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Quantification of end-of-life tyres in West Africa—developing a region-wide estimation framework

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End-of-life tyres (ELTs) represent a significant environmental and public health challenge across West Africa, yet fundamental data on ELT generation rates remain largely unavailable for most countries in the region. This study addresses this critical knowledge gap by developing and applying a comprehensive framework to quantify ELT generation across the 16 West African countries. Through systematic literature review and bottom-up estimation modelling, the current state of ELT data availability and developed region-specific generation estimates were assessed. Using a parametric calculation model that integrates vehicle fleet size, composition, tyre specifications, and replacement frequencies calibrated for West African conditions, ELT generation for 11 countries was quantified. The literature review revealed profound data scarcity, with only 5 out of 16 countries (31%) having any available ELT generation data, ranging from 8,000 tonnes annually in Burkina Faso to 2.5 million tonnes in Nigeria. ELT generation totaling approximately 840,000 tonnes annually was quantified. Nigeria dominates regional ELT generation with 646,288 tonnes per year (77% of quantifiable regional total), followed by Senegal (57,936 tonnes) and Ghana (46,031 tonnes). Vehicle fleet compositions vary significantly across the region, with some countries showing motorcycle-dominant fleets (up to 83% in Burkina Faso) while others are car-dominant (50–67% in most countries). The study reveals substantial methodological challenges, including temporal inconsistencies in available data (spanning 2007–2020), varying institutional data sources, and complete data absence for several countries including Mauritania, Côte d'Ivoire, Guinea-Bissau, and The Gambia. This diversity has important implications for waste stream characteristics and recycling infrastructure requirements. These limitations highlight the urgent need for standardised ELT monitoring systems across the region. The findings demonstrate that ELT generation patterns reflect complex interactions between population size, economic activity, and transportation infrastructure rather than simply following GDP per capita distributions. The concentration of waste generation in a few countries suggests opportunities for regional cooperation in developing processing infrastructure, while the manageable scale in most countries (below 60,000 tonnes annually) indicates potential for cross-border collaborations. This research provides the first comprehensive regional assessment of ELT generation in West Africa and establishes a replicable methodology for ongoing monitoring. The results support evidence-based policy development, infrastructure planning, and regional cooperation strategies for sustainable ELT management across West Africa.

KEYWORDS

end-of-life tyres, West Africa, quantification, vehicle fleet, recycling

Introduction

The management of end-of-life tyres (ELTs) represents a significant environmental and public health challenge across Africa (Nkosi et al., 2025). Despite growing concerns regarding inappropriate disposal practices and missed resource recovery opportunities, fundamental data regarding ELT generation rates remain largely unavailable for most countries in the region. This knowledge gap significantly hinders the development of appropriate waste management infrastructure and policy frameworks.

Improper disposal and management of ELTs are associated with numerous severe environmental and health consequences. When discarded in open environments or landfills, tyres create ideal breeding grounds for disease vectors such as mosquitoes and rodents, which can proliferate in the water that accumulates within the tyre cavity (Okafor et al., 2020). These conditions are particularly conducive to the breeding of *Aedes aegypti* and *Aedes albopictus* mosquitoes, which function as vectors for dengue fever, Zika virus, and other arboviral infections (Abdulai et al., 2024). Additionally, uncontrolled tyre fires, which are frequently observed at informal disposal sites, release toxic emissions containing hazardous compounds including polycyclic aromatic hydrocarbons, benzene, styrene, butadiene, and heavy metals (Narra et al., 2025a). These pollutants have been linked to respiratory distress, cardiovascular complications, and potential carcinogenic effects among exposed populations (Morais et al., 2012).

From an environmental perspective, improperly disposed ELTs present severe challenges to ecosystem health (Aliyu et al., 2025). The non-biodegradable nature of tyre materials results in persistent environmental contamination, with degradation timeframes extending to several decades (Valentini and Pegoretti, 2022). Leachates from ELTs containing zinc, lead, and organic compounds can contaminate soil and groundwater resources, compromising agricultural productivity and water quality (Christou et al., 2025; Selbes et al., 2015). Furthermore, landfill capacity is further strained by the space requirements of whole tyres. Their hollow structure contributes to landfill instability by forming air pockets (Ferrão et al., 2008).

Regional context: vehicle fleet characteristics and operating conditions in West Africa

Understanding ELT generation patterns across West Africa requires comprehensive knowledge of the region's unique vehicle fleet characteristics, usage patterns, and operational environment (Liu et al., 2025). The transportation sector in West Africa exhibits distinct features that significantly influence tyre consumption and replacement frequencies, differing markedly from developed economies where conventional ELT estimation methodologies have been established.

The vehicle fleet across West Africa is characterised by low overall vehicle density and distinctive composition patterns. Africa owns only 3% of the global vehicle fleet despite containing 15% of the world's population, reflecting significant disparities in vehicle accessibility (WHO African Region, 2024; Altenburg et al., 2025). However, the region experiences rapid fleet growth, with annual expansion rates of approximately 7%, driven by economic development and urbanisation trends (Johansson and Mutiso, 2025).

Regional vehicle fleet composition varies considerably by location and road type, with studies from West African cities revealing specific patterns. Personal cars typically represent 27–57% of the fleet depending on the area, while minibuses constitute 10–32% and serve as the dominant public transport mode. Motorcycles account for 3.5–10% of the fleet but are experiencing rapid growth in urban areas, while heavy goods vehicles comprise 2–18% of the total fleet (Osei et al., 2025). Large buses represent 1.5–11% of vehicles, and tricycles constitute an emerging category representing 4.5–35% in certain areas.

The fleet is characterised by ageing vehicles, poor fuel quality, and limited mandatory roadworthy emission testing. Heavy reliance on used vehicle imports from Europe and Asia contributes to an older average fleet age compared to developed regions (Doumbia et al., 2018; Ayetor et al., 2021). Limited maintenance infrastructure results in extended vehicle lifespans under harsh operating conditions, though this often comes at the expense of component reliability and replacement frequency.

Vehicle usage patterns in West Africa differ substantially from those in developed economies, with implications for tyre wear and replacement requirements (Gicha et al., 2024). Commercial vehicles operate with high daily utilisation rates due to economic necessity. Many vehicles operate extended hours compared to developed countries, driven by economic pressures and the need to maximise return on investment.

The operational environment presents significant challenges that accelerate component wear (Kang et al., 2025). Vehicles commonly operate under overloaded conditions, exceeding manufacturer specifications due to economic incentives and limited enforcement of load regulations. High ambient temperatures, dust exposure, and humidity create harsh operating conditions that accelerate tyre degradation beyond normal wear patterns.

Road infrastructure quality across West Africa significantly impacts tyre consumption patterns. The region faces substantial deficits in asphalt road coverage, with many areas lacking adequate paved road infrastructure. Without proper road networks, goods flows are restricted and access to services is limited, forcing vehicles to operate on challenging surfaces (Ouni et al., 2025).

Poor road maintenance compounds these challenges, with existing paved roads often suffering from inadequate upkeep. Potholes, rough surfaces, and unpaved roads substantially increase tyre wear rates, potentially increasing replacement frequency by 2–3 times compared to good paved road conditions. The prevalence of unpaved roads in rural areas creates particularly challenging conditions for tyre longevity (Aderibigbe et al., 2024).

