Data Analytics for Dynamic Urban Operations: A Test-Based Study on Data Analytics Efficiency

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Abstract: This paper explores the field of data analytics for dynamic urban operations and provides a systematic analysis of the importance and possible implications of this field. Our investigation indicates significant data volumes in an urban setting that is data-rich: 500 GB are generated by traffic sensors, 300 GB by environmental monitors, 150 GB by mobile apps, and 75 GB by emergency calls. A variety of analytics techniques, each with a different processing time, are built upon these data sources. These techniques include descriptive, predictive, prescriptive, and diagnostic analytics. The outcomes, which include 90% accuracy, an average processing time of 40 minutes, 80% resource utilization, and 4.2 user satisfaction ratings, highlight the benefits of data analytics. According to the comparison study, diagnostic analytics has a score of 7.8, indicating room for development, while prescriptive analytics leads with an efficiency score of 8.4. As urban stakeholders and academics work to improve urban systems and solve urban issues, the results give a thorough understanding of the effectiveness and application of data analytics in the context of dynamic urban operations.

Keywords: efficiency, data-driven decision-making, urban operations, data analytics, and user pleasure.

1 INTRODUCTION

The use of data analytics has become essential for improving dynamic urban operations in the quickly changing urban scene. The increasing complexity of urbanization is posing a challenge to cities globally. One important tool for improving the sustainability, responsiveness, and efficiency of urban systems is data analytics. In order to better understand the critical field of data analytics for dynamic urban operations, this article presents a systematic investigation of the usefulness of data analytics in urban settings[1]–[6]. A revolutionary paradigm in urban governance and decision-making has been made possible by the combination of data science, analytics techniques, and urban dynamics. Cities are becoming data-rich settings that produce enormous volumes of data from many sources, including emergency response calls, mobile apps, traffic sensors, and environmental monitors[7]–[11]. In order to solve urban concerns ranging from public safety and service delivery to traffic congestion and air quality control, it is imperative to use this data for practical insights. The effectiveness of data analytics techniques in an urban setting is the main subject of this study's empirical investigation. We explore the complexities of data analytics and its real-world applications in urban operations via an extensive test-based study. Our study is designed to examine measures related to user satisfaction, processing speed, accuracy, and resource use in order to assess how well different data analytics techniques work. This study's main goal is to provide a methodical evaluation of data analytics techniques and how well they can improve dynamic urban operations. In order to help urban policymakers, city planners, and tech entrepreneurs harness the potential of data analytics to create more responsive and efficient urban environments, we seek to deliver insights by analyzing the efficacy of various analytics methodologies. It is impossible to overestimate the importance of data analytics in managing the benefits and problems of urban life, as urbanization remains a distinguishing feature of the contemporary period. By providing actual data and insights that will be crucial for urban stakeholders, city planners, and academics in their quest for more intelligent and adaptable urban systems, this study aims to add to the expanding body of knowledge on data analytics for urban operations[12]–[17].

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2 REVIEW OF LITERATURE

Urban Operations using Data Analytics

Urban governance and planning are undergoing radical change as a result of the confluence of data analytics and urban operations. The field of data analytics has expanded to include a number of facets of urban life, such as public safety, traffic control, environmental monitoring, and service provision. According to the literature, data analytics is essential for gleaning insightful information from the vast amounts of data produced in cities, facilitating well-informed decision-making for more responsive and effective urban systems[18]–[23].

1 Data-Informed Judgmentation

Cities are realizing more and more how important data-driven decision-making is. The use of data analytics technologies, which provide politicians and city planners useful insights into urban operations, is a trend that is highlighted. Empirical studies underscore the notion that data-driven decision-making not only optimizes the effectiveness of urban services but also plays a role in more efficient resource allocation, hence augmenting the standard of living for inhabitants of urban areas[24]–[26].

2 Opportunities and Difficulties

The literature recognizes the difficulties in implementing data analytics, despite the fact that it has enormous potential for urban operations. These difficulties include the requirement for a strong data infrastructure, worries about data privacy, and the creation of sophisticated analytical models. However, the advantages that data analytics brings in terms of finding trends, streamlining procedures, and strengthening urban resilience in the face of shifting obstacles exceed them[27]–[33].

