Enhancing End-of-Life Vehicle Component Management through an AI-Based Software Engineering Decision Support System

Wan Muhammad Haziq Darwisy Wan Remle[1*], Noorrezam Yusop[1], Mazlan Mohamed[2], Khairul Nizam Suhaimin[3], Ahmad Fadzil Mohamad[4]

[1]Fakulti Teknologi Maklumat dan Komunikasi, Universiti Teknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, Melaka,76100, Malaysia

[2]Fakulti Kecerdasan Buatan dan Keselamatan Siber, Universiti Teknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, Melaka, 76100, Malaysia

[3]Faculty of Technology and Mechanical Engineering (FTKM), Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

[4]Institute of Sustainable Technology, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

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ABSTRACT

End-of-Life Vehicles (ELVs) contain various components and materials that may retain functional, economic, and recyclable value after reaching the end of their useful life. Effective management of these components is essential for sustainable waste management, resource recovery, and circular economy practices. However, conventional approaches often rely on manual assessment and traditional decision-making methods, which can be time-consuming and inconsistent when multiple component characteristics must be considered. This paper proposes an enhanced Artificial Intelligence (AI)-based Software Engineering Decision Support System to improve ELV component management. The proposed system will analyse relevant component information, including condition, material characteristics, age, damage, economic value, and recovery potential, to recommend suitable end-of-life management options such as reuse, remanufacturing, recycling, recovery, or disposal. The research will involve identifying relevant decision factors, analysing existing decision-support approaches, designing and developing the system, integrating an AI-based decision mechanism, and evaluating its effectiveness using appropriate AI and software performance criteria. The proposed solution will incorporate a web-based user interface, a Python-based backend, and a relational database, with the specific AI algorithm and dataset determined through literature review and data availability. The expected outcome is a functional prototype that supports more consistent and efficient decision-making in ELV component management while contributing to sustainable automotive waste management and circular economy objectives.

Keywords: End-of-Life Vehicles, Artificial Intelligence, Decision Support System, Software Engineering, Component Management

BACKGROUND OF THE STUDY

The increasing number of vehicles reaching the end of their useful life creates a need for effective strategies to manage automotive components and materials. End-of-Life Vehicles (ELVs) consist of various parts that differ in material composition, physical condition, remaining serviceability, and potential economic value. Some components may still be suitable for further use, while others may require remanufacturing, recycling, recovery, or disposal. Selecting an appropriate option for each component is therefore an important part of the ELV management process.

In practice, determining the most suitable treatment for an ELV component can be challenging because decisions depend on multiple criteria. For example, a component's physical condition and degree of damage may influence

its suitability for reuse, whereas its material composition may determine its recycling potential. Economic considerations and environmental impacts may also affect the decision. These factors need to be considered together to avoid overlooking valuable resources and to support more responsible waste management.

Existing approaches to ELV component management include manual inspection, conventional assessment methods, and optimisation techniques. Although these approaches can support decision-making, evaluating numerous components against different criteria may be complex and time-consuming. The consistency of decisions may also depend on the information available and the judgement of the individuals conducting the assessment. These challenges indicate the need to investigate more structured and technology-supported methods for component evaluation.

Software engineering provides a systematic foundation for developing applications that organise data, implement decision-making processes, and deliver information to users. Meanwhile, Artificial Intelligence (AI) techniques offer opportunities to analyse component characteristics and support recommendations based on available data. Combining these capabilities may provide a practical approach to improving the assessment of ELV components. Nevertheless, the effectiveness of such an approach depends on the relevance of the decision factors, the quality and availability of data, the suitability of the selected AI technique, and the performance of the developed system.

Therefore, this study focuses on the development of an AI-based Software Engineering Decision Support System for ELV component management. It addresses the need for a structured system that considers relevant component characteristics and supports the selection of suitable management options. By investigating the integration of AI techniques with software engineering principles, the study seeks to establish a practical basis for more systematic component assessment and to support resource efficiency and circular economy objectives in automotive waste management.

METHODS

The proposed research will follow a systematic development and evaluation process guided by Software Engineering principles. The specific AI algorithm and dataset will be selected after the literature review and assessment of available ELV component data.

