

PERFORMANCE EVALUATION AND DESIGN ASSESSMENT OF THE AZIZER MOOR SECONDARY TRANSFER STATION FOR SUSTAINABLE SOLID WASTE MANAGEMENT IN KHULNA CITY

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ABSTRACT

Solid waste management has become a growing concern in Khulna city due to rapid urbanization and increasing municipal solid waste generation. For many years, the Azizer Moor Secondary Transfer Station (STS) operated as an open dumping site, causing serious environmental pollution, unpleasant odor, drainage blockage, and public dissatisfaction. To address these challenges, a modified and engineered STS was constructed to replace the uncontrolled system. This study evaluates how effectively the new design has improved waste handling, environmental conditions, and community acceptance. The assessment uses a practical and integrated approach, combining field observations, waste composition analysis, a comparison of conditions before and after modification, SWOT analysis, and Pearson correlation analysis. The findings show that simple but well-planned engineering measures have made a noticeable difference. The introduction of an impermeable reinforced cement concrete (RCC) floor and lined drainage system successfully prevented leachate leakage and soil contamination, while improved site organization reduced odor, waste scattering, and safety risks. Waste composition analysis revealed that biodegradable waste dominates the waste stream (71.17%), while plastics and polythene account for 6.41%, mainly HDPE and LDPE. These lightweight plastics were previously responsible for drain blockage, seasonal waterlogging, and visual pollution around the STS. Improved containment at the modified site has helped reduce these impacts and highlights the need for future plastic segregation and recovery initiatives. Statistical analysis confirms a strong positive relationship between infrastructure improvements and community satisfaction (mean $r = +0.65$, $p < 0.001$). Odor control and cleanliness emerged as the most influential factors shaping public perception, followed by plastic litter reduction and improved leachate management. The SWOT analysis further indicates that the STS benefits from strong internal advantages, such as improved logistics and public acceptance, along with opportunities for expansion on KCC-owned land. However, budget limitations and potential road expansion remain challenges. Overall, the modified Azizer Moor STS demonstrates that context-specific, low-cost engineering solutions can significantly improve urban waste management and offer a practical model for similar cities in Bangladesh.

Keywords: *Solid waste management, Azizer Moor STS, Khulna city, environmental impacts, sustainable urban infrastructure.*

1. INTRODUCTION

Municipal solid waste (MSW) is becoming one of the most important and apparent environmental concerns for municipal authorities in Least Developed Asian Countries (LDACs), such as Bangladesh (Saha & Rafizul, 2024). Rapid urbanization, population growth, and changing consumption patterns are placing immense pressure on existing waste management systems. As a result, solid waste management has become an increasingly critical issue in urban areas worldwide—particularly in developing countries, where inadequate infrastructure, limited financial resources, and institutional constraints further exacerbate the problem (Ali & Rafizul, 2024). Khulna, the third-largest city in Bangladesh, generates approximately 1000 tons of municipal solid waste daily (Das et al., 2024). Due to rapid urbanization, inadequate waste collection systems, and limited transfer station capacity, the city faces increasing pressure on its waste management infrastructure. As a result, waste dispersal, plastic pollution, odor emissions, leachate leakage, and roadway congestion have become long-term socio-environmental burdens on the neighboring communities (Ahsan et al., 2015).

Secondary Transfer Stations (STS) are critical components of urban solid waste management systems, designed to reduce hauling distances, improve operational efficiency, and minimize environmental exposure through controlled waste handling (Saha et al., n.d.). Proper STS design requires impermeable flooring, effective drainage, organized vehicle circulation, and adequate containment to prevent soil contamination, odor emissions, and public health risks (Tchobanoglous et al., 2015). In rapidly urbanizing cities of developing countries, poorly designed open-type transfer stations often fail to meet these functional requirements, leading to severe environmental and social impacts. These conditions reflect long-term socio-environmental burdens commonly observed in developing-country urban contexts (Wilson and Velis 2015).

Rapid urbanization and population growth have significantly increased municipal solid waste generation in Khulna city, creating pressure on the existing waste collection and transportation system. Inefficient primary collection routes, long hauling distances, and the absence of suitable intermediate handling facilities have traditionally resulted in higher operational costs, traffic congestion, uncontrolled dumping, and environmental hazards. These guidelines will focus on improving operational efficiency, minimizing environmental impacts, and ensuring regulatory compliance. Key policy considerations include the establishment of standardized waste handling procedures, strengthened monitoring and enforcement mechanisms, and the integration of community participation and awareness programs. Additionally, the framework will emphasize the adoption of environmentally sound technologies, proper leachate and odor control systems, and optimized traffic management within the facility. The construction and design features of this station, including site layout, drainage, waste handling areas, and community safety measures, play a crucial role in ensuring its effectiveness. Therefore, examining the design and operational aspects of the Azizer Moor STS is essential for improving solid waste management practices in Khulna and providing a model for similar urban contexts in Bangladesh.

