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Assessing the Effect of Sustainability Measures on the Operational Performance of the Lagos Rail Mass Transit System in Lagos, Nigeria

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Abstract— *Sustainable operation of railways cannot rely on green rhetoric alone; instead, it needs to rely on maintenance routines, management of stations and a level of demand sufficient for sustainable service delivery. This paper has considered the effect of sustainability initiatives on the operations of Lagos Rail Mass Transit (LRMT). An empirical cross-sectional study involving a questionnaire survey of staff from the Lagos Metropolitan Area Transport Authority involved in planning and operations of the railway has been carried out. Staff numbers were 991, Yamane's formula suggested 285 as an optimal sample size, which has yielded 243 valid responses. The sustainability was defined in terms of waste management plans implementation, ridership level and maintenance culture, whereas LRMT operations have constituted the dependent index. The result showed that sustainability measures significantly influenced the operational performance of the Lagos Rail Mass Transit system, explaining 95.6% of the variation in operational performance (R2 = 0.956). Maintenance culture had the strongest influence (β = 0.384), followed by waste management plan implementation (β = 0.355) and ridership level (β= 0.338). All three factors had positive and statistically significant effects on LRMT operational performance (p < 0.001). It has become evident that operational sustainability is a result of interconnected technical, environmental and demand factors rather than the individual practices. The unusually high fit of the model calls for special caution in interpreting the results due to the conceptual closeness of the survey indices and the cross-sectional design.*

Keywords— *Sustainability measures; maintenance culture; waste management; ridership; rail operations; Lagos.*

I. INTRODUCTION

Sustainable operation of urban rails requires the ability to operate reliably in the face of various pressures such as environmental pressures, asset pressures, and demand pressures (Awada et al., 2023). Research into energy-efficient rail operation also indicates that the operational process is linked with sustainability at the level of urban rails (Gao and Yang, 2019). This is because sustainability is not limited to emissions as a poorly maintained system that is environmentally disorganized or incapable of retaining its passengers cannot provide sustainable mobility. This means that sustainability efforts need to be examined in relation to operational efficiency. Additionally, LRMT functions as an intricate technical and organizational system including rolling stock, signals, power supply, stations, cleaning processes, passengers' movements and maintenance staff. Failure of assets in one component of the service spreads over the entire service as a result of cancellation, overcrowding, and passenger frustration. Current disruption studies point to the ageing infrastructure and operational disruptions as the major threat to urban rail reliability (Wang et al., 2024). Evidence from reliability-centred maintenance studies further confirms that a maintenance culture is associated with the continued availability of metro railway assets (Singh et al., 2020). Therefore, maintenance culture is expected to impact on the operations through inspections and preventative servicing.

Further, waste management has a role not only in environmental but also in operational terms. Untamed waste can block passenger movement, cause problems with drainage, harm the station setting and undermine public trust in the orderliness of service provision. Urban rail loyalty research proves that physical and social environments have an impact on satisfaction and loyalty (Nguyen-Phuoc et al., 2024). Moreover, passenger-oriented rail research identifies physical service environment as a component of service quality perception (Eboli and Mazzulla, 2015). Thus, waste management can assist operations in sustaining the functionality of stations and upholding service order, despite the fact that its contribution will partially reflect the culture of adherence to procedures. Moreover, ridership volume has a link with sustainability as far as capacity utilization, financial stability and energy usage per passenger are concerned. New research into low-carbon railways indicates the need for coordination of passenger demand and schedule since light rail operation increases per capita costs and emissions (Zang et al., 2025). Energy-efficient timetables research confirms the necessity to account for passenger demand alongside train operations when assessing energy performance of rail transport (Huang et al., 2023). Nevertheless, the relationship can go in both ways: demand stability supports regular service, while reliability of operation attracts and retains passengers. That is why this research is going to investigate the impact of the implementation of the waste management plan, ridership volume and maintenance culture on operations of LRMT. This investigation will rely on LAMATA staff with practical experience in administration, technical activities and management. This research contributes to an integrated perspective on environmental practices, demand conditions and asset management as interconnected factors of rail operations.

