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Research Article

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Adaptive Life Cycle Costing as an Approach to Achieving Environmental Sustainability: A Study of the Iraqi Soft Drinks Company

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Abstract: The purpose of this study is to create an adaptive framework for Life Cycle Costing (LCC) analysis which can be utilized to improve environmental and economic sustainability in the soft drinks industry by including recycling practices of packaging materials and recycled raw materials in the scope of cost analysis. To meet the aim of the study, a multi-stage exploratory and explanatory approach was used based on the Abductive Methodology with ISO 15686-5:2017 as a key basic for the development of Adaptive Life Cycle Costing framework. An Environmental and Circular Life Cycle Costing (EC-LCC) model was designed and then tested for its applicability by applying it to a case study of Baghdad Soft Drinks Company with available financial information. Analysis results indicate that the benefits of circular economy practices result in lower life cycle costs than in the conventional practice. The study suggests to apply 'Adaptive Life Cycle Costing' in industrial companies for economic and environmental decisions, with the highest priority being the investment in the recovery and recycling of PET bottles and packaging materials, the progressive adoption of recovered materials and enhancement of energy and water use efficiency. It also calls for creating more precise waste collection and monitoring systems, to verify in the field the expected results of the model and to refine the results of investments in circular economy practices.

Keywords: Adaptive Life Cycle Costing; Soft Drinks; Environmental Sustainability; Supply Chains.

Introduction

Creating value is one of the challenges that all companies need to solve to develop growth opportunities, meet the investors' expectations, and be competitive in markets (Dyer et al., 2018: 3141). Value is quite general; it can refer to the unique features that a product or service offers to customers or it can refer to the fact that the consumer gets a high-quality product for the price he/she pays (Salazar, 2017: 27–28). However, at the company level, accounting profit at the end of the fiscal year is not enough to generate value, it does not necessarily mean that the company has paid all the expenses of the resources. The integrated approach is the most frequent approach as it is the business evaluation of the total value chain during the process of value generation, where each company involved in the business is engaged in the approach. This involves the study of inputs and outputs which seek to maximize the value-to-cost relationship; also the definition of the company role, in order to focus more on the activities that generate added values, clearly distinguishable from the rest of the activities (Liao et al., 2017: 144).

Currently, companies must broaden their scope beyond the supply chain to the value chain, since key stakeholders have started to expect companies to take responsibility for the social and environmental consequences arising from the chain of activities that make up the value chain (Medina-Salgado et al., 2021: 1–2). As a result of the current emphasis on responsible use of resources in their environmental, social and economic aspects, the idea of a value chain has been extended by the notion of sustainable development. Thus, the extension of the value chain, namely the creation of sustainable value, not only improves the reputation of the company, but also allows the exploitation of new opportunities within the market, making the company grow and develop (Kaplinsky & Morris, 2018: 323).

Increased awareness of effective resource management, especially non-renewable resources, has come about with rationalization of their use and recycling (Winning et al., 2017: 383). While circular practices have a great positive effect on the environment, they need to be socially and economically viable. Hence, it is essential to have the right instruments to embed sustainability in business models, trying to arrive at the best possible methods to calculate value-added by the company and track the value creation along the value chain.

In the context of impact assessment, companies use a methodology often used in the operational field in the framework of Life Cycle Sustainability Assessment (LCSA). This methodology is used to evaluate the effect of a product or process and considers environmental, economic and social issues regarding sustainability. On the economic side, in particular, the LCSA methodology suggests using LCC as an economic assessment method (Naves, 2019: 293).

There are limited published studies on this subject, which suggest that at least two types of Life Cycle Costing exist: conventional costing and environmental costing. The conventional costing is only concerned with the cost of the company and considers the lifetime of the product. However, in contrast to environmental costing, it takes into account the role and activities of stakeholders that should be internalized, and the external factors that should be internalized are analyzed.

But in terms of decision-making, LCC is perceived only as an additional element of environmental sustainability assessment (ESA), as its economic dimension, is still badly affected by its limitations (Werning & Spinler, 2020: 245). It is not a clear way to establish boundaries of the system and therefore doesn't include the various points of view held by relevant economic actors.

Based on these premises and to counteract the limitations from the previous studies, this research is an exploratory study that will be carried out in several stages, aiming to overcome the aforementioned limitations of Life Cycle Costing (LCC) analysis. The research is divided into two parts: a descriptive analysis to present two models of Life Cycle Costing analysis for assessing the economic aspect of sustainability, which begin with the sector of manufacturing soft drinks. The sector is known for its high raw material, energy and water intensity, and environmental sustainability challenges along the supply chain are a key element for improving the competitiveness and sustainable development. Thus, the research problem is put forward in the form of a research question: How can the use of Adaptive Life Cycle Costing help achieve environmental sustainability by quantifying and managing the environmental costs across the product life cycle?

For this, two integrated frameworks are presented. The first framework was developed from a life cycle perspective to the soft drinks industry based on the nature of the continuous production process starting from the supply of raw materials, manufacturing processes and packing processes, to distribution processes and waste management. The second framework was developed by applying International Organization for Standardization (ISO) principles on LCA to each soft drink product as something considered as a single investment project.

Both models also include the consideration of recycling processes, including waste reduction, the rationalization of water and energy use and bottle recycling, in the right balance and from an environmental and economic point of view. The validity of the two models is then checked in the last step of the analysis by using an applied case study of a soft drinks manufacturing company.

The overarching goal of this research is to give the concept of Life Cycle Costing in a more practical way by building a case with a real scenario and to provide an example of the potential of applying an extended Life Cycle Costing concept in a manufacturing environment such as the Soft Drinks industry, as well as an example of the potential of analysing economic sustainability from the perspective of open innovation. Lastly, the results gained could serve as a basis for further economic assessments of sustainability in production processes in the soft drinks sector

or other industrial sectors where production processes have similar characteristics.
The present study is somewhat alike the one conducted by Medina-Salgado et al. (2021) on ceramic tile sector in Italy. The present study, however, extends the same research for the specific context of Iraq and is applied to the soft drinks manufacturing industry, which is very sensitive to supply chains and emphasizes on recycling. It is the first study that covers Adaptive Life Cycle Costing in Iraq.

