Enhancing Class Diagram Dynamics: A Natural Language Approach with ChatGPT

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Abstract

Integrating artificial intelligence (AI) into software engineering can transform traditional practices by enhancing efficiency, accuracy, and innovation. This study explores using ChatGPT, an advanced AI language model, to enhance UML class diagrams dynamically, an underexplored area. Traditionally, creating and maintaining class diagrams are manual, time-consuming, and error-prone processes. This research leverages natural language processing (NLP) techniques to automate the extraction of methods and interactions from detailed use case tables and integrate them into class diagrams.

The methodology involves several steps: (1) developing detailed natural language use case tables by master's degree students for a "Waste Recycling Platform," (2) creating an initial static class diagram based on these tables, (3) iteratively enriching the class diagram through ChatGPT integration to analyze use cases and suggest methods, (4) reviewing and incorporating these methods into the class diagram, and (5) dynamically updating the PlantUML [1] class diagram, followed by evaluation and refinement. Findings indicate that the AI-driven approach significantly improves the accuracy and completeness of the class diagram. Additionally, dynamic enhancement aligns well with Agile development practices, facilitating rapid iterations and continuous improvement.

Key contributions include demonstrating the feasibility and benefits of integrating AI into software modeling tasks, providing a comprehensive representation of system behaviors and interactions, and highlighting AI's potential to streamline and improve existing software engineering processes. Future research should address identified limitations and explore AI applications in other software

models.

Keywords: Use Case-Driven Modeling, Method Identification Automation, Class Diagram Dynamics Enrichment, AI-driven Software Engineering, Agile Development

1 Introduction

Recent advancements in artificial intelligence (AI) have profoundly impacted various domains, including software engineering [2, 3]. AI technologies are now employed in multiple areas of software development, such as requirements engineering, automated testing, and defect prediction [3–5]. The integration of AI, particularly natural language processing (NLP), is anticipated to revolutionize traditional software engineering practices by enhancing efficiency, accuracy, and innovation [6, 7].

Unified modeling language (UML) class diagrams are essential in software engineering for designing and documenting systems, they offer a structured representation of a system's components, their attributes, methods, and relationships [8, 9]. Traditionally, creating and maintaining UML class diagrams is a manual, labor-intensive process, often resulting in time-consuming and error-prone tasks, leading to inconsistencies and inaccuracies throughout the software development lifecycle [10]. However, advancements in AI, particularly NLP, provide opportunities to automate and improve this process.

AI-driven approaches have been applied to various aspects of software development, including requirements engineering, code generation, and system modeling [5]. One critical area where AI has shown significant potential is in creating UML class diagrams [10]. Capturing dynamic aspects, such as interactions and behaviors within a system, is crucial for a comprehensive understanding of system functionality and for creating accurate and maintainable designs. Including methods in class diagrams provides detailed specifications of class functionalities, enhancing documentation, design clarity, and maintainability while supporting modularity and object-oriented design principles.

Despite these advancements, existing automated tools often struggle with the intricate details and dynamic aspects of complex systems [11]. A critical gap remains in the literature: the dynamic enhancement of UML class diagrams using AI to capture interactions and behaviors within a system. Current methodologies predominantly focus on static components, overlooking dynamic aspects.

Translating use case scenarios into UML class diagrams manually is error-prone and inconsistent [12]. Developers must interpret use case scenarios, identify relevant methods, and integrate these methods into class diagrams. This process is time-consuming and susceptible to human error, leading to incomplete or inaccurate diagrams. Additionally, maintaining these diagrams to reflect changes in requirements or system functionalities adds complexity and effort. While intermediary models such as sequence diagrams, state diagrams, or activity diagrams provide detailed understanding, their creation requires additional expertise and time, complicating the overall development process.

Integrating AI into the dynamic enhancement of UML class diagrams through NLP represents a significant advancement in the field. This study explores using ChatGPT, an advanced AI language model developed by OpenAI [13], to enhance the accuracy and completeness of UML class diagrams. ChatGPT's natural language understanding and generation capabilities make it a valuable tool for analyzing use case scenarios and iteratively incorporating extracted insights into class diagrams. By leveraging ChatGPT, we aim to automate the identification and integration of methods into class

diagrams, transforming them from static representations into dynamic models that accurately reflect both the structure and behavior of the system, providing a more comprehensive system representation.

The objectives of this study are threefold:

- 1. **Automate Method Identification:** Utilize ChatGPT to analyze natural language use case tables and identify relevant methods for each class.
- 2. **Dynamic Diagram Enhancement:** Iteratively update the UML class diagrams to include identified methods, ensuring the diagrams evolve to accurately represent the complete functionality of the system.
- 3. Evaluate Effectiveness: Assess the accuracy, efficiency, and comprehensiveness of the AI-enhanced class diagrams compared to the initial ones.

To guide this study, we formulated the following research questions:

- **RQ1:** To what extent is it feasible to integrate ChatGPT to dynamically enhance the class diagram dynamics effectively?
- **RQ2**: How does the AI-driven enhancement of UML class diagrams impact the efficiency and accuracy of software modeling compared to traditional methods?
- RQ3: What are the limitations and challenges of using ChatGPT for dynamic class diagram enhancement, and how can these be mitigated?

This study focuses on an exemplary use case, a "Waste Recycling Platform," developed by master's degree students in computer science. The PlantUML code representing the initial class diagram for this platform includes core classes, attributes, and basic relationships but lacks detailed methods. The study leverages 23 detailed use case tables formulated in natural language, structured with columns such as Use Case ID, Actor, Description, Pre-condition, Trigger, Main Scenario, Post-condition, and Exceptions.

The findings indicate that the AI-driven approach significantly improves the accuracy and completeness of class diagrams while reducing the manual effort required. The dynamic enhancement aligns well with Agile development practices, facilitating rapid iterations and continuous improvement. This methodology not only provides a more comprehensive representation of system behaviors and interactions but also streamlines the process of maintaining and updating class diagrams.

While the findings demonstrate significant benefits, the methodology's effectiveness depends on the quality of the input use case tables and may require human oversight to ensure accuracy. Additionally, the study uses a single use case for validation, which may affect the generalizability of the results. Future research will focus on addressing these limitations and expanding the methodology's applicability to broader and more complex systems.

Integrating AI, particularly NLP, into the software modeling process represents a significant advancement in software engineering practices. By automating routine tasks such as method extraction and incorporation, AI can significantly reduce manual effort, minimize human error, and ensure more accurate and comprehensive class diagrams. This study not only demonstrates the feasibility and benefits of such an integration

but also paves the way for further research and development in AI-assisted software engineering methodologies.

In summary, this study presents a novel approach to dynamically enhancing UML class diagrams by leveraging ChatGPT's capabilities. The findings highlight the significant improvements in the accuracy, efficiency, and comprehensiveness of class diagrams, demonstrating the transformative potential of AI in software engineering.

The remainder of this paper is structured as follows: Section 2 details the methodology used in this study, including the initial class diagram, use case tables, analysis, and dynamic incorporation. Sections 3 and 4 present the results and discuss the implications of our findings. Section 5 concludes the paper and suggests directions for future research.

2 Literature Review

The integration of artificial intelligence (AI) into software engineering has garnered significant attention, with numerous studies highlighting its potential to transform traditional practices [6]. One critical area where AI has shown promise is in creating UML class diagrams, which are pivotal for visualizing system structures and dynamics [8, 9]. Historically, the creation and maintenance of class diagrams have been manual processes, often resulting in time-consuming, error-prone, and resource-intensive tasks [8]. These traditional methods struggle to keep pace with the complexities of modern software systems, leading to inconsistencies and inaccuracies that can cascade through the software development lifecycle [10].

2.1 AI and NLP in Software Engineering

To address these challenges, various automated and semi-automated tools have been developed. The advent of AI, particularly natural language processing (NLP), has introduced new paradigms in software engineering. AI-driven approaches have been applied to numerous aspects of software development, including requirements engineering, code generation, and system modeling [5]. For instance, Zhao et al. [4] highlighted the potential of NLP in automating requirements engineering processes, showcasing significant efficiency and accuracy gains.

Pre-trained language models, such as those developed by OpenAI, have demonstrated significant capabilities in understanding and generating human-like text, which can be leveraged to automate code generation tasks and improve the consistency of generated artifacts [14]. This presents a transformative opportunity for bridging the gap between natural language specifications and software artifacts.

2.2 Methods to Enhance Class Diagrams

Several studies have proposed methods to enhance class diagrams. Elena [15] suggests analyzing behavioral models represented by collaboration diagrams to define relationships between class diagram constituents. Similarly, Egyed [16] introduces automated abstraction techniques to simplify complex structures, while Guéhéneuc [17] discusses reverse engineering tools for building precise class diagrams from Java programs.

Huang et al. [18] suggest using knowledge graphs to provide additional context and facilitate better abstraction.

Eichelberger [19] presents aesthetic criteria and layout algorithms to standardize and enhance the visual quality of UML class diagrams. Anda and Sjøberg [12] investigate the role of use cases in constructing class diagrams and how different techniques affect the quality of the resulting diagrams. Sharma et al. [20] introduce a dependency analysis-based approach to derive UML class diagrams automatically from natural language requirements, addressing challenges of manual intervention and pre-processing.

Osman et al. [21] study machine learning techniques to condense class diagrams, highlighting key classes. Similarly, Alashqar [22] presents an approach for the automatic generation of UML diagrams from scenario-based user requirements, showcasing the efficiency of NLP in processing user requirements. Nasiri et al. [23] propose methods for generating class diagrams from user stories in agile methodologies, emphasizing the integration of dynamic and static aspects to enhance accuracy. Kumar and Sanyal [24] develop the SUGAR tool for generating static UML models from requirement analysis, simplifying the translation of requirements into visual models. Lucassen et al. [25] explore the extraction of conceptual models from user stories, leveraging visual narrators to improve the accuracy and relevance of generated UML class diagrams.

2.3 AI and Optimization Techniques

Several researchers have explored AI and optimization techniques to improve UML class diagrams. Tantithamthavorn et al. [26] emphasize the importance of explainable AI in software engineering, particularly in improving software defect prediction models. Sergievskiy and Kirpichnikova [27] discuss optimizing UML class diagrams using design patterns and anti-patterns, proposing a plugin for analyzing XMI files that contain class diagram descriptions. Eiglsperger et al. [28] propose using the topology—shape—metrics paradigm for the automatic layout of UML class diagrams in orthogonal style, significantly improving readability and aesthetics by minimizing edge crossings and bends.

2.4 Enhancing Consistency and Comprehension

Ha and Kim [29] propose cross-checking rules to enhance the consistency of UML diagrams, focusing on the consistency between UML static and dynamic diagrams. Their methodology emphasizes the importance of maintaining consistency without requiring complex intermediate representations. Briand et al. [30] enhance interaction testing by combining UML sequence and state machine diagrams. Another and Saake [31] propose integrating UML structural and behavioral diagrams using rewriting logic, enhancing consistency, and supporting rapid prototyping.

