Vol 3 Issue 1 (July-September 2025)

ISSN (Online): 3006-4740

ISSN (Print): 3006-4732

Optimizing Sustainable Solid Waste Management through Success Factor Adoption: A Case Of Karachi

Furqan Javed Arain

Department of Architecture and Planning, Dawood University of Engineering and Technology, Karachi, Sindh, Pakistan

Sania Rehman Memon

Department of Architecture, Mehran University of Engineering and Technology, Jamshoro, Sindh, Pakistan.

Sabeen

Department of Architecture, Mehran University of Engineering and Technology, Jamshoro, Sindh, Pakistan

Salman Mateen

Department of Architecture and Planning, Dawood University of Engineering and Technology, Karachi, Sindh, Pakistan

Muhammad Zakir Raza

Manager HSE Generation & Transmission

* Corresponding author**:** Email: furqan.arian@duet.edu.pk

ABSTRACT

This study examines Karachi's urban status as well as the social and environmental effects of garbage on urban development. The population has increased so quickly in recent years that an unmanageable amount of trash is produced. The fact that only 4,000 tons of the 10,000 tons of Pakistani solid garbage generated every day in a metropolis like Karachi are hauled and disposed of at landfills by SSWMB raises serious concerns. In addition to destroying Karachi's aesthetics, the haphazard treatment and inappropriate disposal of solid waste have a serious negative influence on the city's health by causing environmental pollution and chronic illnesses. way. Solid waste disposal is a pervasive and painful issue in Karachi. One of the main issues facing the authorities of megacities is the solid waste management problem, which needs to be managed in a way that is as technically possible, compatible, socially

acceptable, and financially viable. In the current scenario, conventional landfill sites play a significant role as well. Therefore, this thesis aims to comprehend SSWM Karachi and develop a sustainable solution. This study will examine the most feasible ways to responsibly address Karachi's solid waste issues without compromising those now employed in the industry.

Keywords: WASTE COLLECTION AND DISPOSAL, URBAN WASTE MANAGEMENT, Sindh Solid Waste Management Board (SSWMB), Plastic Waste Reduction, Waste-To-Energy Solutions

1. INTRODUCTION

In the modern era, waste has grown to be a significant issue in both developed and developing nations (Ferronato & Torretta 2019). As people have become more sedentary and have moved into urban areas as cities and towns have increased, waste management has become more complex and challenging (Maalouf & Agamuthu, 2023). As more people began to gather in comparatively small areas in search of employment, garbage disposal became a more significant issue (Hardoy, J. E., et al., 2013). The amount of land available for waste disposal decreased as the population of urbanized cities increased and the amount of garbage produced per person increased (Okai, 2020). The nation's economy is at stake due to inadequate garbage management (Awino & Apitz, 2024). The classification, production, prevention, and processing of waste, as well as their processing, treatment, recycling, and disposal, are all included in waste management (Aziz, H. A., et al, 2022). Human health and well-being depend on efficient solid waste management (Awuchi, C. G., et.al 2020).

2. LITERATURE

The quick and dynamic growth of cities frequently puts a higher priority on utilities and roads, which unintentionally leads to urban sprawl and wasteful land usage (Bhattarai & Conway, 2020). The municipal garbage systems are being strained by this unrestrained urban expansion. The foundation of sustainable urban life is universal access to sufficient sanitation and waste management services, as highlighted by the United Nations Sustainable Development Goal 6 (United Nations, 2022). Effective solid waste management (SWM), according to Mwanza and Mbohwa (2017), is essential for attaining sustainability in expanding cities as well as for public health.

According to Domfeh et al. (2012), considerable waste reduction and resource efficiency enhancements must be sought to achieve SDG 6's goals. Like this, Zaman and Lehmann (2011) point out that unsustainable amounts of solid waste have been produced in cities all over the world because of urban development fueled by population growth and high consumption habits. Recent research confirms this worry, pointing out that inadequate infrastructure, bad governance, and low public knowledge undermine the efficacy of SWM systems in growing megacities like Karachi (Khatri et al., 2021; Mahmood & Khan, 2019). Thus, the purpose of this study is to examine Karachi's SWM framework, pinpoint systemic

shortcomings, and suggest crucial success criteria that help direct the city's shift to a more robust and sustainable waste management approach (Iqbal, A., et al, 2022).

