



Enhancing waste management efficiency through devops application development

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ABSTRACT

DevOps is an application development methodology that has been successfully applied in the context of waste management. This research aims to investigate the potential of DevOps implementation in developing waste management applications, emphasizing improving operational efficiency, reducing costs, and regulatory compliance. By collecting data on waste volume, operating costs, and compliance levels, this research shows that the application reduced operating costs by 18% while improving operating efficiency and achieving high compliance with applicable regulations. These findings confirm the significant potential of DevOps in benefiting the waste management industry and its contribution to supporting environmental sustainability. In addition, this research identifies further research possibilities to explore the adaptation and development of applications using more specific DevOps approaches, as well as the scalability of implementation in various organizational contexts.

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1. INTRODUCTION

A significant challenge in waste management is the continuous growth in the volume of waste generated by society and industry. Along with economic development and a growing population, the volume of waste has also significantly increased. This presents complex issues related to waste collection, transportation, and processing. Organizations that manage waste must face pressure to handle the growing volumes efficiently and sustainably (Pardini et al., 2020; Zhang et al., 2022a).

Inefficient waste management can cause severe impacts on the environment. Improper waste processing can result in water, soil, and air pollution. Moreover, toxic or hazardous wastes that are not adequately managed can endanger human health and natural ecosystems. Therefore, the problem of inefficient waste management is not only a threat to the environment but also to the well-being of society. Various government rules and regulations govern waste management. The challenge in this regard is to maintain compliance with these regulations. Strict waste regulations include waste processing, handling, and disposal requirements. Organizations must invest in infrastructure and

processes that comply with these regulations, which can be a significant cost burden. In addition, regulatory changes that may occur occasionally can pose additional challenges in waste management (Kumar & Agrawal, 2020a; Nanda & Berruti, 2021; Nizetić et al., 2019a).

Waste management is a critical aspect of maintaining environmental sustainability and regulatory compliance. However, the challenges faced in managing waste, such as growth in waste volumes, environmental issues due to inefficient waste management, and complex regulatory requirements, continue to be critical issues that need to be addressed (Aldaco et al., 2020; A. K. Das et al., 2021; Tripathi et al., 2020).

One of the key potential benefits of applying information technology in waste management is process automation. In this context, automation refers to using tools and software to automate tasks that previously took significant time and human resources. A concrete example is the development of applications for waste data collection and processing in hazardous waste management. Automation helps reduce human error, increases efficiency, and enables faster reaction to changes in the waste management environment. It can also reduce long-term operational costs and assist organizations in complying with waste management regulations (S. Das et al., 2019; Kumar & Agrawal, 2020b; Nizetić et al., 2019b; Sharma et al., 2020a; Xia et al., 2022; Zhang et al., 2022b).

This research focuses on developing waste management applications in one organization that uses the DevOps method to develop waste management applications. The selection of the DevOps method in application development because DevOps can help improve the collaboration of teams involved in waste management (Almeida et al., 2022a; Enoiu et al., 2023; Kolisnichenko et al., n.d.-a; Sindhu Battina, 2021a). In many cases, various departments and teams, such as waste processing, IT, and regulatory compliance, must work together to manage waste effectively. DevOps fosters better team collaboration by encouraging better communication, knowledge sharing, and working on common goals (Almeida et al., 2022b; Kolisnichenko et al., n.d.-b). Better collaboration can help organizations overcome communication barriers often in waste management (Aliev et al., 2020a; Sharma et al., 2020b). It also enables better decision-making and faster response to urgent situations.

The developed application enables continuous real-time monitoring of the waste management process. This enables early detection of problems or discrepancies so that corrective actions can be taken immediately. Real-time monitoring can also improve visibility over the entire waste supply chain, which helps in better planning and decision-making. In addition, real-time monitoring can support environmental impact monitoring, an essential aspect of sustainable waste management (Aliev et al., 2020a; Almeida et al., 2022b; Sindhu Battina, 2021b).

Applications enable organizations to increase scalability and flexibility in waste management. In this context, organizations can quickly adjust capacity and resources according to fluctuations in waste volume or regulation changes. This helps organizations in facing the challenges of ever-increasing waste volumes. In addition, DevOps enables the use of various tools and technologies that can be adapted to different waste management needs. This provides the necessary flexibility to address different types of waste and different situations (Aliev et al., 2020b; Dileepkumar & Mathew, 2021; Enoiu et al., 2023; Khan et al., 2022; Sharma et al., 2020c).