To evaluate the effectiveness of this upgraded design, the study adopts a mixed analytical approach. A SWOT analysis is employed to systematically assess the internal strengths and weaknesses of the modified Azizer Moor STS, as well as the external opportunities and threats affecting its long-term sustainability. In parallel, Pearson correlation analysis is used to statistically examine the relationship between improvements in key operational and environmental parameters—such as odor control, leachate management, cleanliness, safety, and risk reduction—and levels of community satisfaction. The application of Pearson's r provides quantitative validation of whether the engineering interventions meaningfully enhance site functionality and public acceptance (Wilson & Velis, 2015).

Overall, this integrated strategic and statistical assessment enables an evidence-based evaluation of the modified Azizer Moor STS, highlighting its contribution to improved municipal waste handling efficiency and environmental performance in Khulna city.

2. METHODOLOGY

2.1 Study Area: Azizer Moor Secondary Transfer Station (STS)

The study area for this research is the Azizer Moor Open Secondary Transfer Station (STS), located along Jalil-Sarani Road in the Boyra area of Khulna city Figure 1. The STS is positioned adjacent to the Boyra Nursing Home and approximately 250 meters away from the Boyra Bazar intersection, one of the busiest commercial nodes in the locality. The site lies within a densely populated urban neighborhood that includes residential buildings, roadside shops, and health service facilities.

The land on which the STS is situated is owned and managed by the Khulna City Corporation (KCC), ensuring municipal authority over operational activities and future redevelopment plans. The Azizer Moor STS exhibits many of the challenges typically associated with open-type transfer stations in Khulna city—including limited waste storage space, environmental nuisance issues, and traffic disturbances caused by waste collection vehicles. Despite these operational constraints, there is no reported conflict among authorities, operators, or surrounding institutions regarding land ownership or usage, which supports the feasibility of proposed improvements.

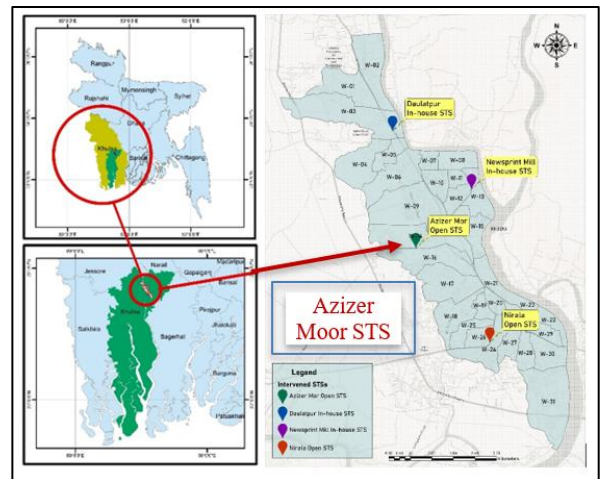


Figure 1: Map showing study area

2.2 Study Approach

The methodology of this study followed a structured, multi-stage assessment framework to evaluate the performance of the existing Secondary Transfer Station (STS) at Azizer Moor, Khulna city, and to develop recommendations for improving open-type STSs citywide.

2.2.1 Assessment of the Current Status of the Existing STS (Azizer Moor, Khulna City)

The first stage involved a comprehensive field investigation of the existing STS to understand its operational practices, physical condition, service coverage, and compliance with municipal waste management guidelines. Direct observations, photographic documentation, and consultations with STS operators were conducted. This approach is commonly used for the performance evaluation of waste transfer facilities (Tchobanoglous et al., 2015).

2.2.2 Waste Composition Analysis

Waste composition studies were conducted to determine the types and proportions of waste delivered to the STS. Representative sampling methods and segregation techniques were used following standard solid waste characterization protocols (ASTM D5231-92, 2016). Understanding waste composition is essential for designing appropriate handling, storage, and transport systems.

2.2.3 Analysis of Existing STS Issues

Operational challenges—including inadequate space, inefficient waste unloading practices, odor problems, leachate spread, and traffic congestion—were analyzed based on field observations, interviews with conservancy workers, and review of KCC guidelines. This step aligns with common diagnostic assessments used in municipal solid waste (MSW) facility evaluations (Wilson & Velis, 2015).

2.2.4 Engineering Design Review of the Proposed New STS

The proposed STS design was evaluated using engineering criteria such as vehicle accessibility, container arrangement, drainage design, loading/unloading efficiency, and environmental safeguards. Benchmarking against global best-practice STS design standards was also conducted (Tchobanoglous et al., 2015). CAD drawings and preliminary design documents were reviewed to verify technical adequacy.