2.5 NLP and Heuristic Rules

Abdelnabi et al. [32] explore generating UML class diagrams using NLP techniques combined with heuristic rules, addressing the complexity and computational cost issues associated with traditional approaches. Their research demonstrates how automated

processes can significantly reduce human intervention and errors in diagram creation. Maatuk and Abdelnabi [33] further the research by developing methods to generate UML use case and activity diagrams using similar NLP techniques and heuristic rules, providing a comprehensive framework for automatic diagram generation. This work emphasizes the integration of different types of UML diagrams for a cohesive modeling process. P., D. et al. [34] enhance the extraction of business vocabularies and rules from UML use case diagrams using natural language processing, demonstrating the advanced capabilities of NLP in handling complex software engineering tasks. Their work highlights how NLP can be used to improve the precision and comprehensiveness of business models. Their research highlights the importance of visual tools in enhancing the understanding and clarity of conceptual models.

2.6 Consistency and Traceability

Omer et al. [35] and Dawood and Sahraoui [36] focus on the consistency and traceability of requirements and design, utilizing bi-directional traceability and natural language processing to ensure the alignment of requirements with design artifacts. Their studies emphasize the importance of maintaining consistency throughout the software development lifecycle. Arellano et al. [37] provide a framework for processing textual requirements using natural language processing, facilitating the extraction and organization of requirements into structured formats. This framework aids in managing complex requirements and translating them into formal models. Yue et al. [38] introduce ATOUCAN, an automated framework that derives UML analysis models from use case models, underscoring the potential of automation in improving the consistency and completeness of UML diagrams. This framework highlights the benefits of automating analysis model generation from detailed use case descriptions.

2.7 Reviews and Surveys

Several comprehensive reviews and surveys have been conducted to consolidate the findings and methodologies in this domain. Salehi and Burgueño [39] review emerging AI methods in structural engineering, highlighting AI-based solutions' efficiency and accuracy over traditional approaches. Abdelnabi et al. [40] provide a thorough survey of approaches for generating UML class diagrams from natural language requirements, highlighting ongoing challenges and the need for more advanced tools. Ahmed et al. [11] conducted a systematic literature review focusing on the automatic transformation of natural language to UML. Their study emphasizes the limitations of existing approaches, including constraints on ambiguity, length, structure, anaphora, incompleteness, and atomicity of input text. They argue that while heuristic rule-based and machine learning-based approaches have shown promise, they still face significant challenges in fully automating the generation of UML diagrams. Ahmed et al. also highlight the necessity for a common dataset and evaluation framework to advance research consistently. Their findings suggest that a combination of heuristic rules and machine learning techniques could provide a more robust solution for translating natural language into UML diagrams.

2.8 Addressing Gaps in Literature

Despite advancements in AI applications in software engineering, there remains a gap in the literature regarding the use of AI, particularly NLP, to enhance the dynamics of class diagrams. Existing methodologies predominantly focus on static aspects, such as automating class diagram generation or leveraging AI for requirements engineering and code generation. However, the dynamic aspects of class diagrams, which capture interactions and behaviors within a system, remain underexplored and are often overlooked.

Our research attempts to address this gap by proposing a novel methodology that utilizes ChatGPT to analyze natural language use cases and integrate the extracted insights into UML class diagrams. This approach automates the extraction of methods and interactions from textual descriptions and iteratively refines the class diagrams to improve their accuracy and completeness.

3 Methodology

This study leverages an iterative approach to dynamically enrich a PlantUML class diagram using ChatGPT and pre-generated use case tables. The use case in focus is a "Waste Recycling Platform," with the initial natural language use case tables and class diagram developed by master's degree students in computer science.

Our objective is to automate method identification and incorporation, addressing the gap in the initial static diagram. Adding methods to class diagrams is crucial. It specifies the functionalities of each class, representing both the system's structure and behavior. This enhances the clarity, maintainability, and comprehensiveness of the diagrams.

The steps involved in our methodology are as follows:

- 1. **Use Case Development:** Master's degree students created detailed natural language use case tables for the "Waste Recycling Platform." These tables describe various interactions and functionalities required by the system.
- 2. **Initial Class Diagram:** Based on the use case tables and other artifacts, students created an initial static class diagram. This diagram includes classes, attributes, and basic relationships but lacks detailed methods.

3. Iterative Enrichment:

- ChatGPT Integration: We used ChatGPT to analyze the pre-generated use case tables and suggest relevant methods for each class. ChatGPT's natural language processing capabilities enabled the extraction of functional requirements from the use cases.
- Method Identification: Suggested methods were reviewed and iteratively incorporated into the class diagram. This step involved verifying the relevance and correctness of the methods in the context of the system's functionalities.
- Diagram Update: The PlantUML class diagram was dynamically updated to include the identified methods, ensuring that the diagram evolves to reflect the complete functionality of the system.

4. **Evaluation and Refinement:** The enriched class diagram was evaluated for completeness and accuracy.

This approach ensures that the final class diagram is not only structurally sound but also behaviorally comprehensive, providing a robust blueprint for system implementation.

3.1 Use of PlantUML

PlantUML was chosen for this study due to its simplicity, flexibility, and integration capabilities. As a tool that uses a simple textual description to generate diagrams, PlantUML allows for easy updates and modifications, making it ideal for iterative processes. Its support for various UML diagrams, including class diagrams, sequence diagrams, and state diagrams, provides comprehensive modeling capabilities. Furthermore, PlantUML integrates seamlessly with version control systems, allowing for efficient tracking of changes. The ability to embed PlantUML in documentation and its compatibility with various IDEs and text editors further enhance its usability, making it a powerful tool for dynamic and collaborative software design.

3.2 Use Case Tables (Guiding Method Identification)

This study utilizes 23 detailed use case tables (Appendix A.1 to A.23), formulated in natural language, and structured with columns like Use Case ID, Actor, Description, Pre-condition, Trigger, Main scenario, Post-condition, and Exceptions. Originally derived by master's degree students in computer science from a waste recycling platform specification document, these tables serve as the primary reference for identifying methods necessary for each class to facilitate described functionalities.

A representative subset of nine User actor use cases is provided below in Table 1. For this example; in all scenarios, the actor is the "User," who must be logged in to perform the described actions (except for UC1).

ID	Description	Trigger (User)	Main Scenario (User)	Post-condition
UC1	Registration	accesses registration page	provides information	User account created
UC2	Buying Recyclable Waste	selects a product	completes purchase	Transaction processed
UC3	Selling Recyclable Waste	accesses selling page	enters sale details	Sale submitted
UC4	Requesting Waste Collection	fills collection form	submits request	Collection scheduled
UC5	Viewing Collection Points	accesses map/list	browses points	User views details
UC6	Listing Recyclable Waste	accesses listing page	enters product details	Listing published
UC7	Requesting Waste Transport	fills transport form	submits request	Transport scheduled
UC8	Submitting Feedback	fills feedback form	submits feedback	Feedback processed
UC9	Managing Profile	accesses profile settings	updates profile	Profile updated

Table 1 Representative Use Cases for User Actor

This selection highlights the iterative integration of user-centric functionalities into the dynamically enriched class diagram, demonstrating the method's feasibility and effectiveness in capturing requirements and translating them into actionable design elements. **Note:** For global clarity and comprehensive understanding, the detailed use case tables for all actors, including the representative subset provided here, are available in Appendix A.

3.3 Initial Class Diagram

The original PlantUML class diagram, developed by master's degree students in computer science, lacked methods and served solely as a static representation of the system's structure. Despite existing class relationships, the absence of detailed methods significantly limited understanding of system functionality. By dynamically enriching the diagram with methods from detailed use case tables, we transformed it into a dynamic representation, facilitating a more complete understanding of system dynamic behaviors. This enriched diagram now serves as a valuable tool for communication, design, and implementation. Figure 1 depicts the initial diagram. For clarity and to support the main narrative of the article, the initial diagram PlantUML code is included in Appendix B.

The primary classes include:

- Users: Categorized as Individual and Corporate, with attributes like name, address, and registration date.
- **Products**: Represented by diverse materials like Plastic, Paper, and Metal, with details like quantity, price, and listing date.
- **Transactions**: Capturing purchase activities with buyer/seller information, quantity, and total price.
- Reviews: Enabling users to rate and comment on products.
- Service Requests: Associated with users and categorized by type and status.
- Collection/Recycling Points: Differentiated by types accepted and operating hours.
- Additional entities: Including Transport Companies, State Administration, Payment Gateways, Information Resources, and Reward Systems.

3.4 Analysis, Identification, and Dynamic Incorporation

ChatGPT employs various NLP techniques to discern relevant classes and actions within the use case tables. Leveraging its natural language comprehension capabilities, it analyzes each scenario to identify necessary methods for each class, ensuring a thorough grasp of system behaviors. These insights form the foundation for method definition and subsequent dynamic updates to the PlantUML code, by incorporating the identified methods.

The process maintains consistency and accuracy through version control and validation against both the use cases and the original class diagram. The outlined algorithm (Algorithm 1) delineates this methodology.

3.5 The Guiding Main Prompt

A central "main prompt," presented below, directs the approach with specific instructions:

Algorithm 1 Dynamic Class Diagram Enhancement

1: Step 1: Use Case Analysis and Method Identification

- ChatGPT-assisted Analysis: Extract actions, behaviors, inputs, and outputs from each use case table for involved classes.
- Method Definition: Define required methods for each class based on extracted information, adhering to PlantUML syntax and UML best practices.

2: Step 2: Dynamic Diagram Update

- Generate PlantUML code and update the diagram with identified methods, preserving existing elements.

3: Step 3: Validation and Iteration

- Validate the updated diagram against the use case and original diagram.
- Address discrepancies and iterate with new use case tables.
- 4: while New use case tables are available do
 - Repeat from Step 1.
- 5: end while

Prompt 1: "You are assigned the task of enriching the dynamics of a given PlantUML class diagram based on detailed use cases presented in table format. Your role involves deeply analyzing each use case table to determine the interactions and behaviors necessary within the system. Utilizing the provided class diagram, identify the involved classes and define the methods or operations required for each class to support the described functionality. Generate PlantUML code to update the class diagram, ensuring adherence to syntax and UML best practices. Maintain consistency in property names and utilize only existing attributes in the class diagram for method definitions. As new use case tables are provided, dynamically update the class diagram to accurately represent the system's behavior. Validate the completeness and accuracy of the updated diagram after each iteration. Your process must follow guidelines for thorough analysis, method incorporation, and validation, ensuring consistency throughout. Additionally, preserve all added methods in each iteration and maintain consistency in naming conventions, formatting, and UML notation."

This prompt stresses thorough analysis, accurate method incorporation, and consistent validation. Following this framework ensures systematic enhancement of the class diagram, guaranteeing completeness and accuracy in representing the system's behavior.

3.6 Conclusion

In summary, our methodology leverages ChatGPT to dynamically enhance UML class diagrams by analyzing natural language use cases and integrating the extracted methods and interactions. This approach automates the traditionally manual and error-prone process of class diagram creation and maintenance, improving both accuracy and efficiency. While our findings demonstrate significant benefits, the methodology's reliance on the quality of input use cases and the use of a single use case for validation highlight areas for further research and improvement. Future work will focus on addressing these limitations, expanding the methodology's applicability, and exploring the long-term impacts of AI integration in software engineering practices.