Theoretical Background:

Corporate Sustainability (CS) is a company's capacity to sustain its operations in a way that engenders value for the company and society over a long period of time, and Corporate Social Responsibility (CSR) is the commitment to sustaining the balance (Camilleri, 2017: 60). Corporate Social Responsibility (CSR) is based on five main economic theories that have been used as references. According to Agency Theory, the effectiveness of an organization can be understood in terms of coordination and division of tasks, carried out in legal formal contracts wherein the "principal" entrusts the "agent" to fulfill the assigned task efficiently (Calvo & Calvo, 2018: 1224). Conversely, Stakeholder Theory emphasizes the connection between stakeholders and companies, and it attempts to balance the needs of all interested parties who may be in favor of or against the attainment of organizational goals (Freeman & Dmytriyev, 2017: 8). Legitimacy Theory assumes that companies are socially accepted and that good economic and financial results are not enough; companies need to be active in the economic and social development of the societies in which they are present (Islam, 2017: 225). Institutional Theory is a theory that concentrates on the social behaviour of companies according to guidelines, rules or laws. Lastly, Resource Based Theory (RBT) focuses on internal, rather than external, variables of an organization, making the resources and unique capabilities of the firm the key elements of its competitive advantage (Brower & Dacin, 2020: 806).

The two terms Corporate Social Responsibility (CSR) and Corporate Sustainability (CS) are closely linked and are part of Corporate Sustainability, both with the objective of fostering ethical business development (Haslinger et al., 2026: 2). Corporate Sustainability aims to formulate strategies that will increase the corporate growth and profit while providing long-term value to the stakeholders without compromising people, environment and economy. For Corporate Sustainability, this means that it concentrates on all actors of the value chain in search of new market opportunities. Unlike CSR, the scope of the analysis of the outcome of the company through CSR is directed towards the social dimension (Li et al., 2026: 3). Corporate Sustainability consequently has a future-oriented perspective while Corporate Social Responsibility has a historical perspective that focuses on preserving and enhancing the company's reputation.

The implementation of these changes requires companies to completely change their approach to creating value: from value adding through material flow processes to the creation of value through waste extraction (Lacirignola & Blanc, 2013: 2–3), with the purpose of reducing the depletion of resources (Bressanelli, 2019: 7396) in the various supply chains. The industrial system should be able to incorporate and recycle wastes and residues at the end of their life cycle. Thus, recycling is understood as a development model of waste being a raw material for another company (Rosemann et al., 2025: 68-69). That is, it is a model that is constantly renewed, and a bridge can be built from the business sector to the natural sector!

The literature on sustainability focuses on two or three kinds of LCC estimates. First, Conventional Life Cycle Costing (C-LCC), which deals with the private costs; that is, a purely economic assessment that reflects the costs of the various life cycle stages that are borne only by the company itself. External costs or not directly experienced costs by the producer are not considered (Song et al., 2020: 8). Environmental Life Cycle Costing (E-LCC), on the other hand, accounts for the life cycle costs of the product accrued by the concerned actors and includes the external impacts which are expected to be internalized (Barkhausen et al., 2023: 407). For instance, a new carbon tax is anticipated to be imposed in the future, or subsidies for the employment of unskilled labor are anticipated over the next two years, so the costs and benefits of that would be included in the calculations of Life Cycle Costing [59].

Last but not least, Societal Life Cycle Costing (S-LCC) incorporates external effects by giving a monetary value to external environment and social impacts identified by Life Cycle Assessment (LCA) and Social Life Cycle Assessment (S-LCA) respectively and translating them to monetary units (Koroma et al., 2025: 2–3). This is how Societal Life Cycle Assessment can support decision making at the societal level – be it by companies or public institutions (Schneider et al., 2021: 1830). Hence these approaches are a complement to the environmental analysis of Life Cycle Assessment.

To operationalize this technique, the economic cost of pollutant emissions should be estimated based, for example, on the willingness to pay of the responsible company to prevent further deterioration or to remedy the resulting damage, while assigning an economic value to the damage according to the selected damage categories, such as human health, ecosystem productivity, abiotic resource stocks, and biodiversity. It should be noted that the objective of Life Cycle Assessment, which is to aggregate all costs and impacts associated with the environmental aspects of the life cycle, entails a significant risk of double counting when environmental damages are monetarily valued (Medina-Salgado et al., 2021: 4).

Research Objective and Methodology:

This study aims to overcome the aforementioned limitations related to Life Cycle Costing by introducing a new approach to the economic dimension of sustainability, based on the context of the soft drinks industry. To achieve this objective, a two-stage exploratory research methodology was adopted:

1. Designing a new expanded framework for Life Cycle Costing analysis.
2. Quantitatively validating the models using production and industrial cost data from the sector.

The study adopted an exploratory and explanatory approach to simulate a set of scenarios related to the applications of Life Cycle Costing (LCC) based on the guidelines provided in various ISO standards. By employing abductive reasoning, a new proposed cost assessment framework was developed to enhance the accuracy of the analysis and the effectiveness of its results. This abductive approach has proven successful in numerous previous studies related to the field of sustainability.

In the second stage of the research, the proposed framework was developed based on ISO 15686-5 (2017) as the primary reference for the analysis. The methodological design of the framework was initially based on the concept of traditional internal costs associated with Life Cycle Costing analysis and was subsequently expanded to incorporate the full-costing philosophy, thereby allowing for the inclusion of a broader range of costs associated with production and consumption processes.

ISO standards in this field constitute an important methodological tool that contributes to standardizing the concepts and terminology associated with Life Cycle Costing measurement, in addition to providing clear and consistent foundations for assessment and decision-making processes. These standards also help establish more consistent expectations regarding life cycle costs and the long-term performance of assets, thereby enhancing the reliability of analytical results and their applicability in practical contexts.

Although the aforementioned standard was primarily designed to assess and forecast the costs of buildings and construction assets, it was adapted in this study to suit the industrial sector by restructuring cost elements according to the different stages of the production process and from a supply chain perspective. In addition, to strengthen the sustainability dimension of Life Cycle Costing analysis, a set of costs associated with circular economy practices was incorporated into the proposed framework, with the aim of supporting the transition toward more sustainable and resource-efficient business models and contributing to achieving a balance between the economic and environmental dimensions in decision-making.

System Boundary

All the factors involved in the final cost of a product in the different steps of the production chain have to be taken into account when assessing the economic impact of a product. When Life Cycle Costing (LCC) is incorporated into the supply chain, a more holistic view of costs is available and the costs' sources can be identified and allocated across the product life cycle. For this reason, it is necessary to generate an inventory analysis of the inputs and outputs of the production process: raw materials, energy, water, etc. used, waste, emissions and final products produced at every stage of the production process.