These operational characteristics create unique conditions for tyre consumption across West Africa. Road surface quality serves as a primary accelerating factor, with poor and unpaved roads dramatically increasing wear rates. Vehicle overloading, common throughout the region, increases tyre stress and reduces operational lifespan. Climate conditions including high temperatures and ultraviolet radiation (UV) exposure accelerate tyre degradation processes beyond mechanical wear.

Limited maintenance practices, including infrequent pressure checks and rotation schedules, further reduce tyre life. However, economic constraints drive extended use practices, with tyres often used beyond recommended replacement points. Retreading is

commonly practiced, with tyre casings typically retreaded 2–3 times before final disposal. Widespread informal repair services extend tyre life through various interventions (Narra et al., 2024).

These factors necessitate region-specific approaches to ELT estimation that account for accelerated wear patterns, extended use practices, and the complex interaction between vehicle characteristics, operating conditions, and infrastructure quality. The unique transportation dynamics of Sub-Saharan Africa (SSA) require estimation methodologies that capture these contextual factors rather than applying standard approaches developed for different operational environments.

The absence of reliable data regarding ELT generation in West African contexts represents a fundamental barrier to effective waste management planning. Without quantitative understanding of waste streams, resource allocation for collection infrastructure, recycling facilities, and regulatory enforcement cannot be appropriately dimensioned (Moyen Massa and Archodoulaki, 2023). This data deficiency impedes the development of circular economy initiatives that could otherwise transform waste tyres into valuable resources through processes such as pyrolysis, devulcanisation, or mechanical recycling (Maga et al., 2023). Furthermore, the lack of regionally specific data prevents policymakers from establishing realistic extended producer responsibility schemes, which have demonstrated effectiveness in other regions for ensuring sustainable funding mechanisms for waste management systems (Bahman et al., 2025; Narra et al., 2025b).

Whilst established methodologies for estimating ELT generation exist for developed economies, these approaches typically rely on comprehensive vehicle registration databases, manufacturer sales figures, or systematic waste auditing (Winternitz et al., 2019)—resources that are often unavailable or unreliable in many SSA contexts. Furthermore, the unique characteristics of transport systems across SSA—including the predominance of informal transport services, variable road conditions, and distinct vehicle usage patterns—necessitate tailored approaches to ELT estimation.

This research seeks to address this methodological gap by developing and validating a parametric framework for estimating ELT generation that is specifically calibrated for West African contexts. The approach prioritises practical applicability by relying on widely available socioeconomic and demographic indicators rather than detailed transport statistics. Through this methodological innovation, it is anticipated that data barriers can be overcome, thereby enabling evidence-based decision-making for ELT management across diverse SSA contexts where conventional data collection mechanisms remain challenging to implement.

The establishment of reliable baseline estimates for ELT generation rates is expected to facilitate informed policy development, infrastructure planning, and resource allocation. Additionally, these data can support the identification of opportunities for entrepreneurial ventures in tyre recycling and material recovery, potentially contributing to both environmental protection and economic development objectives within the region. The integration of waste tyre management into broader sustainable development strategies requires this foundational quantitative understanding that has heretofore been absent from waste management discourse in many West African countries.

Materials and methods

In order to analyse the distribution and quantities of end-of-life tyres (ELTs) in West Africa, countries, according to the classification system provided by the World Atlas (2024) (see Table 1) were selected. The World Atlas classification was selected for its clear regional boundaries and frequent application in geographical research.

It should be noted that several classification systems exist for grouping African countries, including those based on economic, cultural, or political criteria, such as the African Union regions or World Bank income groups. These different approaches often lead to overlapping or inconsistent country groupings. For the present study, a strictly geographical subdivision was considered more appropriate in order to ensure consistency in spatial analysis and regional comparison. The World Atlas classification was therefore adopted as the most suitable reference framework.

The countries included in this research are listed in Table 1. This regional grouping served as the basis for data collection, estimation procedures, and comparative interpretation of ELT volumes across West Africa.

Database

In order to identify existing information on end-of-life tyre (ELT) generation, a structured literature research was carried out for each country listed in Table 1. The main goal of this step was to evaluate the current state of knowledge regarding ELT volumes, available datasets, policy frameworks, and relevant academic or technical reports. This step also aimed to identify knowledge gaps, which was then taken into account during the development of the estimation method.

TABLE 1 West African countries according to World Atlas (2024) and official languages used for literature research.

Country name (World Atlas)	English	French	Portuguese
Benin	x	x	
Burkina Faso	x	x	
Cape Verde	x		x
Côte d'Ivoire	x	x	
Ghana	x		
Guinea	x	x	
Guinea-Bissau	x		x
Liberia	x		
Mali	x	x	
Mauritania	x	x	
Niger	x	x	
Nigeria	x		
Senegal	x	x	
Sierra Leone	x		
The Gambia	x		
Togo	x	x	

The literature research was primarily conducted in English using academic databases such as Scopus, Google Scholar, and ScienceDirect, as well as official publications and databases and the websites of international organisations (e.g., UNEP, World Bank, and AfDB). In addition, for countries where French or Portuguese are official or commonly used languages, supplementary literature searches were carried out in these languages. This multilingual approach was considered necessary, as many national reports and sectoral documents in Sub-Saharan Africa are published in local official languages and may not be available in English.

Both peer-reviewed publications and grey literature (e.g., government reports, policy documents, and consultancy studies) were included in the search. Table 1 provides an overview of the countries considered and the languages used in the literature research.

Primary terms used in the literature research were: End-of-life tyres/tires, Waste tyres/tires, Used tyres/tires, Scrap tyres/tires, Tyre/tire recycling, Tyre/tire disposal, Tyre/tire management coupled with Geographic terms such as the country names from Table 1, Sub-Saharan Africa, West Africa. The technical and geographical terms were combined using Boolean operators (AND) and country specific spelling variations (tyres/tires) were applied.

For the French research the following key words were used: Pneus usages, Pneus en fin de vie, Déchets de pneus, Pneumatiques usages, Recyclage des pneus, Élimination des pneus, Gestion des pneus usages and the geographic terms: Afrique subsaharienne, Afrique de l'Ouest and the Portuguese key words respectively: Pneus usados, Pneus em fim de vida, Resíduos de pneus, Pneumáticos usados, Reciclagem de pneus, Eliminação de pneus, Gestão de pneus usados with the respective geographic terms: África subsaariana, África Ocidental.

ELT estimation

The estimation of End-of-life tyre (ELT) quantities in West African countries has been carried out using a bottom-up, parameter-based model which integrates transport, demographic, and economic indicators, loosely based on the model of Arthur et al., 2020 and Narra et al. (2024). The objective of the model is to provide a replicable and adaptable method to approximate the annual mass of waste tyres generated within a country. It is designed to be applied across West African countries and can be adjusted according to the level of available national data.

