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Analysis of Nigerian Leather Industries Economic Sustainability Using Parametric Cost Model Approach: A Case Study of Establishing Aba Leather Industry

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Abstract

The Nigerian leather industry is a major driver of sustainable employment and Nigeria's output. The industry is a significant source of non-oil revenue for Nigeria, with a nationwide supply chain and rippling value. Nigeria's leather sector has produced N24.5 billion ($700 million) in revenue annually and has the potential to support the creation of around 700,000 direct and indirect jobs. However, one of Nigeria's leather industries in Aba, Abia State, is thriving in chaos, hampered by the government's inability to provide the right environment. The aim of this study is to analyze Nigeria's leather industry processes, economic sustainability, and alternative advancements by developing recycling and processing strategies for the recovery of leather waste and also proposing a cost model to support economic decisions regarding the implementation of a circular approach in the leather industry. The result of the finding using the parametric cost model shows that an overall economic gain is conceivable with only 52% of the expenses incurred in the direct conversion of waste into recycled products. It can also be said that the largest category of expenditures is capital equipment for waste collection and processing, with transportation costs double that of the case study.

***Keywords**: Leather, CAL framework, Waste, parametric cost model.*

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1. Introduction

A significant international commodity is leather. Leather is a flexible, strong (high tensile strength), moldable, supple, and durable product. It is also a good thermal insulator. Leather is resistant to tearing, piercing, abrasion, water, fire, and mold; it is permeable to water vapor. Leather is valued by humans for clothing and shelter and can be dyed and buffed to a shiny or velvety (in suede) appearance [1]. Processing of skin or hides into stable material – leather is known as tanning. Leather, the primary product from the tanning industry, where the product has got its applications in making footwear, furniture, bags, etc. With an estimated annual global trade value of over $200 billion for leather and leather goods, the leather sector is significant to the economy [2].

The commercial center of Abia State, Aba, is a bustling, vibrant town. The city is well-known for its increasing number of business-minded citizens, the majority of them are lured by the chance to pursue education and start their own businesses. With a population of over 600,000, of which over 15% are craftsmen making leather shoes, clothing, and other machinery, it has been estimated that one in six Aba residents work as both an employer and a manufacturer. With the renowned Igbo apprenticeship system as its cornerstone, Aba takes pride in being Nigeria's industrial capital.

Once used to disparagingly suggest that the product is of inferior quality, "Na Aba Made" and "Made in Aba" are quickly evolving into positive expressions. The Shoe Manufacturing sector in Aba has expanded to an estimated value of N120 billion as a result of this shift in perspective and increased recognition internationally [3]. Pillai and Archana [4] successfully grew microorganisms on chromium-containing tannery shavings. This produced a useful protease byproduct that could be used in the pre-tanning process.

The creation of fertilizer from vegetable-tanned leather dust is one instance of the biological treatment of waste from the leather manufacturing process. As shown in Figure 1, this dust is created during the carding and cutting processes used in the footwear manufacturing business. It is then combined with calcium carbonate and water to create fertilizer for use in agriculture. It is critical to note that during the production process, this dust must be kept apart from leather dust that has been chrome-tanned; otherwise, the application cannot be completed due to the dangerous nature of the chromium-containing dust. [6, 7].

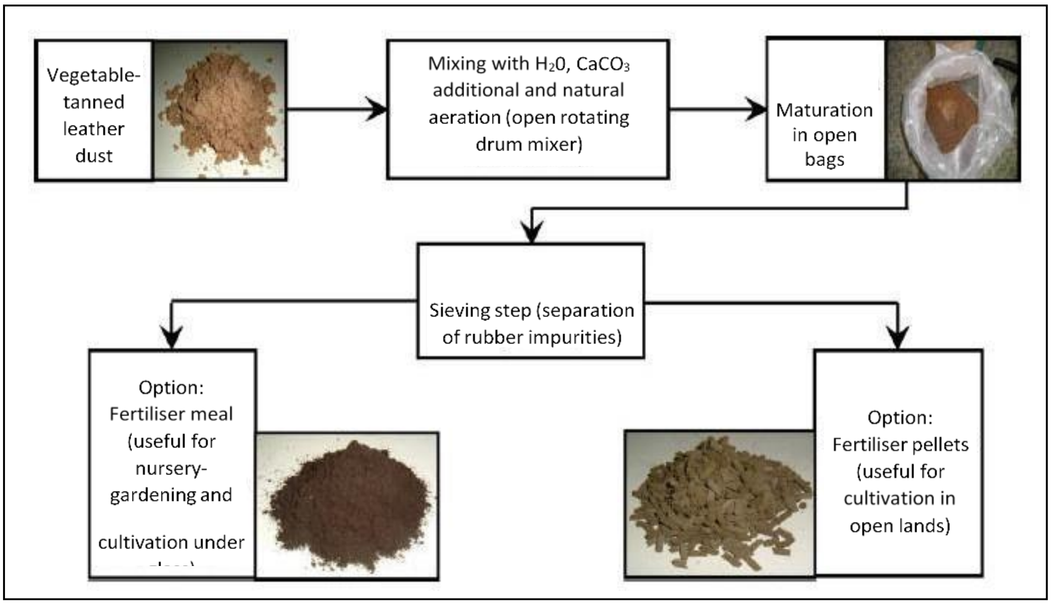

Figure 1: Production of fertilizer from chrome-tanned leather dust [6]

In the United Kingdom (UK), for example, municipal recycling systems have been established for high-volume home garbage, including cardboard, plastics, metals, and glass. Waste products are separated at the source by people (households or small businesses), collected by local authorities, and sent to Material Recovery Facilities (MRFs). Once the waste materials reach the MRF, they are sorted and baled, ready to be sold on the recycled materials market for use in other products.