The life cycle of a soft drink product is applied to all stages of the product's journey from the acquisition of raw materials to the end of the useful life of the packaging and the subsequent recovery, treatment or recycling processes, to maximize the use of resources and reduce environmental effects associated with production operations, as shown in Figure (1). This holistic view helps to monitor the material and financial flows that are connected to the product throughout its life cycle, which will aid more efficient and sustainable decision making.

The soft drink life cycle model encompasses all operations involved in the production of a soft drink and the nature of the interdependencies among these operations, from acquisition of raw materials (such as water, sugar, flavourings, carbon dioxide and packaging materials), manufacturing, filling, distribution and consumption through to waste management and the treatment of used packaging. This model assists in identifying the inputs and outputs involved in each step of the production chain, thus offering an integrated perspective of resource, energy and material flows, and helping to increase energy usage efficiency and meet environmental sustainability goals.

The production process starts by receipt of raw materials, inspection and storage to specific quality and safety parameters in order to use them for the mixing, production and filling processes. Before conducting these operations, it is essential to consider strategic options regarding sources, transportation and storage, in order to limit energy consumption, emissions to the environment and costs along the supply chain. Collaborating with suppliers, transportation firms, and packaging material suppliers is also a critical component in the goal of enhancing the environmental performance of the facility through selecting materials with lower environmental impacts, and more efficient and sustainable transportation options.

The main focus at this stage is on minimising losses of raw materials, energy and water in the production process and reducing waste and emissions in the manufacturing and packaging process. These measures also involve optimising use of resources, recycling industrial water as far as possible, and setting up systems for waste and used packaging management. The environmental benefits are essential to ensure environmental sustainability as it is associated with the rational use of natural resources, the reduction of environmental burdens and the improvement of the economic and environmental long-term performance of the facility.

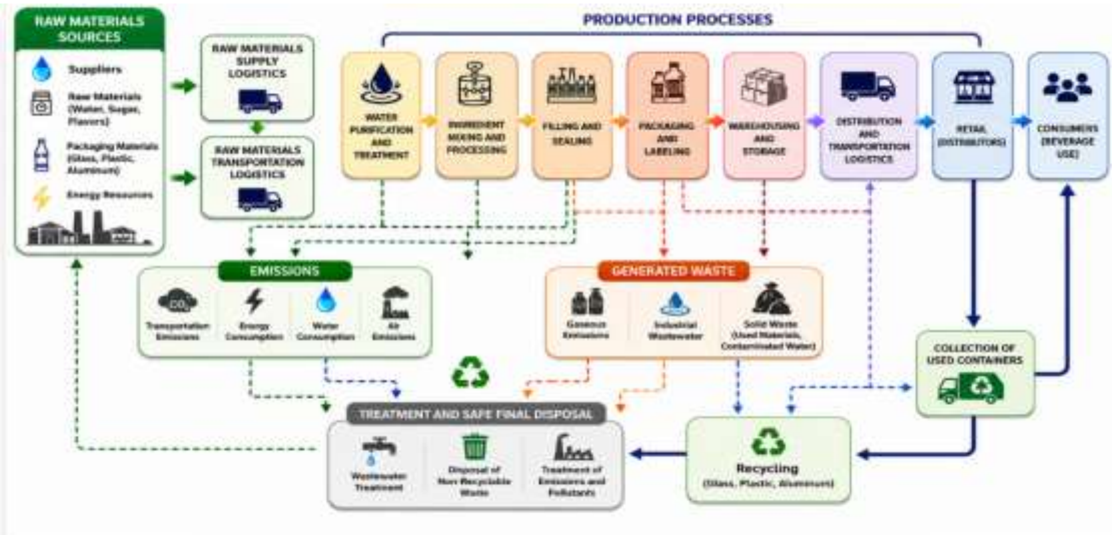

Figure 1. Circular Process Flow Diagram for Soft Drinks Production (Source: Prepared by the Researcher)

Energy recovery and production process efficiency are core pillars in the soft drinks industry, which strives to find operational alternatives and implement advanced production technologies that help reduce the loss of raw materials, energy and water to as low as possible, following lean management and sustainable production principles. Outstanding cooperation with particular external organizations and companies plays an important role here, such as recycling companies, waste treatment service providers and suppliers who can offer more efficient and sustainable solutions concerning raw material and packaging materials.

Once the mixing, processing, filling and sealing are finished the product can take one of two ways. It can be transferred straight to finished product warehouses, ready for shipping to markets, or it may be subjected to other procedures such as final quality checks, labeling and packing according to the specifications of the target market. In these phases, quality control processes play a critical role in minimizing losses caused by filling and packaging mistakes or handling errors and decreasing defective products.

The issue of packaging materials (such as plastic, glass, aluminium and cardboard containers) is also becoming a growing concern through working in cooperation with packaging suppliers and organisations that specialise in the recycling and recovery of packaging materials, aiming to minimise waste and maximise the use of resources. These practices help minimize the environmental and economic impacts of production and distribution systems.

During the last step, soft drinks are channeled to different points of sale, distributors and end consumers. In this phase, the plan should focus on distribution and marketing methods for maximizing efficiency in transport, storage and minimizing fuel consumption and emissions involved in the distribution chain. In addition, programs for empty container recovery and recycling/reuse are becoming more significant to provide opportunities to reduce waste and improve resource-use efficiency.

Therefore, the effective implementation of systems for collecting, treating and recycling used containers, along with environmental management practices all the way from the production to distribution and consumption stages, help to minimise the environmental footprint of the soft drinks sector and increase the sector's capacity to deliver environmental and economic sustainability in the product life cycle.

Calculate the range and costs of life cycle costing (LCC) analysis, including 4-1 Cost Identification.

The scope of the Life Cycle Costing (LCC) methodology is a description of what kind of costs should be considered in the process of performing the LCC. It is important to note that the goal of Life Cycle Costing analysis is to be able to measure the total cost of a product throughout its life cycle and to give quantitative information to aid the management and strategic decision making process in this context.

The life cycle costing analysis in the soft drinks industry does not only account for direct costs of raw materials, production, filling, packaging and distribution processes. Instead, the term applies to indirect costs as well as costs incurred due to legal, environmental and health regulations and costs incurred due to compliance with national and international standards relating to environmental protection and product safety and quality.

It can be seen that this method is also incorporated in the international standard ISO 15686-5:2017, which offers a methodical approach for categorizing costs that can be included in LCA. This standard was originally designed for the construction industry but the principles can be applied to the soft drinks industry by associating costs with the phases of the product life cycle, from the acquisition of raw materials, through production, packaging, distribution and consumption, and finally to waste management and recycling processes.

