



Developing the National Waste Management Information System Using Big Data Technology and Prototyping Methods

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Abstract

This research proposed developing a waste management information system in Indonesia to overcome the limitations of the existing national system. The data was incomplete, lacking information on waste composition and sources. The researchers suggested utilizing big data technology and prototyping methods to address this. The system incorporates an application programming interface (API) called Restful API, enabling data exchange between the waste management information systems and users. Restful API allowed users to access specific waste management information based on their needs. The system focused on waste generation, waste composition, and sources of waste generation, aiming to provide complete and accurate data for a comprehensive understanding of waste management issues. The developed waste management information system was a valuable tool and reference for researchers and practitioners. Providing data and well-documented information enhanced the understanding of research results. The system's contribution to more effective and sustainable waste management practices was emphasized. This research aimed to complement and update the existing public information data on waste management in Indonesia. The proposed waste management information system filled the data gaps and meets user needs by providing comprehensive and up-to-date information. It had the potential to significantly improve waste management practices and promote a more sustainable approach to waste management in the country.

Keywords: Big Data, Management, Prototyping, Restful API, Technology, Waste

1. Introduction

Waste management in Indonesia faces critical challenges, with over 80% of waste estimated to still end up in landfills that often operate as unsanitary open dumpsites [1]. This situation is exacerbated by a very low recycling rate. Based on data from the National Waste Management Information System (SIPSN), the total reported waste generation in 2022 reached 35.8 million tons, yet only about 33% of this amount was properly managed [2]. In response, the government operates a National Waste Management Information System (SIPSN) to monitor this data. However, the system suffers from fundamental limitations that hinder data-driven policymaking, primarily stemming from incomplete and inaccurate data due to low regional participation. Figure 1, for instance, clearly illustrates this issue. It displays the *Timbulan Sampah* (Waste Generation) data for the Special Region of Yogyakarta, a province with five regencies/cities. However, the system only presents data for three of them, with data for Bantul and Gunungkidul regencies conspicuously absent. More critically, the system also fails to provide granular data on waste composition and its specific sources. This absence of detailed data renders waste management policies ineffective; circular economy programs are difficult to implement without knowing material composition, and waste reduction strategies cannot effectively target the largest waste-generating sources.