This research has significant potential benefits for the waste management industry. By exploring the application of DevOps in the development of waste management applications, this research can provide a more in-depth view of how information technology can increase operational efficiency, reduce costs, and improve overall waste management. The results of this research are expected to assist the waste management industry in improving its competitiveness and addressing the challenges of growing waste volumes. This research has a significant contribution to environmental sustainability. By improving waste management efficiency, DevOps deployments can help reduce the negative

environmental impacts of the waste management process. This includes the reduction of water, soil, and air pollution that can be caused by inefficient waste management. In addition, by focusing on regulatory compliance, this research can also support more sustainable environmental management efforts, such as reduced carbon emissions and more efficient use of resources. Therefore, this research directly relates to the global goal of maintaining environmental sustainability.

2. RESEARCH METHOD

The research consisted of six main stages, as shown in Figure 1.

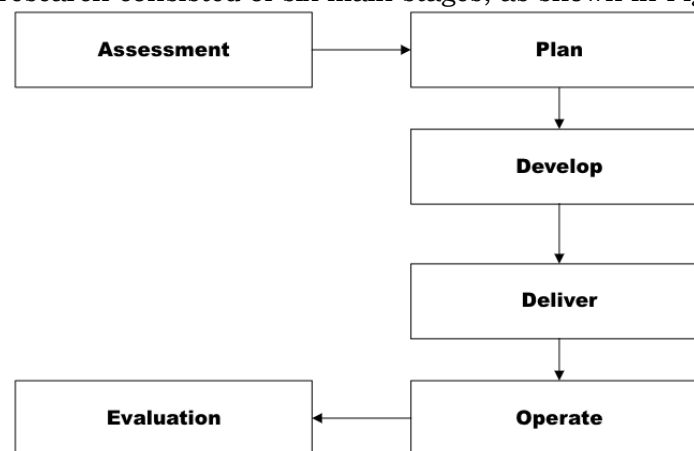


Figure 1. Research Stages

Assessment

In this stage, the first step is to collect waste volume data. Next, audit and analyze historical data on the volume of waste generated in a given period. In addition, it will analyze the current operational costs associated with waste management, including the costs of waste collection, transportation, and processing. At this stage, a user needs analysis is also conducted, in this case, one of Tangerang, Indonesia's non-profit waste management organizations.

Plan

The next stage is planning. In it, the team plans the steps based on the assessment results. The first step is identifying the DevOps team that will be involved in implementing DevOps in waste management. This team will consist of various members who have specific roles and responsibilities. Next, in this stage, the team sets clear objectives for the DevOps implementation in waste management. These goals may include reduced operational costs, increased efficiency, or improved regulatory compliance. In addition, KPIs (Key Performance Indicators) are also set to measure the success of the implementation later. All these planning steps are essential to steer the DevOps implementation with clear and measurable goals.

Develop

The development stage is an essential step in DevOps implementation in waste management. DevOps teams should focus on developing solutions that will increase efficiency and effectiveness in waste management. The first step is to identify the DevOps tools and technologies that best-fit waste management needs, including tools for process automation, real-time monitoring, team collaboration, and project management. Next, the team should design and develop a DevOps process tailored to the waste management needs, with concrete steps to achieve the goals set earlier in the planning phase. A DevOps

implementation prototype should be created and tested to identify potential issues before implementation. In addition, good integration with existing systems in waste management must also be considered so that the DevOps solution can operate synergistically. Finally, training the team involved in the DevOps implementation is an important step to ensure they have sufficient understanding to operate the DevOps solution effectively. This stage of development is the critical foundation for a successful DevOps implementation in waste management.

Deliver

The Deliver stage is where the implementation of DevOps in waste management takes place. The team will move the solution developed during the previous stages into daily operations. The first step is to practically apply the DevOps solution, integrating it into waste management operations. This involves using DevOps tools and technologies, as well as implementing the processes that have been designed during the development stage. It is essential to ensure that all elements of the DevOps solution are working as planned. Before implementing a DevOps solution widely, a limited trial can be conducted. These trials can take place on a small scale or in specific locations to identify potential issues and adjust processes if needed before full deployment.