The standard makes a distinction between Conventional Life Cycle Costing (LCC) and Whole Life Cycle Costing (WLCC). In contrast to traditional Life Cycle Costing analysis, which only considers direct costs of operation and production, Whole Life Cycle Costing extends the analysis to all economic, environmental and social cost of the product as it goes through its life cycle.

Therefore, all costs and expenses incurred in the procurement of raw materials, water treatment, energy usage, production, packaging, storage, transportation, distribution, operation and maintenance of equipment, waste management, treatment and recycling of the wastewater and containers after their use should be included in the assessment of the economic sustainability of soft drink products.

While the benefits from increased efficiencies in resource use and higher rates of container recovery and recycling are important indicators of environmental sustainability, the conventional Life Cycle Costing system may not be able to capture all the economic benefits. However, only conventional costs may be considered, and this could result in the exclusion of many indirect environmental consequences of production processes.

Environmental costs are typically only considered if they can be quantified, for example environmental fees, fines for pollution, compliance costs to environmental legislation or the costs of environmental policies and exemptions. The conventional costing system may not fully reflect other external environmental impacts, including the depletion of natural resources or the longer-term impact on the environment from energy use, emissions and waste. This requires the development of a more complete Adaptive Life Cycle Costing framework that considers these aspects and fortifies the capacity of the facility to reach environmental and economic sustainability at the same time. See Figure (2).

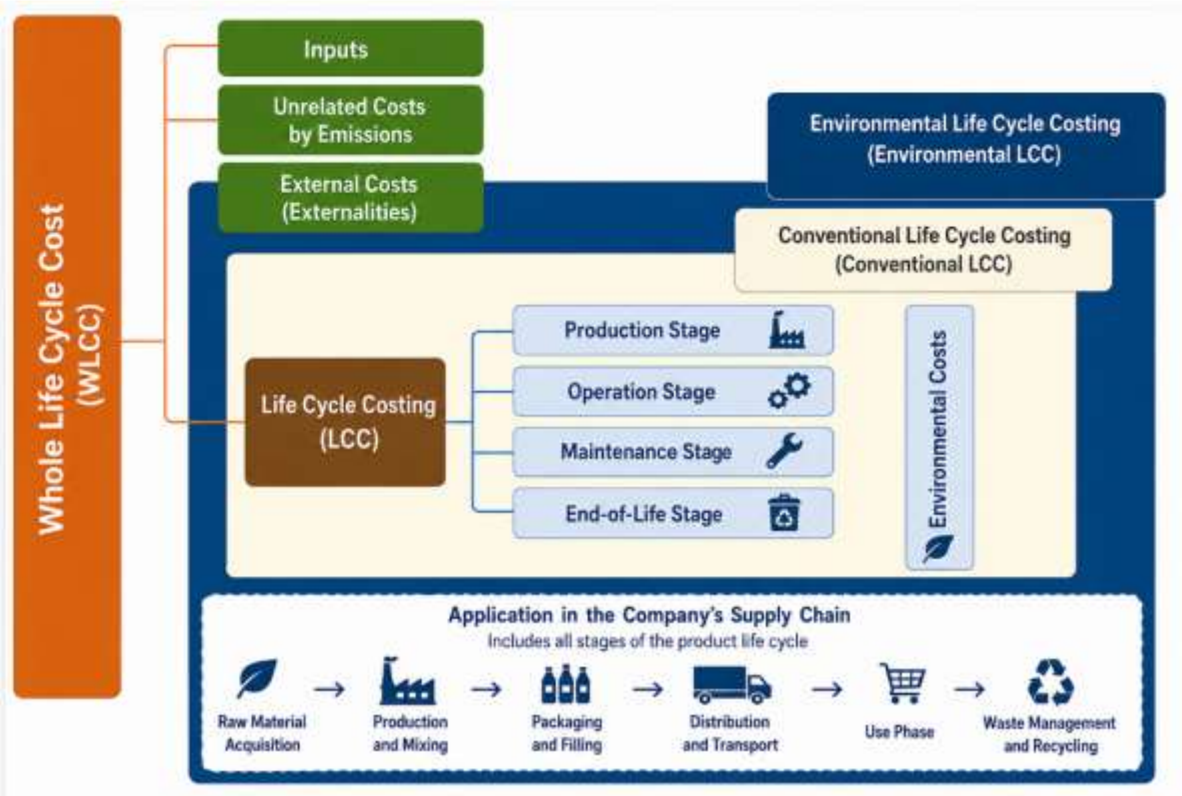

Figure 2. Elements of Whole Life Cycle Costing (WLCC) and Life Cycle Costing (LCC) Based on ISO 15686-5:2017. Source: Medina-Salgado et al. (2021), Adapted by the Researcher to Suit the Soft Drinks Industry.

The Full Cost Method is recommended by the standard for the inclusion of externalities in cost analysis. The approach consists of monetary estimation of potential costs or savings that could occur during the product life cycle due to its impacts on the environment or society. The term "costs" as used here defines costs likely to be levied on the facility in the future as taxes, fees, incentives or government subsidy. It does not mean, in other words, that if the future impact of the externalities on the cost of the product are not known or known but uncertain, it is not recommended to convert the externalities into monetary value.

The recommendation is especially significant from an accounting point of view because a product's economic feasibility and competitiveness in the market could be impacted by the increase in the cost of the product as the externalities are added. But a more holistic approach to sustainability involves considering all environmental and social impacts, whether they are likely to become real costs or not, in the future. In fact, the impacts can either reduce the value of the product, if the negative environmental impacts are more significant, or increase the value of the product, if the pollution is lowered and environmental performance improved.

This is because the monetary value based on the outcome of an Environmental Life Cycle Assessment (LCA) can be more accurate and complete than relying only on current environmental taxes or fees, which will only reflect the magnitude of the environmental and social impacts that the product has had in the past.

The company-specific application of this concept to a soft drinks manufacturer introduces the issue of whether the cost structure matches the product life cycle of the company, and the many actors that are involved in the process of creating the product. There are certain costs that are not the exclusive responsibility of the soft drink manufacturer, but are shared with the several parties in the value chain.

A More Comprehensive Tool for Life Cycle Costing (LCC) Analysis

As per the soft drinks industry environment, a more extensive tool for Life Cycle Costing (LCC) analysis was established by creating two sequential and integrated models as shown in Figure (3) which is copied from the International standard ISO 15686-5 (2017) as reference model.