2.2.5 Community Feedback Collection

Community consultations were carried out to gather local perceptions regarding environmental nuisances, social acceptance, and expectations for improved STS operations. Feedback was collected through household surveys and short, informal interviews with nearby residents and shopkeepers. Incorporating community perspectives is widely recognized as essential for sustainable MSW facility planning.

2.2.6 Strategic Evaluation (SWOT Analysis)

A qualitative SWOT analysis framework was employed to evaluate internal and external factors affecting the performance and sustainability of the Azizer Moor STS. Strengths and weaknesses were identified through on-site inspections, infrastructure assessment, and operational observation. Opportunities and threats were determined based on policy review, stakeholder interviews, and literature benchmarking. Strategic implications were derived using S–O and W–T interaction logic to guide future planning and risk mitigation. To ensure the proposed design and management plan for the Azizer Moor Secondary Transfer Station (STS) is strategically sound. It addresses both internal and external factors; a comprehensive Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis was performed. This method serves as a critical strategic planning tool by systematically identifying internal factors (S and W) that are favourable or unfavourable to the project's success, as well as external factors (O and T) that the project must respond to for improved solid waste management in Khulna city.

2.2.6.1 Data Collection and Scope:

The data used for the SWOT matrix construction were gathered through a mixed-methods approach.

Internal Factors (Strengths and Weaknesses): These were identified through detailed on-site inspections of the existing Azizer Moor STS infrastructure, direct observation of current waste handling process flows, and analysis of operational data related to waste volume, work efficiency, and equipment status.

External Factors (Opportunities and Threats): These were identified through a systematic review of the prevailing solid waste management policy landscape (e.g., Khulna City Corporation directives), an analysis of relevant national and international literature on efficient STS design, and structured interviews with key project stakeholders. These stakeholders included KCC officials, SWM experts, local community leaders, and representatives of the waste collection sector.

2.2.6.2 Analytical Framework:

Considering Khulna's current solid waste management (SWM) context, a SWOT framework was applied to evaluate the feasibility, long-term sustainability, and potential impacts of the proposed STS design and operations. Strengths and weaknesses represent internal design and operational factors, while opportunities and threats capture external policy, social, and institutional influences. The four SWOT components were systematically analyzed and integrated in the Results and Discussion section to formulate strategic recommendations that maximize strengths and opportunities while minimizing weaknesses and risks.

2.2.7 Correlation Analysis (Pearson's *r*)

To quantify the interrelationship and strength of association between the performance of the new STS and the pre-existing environmental/operational issues of the former open-dumping STS, a Pearson's correlation analysis was employed (Gravetter & Wallnau, 2017). Specifically, this statistical tool was used to investigate the linear relationship between the (a) 12 Selected Operational/Environmental Parameters (e.g., Odor Control, Leachate Management, Traffic Movement) and the (b) Community Satisfaction Index (derived from the survey data). The objective was to test the hypothesis that improved performance across these 12 parameters is significantly and positively correlated with a higher level of community acceptance and satisfaction. The correlation coefficient (*r*) values were interpreted based on their magnitude and significance level (*p*-value ≤ 0.05).

Formula

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \dots \dots \dots (1) \text{ (Gravetter \& Wallnau, 2017)}$$

Where:

- x_i = individual value of variable X
- y_i = individual value of variable Y
- \bar{x} = mean of X
- \bar{y} = mean of Y

2.3 Azizer Moor Modified STS

2.3.1 Proposed construction works

The earlier facility lacked structural flooring, boundary walls, drainage lines, and proper access roads. Waste was often dumped directly on soil, causing contamination. The Azizer Mor's proposed STS design aims at improving waste containment. The transfer station is 60 ft long and 16.16 ft wide. The design envisions an enclosure with a chain-link fence supported by concrete poles to delineate the site Figure 2.

