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# The Eco-Cost And Application Of Life Cycle Assessment (LCA) To Determine Eco-Cost And Sustainable Level Of Enterprises

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## Abstract

**Purpose -** The paper researches eco-cost and uses the LCA method to determine eco-cost. The article also demonstrates the factors affecting the application of LCA to assess eco-cost and the factors affecting the sustainability of enterprises through eco-cost and LCA.
**Methodology -** Through the investigation of 193 manufacturing enterprises, the article analyzed and evaluated the factors affecting the application of LCA to determine the ecological costs and factors affecting the sustainable development of manufacturing enterprises
**Findings -** By using AMOS software, the article has highlighted the factors affecting the application of LCA to determine eco-cost and factors affecting the sustainability of the business.
**Research limitations/implications**: The study only reports on manufacturing firms, not all business types.
**Practical implications -** The article shows the applicability of LCA to determine eco-cost.
**Social implications**: The article has studied aspects of sustainable development, environmental accounting, and the urgency of saving natural resources. On that basis, the article mentioned measuring natural resource consumption in sustainable development.
**Originality/value -** This article is unique because it assesses the factors influencing the adoption of LCA to determine eco-cost and assess sustainability in manufacturing enterprises.

**Keywords -** Eco-costs, Life Cycle Assessment (LCA), indirect eco-costs, direct eco-costs, marginal prevention costs, Eco-cost Value Rate (EVR)

## 1. Introduction

The eco-costs are the virtual costs associated with the measures taken to recycle the product to match the earth's estimated carrying capacity. The eco-costs are the sum of the marginal prevention costs of each type of pollution and the costs of preventive measures for physical and energy depletion. The marginal prevention costs selected here are comparable to other sustainability issues. Essentially, the marginal prevention costs are the last and most expensive measure used to bring about a sustainable state. Marginal prevention costs are not equal to external costs because external costs involve damage and are not prevented.

When society has not reached a sustainable level, eco-costs are virtual because they are determined based on assumptions only. The costs required to take preventive measures are not included in the current costs of the current Life Cycle Costs. In the future, eco-costs will become part of product costs in the form of 'eco-tax,' 'tradable emission rights,' or as fees that the government requires each business to pay (Bengtsson, M., & Steen, B.,2000)

Eco-costs are the only LCA representing environmental burdens based on marginal prevention costs (e.g., costs incurred to bring about environmental sustainability by measuring the end of a pipeline or system of solutions. combination method).

According to Vogtländer, Baetens, Bijma, Brandjes, Lindeijer, Segers, and Witte (2010), this indicator is the sum of marginal prevention costs caused by: Toxic emissions, called the eco-costs of emissions; Materials depletion called the eco-costs of materials depletion, and energy consumption reached the eco-costs of energy.

The article researches ecological costs and uses the LCA method to determine ecological costs. The paper also presents factors affecting the application of LCA to determine ecological costs and factors affecting the sustainability of enterprises through ecological costs and LCA. By analyzing data of 193 manufacturing enterprises, the article investigated and measured factors affecting the application of LCA to determine ecological costs and factors affecting sustainable development. In manufacturing enterprises. The article answered the following questions:

1. The nature of eco-cost?
2. What are the components of eco-cost?
3. What factors and how much influence each aspect has on the application of LCA to determine eco-cost in enterprises?
4. What factors and how much influence each factor has on the level of sustainable development in the enterprise?

## 2. Litterature reviews

The eco-costs system was introduced in 1999 during conferences and published between 2000-2004 (Zhang, Y., 1999).

The eco-costs approach is based on the total marginal prevention costs (end of pipe and system integrated) for wastes that are hazardous to human health and the ecological environment, which cause global warming. And depletion of resources such as metals, rare earth, fossils, water, etc.).

A no-effect level for hazardous waste is a level at which levels exist in nature much below the hazardous threshold or below the natural background. The toxic level to humans usually uses the 'no-observed-adverse-effect level.' The eco-costs are the marginal prevention costs of the last measure of the prevention curve to reach the no-effect-level (Finnveden, G., Hauschild, M. Z., Ekvall, T., Guinea, J., Heijungs, R., Hellweg, S., ... & Suh, S.,2009)

The standard calculation for the single indicator in the LCA is based on the damage of emissions. The specific measure is as follows: Pollutants are classified into each category, then multiplied by the 'characterization' factor to get their relative importance in each category, and finally summed up the level of their 'midpoint' effect ( global warming, acidification, etc.). The relatively crucial remaining issue is determining the relative importance of each midpoint effect. This level should be standardized (giving each midpoint a weight to take the relative importance into account) by a panel of experts.

Calculating eco-costs based on standardization and weighting can be done differently. Standardization is done by calculating the marginal prevention costs for a sector; weighting is not required because the resulting total is the sum of eco-costs of all midpoints. The advantage of this calculation is that the marginal prevention costs are related to the cost of the most expensive Best Available Technology, meeting the Tradable Emission Rights level required in the future.

It can be argued that eco-costs also indicate the marginal costs of prevention for many countries globally, leveling the playing field for businesses. Preventive measures will reduce the cost of damage related to environmental pollution. The cost of damage is usually equal to or higher than the cost of prevention. Therefore, the overall impact of preventive measures on society is to improve the environment at no additional cost (Vogtlander, J. G., & Bijma, A., 2000).

