

CHAPTER 5 – CONCLUSION AND DISCUSSIONS

5.1 Conclusions

This research presents a proof-of-concept framework for improving HS code classification in the heavy equipment industry, addressing challenges such as classification complexity, regulatory compliance, and transparency. Key conclusions are:

1. Fulfillment of Research Objectives:

- 1) The proof-of-concept system effectively integrates KGs and LLMs, improving accuracy and transparency. The system significantly streamlines workflows, reducing processing time and delivering explainable and interpretable results.
- 2) The Knowledge Graph maps relationships between part numbers, attributes, and HS code rules, enabling contextual and hierarchical classification.
- 3) Transparent and traceable reasoning for classification decisions was achieved, supporting expert validation and compliance with BTKI regulations.
- 4) Using real-world data from PT XYZ, the framework demonstrates its capability to address challenges such as material variations and ambiguous descriptions, validating the system's practical utility.

2. Answers to Research Questions:

- 1) Question 1: An AI classification system integrating KGs and LLMs enhances accuracy and transparency by leveraging hierarchical relationships and contextual insights. The system's explainability builds trust and ensures alignment with BTKI regulations.
- 2) Question 2: The design and validation of the proof-of-concept framework were achieved through systematic integration of structured KGs and LLMs, enabling transparent and traceable decision-making. Evaluation using real-world data highlighted its robustness and scalability.

3. Feasibility of Integrated Technologies:

- 1) The integration of Knowledge Graphs (KGs) and Large Language Models (LLMs) has demonstrated significant potential in automating HS code classification while maintaining compliance with Indonesia's *Buku Tarif Kepabeanan Indonesia* (BTKI).
- 2) The Random Forest model emerged as the most effective classification tool, achieving the highest accuracy among evaluated methods.
4. **Transparency and Explainability:** incorporating Explainable AI principles, the framework provides stakeholders with traceable and auditable classification decisions, ensuring compliance with regulatory standards.
5. **Operational Impact:** The framework optimizes classification processes, minimizes errors, and accelerates decision-making. Positive feedback from domain experts affirms its practicality and relevance in industrial applications.
6. **User Validation:** Positive feedback from Focus Group Discussions underscores the practicality and relevance of the framework, while highlighting areas for future improvement.

Overall, the proposed framework demonstrates that combining structured knowledge (via KGs) with advanced language understanding (via LLMs) offers a promising path for accurate, transparent, and compliant HS code classification. This integration not only enhances the operational efficiency of classification processes but also ensures explainability, a critical factor in maintaining regulatory and organizational trust.

5.2 Recommendation

Building on the conclusions presented, this section outlines several recommendations aimed at guiding future enhancements and broader adoption of the proposed HS code classification framework. These recommendations focus on both technical improvements and organizational considerations to ensure the solution remains robust, scalable, and aligned with evolving industry needs:

1. **Enhance the Knowledge Graph Schema**
 - 1) **Expand Product Information:** Integrate additional attributes—such as material composition, functional details, and associated product images—into the

Knowledge Graph (KG). Where possible, link or merge the KG with a Product Information Management (PIM) system to ensure that the classification process accounts for the most accurate and up-to-date details.

- 2) Ongoing Ontology Refinement: Collaborate closely with domain experts to refine the KG ontology in response to regulatory updates (e.g., BTKI changes) and new product categories. This ensures that the KG remains relevant and continues to capture the full range of attributes that influence HS code classification.

2. Leverage Advanced LLM Capabilities

- 1) Adopt State-of-the-Art Models: Employ the latest generation of Large Language Models, which can better interpret complex product descriptions and regulatory text. This can involve fine-tuning and prompt engineering to fit domain-specific requirements.
- 2) Utilize Retrieval-Augmented Generation (RAG): Incorporate RAG-based pipelines to dynamically query domain-specific knowledge sources (including the KG) during inference, enhancing the accuracy and context-awareness of the classification process.

3. Explore Knowledge Graph and Graph RAG Technologies for Scalability

- 1) Scalable Data Storage: Investigate graph databases or distributed data management solutions that can handle growing data volumes without compromising performance.
- 2) Graph RAG Integration: Combine Graph-based Retrieval-Augmented Generation with the existing KG to provide more contextual insights, enabling the system to handle evolving product lines and regulations more efficiently.