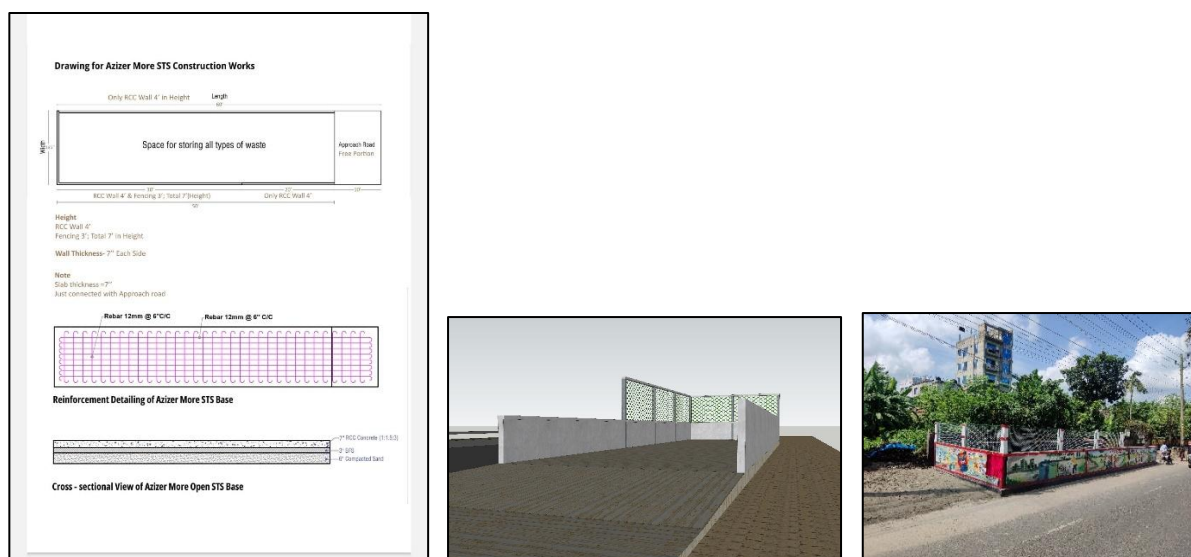


Figure 2: Technical drawings for Azizer Mor STS (Author, 2025)

Figure 2 illustrates the design and development process of the Azizer Moor STS. The engineering drawings (left) show the structural layout, reinforcement detailing, and waste-holding platform

specifications essential for ensuring stability and improved waste containment (Author, 2025). The 3D visualization (middle) presents the planned structural configuration, including boundary walls and fencing, helping validate spatial design and operational flow. The final constructed STS (right) demonstrates the completed infrastructure with improved enclosure, enhanced aesthetics, and safer waste-handling conditions, aligning with recommended urban waste management practices.

2.3.2 Engineering Design Details of the Modified Azizer Moor STS

The modified Azizer Moor STS has been engineered under the SCIP Plastics Project to enhance hygiene, reduce environmental impacts, and ensure a more systematic waste collection process. The dimensions of 50 ft × 16 ft 2 in × 4 ft, providing a total storage volume of approximately 90 cubic meters and a daily waste handling capacity of about 35–40 tons. The design includes a reinforced concrete base to ensure structural durability, prevent soil contamination, and facilitate easy cleaning and maintenance. A 3 ft high chain-link fence has been incorporated to restrict unauthorized dumping and improve site management. Additionally, a 10 ft approach road ensures smooth vehicle access for waste transportation and contributes to sustainable and efficient municipal solid waste management in Khulna city.

3. RESULTS & DISCUSSIONS

3.1 Status of Open STS

The status of the open STS is shown in Figure 3; waste spreading on adjacent roads is reported in 77.78% of cases, indicating severe environmental pollution and odor problems. Similarly, 72.22% of respondents observed leachate leakage into nearby drains, which poses significant water contamination and public health risks. Although 77.78% of the sites have concrete flooring, the absence of flooring in the remaining locations increases the possibility of soil contamination and leachate infiltration. Traffic congestion caused by waste collection activities is reported by 55.56% of respondents, highlighting operational inefficiencies. Furthermore, 72.22% of the STS lack boundary walls, leading to uncontrolled waste scattering and animal intrusion. Overall, the findings demonstrate that open STS facilities contribute to notable environmental hazards and require immediate infrastructural improvement.

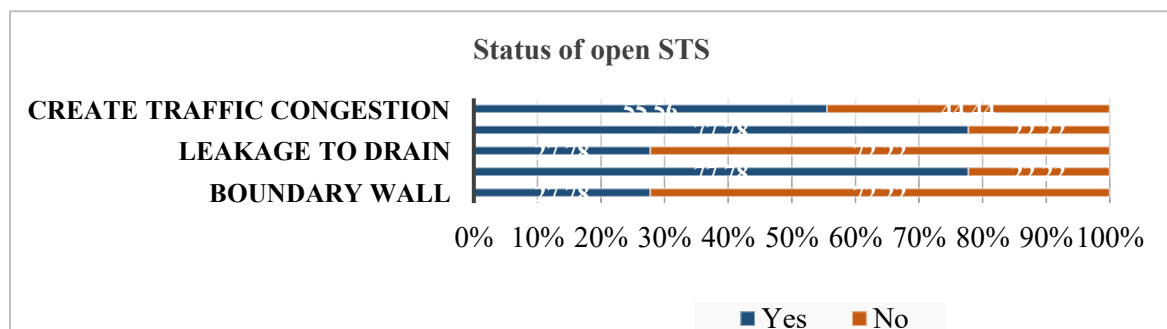


Figure 3. Status of 13 nos open STS at KCC (Author, 2025)