Table No.1: Categories of Solid Waste Generators and Associated Waste Types

Source: Ahmed, S., et al 2022

Category	Typical Generators	Types of Solid Waste
Residential Waste	Single-family and multi-family housing units	Food scraps, paper, cardboard, plastics, textiles, yard trimmings, glass, metals, ashes, e-waste, batteries, tires
Commercial Waste	Offices, markets, restaurants, hotels, retail stores	Packaging materials (paper, plastics), food waste, broken glass, metals, hazardous and special wastes
Institutional Waste	Hospitals, schools, government buildings, prisons	Paper, plastics, food waste, glass, metals, biomedical and hazardous materials
Construction & Demolition	Building sites, roadwork, renovations, and demolition areas	Concrete, soil, rubble, steel, bricks, timber, and other construction debris
Municipal Services Waste	Parks, beaches, street cleaning, water treatment plants	Litter, landscaping debris, street sweepings, sludge
Industrial Process Waste	Refineries, chemical and power plants, mining and manufacturing facilities	Industrial offcuts, process waste, scrap metals, slag, defective goods, chemical residues
Agricultural Waste	Farms, dairies, feedlots, orchards, crop fields	Spoiled produce, organic farm waste, pesticide containers, hazardous agricultural residues
Manufacturing Waste	Fabrication plants, construction suppliers, energy and chemical factories	Mixed domestic-type waste, packaging, food remnants, industrial by-products, ashes, and special wastes

2.1 Study Area

The visible deterioration of Karachi's urban landscape reflects the deep-rooted structural and physical challenges arising from unregulated inner-city growth (Yao, X., 2025). Recognized historically as the "City of Lights," Karachi remains Pakistan's most populous and economically significant metropolis (Khan, S., 2015***)***. It ranks as the 12th largest city in the world and serves as a critical hub for national services, including water supply, energy, transportation, healthcare, and education, though many of these services remain inadequate and unevenly distributed (Viqar, S., 2016).

According to the United Nations' *World Urbanization Prospects* (WUP, 2022), Karachi's population reached approximately 16.09 million in 2016, up from just over 1 million in 1950. Since 2015, the city has experienced an average annual population growth rate of 2.41%, adding nearly 1.8 million residents in less than a decade (Lanjwani, M. U., et.al, 2024). This

consistent urban expansion, including spillover into peripheral suburban zones, has placed immense strain on infrastructure, governance, and waste management systems (Baig, A., et al, 2024). Karachi's demographic and spatial growth presents both an opportunity and a challenge, especially in terms of sustainable urban planning and environmental resilience. (Niazi & Azad, 2018).