There are many 'single indicators' for LCA; basically, there are three types: single issue, damage based, and prevention-based. The best known 'single issue' indicator is the carbon footprint: the total emissions of kg CO2 or kg CO2 equivalent (taking methane and other greenhouse gasses into account). The advantage of a single issue indicator is that the calculation is simple and transparent, without complicated assumptions, and easy to communicate with the public. Its disadvantage is that it ignores other types of pollutants caused, which is not suitable for end-to-end calculations because materials depletion is not considered. The most common single indicators are damage based. This pattern originated in the 1990s when LCA was developed to make people aware of damage in production and consumption. The advantage of damage-based single indicators is that people are aware that they can consume less but businesses are aware they need cleaner production. The downside is that this approach is quite complicated to calculate, not transparent due to the need to use many assumptions, follow the subjective normalization process and the weighting procedure, and combine three health issues: human health, ecosystems, and resource depletion. Communicating results is more difficult because results expressed in “points” are challenging to represent in monetary and methodological uncertainty. Prevention-based indicators considered eco-costs is a relatively new point of view. This method has the advantage that it is compared to the damage-based systems method; it is relatively quickly transparent, the results can be expressed in monetary terms, and the performance measures are relatively straightforward. This system supports the decision-making process of many audiences, such as architects, businesses, designers, and engineers. The benefit of this approach is that it provides monetary evaluation without the need for normalization and weighting. The disadvantage of this system is that it does not focus on the problem that people can consume less (Vogtländer, J., Van der Lugt, P., & Brezet, H., 2010).

The eco-costs were initially calculated for the case of the European Union but are applied worldwide to level the playing field for business and follow the precautionary principle. Two other prevention-based systems developed after the introduction of eco-costs based on the specific circumstances of each country.

In the Netherlands, 'shadow prices,' developed in 2004 by TNO/MEP based on a local prevention curve, is the most expensive preventive measure required by the Dutch government for each midpoint. Such costs are related to local businesses, but such a shadow price system makes no sense to place outside the Netherland because it is not based on the no-effect level.

In Japan, a group of universities has developed a database of maximum cost minimization (MAC is similar to the midpoint multiplied by eco-costs) with Japanese terms. The development of MAC began in 2002 and was published in 2005. This approach's so-called avoidable abatement cost (AAC) is comparable to eco-costs (Van Vliet, O., Brouwer, A. S., Kuramochi, T., van Den Broek, M., & Faaij, A.,2011).

According to the policy of the Delft University of Technology, to make LCA calculations available to everyone, the data excel files are available on the internet at no cost. LCA professionals who want to use the eco-costs as a sole indicator can obtain a complete database for Simapro (eco-costs method, as well as Idematapp LCIs) once they have a Simapro license. Engineers, designers, and architects can obtain accessible databases for CES and ArchiCAD (Vogtlander, J. G., 2002).

## 3. Theoretical framework of research

### 3.1. LCA method

Life cycle assessment (LCA) is a technique for assessing environmental aspects of the product life cycle. According to this method, it is of utmost importance to analyze the contribution of each stage to the overall ecological load with the goal of product improvement and process comparison between products. According to Norris G. A. 2001, LCA consists of 3 phases:

**Stage 1:** Determination of objective and scope of the product life cycle assessment process, criteria for comparison at different times

**Stage 2:** Inventory analysis

This allows us to describe the flow of materials, the energy used in producing products, especially their interactions with the environment, the consumption of materials, and emissions to the environment.

**Stage 3**: Detailed descriptions of inventory analysis for impact assessment

The results of the impact assessment are detailed in this phase. The level of influence is calculated, compared with the norm, and measured by the ratio.

**Stage 4**: Interpretation of a life cycle involves critical review, determination of data sensitivity, and result presentation

### 3.2. The components of the eco-costs

The eco-costs are the sum of the factors:

- ✓ The virtual pollution prevention costs
- ✓ The eco-costs of energy
- ✓ The eco-costs of material depletion
- ✓ The eco-costs of depreciation (use) of equipment, buildings, etc.
- ✓ The eco-costs of labor.

All of the above factors are calculated according to the LCA method.

### The virtual pollution prevention costs

The virtual pollution prevention costs are emissions-related pollution prevention costs for using energy to produce and transport materials.

### The eco-costs of energy

The calculation of eco-costs of energy is based on the assumption that sustainable energy sources will replace the fossil energy. Following is the category of primary sustainable energy sources Eco-costs of energy (Euro/GJ)

**Table 1 - The eco-costs of energy**

| | | |
|---|---|---|
| Industrial heat | Biomass | 11,82 |
| Diesel (including combustion) | Ethanol from biomass | 29,87 |
| Electricity (industry) | Biomass +wind | 26,27 |
| Electricity (domestic) | Biomass +wind | 30,20 |
| Petrol (including combustion) | Ethanol from biomass | 29,87 |
| Domestic heating | Suncollectors+heatpumps | 13,5 |

### Eco-costs of materials depletion

Given the shortage of raw materials, one can assume that:

• The eco-costs of materials depletion are equal to the raw materials' market value when the materials are not recycled.

• When a fraction α of the sourced material is recycled, a factor (1-α) is applied to the market value of the raw material for the new product to calculate the eco-costs of materials

Therefore:

**Eco-costs of materials depletion = The market value of the raw material x (1 - α)**

For most materials, the 'present market value' typically does not deviate much from the current average material prices because, functionally, these materials can be substituted by other inexpensive materials of the same function.

## Indirect eco-cost: the eco-costs of labor

Labor's eco-costs are indirect because labor is seen as not burdening the environment. However, there are also environmental burdens related to work such as environmental effects of heat, light, computers, travel... The calculation of eco-costs is quite specific for each type of labour (Vogtlander, J. G., Baetens, B., Bijma, A., Brandjes, E., Lindeijer, E., Segers, M., ... & Hendriks, C. F., 2009)

An example is given here for work in offices with average salary costs of € 32,500 per annum (including taxes, insurance, and pension funds), having an office space of 33 m2 (average for the banking and insurance sector):

### 1. Eco-costs of energy per annum per employee (for eco-costs of energy, see table 1):

♣ Commuting by car, 30 km for 210 days per year, fuel required:

1000 litres of petrol = 35 GJ > eco-costs = 35 GJ x 29,9 €/GJ = € 1.046

♣ Heating of the office per annum per employee CBS

0.42 GJ/m2 x 33 m2 = 14 GJ > eco-costs = 14 GJ x 13,5 €/GJ = € 189

♣ Electricity for the office per annum per employee

0.85 GJ/m2 x 33 m2 = 28 GJ > eco-costs = 28 GJ x 30,2 €/GJ = € 845

### 2. Eco-costs of the office building per employee per annum:

Total costs related to construction, maintenance, and demolition

(giả thiết 16,54 Euro/m2)

Eco-costs = 16,54 Euro/m2 x 33 m2 = € 546

### 3. Eco-costs of office products per employee per annum:

Typical total eco-costs for office products (paper, printing ink, etc.) € 200

**Total eco-costs labour = € 2.826**

(Vogtlander, J. G., Baetens, B., Bijma, A., Brandjes, E., Lindeijer, E., Segers, M., ... & Hendriks, C. F., 2009)

## Indirect eco-costs: the eco-costs of depreciation of production facilities

The indirect eco-costs are eco-costs related to the fixed assets used to produce the product. Calculating these costs is similar to cost estimates for investments, including materials and operating labor costs.