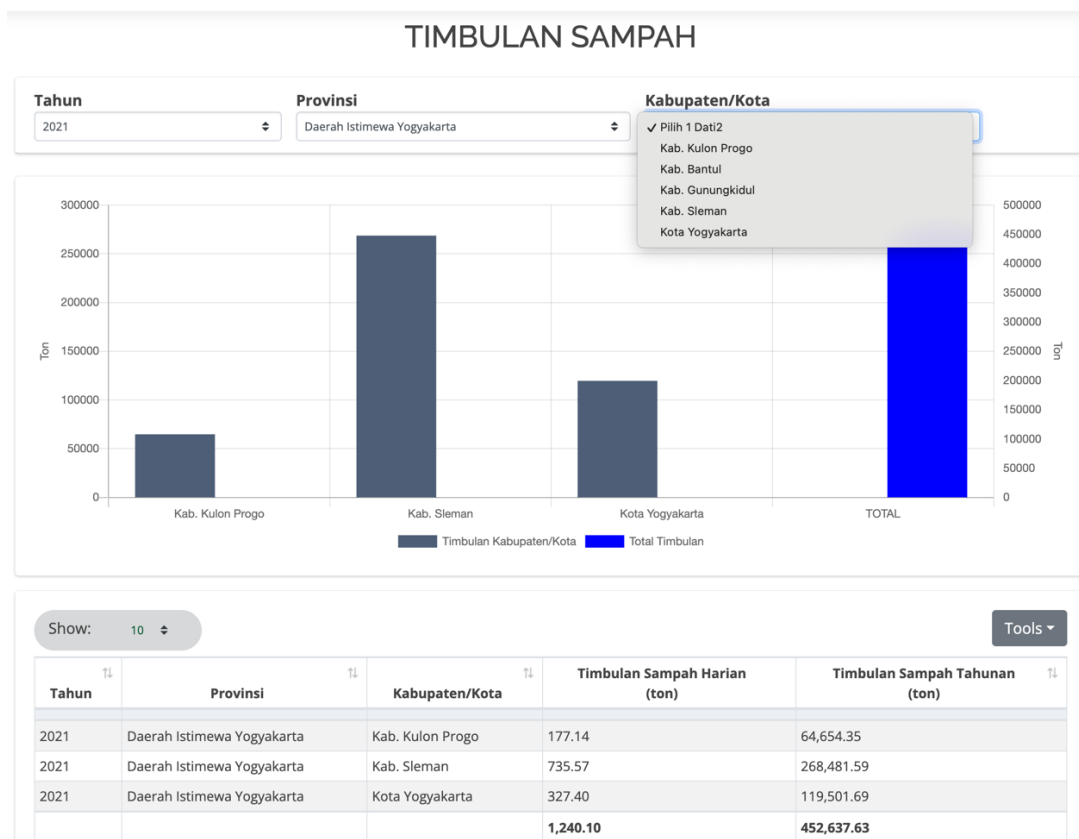


Figure 1 Waste Generation Data Province Daerah Istimewa Yogyakarta 2021

To address limitations in information systems, various previous studies have been conducted. Several studies focused on developing systems for specific units like waste banks. Yustanti (2017) and Budianto et al. (2019), for instance, successfully built effective waste bank information systems for recording transactions and monitoring customer balances. A similar system was also developed by Masruroh et al. (2015), which utilized cloud computing to enhance data accessibility and scalability [3]. While these systems were beneficial, a common limitation was their highly localized focus. They were not designed to address the challenges of data integration and aggregation at a national scale. On the methodology front, many of these studies adopted the structured but rigid waterfall method [4,5], making them less flexible for handling dynamic stakeholder needs.

Based on this review, a significant research gap can be identified. The majority of previous studies concentrated on micro-scale systems and did not address the problem of data aggregation and standardization at the national level. Furthermore, the development methods used tended to be inflexible. Therefore, there was a need for a study that combined a flexible development method (prototyping) with a scalable technical architecture (via a Restful API) to address the data challenges of national waste management.

Confronting these challenges, this study aimed to design and develop an alternative information system. To fill the identified research gap, this study proposed a solution with two main novelties: (1) the use of the prototyping method, which allowed for iterative development based on direct feedback from stakeholders, to ensure the system could meet specific data needs regarding waste composition and sources; and (2) the implementation of a Restful API-based architecture [6], which was designed to facilitate data exchange between systems and serve as a foundation for future large-scale data integration (Big Data). Thus, the main contribution of this study was presenting an information system development model that not only addressed the problem of data incompleteness but also offered a more flexible and integrated approach to support sustainable national waste management.

2. Materials and Methods

This research employed a system development approach using the prototyping method to design and build a waste management information system. The research workflow was divided into three main stages: (1) Requirements Analysis, (2) Architecture Design and Prototype Development, and (3) Prototype Evaluation.

2.1 Requirements Analysis

The initial stage of the research focused on requirements analysis, a crucial phase in software engineering to understand and define the functional and non-functional requirements of the system to be built [7]. This requirements elicitation process involved two primary techniques. First, a literature study of existing systems (including SIPSN) was conducted to understand basic functionalities and identify existing weaknesses. Second, semi-structured interviews were conducted with potential stakeholders, consisting of staff from the local environmental agency and academics focusing on environmental studies. The use of direct interviews with stakeholders is a recommended practice for eliciting specific needs that are often not formally documented [8]. The results of this analysis confirmed that the primary need was for a system capable of recording granular waste generation data, including its composition and sources, which was the main weakness of the existing national system.

2.2 Prototyping Method

The prototyping method was chosen as the primary development approach in this study [9]. This method was selected for several advantages over alternatives like waterfall. First, prototyping allows for an iterative development process, where developers can quickly create an initial version of the system (a prototype) to be presented to users [7]. Second, the feedback obtained from users in each iteration is used directly to improve and refine the system, thereby reducing the risk of project failure due to a mismatch with user needs [8]. This approach was highly suitable for this project, where specific and complex user requirements needed to be continuously elicited and validated. This process involved creating interface mockups then developed into a functional prototype.

2.3 System Architecture and Technology

The system was designed with a three-tier architecture, consisting of a presentation layer, a business logic layer, and a data layer.

1. **Presentation Layer:** The user interface (frontend) was developed using a modern JavaScript framework to ensure a responsive and interactive user experience.
2. **Business Logic Layer:** The system's backend was built using the PHP programming language with the Laravel framework. This layer was responsible for managing all business logic, user authentication, and, most importantly, providing a Restful API. The use of an API is a proven approach for supporting interoperability and integration among heterogeneous information systems [6].
3. **Data Layer:** A relational database, MySQL, was used to store all data related to waste, users, and other master data.