3 Methods for Urban Analytics

The variety of analytical techniques used in urban environments is highlighted by the literature. These include diagnostic analytics, which determines the underlying causes of data patterns, prescriptive analytics, which makes actionable suggestions, predictive analytics, which utilizes models to estimate future trends, and descriptive analytics, which summarizes previous data for insights. When used effectively, urban analytics techniques provide a wide range of tools for tackling urban problems[34]–[38].

4 The Significance of User Contentment

An essential component of data analytics in urban operations is user happiness. Studies reveal that residents' and users' acceptance and involvement are critical to the success of data-driven projects. High user satisfaction scores show that data analytics are successfully implemented and that they meet the demands and expectations of urban people. The studied literature emphasizes how data analytics has the potential to revolutionize urban operations. The transformation of contemporary cities into data-informed and adaptable urban environments depends critically on the cooperation of data-driven decision-making, urban analytics techniques, and user satisfaction considerations. While acknowledging and addressing the challenges associated with the adoption of data analytics in an urban context, the insights gathered from this body of work offer a promising pathway toward more responsive, efficient, and sustainable urban systems as cities continue to expand and face new challenges.

3 RESEARCH METHODOLOGY

Utilizing a mixed-methods research methodology, this study thoroughly evaluates the effectiveness and real-world applications of data analytics within the framework of dynamic urban operations by combining quantitative and qualitative methodologies. The study design is divided into many major stages that include gathering, analyzing, and interpreting data.

Data Gathering

Selection of Urban Operation Areas: Public safety, environmental monitoring, traffic management, and service delivery are the four main areas of urban operations that were chosen for analysis. These locations were chosen because they are typical of and relevant to the urban setting. Data Sources and Types: A wide range of data sources were found, including environmental monitors for environmental data, traffic sensors for traffic management, emergency calls for public safety, and user data from mobile apps for service provision. These sources provide actual data that is often accessible in metropolitan environments.

Metrics for Data Volume: For every data source, data volumes were measured in gigabytes (GB). These metrics function as a gauge for the amount of data and the processing power needed for every data source.

1 Analyzing Data

The effectiveness of data analytics techniques in dynamic urban operations was evaluated using quantitative data analysis. To assess how well different data analytics techniques performed in an urban setting, key parameters like accuracy, processing speed, resource consumption, and user satisfaction were calculated. The data were summarized using descriptive statistics, such as means, standard deviations, and percentages.

2 Computing Efficiency Metrics

The accuracy, processing speed (measured in minutes), resource usage (expressed as a percentage), and user satisfaction (based on a 1–5) were the efficiency measures that were computed for each data analytics approach. These measures made it possible to conduct a thorough assessment of how well data analytics techniques performed in an urban setting.

3 A Comparative Study

This study is centered on a comparative analysis. The purpose of this investigation was to assess each data analytics method's overall effectiveness in dynamic urban operations. The study compares accuracy, processing speed, resource use, and user satisfaction to find patterns and variations in how well data analytics techniques function in different metropolitan operating regions.

It is important to recognize certain constraints associated with this research. The results rely on the context since the scope is restricted to four urban operating regions and certain data sources. It is possible that this research did not thoroughly investigate the complexity and scalability of data analytics methodologies. Furthermore, even if they are informative, user satisfaction ratings are subjective and sensitive to a variety of outside influences. To sum up, this study approach offers a well-organized framework for a thorough assessment of data analytics in dynamic urban operations. The goal of the study is to further our knowledge of how data analytics techniques affect the efficacy and efficiency of municipal operations. Researchers, city planners, and other stakeholders in urban systems will find great value in the results as they work to use data analytics to create more sustainable, efficient, and responsive urban systems.

4 RESULTS AND DISCUSSION

TABLE 1 TYPES AND SOURCES OF DATA

Data Source	Data Type	Data Volume (GB)
Traffic Sensors	Traffic Flow Data	500
Environmental Sensors	Air Quality Data	300
Mobile Apps Data	User Behavior Data	150
Emergency Calls Data	Response Time Data	75

Fig 1 Types and Sources of Data

Data sources, together with the corresponding kinds and volumes, are shown in Table 1. Interestingly, 500 GB of data is produced by traffic sensors, demonstrating the volume of traffic-related data produced in metropolitan settings. The 300 GB contribution from the environmental sensors highlights the need of keeping an eye on urban air quality. Moreover, 150 GB of data are produced by mobile apps, demonstrating the importance of user behavior data in improving service delivery. With 75 GB, emergency calls highlight the need of response time information for public safety. The data environment in urban operations is complex, with many data kinds having unique meanings and ramifications, as this research demonstrates.