4 Results

This section presents the findings from the analysis and enhancement of the class diagram using ChatGPT for natural language processing of use cases. These findings highlight the methodology's effectiveness in refining system design and enhancing functional requirements. Initially, the system's class diagram contained core classes with basic relationships. After applying the ChatGPT methodology, we observed significant improvements in added methods, class structures, and modified relationships. This section provides a comprehensive overview of the enhanced system design.

4.1 Overview of Initial and Enhanced Class Diagrams

The initial class diagram consisted of core classes and their relationships, establishing the basic framework for entities including:

- Users
- Products
- Transactions
- Reviews
- Collection points
- Recycling points
- Service requests
- Transport companies
- State administration
- Payment gateways
- Environmental impacts
- Information resources
- Reward systems
- Payment details
- Shipping details

Each class was defined with pertinent attributes, and associations were depicted to represent the interactions among these entities.

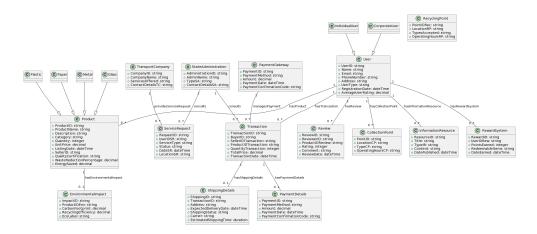
4.1.1 Enhanced Class Diagram

Upon implementing the methodology with ChatGPT to analyze the natural language use cases, the enhanced class diagram was developed. This diagram features additional methods and refined relationships. Methods were specifically incorporated into the User, Transaction, Review, ServiceRequest, PaymentGateway, and PlatformManager classes to meet the functional requirements derived from the use cases.

4.2 Visualizing the Transformations

The transition from the initial static class diagram to the dynamically enriched diagram illustrated substantial improvements in representing system behaviors. Figures 1 and 2 depict these transformations, highlighting the inclusion of methods and interactions that were previously missing. The enhanced diagram provides a more

detailed view of the system's dynamics, facilitating improved understanding and communication among stakeholders.



 $\bf Fig.~1~\rm~Initial~Class~Diagram$

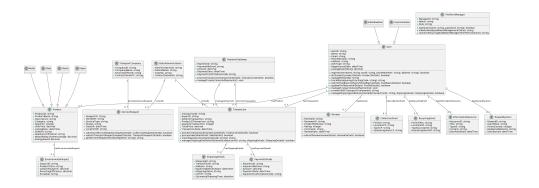


Fig. 2 Enhanced Class Diagram

Note: The corresponding PlantUML codes for the initial and enhanced class diagrams are provided in Appendix B and Appendix C for clarity and to maintain the main flow of the article.

4.3 Comparative Analysis

The enhanced class diagram provided a more functional and detailed representation of the system compared to the initial diagrams. This improvement is quantified in Table 2, which compares the number of classes, methods, and relationships before and after the enhancement.

Feature	Initial Diagram	Enhanced Diagram
Number of Classes	21	22
Number of Methods	0	22
Number of Relationships	19	21
Dynamic Behaviors Captured	No	Yes

Table 2 Comparative Analysis of Initial and Enhanced Class Diagrams

4.4 Behavioral Alignment

The methods incorporated into the enhanced class diagram were validated against 23 distinct use cases to ensure their applicability and effectiveness. This validation confirms the precision and relevance of the AI-driven enhancements, demonstrating the role of AI in refining software design and enhancing system functionality. Each method, from user registration to managing transport services, was meticulously aligned with corresponding use case requirements, underscoring the comprehensive approach taken in this study.

4.4.1 Added Methods to Classes

The enhancement process introduced new methods to several key classes, ensuring that the functional requirements derived from the use cases are adequately addressed.

User Class

Key Changes and Impact: New methods were added to enhance user interaction and management of products, rewards, waste tracking, feedback, profile updates, transactions, and shipping details.

- registerUser(name: string, email: string, phoneNumber: string, address: string): boolean Registers a new user with necessary details and returns a boolean indicating registration success.
- listProduct(productDetails: ProductDetails): boolean Lists a product with provided details and returns a boolean indicating listing success.
- manageRewards(): string Manages user rewards and returns relevant reward information.
- trackWasteJourney(trackingCode: string): string Tracks the waste journey and returns the current status.
- submitFeedbackOrReport(feedbackDetails: FeedbackDetails): boolean Processes user feedback or reports and returns a boolean indicating success.
- updateProfile(profileDetails: ProfileDetails): boolean Updates user profile details and returns a boolean indicating success.
- manageTransactionsAndPayments(): void Manages all transactions and payments for the user.
- connectWithTransportCompanies(): string Connects the user with transport companies and returns relevant information.
- manageShippingAndDeliveryDetails(transactionID: string, shippingDetails: ShippingDetails): boolean - Manages shipping details for a transaction and returns a boolean indicating success.

Transaction Class

Key Changes and Impact: Methods added to handle transaction processing, sale processing, waste tracking, and shipping details management.

- processTransaction(transactionDetails: TransactionDetails): boolean Processes a transaction and returns a boolean indicating success.
- processSale(saleDetails: SaleDetails): boolean Processes a sale and returns a boolean indicating success.
- trackWasteJourney(trackingCode: string): string Tracks the waste journey and returns the current status.
- manageShippingAndDeliveryDetails(transactionID: string, shippingDetails: ShippingDetails): boolean - Manages shipping details for a transaction and returns a boolean indicating success.

Review Class

Key Changes and Impact: Method added to handle review submissions.

• submitReview(reviewDetails: ReviewDetails): boolean - Accepts review details and returns a boolean indicating success.

$ServiceRequest\ Class$

Key Changes and Impact: Methods added to handle collection and transport requests, and to provide request details.

- submitCollectionRequest(requestDetails: CollectionRequestDetails): boolean Processes a collection request and returns a boolean indicating success.
- submitTransportRequest(requestDetails: TransportRequestDetails): boolean Processes a transport request and returns a boolean indicating success.
- getServiceRequestDetails(requestID: string): string Provides details for a service request based on request ID.

$PlatformManager\ Class$

Key Changes and Impact: Methods added to handle login, waste management data analysis, and performance monitoring.

- login(username: string, password: string): boolean Handles the login process and returns a boolean indicating success.
- viewAndAnalyzeWasteManagementData(): string Provides analysis of waste management data.
- monitorRecyclingAndWasteManagementPerformance(): string Monitors performance metrics and provides analysis.

PaymentGateway Class

Key Changes and Impact: Method added to manage transactions and payments.

• manageTransactionsAndPayments(): void - Manages all transactions and payments.

4.4.2 Analysis of Method Parameters in the Enhanced Class Diagram

The integration of method parameters within the class diagram in our system design was meticulously analyzed to demonstrate their alignment with the respective class attributes, thereby illuminating the intrinsic functionalities of the system. Here, we elaborate on several key methods to illustrate how method parameters encapsulate system operations and enhance the overall clarity of the design documentation.

User Class Methods

- registerUser(name: string, email: string, phoneNumber: string, address: string): boolean This method ensures comprehensive data collection essential for user registration by directly mapping each parameter to an existing class attribute. It is fundamental for maintaining data integrity and managing user information effectively.
- listProduct(productDetails: ProductDetails): boolean The parameter productDetails indicates a structured interaction with the ProductDetails class, facilitating user-driven product management within the marketplace
- trackWasteJourney(trackingCode: string): string Utilizing trackingCode, this method provides critical functionality for tracking the disposal or lifecycle of products, enhancing transparency in waste management processes.
- submitFeedbackOrReport(feedbackDetails: FeedbackDetails): boolean The structured input *feedbackDetails* supports a detailed feedback mechanism, pivotal for system improvements and user satisfaction monitoring.
- updateProfile(profileDetails: ProfileDetails): boolean This method, vital for user data accuracy and currency, allows for detailed modifications within user profiles using profileDetails.
- manageShippingAndDeliveryDetails(transactionID: string, shippingDetails: ShippingDetails): boolean Integrating transactionID and shippingDetails, this method underscores the complex logistics management associated with user transactions.

Transaction Class Methods

• processTransaction(transactionDetails: TransactionDetails): boolean - Here, transactionDetails encompasses several critical attributes such as quantity, total price, and product identifiers, ensuring efficient and secure transaction processing.

Service and Payment Infrastructure

• The ServiceRequest and PaymentGateway classes illustrate the system's infrastructure capable of handling detailed and complex service requests and financial transactions, respectively.

The detailed parameter analysis not only enhances the understanding of the system's operations but also underscores the importance of precise and thoughtful parameter documentation in UML diagrams. This approach significantly contributes

to the transparency and functionality of the system design, crucial for stakeholder comprehension and system maintenance.

4.4.3 Method Validation

The following table 3 presents a detailed mapping of each method to its corresponding use case, illustrating the thorough validation of the methods added to the enhanced class diagram:

Table 3: Method Validation Against Use Cases

Use Case	Method
UC1: User Registration	registerUser(name: string, email: string,
	phoneNumber: string, address: string): boolean
UC2: Listing Recyclable	listProduct(productDetails: ProductDetails):
Waste Products	boolean
UC3: Buying Recyclable	processTransaction(transactionDetails:
Waste Products	TransactionDetails): boolean
UC4: Selling Recyclable	processSale(saleDetails: SaleDetails): boolean
Waste Products	
UC5: Reviewing Products	<pre>submitReview(reviewDetails: ReviewDetails):</pre>
or Services	boolean
UC7: Requesting Waste	<pre>submitCollectionRequest(requestDetails:</pre>
Collection Services	CollectionRequestDetails): boolean
UC8: Requesting Waste	<pre>submitTransportRequest(requestDetails:</pre>
Transport Services	TransportRequestDetails): boolean
UC11: Managing User	manageRewards(): string
Rewards	
UC12: Tracking Waste	trackWasteJourney(trackingCode: string): string
Journey	
UC13: Submitting Feed-	<pre>submitFeedbackOrReport(feedbackDetails:</pre>
back or Reports	FeedbackDetails): boolean
UC14: Viewing Service	<pre>getServiceRequestDetails(requestID: string):</pre>
Requests and Status	string
UC15: Managing Platform	login(username: string, password: string):
Services	boolean
UC16: Managing User	updateProfile(profileDetails: ProfileDetails):
Profiles and Accounts	boolean
UC17: Managing Transac-	manageTransactionsAndPayments(): void
tions and Payments	
UC18: Connecting with	connectWithTransportCompanies(): string
Transport Companies	
UC19: Viewing and Ana-	viewAndAnalyzeWasteManagementData(): string
lyzing Waste Management	
Data	

Use Case	Method	
UC22: Monitoring Recy-	monitorRecyclingAndWasteManagementPerformance():	
cling and Waste Manage-	string	
ment Performance		
UC23: Managing Shipping	manageShippingAndDeliveryDetails(transactionID:	
and Delivery Details	string, shippingDetails: ShippingDetails):	
	boolean	

Incorporating ChatGPT's insights to enhance class diagrams with methods tailored to specific use cases demonstrates AI's usefulness in software design. The validation of each method, such as registerUser and manageShippingAndDeliveryDetails, against 20 distinct use cases confirms their relevance and specificity. This approach not only showcases the effectiveness of AI in iterative software development processes but also enhances system integrity and usability by ensuring that every component is tested for its intended purpose.

