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Do life-cycle costing and assessment integration support decision-making towards sustainable development?

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Do life cycle costing and assessment integration support decision making towards sustainable development?

Abstract

This study examines whether the integration of life cycle costing and life cycle assessment based on the sequence of activities within the value chain support decision making towards sustainable development. In this research, a framed field experiment with a case study within the Egyptian medical sector was employed, since the waste generated by this sector is not only large but also toxic. In total, 209 accounting and auditing staff employed in central hospitals in Egypt were interviewed. The study shows that integrating life cycle costing and life-cycle assessment through the value chain reduces costs improves environmental performance and improves economic and environmental efficiency to make strategic decisions. This demonstrates that integration supports decision making to achieve sustainable development. Also, the study provides a framework for the integration of life cycle costing and life cycle assessment based on the value chain. Our evidence related to the important role played by the integration of life cycle costing and life cycle assessment in the configuration of economic and environmental performance can be useful for informing future policy and regulatory initiatives, especially in developing countries such as Egypt. The implications of integration are of primary interest not only to government regulators and management accountants but also to investors, analysts, researchers and managers.

Keywords Life Cycle Cost, Life Cycle Assessment, Value chain, Decision-Making, Sustainable Development, Egypt.

Paper type Research paper.

Acronyms

LCC	life cycle costing
LCA	Life Cycle Assessment
SD	Sustainable Development
MFCA	Material Flow Cost Accounting
WMS	Waste Management System
LCM	Life Cycle Management
MWMS	Medical Waste Management System
IPCC	Intergovernmental Panel on Climate Change
GHG	Greenhouse Gas.
GPM	Good Practices Management in inventories and uncertainty estimates

1. Introduction

In recent years, growing concerns about climate change have driven business organizations to change their priorities not only to achieve economic objectives but also to consider ecological objectives (Knauer and Möslang, 2018; Rodríguez and Emblemsvåg, 2007). This coincides with the recent global trend towards sustainable development (SD) and customers looking to utilize environmental products and services (Turner et al., 2016; Zhang et al., 2020). However, it could be argued that this goes against the nature of producers' efforts to reduce costs as they may think that meeting environmental requirements would increase costs, which leads to a conflict of priorities between economic and environmental aspects. Hence, the integration among the increasing environmental demands, resource scarcity and the paramount importance of economic success is a significant challenge (Roure et al., 2017).

Life Cycle Costing (LCC) and Life Cycle Assessment (LCA) are promising modern cost management tools that are well known in practice, which can be used to integrate economic and environmental aspects (Bierer et al., 2015). LCC and LCA are distinctive because they focus on a long-term life cycle perspective in cost accounting practices and counteract management tendencies to focus on the short term (Knauer and Möslang, 2018). According to ISO 15686, LCC calculates the total costs arising through the life cycle of a product/service from raw materials acquisition to disposal (Dunk, 2004; He et al., 2020). In contrast, LCA aims to assess processes' and products' environmental impacts, where it focuses on environmental emissions during a product/service life cycle (Aryan et al., 2019; Emblemsvag, 2001). Moreover, LCC evaluates all economic outcomes, such as costs and revenues. Therefore, LCC directs costs not only during the manufacturing stage but also in earlier and/or later stages of a system (Dunk, 2004). While LCA captures and evaluates inputs and outputs of environmental impacts (Bierer et al., 2013).

Although LCC and LCA use the life cycle in assessment, they are often applied independently. Thus, important relationships between the economic and environmental aspects are ignored (Norris, 2001). In this regard, the purpose of this study is to examine whether the LCC and LCA integration through an appropriate life cycle framework based on the activities sequence in the value chain, to reach cost-justified and Eco-friendly products or services support decision making towards SD in the medical sector.

Not unexpectedly, there has been increasing interest in the issue of LCC and LCA integration in recent years (Ingwersen et al., 2012; Peças et al., 2013). However, a careful assessment of prior literature reveals a number of discernible weaknesses. First, there is a paucity of studies that examine LCC and LCA integration especially by using value chain, where previous studies either use LCC, or use LCA only, or combine their results for making decisions. For example, current research regularly focuses on a specific waste category, for example, infectious waste (Zhao et al., 2009) or specific procedures such as disinfection (Eberle et al., 2007). Studies modelling an integrated system LCC and LCA of hospital waste disposal are limited (Ali et al., 2016), especially in developing countries such as Egypt (Ahmad et al., 2019). Additionally, none of these studies addresses integration on a common basis except for Bierer et al. (2015), which uses material flow cost accounting (MFCA) to link LCC and LCA with an only theoretical framework (Biere et al., 2013, 2014). Second, to the best of our knowledge, no study addresses economic and environmental assessment integration towards SD in Egypt to date. Third, there is a paucity of studies applied to waste management systems (WMS), especially medical waste in Egypt. This study attempts to close this research gap by implementing the LCC and LCA integration using an appropriate life cycle framework by value chain, which enables the precise identification of activities and thus excludes any activity that does not add value and therefore leads to continuous improvement.

Health care waste management is a significant challenge in most health care facilities in developing countries. Regulatory agencies must ensure the safety of waste management alternatives. In addition, the methods of malpractice exercised during the handling and disposal of these wastes are creating significant health hazards and environmental pollution due to their infectious nature (Soares et al., 2013). Also, improper disposal and mishandling of hazardous medical waste lead to a high incidence of many diseases, especially liver patients, where 80% of people infected with Hepatitis C are due to these wastes. Additionally, government reports revealed that the total costs of treating the infectious diseases caused by medical waste are about 2.5 billion Egyptian pounds annually (Egyptian Association for Liver Diseases Studies). Also, new techniques have emerged for medical waste disposal, including steam sterilization, which is one of the safest ways to destroy microbes but is very expensive (Soares et al., 2013). So, this paper examines whether integration provides economic and environmental information to management and thus supports decision making for these practices.

In this study, framed field experiments with a case study were employed within the Egyptian medical sector since the wastes generated by this sector is not only large but also toxic. In total, 209 accounting and auditing staff employed in central hospitals in Egypt were interviewed. The findings indicate that the integration of LCC and LCA on a value chain basis improves costs and environmental impacts. Moreover, this integration provides a starting point to inform efforts towards SD. With respect to the benefits of integration, the findings show that integration enables the identification of costs and environmental drivers. Consequently, the integration improves gathering relevant information for decision making.

Moreover, this integration provides a starting point for reporting efforts towards SD. Performing integration using an appropriate life cycle framework on the basis of activities sequence in the value chain excludes activities that do not add value and improve performance without affecting the value of the product/service. Through a field experiment, the paper demonstrated the practical feasibility to support decision making on medical waste management, to achieve ecological products/services and justified by the costs that support decision making towards SD. This information could provide guidance for management accountants and a basis for decision-makers on sustainable systems and management.