However, recycling inside commercial and industrial spaces is occasionally handled independently of municipal recycling initiatives. The reason for the split is that industrial uses need more complicated materials, and specialized recycling contractors are required to properly process the materials for reuse. [8]

1.1 Environmental Concerns and Sustainability in Leather Manufacturing

The production of leather poses serious sustainability and environmental issues. The use of dangerous chemicals, excessive water consumption, air and water pollution, and deforestation are some of the primary environmental issues related to the manufacture of leather [10].

The use of dangerous chemicals during the tanning process is one of the biggest environmental issues in the leather industry. Usually, chemicals like chromium, which are hazardous to both people and the environment, are used to tan leather. These substances have the potential to pollute the air, land, and water, causing harm to the ecosystem and health issues [11, 12,].

The development of sustainable leather production techniques aims to address these environmental issues. In order to produce leather in a sustainable manner, less hazardous chemicals, less water, and renewable resources must be used. Using tanning ingredients derived from plants and reusing wastewater are two examples. Furthermore, several businesses have put traceability mechanisms in place to guarantee that the leather they buy comes from ethical and sustainable suppliers.

In conclusion, the production of leather can have a substantial negative influence on the environment, but these effects can be lessened by implementing sustainable techniques. To guarantee a more sustainable and accountable future for leather manufacturing, the industry must give environmental issues top priority and take appropriate steps to solve them.

2. Materials and Methods

2.1 Study Area and Data Collection

The study was conducted in Aba, which is the commercial hub of Abia State, which is located in southeast Nigeria. Aba is home to several sizable marketplaces, enormous agricultural areas, and a sizable number of small- to medium-sized businesses. The people who live there are renowned for being hardworking and creative. However, as the geographical map in Figure 2 illustrates, Aba metropolitan is situated between 5° 07' N and 7° 22' E, and it is bordered by four other states: Imo, Enugu, Akwa Ibom, and Rivers.

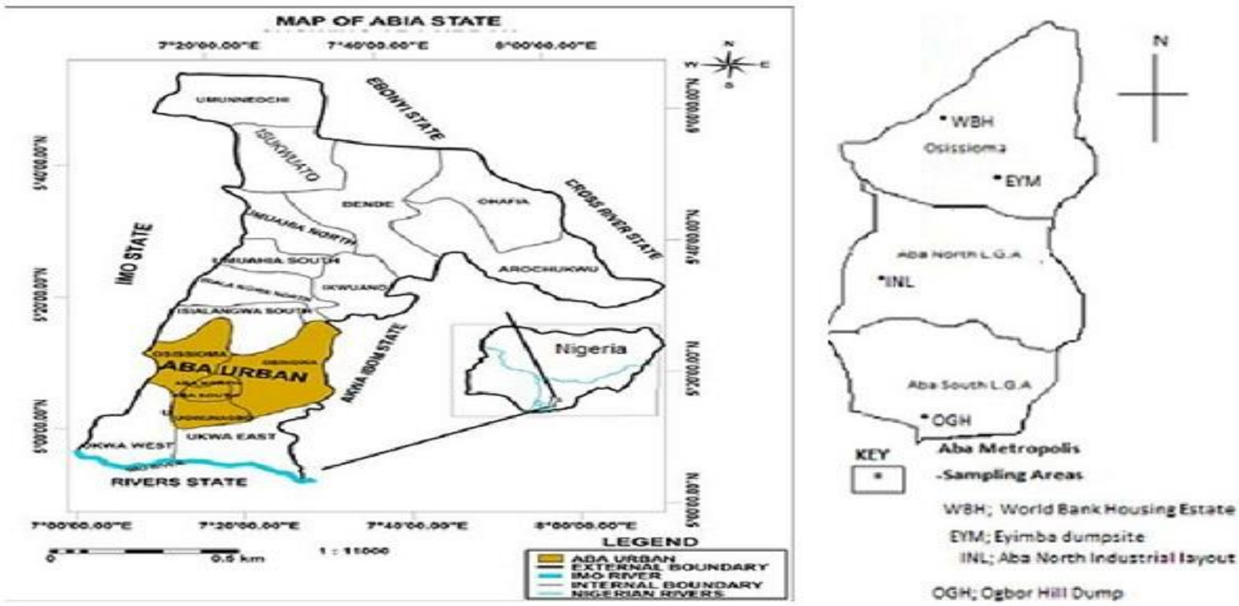

Figure 2: Map of Abia State and Aba metropolis -the study area

2.2 Research Design

In this study, a framework named The Circular Approach within the Leather Industry (CAL) framework was adopted. It is based on the core ideas of the circular manufacturing concept, which include reducing waste and increasing resource productivity.

By characterizing existing leather waste streams at various points throughout the material and product lifecycles, the characteristics of the waste may be recognized. This makes it possible to determine the waste's primary characteristics and will show which material combinations are most frequently found in leather-containing products.
As shown in Figure 3, the second stage of the CAL framework establishes collecting techniques and creates waste grouping strategies that may help the leather sector adopt a circular strategy.

In this framework stage, two waste grouping strategies are developed once the mechanisms for collecting leather waste throughout its lifespan are identified. These tactics are designed to boost the quantity and quality of recycled materials, which will improve a leather recycling system's financial sustainability.

Evaluating the recycling methods that may be used to recover leather material from waste is essential to developing a circular approach within the leather Industry. A thorough analysis of the usual material content of leather waste and products will be provided at Stage 3 of the framework. In this analysis, material properties will be described and connected to end-of-life technology aspects; Figure 4 depicts this phase.