The basic idea behind the ‘eco-costs of depreciation’ is that the production facilities have to be allocated to the products made in or with these facilities. The sequence of calculation steps is as follows:

1. Determine the eco-costs of the production facility
2. Divide the eco-costs in step 1 by the life of the facility's assets (years)

The 'economic lifetime' can be used instead of the 'technical lifetime' since the economic lifetime is usually longer than the 'technical lifetime.'

3. Divide the result in step 2 by the number of products produced per year.

Eco-costs of depreciation = (Eco-costs of the production facility) / (T x N)

This formula is also used to calculate the same for the eco-costs of the office building per employee per annum.
Since the Eco-cost Value Rate (EVR) model applies the economic lifetime of the facility, the equation has a high similarity with the normal, linear equation for production costs related to depreciation:

Costs of depreciation = (Value of the production facility) / (T x N)

And:

**Eco-costs of depreciation = Costs of depreciation x (Eco-costs /value) production facility**

If a business manufactures more than one type of product, the 'cost breakdown structure' of the product is available; the formula above can be used to allocate costs.

### 3.3. Positive eco-costs và negative eco-costs

The eco-costs is a metric representing the environmental burden of a product that is spent if it is to be prevented (Mora, M. A. M., Dominguez, E. R., Ibarra, A. A., Reynaga, N. S., & Delgadillo, S. A. M.,2014). This cost can be recognized to reduce pollution and material loss to a level suitable for the earth's tolerance. Two types of eco-costs can be identified: positive eco-costs and negative eco-costs.

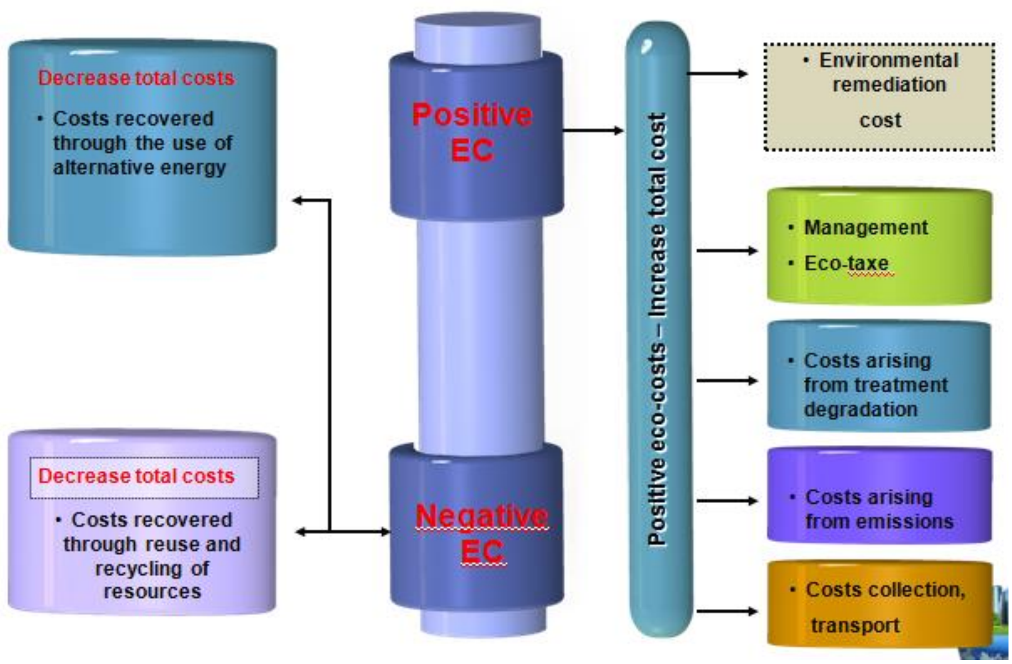

**Figure 1 – Positive eco-costs and negative eco-costs**

(Vogtlander, J. G., Scheepens, A. E., Bocken, N. M., & Peck, D. (2017)

The eco-costs of products are based on marginal prevention costs over the product life cycle due to hazardous emissions, waste of materials, energy consumption, and land conversion. The calculation of eco-costs is based on LCA (Morales-Mora, M. A., Rosa-Dominguez, E., Suppen-Reynaga, N., & Martinez-Delgadillo, S. A. ,2012). In terms of environmental economics, according to the cost-based pricing method of goods and services, the absorption of eco-costs will increase the corresponding price and the tasks to be performed to rebalance the environment. This sequence will lead to a tendency to reduce consumption, restore the environment and ecological balance, and support sustainable operations. The critical issue in this argument is that the product life cycle correlates with the value chain. The LCA approach is included in ISO 14000 (Rezaee, Z., & Elam, R.,2000) on environmental management standards. Procedures under the LCA are designed and developed to meet the entity's requirements regarding integrating environmental protection in the development process with product and service improvement. Brner, J., & Wunder, S. (2008) argue that the quantitative measurement of the product lifecycle of an accounting system is concerned with determining the (quantifiable, measurable) value of the environmental effects when achieving corporate goals. The combination of quantitative product lifecycle measurement and environmental accounting systems ensures a full assessment of the impact of a business's operations on the environment. It forecasts the effects of transactions and related financial events (Wagner, W., Barnes, K., & Peters, L., 2011). More and more entities desire the interest in eco-costs in sustainable development. The relationship between eco-costs and the total cost over the product life cycle is well defined. The total cost of a product over the product life cycle includes all costs associated with research and development, materials, handling, and other operating costs, as well as costs for dismantling and removing the product at the end of the life cycle.