The integration of LCC and LCA is important for a number of reasons. First, the paper helps explain previous ambiguous results on the effects of the trade-off between economic and environmental aspects. Specifically, our study investigates strategic cost management instruments (LCC, LCA), which has received less attention. Second, it is necessary to provide appropriate information about the products/services life cycle, which raises performance efficiency and accuracy in decision making. So, this paper adds to the literature by analyzing the various benefits of LCC and LCA integration. Finally, provide more efficient systems where LCC and LCA integration can be used to overcome deficiencies and improve waste management systems. Overall, our study contributes to analyzing the alignment between theoretical and practical perspectives on the integration of LCC and LCA.

The remainder of this study is organized as follows. Section 2 presents LCC and LCA for SD. Section 3 develops hypotheses. Section 4 describes the methodology. Section 5 portrays the study sample, and the discussion is in section 6. Finally, Section 7 represents the conclusion.

2. LCC and LCA for sustainable development (SD)

2.1 LCC for SD

LCC is considered an important management accounting method (Dunk, 2004; Knauer and Möslang, 2018). A distinctive feature of the LCC concept is that it supports a long-term perspective in cost accounting (Albuquerque et al., 2019; Knauer and Möslang, 2018). As, LCC is a technique for a regular economic assessment by identifying and evaluating the economic effects (all direct and indirect costs, internal and external costs), where, the costs of investment, operation, maintenance, and disposal are taken into account "from the cradle to the grave "(ISO14040; Oduyemi et al., 2018; Silalertruksa et al., 2012). In addition, LCC deliberately includes upfront and follow-up costs; consequently, it allows comparing alternatives, supports the evaluation of investments, provides cost savings, and evaluates performance to make appropriate strategic decisions (Animah et al., 2018). More precisely, LCC can result in cost reductions and maximize value (Heralova, 2014; Oduyemi et al., 2018)[1]. According to ISO 14040, the life cycle includes six stages. LCC can cover all or part of these stages (Hasan et al., 2017). It should be noted that LCC depends on discounted cash flows taking into account the inflation rate (Seo et al., 2015).

The relative accuracy to improve the different results during the life cycle stages is the main objective of LCC. It is clear that LCC achieves an accurate evaluation and continuous improvement (Rodríguez and Emblemsvåg, 2007; Wee et al., 2011). Therefore, LCC is suitable for the SD economic dimension, where it increases effectiveness and quality improvement. Also, its potential could be related to the sustainable economy by strengthening the knowledge-based economy, the adoption of sustainable mechanisms and innovation.

2.2 LCA for SD

To improve environmental efficiency (reduce harmful emissions such as carbon dioxide) (Soust-Verdaguer et al., 2016) and ensure environmental sustainability, LCA is an important factor. LCA is a technique used to examine and evaluate possible environmental impacts for products/services, from obtaining raw materials to disposal (Lo-Iacono, 2016). LCA evaluates the available alternatives by identifying the vital environmental points (Curran, 2013; Hu et al., 2020); to avoid or minimize these impacts (Ingwersen et al., 2012). Therefore,

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[1] Notably, most authors use LC Cost, LC Costing, Whole LCC, and LCC analysis for referring to the same meaning, while others differentiate between them. Thus, the authors think these terms are only sequence events where; total costs are determined via LC Cost, and then these costs are assessed by LC Costing. For a comprehensive assessment, revenues are added to LCC (whole LCC), then analyze it by LCC Analysis. According to ISO, LC Costing (LCC) is a technique for assessing total cost.

it is a continuous, systematic evaluation to support environmental improvement based on the results of the life cycle inventory analysis (Castellani et al., 2017; Stazi et al., 2012; Pradel et al., 2016; Shah and Unnikrishnan, 2018; Soust-Verdaguer et al., 2016). It has been widely used to make strategic environmental decisions (Chang et al., 2014).

In addition, LCA is a structural analysis to meet environmental requirements; it provides a comprehensive set of environmental efficiency indicators for optimal use of energy and materials (Kara and Ibbotson, 2011). LCA promotes the clean development mechanism, support ecological consumption, and achieves safety and well-being (Nie, 2016). Therefore, LCA is important to guarantee the SD in different sectors, where it is extending research trends from the identification of environmental impacts to an exhaustive study that includes social aspects.

It is worth mentioning that Bierer et al. (2013, 2015) summarize some similarities between LCC and LCA as follows. Both are continuous evaluations during the life cycle stages and follow the same system database. As they share the same goals and scope and support long-term priorities and planning. They are means to control the performance of the business (for example, costs achieved, and environmental objectives). Moreover, they have the same design and documentation methods (flow models and graphics); data acquisition is the slowest activity in each. Finally, both face the same problem to evaluate complex production systems. Therefore, LCC can be considered to be the economic equivalent of LCA; this is the starting point for integration (Settanni et al., 2014). Meanwhile, the differences between LCC and LCA lie in LCC and LCA are designed to answer different questions (determine alternatives and commercial decisions of the economic decision maker through LCC, but LCA compares alternative environmental impacts through the social perspective) (Bierer et al., 2015). Table 1 summarizes these differences.

Table 1 LCC and LCA differences (ISO 15686-5, ISO14040).

Tool/ Method	LCC	LCA
Definition	Calculate total cost arising during the life cycle to eliminate unwanted costs, thereby reduces risks, designs that satisfy customers.	An environmental audit focuses on environmental emissions during life cycle stages from the acquisition of raw materials to disposal.
Objective	Determine alternatives and business decisions from the economic decision-maker perspective, such as owners.	Compare alternatives environmental performance to meet the same end-use function from a social perspective.
Flows considered	Cost and cash flows that directly affect the decision-making.	Pollution, resources, material, and energy flows.
Units	Monetary units (e.g., Dollar).	Physical units (e.g., mass).
Time treatment	Time is a vital factor in current cost assessment, based on a specific time, neglecting any costs/benefits that occur outside this range (current value and discount rates) (Norris, 2001).	Neglecting time; timing of processes environmental impacts are ignored, where environmental impacts valued equally regardless of timing. (Norris, 2001).
Uses	1. Identify problems related to the production design, products. 2. Determine economic success (profit terms). 3. Cost control.	1. Detect vital environmental areas. 2. Compare alternatives environmental. 3. Disclosure opportunities for environmental development.
Method	Bottom-up; which means the total cost is sum up by the cost of each step during the life cycle (Biernacki, 2012)	Top-down means that environmental impacts are collected at the company level. Then, the top-down method involves the assignment of company-level cost information to individual products or functional units. (Biernacki, 2012).
purpose	1. Determine cost savings. 2. Cost management to evaluate all financial results.	1. Reduce environmental damage. 2. Support environmental products.
Range	Costs.	Materials, products.
Functional unit	No specific term.	E.g., Ton/ Kilo.
dimension	Economic.	Environmental.
main motive	Cost-effectiveness.	Improve resource efficiency.
Time scope	Short time view of investors in LCC (20–30 years), (König and cristofaro, 2012).	The long view used in LCA50: 100 years), (König and cristofaro, 2012).
Cost calculation	Total cost.	Not considered.
Environmental impacts	They are not considered.	Air, soil, water....
Supports	Rationalize costs via: 1. Identify cost drivers. 2. Determine cost elements importance (Bierer et al., 2013, 2015).	Support environmental product where: 1. Select environmental indicators. 2. Cover environmental burdens. (Bierer et al., 2013, 2015).