Figure 3: The four stages in the Circular Approach within the Leather Industry (CAL) framework

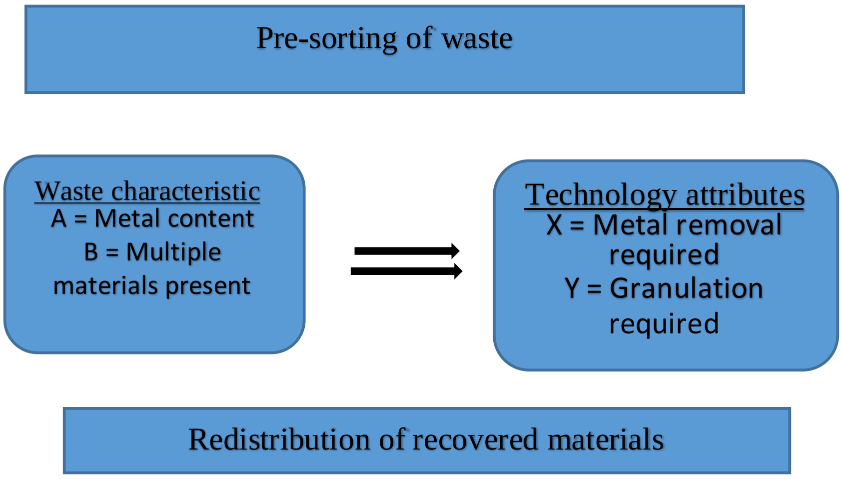

Figure 4: Stage 3 of the CAL framework

Figure 5 shows the last step of the framework, which develops a cost model to assess the economic feasibility of adopting a circular strategy. In this framework stage, the initial job is to specify how the cost model may assist decisions related to leather recycling systems. In the next part, the basics of decision-making are covered.

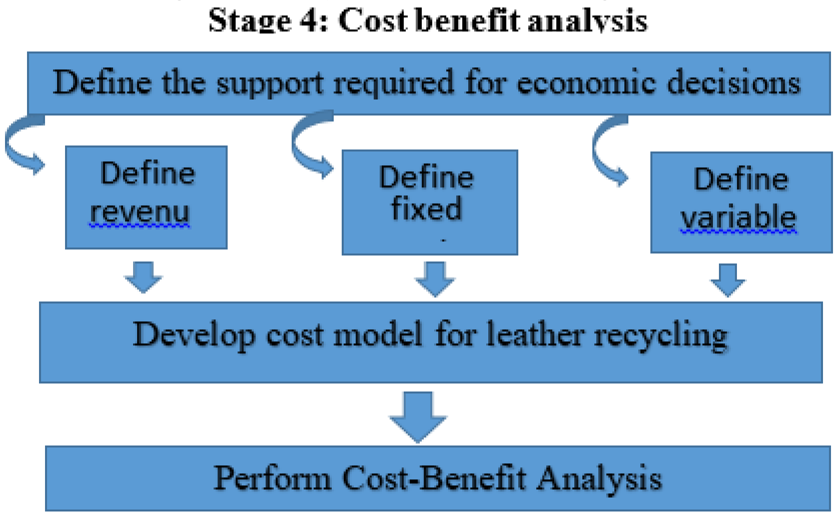

Figure 5: Stage 4 of the CAL framework

Determining whether decisions are made proactively or reactively is crucial since it has a significant impact on choices in the three main categories. At the start of a product's lifespan, proactive decisions are taken that aid in the planning of recycling and recovery systems for undeveloped items. After waste has been generated, reactive decisions are taken, and recycling systems are developed to handle the waste and recover materials. Both methods of decision-making have an impact on how choices are made.

The economic assessment of the selected recycling systems is the second step of developing a cost model. A proven, reproducible, and verifiable approach to the economic assessment of various scenarios is required for this aim. We examined a number of techniques throughout the framework's development, including: Cost-effectiveness and cost-benefit analyses. The economic analysis technique known as cost-effectiveness analysis (CEA) contrasts the costs and results of two or more different courses of action. It is frequently employed in fields like health care, where it is not necessarily suitable to profit from a project's results. It has been used in various areas, including recycling programs [8].

Cost-benefit analysis is a method that assesses the financial advantages and disadvantages of various options, choices, or regulations.

CBA's two primary goals are:
1. To offer a means of project comparison by weighing the entire anticipated costs and benefits.
2. To determine if an investment is wise and if its advantages exceed its drawbacks.

Cost benefit analysis proceeds in four essential steps:
1. Identification of relevant costs and benefits
2. Measurement of costs and benefits
3. Comparison of cost and benefit streams
4. Project selection

2.3 Parametric cost model

A cost-benefit analysis (CBA) technique is applied to offer an economic measure for assessing various leather recycling scenarios. A comprehensive range of scenarios can be supported by CBA, which necessitates the quantification of all pertinent costs (C) and revenues, or benefits (B). The word "benefits" in this research refers primarily to the monetary advantages of a recycling system. The present value (PV), which incorporates a discount rate (i) to account for changes in the monetary worth over time (t), is used to quantify these values [5]. The equations used to express the total costs and revenues associated with a given scenario are shown in Equations 1 and 2, respectively:

$$PV(C) = \sum_{t=0}^{n} \frac{C_t}{(1+i)^t} \quad (1)$$

$$PV(B) = \sum_{t=0}^{n} \frac{B}{(1+i)^t} \quad (2)$$

A parametric cost-benefit model that can depict any leather recycling scenario is needed to assess leather recycling situations. All expenses and income generated throughout the recycling process should be included in the model. As a result, a parametric cost model that serves as an example has been created and can be easily modified to fit various scenarios.