The model calculates the total annual ELT generation by summing the contribution of each vehicle category based on the size of the total vehicle fleet, the relative share of each vehicle type, the number and weight of tyres per vehicle, and the annual replacement frequency. Additionally, an adjustment is applied for the economic context of the country by using a GDP per capita correction factor. The following equation has been used for the calculation:

$$ELTtotal = v = 1 \sum n \left(TVF \times VDv \times NTv \times TWv \times RFv \right) \quad (1)$$

In Equation 1, ELT_{total} refers to the total mass of End-of-life tyres generated per year (in tonnes). TVF represents the total vehicle fleet in the country. VD_v is the fraction of the total fleet made up by vehicle type $_v$, for example motorcycles, passenger taxis, private vehicles, or commercial trucks and buses.

The number of tyres per vehicle (NT_v) is defined based on standard configurations based on Narra et al. (2024) and varies between 2 (for motorcycles), 4 for passenger vehicles (private cars, taxis etc.) and 4 for Light-duty vehicles (small trucks and mini-buses/vans), 6 for buses (overland, coaches, city bus) and 10 for heavy-duty vehicles (heavy trucks).

The average weight of one tyre (TW_v) has been assessed through the weighing of 6.163 ELTs, collected in the greater Lomé area in Togo in May 2024. Each collected tyre has been weighed on an electric scale.

The average weight of the different tyre types are depicted in Table 2 and Figure 1.

The tyre replacement frequency (RF_v) is the average number of times tyres are replaced per vehicle per year, which is influenced strongly by vehicle usage intensity, road conditions, overloading, and the type of tyre. The tyre replacement frequency is taken from literature (Narra et al., 2024), see Table 3, where the tyre replacement frequencies were estimated from road quality assessments, expert interviews, and informal market observations.

Tyre replacement frequencies are based on empirical data from only two West African countries: Togo (Narra et al., 2024) and Ghana (Arthur et al., 2020). Given the absence of tyre replacement data for the remaining 14 countries in this study, country-specific adjustment factors were taken into account, but the decision to use the same tyre replacement frequencies for all countries has been made. The decision follows a conservative approach that avoids adding more uncertainty to the model. Creating adjustment factors without proper scientific validation would introduce speculative assumptions that could make the results less reliable. Since there are no studies that measure how different road conditions in West Africa affect tyre wear rates, any adjustment factor would be based on speculation rather than evidence. Therefore, using the available data from Togo and Ghana without modifications provides a more scientifically sound foundation for the regional estimates.

While this uniform approach provides methodological consistency, it potentially introduces systematic over- or underestimation in countries with markedly different operating conditions. Countries with predominantly unpaved road networks

TABLE 2 Average weight of tyres per vehicle tyre type.

Vehicle tyre type	Commercial Van/ Truck tyres	Light truck and SUV bus	SUV tyres	Passenger car tyres	Motorcycle tyres
Total number of tyres weighed	231	1,535	1712	2039	646
Average weight of each tyre	43 kg	19 kg	9.5 kg	7.5 kg	1.4 kg

The average weight was assessed through weighing the total number of tyres per type.

FIGURE 1
Representative image of tyres types and their weight from ELTs analysed in Togo. Golf cart sized tyres, such as used on tricycles and autorickshaws are not depicted.

TABLE 3 Average frequencies between tyre changes (Narra et al., 2024).

Vehicle type	Average time between tyre changes
Passenger vehicles	
Private passenger cars (new tyres)	14.5 months
Private passenger cars (used tyres)	12.1 months
Official (e.g., business) cars (new tyres)	31.5 months
Taxis (used tyres)	3.4 months
Commercial vehicles	
Trucks (new tyres)	5.7 months
Buses (new tyres)	2.4 months
Smaller vehicles	
Tricycles	6.8 months
Autorikshaws	2.9 months
Taxi-Motorcycles	11.8 months
Private Motorcycles	28.1 months

and harsh climatic conditions (such as those in the Sahel region) may experience accelerated tyre wear, potentially leading to underestimation of actual ELT generation. Conversely, countries with better road infrastructure and milder operating conditions may generate fewer ELTs than the model predicts. Similarly, lower-income countries often rely more heavily on used tyres and intensive vehicle utilisation patterns, which could increase replacement frequencies beyond the baseline assumptions. Higher-income countries within the region may have access to higher-quality tyres and less intensive vehicle usage, potentially reducing actual replacement rates. However, quantifying these variations would require extensive empirical data collection across diverse regional contexts. This data is currently unavailable.

The necessary input parameters for the ELT generation model include the total national vehicle fleet, which has been taken from national vehicle registration statistics and international transport databases, and the distribution of vehicle types, which are also based on national transport surveys or estimated from neighbouring countries with similar road and mobility patterns. The majority of vehicle fleet information utilised in this study is derived from the Climate Compatible Growth (CCG) programme's data compilation by Tan et al. (2023a,b,c,d,e,f,g,h,i,j,k,l,m,n,o). Climate Compatible Growth is a research initiative funded by the UK's Foreign, Commonwealth & Development Office that focuses on supporting developing countries in achieving economic growth while addressing climate change challenges. The CCG vehicle fleet database represents a systematic effort to aggregate transportation data across developing regions, though its reliability is inherently dependent on the quality and availability of underlying national data sources.

Within the CCG compilation, data sources vary considerably in their institutional origin and methodological rigour. Some information is sourced directly from national statistical offices, representing the most reliable tier of data with official governmental validation. Other data points are derived from the International Road Federation's (IRF) World Road Statistics, a global database that compiles transportation infrastructure and vehicle data from member countries. While the IRF maintains standardised reporting frameworks, the quality of submitted national data varies significantly, and reporting frequency is inconsistent across countries.

Additional sources include individual academic studies and media reports, which provide supplementary information but with varying degrees of methodological transparency and peer review.

Results

The Results section is organised into two main components: an assessment of existing literature on ELT generation in West Africa, which highlights the scarcity and uneven reliability of available data, followed by the presentation of vehicle fleet-based estimations that provide a more comprehensive and comparable quantification of ELT generation across the region.

ELT generation information

The structured literature research across West African countries revealed significant limitations in available data on end-of-life tyre generation. Despite conducting searches in English, French, and

Portuguese across multiple academic databases (Scopus, Google Scholar, ScienceDirect) and official publications from international organisations, the volume of published data was remarkably low.

Out of all the countries examined, only four yielded any relevant data on ELT generation. These included Burkina Faso, Côte d'Ivoire, Ghana, Nigeria, and Togo.

The reported ELT generation figures varied dramatically across countries, ranging from 8,000 tonnes annually in Burkina Faso to 2.5 million tonnes in Nigeria, though the reliability of these figures differs substantially. The absence of data from the remaining countries highlights the substantial knowledge gap that exists across the continent regarding ELT quantification and management.

The quality and methodological rigour of the identified data varied considerably across these countries. Several countries demonstrated relatively high reliability in their ELT data. As depicted in Table 4, Ghana reported 106,000–147,000 tonnes annually for 2019, while Togo estimated 30,000–78,000 tonnes annually for the same year, both using clearly defined estimation methods based on official vehicle registration data from government sources that incorporated various relevant variables (Arthur et al., 2020; Narra et al., 2024). Similarly, Burkina Faso's estimate of 8,186 tonnes annually for 2015 was based on official vehicle registration data from government sources (Toure, 2015), and Nigeria provided a number of 2.5 million tonnes for 2017 based on the Abuja Chamber of Commerce and Industry (Iloani, 2019).