2.3 LCC and LCA integration using value chain:

A product life cycle is a period from research and development to customer service. The life cycle has five stages over the life of a product: product development, introduction, growth, maturity and decline stages. However, the term ‘‘value chain’’ denotes a sequence of activities within the firm that delivers value to the firm’s clients in the form of either a product or a service (Porter, 1986). The value chain analysis usually includes research and development, design, production, distribution and service (Wiryawan et al., 2020). Remarkably, the sequence of commercial functions within the value chain are equivalent to the life cycle stages; for example, research, development activities from the value chain are equivalent to the research and development stage from life-cycle. Based on the objectives of LCC and LCA that assess life cycle costs and environmental impacts, the value chain is an appropriate starting point to integrate and strengthen the relationship between LCC and LCA. Where an appropriate life cycle framework can be established for the system according to the sequence of activities within the value chain. Also, the value chain allows excluding activities that do not add value according to the objective and scope of the study and improve performance without affecting the value of the product/service.

It is worth mentioning that before integration, Coca-Cola implemented the first use of the LCA, in 1969 to evaluate the consumption of resources. Then, plastic containers were used instead of glass. In the year 2000, with the use of software such as PT Lase, to integrate the results of LCA and LCC, Coca-Cola discovered that plastic containers have low costs and are easy to recycle. Thus, it is the best alternative; plastic was easier to recycle than glass (Jiawei, 2014).

The integration steps are illustrated below: the first step is to carry out a common definition for the objectives and scope of the evaluation. The second step is to determine the appropriate life cycle framework according to the sequence of activities in the value chain (limitations and evaluation period), this refers to the definition of the life cycle (market or productive ... cycle of life). Then, the third step is to identify the target numbers and calculation methods, such as the net present value and the average. Step four, divide the production structure, its processes, and activities; for example, divide the production process into the assembly, supply lines, and design available alternatives. To ensure the inclusion of all influential factors (internal as technology or external as competitors), more than one scenario must be developed within the five-step model.

Meanwhile, step six is to collect data for sub-levels according to step 4 (economic or environmental data only). After recording all the data, evaluate the available alternatives according to the target numbers, this is the seventh step. Step 8, analysis of results; apply multiple criteria decision making to find the best environmental, economical alternative. Finally, perform a sensitivity analysis. In particular, the value chain allows identifying deficiencies that cause economic and environmental impacts; its main advantage lies in identifying activities that add value and those that do not add value, therefore, exclude activities that do not add value. Figure 1 illustrates the integration steps.

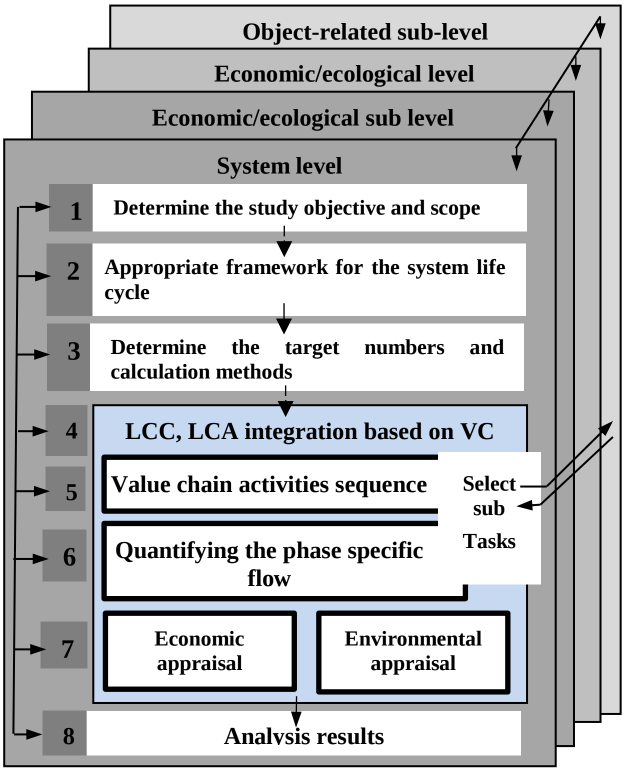

Fig 1: LCC and LCA integration based on the value chain.

3. Literature review and hypothesis development

3.1 LCC for decision making

The selection of the most appropriate strategy from a wide range of potential options remains a challenging task that involves several technical, economic and organizational complexities. To meet this challenge, it is crucial to develop analytical tools and methods capable of evaluating strategies concerning their associated costs and quantifiable benefits. The optimization of the LCC of a system is essential for a complex decision-making process (Animah et al., 2018; Heralova, 2014). Where Patil et al. (2017) find that LCC plays a vital role in the reliability and maintainability of the system. LCC allows companies to obtain improvement measures in the design phase (Mannuß et al., 2012). Also, the benefits of this methodology not only reduce the cost of the life cycle but also improve service availability/capacity through fewer failures (Ghosh et al., 2018).

On the other hand, it may also be related to the growing need to find more sustainable alternatives. These trends led to a significant increase in scientific publications related to LCC

(Goh and Sun, 2016). Woon and Lo (2016) point out that the results of the economic evaluation could be linked to environmental efficiency indicators to improve the efficiency of the waste management system and to make decisions about waste disposal management towards sustainability. In addition, Spickova and Myskova (2015) emphasize that recent developments (such as LCC) support decision making for strategies and improve the economic efficiency of investments (Albuquerque et al., 2019). Finally, the results of the Knauer and Möslang study (2018) show that the scope of LCC adoption is positively associated with the scope of the initial and follow-up costs for ecological sustainability.

This paper focuses on the types of significant costs that are relevant to decision making, which supports decision making to achieve the objectives of SD. In general, LCC seems to be particularly appropriate to help decision-makers consider the impacts of multiple attributes of a product/service. However, the link between the availability and knowledge of the information and the quality of the decision can be distorted since other factors also influence decision making. Therefore, we generally expect a positive association between LCC and decision making towards SD. These hypotheses are not intended to be counter-intuitive, but they allow us to connect the theoretical concept of LCC with its practical perspective. Therefore, the first hypothesis is:

H1. LCC is positively associated with information related to decision making, which supports decision making, especially to achieve the objectives of SD.

3.2 LCA for decisions making

The primary purpose of using LCA is to calculate environmental impacts, especially in the initial phases. Stazi et al. (2012) propose a method to improve energy and environmental efficiency. They find that LCA is an effective technique to achieve environmental sustainability, where it was used to select design components at each stage, thus improving environmental performance (Adghim et al., 2020). While some studies like Parkes et al.