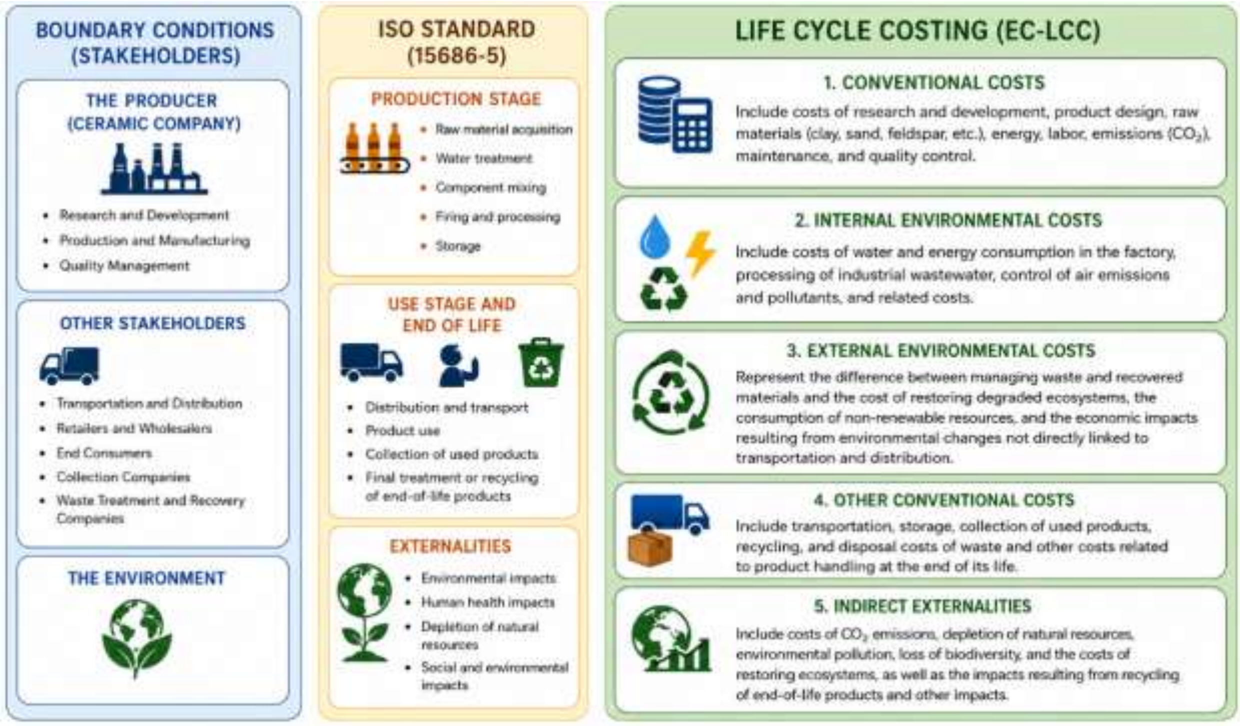

Figure 3. Environmental-Circular Life Cycle Costing (EC-LCC) Diagram. Source: Medina-Salgado et al. (2021), adapted by the researcher to suit the soft drinks industry.

Initially, an aggregate framework based on the circular flow approach was explored, as it is more closely aligned with the reality of continuous production processes. Through this first framework, represented by the Environmental and Circular Life Cycle Costing (EC-LCC) model, the analysis aims to identify the circular economy practices most closely related to and influential on the production process. The model also seeks to adhere to the life cycle concept as defined in the international standard, while allowing its application and calculation over relatively short periods not exceeding one year or less.

Within this framework, costs are proposed to be identified based on three main criteria:

- Conventional costs directly associated with the product life cycle.
- Circular and environmental economy costs associated with practices and principles that support the circular economy.
- Externalities resulting from the monetary valuation of the environmental impacts of emissions and non-recoverable or non-reclaimable waste.

Product life cycle costs are identified without adopting the concept of full and comprehensive costing, but rather by focusing on costs associated with production, operation, maintenance, and the end of the product’s useful life. In other words, the measurement process includes costs directly associated with design and quality control, acquisition of raw materials, labor and energy costs, as well as depreciation, maintenance, and repair costs related to production investments.

These costs are taken into account regardless of the party that bears them. Reasonable estimates should also be prepared for transportation, installation, and maintenance costs borne by other parties throughout the product life cycle as a result of its characteristics and specifications.

However, the total installation or maintenance costs borne by the installer or final customer should not be calculated, as these costs may be affected by other factors that are not directly related to the characteristics of the product itself. Rather, they are more closely associated with factors beyond the product's functional characteristics, such as performance, durability, weight, fragility, or other technical characteristics.

In this context, Adaptive Environmental Sustainability Costs are defined as all costs arising from investments and initiatives aimed at enhancing the efficiency of natural resource use, reducing waste and emissions, conserving resources, and restoring ecosystems. These costs are consistent with modern principles of environmental sustainability, which seek to reduce pollution, improve resource-use efficiency, and minimize the negative environmental impacts of production activities.

For the purpose of measuring these costs, two main types can be distinguished:
The first step is Internal Environmental Sustainability Costs.The first step is internal environmental sustainability costs.

These are the expenses incurred by the firm for measures and systems which help to optimise the environmental performance of the production process. This involves, among others, the cost of reusing water in production lines, the cost of recovering materials which can be reused and the cost of implementing energy efficiency systems.
Second: External Environmental Sustainability Costs

These are expenses incurred through practices that involve working with external actors in the value chain for example systems to collect used containers, recycling programs, recovery of packaging materials, cooperating with waste treatment companies, or companies specialised in plastics, glass and aluminium recycling. They also cover the expenses of returning materials from the consumption stage and activities that seek to recover and reuse materials following the consumption stage.

For a soft drinks company, these costs can include the cost of collecting empty containers from distributors, PoS or consumer as well as costs associated with transporting, sorting, processing and recycling. Costs of the measurement process should also include the economic benefits obtained from the sale or reuse of recovered materials, including the value of recycling plastics, glass and aluminum containers. These costs are not counted towards conventional costs, as that may lead to double counting.

As far as environmental externalities are concerned, they should be measured based on information obtained from Environmental Life Cycle Assessment (LCA), and results of environmental analysis should be included in the results of Life Cycle Costing (LCC) analysis in an integrated framework. This means that it is important to have similar and consistent system boundaries when comparing the two analyses, with all stakeholders in the value chain represented, such as the producing company, distributors, retailers, end users and recycling companies.