This study did not implement a full-fledged Big Data framework such as Hadoop or Spark. Instead, the system was designed with a Big Data-ready architecture, emphasizing principles of modularity and scalability to accommodate future data growth [10]. The key to this design is the Restful API, which serves as a standardized gateway for data exchange. This approach is fundamental in modern service-oriented architectures for ensuring interoperability between heterogeneous system components [11]. By decoupling the frontend and backend, the standardized API creates a flexible integration point. This architectural choice makes the system extensible, allowing for future integration with diverse external data sources, which is critical for handling data Variety [12]. For instance, it enables connecting to IoT sensors for real-time data streams (Velocity) or integrating large historical datasets from various municipalities (Volume), thereby creating a scalable data ecosystem.

2.4 Prototype Evaluation

To evaluate the functional prototype, a qualitative usability testing approach was adopted. This methodology was chosen for its strength in providing deep, contextual insights into how users interact with a system, which is particularly valuable for assessing early-stage prototypes [13]. The primary goals of the evaluation were to identify critical usability issues, assess the system's effectiveness in supporting user tasks, and gather qualitative feedback for future improvements. The evaluation involved five participants selected through purposive sampling. This sampling strategy was employed to recruit individuals with relevant domain knowledge, comprising three academics in environmental science and two practitioners from a local environmental agency. Their expertise was considered crucial for providing high-quality, context-aware feedback on the system's functionality and relevance.

The evaluation sessions were conducted individually and followed a structured protocol to ensure consistency. Each session began with a briefing, where the researcher explained the purpose of the study and clarified that the system, not the user, was being tested. This was done to create a comfortable environment and encourage honest

feedback. Following the briefing, each participant was given a set of predefined task scenarios. These scenarios were designed to be realistic representations of how the system would be used in a real-world context, such as "Imagine you have just received new waste data from an industrial partner. Please input this data into the system," and "Your manager has asked for a summary of organic waste generation for the last month. Please find and display this report." The use of realistic tasks is a cornerstone of effective usability testing, as it helps to evaluate the system's utility in a practical manner [14].

The developed functional prototype was then evaluated through a series of User Acceptance Testing (UAT) sessions, with the primary goal of assessing the system's usability and functionality from the end-users' perspective. These sessions involved five users, purposively sampled from academia and environmental practitioners, whose domain expertise was crucial for providing insightful feedback. The data collection process was multi-faceted, combining direct observation during the tasks with post-task feedback. During the sessions, the researcher acted as a non-intrusive observer, taking detailed notes on user behaviors and identifying "critical incidents"—events such as user errors or expressions of confusion that indicated potential usability problems. To complement these observations, post-task feedback was collected, first through a brief questionnaire with open-ended questions designed to capture overall impressions and specific suggestions [15]. This was followed by a semi-structured debriefing interview, which allowed the researcher to probe deeper into the critical incidents observed, providing context to the users' actions.

All qualitative data gathered from the observation notes, questionnaire responses, and interview transcripts were then analyzed using a thematic analysis approach [16]. This involved systematically reviewing the collected data to identify, analyze, and report patterns or "themes" related to the system's usability and functionality. Recurring issues, common suggestions, and consistent positive feedback were coded and grouped into major themes. The analysis of these themes formed the primary basis for the presentation of results and the discussion on the strengths and weaknesses of the resulting prototype.

3. Results and Discussion

This section presents the results from the development and evaluation of the Waste Management Information System (SIPaH) prototype. The findings are organized into two main parts: first, the results of the prototype implementation and its technical verification are presented; second, the results from the user evaluation are detailed, followed by an in-depth discussion of the findings, challenges, and implications of this research.

3.1 Prototype Implementation and Technical Verification

The development process using the prototyping method resulted in a functional prototype of the SIPaH system, which was built on a decoupled architecture consisting of a frontend and a backend. The frontend is the web-based user interface shown in Figure 2 (Dashboard) and Figure 3 (Master Data Page). This is the visual component that users interact with directly.