(2015) examine the LCA to identify the best environmental alternative. They find that the use of LCA supports the decision making process to plan strategies towards SD. LCA achieves an ideal product that balances profitability and environmental efficiency. Brogaard and Christensen (2016) find savings from the early replacement of materials for some recycled capital goods. They point out that the environmental impacts of recycling these metals are less than those arising from the virgin production of the same materials. Capitanescu et al. (2016) show how to cover operating costs and environmental impacts, provide practical solutions to achieve sustainability. Furthermore, more recent studies demonstrate that the results obtained through LCA can be used in the decision-making framework for the selection of appropriate technology (Kamble et al., 2018; Shah and Unnikrishnan, 2018). Finally, Choudhary et al. (2019) study found that the enterprises can do the microanalysis of environmental effects of processes to improve environmental performance, and the data can provide useful information for decision-makers to adopt green projects (Shafique et al., 2020). These studies are evidence of the significant relationship between the LCA and decision making.

Other studies provide a systematic presentation on the LCA, such as Chang et al. (2014), which considers a thorough investigation from the practical perspective where it provides an organized review of more than 100 LCA studies, highlights the use of LCA to support decision making towards the development of sustainable products. Similarly, Peters (2016) finds how to adapt, LCA, to remanufactured products, illustrates methodological difficulties when LCA is used within recycling policies. A recent study by Ripa et al. (2017) investigates environmental efficiency by focusing on environmental costs towards sustainability. Also, Kjaer et al. (2016) address some of the limitations faced by the use of LCA to assess the environmental impacts of service systems. They developed and adapted LCA principles to identify and ensure real environmental benefits.

In summary, previous studies examine the relationship between LCA, and decision making towards sustainability provides a simplified set of tools to be a reference for users to support decision making towards SD. Unfortunately, empirical evidence regarding the relationship between LCA and decision making towards SD and its applicability in developing countries, especially for WMS, is scarce. Therefore, this study hypothesis a significant relationship between LCA and decision making to address waste, especially medical waste, towards SD as follows.

H2. LCA is positively associated with information related to decision making, which supports decision making, especially to achieve the objectives of SD.

3.3 The integration of LCC and LCA to support decision making towards SD

LCC and LCA measure the cost and environmental performance of business activities, respectively. Previous studies use economic and ecological consequences related to the life cycle to make effective decisions. Some of these studies depend on LCC as the central concept for the evaluation of the entire life cycle of all monetary consequences of the system. Through the combination of LCA and LCC, Martinez et al. (2011) find that the environmental designs of the product lead to reduce the costs of other designs. Furthermore, the use of LCC, together with LCA, contributes significantly to SD, where LCC and LCA are necessary to achieve economic well-being (Schau et al., 2011). Rossi and Sihn (2013) point out that the design of industrial products based on the life cycle meets environmental requirements and provides maximum economic benefits (Martinez-Sanchez et al., 2015). Other studies integrate aspects of costs in LCA, so the results provide a consistent basis for understanding the implications of decision making in the early stages (Peças et al., 2013). Therefore, life cycle management (LCM) has been derived as a new concept (Ingwersen et al., 2012).

Other studies refer to the parallel application of LCC and LCA. For example, Soares et al. (2013) find the best economic-environmental alternative by combining LCA and LCC results. Other studies also support this notion (for example, Jiawei, 2014; König and cristofaro, 2012; Ristimaki et al., 2013; Woon and Lo, 2016). To assess the environmental and economic impact, Turner et al. (2016) find that the life cycle approach is highly innovative, especially in its interdisciplinary approach, which provides the tools for preparing management plans. In addition, companies can use the results for marketing and communication with shareholders, where this integration provides a starting point to inform about the efforts of companies to achieve sustainable objectives (Biernacki, 2012). However, Bierer et al. (2015) extend MFCA according to the analysis requirements of the entire life cycle to overcome some of the challenges of economic and environmental integration. Similarly, D'Incognito et al. (2015) evaluate the existing barriers to the slow adoption of the LCA and LCC and the main actors responsible. Roure et al. (2017) propose a framework for the systematic integration of sustainability through the lenses of the life cycle approach and the associated tools to achieve effective integration of the curriculum. Jeong et al. (2018) also find the effectiveness of the new lifecycle platform for optimal selection of ship designs was demonstrated in a way that the module-based analysis can greatly simplify the LCA and LCC by eliminating the user modelling/analytic procedure, thereby speeding up the decision-making process.

To conclude, the literature suggests that LCC and LCA are considered a good starting point for the integration of sustainability components, but much research should be directed towards understanding the mutual relationships between the different methods that are currently applied independently. From each other to support decision making in light of recent trends towards SD. Besides, to our knowledge, there is no study of the integration of LCC and LCA frequently use the value chain. This is related to our main study questions that indicate whether LCC and LCA can be integrated throughout the value chain, which allows a good understanding of the course of activities and, therefore, excludes all activities that do not add value, and they improve performance without affecting the value of the product /service.

Consequently, this integration can support decision making towards SD and achieve its objectives. Therefore, the third hypothesis is:

H3. The integration of LCC and LCA supports decision making towards sustainable development, especially in the medical sector.

4. Methodology

4.1 Data collection

The integration of LCC and LCA as a methodology improves the analysis because it offers multiple dimensions that define different strategic options, to support decision making and in line with the criteria of economic, environmental and social sustainability. A better understanding of a complex phenomenon requires multidisciplinary approaches and qualitative research methods for the collection of prior knowledge (Salvado et al., 2018). Thus, this study was conducted in two successive phases. Case studies are among the most appropriate methods to appreciate the complexity of organizational and social phenomena. Also, they are suitable for addressing the "how" or "why" research questions (Yin, 2009). Therefore, the first research method is a case study of the Medical Waste Management System (MWMS) in Egyptian government hospitals to explore the complexity of organizational processes, describe current practice and procedures adopted and carry out the integration between LCC and LCA in a precise basis. The second research method is a field experiment conducted with 251 managers, accounting and auditing staff employed in central hospitals in Egypt, which have a direct relationship with MWMS, to measure the degree to which this integration relates to the decision making through data obtained in the case study to make effective decisions towards SD. Specifically, in this paper survey methods were mixed with experimental methods. As the participants were provided with a situation, they had to read about and assess using the survey.

The health services sector is one of the most important sectors, especially in Egypt. Consequently, government hospitals were chosen for several reasons. First, for the reliability of government data and unavailability of such sensitive data in the private sector. Second, medical waste from government hospitals accounts for a large proportion of medical care waste in this sector. Poor practices and improper disposal methods that are exercised during the handling and disposal of these wastes are creating significant risks to health and environmental pollution due to their infectious nature. In addition, the costs of treating infectious diseases caused by medical waste are approximately 2.5 billion Egyptian pounds annually. Furthermore, new techniques have emerged for the disposal of medical waste, including steam sterilization, which is one of the safest ways to destroy microbes but is very expensive (Soares et al., 2013). The information from LCC and LCA was collected to provide a framework for its integration through the case study.