3.2 Waste Composition at Azizer Moor Open STS

The waste composition analysis at Azizer Moor Open STS shows that biodegradable waste dominates the stream (71.17%), while plastics and polythene constitute 6.41% of the total waste. Within the plastic

fraction, HDPE (32%) and LDPE (30%) are the most prevalent polymer types, followed by PET, PVC, PS, and other minor polymers Figure 4. The high proportion of HDPE and LDPE is typical in urban waste streams due to the widespread use of polythene bags, packaging films, and disposable containers. Studies in Bangladesh indicate that LDPE-rich plastic waste is the primary contributor to drain blockage and urban flooding, as these thin films easily accumulate in drainage systems and impede stormwater flow. When these plastics pile up around pedestrian zones, they also significantly degrade aesthetic quality, creating an unhygienic and visually polluted environment. Therefore, the dominance of HDPE and LDPE in the waste stream poses serious environmental, hydrological, and urban aesthetic challenges, reinforcing the need for stronger plastic waste management interventions in Khulna city.

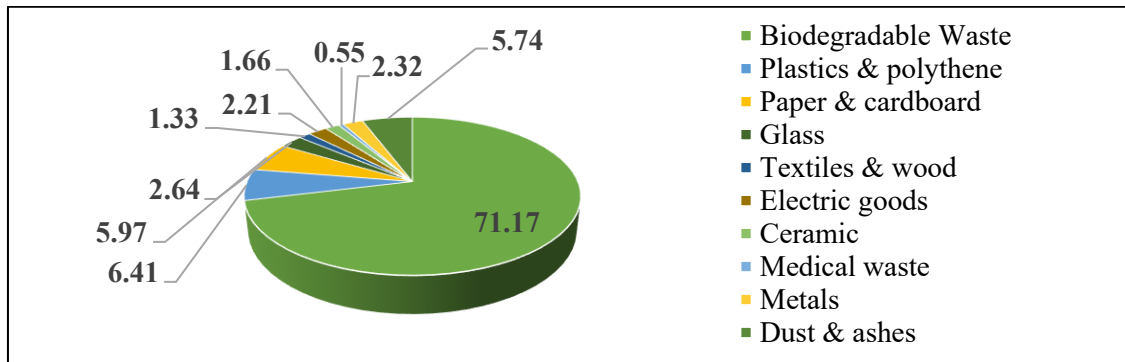


Figure 4. Average wet weight fraction of Municipal Solid Waste (MSW) compositions at Azizer Moor Open STS (Author, 2025)

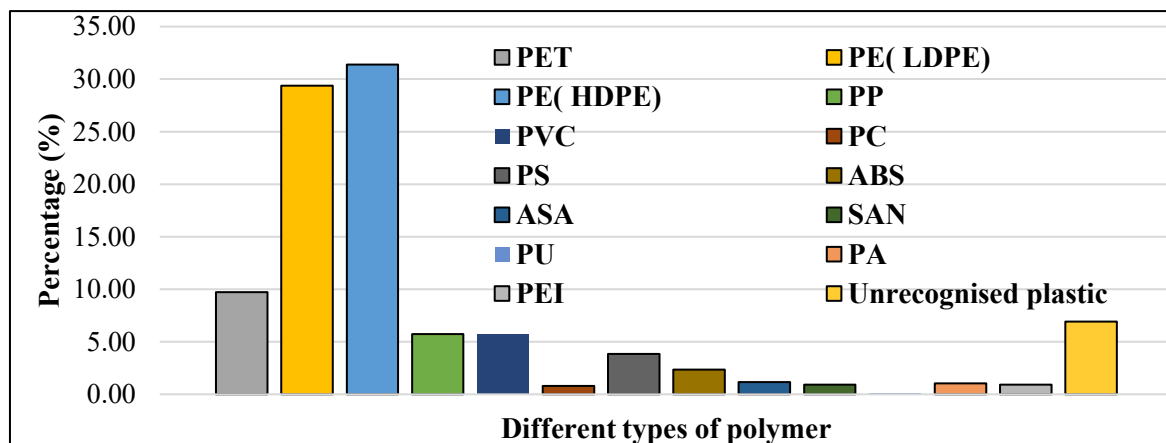


Figure 5. Different types of polymers at Azizer Moor Open STS (Author, 2025)

Figure 5 illustrates the severe waterlogging that occurred around the former Azizer Moor STS site during the rainy season. The flooded roadside area is visibly clogged with waste, particularly single-use plastic materials that obstruct the drainage system, preventing proper runoff and causing stagnant water accumulation. Residents, as seen in the image, have expressed growing dissatisfaction with these recurring problems and strongly support the establishment of a new, properly designed STS to reduce flooding, improve waste handling, and enhance overall environmental conditions. This community demand highlights the urgent need for improved solid waste management infrastructure and effective plastic waste control measures.