### 3.4. The value, costs, and eco-costs of a product

The value of a product is determined by: product quality, service quality, and image. These three factors are components: Materials purchased, energy used, equipment wear and tear, buildings..., and labor.

In its value chain, each enterprise has: the tax + profit equal the value minus the costs.

The direct eco-costs are determined by:

• Virtual pollution prevention cost is the necessary cost required to reduce emissions in the product production chain to reach sustainable levels.

• Eco-costs of energy, being the price for sustainable energy sources.

• Eco-costs of materials depletion, being (costs of raw materials) (1-α) where is the recycled fraction of materials to make a product.

The indirect eco-costs are:

• Eco-costs of depreciation, being the eco-costs related to the use of equipment, buildings, etc.

• Eco-costs of labor, being the eco-costs related to commuting and the use of the office (building, heating, lighting, electricity for computers, paper, office products, etc.)

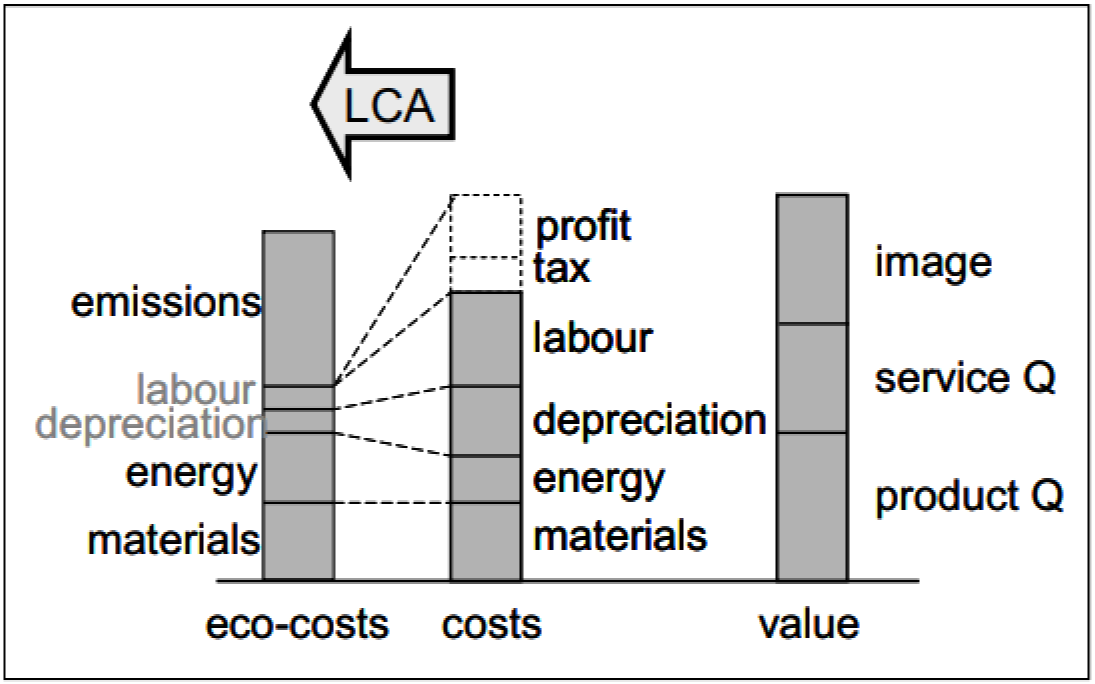


**Figure 2 The decomposition of 'virtual eco costs,' costs, and value of the product**
(Vogtlander, J. G., Baetens, B., Bijma, A., Brandjes, E., Lindeijer, E., Segers, M., ... & Hendriks, C. F., 2009).

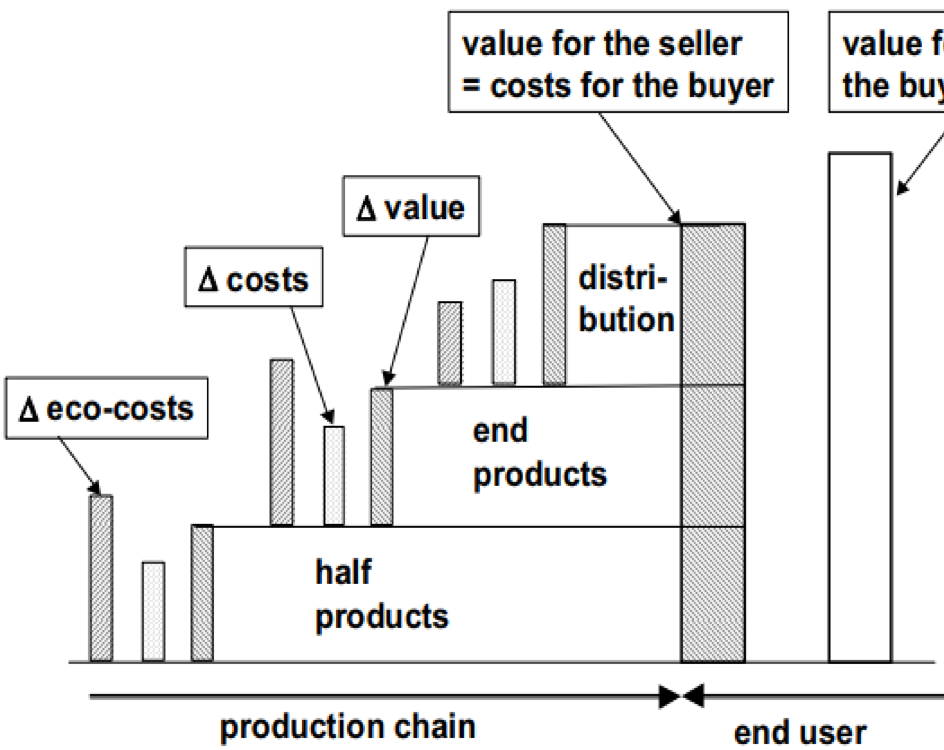


**Figure 3. The decomposition of the value in the chain**
(Vogtlander, J. G., Baetens, B., Bijma, A., Brandjes, E., Lindeijer, E., Segers, M., ... & Hendriks, C. F., 2009).