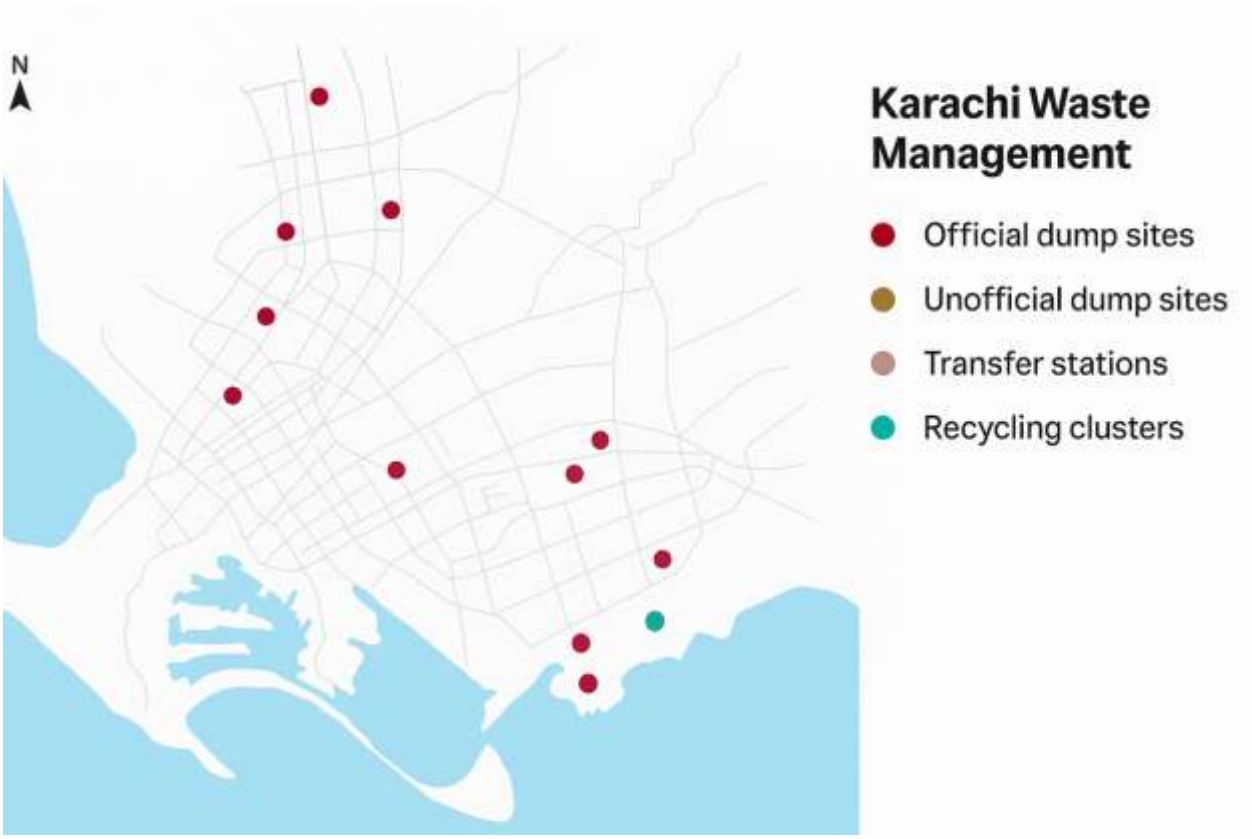

Figure 01: Location of Official and Unofficial Dumping Sites, Sorting Areas, and Recycling Industry
Source: Aslam, S., et al 2022

The identities of the organizations in Karachi in charge of garbage collection and transportation were supplied by KMC representatives. The KMC has investigated the exact figures for waste created or cleared through the Karachi Strategic Development Plan 2020 (Mukherji, 2018).

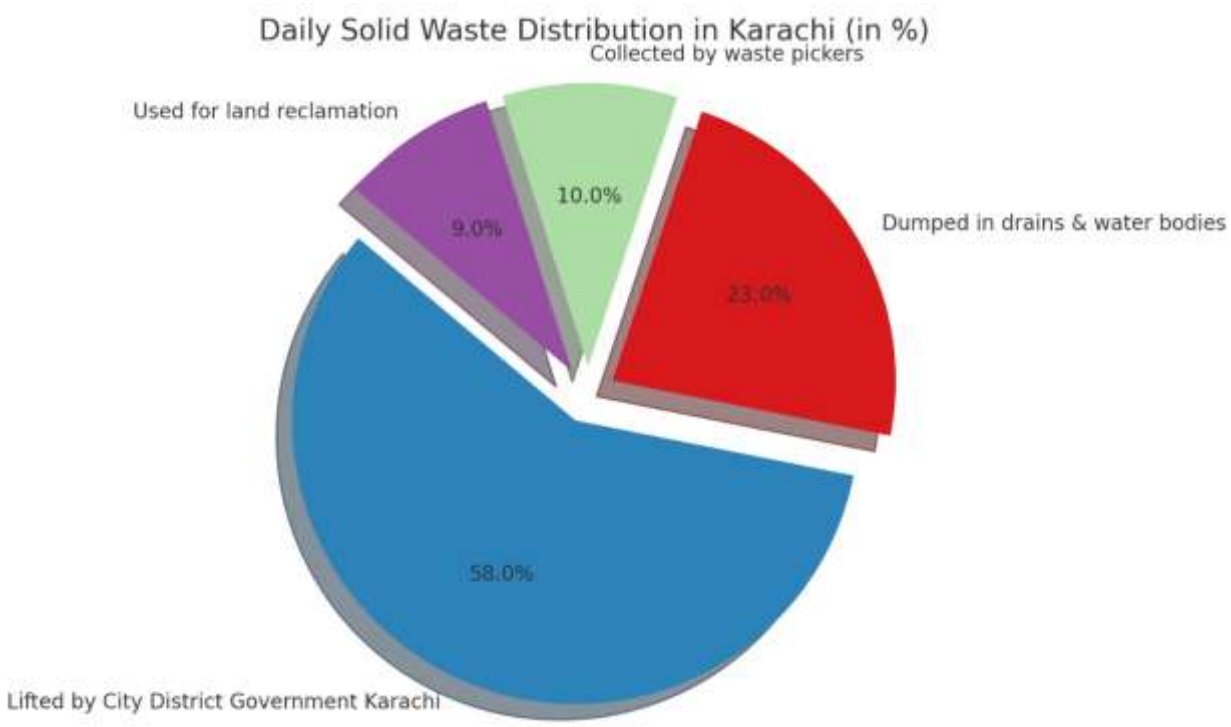

Figure 02: Karachi Waste Collection and Dumping

Based on a survey conducted by the Strategic Development Plan 2020 for Karachi. According to Khatri et al. (2021), KMC transportation is accountable for around 59% of the waste generated.