4.4.4 Illustrative Examples of Enhanced Relationships

The enhanced relationships within the class diagram are crucial for illustrating how the system components interact more effectively post-enhancement. Here are a few key examples:

- Inclusion of PlatformManager Class: The newly introduced PlatformManager class, featuring methods such as login, viewAndAnalyzeWasteManagementData, and monitorRecyclingAndWasteManagementPerformance, embodies essential administrative functionalities for platform management. These methods signify the platform manager's responsibility for overseeing and analyzing waste management data and performance, aligning with use cases UC19 and UC22.
- User and CollectionPoint/RecyclingPoint Classes: Significant improvements include direct connections between the *User* class and the *CollectionPoint* and *RecyclingPoint* classes, highlighted in use cases UC7 (*Requesting Waste Collection Services*) and UC9 (*Viewing Collection and Recycling Points*). These connections clarify essential functionalities and interaction points for user interactions with waste management services.
- Transaction and PaymentGateway Classes: The enhanced relationship between PaymentGateway and Transaction with the processTransaction() method implies an active role for the payment gateway in transaction processing, in accordance with use cases such as UC3 (Buying Recyclable Waste Products) and UC17 (Managing Transactions and Payments).
- WasteManagementService and CollectionPoint/RecyclingPoint Classes: The newly established link between WasteManagementService and the Collection-Point and RecyclingPoint classes underscore its critical reliance on these entities for effective waste management, aligning with use cases UC1 and UC10 for service registration and waste management.

4.4.5 New and Modified Relationships

New and modified relationships were added to the class diagram based on the detailed use case analysis. This section presents the relationships observed after the enhancements (Table 4).

Table 4: New and Modified Relationships in the Class Diagram

Entities	Original	New/Modified Relationship
	Relationship	
User and	User "1" - "0*"	User interactions with products
Product	Product : hasProd-	have been enhanced with methods
	uct	like listProduct(productDetails:
		ProductDetails): boolean.
User and	User "1" - "0*"	Methods like
Transac-	Transaction : has-	manageTransactionsAndPayments()
tion	Transaction	in the User class and
		processTransaction(transactionDetails:
		TransactionDetails): boolean in the
		Transaction class have been added.
User and	User "1" - "0*"	The Review class now includes the
Review	Review : hasReview	method submitReview(reviewDetails:
		ReviewDetails): boolean.
User	Implicit through	The ServiceRequest class
and Ser-	use cases	includes methods such as
viceRequest		submitCollectionRequest(requestDetails:
		CollectionRequestDetails): boolean.
Transaction	PaymentGateway	The PaymentGateway class
and	"1" – "0*"	now includes the method
Payment-	Transaction: man-	manageTransactionsAndPayments().
Gateway	agesPayment	

4.4.6 Relationship Validation

To ensure that the new and modified relationships in the class diagram accurately represent the system's functionality, we validated them against the detailed use cases. Table 5 presents this validation, showing how each new or modified relationship maps to the corresponding use cases.

Table 5: Validation of New and Modified Relationships Against Use Cases

New/Modified Relationship	Referenced in Use Case(s)
User interactions with products	UC2: Listing Recyclable Waste
have been enhanced with methods	Products
like listProduct(productDetails:	UC3: Buying Recyclable Waste
ProductDetails): boolean	Products
	UC4: Selling Recyclable Waste
	Products
Methods like manageTransactionsAndPayments()	UC3: Buying Recyclable Waste
in the User class and	Products
<pre>processTransaction(transactionDetails:</pre>	UC4: Selling Recyclable Waste
TransactionDetails): boolean in the	Products
Transaction class have been added	UC17: Managing Transactions
	and Payments
The Review class now includes the	UC5: Reviewing Products or Ser-
method submitReview(reviewDetails:	vices
ReviewDetails): boolean	
The ServiceRequest class	UC7: Requesting Waste Collec-
includes methods such as	tion Services
<pre>submitCollectionRequest(requestDetails:</pre>	UC8: Requesting Waste Trans-
CollectionRequestDetails): boolean	port Services
The PaymentGateway class now includes the	UC3: Buying Recyclable Waste
method manageTransactionsAndPayments()	Products
	UC4: Selling Recyclable Waste
	Products
	UC17: Managing Transactions
	and Payments

This validation ensures that the system's functionality aligns with the user requirements and the platform's operational goals. The relationships such as enhanced product interactions, transaction and payment management, review submissions, and service requests have been effectively mapped to their corresponding use cases, confirming their necessity and implementation correctness. These validated relationships confirm that the class diagram accurately represents the system's necessary interactions and supports the comprehensive functionality required by the platform. This alignment between the class diagram and use cases ensures that the design is robust, user-centric, and prepared to handle real-world operations effectively.

4.5 Classes Without Methods

The following classes do not contain any methods and were not initially covered in the documentation:

- Product
- CollectionPoint

- RecyclingPoint
- EnvironmentalImpact
- InformationResource
- RewardSystem
- PaymentDetails
- ShippingDetails
- TransportCompany
- StateAdministration

Additionally, subclasses such as IndividualUser and CorporateUser (extending the User class) and Plastic, Paper, Metal, and Glass (extending the Product class) also do not have any specific methods defined for them.

Future iterations should focus on integrating these unimplemented methods and refining class roles to optimize system functionality and user interaction, ensuring a robust and comprehensive software architecture.

4.6 Conclusion

The results section has provided a comprehensive presentation of the enhanced class diagrams, the methods added to key classes, and the new and modified relationships among classes. These enhancements, guided by the functional requirements extracted through the use of ChatGPT to analyze natural language use cases, demonstrate the methodology's effectiveness. Further discussions and interpretations of these results will be presented in the subsequent "Discussion" section.

5 Discussion

Our study presents a novel AI-assisted methodology to enhance UML class diagrams by integrating NLP capabilities through ChatGPT. Unlike traditional methodologies that rely on manual translation of use case scenarios into design elements, our approach leverages AI to automate and refine this process, leading to more accurate and dynamic class diagrams.

5.1 Key Findings and Methodological Advancements

Traditional methodologies for enhancing UML class diagrams often involve substantial manual effort and are susceptible to errors and inconsistencies, such as:

- Errors in Translation: Misinterpretation of use case scenarios leading to incorrect or incomplete design elements.
- Inconsistencies: Variations in how different team members interpret and document use cases.
- Time-Consuming Processes: Manual processes are slow and require significant effort from skilled developers.

To address these challenges, our study introduces a novel AI-assisted approach leveraging ChatGPT to automate the extraction of methods from natural language use case tables and integrate them into UML class diagrams. This advancement significantly enhances system understanding and streamlines the software development process. The key methodological advancements include:

- 1. Automated Method Extraction: ChatGPT analyzes natural language use case tables to identify potential methods and their relationships, reducing the manual effort required for this task.
- 2. **Dynamic Diagram Enhancement:** The extracted methods are iteratively integrated into the UML class diagrams, transforming them from static to dynamic representations that accurately reflect system behaviors.
- 3. **Improved Accuracy and Consistency:** The automation process minimizes human error and ensures consistent application of design elements across the entire diagram.
- 4. **Time Efficiency:** By automating the extraction and integration process, the time and effort required to enhance class diagrams are significantly reduced.

These advancements showcase the significant benefits of integrating AI with traditional software design processes, making the overall design process more efficient and less prone to error.

5.2 Interpretation of Results and Practical Implications

Integrating ChatGPT to enhance UML class diagrams led to substantial improvements in system design accuracy and comprehensiveness. Initially, the class diagram was a static representation of the system's structure. Through iterative applications of ChatGPT, the diagram was enriched by adding methods and refining relationships, capturing the full spectrum of system behaviors outlined in the use cases.

5.2.1 Practical Implications:

- Accuracy and Comprehensiveness: ChatGPT identified and incorporated methods from natural language use cases, ensuring the diagram accurately reflected system functionalities and served as a more complete blueprint for implementation.
- Dynamic Method Integration: The iterative use of ChatGPT allowed continuous refinement of the class diagrams. Each method added was evaluated for alignment with system requirements, ensuring relevance and accuracy.
- System Behavior Representation: Adding methods bridged the gap between structural design and system behavior, providing a dynamic representation of functionalities
- Broad Implications for Software Engineering: Beyond our project, ChatGPT's capabilities have significant implications for software engineering. It can generate documentation, suggest code improvements, and facilitate real-time collaboration among development teams. However, challenges such as ensuring the contextual accuracy of extracted methods and the need for continuous training to adapt to domain-specific language remain. Addressing these challenges is crucial for maximizing the effectiveness of AI tools in software development.

5.2.2 Examples of Enhancements:

- Transforming StaticDiagrams: By interpreting language cases. ChatGPT autonomously transforms static class diagrams into models reflecting system functionalities. For instance, dynamic login, monitorRecyclingAndWasteManagementPerformance, viewAndAnalyzeWasteManagementData were added to relevant classes like User, Transaction, and PlatformManager, resulting in more comprehensive and functional diagrams.
- IntuitiveAugmentations: ChatGPT's advanced analytical capabilities were demonstrated when autonomously added the PlatformManager class established relationships based requirenew on use case ments, without explicit instructions. This included the addition methods like login, viewAndAnalyzeWasteManagementData, monitorRecyclingAndWasteManagementPerformance, enriching the diagram's detail and accuracy.

5.3 Agile Adaptability

Our AI-driven approach enhances flexibility and responsiveness in Agile software development by dynamically updating class diagrams based on new use cases and requirements. This ensures the diagrams remain relevant throughout the development process, supporting continuous improvement and rapid iterations, key principles of Agile methodologies like Scrum [41] and Kanban [42].

5.3.1 Practical Benefits:

• Flexibility and Responsiveness: Dynamic updates keep class diagrams accurate and adaptable to changes without disrupting development.

- Enhanced Clarity and Usability: Updated diagrams improve traceability and alignment with system requirements, providing a comprehensive view of class interactions and relationships.
- Support for Agile Principles: Continuously refined diagrams align with evolving use cases, supporting iterative development, continuous feedback, and rapid adaptation.

5.4 Method Implementation Based on Use Case Availability

Implementing class methods based on use case availability provides a structured, efficient, and user-focused approach to software development. This ensures that each class in the system is functional, maintainable, and aligned with real-world requirements, leading to a more robust and user-friendly application.

5.4.1 Key Aspects:

1. Targeted Development:

- Efficiency: Focuses development efforts on explicitly required functionalities, avoiding unnecessary code.
- Relevance: Ensures methods implemented are directly relevant to the application's needs.