### 3.5. The Eco costs-Value Ratio (EVR)

The Eco costs / Value Ratio, EVR, is an indicator that has the following characteristics: (1) is an indicator of sustainability in the LCA in addition to the eco-costs indicator in the case of products with the same function, but the quality difference, (2) is an index related to the strategy and leadership policy of the enterprise, linking the consumer side to the production side, (3) is a parameter called 'economic allocation' in the calculation's accounting of the LCA. LCA aims to compare two products or services, provided that the two products have the same function and quality. However, in reality, green designs often have the same function but differ in design, so the quality is not the same in these cases. There is usually a misunderstanding that a plan with the lowest eco-costs is often the choice for sustainability. When the eco-costs of the new design are lower, and the quality is better, the new design will be more sustainable. However, in the case of different quality, the Eco costs/Value Ratio, EVR is the best indicator to measure sustainability because the fair price is a good indicator to assess quality.

The EVR is called the E/E indicator, which describes the eco-efficiency of a product and service. The EVR is a dimensionless number indicating the destruction of economic and ecological linkages. Several other E/E ratios represent ecological cost burdens. However, EVR takes the customer into account. From EVR's point of view, a product or service has three distinct dimensions: the costs, the eco-costs, and the value, all expressed in monetary terms but with different ranges and degrees.

In terms of consumers in economic and ecological linkages, assuming families spend their lives with what they earn, the total EVR of the spending of households is the key to sustainability. If the total EVR of the expenditure is lower than the eco-costs related to the total, new spending can be reduced even with higher spending. There are two ways to do this: (1) On the production side: Improve the ecological efficiency (reducing EVR) of the product or service, and (2) On the consumer side: Change the way of life of consumers. towards reducing the product's EVR (Vogtländer, J. G., Bijma, A., & Brezet, H. C. ,2002)

Ecological costs include the burdens resulting from the extraction of raw materials, primary processing, and disposal of hazardous products or the purification of contaminated products, the transportation of raw materials to the factory, the distribution of the product to the consumer, and from the transport of the product to the disposal site.

## 4. Research on factors affecting the application of LCA in determining eco-cost in enterprises

### 4.1. Research sample

We surveyed 193 enterprises through a questionnaire to identify and measure the factors affecting the application of LCA in determining eco-cost in manufacturing enterprises. Survey respondents are representatives of the company's board of directors, technical experts, production workers, accountants, and corporate governance experts. The survey and data collection period is from December 2021 to April 2022. This study's primary data analysis method is the structural equation modeling method (SEM) with AMOS - SPSS. To obtain a reliable estimate for this method, according to Tauchen (1986), the sample should usually have a significance greater than 200 ($n > 200$). Based on the empirical rule of Hair et al. (2010), for an estimator, the minimum sample size needed for this study is n > eight × the number of variables = 8 × 24 = 192. Combining the above principles and the sample size, we choose n = 193.

### 4.2. Identify and measure factors affecting the application of LCA to determine eco-cost in enterprises

#### 4.2.1. Research model and hypothesis

According to the study, the application of LCA to determine eco-cost is affected by the legal system related to LCA, product manufacturing process characteristics, business development strategy, enterprise accounting system, and business characteristics. (Allen, SR; Hammond, GP; Harajli, HA; Jones, CI; McManus, MC; Winnett, AB (May 2008). At the same time, the paper also demonstrates applying LCA to determine eco-cost effects on corporate sustainability.

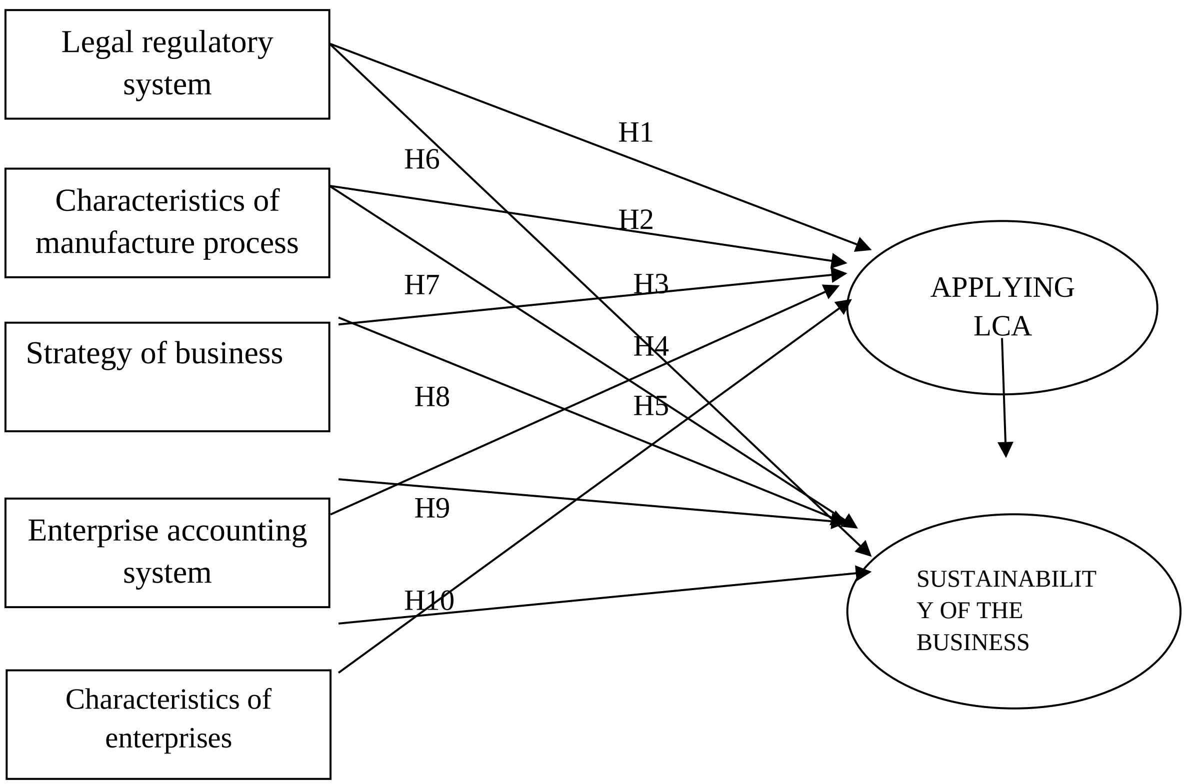


**Figure 4- Model of research**

**Table 2 – Variables affecting the application of LCA for determination of eco-costs and the level of sustainability of the business**