3. METHODOLOGY

Reviewing the literature on solid waste management, reduction strategies, and the adoption of crucial success criteria for effective, long-term solid waste management in Karachi is the first step in the research process.

Additionally, we create questionnaires to get data from various respondents, including solid waste management boards, garbage collecting experts, the general public, and all stakeholders or municipal committees.

3.1 Research design

The study utilized a case study methodology to identify the key success factors for waste management control in the growing city of Karachi. Important information was obtained by conducting one-on-one interviews with respondents. Conducting in-depth individual interviews with a small number of people to find out their opinions on a problem, idea, or program is known as "complete interviewing," a qualitative research method (Boyce 2006).The primary target population for this study was men and women, employees of the Karachi Municipal Corporation and Provincial Assembly, waste management firms, the SSWMB Agency, and workers at landfills. Using a straightforward random sample technique, district residents, union council members, and provincial parliament members were selected for interviews. Ten residents, four members of the provincial legislature, three members of zonal councils, two representatives from the Karachi Municipal Corporation, one representative from the Sindh Environmental Protection Agency (SEPA), and two representatives from Sindh waste management companies operating in the study district were all questioned.

Table 02: Respondents by Agency and Role Description

Agency / Stakeholder Group	Number of Respondents	Designated Roles
Landfill Site Operators	20	Operations Managers, Transport Supervisors
Environmental Protection Agency (EPA)	25	Sanitation and Environmental Officers
Members of Provincial Assembly (MPAs)	30	Local Government Representatives
Private Waste Management Companies	35	Operations and Field Managers
Karachi Municipal Corporation & SSWMB Staff	25	City Nazim, Administrative Officers, Municipal Budget Officers
Union Council Representatives	20	Town Nazims, District Administrators
Students (Academic Institutions)	25	University and College Students
General Public (Residents)	30	Homeowners, Tenants
Total	**210**	

3.2 Data Collection & Analysis Technique

200 people will be surveyed and interviewed in order to get primary data. Reports from national and international surveys will be used to collect secondary data. 210 business owners in Karachi will receive a prepared survey with 25 questions. Hoyle says data from 210 populations are reliable. The reliability of the questionnaire, the elements and variables I'll be working with, and other tests like Cronbach's Alpha, Regression, Correlation, Coefficient, and ANOVA will all be evaluated using PLS Smart.