However, several countries presented data with significant methodological limitations. The reliability concerns are most pronounced for data from Nigeria, which reported 2.5 million tonnes annually for 2017 based solely on newspaper articles citing the Abuja Chamber of Commerce and Industry, and Côte d'Ivoire's figure of 350,000 tonnes annually for 2024 was sourced only from newspaper articles (Iloani, 2019; Kouassoi, 2024) without methodological backing.

The literature research revealed several critical knowledge gaps that extend beyond simple data availability. The geographic coverage of ELT data across West Africa (and other developing regions) is extremely limited, with the vast majority of countries lacking any published information on tyre waste generation. This shortcoming has also been noted by other researchers (Aliyu et al., 2025; Zhao et al., 2025), who emphasise that the absence of standardised approaches to ELT quantification severely limits the possibility of meaningful regional comparisons or the development of continent-wide management strategies. The academic research gap is particularly pronounced, with very limited peer-reviewed literature addressing ELT management in the region, despite the growing importance of waste management in developing countries. In total, only five out of 16 countries (31%) had any available data on ELT production.

These findings underscore the necessity for developing alternative estimation methods for ELT generation in West Africa. The scarcity of reliable, methodologically sound data across the region highlights the importance of the estimation approach developed in this study to address these significant knowledge gaps. The wide variation in reported figures, along with the heterogeneous nature of available data sources and quality levels, emphasises the urgent need for standardised data collection and reporting frameworks for ELT management across West African countries, which would facilitate better policy development and regional cooperation in addressing this growing waste management challenge.

TABLE 4 Overview on identified ELT generation in various Sub-Saharan African countries.

Country	ELT generation	Baseline year	Source	Methods	Reliability
Burkina Faso	8,186 t/a	2015	Toure (2015), Master thesis	Number estimated based on official vehicle registration data from government	High
Cote d'Ivoire	350,000 t/a	2024	Kouassoi (2024), Newspaper article	No source	Low
Ghana	106,000–147,000 t/a	2019	Arthur et al. (2020), Industry report	Number estimated based on official vehicle registration data from government, takes various variables into account	High
Nigeria	2,500,000 t/a	2017	Iloani (2019), Newspaper citing Abuja Chamber of Commerce and Industry	Information from Abuja Chamber of Commerce and Industry	Low
Togo	30,000–78,000 t/a	2019	Narra et al. (2024), scientific article	Number estimated based on official vehicle registration data from government, takes various variables into account	Medium-high

ELT estimation based on available data

Extensive data has been gathered from different sources in regards to total vehicle fleet and the fraction of the total fleet made up by vehicle type in each West African country (Table 5).

The compilation of vehicle fleet data across West Africa (Table 5) reveals significant challenges in data availability, consistency, and reliability that constitute a key finding of this research. Rather than attempting to standardise or interpolate missing data, this study documents these limitations as indicative of broader systemic issues in regional transportation data collection and reporting. The compiled data in Table 5 encompasses 15 countries with total fleet sizes ranging from approximately 9,455 vehicles (The Gambia, 2010) to nearly 12 million vehicles (Nigeria, 2018). No data on vehicle fleet size could be found for Mauritania.

The vehicle fleet data sources can be categorised into three distinct reliability tiers based on their institutional origin and methodological transparency. The highest reliability tier comprises countries whose data originates from official national statistical institutions, including Benin, Côte d'Ivoire, Ghana, Nigeria, and Senegal. These sources represent the most credible data available, as they are produced by governmental agencies with established data collection protocols and quality assurance mechanisms.

The second reliability tier encompasses countries that source their vehicle fleet information through International Road Federation compilations, including Burkina Faso, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Sierra Leone, and Togo. While the IRF maintains standardised reporting frameworks that provide consistency across countries, these sources offer secondary reliability as they depend on the quality and timeliness of national reporting to the international organisation.

The third and lowest reliability tier includes Cape Verde and The Gambia, which rely on non-governmental sources with limited methodological transparency. Cape Verde's data originates from a media source (Panapress, 2021), while The Gambia's information is derived from World Bank development indicators. The estimation of The Gambia's vehicle fleet size (cars only) estimated to 9.455 cars, based on a population of 1.793.199 people (World Bank, 2022).

These alternative sources, while providing valuable information in the absence of official statistics, lack the institutional validation and systematic data collection approaches characteristic of governmental statistical agencies.

Complete data absence is exemplified by Mauritania, for which no accessible vehicle fleet information was identified even within the comprehensive CCG database, highlighting gaps in regional data coverage that affect comprehensive West African transportation analysis.

The temporal span of available data, ranging from 2007 to 2020, represents more than a methodological limitation—it reveals the absence of coordinated regional vehicle registration and reporting systems. This 13-year spread indicates that countries operate on different data collection cycles, with some nations having not updated (or published) their fleet statistics in over a decade. Such inconsistencies severely constrain the ability to conduct meaningful transportation and waste management planning.

The Nigerian case illustrates the complexities inherent in vehicle fleet data categorisation across the region. Official sources for the vehicle stock in Nigeria are made available by the National Bureau of Statistics for 2018. The statistic does not separate into vehicle type, but into private, commercial, official and diplomatic vehicles. Another statistic by Dioha et al. (2022) indicates a breakdown on the light-duty vehicle fleet (heavy duty vehicles excluded). The IRF also has data on the Nigerian vehicle fleet for 2016, with numbers only slightly differentiating from the data of the Nigerian National Bureau of Statistics. This data has been used for the breakdown into vehicle type fractions as it has a better comparability with the data of the other countries.

These different categorisation systems demonstrate how, even within a single country, different data collection approaches can yield incompatible datasets, further complicating regional standardisation efforts.

The analysis of vehicle fleet compositions across West African countries reveals distinct regional patterns that have significant implications for tyre waste generation and recycling infrastructure planning. These compositional differences, observable across the 10 countries providing complete vehicle type breakdowns, directly influence the volume, type, and characteristics of end-of-life tyres that require management across the region.

Three countries demonstrate motorcycle-dominant fleet structures, with Burkina Faso leading at 83% motorcycle composition, followed by Benin at 70%, and Togo at 67%. These motorcycle-heavy fleet compositions generate substantially different tyre waste streams compared to car-dominant countries.

In contrast, most countries with available vehicle type data demonstrate car-dominant fleet structures, where passenger cars constitute either the largest or second-largest vehicle category. The proportion of passenger cars varies considerably across the region, ranging from 11% in Burkina Faso to 67% in Liberia, with countries such as Guinea (52%), Ghana (54%), Mali (50%), Sierra Leone (54%), Nigeria (57%), and Senegal (57%) maintaining substantial car fleets. Car-dominant fleets generate larger tyre volumes per vehicle and produce tyre waste with different material compositions and recycling potential compared to motorcycle tyres.