Costs that could be directly allocated to the producing company should be separated from the costs borne by other parties along the value chain, to avoid the double counting of environmental costs. This study allows estimating external environmental impacts and independently monetarily valuing them, which gives a more accurate measurement of the true product cost and improves management's ability to evaluate the environmental and economic performance in the context of environmental sustainability.

This is a case study and empirical validation of a soft drinks company.

The soft drinks industry is one of the fast expanding consumer industrialized sectors and one of the significant segments of the food industry, with a wide distribution in the international market. The sector has been the most productive due to rising demand by consumers and has created significant revenue, directly and indirectly accounting for thousands of jobs throughout supply and distribution chains.
The analysis started with the basic industrial cost of soft drinks companies, which included the raw material (sugar or other sweeteners, carbon dioxide, flavors and concentrates) cost, treated water cost, packaging cost (glass, metal cans, plastic containers) and energy consumption in mixing, carbonation, filling and cooling processes.

The level of analysis here is Conventional Life Cycle Costing (Conventional LCC), which is explained above. In this model, the cost of the production and operation phases of the product in the product life cycle are emphasized directly and indirectly.

The analysis also indicates that soft drinks constitute the primary product in this sector, both in terms of production volume and sales; therefore, the cost analysis focuses on this product.

Concentrated syrup of the soft drinks industry should be prepared and then diluted with treated water and then carbonated by injecting carbon dioxide gas at a known pressure to develop the carbonated property. Beverages are then filtered and fine processed and subsequently filled by using high-speed automated production lines into containers of various sizes and materials.

In general, a certain amount of treated water and sugar or sugar substitute is required along with precise amounts of flavor concentrate and CO_2 gas, depending on the type of soft drink: regular, diet or low calorie. The demand for these inputs for this sector could be estimated based on production average, as the total production in this sector over the study period, and the cost associated with each stage of production could be measured from a life cycle perspective.

Application Approach

The purpose of this application is to show how the Life Cycle Costing (LCC) model can be used to evaluate the effect of recycling of resources and optimization of resource use on overall production costs.

The application was based on the actual financial data of Baghdad soft drinks company for the year ended December 31, 2025, which contained detailed data for the cost components of production including raw materials, packaging materials, energy, water, wages, maintenance, and transportation.

However, the published financial statements do not give any data separately for the quantity of industrial waste, recycling costs, and revenue from the sale of recovered materials. Thus, a scenario was built by using realistic technical ratios that are typically found in sustainability and recycling reports (Medina-Salgado et al., 2021) to estimate the potential economic gain of such practices in the company. It is important to note that the results are based on research and are not the actual performance of the actions.

The following are some of the factors that made the choice of Bagdad Soft Drinks Company one of the most appropriate industrial companies for implementing the Life Cycle Costing model:

- Large annual production volume and product diversity.
- High dependence on plastic, glass, and metal packaging materials.
- High consumption of water, electricity, and gas.
- The potential for recycling PET containers.
- The potential for treating and reusing washing water.
- The relatively high value of packaging materials compared with other cost components, which increases the potential for achieving economic savings through recycling.

The financial data indicate that the company achieved growth in revenues and profits during 2025 while production costs continued to increase, making the search for ways to reduce operating costs increasingly important.

Life Cycle Cost Elements Used in the Application

The items most closely related to the product life cycle were extracted from the financial statements, as shown in the following table:

Table 1. Costs Incurred in the Soft Drinks Industry for the Year Ended December 31, 2025

S	Item | Cost	Value (Iraqi Dinars)	Value (Billion Iraqi Dinars)

1	Main and Auxiliary Raw Materials	228,681,123,628	228.681
2	Packaging Materials	327,437,716,625	327.438
3	Gas, Oils, and Lubricants	12,132,683,060	12.133
4	Electricity	11,681,071,960	11.681
5	Water	7,808,000	0.008
6	Salaries and Wages	36,393,321,497	36.393
7	Maintenance	2,906,285,020	2.906
8	Transportation and Communications	11,770,775,862	11.771
	Total Costs Under Study	631,010,785,652	631.011

The table shows that packaging materials accounted for the largest cost component, amounting to more than IQD 327 billion, representing more than half of the costs under study. This was followed by raw materials, at approximately IQD 228 billion, while energy and water costs represented a smaller proportion. These results indicate that any improvement in the management or reuse of packaging materials would have greater financial impacts than limited improvements in lower-cost items.

From a managerial perspective, the above table demonstrates the need not to distribute cost-reduction efforts equally across all components, but rather to direct them according to the relative importance of each item. Even a limited improvement in the efficiency of packaging material use could result in substantial financial savings compared with a similar improvement in a lower-cost item, such as water or maintenance.

Product Life Cycle Description

The company's products pass through a number of interconnected stages, beginning with the procurement of raw materials and ending with waste disposal, recycling, or reuse.

Table 2. Description of Materials Used in the Production Process of the Soft Drinks Company

Stage	Description
Procurement of Raw Materials	Procurement of sugar, concentrates, chemicals, and packaging materials
Material Preparation	Water treatment and preparation of concentrates and gases
Manufacturing	Mixing, Carbonation, and Production
Packaging	Filling the product into PET bottles, glass bottles, or cans
Packaging	Packing the containers into cartons and preparing them for shipment
Transportation	Distribution of Products to Markets
Consumption	Consumer Purchase and Use of the Product
Waste Collection	Collection of Empty Containers
Recycling	Reuse of Containers or Sale to Recycling Facilities

The cycle is closed in the traditional system with the disposal of containers. The opposite of this is a modern economy with a recycling and sustainability model where the end of one cycle is the beginning of a new production cycle through the recovery of recyclable materials and reintegration in the value chain. The table above depicts the different stages and the fact that opportunities for implementing a sustainable economy are spread over more than one stage of the product life cycle. Recycling can be encouraged, for instance, in the procurement and preparation of material stage. Energy and water use efficiency can be increased during the manufacturing, production stage. The resources can be reduced or recovered and the waste collection and recycling stage is the basic connection which returns resources to the production system in the filling and packaging stage.

The difference between the conventional and the sustainable economy model is apparent here. The traditional approaches view the container and the remaining materials as waste at the end of the economic value of the resource. The sustainable economy, on the other hand, sees this waste as a resource that can be used and reused in the production process.

Preparation of the Conventional Scenario

The conventional scenario assumes the following:

- Purchasing all raw materials from suppliers.
- No reuse of water.
- Disposal of all plastic and cardboard waste.
- No revenues generated from recovered materials.

Accordingly, the Life Cycle Cost is: IQD 631.011 billion.