The cost-benefit ratio for leather recycling ($CBR_{leather}$) is defined in Equation 3:

$$CBR_{leather} = \frac{\sum_{m=1}^{n} C_m}{\sum_{m=1}^{n} B_m} \quad (3)$$

The following areas of emphasis are crucial to developing the cost model and mapping revenue potential with fixed and variable costs:

- Waste collection
- Logistics
- Processing
- Redistribution

The economic parameters defined for these fixed costs are:

1. Fixed cost of industrial collection equipment, CF_{ICE}
2. Fixed cost of retail collection, CF_{RC}
3. Fixed cost of postal collection, CF_{PC}
4. Fixed cost of kerbside collection, CF_{KC}
5. Fixed cost of localised recycling centres, CF_{LRC}
6. Fixed costs of waste transportation vehicles, CF_{WTV}
7. Fixed costs of renting/leasing premises, CF_{PREM}

The aforementioned parameters are interpreted to include all fixed costs related to each method for the purpose of simplicity. For example, a localized recycling center may have additional fixed costs related to it, such as collection infrastructure, drainage, power, lighting, and security, among other costs.

Variable costs

Costs that change according on the amount of output material generated are known as variable costs. The following should be taken into account when estimating the variable expenses related to gathering and shipping leather waste:

- The operational characteristics of the waste such as the geographic location and the volume of waste will impact the costs of transporting the waste from the site where it is generated to the site that it will be processed. For instance, if two leather wastes streams are generated, one from a tannery in Kano State and one from a footwear manufacturer in the Aba, Abia State, then transporting them both to a processing plant in West region of Nigeria will have different economic implications.
- The waste collection strategy, since the variable costs linked to an in-store recycling program will differ from those linked to an in-factory waste collection program.
- The material or product density in the waste stream affects the variable transportation costs since the price of shipping large, heavy leather furniture will differ from the price of shipping small amounts of wasteful footwear.
- What is the volume of waste that is going to be collected? What is the frequency of collection?
- What form will the transportation take? Road, rail, air or sea?
- What is the distance from the collection point to the central waste storage or processing depot?

The cost of hiring personnel to collect the waste, the cost of fuel for the transportation vehicles, and the cost of maintaining and repairing the collecting equipment are the variable expenses related to the collection and transportation of leather waste.

As mentioned earlier, it may be necessary to purchase the waste materials from waste producers depending on the material value; this can also be a variable cost because it is dependent on the tonnage purchased.

The economic parameters defined for these variable costs are:

1. Variable cost of waste acquisition, CV_{WA}
2. Variable cost of collection and transportation staff (labour), $CVCTS$
3. Variable cost of fuel for transportation, CV_{FT}
4. Variable cost of maintenance and repair, CV_{MR}

It is necessary to realize that the majority of these expenses are products of other expenses. For instance, maintenance expenses can be divided into reactive, or unscheduled, maintenance and planned maintenance. Predicted maintenance tasks are simple to forecast and incorporate into a recycling system's economic model. The more complex reactive maintenance tasks have a higher cost, which is determined by the following factors:

- The cost of replacement parts for equipment
- The hourly rate or call out rate for a maintenance engineer
- The revenue lost due to the downtime of the machine

These costs are represented in Equation.4:

CV_{MR} = (*cost replacement parts* + (*cost per hour for engineer x No. of hours repair time*) + (*cost per hour of revenue lost x No. of hours downtime of machine or system*))

$$CV_{MR} = CV_{RP} + (CV_{ET} \times H_{RT}) + (R_{L-DT} \times H_{DT}) \quad (4)$$

Where:

CV_{RP} = *Cost of replacement parts*

$CVET$ = *Cost per hour for maintenance engineer*

H_{RT} = *No. of hours the maintenance engineer took to repair equipment*

R_{L-DT} = *Revenue lost per hour due to downtime of equipment or system*

H_{DT} = *No. of hours that the equipment or system was out of action*

The location and quantity of accessible reprocessing sites will play a major role in determining the variable transportation costs, which might be large given the possibility for worldwide selling of leather goods. It is essential to remember that the amount of material being gathered, processed, or disposed of determines how much each variable will cost. For example, the amount of money required to dispose of waste in a landfill will vary depending on the quantity of materials that must be disposed of. The cost per tonne for material collection, processing, or disposal is multiplied by the total amount of material being collected, processed, or disposed of to get all the parameters for variable costs.

Variable costs

Variable costs, which include labour, consumables, and energy, are expenses related to the daily operation of the recycling line that change depending on the volume of material processed. As a result, variable costs are expressed in terms of cost per tonne of material.