Commercial vehicle representation, particularly buses and heavy-duty vehicles, exhibits high variation across the region with critical implications for tyre recycling infrastructure capacity. Bus percentages range from 1% in Benin, Burkina Faso, and Togo to 20% in Nigeria, while heavy-duty vehicle proportions vary from 3% in Togo to 25% in combined light and heavy-duty categories in Liberia. Commercial vehicle tyres are significantly larger, heavier, and more complex than passenger vehicle tyres, requiring specialised recycling equipment and generating substantially more recoverable materials per unit.

No adjustments were made to the raw data presented in this study. Missing data points remain explicitly documented, temporal inconsistencies are preserved as found, and no interpolation or proxy estimates were applied for countries lacking data.

Table 6 presents the estimated annual quantities of end-of-life tyres (ELTs) across the West African countries, based on the data from various baseline years ranging from 2007 to 2020. The analysis successfully quantified ELT generation for 11 countries, while estimation was not possible for 4 countries due to insufficient data availability.

Nigeria demonstrated the highest ELT generation at 646,288 tonnes per annum (t/a) (see Figure 2). This represents approximately 77% of the total quantifiable ELT waste in the region. This was followed by Senegal with 57,936 t/a and Ghana with 46,031 t/a ELT generation. Together with Nigeria these three countries account for nearly 90% of the estimated regional ELT generation.

Burkina Faso contributed 42,894 t/a, while Liberia generated an estimated 26,030 t/a. Mid-range generators included Niger (23,068 t/a) and Guinea (19,314 t/a). Several smaller economies showed lower ELT quantities: Cape Verde (5,138 t/a), Benin (4,667 t/a), Sierra Leone (2,252 t/a), and Togo (1,645 t/a). Mali showed the lowest quantifiable generation at 583 t/a.

Several methodological considerations affected the estimation process. The data for Cape Verde does not include a separation into

TABLE 5 Vehicle fleet information for West Africa.

Country	Total vehicle fleet	Year	Vehicle type fractions	Source
Benin	219,118	2019	Motorcycles = 70%, Cars = 23% Buses = 1% Light-duty vehicles = 4% Heavy-duty vehicles = 3%	Tan et al. (2023a) via Direction de la Programmation et de la Prospective (2014)
Burkina Faso	2,704,591	2017	Motorcycles = 83%, Cars = 11% Buses = 1% Light-duty vehicles = 2% Heavy-duty vehicles = 3%	Tan et al. (2023b) via IRF (2023)
Cape Verde	81,000	2020	Motorcycles = 15% Cars = 71%, Heavy-duty vehicles = 14%	Panapress (2021)
Côte d'Ivoire	474,873	2007	Breakdown not available	Tan et al. (2023c) via Institute National de la Statistique
Ghana	891,414	2013	Motorcycles = 5% Cars = 54% Buses = 14% Light duty vehicles = 17% Heavy duty vehicles = 10%	Tan et al. (2023d) via Ghana Statistical Service (2015)
Guinea	439,966	2019	Motorcycle = 24 Car = 52 Bus = 7 Light-duty vehicle = 2 Heavy duty vehicle = 15	Tan et al. (2023e) via IRF (2023)
Guinea-Bissau	62,239	2016	Breakdown not available	Tan et al. (2023f) via IRF (2023)
Liberia	11,087	2007	Motorcycle = 3% Car = 67% Bus = 5% Light-duty vehicle & Heavy duty vehicle = 25%	Tan et al. (2023g) via IRF (2022)
Mali	279,029	2013	Motorcycles = 17% Cars = 50% Bus = 9% Light-duty vehicles = 8% Heavy duty vehicles = 15%	Tan et al. (2023h) via IRF (2022)
Mauritania	No information available			Tan et al. (2023i)
Niger	557,637	2020	Motorcycle = 36% Car = 46% Bus = 2% Light-duty vehicle = 7% Heavy duty vehicle = 8%	Tan et al. (2023j) via IRF (2022)
Nigeria	11,760,871	2018	Motorcycle = 11% Car = 57% Bus = 20% Heavy-duty vehicle = 11%	Tan et al. (2023k) via National Bureau of Statistics and Dioha et al. (2022)

(Continued)

TABLE 5 (Continued)

Country	Total vehicle fleet	Year	Vehicle type fractions	Source
Senegal	820,289	2018	Motorcycle = 7% Car = 57% Bus = 3% Light-duty vehicle = 15% Heavy duty vehicle = 20%	Tan et al. (2023l) via Agence Nationale de la Statistique et de la Demographie (2018)
Sierra Leone	68,470	2013	Motorcycle = 29% Car = 54% Bus = 12% Light-duty vehicle & heavy duty vehicle = 5%	Tan et al. (2023m) via IRF (2022)
The Gambia	5.27 passenger cars per 1,000 inhabitants for 2010 = Fleet size of 9,455 cars in 2010			Tan et al. (2023n) via World Development indicators
Togo	76,132	2019	Motorcycle = 67% Car = 24% Bus = 1% Light-duty vehicle = 5% Heavy duty vehicle = 3%	Tan et al. (2023o) via IRF (2023)

TABLE 6 Estimated ELT quantities for West Africa.

Country	Estimated ELTs (t/a)	Percentage of total ELT generation in W. Africa	Baseline year
Benin	4,667	0.5	2019
Burkina Faso	42,894	4.9	2017
Cape Verde	5,138	0.6	2020
Côte d'Ivoire	Not possible	Not possible	2007
Ghana	46,031	5.3	2013
Guinea	19,314	2.2	2019
Guinea-Bissau	Not possible	Not possible	2016
Liberia	26,030	3	2007
Mali	583	0.1	2007
Mauritania	Not possible	Not possible	No data
Niger	23,068	2.6	2020
Nigeria	646,288	73.8	2018
Senegal	57,936	6.6	2018
Sierra Leone	2,252	0.3	2013
The Gambia	Not possible	Not possible	2010
Togo	1,645	0.2	2019

light-duty vehicles and buses, with the assumption that these vehicle categories are absorbed in cars and heavy-duty vehicles. For Liberia and Sierra Leone, only a mixed category of light- and heavy-duty vehicles is available, requiring a 50:50 distribution assumption with mean values of NTv of 7, TWv of 26 kg, and RFv of 0.38. Complete vehicle category breakdowns were unavailable for Côte d'Ivoire and Guinea-Bissau, where using only one vehicle type would introduce unacceptable error margins that could not be justified scientifically. For Mauritania, no data was available for analysis.

Data limitations thus prevented ELT estimation for Côte d'Ivoire, Guinea-Bissau, The Gambia, and Mauritania. The baseline years varied considerably across countries, with some estimates based on data as old as 2007 (Côte d'Ivoire, Liberia, Mali) while others used more recent data from 2019 to 2020 (Benin, Cape Verde, Niger, Togo).

Figure 3 illustrates the relationship between estimated ELT generation (t/a) and GDP per capita (current US$) for the 11 West African countries where ELT quantification was possible. The data points are distributed across a wide range of economic conditions, with GDP per capita values spanning from less than $500 to $3,500 and ELT generation ranging from under 1,000 t/a to over 500,000 t/a (World Bank, 2024).

