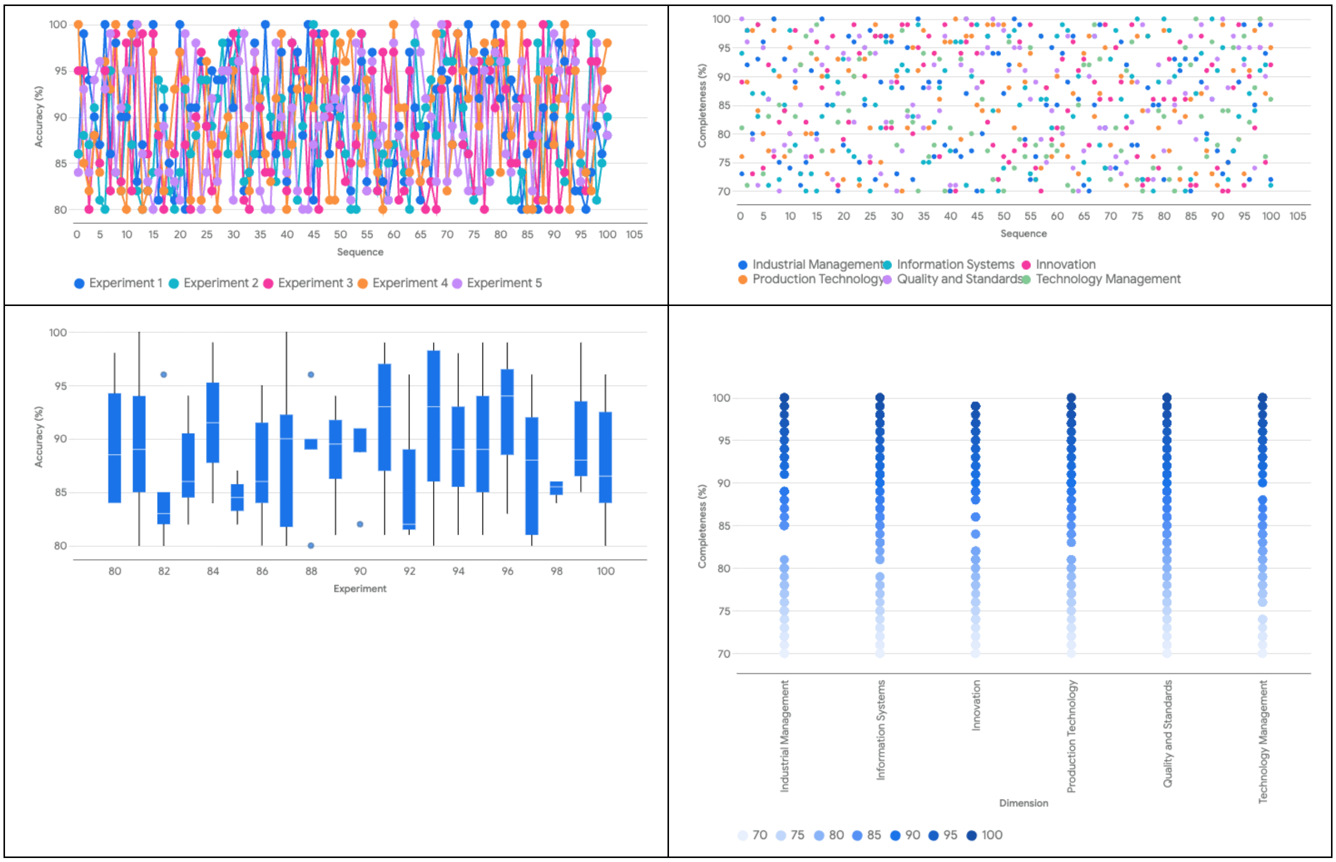

Fig. 2: Designed Ontology Evaluation Results

4.3. System Evaluation:

The ontology system was evaluated and summarized in Fig. 2, in four key areas [5]:

1) **Accuracy**: The system demonstrated high accuracy, with results consistently between 80% and 100% across multiple trials. The mean accuracy across trials ranged from 83% to 87%, with limited outliers, indicating strong reliability.
2) **Completeness**: The ontology's completeness was evaluated across six dimensions: Production Technology, Information Systems, Innovation, Industrial Management, Quality and Standards, and Technology Management. The evaluation revealed distinct distribution patterns and a high degree of coverage in key areas.
3) **Consistency**: The evaluation of the ontology's consistency showed that the inconsistency of terms and meanings decreases as the number of experiments increases
4) **Reusability**: The potential reusability of the developed ontology in other industrial technology domains was considered.

5. Discussion and Conclusion

This research aimed to design a knowledge management system for industrial technology management, utilizing ontology as a tool for knowledge representation and organization. The study successfully developed ontology comprising 11 core classes and demonstrated its potential for organizing both explicit and tacit knowledge. The system evaluation revealed high accuracy and completeness, suggesting the feasibility of the proposed approach.

(a) Before Improvement (b) After Improvement

Fig. 3 Trend of Decreasing Inconsistency in 500 Trials

The findings support the idea that ontology can be effectively employed to structure the complex and diverse knowledge within industrial technology management as shown in Fig. 3. By providing a shared understanding of key concepts and their relationships, the developed ontology can facilitate knowledge sharing, retrieval, and application, ultimately leading to improved decision-making and innovation in industrial settings.

5.1. Study Limitations and Future Research

Despite the promising results, this study has some limitations. First, the evaluation of the ontology system was primarily conducted within the context of the research team. Further evaluation in real-world industrial settings with actual end-users is needed to validate its effectiveness and usability. Second, while ontology covers a significant portion of the industrial technology domain, there may be other relevant concepts and relationships that were not included. Future research could expand ontology to incorporate a broader range of knowledge. Finally, the current system focuses on knowledge representation and organization. Future work could explore the integration of ontology with other knowledge management tools and technologies, such as machine learning and natural language processing, to enhance its functionality and automation. It is also recommended to study the maintenance and updating of the ontology.

5.2. Conclusion

The research contributes to the field of knowledge management by providing a practical approach for designing and implementing ontology-based systems in industrial technology management. The developed ontology and system prototype offer a foundation for future research and development in this area, with the potential to improve knowledge management practices and drive innovation in the industrial sector.

6. References

[1] Rasamee, A., “Industrial Technology Management in Thailand,” *Journal of Industrial Technology Academic: Suan Sunandha Rajabhat University*, vol. 5(1), pp. 106-1148, 2017. (In Thai)

[2] Kabmala, M., Maenmat, L., & Malaivong, K., “Ontology: Development concepts,” *Journal of Information Science Research and Practice*, vol. 24(1-3), pp. 24-49, 2006. (In Thai)

[3] Niwattanakul, S., “A Research Report on a Semantic Retrieval Model for Knowledge of Thai Economic Fruits based on Ontology,” Suranaree University of Technology. (In Thai)

[4] M. J. Eppler, “Making Knowledge Visible through Knowledge Maps: Concepts, Elements, Case.,” in *Holsapple, C.W.*, Ed. Handbook on Knowledge Management 1. 1, Berlin: Springer, 2004. https://doi.org/10.1007/978-3-540-24746-3_10

[5] A. Maedche, & S. Staab, “Measuring Similarity Between Ontologies,” in *Proc. International Conference on Knowledge Engineering and Knowledge Management*, 2002, pp. 251-263. https://doi.org/10.1007/3-540-45810-7_24

[6] *What is Knowledge Management?* IBM, accessed March 9, 2024, https://www.ibm.com/think/topics/knowledge-management.