4.2 LCC model description of MWMS:

To use LCC and LCA, a basic understanding of them is required. Thus, a case study approach was adopted, where accurate information is beneficial for the validity of variables measurement. The fourth LCC model and the actual costs were used to eliminate the uncertainty associated with the prediction. Where, the models used to calculate LCC are multiple. There is a binary and triangular model, but the Quaternary model is the most frequently used; where the calculation can be formulated as follows (Rivera and Azapagic, 2016):

$$LCC = C1 + C2 + C3 + C4$$

where C1 denotes research and development costs, C2 denotes construction costs, C3 denotes operating and support costs, and C4 denotes waste disposal costs (Spickova and Myskova, 2015).

MWMS costs are derived from the actual data of the Egyptian Ministry of Health. The data is obtained from the analysis of official documents, such as budgets and environmental reports for the years 2012 till 2017, unstructured interviews with key informants, and participants' observation. Therefore, the result of the LCC model is an Egyptian pound value determined from the sum of LCC in real terms, for 5 years. Where, Costs have not been converted from Egyptian pound to dollars due to the significant change in the price of the dollar and the floating of the Egyptian currency in the recent period. The results of LCC for MWMS can be compared directly. The variables used in the LCC model are detailed in Tables 2 and 3. A real cost would have been more appropriate because the model was required to determine the actual amounts of money to be paid at specific times throughout MWMS. In addition, for this evaluation, the principal interest is to determine the total cost of MWMS.

Table 2: LCC results of the medical waste management system.

Phase/Year	**2013**	**2014**	**2015**	**2016**	**2017**
Sorting/Collection	269,640 44.25%	300,780 44.52%	325,620 44.19%	350,460 44.22%	383,940 40.95%
Non-hazardous 80%	215,712 35.41%	240,624 35.62%	260,496 35.36%	280,368 35.38%	307,152 32.77%
hazardous 20%	53,928 8.85%	60,156 8.9%	65,124 8.83%	70,092 8.84%	76,788 8.19%
Storage	17,070 2.8%	17,820 2.64%	18,520 2.51%	18,900 2.38%	20,670 2.21%
Treatment	275,280 45.18%	294,000 43.52%	313,940 42.61%	331,760 41.86%	422,540 45.08%
Autoclave	209,280 34.35%	213,600 31.61%	217,940 29.58%	221,360 27.93%	284,540 30.35%
Incineration	66,000 10.83%	80,400 11.91%	96,000 13.03%	110,400 13.93%	138,000 14.73%
Landfilling	47,250 7.76%	63,000 9.32%	78,750 10.69%	91,350 11.54%	110,250 11.76%
Total	609,240	675,600	736,830	792,470	937,400
Non-hazardous	215,712 35.41%	240,624 35.62%	260,496 35.35%	280,368 35.38%	307,152 32.77%
hazardous	393,528 64.59%	434,976 64.38%	476,334 64.65%	512,102 64.62%	630,248 67.23%

Notes: Percentages show the ratios of each figure to the total costs of the stage in the same year**.** Whole numbers are in Egyptian pounds, where, Costs have not been converted from Egyptian pound to dollars due to the significant change in the price of the dollar and the floating of the Egyptian currency in the recent period**.**

Table 3: LCC of the medical waste management system.

Phase	Cost calculation
Sorting and Collection	Labour cost + environmental Cost. Labour cost = number of workers x worker's wage x 12 months/year. Environmental cost = bags cost + supplies cost. Bags cost = number of kilos used from bags x price per bag kilo x 12 months/year. Supplies cost = number of workers x worker personal supplies x 30 days/month x 12 months/year. Worker personal supplies = mask + glove.
Storage	Supervisors salaries + scales depreciation + sterilization costs+ equipment costs. Supervisor salary = monthly salary x 12 months/year. Scales depreciation = scales cost ÷ number of the life span years. Sterilization costs = gloves + alcohol, Dettol, and some other substances. Electricity and water costs that the storage room consumes have been neglected due to its relative negligence.
Autoclave	Sterilization machine depreciation + Labour cost + employment personal requirements+ disinfectants cost + environmental analysis costs. Machine depreciation = machine cost ÷ number of the life span years. Employment personal requirements = personal supplies of the worker x number of workers x 30 days/month x 12 months/year. Disinfectants cost = average disinfectants and detergents required for sterilization. Environmental analysis costs = monthly sterility analysis + TCLP Analysis. Monthly sterility analysis = monthly cost x 12 months/year. TCLP Analysis = Cost x 2. TCLP Analysis: An analysis to ensure the degree of sterilization of waste is done twice a year in accordance with the Egyptian Environmental Law.
Incinerator	Transfer cost + burning cost. Transport cost = total incinerated waste in kilograms × number of times transportation × cost of waste transporting kilo × 12 months/year. Burning cost = total waste in kilograms × number of times transportation × Cost of burning kilo × 12 months/year.
Landfill	Transporting cost for all sterile and incinerator waste + landfill cost. Landfill cost = total waste in kilograms × daily cost of burial × 30 days/month × 12 months/year.

Notes: This table is a depth view of how the results were computed in the previous table. Sterilization machine depreciation cost, which purchased with 1,600,000 Egyptian pounds a life span of 10 years _machine maintenance cost is not calculated during a warranty.

4.3 LCC model analysis

The total cost of the WMS life cycle can be calculated over five years, where LCC of the MWMS for the fiscal year 2013, 2014, 2015, 2016, and 2017 was 609,240, 675,600, 736,830, 792,470 and 937,400, Egyptian pounds respectively. The importance of the stages of sorting, collection, and treatment are evident due to its higher cost, reflected in percentages that amounted to 44.26%, 44.5%, 44.19%, 44.22%, and 40.95%, respectively. In particular, costs and their percentage for each year are higher than others, due to higher wages and inflation. In addition, the cost of the highest treatment stage for the 2017 fiscal year due to the additional financial charges incurred by the spare parts for the machine beyond its warranty, where the percentage was 45.8% (depreciation plus spare parts 55,000), as well as high prices and inflation rate in this year since the previous one. Then, the causes of cost deviations can be discovered.

4.5 *LCA model description of MWMS:*

The objective of the study is to determine the environmental impacts of MWMS. MWMS can be divided into several consecutive stages. According to the Egyptian Environmental Protection Law, medical waste sorted at source and collected within sections (sorting and collection stage). Then, Non-hazardous waste is disposed of by the household way. While hazardous waste transported to a designated warehouse, weighed, recorded and prepared for processing (storage stage). The medical waste treatment carried out in two phases: inside and outside the hospital _transfer of incinerators_ (treatment phase). Finally, the treated waste transferred to the landfill (landfill stage). Therefore, the scope of the study was limited to the stages of the MWMS life cycle, and the functional unit was a ton of waste. Then, the life cycle inventory is calculated by identifying environmental emissions from inputs in the sorting stage to outputs in the landfill stage. To complete the environmental assessment purposes, by using IPCC and GPM for GHG emissions, CO2 emissions were calculated, which account for about 60% of greenhouse gases (IPCC, 2007; EEAA Procedures Manual, 2009)[1].

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[1] IPCC is an Intergovernmental Panel on Climate Change, 2007. GPM is Guide to good practices in Management GHG inventories and uncertainty estimates, and GHG is Greenhouse Gas.