The following variables have an impact on the variable expenses that are incurred:

- Flow rate of the recycling system
- The quantity of processes utilized in the recycling system; the more processes, the greater the energy consumption for their operation.
- The volume of material that is being processed

The waste stream's material composition. For instance, the cost of sorting a waste stream containing more embedded metal will be higher than that of a waste stream containing no metal. The variable costs associated with creating a leather recycling line are:

1. Cost of labour for sorting waste materials, CV_{LS}
2. Cost of energy for equipment, CV_{EE}
3. Cost of labour for operating the processing equipment, CV_{LP}
4. Cost of consumables for use during processing, CV_{CC}
5. Cost of redistribution (shipping) of recovered materials, CV_{CRD}
6. Costs of disposing of unrecoverable materials (landfill costs), CV_{DIS}

Cost of energy for processing equipment

It is significant to remember that a large number of the expenses mentioned above are products of other expenses. For example, the following factors affect how much energy is needed to run the processing machinery:

• Throughput rate of the recycling system (in tonnes per hour)

• The standing rate fee that a company will pay on an annual basis to their energy supplier

• The price per kwh for the energy that the company uses

These costs are represented in Equation

Running cost = (energy consumption x energy cost/throughput)

$$CV_{EE} = \frac{CV_{SC}/24}{T_S} + \left(U_{EPE} * \frac{CV_{KWH}}{T_S}\right) \quad (5)$$

Where:

CV_{SC} $= Cost\ of\ standing\ charge\ imposed\ by\ energy\ company\ in\ pounds\ per\ day$ (24 *hrs*)

U_{EPE} = *Power rating for equipment in kW*

CV_{kwh} = *Cost per kwh of energy from energy supplier (£/kwh)*

T_S = *System throughput in tonnes per hour (T/h)*

Cost of labour for operating processing equipment

Cost of labour for operating the process equipment is a function of the following things:

- *Basic pay rate (age dependent if minimum wage is used)*
- *National insurance contributions*
- *Holiday provision*
- *Statutory pay provision*
- *Pension pay provision*
- No. of hours that the employee is contracted to perform

These costs are represented in Equation 6

$$CV_{LP} = H_{EW} * CV_{BR}\left(1 + \frac{ENIC + HP + SPP + PPP}{100}\right) \quad (6)$$

Where:

$CVLP$ = *Cost of labour for operating processing equipment per annum*

H_{EW} = *hours worked by the employee per annum*

CV_{BR} = *basic rate of pay per hour*

$ENIC$ = *Employers National Insurance Contributions* (% *of basic rate*)

HP = *Holiday Provision* (% *of basic rate*)

SPP = *Statutory Pay Provision* (% *of basic rate*)

PPP = *Pension Pay Provision* (% *of basic rate*)

An overview of the processing and redistribution's economic characteristics

The economic parameters for the processing and redistribution stages of the cost model are summarised in Table 1

Table 1: Economic parameters for the processing and redistribution stages

Economic parameter name	Revenue	Fixed costs	Variable costs
Sale of leather materials	R_{LM}		
Sale of other recovered materials (rubber, textiles, metals)	R_{OM}		
Cost of metal detection and removal equipment		CF_{MD}	
Cost of fragmentation equipment		CF_{FG}	
Cost of post-fragmentation separation equipment		CF_{PFSE}	
Cost of post-fragmentation processing equipment		CF_{PFPE}	
Cost of labour for sorting waste materials			CV_{LS}
Cost of energy for equipment			CV_{EE}
Cost of labour for operating the processing equipment			CV_{LP}
Cost of consumables for use during processing			CV_{CC}
Cost of redistribution (shipping) of recovered materials			CV_{CRD}
Costs of disposing of unrecoverable materials (landfill costs)			CV_{DIS}

The financial gain derived from preventing material from being dumped in a landfill is another advantage of developing and implementing a leather recycling system. The waste producer saves money for each tonne of waste that is kept out of the landfill.

This benefit will be included into the cost model and assigned the economic parameter $RLDF$. The whole benefits of any leather recycling scenario, $B_{leather}$, are determined by adding up all of the money produced from the sale of the components that are recovered throughout the recycling process, the costs incurred for collecting garbage, and the money saved by not disposing of the materials in a landfill. (as expressed in equation 7)

$$B_{leather} = R_{WCS} + R_{LM} + R_{OM} + R_{LDF} \quad (7)$$

$$B_{leather} = R_{WCS} + \left(LM_{weight} * LM_{value}\right) + \left(OM_{weight} + OM_{value}\right) + \left(T_{AL} * L_{TAX}\right) \quad (8)$$

Where,
LM = leather materials
OM = other materials
T_{AL} = Material averted from landfill (tonnes)
L_{TAX} = Cost per tonne of sending material to landfill (N/T)

Equation for fixed costs

The equation presented in this section combines the economic parameters for fixed costs to create an equation that represents the total fixed costs for the system. This provides a parametric equation, shown in Equation 9, for the fixed costs, CF, related to a leather recycling plant.

$$CF = CF_{ICE} + CF_{RC} + CF_{PC} + CF_{KC} + CF_{LRC} + CF_{WTV} + CF_{PREM} + CF_{MD} + CF_{FG} + CF_{PFSE} + CF_{PFPE} \quad (9)$$

Equation for variable costs

The economic characteristics for each variable cost will be combined in the equation given in this section to indicate the overall variable costs for the system. This provides a parametric equation, shown in Equation 10, for the variable costs, VC, related to a leather recycling system.

$$CV = CV_{WA} + CV_{CTS} + CV_{T} + CV_{MR} + CV_{LS} + CV_{EE} + CV_{LP} + CV_{CC} + CV_{CRD} + CV_{DIS} \quad (10)$$

When equations 4 to 6 are substituted into Equation 10 it becomes

$$CV = CV_{WA} + CV_{CTS} + CV_{FT} + [CV_{RP} + (CV_{ET} * H_{RT}) + (R_{L-DT} * H_{DT})] + CV_{LS} + \left(\frac{\frac{CV_{SC}}{24}}{TS} + \left(U_{EPE} * \frac{CV_{kwh}}{T_s}\right)\right) + \left(H_{EW} * CV_{BR}\left(1 + \frac{ENIC + HP + SPP + PPP}{100}\right)\right) + CV_{CC} + CV_{CRD} + CV_{DIS} \quad (11)$$