Preparation of the Circular Economy Scenario

The proposed scenario was based on the following practical assumptions:

Table 3. Savings from Implementing the Proposed Scenario

Practice	Savings Rate	Implementation Cost
Use of Recycled Raw Materials	3%	1%
Recycling of PET Containers and Packaging Materials	8%	3%
Improving Electricity Efficiency	5%	1%
Recycling of Washing Water	40%	15%

Research based estimates that consider the nature of the soft drinks industry are used for these percentages. Rates higher than those selected would need a major capital investment and specialized infrastructure to measure a substantial, though not to the exclusion of a realistic, economic impact; the selected rates would allow for measurement of a relatively realistic economic impact without exaggerating results. These percentages are based on previous studies that have been done on sustainability and recycling in the soft drinks industry.

The scenario for the sustainable economy that is proposed in the table above does not assume that there will be cost free savings, but rather it considers the expected benefits and the cost of recycling. This is an important factor to consider in evaluating the economic feasibility of recycling and the use of improved resource efficiency, since investment in equipment, processing, collection, sorting and maintenance, and operations is often necessary for recycling and use of resource efficiency.

The cost of implementation and savings rate depend on the type of resource. The scenario uses the savings that can be achieved through the use of recycled raw materials, recycling of PET containers and packaging materials, the use of more electricity efficiently, and recycling of washing water. This diversity is evidence of the potential for simultaneously applying the sustainable economy approach on material resources, energy and water, instead of just recycling waste.

For this reason, the above table is based on the above. The savings rates and implementation costs are calculated for the original cost components to calculate the new cost for each component and then to assess the overall effect on Life Cycle Costing.

Calculation of the Cost of Each Component

(1) Raw Materials

1 Table 4. Costs After Applying the Recycling-Based Scenario

Description	Value (Billion Iraqi Dinars)

Original Cost	228.681
Savings (3%)	6.860
Implementation Cost	2.287
New Cost	**224.108**

The amounts of recycled materials used also lowered the cost of raw materials by IQD 4.573 billion as it cut the need for buying new raw material and mitigated the effects of price fluctuations.

As can be seen from the table, the estimated raw material cost is IQD 228.681 billion with an estimated saving of IQD 6.860 billion and an implementation cost of IQD 2.287 billion, which means that the expected cost will be approximately IQD 224.108 billion. Therefore, the total savings should not be considered but the impact of the sustainable economy practice after deducting the cost of the sustainable economy practice implementation should be taken into account.

The assumed results show that recycled/recovered materials may lead to lower costs for new materials, thus minimising the company's risk of market price volatility. It can also lessen the reliance on external vendors and boost the effectiveness of leveraging existing resources.

In addition to the direct savings, from a Life Cycle Costing point of view, the importance of such practice lies in the ability to increase the economic life of materials and hence to keep them in the value chain for a longer time as they rapidly become waste without any value. This is one of the main concepts of the sustainable economy, which is aimed at extracting the highest value from a resource before it is "wasted" in the final disposal.

The results also reveal that implementing a sustainable economy entails operating costs. Thus, the most relevant measure to be used in decisions is the net savings and not the value of recovered materials. For raw materials, the results show that a positive economic benefit is obtained when implementing the practice, which supports the economic feasibility of the practice based on the assumed conditions in the study.

Packaging and Packaging Materials

Table 5. Savings from Recycling Packaging Materials within the Proposed Model

Description	Value (Billion Iraqi Dinars)
Original Cost	327.438
Recovered Materials	26.195
Recycling Cost	9.823
New Cost	**311.066**

Analysis

This item achieved the largest financial savings because plastic and cardboard containers represent the largest component of production costs, and their recycling allows a high economic value to be recovered compared with other cost components. See Table (5).

When the value of recovered materials is compared with the recycling cost, a saving of approximately IQD 16.372 billion is achieved for this item alone. This result is particularly significant because packaging already represents the largest cost component under study. Therefore, targeting it through sustainable economy practices generates a greater financial impact than targeting lower-value cost components.

The result also supports the move toward establishing a more effective system for the collection, sorting, and recovery of PET containers and packaging waste, because economic value is not generated merely because a material is recyclable; rather, it requires a system capable of recovering, processing, and reintegrating it into the value chain at a cost lower than the value recovered.

Gas and Oils (Fuel)

Table 6. Savings from Recycling and Disposal of Oils

Description	Value (Billion Iraqi Dinars)
Original Cost	12.133
Savings Achieved	1.213
Implementation Cost	0.243
New Cost	**11.162**

The above table shows that the original cost of gas, oils, and lubricants amounted to approximately IQD 12.133 billion, and that implementing fuel-use efficiency measures could generate estimated savings of approximately IQD 1.213 billion. In contrast, implementing these measures requires an estimated cost of approximately IQD 0.243 billion, reducing the final cost of this item to approximately IQD 11.162 billion.

The results also show that the total savings achieved exceed the implementation cost of the recovery system, indicating a net economic benefit from implementing this practice. The net reduction in the cost of this item amounts to approximately IQD 0.971 billion, representing the difference between the savings achieved and the implementation cost.

Although the savings in gas and oils are lower than those resulting from recycling packaging materials and raw materials, the importance of this item is not limited to the financial aspect. Reducing fuel consumption contributes to lowering emissions generated by production processes and improving energy-use efficiency, thereby generating economic and environmental benefits simultaneously. This encourages the company to invest in clean energy and reduce its dependence on fossil fuels that pollute the environment.

Electricity

Table 7.

Description	Value (Billion Dinars)
Original Cost	11.681
Savings	0.584
Implementation Cost	0.117
New Cost	**11.214**

The above table shows that although the savings achieved are lower than those associated with the packaging item, they reflect the importance of implementing smart energy management systems and equipment maintenance to improve consumption efficiency.

The table above shows that the original cost of electricity amounted to approximately IQD 11.681 billion, and that improving electricity consumption efficiency results in estimated savings of approximately IQD 0.584 billion, against an implementation cost of IQD 0.117 billion, bringing the new cost to approximately IQD 11.214 billion.

Despite the limited financial savings compared with the packaging and packaging materials item, the results indicate that improving energy efficiency can generate a positive economic benefit after accounting for implementation costs. This can be achieved through the use of more efficient equipment, improving preventive maintenance programs, monitoring electricity consumption, and reducing unnecessary operation of machinery and equipment. The company can also invest in solar energy as part of a plan adopted by the company.