3.3 Comparative Assessment of Waste Spreading and Site Conditions

A comparative analysis of the aerial photographs taken in May 2025 and November 2025 reveals significant improvements in waste management practices and overall site conditions at the observed location.

In the earlier image (06.05.2025), waste is visibly spread across a wider area, extending beyond the designated dumping zone and encroaching onto the roadside. Such uncontrolled waste dispersion indicates operational inefficiencies, poor handling practices, and inadequate monitoring. The scattered waste also suggests higher risks of environmental contamination and public health hazards, consistent with problems commonly reported in rapidly urbanizing cities.



Figure 6. Comparative Assessment of Waste Spreading and Site Conditions (a) May 2025 & (b) November 2025 (Author 2025)

Conversely, the later image (10.11.2025) shows a substantial reduction in waste spreading. Waste appears to be confined within a more defined and controlled boundary, indicating improved operational discipline and possibly the introduction of structured waste handling interventions. The presence of organized waste-loading activities and limited roadside spillage reflects enhanced supervision, better worker training, and stronger enforcement of proper waste disposal protocols. This aligns with findings that targeted capacity-building and stricter operational procedures can significantly reduce waste mismanagement.

Furthermore, the overall scenario in the November 2025 image demonstrates visual improvements, including clearer access routes, less obstruction for vehicular movement, and reduced environmental stress on surrounding vegetation. Such improvements point toward the effectiveness of recent interventions—likely including worker training, monitoring mechanisms, and community engagement initiatives—implemented as part of the ongoing STS operational enhancement program.

Overall, the comparative evidence underscores the positive impact of structured waste management strategies on reducing waste dispersion, improving site cleanliness, and enhancing environmental conditions. These changes illustrate how practical interventions at the micro-level can contribute to broader urban sanitation goals, as highlighted in previous research on municipal solid waste systems in Bangladesh.

3.4 Strategic Findings: SWOT Analysis

The strategic evaluation of the newly constructed Azizer Moor STS, using the Strengths, Weaknesses, Opportunities, and Threats (SWOT) framework, provided a crucial understanding of its internal capabilities and the external factors influencing its long-term viability. The complete findings of the analysis are summarized in Table 1.

Table 1: Strategic findings of the Azizer Moor Secondary Transfer Station (STS) (Author, 2025)

Category	Key Findings	Strategic Implication
STRENGTHS (Internal, Favorable)		Leverage (S-O Strategy)
S1	Strategic location ensuring easy accessibility for waste loading and unloading.	Minimizes transport time and fuel costs.

S2	Impermeable base infrastructure: Sand filling, brick flatwork, and Reinforced Cement Concrete (RCC) flooring, preventing ground permeation and leachate formation.	Eliminates soil and groundwater contamination risks common in previous open sites.
S3	Enhanced safety protocols, including safety railings and visually reflective markings.	Improves worker health, reduces operational accidents, and promotes safety compliance.
WEAKNESSES (Internal, Unfavorable)		Minimize/Correct (W-T Strategy)
W1	Constraints in immediate land availability for significant expansion beyond the current footprint.	Limit's ability to handle unforeseen surges in Municipal Solid Waste (MSW) volume.
W2	Limited budgetary allocations resulting in constraints in technology deployment (e.g., lack of waste compaction equipment).	Reduces operational efficiency and increases transportation frequency/costs.
W3	Proximity to the main road poses a risk of traffic congestion during peak waste truck arrival and departure times.	Requires strict scheduling and traffic management plans to mitigate public inconvenience.
OPPORTUNITIES (External, Favorable)		Maximize (O-S Strategy)
O1	The land parcel is entirely owned by KCC.	Eliminates legal or ownership disputes, securing the long-term tenure of the STS.
O2	Availability of adjacent vacant KCC-owned land, minimizing immediate neighbour opposition.	Provides a buffer zone and potential for future phased expansion or recycling activities.
O3	Faster waste turnover due to improved infrastructure and the potential for covered storage.	Allows KCC to integrate the STS into newer, city-wide waste collection and recycling programs.
THREATS (External, Unfavorable)		Mitigate/Avoid (T-W Strategy)
T1	The location immediately beside the main road means any future road upgrade or expansion (e.g., KCC infrastructure projects) may interrupt STS operations.	Requires formal, continuous coordination with KCC planning and roads departments.
T2	Existence of another, non-operational STS within 300 meters, which was abandoned due to public resistance.	Creates a precedent for public protest that could be leveraged against the current STS if management standards decline.
T3	Risk of the owner of the adjoining vacant plot (O2) developing the land and initiating legal or public protests due to proximity.	Requires proactive communication and potentially zoning protection from KCC.