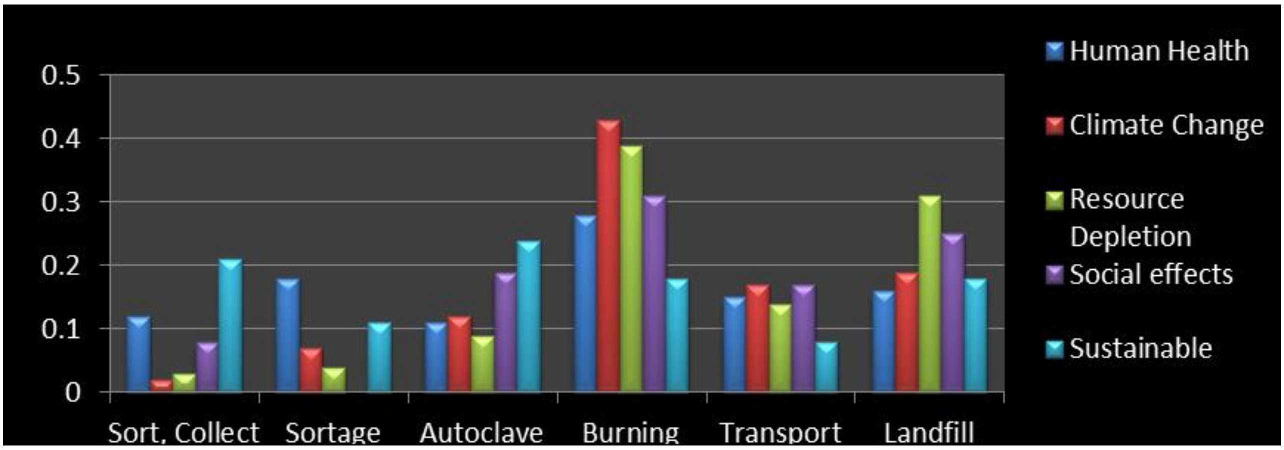


Fig 2 LCA results of the medical waste management system (source: Egyptian Ministry of Environment). The columns sets indicate sort and collection, storage, Autoclave, burning, transporting, and landfill stages, respectively.

4.6 LCA model analysis

Figure 2 presents the calculation of the total environmental impact. From there, the incineration phase is characterized by high environmental effects due to high carbon dioxide emissions and high environmental impact on air, soil, and public health, followed by burial. Carbon dioxide emissions, which account for about 60% of greenhouse gases, have been calculated, where estimated emissions to transfer treated waste to the landfill were $249x10^5$ kg CO_2 per litre/year of fuel, while it was $249x10^8$ / kg CO_2 per litre/year for the incineration phase. While the burial stage was characterized by high environmental impacts in the exploitation of natural resources due to the high impact on land use, and these effects were reflected in social effects, where the autoclave had the most significant positive impact on environmental sustainability followed by the sorting and collection stage.

4.7 LCC and LCA integration using the value chain:

The following steps of integration using the value chain can be followed, as depicted in Fig 1:

1) Make a common definition of the objectives and scope of the evaluation. In our case, it is how to manage MWS and support decision making towards SD.

2) Determine the appropriate life cycle framework according to the sequence of activities of the value chain (limitations and evaluation period); this refers to the definition of the life cycle. Therefore, the appropriate framework for the MWMS life cycle model according to the sequence of activities (storage stages, treatment ... burial) was determined.

3) Identify the target figures and calculation methods for LCC such as the net present value and for the LCA, such as the average of environmental estimation emissions. Actual data from previous years have been used. As a goal to reduce costs and reduce environmental emissions total numbers, such as 937,400 E.P for LCC and $249x10^8$ / kg CO_2 per litre/year for the LCA, were used.

4) Divide the structure of the system, its processes, and activities; for example, divide the production process into the assembly, supply lines ... and design available alternatives. The WMS was divided into activities within the stages, for example, classification, then collection activity.

5) To ensure the inclusion of all influential factors (internal as technology or external as competitors), more than one scenario must be developed.

6) Collect data for sub-levels according to step 4 (economic or environmental data only).

7) The current situation and the available alternatives are evaluated according to the target numbers.

8) Analysis of results; apply multi-criteria decision making to find the best environmental, economical alternative.

9) Perform sensitivity analysis.

In particular, the value chain makes it possible to identify deficiencies that cause economic and environmental impacts; its main advantage lies in identifying and excluding activities that do not add value, such as the transfer of waste between stages. It is clear that the treatment stage, especially the incineration, dominated most of the environmental costs and effects.

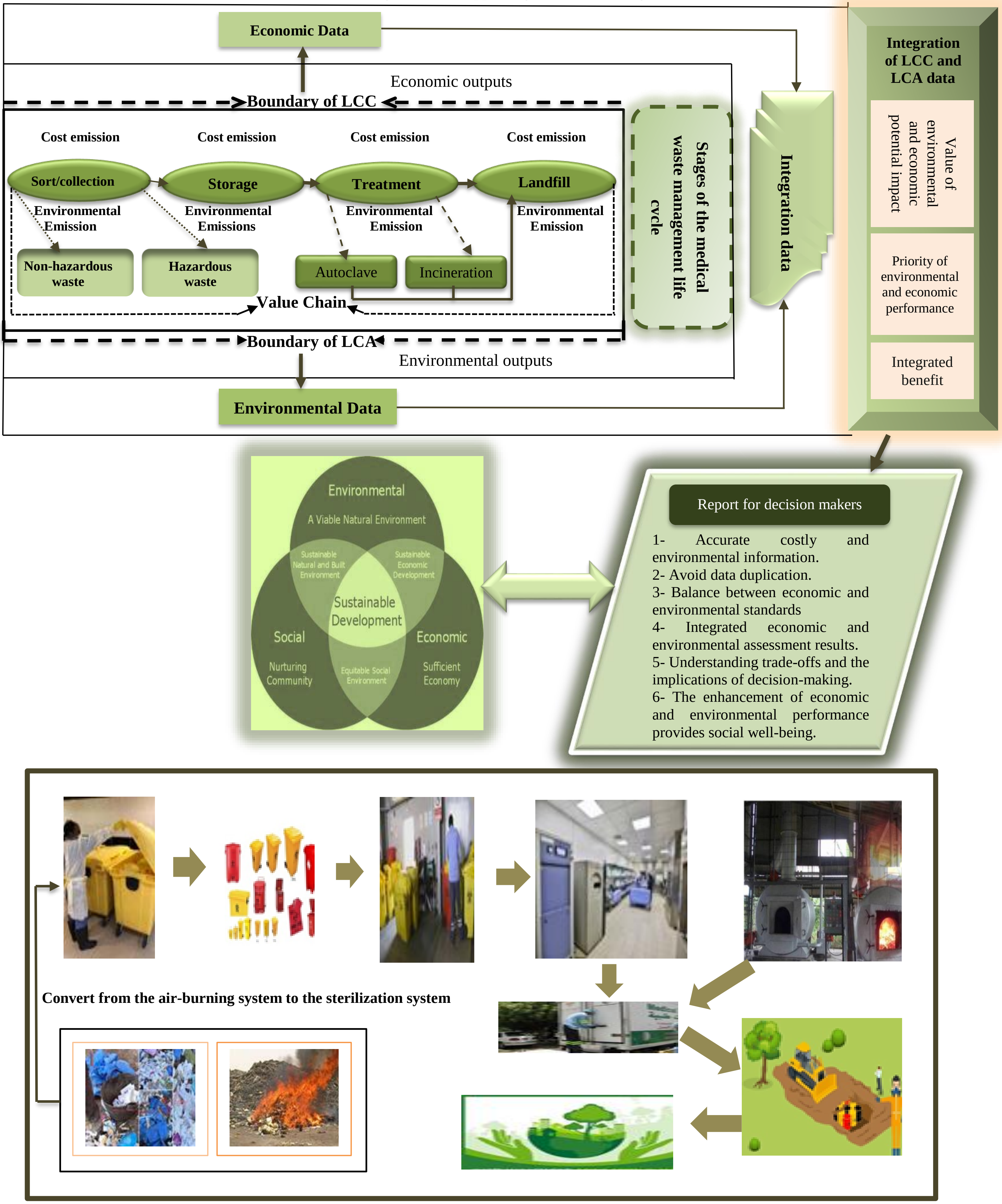
4.8 LCC and LCA integration to support SD decision making