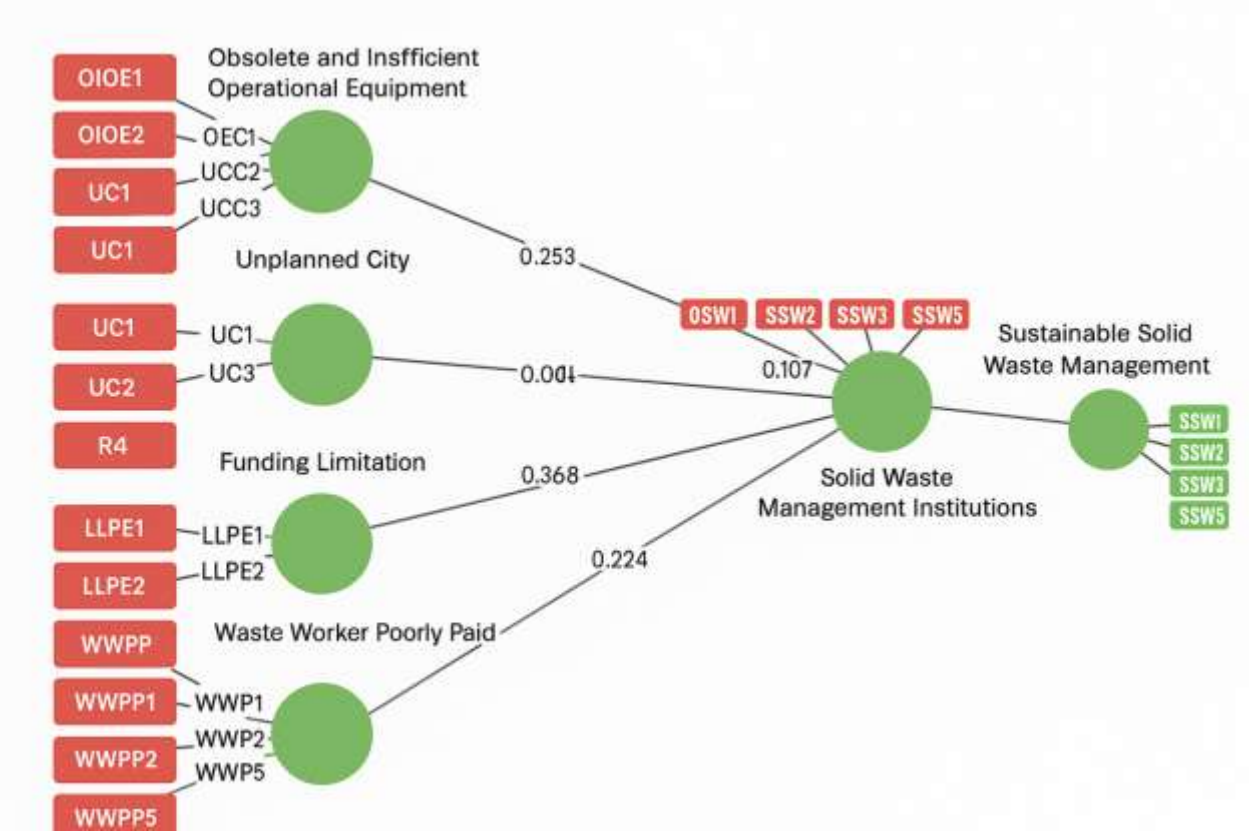

Figure.03: Estimated Model

The PLS-Algorithm approach was used to calculate the study's estimated model, which is seen in the image above. The variables in the round form are referred to be constructs or latent variables in the context of SEM. The items with a rectangular shape are the manifest variables or indicators. The value between the arrows of the construct is known as the route coefficient, whereas the value between the arrows of the indicators is known as a factor loading. Even yet, the constructions display the coefficients of determination (R2) values. We'll go into further depth about the significance of these figures.

Table 03: Descriptive Statistics

Indicator	Mean	Median	Min	Max	Std Dev	Kurtosis	Skewness
Gender	1.21	1	1	2	0.407	0.068	1.438
Age	2.186	2	1	4	0.980	-0.871	0.383
Status	1.429	1	1	2	0.495	-1.934	0.291
OIOE1	3.067	3	1	5	1.115	-0.871	0.137
OIOE2	2.971	3	1	5	1.146	-0.701	0.056
OIOE3	2.957	3	1	5	1.251	-1.036	-0.021
...	...	...	...	...	...	...	...

The different descriptive statistics measures are displayed in the table below; there are 33 indicators in all. None of the indicators has any missing value after the data has been cleaned. The table provides the mean and median data to demonstrate how to compute central tendency. The construction in the route model is operationalized using indicators 5 through 33, which are scaled from 1 to 5. On a scale of 1 to 5, the highest standard deviation is 1.25.

Table 04: Consistency, Reliability, and Convergent Validity

Construct	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Obsolete and Insufficient Operational Equipment	0.845	0.896	0.684
Unplanned City Aspects	0.856	0.912	0.776
Funding Limitations	0.839	0.892	0.673
Low-Level Public Education on SWM	0.854	0.911	0.773
Waste Workers Poorly Paid and Untrained	0.858	0.898	0.637
Solid Waste Management Institution	0.868	0.904	0.655
Sustainable Solid Waste Management	0.863	0.901	0.647

The observed variables are consistent and dependable, as indicated by Cronbach's Alpha and Composite reliability values, which fall between 0.65 and 0.9. It illustrates the strength of the positive correlation between two construction measures of the same structure.

The validity of the indicator is shown when the outer loading value is greater than 0.708. In a similar vein, a construct's indicators cover more than 50% of the variation when its AVE value is more than 0.5. There is convergent validity because all the AVE values are greater than 0.5. Furthermore, all indicators have outer loadings greater than 0.708, proving both the validity of the indicators and their convergent validity.

Table 5 displays the Fornell-Larcker criterion. The square root of the AVE, which is 0.804 and higher than the correlation of all variables, is the highest value in the second column. This proves the discriminating validity of the construction. It is evident that all square root AVE values are greater than all correlations, and this fact is consistent across all conceptions.

Table 05: Fornel-Larcker criterion shows Discriminant Validity

Construct	Unplanned City	Sustainable SWMB	SWM Institutions	Low-Level Public Edu.	Op. Equipment	Waste Workers	Funding Limitations
Unplanned City	**0.881**						
Sustainable SWMB	0.490	**0.804**					
SWM Institutions	0.568	0.702	**0.809**				
Low-Level Public Education	0.406	0.717	0.734	**0.879**			
Operational Equipment (Obsolete/Insuff.)	0.430	0.703	0.654	0.657	**0.827**		
Waste Workers – Poorly Paid/Untrained	0.407	0.669	0.674	0.669	0.585	**0.798**	
Funding Limitations	0.407	0.755	0.553	0.617	0.629	0.502	**0.820**

One metric for evaluating collinearity statistics is the variation inflation factor (VIF). The absence of multicollinearity is indicated by the VIF being less than 5. Tables 5 and 6 demonstrate the VIF values of all indicators and all exogenous constructions, respectively. Collinearity is not an issue because every number is smaller than five.