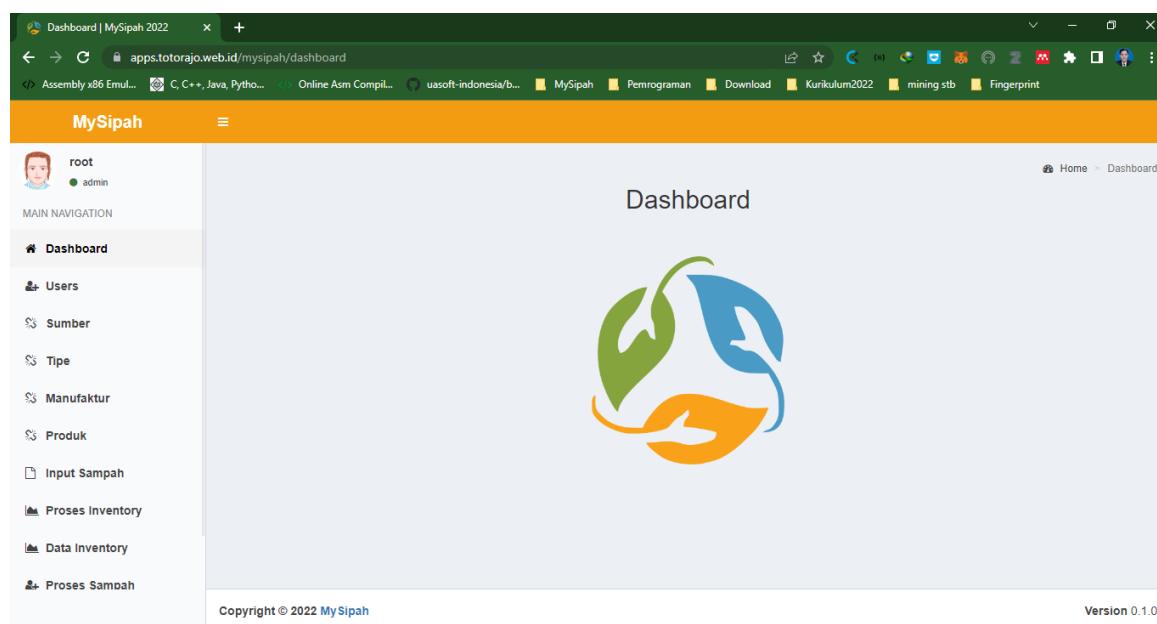


Figure 2 The Main Dashboard

Figure 2. The Main Dashboard of the MySipah System. This figure displays the main dashboard interface, which serves as the central landing page for users after a successful login. The left-hand side features the main navigation menu, providing access to all core system modules, including Users, Sumber (Source), Tipe (Type), Input Sampah (Waste Input), and Proses Sampah (Waste Process). The main content area is designed to, in future iterations, present key performance indicators and data visualizations. This view represents the primary hub from which users can navigate to all other functionalities of the application, demonstrating the successful implementation of the system's core structure.