Nigeria represents a clear outlier in the dataset, generating approximately 646,000 t/a with a GDP per capita of $2,057.9. This data point sits substantially above all other countries in terms of ELT generation while maintaining a mid-range economic position. The remaining countries form a distinct cluster in the lower portion of the plot, with ELT generation values below 60,000 t/a.

Within this main cluster, several patterns emerge. Countries with higher GDP per capita tend to show elevated ELT generation, with Cape Verde (GDP per capita ~$3,200) generating approximately 5,100 t/a, and Ghana (GDP per capita = $2,294.8) producing around 46,000 t/a. Senegal demonstrates substantial ELT generation (~58,000 t/a) with a GDP per capita of $1,452.6.

The lower economic tier countries (GDP per capita below $1,000) show variable ELT generation patterns. Mali exhibits the lowest ELT production at under 1,000 t/a with a GDP per capita around $850, while countries like Burkina Faso, Niger, Guinea, and Liberia demonstrate ELT generation between 19,000 and 43,000 t/a despite similar or lower economic indicators.

Countries in the intermediate economic range ($1,000–$2,000 GDP per capita) include Benin, Sierra Leone, and Togo, showing ELT

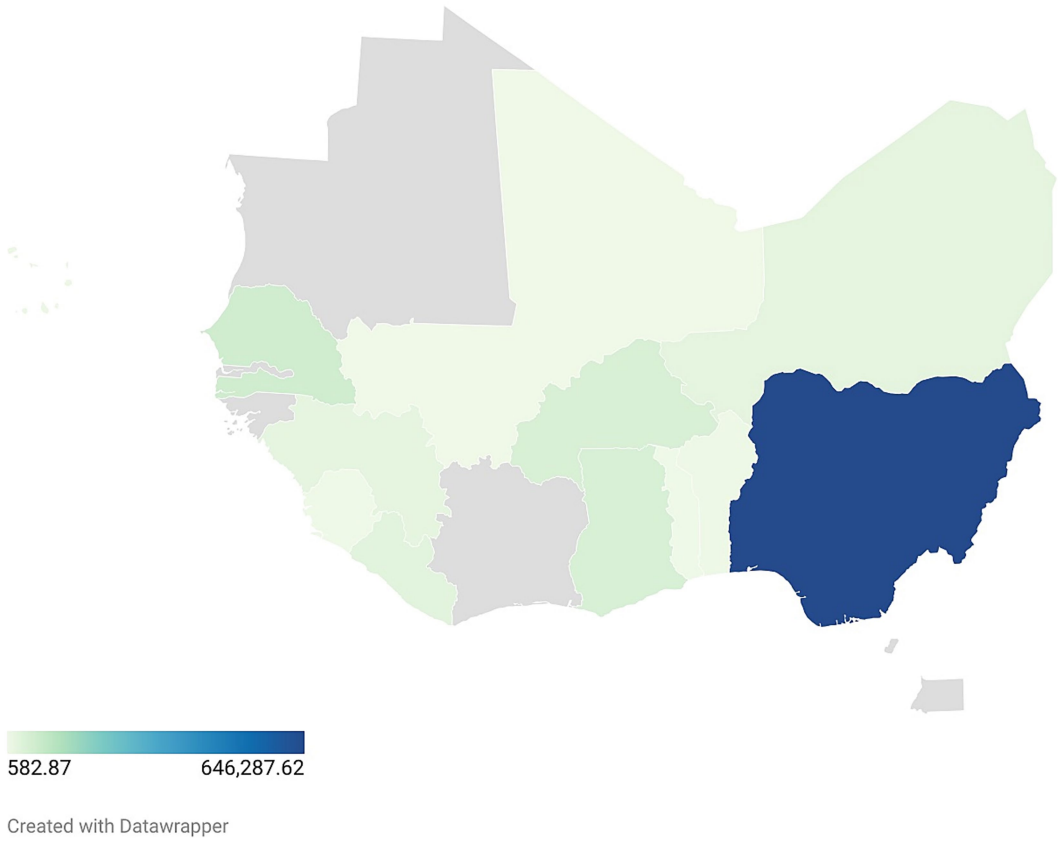

FIGURE 2
Map of West Africa, highlighting the estimated ELT generation per country, for countries represented in grey, no estimation was possible.

generation between 1,600 and 4,700 t/a, representing relatively modest tyre waste production compared to their economic peers.

Discussion

The Discussion examines the implications of data scarcity and methodological limitations for regional tyre waste management. It explores the economic and demographic drivers of ELT generation patterns, considers how vehicle fleet compositions and data reliability affect policy and infrastructure planning, and reflects on the governance, international cooperation, and research needs required to advance sustainable ELT management in West Africa.

Data scarcity as a regional challenge

The documented data scarcity in West African ELT management aligns with broader patterns observed in developing country waste management systems (Caruso and Gattone, 2019). Research on waste management in developing countries has identified that the increase in global population and improved living standards has resulted in higher solid waste generation, while solid waste management increasingly represents both a challenge and opportunity for municipal authorities (Morton, 2017). This challenge is particularly acute in the African context, where ineffective policy implementation and monitoring, combined with lack of systematic and targeted orientation, has led to inefficient development in many areas (Debrah et al., 2022).

The 31% data availability rate for ELT across West African countries reflects these systemic challenges that extend beyond simple data collection.

The most striking finding of this research is the profound data scarcity regarding end-of-life tyre generation and vehicle fleet information across West Africa. With only 5 out of 16 countries (31%) having any available ELT data, and successful quantification possible for just 11 countries, this study reveals a critical knowledge gap that extends far beyond simple data collection challenges. This scarcity reflects broader systemic issues in waste management infrastructure, regulatory frameworks, and environmental monitoring capabilities across the region, as already mentioned by Zurbrügg et al. (2014).

This pattern is consistent with earlier observations that the African continent—apart from a few isolated cases in South Africa, Morocco, and Ghana—remains poorly represented in the global ELT research landscape (WBCSD – World Business Council for Sustainable Development, 2018a; Okafor et al., 2020). In contrast, high-income regions such as the European Union, United States, and Japan maintain comprehensive, regularly updated ELT databases supported by well-established regulatory frameworks, including landfill bans, extended producer responsibility (EPR) schemes, and mandatory