Final parametric cost-benefit model

The equations representing the income and the fixed and variable expenses related to developing a leather recycling system are combined in this part from the previous sections. When combined, these formulas provide a comprehensive parametric cost model for the leather industry's adoption of a circular strategy.

$$CBR_{leather} = \frac{\sum_{m=1}^{n} C_m}{\sum_{m=1}^{n} B_m} \quad (3)$$

$$B_{leather} = R_{WCS} + \left(LM_{weight} * LM_{value}\right) + \left(OM_{weight} + OM_{value}\right) + \left(T_{AL} * L_{TAX}\right) \quad (8)$$

$$CV = CV_{WA} + CV_{CTS} + CV_{FT} + [CV_{RP} + (CV_{ET} * H_{RT}) + (R_{L-DT} * H_{DT})] + CV_{LS} + \left(\frac{\frac{CV_{SC}}{24}}{TS} + \left(U_{EPE} * \frac{CV_{kwh}}{T_s}\right)\right) + \left(H_{EW} * CV_{BR}\left(1 + \frac{ENIC + HP + SPP + PPP}{100}\right)\right) + CV_{CC} + CV_{CRD} + CV_{DIS} \quad (10)$$

$$\begin{aligned} &\textit{profitability of the system} \\ &= B_{leather} \\ &- [CF_{ICE} + CF_{RC} + CF_{PC} + CF_{KC} + CF_{LRC} + CF_{WTV} + CF_{PREM} + CF_{MD} \\ &+ CF_{PFSE} + CF_{PFPE}] \\ &- \Bigg[CV_{WA} + CV_{CTS} + CV_{FT} + [CV_{RP} + (CV_{ET} * H_{RT}) + (R_{L-DT} * H_{DT})] \\ &+ CV_{LS} + \left\{\frac{CV_{SC}/24}{T_S} + \left(U_{EPE} * \frac{CV_{kwh}}{T_S}\right)\right\} \\ &+ \left(H_{EW} * CV_{BR}\left(1 + \frac{ENIC + HP + SPP + PPP}{100}\right)\right) + CV_{CC} + CV_{CRD} \\ &+ CV_{DIS}\Bigg] \qquad (11) \end{aligned}$$

By combining Equations 4, 8, and 10 it is possible to calculate the cost-benefit ratio, as shown in Equation 12 below:

$$\begin{aligned} \frac{cost}{Benefit} ratio\,(CBR_{leather}) &= CF_{ICE} + CF_{RC} + CF_{PC} + CF_{KC} + CF_{LRC} + CF_{WTV} \\ &+ CF_{PREM} + CF_{MD} + CF_{FG} + CF_{PFSE} + CF_{PEPE}) \\ &+ W_M\{CV_{WA} + CV_{CTS} + CV_{FT} + \{CV_{RP} \\ &+ (CV_{ET} * H_{RT}) + (R_{L-DT} * H_{DT})\} + CV_{LS} + \{\frac{\frac{CV_{SC}}{24}}{T_S} \\ &+ \left(U_{EPE} * \frac{CV_{kwh}}{T_S}\right) + (H_{EW} \\ &* CV_{BR}\left(1 + \frac{ENIC + HP + SPP + PPP}{100}\right)) + CV_{CC} \\ &+ CV_{CRD} + CV_{DIS}\}/R_{WCS} + (LM_{WEIGHT} * LM_{VALUE}) \\ &+ (OM_{WEIGHT} * OM_{VALUE}) \\ &+ (T_{AL} * L_{TAX}) \qquad (12) \end{aligned}$$

3. Results and Discussion

3.1 Analysis Result

In order to implement the case study, the first step was to apply Stages 1 to 3 of the CAL framework to: characterize the waste streams, define the collection and waste grouping strategy, and define the leather processing scenario. The framework's Stages 1 to 3 application produced data and assumptions that are explained in Section 3.2. These assumptions and data were used to make it possible to apply Stage 4 of the framework, which is the cost model, as explained in Section 3.3

3.2 Data and assumptions for the case study

Wastes from tanning and finishing leather hides as well as wastes from the Tannery A factory's leather products manufacturing make up the waste stream taken into consideration in this case study. Data and waste samples were given to the author during a visit to Tannery A. The data provided were compiled from a variety of sources and are based on actual facts and assumptions. To apply the assessment methodologies to the scenarios, more specific information about the economic characteristics of the process stages mentioned is needed; this information is provided in the next section. However, a number of presumptions are first established:

- -Instead of having an outside contractor collect and process the waste, Tannery A will handle the processing and redistribution of the waste they produce inside.
- Waste skips are already in place at Tannery A to collect the many types of waste that are produced throughout the production site.

3.3 Data for revenue of different grades of material

The price that recycled leather of various grades would fetch on the secondary materials market must be known in order to do the cost-benefit analysis. This data is currently unavailable because the industry for recycled leather is still in its infancy. As a result, estimates of the materials' worth were derived from data from earlier research on the recycling of footwear [9]. This data is included in Table 2.

3.4 Application of the economic cost model

Prior to applying the cost model to this case study and evaluating the horizontal garbage collecting and grouping strategy's economic feasibility, all case study revenues, fixed costs, and variable costs had to be determined. Based on scenario 1 (i.e., the horizontal model), an economic assessment of the adoption of a circular strategy in the leather sector is constructed using the parametric models specified in equations 3 to 12.

For the objective of this case study, the recycling system waste collecting and transportation phases are free of expenses and income. As a result, the only expenses and income related to the recycling system's processing and redistribution phases are listed in Table 3.