2. Improved Maintainability:

- Clear Requirements: Methods are added based on well-documented use cases, making the code easier to understand and maintain.
- Simplified Updates: Changes in requirements can be addressed by updating specific, well-documented methods, reducing modification complexity.

3. User-Centric Development:

- *User Needs Focus:* Aligns development with user needs and requirements, enhancing user satisfaction.
- Feedback Incorporation: Facilitates incorporating user feedback into specific, actionable changes.

4. Consistency Across Classes:

- *Uniform Enhancements:* Ensures all classes are enhanced consistently based on the availability of use cases, maintaining uniform functionality across the system.
- System Integrity: Maintains overall system integrity by ensuring each class has methods that are necessary and sufficient for its role.

5. Scalability and Extensibility:

- *Modular Growth:* Allows for the addition of new methods as new use cases arise, enabling controlled and modular system growth.
- Adaptability: Adapts to new requirements and use cases without extensive refactoring, making the system more scalable and extensible.

5.5 Implications for Software Engineering

Integrating AI, specifically NLP, into software modeling tasks can significantly enhance efficiency and accuracy by automating routine tasks and ensuring dynamic updates. This reduces the workload on developers, allowing them to focus on crucial design decisions and innovative solutions.

5.5.1 Benefits:

- Enhanced Efficiency and Accuracy: Automating repetitive tasks allows developers to focus on complex design decisions, with continuous updates to class diagrams ensuring they reflect the latest requirements and use cases accurately.
- Reduced Developer Workload: Automation frees developers from routine tasks, allowing more time for critical design aspects, thus accelerating the development process by quickly translating use cases into class diagrams.
- Improved Software Model Quality: Clearer, more maintainable class diagrams improve understanding and communication among team members and stakeholders. Automation minimizes human error, ensuring accurate and consistent diagrams.
- Agile Compatibility: AI-driven approaches support Agile methodologies by facilitating continuous feedback and rapid iterations, keeping design aligned with evolving requirements.
- Innovation and Adaptability: Automated updates to class diagrams enable quick adaptation to changing requirements or new technologies, fostering exploration of alternative designs.
- Adherence to Standards: Ensures diagrams conform to UML best practices and naming conventions.

5.5.2 Challenges:

- **Human Oversight:** Despite the automation capabilities, human judgment remains crucial for overseeing complex decisions and ensuring the integrity of design refinements.
- Bias Mitigation: Addressing inherent biases in AI algorithms is essential to maintain fairness and objectivity in the design process.

This study illustrates the transformative potential of AI in software engineering, paving the way for more innovative, efficient, and adaptive methodologies.

5.6 Ethical Considerations

The integration of AI technologies like ChatGPT in software engineering raises several ethical considerations. These include concerns about data privacy, as the training of such models often requires access to extensive datasets that may contain sensitive information. Additionally, there is the potential for dependency on automated systems, which could lead to a devaluation of human expertise and oversight in critical design processes. Ensuring transparent AI training processes and adhering to ethical standards and regulations is paramount to foster trust and accountability in automated systems.

5.7 Detailed Analyses

5.7.1 Integration of Methods According to Use Cases

The methodology presented in this study effectively integrates methods into a previously static class diagram, based on the detailed analysis of use case tables for a Waste Recycling Platform. Each step in the methodology contributes to the enrichment of the class diagram, ensuring that it reflects the functional requirements of the system.

The methods incorporated into the class diagram are directly derived from the actions and scenarios described in the use cases. For instance, the User class includes methods like registerUser, listProduct, and submitFeedbackOrReport, which align with use cases such as UC1 (Registration), UC2 (Listing Recyclable Waste), and UC8 (Submitting Feedback), respectively. Each method's parameters are meticulously chosen to match the required inputs for these actions, ensuring a seamless integration of functional requirements.

The Transaction class methods, such as processTransaction and processSale, correspond to use cases involving buying and selling recyclable waste (UC3 and UC4). These methods encapsulate transaction details, reflecting the complex interactions between users and the system during these processes.

The iterative process not only adds methods but also refines relationships between classes. For example, the enhanced relationship between User and Product classes, facilitated by methods like listProduct, illustrates the dynamic interaction required for product management. Similarly, the introduction of the PlatformManager class, with methods for logging in, analyzing waste management data, and monitoring performance, highlights the administrative functionalities necessary for platform management.

The study also identifies and integrates new relationships, such as those between Transaction and PaymentGateway classes, ensuring that payment processes are accurately represented. The validation of these relationships against the use cases confirms their relevance and correctness, enhancing the diagram's fidelity to the system's intended behavior.

The enhanced class diagram's behavioral alignment with the use cases ensures that each method added to the classes supports the system's functional requirements. The validation process, detailed in the results section, demonstrates that the methods are not only necessary but also correctly implemented. This validation is critical for maintaining the integrity and usability of the class diagram, providing stakeholders with a reliable blueprint for system implementation.

The validation against 23 distinct use cases ensures comprehensive coverage of the system's functionality, confirming that the enriched class diagram accurately represents both static structure and dynamic behavior. This alignment is crucial for effective communication, design, and implementation, reducing the risk of errors and inconsistencies in the final system.

5.7.2 Unimplemented Methods

The following table (6) provides examples of methods that were not implemented for specific use cases. This highlights the gaps that need to be addressed to ensure comprehensive system functionality.

Use Case	Proposed Implementation	
UC6: Accessing Educa-	Implement accessResources()	
tional Resources	method in InformationResource class.	
UC9: Viewing Col-	Implement viewCollectionPoints()	
lection and Recycling	and viewRecyclingPoints() meth-	
Points	ods in CollectionPoint and	
	RecyclingPoint classes.	
UC10: Monitoring	Implement	
Environmental Impact	<pre>viewEnvironmentalImpact(productID:</pre>	
	string) method in	
	EnvironmentalImpact class.	

Table 6 Not Implemented Methods

Potential Reasons for Omitted Methods

- UC6: Involves information retrieval, which ChatGPT might have deprioritized.
- UC9: Viewing data might have been seen as less dynamic.
- UC10: Monitoring and analyzing data could have been overlooked due to the focus on action-driven methods.

Implementing class methods based on use case availability provides a structured, efficient, and user-focused approach to software development. This ensures that each class in the system is functional, maintainable, and aligned with real-world requirements, leading to a more robust and user-friendly application. For example, while methods for listing, buying, and selling products were added to related classes (User, Transaction), the Product class lacks methods due to the absence of explicit use cases detailing necessary operations for products.

5.8 Comparison with Other Works

This subsection compares our AI-assisted methodology for enhancing UML class diagrams with other approaches in terms of accuracy, efficiency, time, and alignment with Agile practices.

5.8.1 Accuracy

Our methodology leverages detailed use case tables and advanced NLP capabilities of ChatGPT to ensure high accuracy in extracting and integrating methods. This results in more comprehensive and functional UML diagrams compared to other methods. For instance, Egyed's abstracted UML models [16] and Eichelberger's improved layouts [19] lack the depth and accuracy in method extraction. Similarly, while Nasiri [23], Sharma [20], Lucassen [25], and Kumar [24] aim for accuracy, they do not match the

comprehensiveness of our approach. Anda and Sjøberg [12] generate enhanced UML diagrams but fall short in method extraction and integration accuracy.

5.8.2 Efficiency

Our approach enhances efficiency by automating method extraction and integration, reducing manual effort and errors. Unlike traditional methods that require manual translation of use case scenarios [16, 19], our use of AI provides a distinct advantage. Nasiri [23] and Sharma [20] improve efficiency with structured requirements, but our approach further minimizes human intervention, enhancing overall efficiency.

5.8.3 Time

The iterative and real-time updating capabilities of our methodology significantly reduce the time required to generate UML diagrams. This is a substantial improvement over the more time-consuming manual processes used by Egyed and Eichelberger [16, 19]. While Nasiri [23] and Sharma [20] offer moderate support for iterative processes, our real-time updating capability ensures immediate integration of changes, making it more time-efficient.

5.8.4 Alignment with Agile Practices

Our methodology supports Agile practices through iterative development, continuous feedback, and rapid adaptation. The real-time updating and iterative enhancement capabilities ensure class diagrams remain relevant, aligning with Agile principles [41, 42]. Egyed [16] and Osman [21] provide limited Agile support, while Nasiri [23] and Sharma [20] offer moderate alignment. Our strong alignment with Agile methodologies enhances applicability in modern software development.

Automated Method Extraction

Previous tools like those described in [30, 35, 40] lack the capability to automatically extract and integrate methods, resulting in incomplete diagrams. Our methodology automates method extraction, reducing manual effort and enhancing diagram completeness.

Dynamic Enhancement

Tools such as CM-Builder [35], Automated Conceptual Model [4], and REBUILDER UML [40] generate static diagrams that require significant user intervention for updates. In contrast, our approach dynamically enhances class diagrams iteratively, reflecting the latest functional requirements and supporting agile development practices.

Reduced User Intervention

High levels of user intervention required by tools such as the D-H project [35], LIDA tool [34], and semi-automated approaches [14] are a common limitation. Our AI-driven methodology minimizes manual refinement, making the process more efficient and less error-prone, which is especially beneficial in large-scale projects.

Simplicity of Use

The simplicity of use is another significant advantage. Tools like MOVA [40] and RACE [33] are complex to set up and require extensive manual intervention. Our AI-driven methodology automates complex tasks, making the process user-friendly and accessible, even for those with limited technical expertise.

5.8.5 Emphasis on System Behavior/Dynamism

Our methodology excels in capturing the system's dynamic behavior through automated method extraction and iterative diagram enhancement. This focus on behavior is a significant advancement over previous tools. By continuously updating the diagrams to reflect new methods and relationships, our approach ensures structurally sound and behaviorally comprehensive models, providing a robust blueprint for system implementation.

By addressing the limitations of existing tools—such as static diagrams, high user intervention, and limited method extraction—our approach offers a more dynamic, efficient, and comprehensive solution for class diagram generation.

5.9 Limitations and Threats to Validity

While our approach offers significant improvements, it also presents some limitations and potential threats to validity that need consideration.

1. Input Quality Dependence:

- Limitation: The accuracy of the enhancements depends significantly on the quality and clarity of input use case tables. Poor documentation can lead to incorrect method extraction and integration.
- Mitigation: Ensuring high-quality, detailed use case documentation and incorporating a validation step to check clarity before processing can mitigate this limitation.

2. NLP Challenges:

- Limitation: ChatGPT's natural language processing capabilities might require human oversight to ensure accuracy, particularly with domain-specific nuances. Misinterpretations can occur, leading to inaccuracies in the generated diagrams.
- Mitigation: Incorporating domain-specific training data for ChatGPT and including a review process by domain experts can address this issue.

3. Single Use Case Limitation:

- Limitation: The study's reliance on a single use case may affect the generalizability of the methodology. Different systems and use cases might present unique challenges that this study did not address.
- *Mitigation*: Validating the methodology across diverse use cases and larger systems can confirm its effectiveness and scalability.