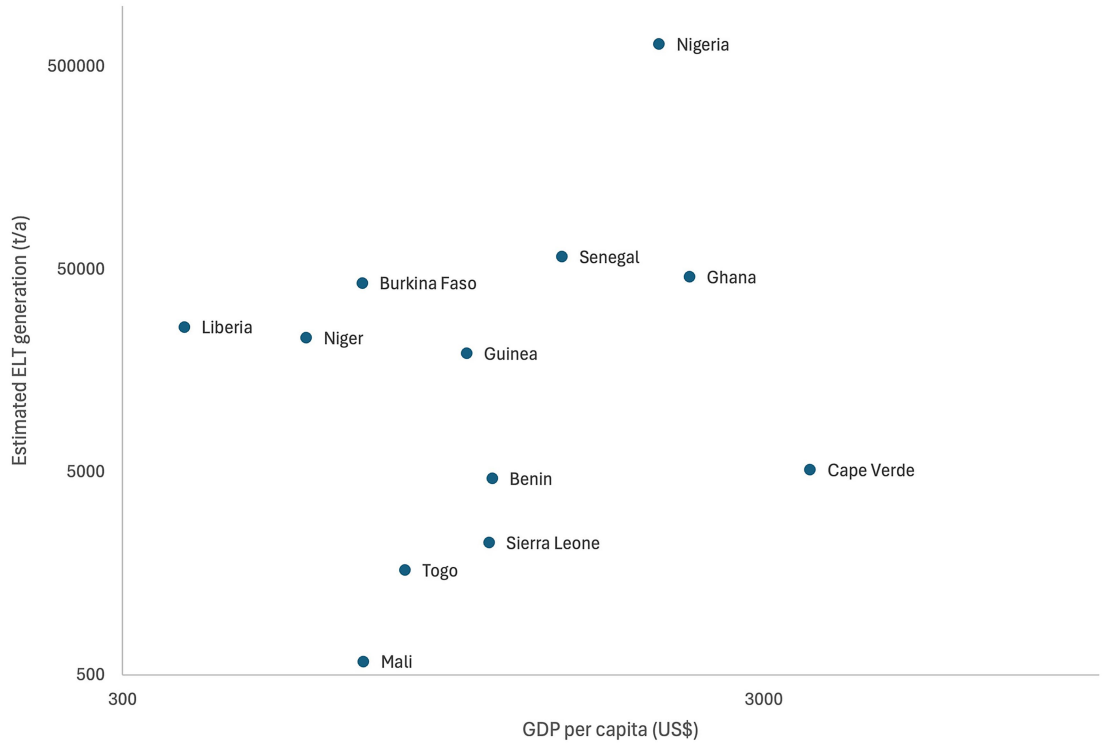

FIGURE 3
Representation of estimated ELT generation (t/a) versus the GDP per capita (in current US$) (World Bank, 2024) in the respective year of estimation (see Table 6).

recycling quotas (ETRMA – European Tyre and Rubber Manufacturers' Association, 2025).

The absence of standardised ELT quantification methods across West Africa represents a significant barrier to effective regional waste management planning (Carlos-Alberola et al., 2021). Unlike developed regions where tyre tracking systems and producer responsibility schemes provide systematic data collection, West African countries operate without coordinated monitoring frameworks. This fragmentation not only limits individual country planning capabilities but also prevents the development of regional circular economy strategies for tyre waste management.

Regional ELT generation patterns and economic drivers

The estimated total annual ELT generation of approximately 840,000 tonnes across the quantifiable countries reveals significant regional disparities that reflect underlying economic and demographic patterns. Nigeria's dominance, accounting for 77% of regional ELT generation despite representing only one of 16 countries, underscores how population size, economic activity, and vehicle fleet density concentrate waste generation in major regional economies.

The relationship between GDP per capita and ELT generation, while showing positive correlation trends, reveals important nuances in West African transportation patterns. Nigeria's position as an outlier—generating massive ELT quantities (646,000 t/a) at moderate GDP per capita ($2,057.9)—suggests that population scale and economic activity density may be more influential factors than per capita wealth in determining regional ELT generation patterns, this is supported by Soltani (2017) who showed a direct correlation between car purchasing power and the income. Together, these findings suggest that while personal wealth drives individual tyre consumption decisions, the total national ELT burden depends on the aggregate effect of population size multiplied by individual economic activity levels.

The clustering of smaller economies with ELT generation below 60,000 t/a indicates that most West African countries face relatively manageable ELT volumes that could potentially be addressed through regional cooperation and shared infrastructure investments. However, countries like Ghana (46,000 t/a) and Senegal (58,000 t/a) represent intermediate-scale challenges requiring substantial but achievable management capacity development.

Vehicle fleet composition and waste stream implications

The diversity in vehicle fleet compositions across West Africa has profound implications for ELT management strategies. The identification of three distinct fleet patterns—motorcycle-dominant (Burkina Faso 83%, Benin 70%, Togo 67%), car-dominant (most countries 50–67%), and mixed commercial vehicle compositions—indicates that regional ELT management approaches must accommodate fundamentally different waste stream characteristics.

Motorcycle-dominant countries generate high volumes of smaller, lighter tyres that may be more suitable for certain recycling processes but offer different material recovery potential compared to passenger car tyres (Sitepu et al., 2020).

The variation in commercial vehicle representation (buses 1–20%, heavy-duty vehicles 3–25%) across countries indicates significant differences in the availability of high-value tyre waste streams (Ross, 2019). Heavy-duty vehicle tyres contain substantially more recoverable materials and often justify more sophisticated recycling investments, suggesting that countries with higher commercial vehicle proportions may have better economic prospects for developing formal ELT management infrastructure (Valentini and Pegoretti, 2022).

A data comparison from the GDP–ELT correlation (Figure 3) highlights the importance of fleet composition. Mali, for instance, has a GDP per capita (711.7 US$) comparable to Burkina Faso's (709.10 US$), yet generates less than 1,000 tonnes/year ELT compared to Burkina Faso's ~ 43,000 tonnes/year ELT. The difference is partly attributable to Burkina Faso's motorcycle-dominated fleet, which—despite smaller tyre sizes—has far greater numbers per capita than Mali's more car-heavy fleet.

Methodological reliability and data quality implications

The reliability assessment of available ELT data reveals critical methodological challenges that affect policy development across the region. The identification of only two countries (Ghana and Burkina Faso) with "high reliability" data, compared to several with "low reliability" sources, indicates that even where ELT data exists, its utility for evidence-based policy development is severely constrained.

The reliance on newspaper sources for substantial ELT estimates (Nigeria's 2.5 million tonnes, Côte d'Ivoire's 350,000 tonnes) highlights the absence of institutional capacity for systematic waste quantification. This methodological weakness has direct implications for investment planning, as private sector and international development partners require reliable data for infrastructure development and technology deployment decisions.

The temporal inconsistencies in vehicle fleet data (spanning 2007–2020) represent more than methodological limitations, they reflect the absence of coordinated regional transportation monitoring systems. This temporal fragmentation severely constrains the ability to track trends, evaluate policy interventions, or develop dynamic waste management planning approaches.

The 13-year span of baseline years (2007–2020) used in this study introduces substantial uncertainty into regional ELT generation estimates, particularly considering the rapid vehicle fleet expansion patterns observed across West Africa during this period (Osei et al., 2025). Vehicle ownership rates in the region have increased substantially over the past decade, driven by economic growth, urbanisation, and improved access to vehicle financing (Yussif et al., 2023). This motorization trend means that ELT estimates based on older baseline data could fundamentally misrepresent current waste generation realities.

The temporal inconsistencies create systematic bias in regional ELT quantification. Countries relying on older baseline data likely underestimate current ELT generation, potentially by substantial margins given the rapid vehicle fleet expansion observed across the region, while those using recent data provide more representative contemporary estimates. This temporal fragmentation, combined with varying data quality and methodological approaches, introduces considerable uncertainty into the regional total of 840,000 tonnes. Such uncertainty significantly constrains evidence-based policy development and infrastructure planning decisions.