SD is an innovative global concept; where it plays an important role in balancing the production and reserves of natural resources, concerned with the development of ways that do not lead to the depletion of natural resources (Biernacki, 2012; Ristimaki et al., 2013; Roure et al., 2017). Therefore, the SD debate is usually considered encompassing three dimensions of impact: economic, environmental and social in all aspects of decision-making processes. In parallel, the study of sustainable processes has evolved from an exclusively production-oriented analysis to a more complete life cycle thinking approach where all stages of the life of a product are evaluated (for example, extraction of raw materials, transport, production, use, and completion). Therefore, the fusion of the concepts of sustainability and life cycle thinking has resulted in the development and use of three different tools to assess economic (LCC), environmental (LCA) and social aspects (Gallego-Schmid et al., 2018).

In an open and liberal economy, there must be an economic reason for the producer or consumer to opt for a more sustainable option for a product or service. Also, climate change, carbon footprint, sustainability assessment, and SD policy formulation are fundamental issues (Alshbili and Elamer, 2019; Elamer et al., 2017, 2019, 2020; Elmagrhi et al., 2019; Gerged and Elheddad, 2020; Gerged and Agwili, 2020; Gerged et al., 2018; Hassan et al., 2019; Gerged et al., 2018; McLaughlin et al., 2019). Therefore, studying complex sustainability assessment problems from a holistic point of view is considered integrative vital (Egilmez et al., 2017). Organizations must take into account their economic and environmental impacts linked to the value chain, so that decision making is effective towards SD. Therefore, the integration of LCC and LCA provides a complete analysis of economic and environmental performance, which provides a basis for understanding compensation and supporting implications; therefore, the "best" is identified. Therefore, life cycle techniques to achieve, SD goals can be relied on.

In addition, the integration of LCC and LCA streamlines costs, improves environmental designs without affecting performance or product characteristics, thus improving customer satisfaction by meeting their environmental requirements. In addition, it admits strategic decisions through a life cycle perspective, which improves life cycle management. It is a continuous evaluation to support justified economic and environmental decisions for urban areas. Therefore, this integration provides relevant information for sustainable management and decision-makers, promotes continuous improvement to provide social prosperity, which is the third pillar of SD, provides a solution to make an appropriate decision towards SD, and provides a report on efforts to achieve SD, can be assumed that. This is related to our third hypothesis, which assumes that the integration of LCC and LCA supports decision making, especially towards the achievement of SD. This is tested in the next section.

FIG 3: LCC and LCA integration for supporting decision making towards sustainable development.



1- Accurate costly and environmental information.
2- Avoid data duplication.
3- Balance between economic and environmental standards
4- Integrated economic and environmental assessment results.
5- Understanding trade-offs and the implications of decision-making.
6- The enhancement of economic and environmental performance provides social well-being.

5. Sample and results

5.1 Design:

To demonstrate that the model of LCC and LCA integration provides valuable information for effective decision making and can be the basis for SD decisions, thus confirming the viability of implementing sustainable measures, in addition, to increase the reliability and validity, the study examines the model of integration via a randomized field experiment. Managers, accounting and auditing staff employed in central hospitals were selected to participate in the study and randomly assigned at central hospitals in 2018. The participants were provided with general study instructions and a research instrument (the above case materials). First, information on LCC was provided, then LCA and finally integration to measure the impact of each of these variables on participants for decision making. Participants answered manipulated questions and provided information at the end of the experiment.

5.2 The task:

The literature shows that many variables are used to examine LCC and LCA integration (D'Incognito et al., 2015; Jeong et al., 2018; Rivera and Azapagic, 2016; Roure et al., 2017). Based on the information contained in this literature, the instrument consists of several main sections, which explore different parts of the research question. The first section asks for information on the respondents' profile, as shown in Table 4. The second section gauged the usage of LCC to determine if it is important to decision making, which supports the achievement of SD goals. The third section gauged the usage of LCA to determine if it is important to decision making, which supports the achievement of SD goals. The fourth section gauged the current level of usage of the value chain. Finally, the participants were provided with information (part 5) to understand the relationship between LCC and LCA and whether this integration supports decision making towards SD and achieves its goals with and without using the value chain as a control variable.

To test the validity of the instrument, three accounting faculty members with professional backgrounds and education in auditing served as experts and reviewed the items for relevance and classification regarding the items' sub construct. These variables were grouped into four variables as follows: LCC for MWMS, LCA for MWMS, value chain, and decision making towards SD.

5.3 Participants:

To test the hypotheses, empirical data from central hospitals were gathered. So, the final instrument was distributed to 251 managers, accounting and auditing staff employed at central hospitals. Out of 251 participants, 42 did not complete the instrument, and/or failed in the manipulation checks questions. Thus, the final sample retained for the analysis consisted of 209 participants' responses. The total response rate was 83.26%. Confirmatory factor analysis showed that all of Cronbach's alpha values are 0.7, 0.8, and 0.9. Participants responded on seven-point Likert-type scales ranging from 1 being extremely low to 7 being extremely high. Table 4 presents the participants' demographic data.