Table 06:Outer VIF values

Indicator	VIF	Indicator	VIF
UC1	2.113	LLPE2	2.194
UC2	2.009	LLPE3	2.194
UC3	2.815	OIOEI2	1.590
SSWMI1	2.319	OIOEI3	2.110
SSWMI2	1.837	OIOEI4	2.197

SSWMI3	1.870	WWPP1	1.991
SSWMI4	1.959	WWPP2	1.873
SSWMI5	2.092	WWPP3	1.971
SSWM1	1.750	WWPP4	1.767
SSWM2	1.887	WWPP5	1.799
SSWM3	2.032	FL1	1.873
SSWM4	2.217	FL2	1.784
SSWM5	2.173	FL3	1.926
LLPE1	1.981	FL4	1.795

Table 07: Inner VIF values

Indicator	SSWM Success	SSWM Intentions
Unplanned City	—	1.320
Sustainable SWM	—	—
SWM Institution	1.747	—
Low-Level Public Education on SSWM	—	2.457
Obsolete & Insufficient Operational Equipment	1.747	2.202
Waste Workers Poorly Paid	—	1.987
Funding Limitations	—	1.926

The PLS-SEM algorithm technique is utilized in Path Analysis to provide a number of measures that are frequently used to report validity and reliability. The significance of these correlations is ascertained in PLS-SEM using the bootstrapping technique. The probability (p-values) and empirical t-values are obtained using the standard error value. At the 0.05 significance level, a significant link between variables is shown by t-values larger than 1.96 and p-values less than 0.05. The hypothesis is supported even if the t-value is more than 2.23 and the p-value is less than 0.01 at the 0.01 significance level.

The direct and indirect effects are shown in Table 7. It concludes that, out of the five factors, four significantly affect outdated and inadequately functioning equipment: low-level public education on solid waste management, unplanned city aspects, funding constraints, and solid waste management institutions.

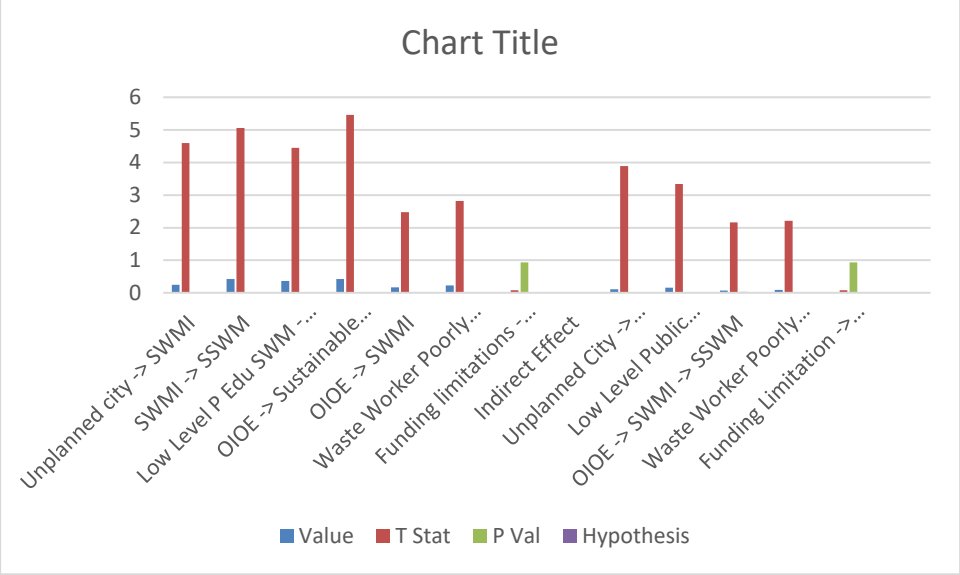

Figure 04: Path analysis with PLS-SEM method

The predictive accuracy of the model is evaluated using the coefficient. The R square represents the combined impact of exogenous and endogenous variables on the endogenous variable. The path model contains two endogenous variables. Solid waste management institutions are explained by five exogenous variables, namely outdated and inadequate operational equipment and solid waste management institutions; sustainable solid waste management is explained by two exogenous variables, namely outdated and inadequate operational equipment and solid waste management institutions.