| | **Legal regulatory system related to LCA and eco-costs (LR)** |
|---|---|
| 1 | Timeliness and suitability of the legal document system related to LCA and eco-costs (LR1) |
| 2 | Completeness of legal documents related to LCA and eco-costs (LR2) |
| 3 | The enforcement of the legal system of legal documents related to LCA and eco-costs (LR3) |
| | **Characteristics of manufacture process (CP)** |
| 4 | Characteristics of materials used (CP1) |
| 5 | Production stages can be segregated (CP2) |

| | |
|---|---|
| 6 | The product life cycle is relatively long (CP3) |
| 7 | Can track and record information in the product life cycle (CP4) |
| | **The strategy of the business (SB)** |
| 8 | Strategies for effective use of resources require businesses to apply LCA for the determination of eco-costs (SB1) |
| 9 | A clean production strategy requires businesses to apply LCA to determine eco-costs (SB2) |
| 10 | Ensuring the interests of stakeholders requires businesses to apply LCA to the determination of eco-costs (SB3) |
| | **Characteristics of the business (CB)** |
| 11 | Production technology is updated with LCA (CB1) |
| 12 | Managers' competencies ensure the application of LCA (CB2) |
| 13 | Information systems ensure the application of LCA (CB3) |
| 14 | Tools and methods of measuring inputs and outputs to enable LCA measurement (CB4) |
| | **Enterprise accounting system (AC)** |
| 15 | The level of accounting staff of the enterprise is capable of applying LCA for the determination of eco-costs (AC1) |
| 16 | The accounting information system ensures the application of LCA for the determination of eco-costs (AC2) |
| 17 | The application of modern technology ensures the application of LCA for the determination of eco-costs (AC3) |
| 18 | Accountants have enough tools to measure eco-cost (AC4) |
| | **Applying LCA to determine eco-costs (LCA) (Dependent variable)** |
| 19 | Using LCI (LCA1) |
| 20 | Using LCIA (LCA2) |
| 21 | Use LCEA (LCA3) |
| | **Level sustainability of business (SUS) (Dependent variable)** |
| 22 | Economically sustainable (SUS1) |
| 23 | Social sustainability (SUS2) |
| 24 | Environmentally sustainable (SUS3) |

## Research hypotheses

H1: Legal regulatory system that affects the application LCA for determination of eco-costs

H2: Characteristics of the manufacturing process that affect the application of LCA for the determination of eco-costs

H3: Business strategy of the enterprise that affects the application LCA for determination of eco-costs

H4: Accounting information systems influence the adoption of LCA for the determination of eco-costs

H5: Enterprise characteristics that affect the application of LCA for the determination of eco-costs

H6: Legal system affects the sustainable development of enterprises

H7: Characteristics of the production process that affect the sustainable development of enterprises

H8: The business strategy of the enterprise has an impact on the sustainable development of the enterprise

H9: Accounting information systems affect the sustainable development of enterprises

H10: Characteristics of enterprises that affect the sustainable development of enterprises

H11: Application LCA for determination of eco-costs affects the sustainable development of enterprises

### 4.2.2. Factors affecting the application of LCA for determination of eco-costs and the level of business sustainability

**Table 3- KMO and Bartlett's Test**

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | .875 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 2789.463 |
| | Df | 276 |
| | Sig. | .000 |

After running the rotation matrix, the coefficient KMO = 0.875>0.5, sig = 0.000 <0.05, so the model is satisfactory, there are seven groups of factors that converge and have cumulative loadings at 66,63%>50%, which showed that the independent variables explained 66,63% of the dependent variable.

**Table 4 - Pattern Matrix[a]**

| | Factor | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| CB2 | .859 | | | | | | |
| CB1 | .829 | | | | | | |
| CB4 | .807 | | | | | | |
| CB3 | .782 | | | | | | |
| AC4 | | .925 | | | | | |
| AC3 | | .795 | | | | | |
| AC1 | | .756 | | | | | |
| AC2 | | .711 | | | | | |
| CP2 | | | .844 | | | | |
| CP1 | | | .809 | | | | |
| CP3 | | | .631 | | | | |
| CP4 | | | .555 | | | | |
| LCA2 | | | | .850 | | | |
| LCA3 | | | | .849 | | | |
| LCA1 | | | | .797 | | | |
| LR2 | | | | | .844 | | |
| LR1 | | | | | .803 | | |
| LR3 | | | | | .702 | | |
| SUS2 | | | | | | .847 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SUS3 | | | | | | .802 | |
| SUS1 | | | | | | .727 | |
| SB1 | | | | | | | .935 |
| SB3 | | | | | | | .715 |
| SB2 | | | | | | | .615 |

Extraction Method: Principal Axis Factoring.
Rotation Method: Promax with Kaiser Normalization.
a. Rotation converged in 7 iterations.

Pattern Matrix rotation matrix is used to analyze factor confirmatory in AMOS software, to see whether the elements are convergent and discriminant.