Equations 11 and 12 were utilized to determine the case study's profitability and cost-benefit ratio following the identification of the fixed costs, variable costs, and revenues. The outcomes of these computations are shown in Table 4.

Table 2: Approximate revenue for four grades of recovered materials [9]

Redistribution scenario	Recycling process	Recovered materials and applications	Revenue (£/tonne)
High grade leather	None required	Primary material types, Off-cuts ofleather suitable for direct re-use in leather products.	£226
Medium -highgrade mixed material	Granulation	100% granulated leather (finished or unfinished) OR mixed material of 80- 95% leather content this is suitable to be reformed into e-leather	£180
Med-low grade mixed material	Granulation, separation	Mixed material of 70-80% leather content, this is suitable to be applied to mop up chemical spills.	£140
Low grademixed material	Granulation, separation	Mixed material (textile, foam and leather) with leather content of less than 70%, this is suitable to be reusedas low-grade insulation material or Underlay	£82

Table 3: Costs and revenues per annum for the processing and redistribution stages of the recycling system presented in case study

Economic parameter name	Revenue	Fixedcosts	Variablecosts
Sale of leather materials (High and med-high quality)	₦403,195		
Sale of low-quality materials	₦ 266.50		
Cost of metal detection and removal equipment		n/a	
Cost of fragmentation equipment		₦ 25,000	
Cost of post-fragmentation separation equipment		₦ 44,000	
Cost of post-fragmentation processingequipment		n/a	
Cost of labour for sorting waste materials			₦ 19,156.80
Cost of energy for equipment/running costs			₦ 4256.20
Cost of labour for operating the processingequipment			₦ 19,156.80
Cost of consumables for use during processing			₦ 5,708.43
Cost of redistribution of recovered materials			₦ 22,790.55
Costs of disposing of unrecoverable materials(landfill costs)			₦ 0.00

Table 4: Annual results of the profitability calculations and the cost-benefit ratio calculations

Cost-benefit results for case study 1	**Benefits**	**Costs**	
Total Revenue generated per annum	N403,461.50		
Total fixed costs for year 1		N69,000.00	
Total variable costs per annum		N71,068.78	
Ratio of fixed to variable costs			1.03
Money saved by avoiding landfill (Based on 100% diversion of waste from landfill)	N190,281.00		
Total annual benefit	**N593,742.50**		
Total annual costs		**N140,068.78**	
Annual profit of the system			**N263,392.72**
Cost-benefit ratio (Inc. landfill avoidance benefit)			**0.24**
Cost-benefit ratio (Exc. Landfill avoidance benefit)			**0.35**

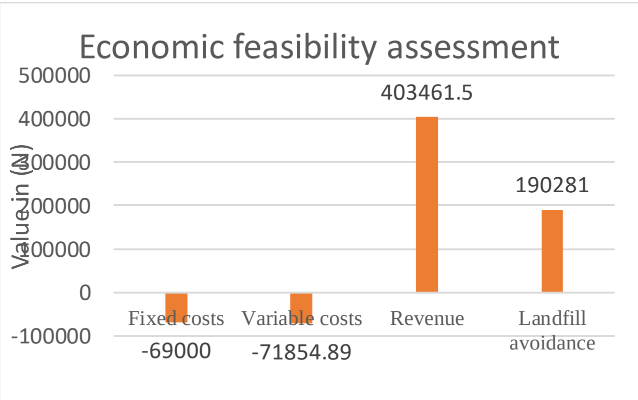

Figure 6: Economic Feasibility assessment

The economic viability dashboard in Figure 6 displays the findings of the economic evaluation for case study one. Revenues and the benefits of avoiding landfills are shown as positive numbers, while costs are shown as negative values. The primary contributor to the system's success is the money made from the sale of the recycled materials, as is seen from Figure 6. When compared to the profits obtained from recycled materials, the system's expenses are negligible. With a ratio of 1.03 for this case study, the fixed costs are more than the variable costs (Table 4). This is explained by the fact that, in contrast to the low operating expenses of the equipment, the initial capital outlay for equipment acquisition is significant

For the economic feasibility evaluations, the cost-benefit ratio forms a single figure result. A low cost-benefit ratio indicates a limited economic impact. An overall economic gain is conceivable and/or extremely plausible for this case study, as shown by the cost-benefit ratio of 0.35 when the landfill avoidance benefit is excluded and 0.24 when it is included (Table 4). Therefore, it is possible to determine that this system will turn a profit in less than a year based on costs of N71,854.89 from year 2 onward (the fixed costs of purchasing equipment do not apply in year 2) and utilizing the cumulative profit each year (see Table 5).:

Table 5: Payback period for case study

Year	Revenue peryear	Cost peryear	Profit	Comments
1	N593,742.50	N140,854.89	N452,887.61	Profit realised in less than 1 year
2	N593,742.50	N71,854.89	N974,775.22	
3	N593,742.50	N71,854.89	N1,496,662.83	
4	N593,742.50	N71,854.89	N2,018,550.44	
5	N593,742.50	N71,854.89	N2,540,438.05	
6	N593,742.50	N71,854.89	N3,062,325.66	
7	N593,742.50	N71,854.89	N3,584,213.27	
8	N593,742.50	N71,854.89	N4,106,100.88	
9	N593,742.50	N71,854.89	N4,627,988.49	
10	N593,742.50	N71,854.89	N5,149,876.10	