TABLE 2 TECHNIQUES FOR DATA ANALYTICS

Data Analytics Method	**Description**	**Processing Time (minutes)**
Descriptive Analytics	Summarizes historical data for insights	30
Predictive Analytics	Uses models to predict future trends	45
Prescriptive Analytics	Provides recommendations for actions	60
Diagnostic Analytics	Identifies reasons behind data trends	50

Fig 2 Techniques for Data Analytics

An overview of data analytics techniques, together with their descriptions and processing timeframes, are given in Table 2. With a half-hour processing time, descriptive analytics summarizes previous data to provide insights. With a 45-minute processing period, predictive analytics makes use of models to predict future trends. Prescriptive analytics provides actionable suggestions based on data analysis and can be processed in 60 minutes. With a 50-minute processing period, diagnostic analytics finds the underlying reasons of data patterns. This research highlights the wide range of analytical techniques—each with unique processing speeds and applicability—that may be used to solve urban concerns.

TABLE 3 METRICS FOR DATA ANALYTICS EFFICIENCY

Efficiency Metric	**Description**	**Value**
Accuracy	Precision of analytics results	90%
Processing Speed	Time taken for analytics processing	40 minutes
Resource Utilization	Efficiency of computational resources used	80%
User Satisfaction	User ratings of analytics insights (1-5 scale)	4.2

Fig 3 Metrics for Data Analytics Efficiency

Table 3 explores the metrics related to data analytics methodologies' efficiency. Remarkably, 90% accuracy reflects the correctness of the analytics findings. The time required for analytics processing is shown by the processing speed, which averages 40 minutes. With an 80% resource utilization rate, effective use of computing resources is highlighted. On a scale of 1 to 5, user satisfaction ratings are noticeably high, averaging 4.2. These metrics—which show high accuracy, effective processing, resource management, and favorable user feedback—highlight the usefulness of data analytics in urban operations.

TABLE 4 OUTCOMES OF COMPARATIVE ANALYSIS

Data Analytics Method	Overall Efficiency Score (1-10)	Cost per Insight ($)	User Satisfaction (1-5)
Descriptive Analytics	8.2	5	4.5
Predictive Analytics	7.9	7	4.3
Prescriptive Analytics	8.4	6	4.7
Diagnostic Analytics	7.8	8	4

Fig 4 Outcomes of Comparative Analysis

The comparative study findings for each data analytics approach across different urban operating regions are summarized in the final table. The efficacy of descriptive analytics is shown by its 8.2 total efficiency score. With a 7.9 score, predictive analytics performs rather well. With a score of 8.4, prescriptive analytics comes out on top due to its powerful recommendation engine. With a score of 7.8, diagnostic analytics is considered to have potential for improvement. Another metric is cost per insight, where $8 is the highest for diagnostic analytics. With a grade of 4.7, user satisfaction surveys show that prescriptive analytics has been implemented successfully. This report provides insights for urban stakeholders in improving urban operations by highlighting the areas of strength and development in data analytics methodologies.These statistics and analysis provide a thorough understanding of the results of using data analytics in dynamic urban operations. The findings demonstrate the usefulness of various data analytics techniques in terms of effectiveness, affordability, and user satisfaction, empowering policymakers and urban stakeholders to decide how best to integrate and optimize these technologies for more responsive and efficient urban systems.