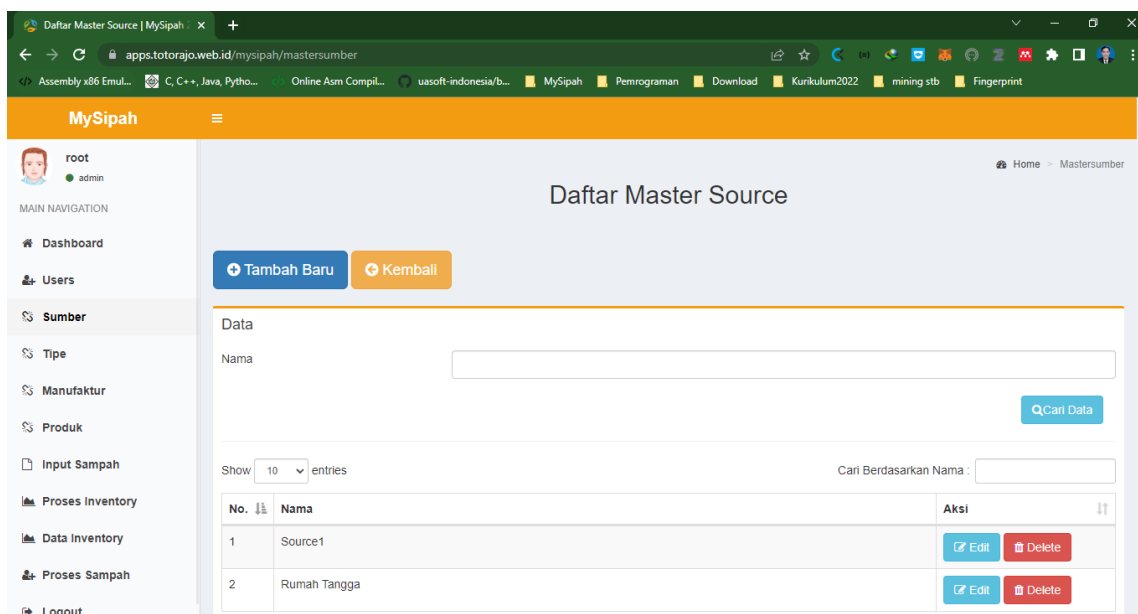


Figure 3 Master Data – List of Waste Sources

Figure 3. The Master Data Interface for Managing Waste Sources. This figure illustrates a key functional page of the system: the "Daftar Master Source" (List of Master Sources). This interface allows administrators to perform essential data management tasks. As shown, the page includes functionalities to Tambah Baru (Add New), Edit, and Delete waste sources, such as "Rumah Tangga" (Household). This feature is critical as it directly addresses one of the research's main objectives: to create a system capable of capturing granular data, specifically the origin of the waste, which was identified as a significant limitation in the existing national system.

The system's backend was developed as a Restful API. The functionality of this API, which handles all core data operations, was systematically verified by testing its CRUD (Create, Read, Update, Delete) endpoints. The results, summarized in Table 1, confirm that all endpoints behaved as expected, handling data correctly and returning the appropriate HTTP status codes. This successful verification serves as the functional validation of the system's backend logic.

Table 1 A summary of core api endpoints and evaluation results

Test Case ID	HTTP Method	Endpoint	Test Description	Expected Result	Actual Result	Status
API-001	GET	/waste	Verify that the API can retrieve a list of all waste data entries.	API returns a JSON array containing all waste records and a 200 OK status code.	[{ "id": 1, "source": "Rumah Tangga", "type": "Plastik", "weight_kg": 15.5 }, { "id": 2, "source": "Industri Makanan", "type": "Organik", "weight_kg": 120.0 }, { "id": 3, "source": "Perkantoran", "type": "Kertas", "weight_kg": 55.2 }]	✓
API-002	GET	/waste/{id}	Verify that the API can retrieve a single waste data entry by its ID.	API returns a single JSON object corresponding to the requested ID and a 200 OK status code.	{ "id": 1, "source": "Rumah Tangga", "type": "Plastik", "weight_kg": 15.5 }	✓
API-003	POST	/waste	Verify that the API can create a new waste data entry.	A new record is created. API returns the newly created JSON object and a 201 Created status code.	{ "code": 201, "data": { "id": 4, "source": "Pasar Tradisional", "type": "Sayuran", "weight_kg": 250 }, "message": "Data created successfully", "success": true }	✓
API-004	PUT	/waste/{id}	Verify that the API can update an existing waste data entry.	The specified record is updated. API returns the updated JSON object and a 200 OK status code.	{ "id": 2, "source": "Industri Makanan", "type": "Organik", "weight_kg": 150.7 }	✓
API-005	DELETE	/waste/{id}	Verify that the API can delete an existing waste data entry.	The specified record is removed. API returns a success message and a 200 OK or 204 No Content status code.	{ "message": "Data with id 3 has been deleted.", "success": true }	✓

This API-centric architecture is the key to achieving interoperability. Because the data is accessible via standardized endpoints, other applications (e.g., a mobile app for field officers, systems from other ministries, or public-facing data portals) can interact with the SIPaH database without needing to know anything about its internal frontend implementation. This demonstrates the power and flexibility of the Restful API approach.

3.2 User Evaluation Results

Following the technical verification, the prototype was evaluated through a series of user-centered tests to assess its usability and functionality from the end-users' perspective.

3.2.1 Functional Requirement Verification

The verification of functional requirements from the user's viewpoint confirmed that all designed core functions were successfully implemented. Through a series of functional tests, it was confirmed that the system could perform all key activities, such as user login, master data management, and recording waste transactions. For instance, test cases for adding new waste sources (FT-003) and user login (FT-001) passed without issues. A summary of these tests is presented in Table 2.