4. Strengthen Explainability and Traceability

- 1) User-Friendly Interfaces: Develop visual dashboards that highlight the key attributes, rules, and inference paths leading to each classification result, fostering trust and enabling easy review by non-technical stakeholders.
- 2) Feedback Loops: Incorporate mechanisms for domain experts to provide corrections or additional information on specific classifications. These inputs

can be used to fine-tune both the KG and the LLM, continuously improving classification accuracy.

5. Address Data Quality and Governance

- 1) **Data Consistency Checks:** Implement automated validation routines to ensure part numbers, materials, and other attributes are complete and consistent before they are ingested into the KG.
- 2) **Metadata Standardization:** Establish organizational standards for naming conventions, data formats, and attribute definitions, promoting uniform data ingestion and reducing ambiguity in classification.

6. Facilitate Organizational Adoption

- 1) **Change Management & Training:** Provide targeted training sessions, documentation, and best practices to ensure staff and stakeholders understand both how and why the AI system produces certain classifications.
- 2) **Incremental Deployment:** Gradually roll out the system—starting with specific product lines or departments—to build confidence and gather feedback for iterative improvements.

7. Prepare for Future Regulatory Changes

Proactive Monitoring: Continuously monitor BTKI updates and any other relevant international trade regulations. Integrate these changes into the KG and LLM training processes in a timely manner.

By following these recommendations, organizations can expand the depth and breadth of their classification systems, maintain high accuracy in the face of evolving regulations, and build robust, scalable solutions that support end-to-end processes in the heavy equipment industry and beyond.

5.3 Suggestions for Future Research (Feasibility-Focused)

To build on the current framework and ensure that advancements are both practical and deliverable, the following suggestions emphasize incremental improvements and scalable approaches:

1. Incremental Integration of Multimodal Data

- 1) **Product Images:** Before expanding to complex visuals (e.g., CAD drawings), start by incorporating simple product images to verify whether visual data improves classification.
- 2) **Pilot Small-Scale Use Cases:** Choose a limited set of products or parts with clearly defined attributes. Monitor performance improvements and refine the approach based on real-world feedback before scaling up.

2. Graph-Based Machine Learning for Domain-Specific Improvements

- 1) **Test Simple GNN Approaches:** Pilot Graph Neural Networks (GNNs) on a subset of the Knowledge Graph to measure any incremental gains over existing methods. Focus on well-curated data to reduce noise and complexity.
- 2) **Refine Ontology Iteratively:** Work closely with domain experts on a targeted subset of the ontology, ensuring that each revision directly addresses real-world classification challenges (e.g., new product lines, updated regulations).

3. Adopt Domain-Adaptive Large Language Models

- 1) **Periodic Fine-Tuning on Updated Regulations:** Establish a schedule (e.g., quarterly) to update the LLM with newly added product descriptions or regulatory changes. This avoids the cost of continuous retraining and keeps the model current.
- 2) **Simplify Retrieval-Augmented Generation (RAG):** Start with a **basic** RAG pipeline—retrieving the most relevant knowledge graph entries or documents—and expand as the system demonstrates tangible improvements in accuracy.

4. Scalable and Real-Time Deployment Strategies

- 1) **Leverage Cloud Architectures First:** Use cloud-based solutions for cost-effective scaling. Monitor performance metrics (latency, throughput) under realistic data loads to validate feasibility.
- 2) **Edge or On-Premise Solutions Where Necessary:** Limit edge or on-premise computing to specific high-security or low-connectivity scenarios, weighing the benefits (real-time classification) against the added complexity and costs.

5. Continuous User Engagement and Feedback Loops

- 1) **Feedback Dashboards:** Develop simple user interfaces where domain experts can view classifications and submit corrections or annotations. Regularly update both the LLM and KG with these insights to reinforce accuracy.
 - 2) **Targeted Training & Documentation:** Offer concise learning resources that show users how AI-driven results are generated, ensuring transparency and trust. Emphasize the direct impact of their feedback on system improvements.
6. **Ethical and Regulatory Compliance Monitoring**
- 1) **Internal Audits for Bias & Accuracy:** Conduct periodic internal reviews to detect anomalies, biases, or potential misclassifications, taking corrective measures early.
 - 2) **Adapt to Evolving Legal Requirements:** Maintain a nimble compliance framework that can integrate new regulatory rules (e.g., reclassified tariff codes, special exemptions) without major system overhauls.

By focusing on incremental pilot projects, targeted enhancements, and user-centric refinement, these future research directions aim to balance innovation with real-world feasibility. The result is a continually improving classification framework that remains both cost-effective and adaptable to the evolving demands of the heavy equipment industry and related sectors.