II. Literature Review

A. Sustainable Urban Rail Operations

Sustainability in rail transit involves environmental performance, cost effectiveness, inclusiveness, and delivery of services. From an analysis of the performance of urban rail systems, one notes that efficiency and service quality complement each other but are evaluated in distinct frameworks (Awada et al., 2023). The research on urban rail asset management shows that there is a need to take into consideration the issues of maintenance, renewals, and service when assessing reliability in long term (Mohammadi and El-Diraby, 2021). Thus, sustainability needs to be analyzed in terms of how well the system manages its resources, assets, and passenger demand to ensure safe and reliable operation.

In addition, energy efficiency is affected by the traction and non-traction operations. In one study on 122 Chinese cities, traction energy was separated from stations and auxiliary energy to indicate the effects of size and performance indicators on energy demands (Chen and Lin, 2025). The recently developed research on passenger flow-aware scheduling suggests that the energy consumption in trains is influenced by the passenger demand and should thus be taken into account when planning energy (Geng et al., 2026). Therefore, sustainability in rail transit cannot be achieved only through electrification because many other factors contribute to operational emissions.

Moreover, efficient low-carbon scheduling is dependent on coordination between capacity and demand. According to Zang et al. (2025), the cost and carbon emissions associated with low load and off-peak periods increase, thus requiring optimisation that takes into account the travel demand and built environment. Additionally, the conflict between energy-efficiency and passengers' transfers is an example of how energy considerations cannot be dissociated from the service provided to the travellers (Huang et al., 2023). However, service cut can harm accessibility and ridership. Thus, sustainable operations require coordination between energy efficiency and frequency and reliability needed for maintaining trust in public transport.

B. Maintenance Culture and Asset Performance

Maintenance culture is the commitment to inspections, preventive servicing, fault reporting, spares planning and renewal. In recent studies on assets in railways, it has been established that an adaptive maintenance approach can minimize risks and costs and also improve availability (Saleh et al., 2024). In reliability centred maintenance literature, it has been indicated that maintenance of the railway must be organized based on the criticality of the assets and the consequences of their failure (Singh et al., 2020). Consequently, maintenance is not an auxiliary engineering function but a precondition for timetable delivery, station access and safety. Additionally, urban rail disruptions often begin with the failure of facilities, aging assets and operational events. According to Wang et al. (2024), disruption risk increases with age and there is a need for preemptive resilience measures.

Moreover, asset procurement needs to be guided by whole-life costs and not just the first cost. According to case studies from rail projects in Manila, inadequate maintenance has been responsible for poor availability, overloading, delays and unsustainability, but has been solved through rehabilitation (Endo et al., 2024). Additionally, from whole-life cost studies in urban rail, operation and maintenance cost must be included in the infrastructure planning process and not just considered after the assets start being used (Chen et al., 2010). Therefore, purchasing at a cheaper price without considering spare parts availability, technical expertise locally and renewal funds may lead to long-term vulnerabilities during operations. Nonetheless, maintenance is more than the planned schedule; work orders need to be completed, faults need to be reported and the maintenance periods need to be protected from service pressure. The asset management literature oriented towards users suggests that investment strategies should relate the status of the assets to passenger services (Mohammadi et al., 2019). Moreover, from the lifecycle-management literature in transit agencies, organizational maturity has been established as a crucial factor to turn asset-related information into sustainable maintenance practices (Dedeke, 2022). Hence, high maintenance coefficient would mean both technical maturity and organizational readiness to prioritize reliability.