4. Human Oversight and AI Bias:

- Limitation: Inherent biases in AI algorithms can affect the interpretation of use cases, highlighting the importance of human intervention. AI bias can lead to skewed results and unfair or incorrect system design decisions.
- *Mitigation*: Implementing rigorous testing and review protocols to identify and mitigate biases and ensuring continuous training and updates to the AI model to adapt to new data and requirements are essential steps.

5. Scalability:

- Limitation: The methodology's performance and scalability when applied to large-scale projects or diverse domains have not been thoroughly tested.
- *Mitigation*: Applying the AI-driven approach to large-scale projects in different domains and analyzing performance metrics can ensure its robustness and flexibility for different project sizes and complexities.

6. Empirical Studies:

- Limitation: The lack of empirical studies measuring the impact of this methodology on development efficiency and project outcomes could limit its perceived validity.
- Mitigation: Conducting empirical studies to compare AI-driven methodology with traditional methods and collecting and analyzing data on development efficiency, accuracy, and user satisfaction can provide quantitative and qualitative evidence of the methodology's benefits and challenges.

5.10 Future Research Directions

Future research will prioritize refining methodologies, expanding applications, and assessing the impact on design efficiency, maintenance, and system scalability in software engineering. The following prioritized areas represent the most critical aspects to be addressed:

1. Improving Use Case Documentation:

- Objective: Enhance the quality and clarity of use case documentation to improve AI-driven method extraction.
- *Plan*: Develop standardized templates and guidelines for writing detailed and unambiguous use cases.
- *Hypothesis*: Standardized and high-quality use case tables will significantly improve the accuracy of method extraction by ChatGPT, resulting in more precise and complete class diagrams.
- Connection to Findings: This direction addresses the identified limitation of input quality dependence, ensuring that the AI-driven process can consistently produce accurate results.

2. Enhancing NLP Capabilities:

 Objective: Integrate advanced NLP models to handle more complex use cases effectively.

- Plan: Incorporate domain-specific training data to fine-tune ChatGPT for better comprehension of specialized terminology and context. Collaborate with NLP researchers to enhance the model's capabilities.
- Hypothesis: Advanced and domain-specific NLP models will improve the accuracy and relevance of method extraction, especially for complex and niche software systems.
- Connection to Findings: This direction aims to mitigate the NLP challenges identified, improving the system's ability to interpret and process domain-specific language accurately.

3. Developing Automated Validation Tools:

- Objective: Create tools to automatically verify the correctness and completeness of class diagrams.
- *Plan*: Develop validation algorithms that can compare generated diagrams against use case requirements and industry standards. Integrate these tools into the AI-driven process for real-time validation.
- *Hypothesis*: Automated validation tools will reduce the need for manual reviews, ensuring the diagrams consistently meet specified requirements and standards.
- Connection to Findings: This addresses the need for human oversight and reduces the dependency on manual validation, enhancing the overall reliability of the AI-generated diagrams.

4. Testing Scalability:

- *Objective*: Evaluate the methodology's performance and scalability on larger, more complex systems.
- *Plan*: Apply the AI-driven approach to large-scale projects in various domains, such as healthcare, finance, and manufacturing. Analyze performance metrics and identify scalability challenges.
- *Hypothesis*: The methodology will be scalable and adaptable across different domains, demonstrating its robustness and flexibility for various project sizes and complexities.
- Connection to Findings: This directly addresses the scalability limitation, ensuring that the methodology can be applied effectively to a wide range of applications.

5. Conducting Empirical Studies:

- *Objective*: Measure the impact of the AI-driven methodology on development efficiency and project outcomes.
- Plan: Design and implement empirical studies to compare AI-driven methodology with traditional methods. Collect and analyze data on development efficiency, accuracy, and user satisfaction.
- Hypothesis: Empirical studies will provide quantitative and qualitative evidence
 of the benefits and challenges of using AI-driven methodologies, guiding future
 improvements and adoption.

• Connection to Findings: This addresses the limitation of lacking empirical validation, providing concrete data to support the efficacy of the AI-driven approach.

6. Addressing Ethical and Bias Considerations:

- Objective: Ensure ethical use and mitigate biases in automated diagram generation.
- *Plan*: Implement protocols for ethical AI use and continuous monitoring to identify and address biases in AI algorithms.
- *Hypothesis*: Ethical guidelines and bias mitigation strategies will enhance the fairness and objectivity of AI-driven processes.
- Connection to Findings: This responds to the identified need for human oversight and AI bias mitigation, ensuring responsible AI implementation.

7. Optimizing Human-AI Collaboration:

- Objective: Integrate human oversight with AI-driven methodologies for optimal performance.
- *Plan*: Develop frameworks for effective human-AI collaboration, leveraging the strengths of both for improved outcomes.
- *Hypothesis*: Balanced human-AI collaboration will enhance the quality and reliability of class diagram generation.
- Connection to Findings: This addresses the need for human intervention in complex decision-making, ensuring that AI complements rather than replaces human expertise.

By clearly prioritizing these future research directions and tying each to specific findings and limitations of the current study, we ensure a focused and actionable path forward for improving and expanding the AI-driven methodology.

5.11 Responses to Research Questions

- RQ1: To what extent is it feasible to integrate ChatGPT to dynamically enhance the class diagram dynamics effectively?
 - Response: The integration of ChatGPT into the process of enhancing UML class diagrams has proven to be highly feasible. ChatGPT successfully analyzed natural language use case tables to identify relevant methods for each class, dynamically updating the initial static diagram. This iterative enrichment process, guided by AI, ensured that the class diagram evolved to accurately represent the system's functional requirements.
- RQ2: How does the AI-driven enhancement of UML class diagrams impact the efficiency and accuracy of software modeling compared to traditional manual methods?
 - Response: AI-driven enhancement of UML class diagrams significantly improves both the efficiency and accuracy of software modeling. By automating the extraction and integration of methods from detailed use cases, ChatGPT reduced the

time and effort required for these tasks, enhancing the efficiency of the modeling process. Additionally, the AI-driven approach minimized human error and ensured consistent application of design elements, leading to more accurate and comprehensive class diagrams.

- RQ3: What are the limitations and challenges of using ChatGPT for dynamic class diagram enhancement, and how can these be mitigated?
 - Response: Using ChatGPT for dynamic class diagram enhancement presents several limitations and challenges. One major limitation is the AI's reliance on the quality and clarity of the initial use case scenarios, which can impact the accuracy of the enhancements. Additionally, ChatGPT may struggle with domain-specific terminology or ambiguous use case descriptions, potentially leading to inaccuracies. To mitigate these challenges, it is essential to ensure high-quality, detailed use case documentation and incorporate human oversight to verify the AI-generated enhancements. Future research should focus on improving the AI's comprehension capabilities and developing automated validation tools to ensure the integrity and accuracy of the enhanced class diagrams.

5.12 Conclusion

In summary, utilizing ChatGPT to enhance class diagrams by analyzing natural language use cases has proven effective. The enhanced diagrams accurately reflect functional requirements, covering most use cases provided. This study highlights AI tools' potential to improve software design processes, contributing to both theoretical and practical advancements in the field. This study presents a novel approach to dynamically enhancing UML class diagrams by leveraging ChatGPT to analyze natural language use cases. The methodology significantly improves the clarity, maintainability, and functional completeness of the class diagrams, offering a robust blueprint for system implementation. Future research will focus on addressing identified limitations and expanding the methodology's applicability to broader and more complex systems.

6 Conclusion

This study explored the integration of ChatGPT, an advanced AI language model, into the process of dynamically enhancing UML class diagrams. By leveraging NLP techniques, we demonstrated that AI can effectively automate the extraction of methods and interactions from detailed use case tables and incorporate them into class diagrams. This approach not only improves the accuracy and completeness of the diagrams but also significantly reduces the manual effort required for their creation and maintenance.

Including methods in class diagrams provides a detailed specification of the functionalities a class offers, representing both the structure and behavior of the system. This practice enhances documentation, design clarity, and maintainability while supporting modularity and facilitating object-oriented design principles. The findings of this study indicate that AI-driven methodologies hold substantial potential for transforming traditional software engineering practices.

The study found that integrating ChatGPT significantly improved the accuracy and efficiency of class diagram creation and maintenance. The dynamic enhancement of class diagrams using ChatGPT provides a more comprehensive representation of system behaviors and interactions, which is crucial for accurate system modeling and design. This approach aligns well with Agile development practices, facilitating rapid iterations and continuous improvement.

However, the methodology's effectiveness is contingent on the quality of the input use case tables and may require human oversight to ensure accuracy. Future research should explore the application of AI-driven methodologies to other types of software models and address the identified limitations to further enhance their applicability.

In conclusion, the integration of AI, particularly NLP techniques like those employed by ChatGPT, represents a significant advancement in software engineering practices. By automating routine tasks and ensuring dynamic updates, AI-driven approaches can transform traditional methodologies, leading to more accurate, efficient, and innovative software development processes. Continued research and development in this area are imperative to harness the full capabilities of AI and advance the state of software engineering.

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- Author contribution:
 - Djaber Rouabhia conceived and designed the study, conducted the experiments and wrote the manuscript.
 - Ismail Hadjadj analyzed the data and reviewed the manuscript.

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Appendix A Detailed Use Case Tables

The purpose of this appendix is to provide a comprehensive reference of the 23 detailed use case tables that support the main article. These tables have been formulated in natural language and structured with columns such as Use Case ID, Actor, Description, Pre-condition, Trigger, Main scenario, Post-condition, and Exceptions. By including these detailed use case tables in a separate appendix, the clarity and flow of the main article are maintained, ensuring that readers can focus on the core content without being overwhelmed by extensive technical details. Each use case table offers a granular view of the interactions and functionalities required by the system, serving as a primary reference for identifying the necessary methods for each class to facilitate the described functionalities. The tables were originally derived by master's degree students in computer science from a waste recycling platform specification document, underscoring their practical relevance and depth.

The following sections present the detailed use case tables for various user interactions and system functionalities, providing a robust foundation for understanding the dynamic behaviors within the system.

A.1 UC1: User Registration

Attribute	Details	
Actor	Visitor	
Use Case	User Registration	
Description	A visitor to the platform registers as a user.	
Pre-conditions	Visitor is not registered.	
Triggers	Visitor selects to register	
Main Scenario		
	 Visitor accesses registration page. Visitor provides required information (name, contact details, etc.). Visitor submits the registration form. System validates the information. System creates a new user account. Visitor receives confirmation of successful registration. 	
Post-conditions	Visitor is registered and can log in.	
Extensions		
	1. Invalid information provided.	
	2. User already exists.	
	3. Technical issues during registration.	

Relationships	
	 Visitor is associated with User Registration. User Registration extends to Authentication for subsequent logins.

A.2 UC2: Listing Recyclable Waste Products

Attribute	Details
Actor	User
Use Case	Listing Recyclable Waste Products
Description	User lists a recyclable waste product for sale.
Pre-conditions	User is registered and logged in.
Triggers	User chooses to list a product.
Main Scenario	
Dest and it is a	 User accesses product listing page. User enters product details. User submits the listing. System validates and publishes the listing.
Post-conditions Extensions	Product is listed on the platform.
Extensions	
	1. Invalid product details.
	2. Duplicate product listing.
	3. Technical issues during listing.
Relationships	Related to User Registration and Product Management.