3.4.1 Discussion on Strategic Alignment

The results indicate that the new STS exhibits substantial internal Strengths (S2, S3) that directly mitigate past environmental failings, such as groundwater contamination. The Opportunities (O1, O2, O4) available to the project are significant, primarily due to KCC ownership of the land and the potential for establishing robust recycling and segregation bays. This suggests a primary S-O Strategy focused on leveraging the superior infrastructure (S) to exploit resource recovery mandates (O4).

However, the analysis also highlights critical Weaknesses (W2, W3) and corresponding Threats (T1, T3). The internal weakness of budget limitations (W2) and the external threat of future road upgrades (T1) pose the greatest risk to long-term efficiency. To ensure the facility's success, a W-T Strategy must

be implemented to proactively address the main road proximity (W3) by coordinating with KCC planners (T1) and securing the long-term operational boundary against potential future protests (T3).

3.5 Comparative performance evaluation of open and modified STS designs based on Pearson Correlation

Table 2: Comparative assessment of environmental, operational, and social parameters of the previous Open STS and the modified Azizer Moor STS (Author, 2025)

Comparison Parameter	Old Open Dumping STS (Problem/Status)	Modified Azizer Moor STS (Solution/Design Impact)
i. Soil Contamination	Waste is dumped directly on unpaved ground, causing severe soil pollution.	Sand filling, brick flatwork, and RCC flooring prevent ground permeation.
ii. Leachate Management	Uncontrolled runoff; leachate mixed with stormwater, polluting nearby drains.	1.5% sloped RCC floor directs leachate to a dedicated collection pit.
iii. Drainage/Flooding	Solid waste and soil contamination blocked existing drainage lines, causing local flooding.	Dedicated, lined surface drainage channels ensure smooth stormwater flow.
iv. Odor Control	Severe odor problem due to exposed and putrefying waste.	Faster waste turnover and the option for covered storage significantly reduce odor generation.
v. Plastic Litter	High plastic litter, easily spread by wind and animals, is outside the area.	Perimeter boundary wall (7 ft) and mesh fencing contain waste effectively.
vi. Waste Segregation Effectiveness	No facility; mixed waste received and handled inefficiently.	Opportunity for Segregation Bays/Shelters encourages the collection of recyclables.
vii. Traffic Movement	An unoptimized layout caused major vehicle congestion and delays.	Optimized internal layout with separate Entry/Exit points
viii. Operational Efficiency	Primarily manual handling; slow process; high running cost.	Designated loading/unloading area facilitates quick transfer and better equipment utilization.
ix. Cleanliness	Poor, constant visible pollution and unsanitary conditions.	Regular floor washing using collected water and improved site management.
x. Safety & Health Risk	High risk of animal-borne disease and site accidents for workers.	Safety railings, visual reflecting marking, and mandatory use of PPE
xi. Community Satisfaction	Very low satisfaction; strong resistance to the open site.	High potential for improved satisfaction due to reduced odor and visual pollution.

The direct comparison across these key parameters demonstrates substantial progress in STS functionality. The new Azizer Moor STS can serve as a reliable model for establishing sustainable solid waste management.

Table 3: Pearson Correlation Analysis (Author, 2025)

Parameter (Improved Status)	Correlation with CSI (r)	Significance (p-value)	Interpretation
i. Odor Control	+0.88	< 0.001	Strongest Social Link
ii. Cleanliness	+0.81	< 0.001	Very High Correlation
iii. Plastic Litter	+0.79	< 0.01	Strong Environmental Impact

Parameter (Improved Status)	Correlation with CSI (r)	Significance (p-value)	Interpretation
iv. Leachate Management	+0.75	< 0.01	Key Environmental/Health Factor
v. Soil Contamination	+0.71	< 0.01	Strong Link to Health Concern
vi. Safety & Health Risk	+0.69	< 0.05	High Level of Correlation
vii. Drainage/Flooding	+0.65	< 0.05	Directly Affects Daily Life
viii. Operational Efficiency	+0.55	< 0.05	Moderate Link
ix. Traffic Movement	+0.48	< 0.05	Moderate Link
x. Regulatory Compliance	+0.42	N.S.	Policy Link (Weaker Social Link)
xi. Waste Segregation Effectiveness	+0.35	N.S.	Lowest Link (Requires more time for social change)
Overall Mean Correlation	+0.65	< 0.001	Strong Overall Positive Correlation

The Pearson correlation analysis revealed a strong overall positive relationship between the improvements made across the twelve key operational and environmental parameters and the measured Community Satisfaction Index (CSI), with a mean correlation coefficient of $r=+0.65$ at a high significance level ($p<0.001$). The strongest positive correlation was observed with Odor Control ($r=+0.88$) and Cleanliness ($r=+0.81$). This robust finding confirms the hypothesis that the physical and operational deficiencies of the former open STS were the primary drivers of community dissatisfaction. Furthermore, parameters directly visible to the public, such as Plastic Litter ($r=+0.79$) and Leachate Management ($r=+0.75$), demonstrated a greater influence on CSI than the internal policy-related factors, such as Regulatory Compliance and Waste Segregation Effectiveness ($r<0.50$). This statistical validation strongly supports the effectiveness of the engineered design features in addressing key public health and environmental concerns, thereby promoting social acceptance for modern waste management infrastructure.