C. Waste Management and Operational Order

Urban rail waste management includes passenger waste, station cleaning, drainage waste, depot waste and maintenance waste. While studies focusing specifically on the causality between waste planning and urban rail operations have been relatively few, studies of passenger perceptions note the importance of cleanliness for service quality and satisfaction (Nguyen-Phuoc et al., 2024). Similar passenger studies on the satisfaction with the rail services note the importance of service environments as part of the perception of the service quality (Eboli and Mazzulla, 2015). Thus, waste planning could affect operations through station circulation, safety, equipment protection and service environment orderliness.

Additionally, environmental management procedures should be coordinated with passenger flow and station design. The high-volume stations will need to coordinate waste collections with busy times, and low-lying environments will need drainage protections. The evidence on sustainable infrastructure from Manila suggests that both environmental and operational results deteriorate in parallel if there is a lack of proper maintenance and management arrangements (Endo et al., 2024). Evidence on passenger perceptions in African light rail demonstrates that physical service conditions are a part of overall assessment of railway service quality (Kumsa, 2020). Thus, waste management needs to be monitored as a regular operating procedure rather than an occasional one. However, the positive correlation between waste management planning and operations might also indicate good organizational practices. Agencies that manage cleaning, segregation and disposal activities effectively would probably also perform better at other procedures. As Awada et al. (2023) state, performance metrics of rail agencies are interdependent. Therefore, the waste-management coefficient is to be treated as evidence of operational relationship without attributing the whole effect on operations index to cleanliness only.

D. Ridership, Energy Efficiency and Operational Viability

In terms of sustainability, ridership level impacts sustainability by distributing fixed costs and energy use among the passengers. Chen and Lin (2025) demonstrate that operational energy consumption is dependent on network and service features, thereby, making passenger volume significant for per-passenger efficiency. Passenger-flow-oriented scheduling of trains is evidence that passenger flow may impact train mass and traction energy consumption in the process of operation (Geng et al., 2026). Higher demands are not only increasing passenger volume but also crowding and cleaning and maintenance requirements. Accordingly, ridership is positive when capacities, maintenance and station management grow with it. In addition, operational planning should be responsive to the imbalance in demand over time and space. Han et al. (2025) present that combined service patterns can improve resource utilization when passenger flows differ along a line. Passenger-flow forecasting studies also reveal that demand information can contribute to the advanced allocation of rail operating resources (Yang et al., 2019). Hence, it can be concluded that demand can be considered an active input to operational planning. As a result, stable demand strengthens service viability, while imbalance may require short-turning, changes in frequency and capacity.

Moreover, causality direction between ridership and operations is uncertain. Improved services attract more riders, while stable ridership can contribute to revenue generation, political legitimacy and resource use efficiency. External factors like weather also impact rail ridership by changing passenger volumes independently of internal management performance (Wang et al., 2020). The performance review by Awada et al. (2023) highlights this interdependence as a major measurement issue. Consequently, cross-sectional coefficients should enable comprehensive management, while longitudinal data are used for analyzing feedback loops.

E. Energy, Climate Resilience and Operational Trade-offs

The energy performance of a railway train cannot be assessed in isolation from its service frequency, stops, passenger volume, and the ventilation and auxiliary systems at stations. According to Chen and Lin (2025), the traction and non-traction energy needs depend on network and service features. The research on energy-saving train operations similarly demonstrates that the timetable and train control belong to the components of energy management in urban railways (Gao and Yang, 2019). This means that a low-carbon operation, which decreases train frequencies disregarding passenger wait time and overcrowdedness, can decrease the immediate energy consumption but degrade the service quality and reduce future ridership, thus limiting the sustainability benefits of the measure. Also, demand-responsive service scheduling represents a compromise for managers. As Zang et al. (2025) prove, the low-load off-peak operation can lead to higher unit costs and greenhouse gas emissions whereas too much service reduction can worsen access conditions. Network-level optimisation shows that energy saving should be combined with opportunities for passenger transfers and travelling (Huang et al., 2023). Therefore, sustainability does not imply the minimum train operation frequency; it implies the proportional to temporal demand train capacity sufficient enough for attracting passengers. Rider volume evaluation, thus, should be linked to the load factor, passenger-kilometers, and energy consumption per passenger-kilometer.