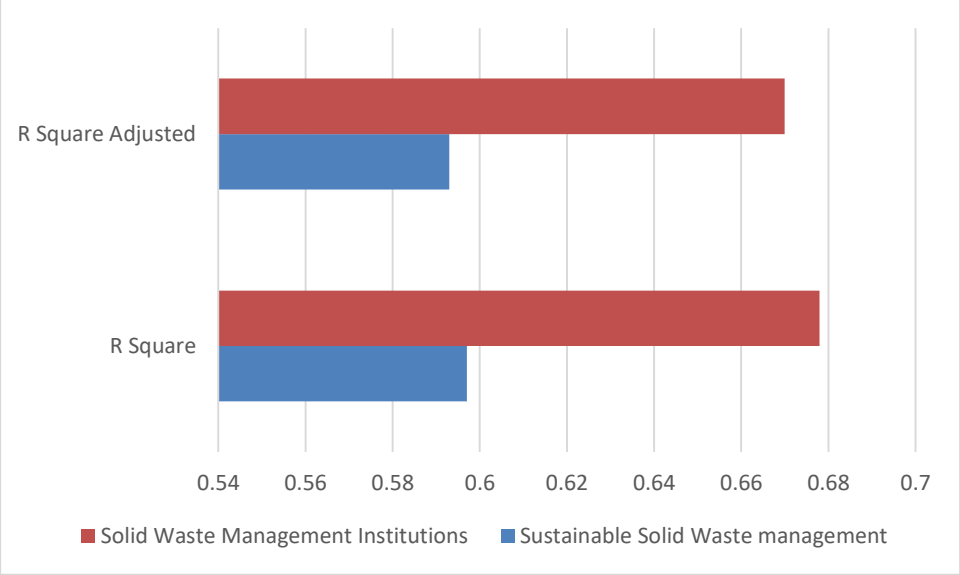

Figure 05: Coefficient of determination (R^2)

When the R^2 (coefficient of determination) is greater than 0.5, it means that more than 50% of the variation in the dependent variable can be explained by the independent variables in the model. In other words, the model has moderate to strong explanatory power, indicating that the predictors account for a significant portion of the outcome.

4. CONCLUSION:

This study highlights serious flaws in Karachi's current solid waste management procedures, most notably the absence of trash separation at the source. The efficacy of the overall waste management system is compromised by the lack of this technique, which is one of the most essential steps in reducing the amount and toxicity of trash. Failure to separate waste before landfill disposal severely hinders decomposition and land reclamation efforts, as plastic, a non-biodegradable substance, makes up about 57.5% of the city's waste.

Furthermore, the study emphasizes how Karachi's overall industrial and economic growth are inextricably tied to sustainable solid waste management. The nation's economic situation has a direct impact on the Sindh Solid Waste Management Board's (SSWMB) operations and the industrial development of the city, both of which profit from a clean and well-run urban environment. Sustainability must thus be given top priority to solve environmental issues as well as to promote economic development and enhance social circumstances in the city.

In conclusion, improving the effectiveness of waste management systems, safeguarding environmental resources, and promoting Karachi's long-term economic and social growth all depend on the adoption of sustainable practices, which begin with efficient trash separation.

5. RECOMMENDATIONS

Several crucial actions are suggested to increase Karachi's solid waste management system's sustainability and efficiency. First and foremost, there must be significant emphasis on enhancing public health by tackling waste management issues, which presently fuel the spread of numerous illnesses. To enable appropriate processing, recycling, or disposal, it is crucial to put systematic waste sorting and segregation procedures into place. This entails separating trash into discrete groups, such as recyclable, non-recyclable, and biodegradable materials. In addition to lowering environmental pollution, improving waste segregation at the source will promote the reduce, reuse, and recycle philosophy. Furthermore, the recycling industry ought to be acknowledged as an essential part of trash management and the local economy, creating jobs and assisting in the recovery of resources for a more sustainable urban environment in Karachi.

To gather recyclable items, including plastic bottles, paper, steel, aluminum, and wooden furniture, the Sindh Solid Waste Management Board (SSWMB) has installed vending machines. This is a positive step that should be extended throughout the city. Additionally, in order to encourage community involvement, SSWMB must improve its public awareness campaigns by teaching people about the value of appropriate waste management and environmental responsibility through print media, electronic broadcasts, and social media

platforms. When combined, these efforts have the potential to greatly improve Karachi's urban environment and make it healthier, cleaner, and more sustainable.