A.3 UC3: Buying Recyclable Waste Products

Attribute	Details
Actor	User
Use Case	Buying Recyclable Waste Products
Description	User purchases a recyclable waste product.
Pre-conditions	User is registered and logged in, product is listed.
Triggers	User selects a product to buy.

Main Scenario	
	1. User browses products.
	2. User selects a product.
	3. User completes the purchase process.
	4. Transaction is processed.
Post-conditions	Product is purchased and removed from listings.
Extensions	
	1. Payment failure.
	2. Product out of stock.
	3. Technical issues during purchase.
Relationships	Related to Product Listing and Payment Processing.

A.4 UC4: Selling Recyclable Waste Products

Attribute	Details
Actor	User
Use Case	Selling Recyclable Waste Products
Description	User sells a recyclable waste product.
Pre-conditions	User is registered and logged in, product is listed.
Triggers	User chooses to sell a product.
Main Scenario	
	 User accesses product selling page. User enters sale details. User submits the sale. System processes the sale.
Post-conditions	Product is sold and transaction is completed.
Extensions	
	1. Payment failure.
	2. Buyer cancels the purchase.
	3. Technical issues during sale.
Relationships	Related to Product Listing and Transaction Management.

A.5 UC5: Reviewing Products or Services

Attribute	Details
Actor	User
Use Case	Reviewing Products or Services

Description	User provides feedback on a purchased product or received
	service.
Pre-conditions	User has completed a purchase or received a service.
Triggers	User opts to write a review.
Main Scenario	
	1. User accesses review page.
	2. User writes and submits the review.
	3. System publishes the review.
Post-conditions	Review is available for other users to see.
Extensions	
	1. Inappropriate content in the review.
	2. Technical issues during review submission.
Relationships	Linked with Product Purchase and Service Utilization.

A.6 UC6: Accessing Educational and Awareness Resources

Attribute	Details
Actor	User
Use Case	Accessing Educational and Awareness Resources
Description	User accesses resources for education and awareness about
	waste management.
Pre-conditions	Resources are available on the platform.
Triggers	User navigates to the educational resources section.
Main Scenario	
	 User selects the resources section. User browses various resources. User reads or downloads the desired materials.
Post-conditions	User gains knowledge or information.
Extensions	
	1. Resource not available.
	2. Technical issues accessing resources.
Relationships	Supports User Education and Engagement.

A.7 UC7: Requesting Waste Collection Services

Attribute	Details
Actor	User

Use Case	Requesting Waste Collection Services
Description	User requests a service for waste collection.
Pre-conditions	User is registered and has waste to be collected.
Triggers	User decides to request waste collection.
Main Scenario	 User accesses the service request section. User fills out and submits the collection request form. Service provider receives the request and schedules the collection.
Post-conditions	Waste collection service is scheduled.
Extensions	
	 Incomplete request form. No service providers available. Technical issues during request submission.
Relationships	Linked with User Registration and Service Management.

A.8 UC8: Requesting Waste Transport Services

Attribute	Details
Actor	User
Use Case	Requesting Waste Transport Services
Description	User requests a service for transporting waste.
Pre-conditions	User is registered and requires waste transport.
Triggers	User decides to request waste transport.
Main Scenario	
	 User accesses the transport service request section. User fills out and submits the transport request form. Transport provider receives the request and schedules the transport.
Post-conditions	Waste transport service is scheduled.
Extensions	
	 Incomplete request form. No transport providers available. Technical issues during request submission.
Relationships	Linked with User Registration and Transport Service Management.

A.9 UC9: Viewing Collection and Recycling Points

Attribute	Details
Actor	User
Use Case	Viewing Collection and Recycling Points
Description	User views the locations of collection and recycling points.
Pre-conditions	Collection and recycling points are registered on the platform.
Triggers	User wishes to locate a collection or recycling point.
Main Scenario	
	 User accesses the map or list of points. User browses or searches for specific locations. User views details of selected points.
Post-conditions	User is informed about the locations.
Extensions	 No points in the user's area. Technical issues accessing the map or list.
Relationships	Supports Waste Collection and Recycling Services.

A.10 UC10: Monitoring Environmental Impact of Products

Attribute	Details
Actor	User
Use Case	Monitoring Environmental Impact of Products
Description	User accesses information about the environmental impact of
	products.
Pre-conditions	Environmental impact data is available for products.
Triggers	User wishes to understand the environmental impact of a
	product.
Main Scenario	
	1. User selects a product.
	2. User views the environmental impact details provided.
	3. User gains insights into the product's sustainability.
	5. Osci gams insignes into the product's sustamability.
Post-conditions	User is informed about the product's environmental impact.
Extensions	
	1. No impost data available
	1. No impact data available.
	2. Technical issues accessing the data.
Relationships	Linked with Product Listing and Environmental Awareness.

A.11 UC11: Managing User Rewards

Attribute	Details
Actor	User
Use Case	Managing User Rewards
Description	User participates in and manages their rewards and incentives.
Pre-conditions	User is eligible for rewards.
Triggers	User engages in activities that accrue rewards.
Main Scenario	
	 User completes qualifying activities. User accumulates rewards points. User redeems points for rewards or incentives.
Post-conditions	User receives rewards or incentives.
Extensions	Oser receives rewards or incentives.
Datensions	 Dispute over reward points. Technical issues in rewards management.
Relationships	Supports User Engagement and Loyalty Programs.

A.12 UC12: Tracking Waste Journey

Attribute	Details
Actor	User
Use Case	Tracking Waste Journey
Description	User tracks the journey of waste from collection to final
	treatment.
Pre-conditions	Waste has been collected and is in the process of being treated.
Triggers	User wants to know the status of their waste.
Main Scenario	
	1. User accesses the waste tracking feature.
	2. User inputs the tracking code.
	3. System displays the current status and location of the waste.
Post-conditions	User is informed about the waste journey status.
Extensions	
	1. Invalid tracking code.
	2. Technical issues in tracking system.
	- *
Relationships	Linked with Waste Collection and Transport Services.

${\bf A.13}\quad {\bf UC13:\ Submitting\ Feedback\ or\ Reports}$

Attribute	Details
Actor	User
Use Case	Submitting Feedback or Reports
Description	User submits feedback or reports related to the platform's
	services.
Pre-conditions	User has used a service or wishes to provide feedback.
Triggers	User has feedback or a report to submit.
Main Scenario	
	 User accesses the feedback section. User fills out and submits the feedback form. Feedback is received and processed by the platform.
Post-conditions	Feedback or report is submitted and acknowledged.
Extensions	 Incomplete feedback form. Technical issues during submission.
Relationships	Supports Continuous Improvement and User Engagement.

A.14 UC14: Viewing Service Requests and Status

Attribute	Details
Actor	User
Use Case	Viewing Service Requests and Status
Description	User views and tracks the status of their service requests.
Pre-conditions	User has made one or more service requests.
Triggers	User wants to check the status of a service request.
Main Scenario	
	 User accesses their service request history. User selects a request to view details. System displays the current status and details of the request.
Post-conditions	User is updated on the status of their service requests.
Extensions	 Service request not found. Technical issues accessing request details.
Relationships	Linked with Service Request Management.

A.15 UC15: Managing Platform Services

Attribute	Details
Actor	Platform Manager
Use Case	Managing Platform Services
Description	Platform manager oversees and manages the services offered
	on the platform.
Pre-conditions	Services are active on the platform.
Triggers	Regular management or response to service-related issues.
Main Scenario	
	 Manager logs into the management portal. Manager reviews and updates service listings. Manager addresses any service-related issues or feedback.
Post-conditions	Platform services are effectively managed and updated.
Extensions	 Unauthorized access attempt. Technical issues in the management portal.
Relationships	Central to Platform Operations and Service Quality.

A.16 UC16: Managing User Profiles and Accounts

Attribute	Details
Actor	User
Use Case	Managing User Profiles and Accounts
Description	User manages their personal profile and account settings.
Pre-conditions	User is registered and has an account.
Triggers	User needs to update profile information or account settings.
Main Scenario	
	1. User logs into their account.
	2. User accesses the profile settings.
	3. User updates their profile or account settings as needed.
	4. Changes are saved and applied.
Post-conditions	User's profile and account settings are updated.
Extensions	
	1. Invalid input in profile update.
	2. Technical issues saving changes.
Relationships	Integral to User Account Management.

A.17 UC17: Managing Transactions and Payments

Attribute	Details
Actor	User
Use Case	Managing Transactions and Payments
Description	User manages their financial transactions and payment
	methods.
Pre-conditions	User has conducted or wishes to conduct transactions.
Triggers	User needs to review or manage transactions or payment
	methods.
Main Scenario	
	1. User logs into their account.
	2. User accesses the transactions section.
	3. User reviews transaction history or manages payment meth-
	ods.
	4. Any changes or updates are saved.
	, ,
Post-conditions	User's transactions and payment methods are managed.
Extensions	
	1. Transaction dispute.
	2. Technical issues with payment processing.
	2. Zeemiest zeeteeen paymone processing.
Relationships	Linked with Financial Management and Security.

A.18 UC18: Connecting with Transport Companies

Attribute	Details
Actor	User
Use Case	Connecting with Transport Companies
Description	User connects with transport companies for waste transport
	services.
Pre-conditions	User requires waste transport services.
Triggers	User decides to arrange for waste transport.
Main Scenario	
	 User accesses the list of transport companies. User selects a company based on their requirements. User contacts the company or books a service directly.
Post-conditions	User is connected with a transport company for waste transport.
	transport.

Extensions	
	 No suitable transport companies available. Technical issues during booking.
Relationships	Supports Waste Management and Transportation Services.

A.19 UC19: Viewing and Analyzing Waste Management Data

Attribute	Details
Actor	Platform Manager
Use Case	Viewing and Analyzing Waste Management Data
Description	Platform manager views and analyzes data related to waste
	management.
Pre-conditions	Data is collected and stored on the platform.
Triggers	Need for data analysis or reporting.
Main Scenario	
	 Manager accesses the data analytics dashboard. Manager reviews various metrics and reports. Manager uses insights for decision making and improvement.
Post-conditions	Manager has an updated understanding of waste management performance.
Extensions	
	 Inaccurate or incomplete data. Technical issues with analytics tools.
Relationships	Integral to Data-Driven Decision Making and Platform Strategy.

A.20 UC20: Monitoring Recycling and Waste Management Performance

Attribute	Details
Actor	Platform Manager
Use Case	Monitoring Recycling and Waste Management Performance
Description	Manager monitors and evaluates the performance of recycling
	and waste management.
Pre-conditions	Recycling and waste management processes are in operation.
Triggers	Regular performance review or specific analysis request.