Operate

In the operation stage, the implemented DevOps solution runs in day-to-day waste management operations. This is a crucial stage to ensure that the DevOps solution operates effectively and delivers the expected benefits. Here are the detailed steps in the operational stage: Manage Daily Operations, Maintenance and Monitoring, Change Management, Performance Monitoring, and Team Collaboration. In this operational stage, the focus is on running the DevOps solution smoothly, ensuring good maintenance and monitoring, and maximizing the benefits of DevOps implementation in waste management.

Evaluation

The Evaluation stage is essential in DevOps implementation in waste management. The stage evaluates the real impact of the implemented solution and identifies further improvement opportunities. Here are the detailed steps in the evaluation stage: Performance Evaluation, Identification of Successes and Challenges, Improvements and Adjustments, Continuous Monitoring, Documentation, and Reporting. The evaluation stage measures the success of DevOps implementation in waste management and identifies further improvement opportunities. The data and information obtained during this stage help in directing the following steps to maintain efficiency and sustainability in waste management. Conduct evaluation by end-users to identify issues or improvements needed. Incorporate user feedback to improve the user experience of the application.

3. RESULTS AND DISCUSSIONS

The results of the Assessment stage are as follows:

Over the past 12 months, the volume of waste generated by non-profit waste management organizations in Tangerang, Indonesia, has increased by 20%. This data provided an initial understanding of the growth in waste volume that needed to be addressed. An audit and analysis of historical data found that the waste volume increase has been ongoing for the past few years. This indicated an issue that needed to be addressed with a sustainable solution. Analysis of current operational costs showed that the organization was spending a sizeable yearly budget on waste collection, transportation, and processing. This data underscores the high operational costs that could be reduced through changes in the waste management process. In the user needs analysis, users need more efficient waste collection at the household and business levels. The need for

environmentally friendly waste processing. The need for transparent monitoring and reporting of waste management performance. The need to raise public awareness of sustainable waste management. This data on user needs becomes an essential guideline in designing DevOps solutions that are operationally efficient and meet the expectations and needs of local communities and stakeholders.

The results of the Plan stage are as follows:

The waste management team has successfully identified the DevOps team involved in the implementation. The team comprises various members with diverse backgrounds and expertise, including waste management experts, information technology engineers, data analysts, and regulatory compliance specialists. Each team member has a specific role and responsibility in this project. The team has set clear objectives for the DevOps implementation in waste management. The main objectives are to significantly reduce operational costs, improve efficiency in the waste management process, and ensure full compliance with all applicable regulations in the industry. Key Performance Indicators (KPIs) have been set to measure the success of the DevOps implementation. The KPI include: 15% reduction in operating costs. 20% improvement in waste collection and processing efficiency. Compliance with waste management rules and regulations is measured in real-time and must always reach 100%. All these planning steps provided clear and measurable guidance for implementing DevOps in waste management. With a team of suitable experts and clearly defined goals, the project has a solid foundation to achieve the expected results.

The results of the development stage are as follows:

The DevOps team has identified DevOps tools and technologies that best fit the waste management needs. These tools include process automation platforms, real-time monitoring systems, team collaboration, and project management tools. These tools were selected based on the availability of relevant features and the ability to integrate with existing systems. A DevOps process tailored to waste management needs was designed and developed. This process includes concrete steps to automate waste management, improve team collaboration, and enable real-time monitoring. The process has been tested internally to ensure its effectiveness. A DevOps implementation prototype has been successfully created and carefully tested. This prototype is the first step to practically test the solution before full implementation. Testing the prototype helps to identify any potential issues or changes required before widespread implementation. The developed DevOps solution has been integrated with existing systems in waste management. These integrations include performance monitoring systems, regulatory compliance systems, and infrastructure used in the waste management process. Smooth integration is critical to ensuring that the DevOps solution functions synergistically. The teams involved in the DevOps implementation have received appropriate training on the use of the tools and DevOps practices implemented. This training helps ensure that the team has sufficient understanding to operate the DevOps solution effectively. These results show that the development phase has gone well, and the DevOps solution has been successfully developed and tested well before its full deployment. With the tools, processes, and team in place, the project is ready to move on to the next stage of DevOps implementation in waste management.