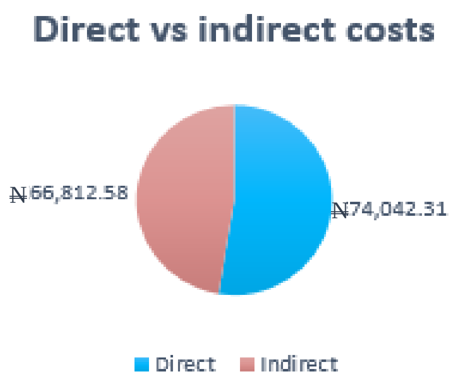

Figure 7: Comparison of direct and indirect costs

Indirect costs, including transportation and consumables, should be minimized in order to maximize the economic efficacy of a recycling system. The majority of the expenditures should be related to the direct production of the recycled materials. It is evident from a comparison of the case study's direct and indirect expenses that the former are greater, with a ratio of 1.1. Figure 7 (b) shows a visual comparison of direct and indirect costs, indicating that only 52% of the expenses are incurred in the direct conversion of garbage into recycled products.

The largest group of costs, which are related to the purchase of capital equipment and operating costs for the system annually. The second largest expense is related to paying staff to operate the equipment, and transportation, predictably, makes up the least amount of the system's cost profile. Lastly, an examination of the system's output quality results shows that, as Figure 8 illustrates, the majority of the material produced is medium quality, while only a small portion is high quality and will fetch the highest price on the recycling materials market.

The revenue profile for system output materials is also useful in this regard. Each output material stream's total revenue is displayed in the chart in Figure 9, with medium quality producing 92.7% of the overall revenue.

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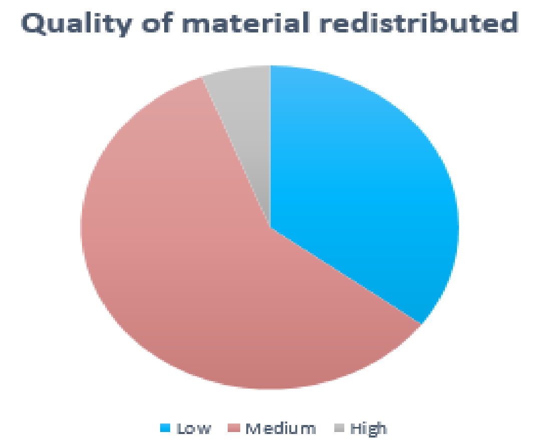

Figure 8: Quality of material redistributed

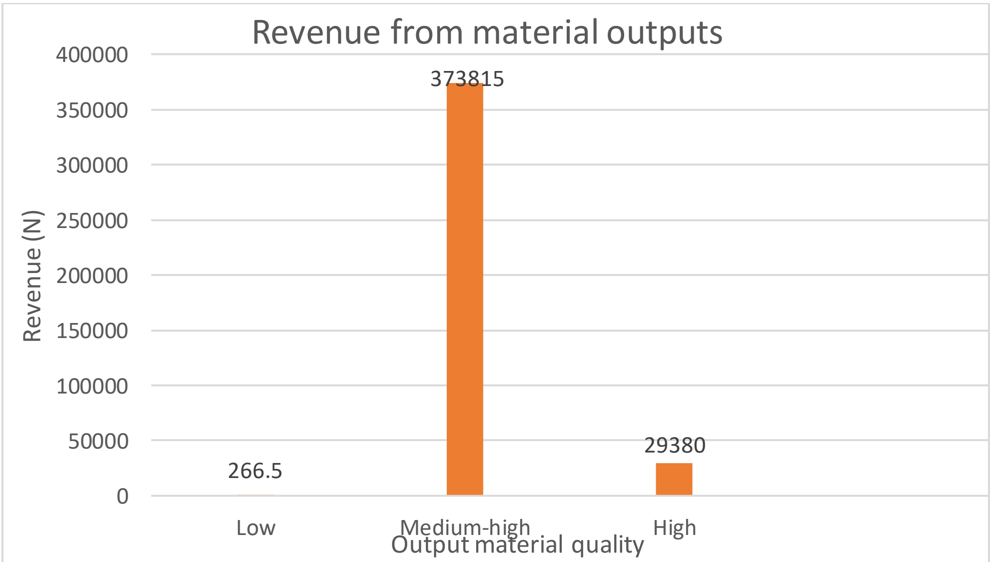

Figure 9: Revenue from material output

Conclusion

To ensure that a systematic strategy was used to address such a complex issue, a framework was methodically developed. The framework offers a four-step process for creating alternate end-of-life scenarios that may be assessed for economic feasibility.

Based to the study, existing infrastructure should be used wherever feasible because the volume of end-of-life leather waste stream did not warrant the creation of custom process technologies.

A number of interrelated variables, such as waste volume, quality, frequency, geographic distribution, and material mix, must be examined holistically in order to determine the economic viability of leather recycling and processing solutions.

A well-known approach that has shown itself to be a helpful instrument for assessing economic viability, CBA is frequently used to assess end-of-life management solutions. The breadth of the model employed in the evaluation process as well as the completeness and quality of the input data have a significant impact on the results produced by CBA; for this reason, the limitations of the research's suggested methodologies are explicitly mentioned in this study.

This study makes the assumption that customers will decide to dispose of their used leather shoes in the regular waste stream, where they will be picked up by their local government. In this case, waste collection authorities throughout Nigeria would gain from avoiding landfills. This raises concerns about who should foot the bill for recycling these leather goods; if several organizations stand to gain from the money generated by avoiding landfills, there may be justification for the Nigerian government and leather product producers to fund the recycling as part of a cooperative initiative.

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Competing interests: The authors declare no competing interests.

Data Availability The authors confirm that the data supporting the findings of this study are available within the article.

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