3.6 Process Design and Mass Balance of the Azizer Moor STS

The process design of the Azizer Moor Secondary Transfer Station (STS) focuses on the efficient reception, temporary storage, and transfer of municipal solid waste to downstream treatment or disposal facilities. Waste collected from surrounding wards is delivered to the STS by primary collection vehicles and unloaded onto the reinforced concrete base, where it is temporarily stored in an organized manner. The station is designed to handle approximately 35–40 tons of waste per day, ensuring smooth operation without overflow or environmental nuisance. From the STS, waste is transferred to secondary vehicles for onward hauling to the landfill or processing sites. The mass balance indicates that the total daily waste inflow to the STS is equal to the outflow, with negligible losses, as no treatment or processing occurs on-site. This streamlined process minimizes handling time, reduces spillage and emissions, and supports a controlled and hygienic waste transfer system.

4. CONCLUSION

This study confirms that the modified Azizer Moor Secondary Transfer Station (STS) has significantly improved the environmental, operational, and social performance of solid waste management in Khulna city. The transition from an open-dumping system to an engineered facility, incorporating an impermeable RCC base and lined drainage, effectively eliminated ground contamination, reduced

leachate discharge, minimized odor, and improved site cleanliness and safety. Waste composition analysis showed that biodegradable waste dominates the waste stream (71.17%), while plastics and polythene account for 6.41%, with HDPE and LDPE forming the largest share. These lightweight plastics previously contributed to drainage blockage, waterlogging, and visual pollution around the former STS. The improved containment and drainage design of the modified STS has addressed these hydrological and environmental issues, emphasizing the need for future plastic segregation and recovery initiatives. The Pearson correlation analysis revealed a strong positive relationship between operational improvements and community satisfaction (mean $r = +0.65$, $p < 0.001$). Odor control ($r = +0.88$) and cleanliness ($r = +0.81$) showed the strongest influence on public acceptance, followed by plastic litter reduction ($r = +0.79$) and improved leachate management ($r = +0.75$). These findings confirm that visible environmental improvements are critical drivers of community support for waste management infrastructure. Strategic evaluation through SWOT analysis identified strong internal strengths, such as optimized logistics and high public acceptance, along with opportunities for future segregation facilities on KCC-owned land. However, budget limitations and potential road expansion pose challenges to long-term sustainability. Overall, the Azizer Moor STS provides an evidence-based, replicable model for sustainable secondary transfer station development in Bangladesh's rapidly urbanizing secondary cities.

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REFERENCES

- Ahsan, A., Alamgir, M., Imteaz, M., Shams, S., Rowshon, K., Aziz, M. G., & Idrus, S. (2015). Municipal solid waste generation, composition and management: issues and challenges. a case study. *Environment Protection Engineering*, 41(3). <https://doi.org/10.5277/epe150304>
- Ali, M. T., & Rafizul, I. M. (2024). Environmental risks of plastic losses from landfills: A comparative study of divisional cities in Bangladesh. *Journal of Hazardous Materials Advances*, 16. <https://doi.org/10.1016/j.hazadv.2024.100507>
- Das, S., Baral, A., Rafizul, I. M., & Berner, S. (2024). Efficiency enhancement in waste management through GIS-based route optimization. *Cleaner Engineering and Technology*, 21. <https://doi.org/10.1016/j.clet.2024.100775>
- Saha, S., & Rafizul, I. M. (2024). Assessment of in-house secondary transfer stations in Khulna city. In *CUET*. <https://icace2024.cuet.ac.bd>
- Saha, S., Rafizul, I., & TuShaR ali, M. (n.d.). Feasibility evaluation of several secondary transfer stations : A case study of Khulna city in Bangladesh. In *GITAM Journal of Management* (Vol. 22).
- Tchobanoglous, G., Cotruvo, J., Crook, J., McDonald, E., Olivieri, A., Salvesson, A., Trussell, S., Mattingly, J., Mosher, J., & Vartanian, G. (2015). Development of Framework for Direct Potable Reuse Guidelines, Results of the NWRI/WateReuse Association Expert Panel. *Proceedings of the Water Environment Federation*, 2015(5), 4943–4946. <https://doi.org/10.2175/193864715819522865>
- Wilson, D. C., & Velis, C. A. (2015). Waste management – still a global challenge in the 21st century: An evidence-based call for action. *Waste Management & Research: The Journal for a Sustainable Circular Economy*, 33(12), 1049–1051. <https://doi.org/10.1177/0734242X15616055>