Moreover, climate resilience is a necessity for a coastal mega city. Heavy rainfall, drainage problems, exposure to heat, and electricity supply problems might cause interruptions and damages to stations and railway tracks. The study of urban rail flood reveals that there are high chances of significant losses in performance and customer demand due to flooding (Bi et al., 2024). The study of transport resilience reveals that severe weather can decrease scheduled train services and require preparedness, ability to recover and system redundancy (Chan and Schofer, 2016). Research on systems-oriented performance highlights the importance of interconnectedness of infrastructure and organizational processes for reliability (Awada et al., 2023). Therefore, it becomes necessary to have proper inspection of drainage and other preparedness measures for weather conditions due to environmental risks that can turn into service risks in absence of proper controls. Moreover, recent studies about recovery processes have revealed that resource allocation during recovery efforts affects the recovery process of urban rail (Bi et al., 2025).

F. Procurement, Skills and Lifecycle Asset Management

The maintenance of assets within lifecycle asset management involves considerations such as maintainability, availability of spare parts, and local technical capability. Saleh et al. (2024) note that intelligent asset management of rail assets involves condition-based monitoring and adaptive intervention plans. Lifecycle cost analysis, on the other hand, reveals that the elements of operation, maintenance, and renewal are some of the elements of urban rail asset expenditures throughout the asset life cycle (Chen et al., 2010). This undermines procurement processes that are solely based on initial acquisition cost as a cheap component can result in extended periods of downtime because of lack of spare parts and technical knowledge of the area.

Furthermore, the use of foreign railway technology may result in dependence on the supplier and foreign currency. Previous literature on metro assets had found fragmentation, obsolescence and resource limitations to be key recurring challenges to maintenance (Mohammadi et al., 2019). Literature on asset-management maturity has also revealed that managing assets throughout their life cycle involves the existence of organizational processes rather than simply having technical information (Dedeke, 2022). Although modern adaptive strategies have proven to be useful in improving decision-making, they are not a substitute for skilled people and proper logistical considerations (Saleh et al., 2024). Therefore, sustainable LRMT needs skills transfer, local logistics planning and the establishment of a contractual arrangement of response time, documentation and responsibilities for the future. Nevertheless, predictive technologies may give the illusion of control in case of low-quality data. Condition-monitoring systems require well-working sensors, proper classification of defects and the readiness of managers to act prior to malfunction. Disruption risk is positively correlated with facility failure and obsolescence, according to Wang et al. (2024), which proves the relevance of early warning. However, the effect is apparent only when notifications lead to maintenance work orders.

G. Environmental Order, Social Sustainability and Passenger Demand

Waste management plays a role both in social and environmental sustainability. The accumulation of waste, the blocking of circulation space and inadequate sanitation can affect the perceptions of safety and respect, especially in highly used stations. In their study, Nguyen-Phuoc et al. (2024) prove that the physical environment and the social context influence rail satisfaction and loyalty. Service quality in rail research also indicates that customer satisfaction depends on a number of observable service characteristics and not just the speed of trains (Eboli and Mazzulla, 2015). Thus, the environmental order can be assessed in terms of passenger circulation, hygiene complaints and hazard reduction, rather than just based on the presence of an established plan. Additionally, the cleaning needs of stations depend on the passenger flow that increases with higher ridership levels. The ridership enhances the public value of rail but generates more waste and wear of the facility at the same time. The approach for performance measurement suggested by Awada et al. (2023) provides the joint consideration of the demand and service indicators. As a result, the cleaning schedule and staffing should be related to the passenger peaks, whereas low demand stations also need to meet certain minimum criteria.

Moreover, high ridership might become unsustainable when the capacity and crowd control does not increase as well. According to the work of Han et al. (2025), the operational plan needs to take into account the passenger imbalance in space and time. The accurate passenger flow forecasting allows operators to predict the congestion and prepare the needed resources before the demand becomes operationally disruptive (Yang et al., 2019). That means that the growth in demand is positive when it allows for efficient operations and does not lead to excessive dwell time, platform crowding and repeated boarding failure.