**Table 5 -Regression Weights**

| | | | Estimate | S.E. | C.R. | P | Label |
|---|---|---|---|---|---|---|---|
| LCA | <--- | CB | .351 | .093 | 3.774 | *** | |
| LCA | <--- | AC | -.022 | .096 | -.235 | .815 | |
| LCA | <--- | CP | -.108 | .124 | -.869 | .385 | |
| LCA | <--- | SB | .221 | .094 | 2.346 | .019 | |
| LCA | <--- | LR | .437 | .111 | 3.923 | *** | |
| SUS | <--- | LCA | .342 | .091 | 3.762 | *** | |
| SUS | <--- | LR | -.014 | .110 | -.130 | .896 | |
| SUS | <--- | SB | -.019 | .090 | -.216 | .829 | |
| SUS | <--- | CP | -.241 | .119 | -2.032 | .042 | |
| SUS | <--- | CB | .215 | .093 | 2.319 | .020 | |

Standardized Regression Weights: (Group number 1 - Default model)

Regression Weights results (Table 5) show that: independent variables SB (Strategy of business), LR (legal regulatory system), CB (Characteristics of the company) have an impact on LCA (sig < 0.05). Hypotheses H1, H3, and H4 are accepted. The independent variables CP ( Characteristics of manufacture process) and AC (Accounting system) do not affect LCA (sig > 0.05). Hypotheses H2 and H5 are rejected. Similarly, CP ( Characteristics of manufacture process), CB (Characteristics of the business), and LCA have an impact on the dependent variable SUS (sig < 0.05). Hypotheses H7, H9, and H11 are accepted. The independent variables LR (Legal regulatory system), SB (Strategy of business), and AC (Accounting system) do not affect SUS (sig > 0.05). Hypothesis H6, H8, and H10 are rejected.

**Table 6 - Squared Multiple Correlations: (Group number 1 - Default model)**

| | Estimate | | Estimate |
|---|---|---|---|
| LCA | .425 | LR3 | .612 |

| | | | |
|---|---|---|---|
| SUS | .407 | LR1 | .681 |
| SB2 | .446 | LR2 | .647 |
| SB3 | .580 | LCA1 | .783 |
| SB1 | .748 | LCA3 | .650 |
| SUS1 | .627 | LCA2 | .713 |
| SUS3 | .660 | AC2 | .668 |
| SUS2 | .661 | AC1 | .682 |
| CP4 | .477 | AC3 | .588 |
| CP3 | .487 | AC4 | .727 |
| CP1 | .613 | CB3 | .725 |
| CP2 | .630 | CB4 | .669 |
| CB2 | .757 | CB1 | .692 |

**Table 7 – Standardized Regression Weights: (Group number 1 - Default model)**

| | | | **Estimate** |
|---|---|---|---|
| LCA | <--- | CB | .340 |
| LCA | <--- | AC | -.022 |
| LCA | <--- | CP | -.092 |
| LCA | <--- | SB | .216 |
| LCA | <--- | LR | .369 |
| SUS | <--- | LCA | .383 |
| SUS | <--- | LR | -.014 |
| SUS | <--- | SB | -.021 |
| SUS | <--- | CP | -.229 |
| SUS | <--- | AC | .360 |

Standardized Regression Weights results (Table 7) show that:

Levels of influence of factors on LCA: The independent variable LR has the most substantial impact with 0.369, followed by CB (0.34) and SB (0.216); AC and CP have no effect.
Levels of influence of factor on SUS: The intermediate variable LCA has the most substantial effect with 0.383, followed by AC (0.36); LR, SB, and CP have no impact.
The summary results of the influences of factors on the application of LCA for the determination of eco-costs and the sustainability of business are as follows:

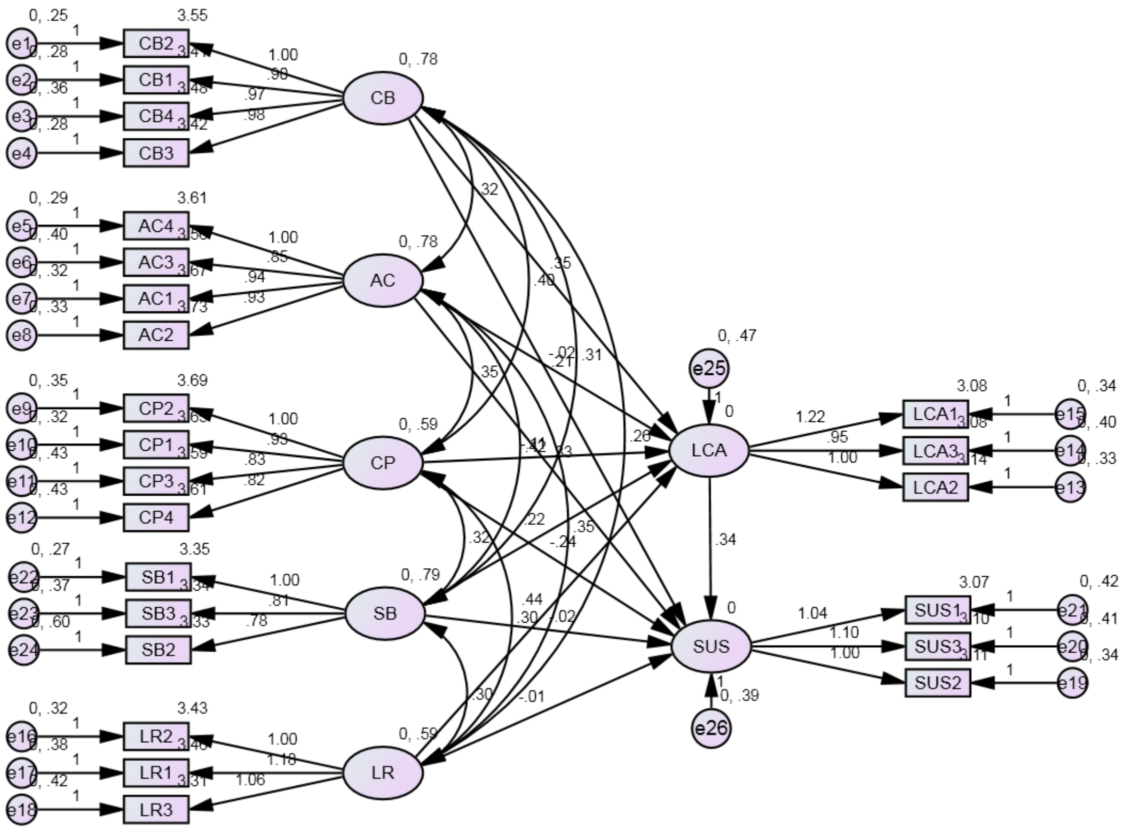


**Figure 5 – The influences of factors on the application of LCA for the determination of eco-costs and the sustainability of the business**