5 CONCLUSION

The results of this study's culminating on data analytics for dynamic urban operations provide a plethora of new information about the opportunities and difficulties associated with using data analytics to improve cities. The comparative analysis's data highlights the usefulness and effectiveness of data analytics techniques in tackling a range of urban issues, including public safety, traffic control, environmental monitoring, and service provision. The substantial data quantities produced by mobile apps, environmental monitors, traffic sensors, and emergency calls highlight the data-rich character of urban operations when looking at the data sources. These data sources provide data analytics a strong platform on which to build in order to produce insightful findings and guide decision-making. Table 2 illustrates the variety of data analytics techniques that highlight the adaptability of these strategies. Descriptive, predictive, prescriptive, and diagnostic analytics each have different processing timeframes and specialized target areas, therefore several tools are available for urban stakeholders to use in addressing different urban concerns. But it's clear that the best data analytics technique should be chosen in accordance with the unique requirements and goals of the urban operation. The data analytics efficiency indicators in Table 3 show how successful these techniques are overall. The benefits of data analytics in urban operations include high accuracy, fast processing, optimal resource usage, and positive user satisfaction scores. Particularly, the high user satisfaction scores demonstrate how data analytics meets the requirements and expectations of urban dwellers. The efficiency ratings for each data analytics technique show how well they perform across urban operating regions in the comparison study (Table 4). Diagnostic analytics indicates possible areas for development, but prescriptive analytics is clearly a good performer. The cost per insight measure gives decision-makers a comprehensive understanding of the financial effects of various data analytics techniques. As a result, our study has shown how data analytics may greatly improve dynamic urban operations by providing insights, streamlining procedures, and enhancing decision-making. The results highlight the value of making decisions based on data and the range of data analytics techniques that may be used to solve urban problems. While identifying and resolving the problems associated with the implementation of data analytics in urban operations, the insights provided by this study provide a road toward more efficient, data-informed, and adaptable urban systems as cities continue to change and urbanization increases. Undoubtedly, data analytics will play a significant part in the development of cities in the future, and its ongoing use should result in more resilient and adaptable urban settings. Moreover, this study makes a valuable addition to the expanding corpus of information on data analytics in urban operations. The study's emphasis on data-driven approaches and analytical tools has the potential to completely change how urban systems are managed and difficulties are addressed. These results provide important direction for academics, politicians, and urban planners who want to use data analytics to build more intelligent, sustainable cities as urbanization grows. Although the results have shown the benefits and shortcomings of data analytics techniques, it is crucial to recognize the dynamic character of urban problems. The study that is being provided here provides an overview of data analytics in urban operations at a particular moment in time. Data analytics is a fast developing discipline with significant potential for even greater effect on urban systems with the emergence of new technology and approaches. Finally, it is critical to stress that a collaborative and interdisciplinary approach is required for the effective integration of data analytics into urban operations. To fully use data analytics in addressing the always changing demands of urban populations, stakeholders, policymakers, data scientists, and residents must all be involved. Data-driven decision-making will be the key to successful urban operations in the future, and this study represents a major advancement in the creation of intelligent, effective, and resilient urban settings.

6 REFERENCES

A. [1] X. Zhu, X. Zhang, P. Gong, and Y. Li, "A review of distributed energy system optimization for building decarbonization," Journal of Building Engineering, vol. 73, Aug. 2023, doi: 10.1016/j.jobe.2023.106735.

B. [2] C. Liu et al., "Supporting virtual power plants decision-making in complex urban environments using reinforcement learning," Sustain Cities Soc, vol. 99, Dec. 2023, doi: 10.1016/j.scs.2023.104915.

C. [3] K. Raghavendar, I. Batra, and A. Malik, "A robust resource allocation model for optimizing data skew and consumption rate in cloud-based IoT environments," Decision Analytics Journal, vol. 7, Jun. 2023, doi: 10.1016/j.dajour.2023.100200.

D. [4] Z. E. Ahmed, A. A. Hashim, R. A. Saeed, and M. M. Saeed, "Mobility management enhancement in smart cities using software defined networks," Sci Afr, vol. 22, Nov. 2023, doi: 10.1016/j.sciaf.2023.e01932.

E. [5] "Optimizing City Services through Data-Driven Dynamic Urban Communication: A Communication Efficiency Test - Search | ScienceDirect.com." Accessed: Nov. 04, 2023. [Online]. Available: https://www.sciencedirect.com/search?qs=Optimizing%20City%20Services%20through%20Data-Driven%20Dynamic%20Urban%20Communication%3A%20A%20Communication%20Efficiency%20Test

F. [6] B. Yu and X. Zhou, "Urban administrative hierarchy and urban land use efficiency: Evidence from Chinese cities," International Review of Economics and Finance, vol. 88, pp. 178–195, Nov. 2023, doi: 10.1016/j.iref.2023.06.033.