H. Governance, Finance and Measurement Discipline

Financial stability and accountability also affect sustainable operations. According to evidence from the Manila railways, financial and organizational factors affect the quality of maintenance and the service delivery performance in the long run (Endo et al., 2024). Transit asset management literature also indicates that lifecycle management is contingent upon organizational capacity, assessment of asset performance, and responsibility for it (Dedeke, 2022). Thus, maintenance culture cannot be maintained by employees' efforts only when budgets for the renewal are unreliable or responsibility is distributed. LRMT performance measures must include links between budget, asset condition, completed preventative work and performance results in order to reveal deferred maintenance that causes problems before that. Finally, measurement discipline is needed in the case of highly correlated survey constructs. Employees who perceive organization as being well-managed will assess maintenance, waste planning and overall service positively at once and increase model fit significantly. Awada et al. (2023) note strong interdependence of urban rail performance areas, although interdependence does not mean completeness of explanation. Thus, further research must combine independent audits, automated passenger statistics, energy consumption figures and asset failure reports with employee surveys in order to test the stability of the relationships.

Moreover, social sustainability implies that efficiency cannot exclude poor commuters from the system. High ridership can positively impact revenues and efficiency, but higher fares that will help pay for maintenance can decrease demand and harm the environmental superiority of the train. Governance research by Endo et al. (2024) proves that financial structure and service performance are directly linked. Moreover, passengers' demands can depend on factors that cannot be controlled within operations, which explains why ridership is not only an indicator of internal performance (Wang et al., 2020). Therefore, LRMT should consider maintenance financing, affordability, and ridership in conjunction, adopting policies for subsidies and fees that do not negatively affect the quality of service provided.

I. Theoretical Foundation and Research Gap

The key theoretical foundation is the system approach, since the performance of LRMT results from interactions among various technical, environmental, organisational, and passengers-related sub-systems. Maintenance culture affects the asset availability, waste management contributes to station cleanliness, and passenger numbers define the capacity and the resources needed. The recent literature on rail performance highlights that operational results cannot be explained using individual indicators (Awada et al., 2023). Hence, systems theory assumes the existence of interrelated positive connections among the three indicators of sustainability and operations. Nevertheless, the system theory can become too general without the transformation of its premises into measurable channels. In the current model, the focus is made on the maintenance, waste planning, and ridership, while acknowledging the significance of finance, governance, reliability of power supply, and employees' skills. Endo et al. (2024) found that the sustainable outcomes in urban rail depend on the maintenance and governance practices during the various project stages. Accordingly, the empirical gap is the lack of data about the connection between the certain sustainability practices and operations in the case of urban rail in Lagos.

Hence, the current study attempts to fill in the gap regarding measurement issues in the research of the integrated urban rail performance. The study focuses on estimating the conditional effect of three practices described by LAMATA employees and does not consider sustainability as a mere environmental slogan or take for granted the positive effect of the higher ridership.

J. Conceptual Framework

This framework considers (see Figure 1) the execution of the waste management strategy, the number of passengers, and the maintenance culture as sustainability measures that are linked and affect the performance of the LRMT system. As was

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found in the research on urban rail transport systems, factors such as quality of service, costs, assets and demand are interconnected (Awada et al., 2023).

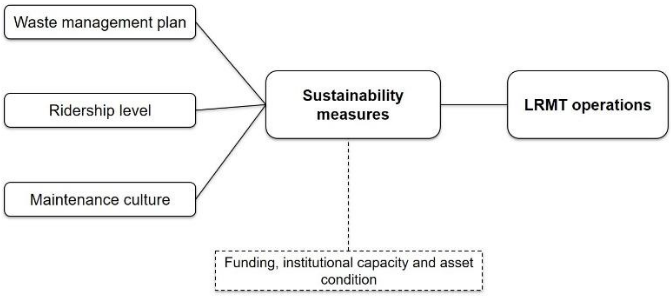

Figure 1. Conceptual Framework for the Study
Source: Researcher's conceptualisation (2026).