## 5. Conclusion

Eco-costs is an indicator based on LCA and describes the environmental burden based on preventing that burden. Eco-costs are the sum of the marginal preventive costs over the product's life, the total ecological costs of material depletion, the ecological costs of energy and transportation, and the ecological costs of emissions. Eco-costs are costs that need to be made to reduce environmental pollution and material degradation to a level consistent with the Earth's load capacity. They are virtual costs and are not yet included in the current price.

We have proven the determination factors and the degree of influence of each element on the LCA for determining eco-costs and the business's sustainable development level. Independent variables SB (Strategy of the company), LR (legal regulatory system), CB (Characteristics of the business) have an impact on LCA (sig < 0.05). Hypotheses H1, H3, and H4 are accepted. The independent variables CP (Characteristics of manufacture process) and AC (Accounting system) do not affect LCA (sig > 0.05). Hypotheses H2 and H5 are rejected. Similarly, CP (Characteristics of manufacture process), CB (Characteristics of the business), and LCA have an impact on the dependent variable SUS (sig < 0.05). Hypotheses H7, H9, and H11 are accepted. The independent variables LR (Legal regulatory system), SB (Strategy of business), and AC (Accounting system) do not affect SUS (sig > 0.05). Hypothesis H6, H8, and H10 are rejected.

Levels of influence of factors on LCA: The independent variable LR has the most significant

impact with 0.369, followed by CB (0.34) and SB (0.216); AC and CP have no effect.
Levels of influence of factors on LCA: The intermediate variable LCA has the most significant effect with 0.383, followed by AC (0.36); LR, SB, and CP have no impact.

**Data Availability Statement information:** Data analyzed in this study were a re-analysis of existing data, which are openly available at locations cited in the reference section. Further documentation about data processing is available at pdfdrive.com.

**Conflict of Interest:** The authors declare that they have no conflict of interest.

## Reference


1. Bengtsson, M., & Steen, B. (2000). Weighting in LCA–approaches, and applications. Environmental Progress, 19(2), 101-109.
2. Brner, J., & Wunder, S. (2008). Paying for avoided deforestation in the Brazilian Amazon: from cost assessment to scheme design. International Forestry Review, 10(3), 496-511.
3. Finnveden, G., Hauschild, M. Z., Ekvall, T., Guinée, J., Heijungs, R., Hellweg, S., ... & cSuh, S. (2009). Recent developments in life cycle assessment. Journal of environmental management, 91(1), 1-21.
4. Morales-Mora, M. A., Rosa-Dominguez, E., Suppen-Reynaga, N., & Martinez-Delgadillo, S. A. (2012). Environmental and eco-costs life cycle assessment of an acrylonitrile process by capacity enlargement in Mexico. Process Safety and Environmental Protection, 90(1), 27-37.
5. Mora, M. A. M., Dominguez, E. R., Ibarra, A. A., Reynaga, N. S., & Delgadillo, S. A. M. (2014). A methodological improvement for assessing petrochemical projects through life cycle assessment and eco-costs. The International Journal of Life Cycle Assessment, 19(3), 517-531.
6. Norris, G. A. (2001). Integrating life cycle cost analysis and LCA. The international journal of life cycle assessment, 6(2), 118-120.
7. Rezaee, Z., & Elam, R. (2000). Emerging ISO 14000 environmental standards: a step-by-step implementation guide. Managerial Auditing Journal.
8. Van Vliet, O., Brouwer, A. S., Kuramochi, T., van Den Broek, M., & Faaij, A. (2011). Energy use, cost and CO2 emissions of electric cars. Journal of power sources, 196(4), 2298-2310.
9. Vogtlander, J. G., & Bijma, A. (2000). The 'Virtual Pollution Prevention Costs '99'. The International Journal of Life Cycle Assessment, 5(2), 113-120.
10. Vogtländer, J. G., Brezet, H. C., & Hendriks, C. F. (2001). The virtual eco-costs '99 A single LCA-based indicator for sustainability and the eco-costs-value ratio (EVR) model for economic allocation. The International Journal of Life Cycle Assessment, 6(3), 157-166.
11. Vogtländer, J. G., Bijma, A., & Brezet, H. C. (2002). Communicating the eco-efficiency of products and services by means of the eco-costs/value model. Journal of cleaner production, 10(1), 57-67.
12. Vogtlander, J. G. (2002). The model of the eco-costs/value ratio: A new LCA based decision support tool.
13. Vogtlander, J. G., Baetens, B., Bijma, A., Brandjes, E., Lindeijer, E., Segers, M., ... & Hendriks, C. F. (2009). LCA-based assessment of sustainability: the Eco-costs/Value Ratio (EVR). VSSD.

14. Vogtländer, J., Van der Lugt, P., & Brezet, H. (2010). The sustainability of bamboo products for local and Western European applications. LCAs and land-use. Journal of Cleaner Production, 18(13), 1260-1269.
15. Vogtlander, J. G., Scheepens, A. E., Bocken, N. M., & Peck, D. (2017). Combined analyses of costs, market value and eco-costs in circular business models: Eco-efficient value creation in remanufacturing. Journal of Remanufacturing, 7(1), 1-17.
16. Wagner, W., Barnes, K., & Peters, L. (2011). Rulemaking in the Shade: An Empirical Study of EPA's Air Toxic Emission Standards. Administrative Law Review, 99-158.
17. Zhang, Y. (1999). Green QFD-II: a life cycle approach for environmentally conscious manufacturing by integrating LCA and LCC into QFD matrices. International Journal of Production Research, 37(5), 1075-1091.