Main Scenario	
	 Manager accesses performance metrics. Manager analyzes recycling rates and waste management effectiveness. Manager generates reports for stakeholders.
Post-conditions	Performance of recycling and waste management is assessed.
Extensions	N/A
Relationships	N/A

A.21 UC21: Managing Shipping and Delivery Details

Attribute	Details
Actor	User
Use Case	Managing Shipping and Delivery Details
Description	User manages and tracks shipping and delivery details for
	their transactions.
Pre-conditions	User has engaged in transactions requiring shipping.
Triggers	User needs to set up or track shipping for a transaction.
Main Scenario	
	1. User accesses their transaction history.
	2. User sets or updates shipping details.
	3. User tracks the delivery status.
Post-conditions	User's shipping and delivery details are managed.
Extensions	
	1. Incorrect shipping information.
	2. Delays or issues with delivery.
Relationships	Linked with Transaction Processing and Logistics
	Management.

Appendix B Original Class Diagram PlantUML Code

@startuml
!define RECTANGLE class

' Main Classes and Subclasses RECTANGLE User {

+UserID: string
+Name: string

```
+Email: string
    +PhoneNumber: string
    +Address: string
    +UserType: string
    +RegistrationDate: dateTime
    +AverageUserRating: decimal
RECTANGLE IndividualUser {
RECTANGLE CorporateUser {
RECTANGLE Product {
    +ProductID: string
    +ProductName: string
    +Description: string
    +Category: string
    +Quantity: integer
    +UnitPrice: decimal
    +ListingDate: dateTime
    +SellerID: string
    +QualityCertification: string
    +WasteReductionPercentage: decimal
    +EnergySaved: decimal
RECTANGLE Plastic {
RECTANGLE Paper {
RECTANGLE Metal {
RECTANGLE Glass {
RECTANGLE Transaction {
    +TransactionID: string
    +BuyerID: string
    +SellerIDTransaction: string
    +ProductIDTransaction: string
    +QuantityTransaction: integer
    +TotalPrice: decimal
    +TransactionDate: dateTime
RECTANGLE Review {
    +ReviewID: string
    +ReviewerID: string
    +ProductIDReview: string
```

```
+Rating: integer
    +Comment: string
    +ReviewDate: dateTime
RECTANGLE CollectionPoint {
    +PointID: string
    +LocationCP: string
    +TypeCP: string
    +OperatingHoursCP: string
RECTANGLE RecyclingPoint {
    +PointIDRec: string
    +LocationRP: string
    +TypesAccepted: string
    +OperatingHoursRP: string
RECTANGLE ServiceRequest {
    +RequestID: string
    +UserIDSR: string
    +ServiceType: string
    +Status: string
    +DateSR: dateTime
    +LocationSR: string
RECTANGLE TransportCompany {
    +CompanyID: string
    +CompanyName: string
    +ServicesOffered: string
    +ContactDetailsTC: string
RECTANGLE StateAdministration {
    +AdministrationID: string
    +AdminName: string
    +TypeSA: string
   +ContactDetailsSA: string
}
RECTANGLE PaymentGateway {
    +PaymentID: string
    +PaymentMethod: string
    +Amount: decimal
    +PaymentDate: dateTime
    +PaymentConfirmationCode: string
RECTANGLE EnvironmentalImpact {
    +ImpactID: string
```

```
+ProductIDEnv: string
    +CarbonFootprint: decimal
    +RecyclingEfficiency: decimal
    +EcoLabel: string
RECTANGLE InformationResource {
    +ResourceID: string
    +Title: string
    +TypeIR: string
    +Content: string
    +DatePublished: dateTime
}
RECTANGLE RewardSystem {
    +RewardID: string
    +UserIDRew: string
    +PointsEarned: integer
    +RedeemableItems: string
    +DateEarned: dateTime
RECTANGLE PaymentDetails {
    +PaymentID: string
    +PaymentMethod: string
    +Amount: decimal
    +PaymentDate: dateTime
    +PaymentConfirmationCode: string
RECTANGLE ShippingDetails {
    +ShippingID: string
    +TransactionID: string
    +Address: string
    +ExpectedDeliveryDate: dateTime
    +ShippingStatus: string
    +Carrier: string
    +EstimatedShippingTime: duration
}
' Subclassing
IndividualUser --|> User
CorporateUser --|> User
Plastic --|> Product
Paper --|> Product
Metal --|> Product
Glass --|> Product
```

```
'Relationships and Associations
User "1" -- "0..*" Product: hasProduct
User "1" -- "0..*" Transaction: hasTransaction
User "1" -- "0..*" Review: hasReview
Product "1" -- "0..1" EnvironmentalImpact: hasEnvironmentalImpact
User "1" -- "0..*" CollectionPoint: hasCollectionPoint
TransportCompany "1" -- "0..*" ServiceRequest: providesServiceRequest
StateAdministration "1" -- "0..*" Transaction: consults
StateAdministration "1" -- "0..*" ServiceRequest: consults
PaymentGateway "1" -- "0..*" Transaction: managesPayment
User "1" -- "0..*" InformationResource: hasInformationResource
User "1" -- "0..*" RewardSystem: hasRewardSystem
Transaction "1" -- "0..1" PaymentDetails: hasPaymentDetails
Transaction "1" -- "0..1" ShippingDetails: hasShippingDetails
```

@enduml

Appendix C Enhanced Class Diagram PlantUML Code

```
@startuml
!define RECTANGLE class
RECTANGLE User {
    +UserID: string
    +Name: string
    +Email: string
    +PhoneNumber: string
    +Address: string
    +UserType: string
    +RegistrationDate: dateTime
    +AverageUserRating: decimal
    +registerUser(name: string, email: string, phoneNumber: string, address: string): boolean
    +listProduct(productDetails: ProductDetails): boolean
    +manageRewards(): string
    +trackWasteJourney(trackingCode: string): string
    +submitFeedbackOrReport(feedbackDetails: FeedbackDetails): boolean
    +updateProfile(profileDetails: ProfileDetails): boolean
    +manageTransactionsAndPayments(): void
    +connectWithTransportCompanies(): string
    +manageShippingAndDeliveryDetails(transactionID:
    string, shippingDetails: ShippingDetails): boolean
}
```

```
RECTANGLE IndividualUser {
RECTANGLE CorporateUser {
RECTANGLE Product {
    +ProductID: string
    +ProductName: string
    +Description: string
    +Category: string
    +Quantity: integer
    +UnitPrice: decimal
    +ListingDate: dateTime
    +SellerID: string
    +QualityCertification: string
    +WasteReductionPercentage: decimal
    +EnergySaved: decimal
RECTANGLE Plastic {
RECTANGLE Paper {
}
RECTANGLE Metal {
}
RECTANGLE Glass {
RECTANGLE Transaction {
    +TransactionID: string
    +BuyerID: string
    +SellerIDTransaction: string
    +ProductIDTransaction: string
    +QuantityTransaction: integer
    +TotalPrice: decimal
    +TransactionDate: dateTime
    +processTransaction(transactionDetails: TransactionDetails): boolean
    +processSale(saleDetails: SaleDetails): boolean
    +trackWasteJourney(trackingCode: string): string
    +manageShippingAndDeliveryDetails(transactionID: string,
    shippingDetails: ShippingDetails): boolean
RECTANGLE Review {
    +ReviewID: string
    +ReviewerID: string
    +ProductIDReview: string
    +Rating: integer
    +Comment: string
    +ReviewDate: dateTime
```

```
+submitReview(reviewDetails: ReviewDetails): boolean
RECTANGLE CollectionPoint {
    +PointID: string
    +LocationCP: string
    +TypeCP: string
    +OperatingHoursCP: string
RECTANGLE RecyclingPoint {
    +PointIDRec: string
    +LocationRP: string
    +TypesAccepted: string
    +OperatingHoursRP: string
RECTANGLE ServiceRequest {
    +RequestID: string
    +UserIDSR: string
    +ServiceType: string
    +Status: string
    +DateSR: dateTime
    +LocationSR: string
    +submitCollectionRequest(requestDetails: CollectionRequestDetails): boolean
    +submitTransportRequest(requestDetails: TransportRequestDetails): boolean
    +getServiceRequestDetails(requestID: string): string
}
RECTANGLE TransportCompany {
    +CompanyID: string
    +CompanyName: string
    +ServicesOffered: string
    +ContactDetailsTC: string
RECTANGLE StateAdministration {
    +AdministrationID: string
    +AdminName: string
    +TypeSA: string
    +ContactDetailsSA: string
RECTANGLE PaymentGateway {
    +PaymentID: string
    +PaymentMethod: string
    +Amount: decimal
    +PaymentDate: dateTime
    +PaymentConfirmationCode: string
    +processTransaction(transactionDetails: TransactionDetails): boolean
    +manageTransactionsAndPayments(): void
```

```
}
RECTANGLE EnvironmentalImpact {
    +ImpactID: string
    +ProductIDEnv: string
    +CarbonFootprint: decimal
    +RecyclingEfficiency: decimal
    +EcoLabel: string
}
RECTANGLE InformationResource {
    +ResourceID: string
    +Title: string
    +TypeIR: string
    +Content: string
    +DatePublished: dateTime
}
RECTANGLE RewardSystem {
    +RewardID: string
    +UserIDRew: string
    +PointsEarned: integer
    +RedeemableItems: string
    +DateEarned: dateTime
RECTANGLE PaymentDetails {
    +PaymentID: string
    +PaymentMethod: string
    +Amount: decimal
    +PaymentDate: dateTime
    +PaymentConfirmationCode: string
RECTANGLE ShippingDetails {
    +ShippingID: string
    +TransactionID: string
    +Address: string
    +ExpectedDeliveryDate: dateTime
    +ShippingStatus: string
    +Carrier: string
    + {\tt EstimatedShippingTime:} \  \, {\tt duration} \\
RECTANGLE PlatformManager {
    +ManagerID: string
    +Name: string
    +Role: string
    +login(username: string, password: string): boolean
```

```
+viewAndAnalyzeWasteManagementData(): string
    +monitorRecyclingAndWasteManagementPerformance(): string
}
' Subclassing
IndividualUser --|> User
CorporateUser --|> User
Plastic --|> Product
Paper --|> Product
Metal --|> Product
Glass --|> Product
' Relationships and Associations
User "1" -- "0..*" Product : hasProduct
User "1" -- "0..*" Transaction : hasTransaction
User "1" -- "0..*" Review : hasReview
Product "1" -- "0..1" EnvironmentalImpact : hasEnvironmentalImpact
User "1" -- "0..*" CollectionPoint : hasCollectionPoint
User "1" -- "0..*" RecyclingPoint : hasRecyclingPoint
TransportCompany "1" -- "0..*" ServiceRequest : providesServiceRequest
StateAdministration "1" -- "0..*" Transaction : consults
StateAdministration "1" -- "0..*" ServiceRequest : consults
PaymentGateway "1" -- "0..*" Transaction : managesPayment
PaymentGateway "1" -- "0..*" Transaction : processTransaction
User "1" -- "0..*" InformationResource : hasInformationResource
User "1" -- "0..*" RewardSystem : hasRewardSystem
Transaction "1" -- "0..1" PaymentDetails : hasPaymentDetails
Transaction "1" -- "0..1" ShippingDetails : hasShippingDetails
```

@enduml

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