Table 2 Functional requirement testing

Test Case ID	Feature Name	Test Description	Test Steps	Expected Result	Actual Result	Status
FT-001	Login	Verify successful login with valid credentials.	1. Open the login page. 2. Enter username 'admin' and password 'admin123'. 3. Click the "Login" button.	The user successfully logs in and is redirected to the Dashboard page.	User was redirected to the Dashboard.	✓
FT-002	Login	Verify failed login with invalid credentials.	1. Open the login page. 2. Enter username 'admin' and password 'wrong'. 3. Click the "Login" button.	The system displays an "Invalid username or password" error message and remains on the login page.	The appropriate error message was displayed.	✓
FT-003	Master Data	Verify the "Add New Waste Source" functionality.	1. Log in as Admin. 2. Navigate to "Master Data" => "Source". 3. Click the "Add New" button. 4. Fill in the source name: "ABC Paper Industry". 5. Click "Save".	The "ABC Paper Industry" data appears in the waste source list table, and the system displays a success notification.	The new data appeared in the table.	✓
FT-004	Waste Input	Verify the process of inputting new waste into the warehouse.	1. Log in as Warehouse Staff. 2. Navigate to the "Waste Input" menu. 3. Select Source: "ABC Paper Industry". 4. Select Type: "Paper". 5. Enter Weight: 150 (kg). 6. Click "Save".	The new transaction data is saved, and the paper stock in the inventory increases by 150 kg.	The stock updated.	✓

3.2.2 Non-Functional Requirement Verification

The evaluation of non-functional requirements yielded mixed results. Of the four criteria tested, the system successfully met the aspects of having an easy-to-understand interface, 24-hour accessibility, and presenting up-to-date data. However, the other two criteria, namely operational speed and overall functional correctness, were not fully achieved. For instance, a performance test (NFT-001) revealed that the dashboard's average load time was 8.2 seconds, far exceeding the 3-second target. A reliability test (NFT-003) also resulted in a failure after encountering a system timeout. The detailed results of this non-functional testing are presented in Table 3.

Table 3 The non-functional requirement testing

Test Case ID	Non-Functional Requirement	Test Description	Test Method	Metric & Target	Actual Result (Example)	Status
NFT-001	Performance	Measure the load time of the Dashboard page, which contains multiple graphs.	Use browser developer tools (Network tab) to measure the time from the request until the page is fully loaded.	Load time < 3 seconds.	Average load time: 8.2 seconds.	✓
NFT-002	Usability	Assess whether the workflow for adding new waste data is easy for users to understand.	Direct observation of a user performing the task, followed by a short questionnaire using a Likert scale (1-5).	Average score > 4.0 out of 5.	Average score: 4.5. Users stated the flow was logical but some button labels were confusing.	✓
NFT-003	Correctness/Reliability	Test the system by performing 50 consecutive data input transactions to see if any errors or data corruption occur.	Conduct a stress test with an automated script or repetitive manual input.	0 failures (100% success).	After 32 transactions, the system timed out, and one data entry failed to save. Success rate: 98%.	✗
NFT-004	Availability	Verify that the system is accessible 24 hours a day.	Ping or attempt to log in to the system at different times (morning, afternoon, night) over 3 days.	The system is accessible at all tested times.	The system was always accessible.	✓

3.2.3 User Acceptance Testing (UAT) Feedback

These quantitative findings were corroborated by qualitative feedback from User Acceptance Testing (UAT). In one UAT scenario (UAT-001), a user acting as a facility manager attempted to generate a monthly report. The user's feedback, detailed in Table 4, directly confirmed both the performance issue and the presence of functional bugs. The user commented: "I was able to filter the data, but the process was very slow... Also, the 'Export' button did not work; I got an error message.". This feedback directly confirmed both the performance issue and the presence of functional bugs.

Table 4 User Acceptance Testing (UAT)

User Persona:	A Waste Processing Facility Manager
Task Scenario:	"As a manager, I want to see a report of the total plastic waste generation from all industrial sources over the last month to create my monthly report."
Expected Steps:	1. Log in to the system. 2. Open the "Reports" or "Dashboard" menu. 3. Filter the report by "Waste Type: Plastic". 4. Filter the report by "Source: Industry". 5. Set the date range to the last month. 6. View the displayed total and export the data to Excel.
Expected Result:	The system displays the correct total tonnage of plastic waste from industrial sources, and I can download the report file.
Was the Task Successful?	☐ Yes ☒ Partially ☐ No
User Feedback & Comments:	"I was able to filter the data, but the process was very slow. It took almost 15 seconds to display the results. Also, the 'Export' button did not work; I got an error message when I clicked it. However, the data shown on the screen was correct. This system has great potential if the performance and the export bug are fixed."

