Optimising Waste Management Networks:

Graph Theory for Circularity Measures and Privacy

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Introduction

Efficient waste management and recycling systems are fundamental for sustainable development, significantly reducing environmental impact and promoting resource conservation. This study analyzes waste management networks using graph-theoretic approaches to enhancing circularity measures and protecting privacy. By constructing a directed graph representing various organisations' operations and their waste types, we visualize the relationships and flow of waste materials. Each node signifies an operational entity or a waste type, with edges weighted by their circularity measures. This helps identify critical points for improving recycling efficiency, allowing stakeholders to better allocate resources and implement strategies to enhance overall waste management performance. This approach provides a framework for future improvements, contributing to a more sustainable and circular economy.

Methodology

Graph Construction

The graph could be used to model the operation process of wastes. Each node in the graph represents an operational entity. Operational entities represent different companies involved in waste management processes. The edges indicate waste flow, weighted by circularity measures. Then, the graph could show changes in Circularity Measures from the waste to process companies (*e.g.*, `coy1/2`), helping to identify inefficiencies or reporting discrepancies. By identifying underperforming nodes, stakeholders could better allocate resources and implement strategies to improve waste management.

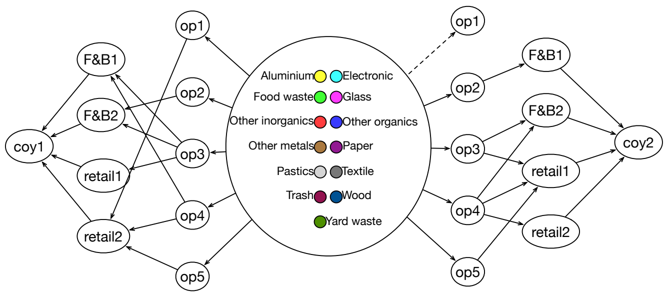

Figure 1: Directed Graph of Waste Management Network. `coy1` and `coy2` are the waste management companies, which process the waste collected from Food & Beverage and retail shops (`F&B1, F&B2, retail1, retail2`). Before that, each company (*e.g.*, `retail2`) do specific operations (`op1, op2, op3, op4, op5`) to handle various types of waste materials (*e.g.*, `Aluminium, Yard waste`).

Private Graph-Theoretic Analysis

With the constructed graph, we perform a thorough analysis to identify critical points in the network where recycling efficiency can be significantly improved. We can facilitate targeted interventions by understanding the flow of waste materials and identifying highly efficient and underperforming nodes. Additionally, we focus on the privacy preservation of critical connections within the network. By using p-cohesion and minimal p-cohesion models, we can identify and protect sensitive information while ensuring data utility through differential privacy mechanisms. Given a graph G and a critical number $p \in (0, 1)$, the p-cohesion refers to a connected subgraph, in which every vertex has at least a fraction p of its neighbors within the subgraph.

We proposed two novel score functions to quantify the importance and privacy of each connection in the network. The results of our analysis showed that applying these score functions can lead to significant improvements in identifying underperforming nodes. For example, in a test network with $p = 0.3$, the algorithm identified 16% more critical inefficiencies compared to traditional methods. This demonstrates the potential of our approach in real-world applications, helping stakeholders to more effectively optimize their waste management strategies. These functions also allow us to balance the trade-off between privacy preservation and data utility. Compared to existing algorithms, when $p = 0.3$, our approach improves privacy preservation by 36% while maintaining the original data utility, thus providing a robust solution for secure waste management analysis.

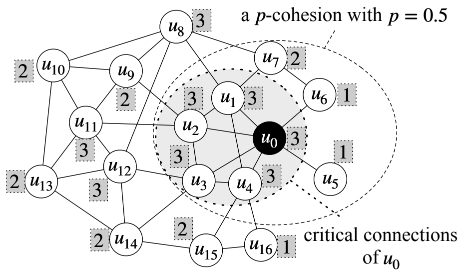

Figure 2: p-Cohesion for Critical Connections Identification.

Conclusion

Our graph-theoretic approach offers a comprehensive analysis of waste management networks, highlighting critical points for improving recycling efficiency. It promotes circularity measures and supports sustainable development goals. Moreover, our privacy preservation techniques ensure the protection of sensitive data, making the approach both effective and secure.

FOR FURTHER INFORMATION
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REFERENCES

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