III. Methodology

This study adopted a quantitative cross-sectional survey design involving Lagos Metropolitan Area Transport Authority personnel connected with LRMT planning, administration and operations. The eligible population was 991 staff across operations, administration, accounts and human resources. Yamane's finite-population formula at a 5% margin of error produced a target sample of 285 personnel (Yamane, 1967). Operational units with direct knowledge of service delivery were prioritised, while systematic selection was applied within accessible staff rosters and duty shifts. A structured questionnaire measured waste management plan implementation, ridership level, maintenance culture and LRMT operations. Expert review established face and content validity, while the sustainability scale recorded a Cronbach's alpha of 0.76. A total of 243 valid questionnaires were analysed, representing an 85.3% response rate.

Moreover, ordinary least squares regression examined the effect of the sustainability measures on the LRMT operations index at the 0.05 significance level. The model was specified as follows:

$$LRMTO_i = \beta_0 + \beta_1 WMP_i + \beta_2 RL_i + \beta_3 MC_i + \varepsilon_i$$

In the equation, LRMTO represents LRMT operations, WMP denotes waste management plan implementation, RL represents ridership level, MC denotes maintenance culture, beta 0 is the intercept, beta 1 to beta 3 are the estimated parameters and epsilon is the error term. Interpretation used coefficients, standard errors, t-statistics, probability values, standardised beta values, 95% confidence intervals, the F-statistic, R-squared, adjusted R-squared and Root MSE. Since all measures were obtained at one time from the same questionnaire, the estimates were interpreted as conditional associations, while possible conceptual overlap and reverse causality were considered in the discussion.

IV. Results

A. Socio-Economic Characteristics of the Respondents

Respondent socio-economic characteristics are summarized in Table 1 below. Most of the respondents fell within the age group of 26-45 years with 33.7% being between 26-35 years and 35.8% falling within 36-45 years age group. Also, 50.2% were bachelors, 25.9% masters and 3.8% doctors. The above statistics show that the majority of the respondents had high levels of educational preparation for analyzing business operations and activities. Professional status and experience reinforce the above information. Technical employees comprised 44.4%, administrative employees were 29.6% and managerial employees were 21.0%. Also, 55.1% had worked for at least seven years while 23.5% had four to six years of experience.

TABLE 1: Selected Socio-Economic Characteristics of LAMATA Personnel

Variable	Category	Frequency	Percentage (%)
Age	18-25	21	8.6
	26-35	82	33.7
	36-45	87	35.8
	46-55	39	16.0
	56 and above	14	5.9
Educational Background	Secondary	11	4.5
	Diploma	38	15.6
	Bachelor's Degree	122	50.2
	Master's Degree	63	25.9
	Doctorate	9	3.8
Position in LAMATA	Administrative Staff	72	29.6
	Technical Staff	108	44.4
	Management	51	21.0
	Other	12	4.9
Years of Experience	Less than 1 year	14	5.8
	1-3 years	38	15.6
	4-6 years	57	23.5
	7-10 years	71	29.2
	More than 10 years	63	25.9

Source: Field Survey (2026).

B. Effect of Sustainability Measures on Operations of Lagos Rail Mass Transit

The results of how the impact of sustainability measures affects LRMT operations are shown in Table 2. The model is statistically significant, $F(3, 239) = 1722.007$, $p < 0.001$, and it explains 95.6% of variations in LRMT operations index. The adjusted R-squared of 0.955 shows that the explanatory power is constant considering the number of predictors used, while the Root MSE of 4.718 shows that the prediction error is relatively small. Both statistics were calculated again since the values of the model summary were inconsistent with the ANOVA table. In spite of having an extremely high adjusted R-squared, it could be caused by the conceptual proximity of both sustainability indices and operations index.