The results of the Deliver stage are as follows:

The team successfully implemented the DevOps solution into day-to-day waste management operations. This solution includes the use of DevOps tools and technologies, as well as the implementation of processes that have been designed during the development phase. All elements of the DevOps solution have been thoroughly integrated into the operation. Prior to broadly implementing the DevOps solution, the team conducted limited trials. These trials are conducted on a small scale or at specific locations to identify

potential issues and improvements needed before full deployment. The results of the trials have been used to refine processes and address issues as they arise. The team has been actively using DevOps tools and technologies in the day-to-day operations of waste management. This includes process automation, real-time monitoring, and better team collaboration. Using these tools helps improve the efficiency of operations and ensure better performance. During this stage, the team has started actively monitoring the performance of the DevOps solution. This includes monitoring operations' performance, evaluating operational costs' impact, and monitoring regulatory compliance. This initial evaluation provides early insight into the impact of the DevOps implementation. The improved team collaboration expected from the DevOps implementation was maintained. The waste processing, regulatory compliance, and information technology teams continue to communicate and collaborate to achieve the common goal of more efficient waste management. These results show that the delivery phase has gone well, and the DevOps solution has been implemented successfully into the waste management operations. Limited trials have helped identify initial issues, and the teams continue to work together to ensure that the DevOps solution delivers the expected benefits.

The results of the Operate stage are shown in Table 1. These data reflect the successful implementation of DevOps in waste management and its positive impact in terms of efficiency, availability, operational costs, compliance, and team collaboration.

Table 1. Operate Stage

Steps	Results and Data
Manage Daily Operations	Improved waste collection, transportation, and processing efficiency by 25% in the first six months after implementation.
Maintenance and Monitoring	The DevOps system availability rate reached 99.8% within the first year of operation.
Change Management	There were no significant disruptions affecting waste management operations during the period. No changes resulted in significant disruptions in waste management operations during the first year of implementation.
Performance Monitoring	Reduced waste management operating costs by 18% in the first two years of implementation. Compliance with regulations always reached 100% with real-time monitoring.
Team Collaboration	There is a high level of cooperation between the waste processing, regulatory compliance, and information technology teams in achieving the common goal of more efficient waste management.

Based on the research, the results of the Operate stage, shown in Table 2, confirm that the implementation of DevOps has had a significant positive impact on waste management, including reduced operational costs, improved efficiency, and regulatory compliance. Careful evaluation and appropriate corrective actions will help maintain and improve sustainable waste management's efficiency and effectiveness.

Table 2. Evaluation Results

Steps	Results and Data
Performance Evaluation	Improved efficiency of waste management operations by 25% in the first two years of implementation. Reduction in operating costs by 18%.
Identification of Successes and Challenges	The compliance rate with regulations reached 100%. Successes include achieving operational cost reduction targets and improving efficiency.

Improvement and Adjustment	Challenges include continuous regulatory changes that require additional customization. Improvements include updating waste management processes, using more advanced technology, and developing more effective DevOps tools.
Continuous Monitoring	Continuous monitoring has been planned to observe the impact of the improvements that have been implemented.
Documentation and Reporting	Complete documentation of the evaluation results, improvement measures, and recommendations for future development has been compiled. Periodic reports will be used for information sharing.

Discussion

This research is a step forward in improving efficiency and sustainability in waste management through DevOps implementation. The data collected, including waste volumes, operational costs, and regulatory compliance levels, helps shed light on the real impact of implementing DevOps in waste management. The results, which reflect an 18% reduction in operational costs within the first two years of implementation, reinforce the potential benefits to the waste management industry and illustrate that DevOps can positively contribute to environmental sustainability. With real-time monitoring and consistent levels of regulatory compliance, DevOps implementation can be an attractive option for organizations and governments in their quest to manage waste efficiently and sustainably. This research opens the door for a paradigm shift in better waste management.