The compounding effects of temporal inconsistency extend beyond simple quantification errors. Vehicle fleet growth rates vary substantially across countries and vehicle categories, with motorcycles and commercial vehicles often showing different expansion trajectories than passenger cars (Schievelbein et al., 2018). Countries experiencing rapid motorcycle adoption, such as Togo, Burkina Faso or Benin, may show ELT generation patterns that differ markedly from historical trends, making temporal extrapolation particularly problematic.

These temporal data limitations have direct implications for investment planning and regional cooperation frameworks. Infrastructure investments for ELT management typically require long planning horizons and substantial capital commitments. The current temporal inconsistencies prevent reliable trend analysis, making it impossible to distinguish between countries with genuinely low ELT generation and those simply using outdated baseline data. This uncertainty creates risks of both over-investment based on inflated projections and under-investment based on obsolete information, ultimately constraining the development of efficient regional ELT management systems.

Economic and environmental policy implications

The findings have clear policy implications. West Africa urgently requires a standardised ELT data collection and reporting framework that ensures harmonised vehicle registration categories, regular updates, and transparent estimation methodologies. Adaptation of Extended Producer Responsibility (EPR) systems to local contexts offers a feasible pathway. Recent proposals for Togo (Narra et al., 2025b) suggest combining manufacturer accountability, import levies and government incentives to fund formal collection and recycling infrastructure.

Investment in recycling and recovery infrastructure is critical (Gui, 2020). While individual facilities, such as the tyre recycling plant under construction in Togo (Narra et al., 2024) mark progress, they must be supported by nationwide collection networks, dealer take-back schemes, and integration with the informal sector (Mutezo et al., 2021).

At the national level, governments should prioritise establishing legal frameworks that mandate systematic ELT data collection through vehicle registration systems and import/export tracking mechanisms. National statistical offices require capacity building to integrate ELT quantification into regular waste monitoring protocols, with standardised reporting formats aligned to regional frameworks. Ministries of Environment and Transport must collaborate to develop vehicle fleet databases that capture replacement frequencies and tyre lifecycle data specific to local operating conditions.

Regional policy coordination through Economic Community of West African States (ECOWAS) frameworks offers substantial

efficiency gains for ELT management. A regional ELT data harmonisation protocol should establish common vehicle categorisation systems, synchronised reporting cycles, and shared database platforms accessible to all member countries. This coordination enables cross-border tyre waste tracking, prevents illegal dumping displacement, and facilitates regional recycling capacity optimization.

Effective ELT management requires coordinated engagement across multiple stakeholder groups with distinct roles and incentives. Tyre importers and vehicle dealers represent primary stakeholders for collection network development through mandatory take-back schemes and deposit systems. These actors possess existing distribution networks and customer relationships that can be leveraged for reverse logistics, but require regulatory frameworks that ensure compliance while maintaining business viability.

Local government authorities serve as essential coordinators between formal waste management systems and community-level collection activities. Municipal governments should establish ELT collection points integrated with existing waste management infrastructure, while district-level authorities can facilitate land allocation for processing facilities and provide regulatory oversight for informal sector integration.

International cooperation should focus on addressing the fundamental accountability gap where multinational tyre manufacturers benefit economically while contributing minimally to waste management costs in West Africa. Analysis of ELT origins in Togo reveals that 97% of tyres originate from non-African manufacturers, with major multinational corporations (Continental AG, Michelin Group, Goodyear, Bridgestone, Hankook) dominating the market while environmental costs are externalised to West African societies (Narra et al., 2025b). This imbalance necessitates international frameworks that extend producer responsibility across borders.

As Narra et al. (2025b) explains, a manufacturer-centric international EPR model represents the most promising cooperative mechanism. Major tyre manufacturers already operate successful EPR programmes in their home regions, with Europe achieving 95% ELT treatment rates and Japan reaching 86% collection rates (ETRMA and EURIC, 2021; WBCSD – World Business Council for Sustainable Development, 2018b). These established systems provide proven frameworks for adaptation to West African contexts, where manufacturers could establish international industry consortiums with explicit waste management responsibilities in developing markets.

The financial mechanism should integrate waste management costs into manufacturers' global pricing structures through cross-subsidisation models. A nominal fee incorporated into retail prices of new tyres sold in primary markets could effectively fund waste management in secondary markets, acknowledging the full lifecycle environmental impact of manufactured products beyond their first useful life. This approach addresses the compressed usage timeframe in West Africa, where tyres typically last 7.4 months compared to multiple years in manufacturing countries.

International platforms such as the World Business Council for Sustainable Development offer established frameworks for voluntary industry commitments. Implementation could commence through multilateral agreements with graduated approaches beginning with basic collection and processing capabilities before expanding to comprehensive recycling systems. A potential success of this model in Togo could provide a demonstration effect for regional expansion across West Africa.

Technology transfer partnerships require particular attention to second-hand tyre import dependencies. Unlike traditional EPR systems focused on new product sales, West African contexts require adapted frameworks that account for the transboundary movement of tyres from developed countries, where they escape origin-country regulations and become waste in destination countries (Narra et al., 2025b). International cooperation must therefore address regulatory gaps in global tyre lifecycle management while facilitating appropriate technology and financing transfers.

Study limitations and future research directions

This study's decision to document data limitations rather than attempt interpolation or standardisation provides an accurate representation of current knowledge gaps but limits the comprehensiveness of regional ELT quantification. Future research should prioritise primary data collection in countries with insufficient information, particularly high-population countries like Côte d'Ivoire where ELT generation is likely substantial.

The reliance on varying baseline years (2007–2020) introduces temporal uncertainties that could affect the accuracy of regional totals. Longitudinal studies examining ELT generation trends over time would provide valuable insights for future planning and policy development.

The absence of data on tyre import/export patterns, average tyre lifespans, and replacement behaviours in West African contexts represents important knowledge gaps that could significantly affect ELT generation estimates. Future research incorporating these factors could substantially improve quantification accuracy.

Conclusion

This study establishes the first comprehensive framework for ELT quantification across West Africa, revealing both the scale of the waste management challenge and the profound data gaps that constrain effective policy development. The estimated 840,000+ tonnes of annual ELT generation across quantifiable countries, dominated by Nigeria's 646,000 tonnes, represents a substantial waste stream requiring coordinated regional management approaches.

The documented data scarcity, methodological inconsistencies, and institutional capacity limitations indicate that addressing West Africa's ELT challenge requires simultaneous investments in monitoring systems, processing infrastructure, and regional coordination mechanisms. The diversity in fleet compositions and economic conditions across countries suggests that successful ELT management will require flexible, adaptive approaches rather than standardised solutions.

Most critically, this research demonstrates that the development of effective ELT management strategies in West Africa must begin with substantial improvements in data collection and monitoring systems. Without reliable, consistent quantification methods, the region cannot develop evidence-based policies, attract appropriate

investments, or measure progress towards sustainable waste management objectives.

Data availability statement

Publicly available datasets were analysed in this study. This data can be found at: Tan et al. (2023a,b,c,d,e,f,g,h,i,j,k,l,m,n,o).

Author contributions

M-MN: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. KA: Supervision, Writing – review & editing. SN: Funding acquisition, Writing – review & editing. MN: Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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