Maintenance culture has the greatest standardized impact on LRMT operations index, beta = 0.384, followed by implementation of waste management plan, beta = 0.355, and ridership level, beta = 0.338. The differences between the coefficients of the three variables used in the study are small. It means that the results of the study cannot justify the idea that only maintenance should be considered. The result shows that the operations of LRMT depend on interconnected asset management, environmental management and demand factors. One-unit increase in maintenance culture leads to an increase of 6.037 points in LRMT operations index. This result is logically

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sound because maintenance influences the availability of assets and disruptions in daily rail operations.

In addition to this, the execution of the waste management plan has a huge impact as well with the coefficient of 5.575. This means that waste management is connected with the operation system, functioning of the station, and quality of the passengers' experience, and not only with compliance issues. The coefficient of the ridership level is 5.310 and still it is statistically significant even taking into account maintenance and waste management. Nevertheless, one should be careful with the direction of the relationship. High ridership may facilitate the efficient usage of the resources and provision of services, whereas the reliable operation of the system may also attract higher ridership at the same time. These two directions cannot be separated in the cross-sectional model.

TABLE 2. OLS Regression Results for Sustainability Measures and LRMT Operations

Variable	**Coef.**	**Std. Err.**	**t**	**P>|t|**	**Std. Beta**	**95% CI Lower**	**95% CI Upper**
Constant	21.788	0.770	28.296	0.000	-	20.271	23.305
Waste management plan (WMP)	5.575	0.378	14.757	0.000	0.355	4.830	6.320
Ridership level (RL)	5.310	0.315	16.849	0.000	0.338	4.689	5.931
Maintenance culture (MC)	6.037	0.377	16.024	0.000	0.384	5.294	6.780
Model statistics - Dependent variable: LRMT operations							
Number of observations	243	**F(3, 239)**	1722.007	**Prob > F**	0.0000		
R-squared	0.956	**Adjusted R-squared**	0.955	**Root MSE**	4.718		

Source: Field Survey (2025).

V. Discussion of Findings

Sustainability Model is significant statistically and accounts for 95.6% variation in the LRMT operations index. Such a strong validation of the systems theory that sees operations linked to environment-related processes, demand circumstances and assets management. As in the case of Awada et al. (2023), the research proves interdependence between the dimensions of urban rail performance. Research on urban rail resilience also finds interactions between infrastructure, demand and operational response in affecting system performance (Chen et al., 2022). Nevertheless, such high fit also indicates conceptual closeness between survey questions, so the model would help to manage processes integratedly without claiming to cover all technical, financial and organizational determinants. Additionally, the maintenance culture variable had the highest standardized impact at beta = 0.384. It confirms the research on the adaptive railways and asset management that sees planned maintenance as an effective way to lower risks and costs while enhancing availability of assets (Saleh et al., 2024). Evidence on reliability-centred railway management also backs planned preventive interventions to reduce failure exposure of assets (Singh et al., 2020). In the case of LRMT, such high coefficient is operationally valid since rolling stock, tracks, signals, electrical systems, fare gates, lifts and other station equipment have to be available for the planned services to take place.

Additionally, the maintenance coefficient fits with evidence in Manila, where improper maintenance led to shortages of vehicles, delays, overcrowding and reduced sustainability until restoration returned the performance levels (Endo et al., 2024). The asset lifecycle literature in transit agency operations reveals that sustaining performance involves organisational processes for tracking condition, prioritising actions and maintenance scheduling (Dedeke, 2022). It is even more applicable to a developing country railway system with imported equipment and lengthy renewal intervals. Yet, the small disparity between maintenance and the other standardised coefficients implies that a pure maintenance approach will be incomplete.