G. [7] X. Pan, J. Tang, T. Yu, J. Cai, Y. Xiong, and F. Gao, "Reposition optimization in the free-floating bike-sharing system considering transferring travels from urban rail transit," Comput Ind Eng, vol. 178, Apr. 2023, doi: 10.1016/j.cie.2023.109127.

H. [8] L. Barth, L. Schweiger, R. Benedech, and M. Ehrat, "From data to value in smart waste management: Optimizing solid waste collection with a digital twin-based decision support system," Decision Analytics Journal, p. 100347, Oct. 2023, doi: 10.1016/J.DAJOUR.2023.100347.

I. [9] Z. Wang, L. Huang, S. Yang, X. Luo, D. He, and S. Chan, "Multi-strategy enhanced grey wolf algorithm for obstacle-aware WSNs coverage optimization," Ad Hoc Networks, vol. 152, Jan. 2024, doi: 10.1016/j.adhoc.2023.103308.

J. [10] A. H. Salem, I. W. Damaj, and H. T. Mouftah, "Vehicle as a Computational Resource: Optimizing Quality of Experience for connected vehicles in a smart city," Vehicular Communications, vol. 33, Jan. 2022, doi: 10.1016/j.vehcom.2021.100432.

K. [11] Z. Cai, Y. Kwak, V. Cvetkovic, B. Deal, and U. Mörtberg, "Urban spatial dynamic modeling based on urban amenity data to inform smart city planning," Anthropocene, vol. 42, Jun. 2023, doi: 10.1016/j.ancene.2023.100387.

L. [12] M. M. H. Sifat, S. K. Das, and S. M. Choudhury, "Design, development, and optimization of a conceptual framework of digital twin electric grid using systems engineering approach," Electric Power Systems Research, vol. 226, Jan. 2024, doi: 10.1016/j.epsr.2023.109958.

M. [13] J. Zhan, S. Dong, and W. Hu, "IoE-supported smart logistics network communication with optimization and security," Sustainable Energy Technologies and Assessments, vol. 52, Aug. 2022, doi: 10.1016/j.seta.2022.102052.

N. [14] M. S. Dahal, "Energy saving in 5G mobile communication through traffic driven cell zooming strategy," Energy Nexus, vol. 5, Mar. 2022, doi: 10.1016/j.nexus.2022.100040.

O. [15] A. S. Ibrahim, K. Y. Youssef, A. H. Eldeeb, M. Abouelatta, and H. Kamel, "Adaptive aggregation based IoT traffic patterns for optimizing smart city network performance," Alexandria Engineering Journal, vol. 61, no. 12, pp. 9553–9568, Dec. 2022, doi: 10.1016/j.aej.2022.03.037.

P. [16] S. Sharif, S. Zeadally, and W. Ejaz, "Space-aerial-ground-sea integrated networks: Resource optimization and challenges in 6G," Journal of Network and Computer Applications, vol. 215, Jun. 2023, doi: 10.1016/j.jnca.2023.103647.

Q. [17] A. Afshari, "Optimization of urban design/retrofit scenarios using a computationally light standalone urban energy/climate model (SUECM) forced by ERA5 data," Energy Build, vol. 287, May 2023, doi: 10.1016/j.enbuild.2023.112991.

R. [18] L. Wang, M. Xu, and H. Qin, "Joint optimization of parcel allocation and crowd routing for crowdsourced last-mile delivery," Transportation Research Part B: Methodological, vol. 171, pp. 111–135, May 2023, doi: 10.1016/j.trb.2023.03.007.

S. [19] P. Thantharate, A. Thantharate, and A. Kulkarni, "GREENSKY: A Fair Energy-Aware Optimization Model for UAVs in Next-Generation Wireless Networks," Green Energy and Intelligent Transportation, p. 100130, Oct. 2023, doi: 10.1016/J.GEITS.2023.100130.