Research and System Development Framework

The proposed work is organised around identifying decision factors, reviewing existing approaches, designing and developing the system, and evaluating its performance.

- **Factor identification: identify component-related factors that influence end-of-life management decisions.**
- **Review of existing approaches: analyse current AI-based decision-support approaches and identify their limitations.**
- **System design and development: design the software architecture and develop the AI-based decision mechanism and user-facing functionality.**
- **The AI decision mechanism will be integrated into a software-based Decision Support System. Evaluation will use suitable AI and software performance criteria; the proposal does not yet specify a final algorithm, dataset, or quantitative evaluation results.**

Thematic and Functional Framework

The proposed system will address the following connected areas:

ELV component information collection and management

1. Component characteristic and condition assessment

2. AI-based classification and recommendation

3. Recommendation of reuse, remanufacturing, recycling, recovery, or disposal

4. Software architecture, database design, testing, and validation

This framework links the decision factors identified in the proposal with system design, AI integration, and evaluation. It is intended to provide a structured basis for development while allowing the specific algorithm and dataset to be selected in light of the literature review and data availability.

Proposed System Components

System Component	Purpose	Proposed Function	Related Scope
Component data input	Collect relevant information	Record selected component characteristics and condition	Data management
Factor assessment	Support multi-factor decisions	Consider material, age, damage, value, and recovery potential	Decision analysis
AI decision mechanism	Generate recommendations	Classify components or recommend management options	AI/ML
Management options	Guide end-of-life treatment	Recommend reuse, remanufacturing, recycling, recovery, or disposal	Decision support
Software architecture	Integrate system functions	Connect interface, backend/API, AI model, and database	Software Engineering
Testing and evaluation	Assess system performance	Evaluate using suitable AI and software criteria	Validation

Expected Outcomes

The proposed research is expected to produce an enhanced AI-based Software Engineering Decision Support System for managing selected ELV components. The system is intended to analyse component information and recommend suitable end-of-life management options.

The expected deliverables include:

- **AI decision mechanism: classification or recommendation of suitable management options for selected ELV components.**
- **Integrated software system: a structured architecture connecting AI capabilities with data input, decision processing, and recommendation presentation.**
- **Improved decision support: potential improvement in the consistency and efficiency of ELV component management decisions.**

Prototype and evaluation: a functional prototype and a systematic assessment using appropriate AI and software performance criteria. These are expected outcomes and have not yet been demonstrated by results in the proposal.

DISCUSSION

The proposed approach addresses ELV component management as a multi-factor decision-making problem and

combines AI capabilities with a maintainable software system.

- **Potential contribution: structured recommendations may help users consider component condition, material type, recovery potential, and other relevant factors more consistently.**
- **Implementation considerations: the system's usefulness will depend on the quality and availability of component data, the suitability of the selected AI technique, and the design of the software architecture and interface.**

Key Design Considerations

- **Decision factors: component condition, material characteristics, age, damage, economic value, environmental considerations, and recovery potential will inform recommendations.**
- **Software Engineering: requirements analysis, architecture, database design, integration, testing, validation, usability, and performance evaluation are central to the proposed system.**
- **Technology choices: the proposal anticipates a web-based frontend, a Python-based backend/API, a relational database such as MySQL, and machine-learning classification or recommendation techniques. Final selections remain subject to the literature review and data availability.**

The proposed system is intended to support—not replace—professional judgement in ELV management. Its effectiveness will need to be established through testing and evaluation against a suitable baseline or existing approach.

CONCLUSION

This proposal presents an AI-based Software Engineering Decision Support System to support the management of selected End-of-Life Vehicle components. The system is intended to analyse component characteristics and provide recommendations for reuse, remanufacturing, recycling, recovery, or disposal.

The research will identify relevant decision factors, examine existing approaches, design and develop the enhanced system, integrate an AI-based decision mechanism, and evaluate the resulting prototype using suitable criteria.

The expected contribution is a structured software solution that may improve the consistency and efficiency of ELV component decisions while supporting resource recovery and circular economy practices. These benefits remain to be validated through the proposed development and evaluation work.

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