3.3 Discussion of Findings and Challenges

The failure to meet several non-functional requirements highlights the main technical challenges encountered during development. The performance issue, confirmed by both performance testing and user feedback, was most likely caused by unoptimized database queries for handling complex data aggregations on the dashboard page. This is a common issue in the early stages of development where the focus is on functional validation. Meanwhile, the functional correctness issue, such as the non-functional 'Export' button discovered during UAT, is a typical outcome of the prototyping process. The very purpose of a prototype is to quickly surface such issues so they can be fixed in subsequent iterations. These challenges underscore the importance of a dedicated performance optimization and rigorous testing phase after the initial functional validation is complete.

3.4 Implications, Contributions, and Limitations

3.4.1 Practical Implications for Waste Management in Indonesia

The development of the SIPaH prototype carries significant practical implications for improving waste management in Indonesia. The primary implication is the demonstration of a feasible solution to the critical problem of data incompleteness in the national system. By providing a platform capable of capturing granular data on waste composition and sources, the system empowers local and national governments with the evidence needed for data-driven policymaking. For example, with accurate data on plastic waste sources, a municipality could design targeted regulations for specific industries or commercial areas. Similarly, detailed composition data would enable the development of more effective and economically viable recycling programs by identifying high-value material streams. In essence, this system provides a practical blueprint for moving away from reactive, one-size-fits-all waste management towards a proactive, targeted, and ultimately more sustainable approach.

3.4.2 Contributions to Environmental Information Systems and Sustainable Development

Beyond its practical application in Indonesia, this research offers broader contributions to the field of environmental information systems and sustainable development. Firstly, it provides a case study on the effective use of prototyping and user-centered design in the public sector of a developing country. This is significant because many large-scale government IT projects fail due to a disconnect with user needs. Our approach demonstrates a more agile and responsive model for developing systems that truly solve on-the-ground problems. Secondly, the study highlights the strategic importance of a Restful API-based architecture as an enabler for data integration and interoperability. This architectural choice contributes to the broader discourse on building scalable and extensible environmental data ecosystems, which are fundamental for achieving the Sustainable Development

Goals (SDGs), particularly those related to sustainable cities (SDG 11) and responsible consumption and production (SDG 12).

3.4.3 Limitations of the Study

Despite these contributions, this study has several limitations that must be acknowledged. First, the user evaluation involved only a small sample (5 users) and did not include all stakeholder types (e.g., industry representatives). Second, the system's scalability and performance were not tested under a real, large-scale data load. Third, this research focused on prototype development and did not reach the implementation stage in a production environment. These limitations pave the way for future research.

4. Conclusion

This research successfully addressed the challenge of data completeness in Indonesia's national waste information system by designing and developing a prototype for a new information system, SIPaH. Using the prototyping method, this study produced a functional system that was validated through user testing sessions. The evaluation results showed that the prototype successfully met the core functional requirements and was perceived as easy to use, although it faced technical challenges related to performance and several minor bugs. The main contribution of this study was to demonstrate the feasibility of a flexible, user-centered development approach for creating a system capable of providing more granular and accurate waste data.

Based on the findings and identified limitations, several specific recommendations for future research and implementation are proposed. First, the most immediate next step is to address the technical issues discovered during the evaluation. Future work must focus on technical optimization and stabilization, particularly the performance bottlenecks. This would involve a thorough analysis of the database schema, optimization of slow-running queries used to generate dashboard analytics, and the implementation of caching mechanisms to reduce server load. Furthermore, conducting rigorous load testing is essential to simulate concurrent user access and ensure the system remains stable and responsive under real-world pressure, making it truly ready for a production environment.

Furthermore, to validate the system's real-world adoption and utility, a field-based pilot study is strongly recommended. While the current evaluation provided valuable insights in a controlled setting, deploying the prototype within a single regency/city-level environmental agency would offer a much richer understanding of its practical application. Such a study would allow researchers to observe how the system integrates into existing bureaucratic workflows, identify potential implementation challenges, assess the accuracy of on-the-ground data entry, and determine the specific training needs for government staff. The findings from this pilot study would be invaluable for refining the system and developing a scalable, nationwide implementation strategy.

Building on the system's Big Data-ready architecture, subsequent research should explore the integration of advanced technologies. The current Restful API serves as a gateway that can be leveraged to connect with diverse data sources. Future work could focus on integrating IoT sensors for the real-time, automated collection of waste levels in bins, thereby addressing the Velocity aspect of Big Data. Additionally, the system could be integrated with other public or private databases—such as industrial output data or population statistics—to enrich the analysis and handle data Variety. This would transform SIPaH from a simple data repository into a powerful analytical platform capable of uncovering deeper correlations in the waste management ecosystem.