Moreover, the beta of 0.355 for waste management plan implementation was positive. It suggests that environmental management affects station performance and organisational discipline. Nguyen-Phuoc et al. (2024) prove that physical environments affect satisfaction and loyalty in urban rail transit systems. Evidence of passenger satisfaction in rail transit services shows that service conditions, as observable by passengers, form parts of the evaluation of railway service quality (Eboli and Mazzulla, 2015). Hence, waste management can assist in the passenger circulation, drainage, safety and quality of the services, but the positive coefficient may be attributed to an organisational inclination towards routine process implementation. Nonetheless, waste management should not be equated with station sweeping. The management of passenger litter, drainage litter and maintenance waste requires different process and control procedures. Sustainable rail literature proves that poor management practices lead to poor environmental and operational results (Endo et al., 2024). Therefore, LRMT should link its waste management plan to station demand, rainfall exposure and depot practices.

Furthermore, the effect of ridership level was positive and statistically significant with beta = 0.338. Sustainable patronage can help sustain the utilization of capacity, fare revenue, and legitimacy of regular services; energy consumption per unit passenger usually becomes smaller when fixed costs of operations are shared by more passengers. The study by Chen and Lin (2025) shows that network and operation conditions affect the traction and non-traction energy demands. Passenger flow-based energy modeling further demonstrates that passenger loads influence the amount of energy needed for train operation (Geng et al., 2026). As such, the ridership should be considered in terms of sustainability planning instead of marketing alone. However, the sign of ridership effect is uncertain. Efficient service operations might attract more passengers, whereas higher passenger demand can help mobilize resources for more efficient operations. Similar feedback loops are noted by Awada et al. (2023) in the context of performance assessment of urban rail systems. Moreover, some external factors like weather can change rail passenger volumes, which makes it more justified to consider ridership effects in relation to broader operational context (Wang et al., 2020). Accordingly, the coefficient proves the association, but it is unclear whether the rise in the ridership led to the increase in efficiency.

In addition, the coefficient patterns validate systems theory in that all three of these measures do not work independently. Good maintenance ensures good service quality, stable service encourages ridership, while changes in ridership determine cleaning needs and wear on the assets. Current research on operation optimization confirms that capacity and demand need to be planned in tandem (Han et al., 2025). Evidence on network resilience further confirms that operational strategies can alter the resilience of the urban rail network to maintain its performance during stress (Zhu et al., 2025). For this reason, management should employ a set of related measures and not rank any single measure as the only sustainability measure.

Moreover, the personnel profile increases the validity of the survey results. The majority of the participants had tertiary education, technical staff were the largest professional category among them, and more than half of them had worked for more than seven years. These features imply a lot of experience of operations procedures. However, common organizational experience can generate common perceptions, which might lead to the relatively high R-squared. Hence, future research is required to combine staff surveys with maintenance logs, waste audits, asset failure records and passenger flows. Therefore, the results suggest institutionalization through accountable routines. Preventive work completed, the average time between failures and the availability of spare parts, waste, collection compliance, drainage events, and audit results, ridership, balance on peak, load factor, and revenue stability are all examples of maintenance indicators. It corresponds to the position on integrated performance advanced by Awada et al. (2023). As a result, sustainability becomes operational if each indicator has an owner, reporting frequency and correction procedure.

VI. Conclusion and Recommendations

Maintenance culture, the implementation of waste management plans, and ridership have been identified as significant positive predictors of LRMT operations in this study. While all three variables predicted significantly, maintenance culture emerged as the most influential predictor, although the differences between the three predictors was marginal. The results of the current research indicate that operational sustainability requires the coordinated approach involving asset discipline, environmental order, and demand stability. Therefore, LAMATA must embrace a preventive and condition-based maintenance approach, keep consistent waste management procedures, and make sure that service planning corresponds with passenger flow patterns. Procurement must take into account spare parts, local expertise, and renewal cost, whereas reporting system must incorporate performance measures in maintenance, environment, and ridership dimensions. Besides, further studies should investigate the directionality of the relationships using longitudinal records of operations and independent environmental audits.

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