T. [20] T. Yang, Z. Chu, and B. Wang, "Feasibility on the integration of passenger and freight transportation in rural areas: A service mode and an optimization model," Socioecon Plann Sci, vol. 88, Aug. 2023, doi: 10.1016/j.seps.2023.101665.
U. [21] X. Zhao, M. Liu, and M. Li, "Task offloading strategy and scheduling optimization for internet of vehicles based on deep reinforcement learning," Ad Hoc Networks, vol. 147, Aug. 2023, doi: 10.1016/j.adhoc.2023.103193.
V. [22] O. P. Agboola, F. M. Bashir, Y. A. Dodo, M. A. S. Mohamed, and I. S. R. Alsadun, "The influence of information and communication technology (ICT) on stakeholders' involvement and smart urban sustainability," Environmental Advances, vol. 13, Oct. 2023, doi: 10.1016/j.envadv.2023.100431.
W. [23] P. He, N. Almasifar, A. Mehbodniya, D. Javaheri, and J. L. Webber, "Towards green smart cities using Internet of Things and optimization algorithms: A systematic and bibliometric review," Sustainable Computing: Informatics and Systems, vol. 36, Dec. 2022, doi: 10.1016/j.suscom.2022.100822.
X. [24] S. Li et al., "Improving air quality through urban form optimization: A review study," Build Environ, vol. 243, Sep. 2023, doi: 10.1016/j.buildenv.2023.110685.
Y. [25] O. P. Agboola and M. Tunay, "Urban resilience in the digital age: The influence of Information-Communication Technology for sustainability," J Clean Prod, vol. 428, Nov. 2023, doi: 10.1016/j.jclepro.2023.139304.
Z. [26] Q. Wu, "Optimization of AI-driven communication systems for green hospitals in sustainable cities," Sustain Cities Soc, vol. 72, Sep. 2021, doi: 10.1016/j.scs.2021.103050.
AA. [27] Y. Kaushik, V. Verma, K. K. Saxena, C. Prakash, L. R. Gupta, and S. Dixit, "Effect of Al2O3 Nanoparticles on Performance and Emission Characteristics of Diesel Engine Fuelled with Diesel–Neem Biodiesel Blends," Sustainability (Switzerland), vol. 14, no. 13, Jul. 2022, doi: 10.3390/SU14137913.
BB. [28] C. Shyamlal et al., "Corrosion Behavior of Friction Stir Welded AA8090-T87 Aluminum Alloy," Materials, vol. 15, no. 15, Aug. 2022, doi: 10.3390/MA15155165.
CC. [29] S. Dixit and A. Stefańska, "Bio-logic, a review on the biomimetic application in architectural and structural design," Ain Shams Engineering Journal, 2022, doi: 10.1016/J.ASEJ.2022.101822.
DD. [30] D. Goyal, R. K. Dang, T. Goyal, K. K. Saxena, K. A. Mohammed, and S. Dixit, "Graphene: A Path-Breaking Discovery for Energy Storage and Sustainability," Materials, vol. 15, no. 18, Sep. 2022, doi: 10.3390/MA15186241.
EE. [31] M. Makwana et al., "Effect of Mass on the Dynamic Characteristics of Single- and Double-Layered Graphene-Based Nano Resonators," Materials, vol. 15, no. 16, Aug. 2022, doi: 10.3390/MA15165551.
FF. [32] R. Shanmugavel et al., "Al-Mg-MoS2 Reinforced Metal Matrix Composites: Machinability Characteristics," Materials, vol. 15, no. 13, Jul. 2022, doi: 10.3390/MA15134548.
GG. [33] A. Nair et al., "Machine Learning for Prediction of Heat Pipe Effectiveness," Energies (Basel), vol. 15, no. 9, May 2022, doi: 10.3390/EN15093276.
HH. [34] A. Kumar, N. Mathur, V. S. Rana, H. Sood, and M. Nandal, "Sustainable effect of polycarboxylate ether based admixture: A meticulous experiment to hardened concrete," Mater Today Proc, 2022.
II. [35] Md. Z. ul Haq, H. Sood, and R. Kumar, "Effect of using plastic waste on mechanical properties of fly ash based geopolymer concrete," Mater Today Proc, 2022.
JJ. [36] M. Nandal, H. Sood, P. K. Gupta, and M. Z. U. Haq, "Morphological and physical characterization of construction and demolition waste," Mater Today Proc, 2022.
KK. [37] H. Sood, R. Kumar, P. C. Jena, and S. K. Joshi, "Optimizing the strength of geopolymer concrete incorporating waste plastic," Mater Today Proc, 2023.
LL. [38] H. Sood, R. Kumar, P. C. Jena, and S. K. Joshi, "Eco-friendly approach to construction: Incorporating waste plastic in geopolymer concrete," Mater Today Proc, 2023.