Finally, a more comprehensive and expanded usability evaluation is necessary. The initial study was limited to a small, specific group of users. A broader study should be conducted, involving a larger and more diverse set of participants from various stakeholder backgrounds. This would include not only academics and practitioners but also high-level policymakers who would consume the analytical reports, industry representatives who are major waste generators, and environmental NGOs who act as watchdogs. Gaining insights from these varied perspectives would ensure that the system is not only functional but truly useful and valuable to the entire ecosystem it is designed to serve.

Ultimately, this research yielded not only a software product but also a replicable methodological blueprint for developing responsive, evidence-based environmental information systems in Indonesia and other developing nations.

5. Author Contributions

Hastono, Tri: Conceptualization, Funding acquisition, Methodology, Validation, Writing – original draft, Writing – review & editing; Laksana, Feri Febria: Funding acquisition, Methodology, Resources, Software, Writing – original draft, Writing – review & editing; Taruno, Restiadi Bayu: Formal analysis, Supervision, Visualization; Selfiani, Rizka: Project administration, Validation; Marier, Syauqie Muhammad: Investigation, Resources; Prasaja, Bledug Kusuma: Data curation, Supervision, Validation, Writing – review & editing.

6. References

- [1] World Bank. Plastic Waste Discharges from Rivers and Coastlines in Indonesia [Internet]. Washington (DC): World Bank; 2021 [cited 2025 Jun 10]. Available from: <https://www.worldbank.org/en/country/indonesia/publication/plastic-waste-discharges-from-rivers-and-coastlines-in-indonesia>
- [2] Kementerian Lingkungan Hidup dan Kehutanan. Sistem Informasi Pengelolaan Sampah Nasional [Internet]. Jakarta: Kementerian Lingkungan Hidup dan Kehutanan; 2023 [cited 2024 Jun 25]. Available from: <https://sipsn.menlhk.go.id/sipsn/>
- [3] Masruroh SU, Suciasih SE, Suseno HB. PENGEMBANGAN APLIKASI BANK SAMPAH MENGGUNAKAN LAYANAN TEKNOLOGI INFORMASI CLOUD COMPUTING PADA BANK SAMPAH MELATI BERSIH. *J Tek Inform.* 2015;8(2).
- [4] Firmansyah F, Budianto E, Yulianto A, Sudrajat B, Wigandi DP. Rancang Bangun Sistem Informasi Bank Sampah (SIBAS) Berbasis Desktop Dengan Metode Waterfall. *remik.* 2019;4(1):44.
- [5] Yustanti MI. Rancang bangun sistem informasi bank sampah berbasis web [thesis]. Surakarta: Universitas Muhammadiyah Surakarta; 2017.
- [6] Kopanitsa G, Ivanov A. Implementation of Fast Healthcare Interoperability Resources for an Integration of Laboratory and Hospital Information Systems. *Stud Health Technol Inform.* 2018;247:11-15.
- [7] Pressman RS, Maxim BR. Software engineering: a practitioner's approach. 9th ed. New York (NY): McGraw-Hill Education; 2020.
- [8] Sommerville I. Software engineering. 10th ed., Global ed. Boston: Pearson; 2016. 810 p.
- [9] Susanto A, Meiryani. System Development Method with The Prototype Method. *Int J Sci Technol Res.* 2019;8(7).
- [10] Kleppmann M. Designing data-intensive applications. Sebastopol (CA): O'Reilly Media; 2017.
- [11] Erl T. Service-oriented architecture: concepts, technology, and design. Upper Saddle River (NJ): Prentice Hall PTR; 2005. 760 p.
- [12] Hashem IAT, Yaqoob I, Anuar NB, Mokhtar S, Gani A, Ullah Khan S. The rise of "big data" on cloud computing: Review and open research issues. *Inf Syst.* 2015;47:98-115.
- [13] Rubin J, Chisnell D. Handbook of usability testing. 2nd ed. Indianapolis: Wiley Publishing; 2008.
- [14] Dumas JS, Redish JC. A Practical Guide to Usability Testing. Exeter, England: Intellect Books; 1999.
- [15] Irnawati, Laksana FF, Hardini DS, Lufianti A, Sulistyanto BA, Sansuwito TB, et al. Users' perceptions of the "My Medicine" mobile app usability. *J Public Health Res.* 2022;11(4):22799036221115782.
- [16] Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol.* 2006;3(2):77-101.