6. REFERENCES

Ahmed, S., Ali, M., & Basti, A. (2022). An overview of solid waste management systems in the city of Karachi: past and present.

Aslam, S., Ali, F., Naseer, A., & Sheikh, Z. (2022). Application of material flow analysis for the assessment of current municipal solid waste management in Karachi, Pakistan. Waste Management & Research, 40(2), 185-194.

Awino, F. B., & Apitz, S. E. (2024). Solid waste management in the context of the waste hierarchy and circular economy frameworks: An international critical review. Integrated Environmental Assessment and Management, 20(1), 9-35.

Awuchi, C. G., Awuchi, C. G., Amagwula, I. O., & Igwe, V. S. (2020). Industrial and community waste management: global perspective. American Journal of Physical Sciences, 1(1), 1-16.

Aziz, H. A., Abu Amr, S. S., Vesilind, P. A., Wang, L. K., & Hung, Y. T. (2022). Introduction to solid waste management. In *Solid waste engineering and management: Volume 1* (pp. 1-84). Cham: Springer International Publishing.

Baig, A., Atif, S., & Tahir, A. (2024). Urban development and the loss of natural streams leads to increased flooding. Discover Cities, 1(1), 9.

Bhattarai, K., & Conway, D. (2020). Urban growth. In Contemporary environmental problems in Nepal: Geographic perspectives (pp. 201-334). Cham: Springer International Publishing.

Domfeh, K. A., Ahenkan, A., & Bawole, J. N. (2012). Is sustainable development achievable in Ghana? An analysis of Ghana's development policy achievements and challenges. International Journal of Environment and Sustainable Development, 11(3), 304-317.

Ferronato, N., & Torretta, V. (2019). Waste mismanagement in developing countries: A review of global issues. International journal of environmental research and public health, 16(6), 1060.

Hardoy, J. E., Mitlin, D., & Satterthwaite, D. (2013). Environmental problems in an urbanizing world: finding solutions in cities in Africa, Asia and Latin America. Routledge.

Iqbal, A., Abdullah, Y., Nizami, A. S., Sultan, I. A., & Sharif, F. (2022). Assessment of solid waste management system in Pakistan and sustainable model from environmental and economic perspective. *Sustainability*, *14*(19), 12680.

Khatri, K. L., Muhammad, A. R., Soomro, S. A., Tunio, N. A., & Ali, M. M. (2021). Investigation of potential for solid waste power in distributed generation development to overcome the power crises of Karachi city. Renewable and Sustainable Energy Reviews, 143, 110882.

Khan, S. (2015). Shattering the public/private divide: role of Mohajir women in the Karachi conflict.

Lanjwani, M. U., Lanjwani, M. F., Hussain, M., & Sodhar, K. (2024). Impact of urbanization on urban heat island intensity-a case study of Larkana City, Sindh, Pakistan: MU Lanjwani et al. Theoretical and Applied Climatology, 155(7), 5875-5885.

Maalouf, A., & Agamuthu, P. (2023). Waste management evolution in the last five decades in developing countries–A review. Waste Management & Research, 41(9), 1420-1434.

Mahmood, H., & Khan, M. M. (2019). Urban solid waste management in Karachi, Pakistan. International Journal of Economic and Environmental Geology, 10(1), 78-83.

Mwanza, B. G., & Mbohwa, C. (2017). Drivers to sustainable plastic solid waste recycling: a review. Procedia Manufacturing, 8, 649-656.

Mukherji, R. (2018). Municipal Solid Waste Crisis in Karachi A Case of Inadequate Devolution.

Niazi, F., & Azad, A. P. (2018). Investigation of Ethnic Diversity In Pakistan: A Case Study of Karachi. Journal of Basic & Applied Sciences, 14, 246-253.

Okai, D. E. (2020). Recycling as a strategy for revenue generation and municipal plastic waste management: The case of Accra Metropolitan Area (Doctoral dissertation.

United Nations. (2022). Sustainable Development Goals Report 2022. UN.org

Zaman, A. U., & Lehmann, S. (2011). Urban growth and waste management optimization towards ‘zero waste city’. City, Culture and Society, 2(4), 177-187.

Viqar, S. (2016). Sovereignty, Modernity and Urban Space: Everyday Socio-Spatial Practices in Karachi's Inner City Quarters (Doctoral dissertation, Concordia University).

Yao, X. (2025). “But Karachi is Always Dual”: Cartography, Placemaking, and Identity in Kamila Shamsie’s Kartography. Critique: Studies in Contemporary Fiction, 1-14.