4. CONCLUSION

The application of DevOps methods in waste management has successfully proven its ability to significantly improve operational efficiency, reduce costs, and increase regulatory compliance. This research has shown that information technology, primarily through real-time monitoring and strict regulatory compliance, can lead to more efficient and sustainable waste management. Implementing DevOps can also address the continuous growth of waste volumes, reduce negative environmental impacts, and enable better adaptation to regulatory changes. For future research, there are several development directions to delve deeper into developing predictive models using artificial intelligence and extensive data analysis to project future waste volumes more accurately. In addition, developing sustainable solutions in waste management, such as using renewable energy for IT operations, could be a focus to pursue environmental sustainability.

REFERENCES

- Aldaco, R., Hoehn, D., Laso, J., Margallo, M., Ruiz-Salmón, J., Cristobal, J., Kahhat, R., Villanueva-Rey, P., Bala, A., Battle-Bayer, L., Fullana-i-Palmer, P., Irabien, A., & Vazquez-Rowe, I. (2020). Food waste management during the COVID-19 outbreak: a holistic climate, economic and nutritional approach. *Science of the Total Environment*, 742. <https://doi.org/10.1016/j.scitotenv.2020.140524>
- Aliev, I., Gazul, S., & Bobova, A. (2020a). The analysis of changes in the payroll of information system support specialists during the Devops methodology implementing. *IOP Conference Series: Materials Science and Engineering*, 862(4). <https://doi.org/10.1088/1757-899X/862/4/042039>
- Aliev, I., Gazul, S., & Bobova, A. (2020b). The analysis of changes in the payroll of information system support specialists during the Devops methodology implementing. *IOP Conference Series: Materials Science and Engineering*, 862(4). <https://doi.org/10.1088/1757-899X/862/4/042039>