Equipment maintenance is also directly related to energy efficiency, as equipment operating without proper maintenance may consume more energy to achieve the same level of production. Therefore, electricity conservation programs should not be viewed merely as measures to reduce consumption, but rather as part of improving overall operational efficiency.

In addition to the financial impact, there is an indirect environmental impact represented by reducing energy demand and the associated resource consumption and emissions resulting from energy production. Therefore, although electricity contributes a relatively small proportion of the total savings, it remains an important component of an integrated strategy for the circular economy and resource efficiency.

Water

Table 8. Savings from Water Recycling

Description	Value
Original Cost	IQD 7,808,000
Savings	IQD 3,123,200
Treatment Cost	IQD 1,171,200
New Cost	IQD 5,856,000

The above table shows that reusing washing water reduces the need for new water and limits the amount of water discharged into the environment, thereby generating both economic and environmental benefits.

The table also shows that the original cost of water amounts to IQD 7,808,000, while the expected savings resulting from the reuse of washing water amount to IQD 3,123,200, against a treatment cost of IQD 1,171,200, resulting in a new cost of IQD 5,856,000.

Although the absolute value of financial savings from water is very small compared with packaging materials and raw materials, the importance of water reuse should not be assessed solely on a financial basis. Water represents an important natural resource in the soft drinks industry and is used in production, cleaning, and washing processes. Therefore, improving water-use efficiency provides an environmental and strategic dimension in addition to financial savings.

The results also indicate the possibility of transitioning from a single-use pattern to a partially closed-loop water system, whereby water from certain processes is treated and reused in applications where quality, health, and safety requirements permit. This reduces the quantity of new water required and decreases the volume of wastewater discharged.

Final Comparison between the Two Scenarios

Table 9. Comparison between the Two Proposed Scenarios

Item	Without Recycling	Savings	Implementation Cost	With Recycling
Raw Materials	228.681	6.860	2.287	224.108
Packaging and Packaging Materials	327.438	26.195	9.823	311.066
Gas and Oils	12.133	1.213	0.243	11.162
Electricity	11.681	0.584	0.117	11.214
Water	0.008	0.003	0.001	0.006
Salaries	36.393			36.393
Maintenance	2.906			2.906
Transportation	11.771			11.771
Total	**631.011**	**34.856**	**12.471**	**608.625**

Based on the results of the applications presented in the above table, the introduction of sustainable economy practices reduced the total Life Cycle Cost from IQD 631.011 billion to IQD 608.625 billion, which corresponds to a net annual saving of around IQD 22.385 billion or 3.55% reduction.

What is interesting to note is that over 73% of the net savings were derived from the packaging and packaging materials item, and this item is the most economically viable area for investment in recovery and recycling programmes. The benefits from using recycled raw materials also helped to lower procurement cost, and energy-efficiency and heat-recovery initiatives provided further savings. While its amounts were not as large, the savings also brought environmental benefits like lower emissions and better resource-use efficiency.

From a Life Cycle Costing point of view, the reduction of costs is not only during the production phase, but also at the end of the product life cycle when materials are recovered and re-enters the production chain instead of being disposed of as waste. This improves economic efficiency, lessens the strain on natural resources and aligns with industry trends focusing on sustainability.

The finding can be applied from the managerial point of view for designing the gradual implementation approach which starts with the highest impact projects, notably the recovery and recycling of PET containers/packaging materials, then extends the use of the recovered materials and later, energy and water-efficiency programmes are integrated. A staged approach ensures that investment funds are allocated to the most economically productive stages of the process in the early stages.

The results also validate the core concept of the Life Cycle Costing model – that decisions on costs should not be limited to the manufacturing phase, but should reflect the entire lifecycle of the resource and product – including the post-consumption phase. If the waste has recoverable value, then waste disposal is a loss of potential economic value, while sustainable economy practices make it possible to return the value to the production cycle.

Therefore, the savings of IQD 22.385 billion and the reduction rate of 3.55% is to be understood within the margins of the model employed. These results do not indicate actual savings that have already been realized by the company, but instead are the result of an assumed research scenario with the company's 2025 financial information and with specific practical assumptions and rates. Thus, field validation of these results would need to have more detailed information regarding the actual quantities of wastes, recovery rates on containers, the actual costs of collection, sorting, transport and processing; and the investment involved in setting up the recycling systems.

Conclusion

Companies engaged in value creation in accordance with the corporate sustainability approach must necessarily take economic sustainability assessment into consideration [89]. In an industrial context, companies should evaluate the environmental and economic sustainability of the sustainable economy practices they plan to undertake, which is especially relevant. This is also critical from a product life cycle standpoint as it is required to predict business performance throughout the supply chain.

The survey results, however, showed that the activity and production of soft drinks manufacturing have also triggered the interest in finding out the economic impact of the operations and products for better communication with stakeholders, which is transparent. For sustainable economy practices, the same interest was seen, considering the practice as a potential enabler for increased competitiveness.

With the analysis results, this study suggested two conceptual models for economic sustainability via Life Cycle Costing (LCC) method. In this context the two proposed models are complementary as they have different goals.

In the first model (Figure 3), the total cost is not taken into account as one of the investment appraisal methods. However, the actual value of the product can be established due to the fact that the model is based on measuring used resources, recycled resources, and external influences (externalities) of the process. This is not just applicable to the life cycle of the product, but also to the circular value chain of the product.

This product cost calculation framework is very similar to the one used in Life Cycle Assessment (LCA) to set the boundaries of a system when calculating the external environmental impacts. In this approach, if the external environmental effects can be economically valued for each part of the value chain emanating from it, it is possible to improve the understanding of the sources of value creation or destruction and to some degree, prevent double counting in the product life cycle.

This would allow a proper appraisal of the economic viability of the product. Moreover, the framework also supports the identification of the costs associated with implementing efficiency systems that reduce waste, showing one of the key principles of an economy of eco-efficiency.

The application revealed that using the Life Cycle Costing model with the practices of circular economy is a practical solution to assess the cost and increase the efficiency of resource utilization in the Baghdad Soft Drinks Company. The proposed scenario showed up to IQD 22.385 billion in annual savings with a reduction of 3.55% in the total Life Cycle Cost.

The findings suggest that economic and environmental benefits can be realised from investment in recycling PET containers as well as in the recovery of packaging waste, better energy efficiency and water reuse. It is important to note, however, that these results are under the assumption of the company's actual financial figures in 2025 and the extrapolation of research-backed assumptions. These estimates can be refined in the future with detailed operational data on waste volumes, recovery and the operating cost of recycling and treatment systems

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