- Almeida, F., Simões, J., & Lopes, S. (2022a). Exploring the Benefits of Combining DevOps and Agile. *Future Internet*, 14(2). <https://doi.org/10.3390/fi14020063>
- Almeida, F., Simões, J., & Lopes, S. (2022b). Exploring the Benefits of Combining DevOps and Agile. *Future Internet*, 14(2). <https://doi.org/10.3390/fi14020063>
- Das, A. K., Islam, M. N., Billah, M. M., & Sarker, A. (2021). COVID-19 pandemic and healthcare solid waste management strategy – A mini-review. In *Science of the Total Environment* (Vol. 778). Elsevier B.V. <https://doi.org/10.1016/j.scitotenv.2021.146220>
- Das, S., Lee, S. H., Kumar, P., Kim, K. H., Lee, S. S., & Bhattacharya, S. S. (2019). Solid waste management: Scope and the challenge of sustainability. *Journal of Cleaner Production*, 228, 658–678. <https://doi.org/10.1016/j.jclepro.2019.04.323>
- Dileepkumar, S. R., & Mathew, J. (2021). Optimize Continuous Integration and Continuous Deployment in Azure DevOps for a controlled Microsoft .NET environment using different techniques and practices. *IOP Conference Series: Materials Science and Engineering*, 1085(1), 012027. <https://doi.org/10.1088/1757-899x/1085/1/012027>
- Enoiu, E. P., Truscan, D., Sadovykh, A., & Mallouli, W. (2023, August 29). VeriDevOps Software Methodology: Security Verification and Validation for DevOps Practices. *ACM International Conference Proceeding Series*. <https://doi.org/10.1145/3600160.3605054>
- Khan, M. S., Khan, A. W., Khan, F., Khan, M. A., & Whangbo, T. K. (2022). Critical Challenges to Adopt DevOps Culture in Software Organizations: A Systematic Review. *IEEE Access*, 10, 14339–14349. <https://doi.org/10.1109/ACCESS.2022.3145970>
- Kolisnichenko, O., Kolomytsev, M., & Nosok, S. (n.d.-a). *Software security risk management in DEVOPS methodology*. <https://quality-lab.ru/blog/>
- Kolisnichenko, O., Kolomytsev, M., & Nosok, S. (n.d.-b). *Software security risk management in DEVOPS methodology*. <https://quality-lab.ru/blog/>
- Kumar, A., & Agrawal, A. (2020a). Recent trends in solid waste management status, challenges, and potential for the future Indian cities – A review. In *Current Research in Environmental Sustainability* (Vol. 2). Elsevier B.V. <https://doi.org/10.1016/j.crsust.2020.100011>
- Kumar, A., & Agrawal, A. (2020b). Recent trends in solid waste management status, challenges, and potential for the future Indian cities – A review. In *Current Research in Environmental Sustainability* (Vol. 2). Elsevier B.V. <https://doi.org/10.1016/j.crsust.2020.100011>
- Nanda, S., & Berruti, F. (2021). Municipal solid waste management and landfilling technologies: a review. In *Environmental Chemistry Letters* (Vol. 19, Issue 2, pp. 1433–1456). Springer Science and Business Media Deutschland GmbH. <https://doi.org/10.1007/s10311-020-01100-y>
- Nížetić, S., Djilali, N., Papadopoulos, A., & Rodrigues, J. J. P. C. (2019a). Smart technologies for promotion of energy efficiency, utilization of sustainable resources and waste management. In *Journal of Cleaner Production* (Vol. 231, pp. 565–591). Elsevier Ltd. <https://doi.org/10.1016/j.jclepro.2019.04.397>
- Nížetić, S., Djilali, N., Papadopoulos, A., & Rodrigues, J. J. P. C. (2019b). Smart technologies for promotion of energy efficiency, utilization of sustainable resources and waste management. In *Journal of Cleaner Production* (Vol. 231, pp. 565–591). Elsevier Ltd. <https://doi.org/10.1016/j.jclepro.2019.04.397>
- Pardini, K., Rodrigues, J. J. P. C., Diallo, O., Das, A. K., de Albuquerque, V. H. C., & Kozlov, S. A. (2020). A smart waste management solution geared towards citizens. *Sensors (Switzerland)*, 20(8). <https://doi.org/10.3390/s20082380>
- Sharma, M., Joshi, S., Kannan, D., Govindan, K., Singh, R., & Purohit, H. C. (2020a). Internet of Things (IoT) adoption barriers of smart cities' waste management: An Indian context. *Journal of Cleaner Production*, 270. <https://doi.org/10.1016/j.jclepro.2020.122047>
- Sharma, M., Joshi, S., Kannan, D., Govindan, K., Singh, R., & Purohit, H. C. (2020b). Internet of Things (IoT) adoption barriers of smart cities' waste management: An Indian context. *Journal of Cleaner Production*, 270. <https://doi.org/10.1016/j.jclepro.2020.122047>
- Sharma, M., Joshi, S., Kannan, D., Govindan, K., Singh, R., & Purohit, H. C. (2020c). Internet of Things (IoT) adoption barriers of smart cities' waste management: An Indian context. *Journal of Cleaner Production*, 270. <https://doi.org/10.1016/j.jclepro.2020.122047>
- Sindhu Battina, D. (2021a). *The Challenges And Mitigation Strategies Of Using Devops During Software Development*. www.ijcrt.org
- Sindhu Battina, D. (2021b). *The Challenges And Mitigation Strategies Of Using DEVOPS DURING SOFTWARE DEVELOPMENT*. www.ijcrt.org

- Tripathi, A., Tyagi, V. K., Vivekanand, V., Bose, P., & Suthar, S. (2020). Challenges, opportunities and progress in solid waste management during COVID-19 pandemic. *Case Studies in Chemical and Environmental Engineering*, 2. <https://doi.org/10.1016/j.cscee.2020.100060>
- Xia, W., Jiang, Y., Chen, X., & Zhao, R. (2022). Application of machine learning algorithms in municipal solid waste management: A mini review. In *Waste Management and Research* (Vol. 40, Issue 6, pp. 609–624). SAGE Publications Ltd. <https://doi.org/10.1177/0734242X211033716>
- Zhang, C., Hu, M., Di Maio, F., Sprecher, B., Yang, X., & Tukker, A. (2022a). An overview of the waste hierarchy framework for analyzing the circularity in construction and demolition waste management in Europe. In *Science of the Total Environment* (Vol. 803). Elsevier B.V. <https://doi.org/10.1016/j.scitotenv.2021.149892>
- Zhang, C., Hu, M., Di Maio, F., Sprecher, B., Yang, X., & Tukker, A. (2022b). An overview of the waste hierarchy framework for analyzing the circularity in construction and demolition waste management in Europe. In *Science of the Total Environment* (Vol. 803). Elsevier B.V. <https://doi.org/10.1016/j.scitotenv.2021.149892>