Table 4: Demographics— managers accounting and auditing staff

		n	percentage
Experience Years	> 10 years.	77	36.8
	= 10 to > 15 years.	102	48.8
	< 15 years.	30	14.4
Highest degree completed	Bachelor's degree	158	75.6
	Master and PhD degree	11	5.3
	others	40	19.1
Administrative level	Senior Manager	15	7.2
	Central Manager	27	12.9
	Executive Manager	167	79.9
Initial size	251		83.26
Final size	209		

5.4 Hypothesis Testing

Table 5 presents the descriptive statistics for the dependent and independent variables. Panels A and B of Table 5 present the descriptive statistics for LCC and LCA adoption. Panel C of Table 5 presents the information of the value chain. Finally, panel D presents the adoption of LCC and LCA integration. With regard to LCC adoption, reducing the expected risks have the greatest impact (mean = 4.68; SD = 0.54; CV = 11.5), followed by the identification of cost drivers (mean = 4.26; SD = 0.63) and improvement of decision-relevant information (mean = 4.14; SD = 0.65), were noted. This finding is in line with prior studies (Knauer and Möslang; 2018) and supports the validity of our results. With respect to LCA adoption, improving the environmental performance have the greatest impact (mean = 4.59; SD = 0.67; CV = 14.9) by our sample, followed by the improvement of decision-relevant information (mean = 4.58; SD = 0.58; C.V = 12.6) a finding that aligns with prior studies (Ahmad et al., 2019), noted that. With respect to value chain information, clear sequence of functions and activities of the MWS has the greatest impact (mean = 4.25; SD = 0.66; CV = 15.5) followed by identify activities that add value and those that do not (mean = 4.17; SD = 0.75; CV = 17.9), were noted. Finally, with regard to LCC and LCA integration, the identification and achieving economic and environmental goals in order to achieve SD goals have the greatest impact (mean = 4.8; SD = 0.8; CV = 19.6), followed by improvement of decision-relevant information for assessing decisions towards SD (mean = 4.6; SD = 0.74; CV = 18.2), a finding that aligns with our expectation.

Table 5: Descriptive statistics.

Items	**Mean**	**SD**	**Variation**
Panel A;			
LCC adoption:			
Identification of cost drivers.	4.26	0.63	14.8
Cost management to assess all financial results associated with the LCC of the waste MWS.	4.05	0.75	18.5
Eliminate unwanted costs.	4.14	0.56	13.5
Reduce expected risks.	4.68	0.54	11.5
Improvement of decision-relevant information.	4.14	0.65	15.7
Panel B;			
LCA adoption:			
Identify the environmental impacts of the different activities for MWS.	4.4	0.72	16.4
Accomplish environmental goals.	3.9	0.99	25.4
Improve environmental performance.	4.59	0.67	14.9
Regular environmental reporting to management.	3.62	1.46	40.3
Improvement of decision-relevant information.	4.58	0.58	12.6
Panel C:			
Value chain information:			
Clear sequence of functions and activities of the MWS.	4.25	0.66	15.5
Identify activities that add value and those that do not.	4.17	0.75	17.9
Panel D:			
LCC and LCA integration:			
It helps decision-makers to determine the costs corresponding to environmental designs.	4.15	0.75	18.1
It helps decision-makers to identify alternatives to support decision-making towards SD.	4.25	0.72	16.9
It helps decision-makers to identify and achieve economic and environmental goals in order to achieve SD goals.	4.8	0.8	19.6
Provide an appropriate framework for assessing decisions towards SD.	4.23	0.71	16.8
Improvement of decision-relevant information for assessing decisions towards SD.	4.6	0.74	18.2

Note: This table presents the descriptive statistics for the dependent and independent variables at significance 0.99, which provides the mean values, medians, and standard deviations (n = 209).

To analyze the associations between the independent and dependent variables, this study initially computes Pearson correlations. The untabulated results show a strong correlation between LCC and decisions making to SD (R=0.844 at p= 1%), Moreover, a strong correlation between the LCA, and decision making towards SD (R= 0.812 at p= 1%).

Table 6 Results of multiple regression models.

Variables	β	t	Sig.	F (Sig.)	Adj. R2	R
Panel A: the impact of LCC on decision making towards SD						
Constant	0.562	4.197	0.000			
Value chain	0.298	9.691	0.000	416.840	0.802	0.896
LCC	0.546	21.109	0.000	(0.000)		
Panel B: the impact of LCA on decision making towards SD						
Constant	0.798	5.308	0.000	291.350	0.739	0.859
Value chain	0.285	7.887	0.000	(0.000)		
LCA	0.513	16.979	0.000			
Panel C: the impact of LCC and LCA on decision making towards SD without controlling the value chain						
Constant	1.109	9.977	0.000	377.937	0.786	0.887
LCC	0.410	11.004	0.000	(0.000)		
LCA	0.313	8.454	0.000			
Value chain						
Panel D: the impact of LCC and LCA on decision making towards SD after controlling value chain						
Constant	0.468	3.918	0.000	371.858	0.845	0.919
LCC	0.378	11.829	0.000	(0.000)		
LCA	0.245	7.527	0.000			
Value chain	0.248	8.822	0.000			

5.5 Multiple regression analysis results:

Table 6 presents the results of our multiple regression analysis that examines whether the LCC and LCA are associated with the decision making towards SD, where the value chain as a control variable or not. Regarding H1, it was predicted that, the LCC is positively associated with information related to decision making, which achieves the objectives of SD, the coefficient β LCC and value chain are positive (β = 0.562, t = 4.197; β = 0.546, t = 21.109; 0.298, t = 9.691, respectively) and statistically significant (p = 5%). The model contributes significantly to explaining the positive relationship between LCC and decision making towards SD (F-value = 416.840; adj. R2 = 0.802, sig = 0.000). This result supports the H1. These results are consistent with many prior studies, such as Heralova (2014), Khandelwal et al. (2019) and Woon and Lo (2016).

Regarding H2, it was highlighted in this hypothesis development that the LCA is positively associated with information related to decision making, which supports decision making, especially to achieve the objectives of SD, coefficients β for the LCA, and value chain (β = 0.798, t = 5.308; β = 0.513, t =16.979; β = 0.285, t=7.887 respectively) are positive and statistically significant (p = 5%). The model contributes significantly to explaining the positive relationship between the LCA, and decision making towards SD (F-value = 291.350 and adj. R2= 0.739), which supports the hypothesis 2. These results are consistent with many prior studies, such as Albuquerque et al. (2019).

To summarize, this study provides empirical evidence on the validity of LCC and LCA to improve decision making towards SD. A significant effect between the LCC and decision making towards SD is found to the extent of 0.546 percent. Moreover, a significant effect between LCA and decision making towards SD is found to the extent of 0.513 percent. These empirical results support the study's first and second hypotheses.

In addition, the results support H3 because the coefficient β of LCC and LCA are positive (β = 1.109, t= 9.977; β = 0.410, t =11.004; β = 0.313, t= 8.454 respectively) and significant (p = 5%). The model contributes significantly to explaining the positive relationship between LCC, LCA and decision making towards SD (F-value = 377.937 and adj. R2 = 0.786, sig = 0.000). There is a significant positive relationship between LCC, LCA, and decision making towards SD, where R= 0.887, which supports H3. These results are consistent with many prior studies for LCC and LCA combination (e.g., König and cristofaro, 2012; Miah et al., 2017; Soares et al., 2013).

Moreover, coefficient β for the LCC is 0.378 (t=11.829), β for the LCA is 0.245 (t=7.527), and β for the value chain is 0.248 (t=8.822) as a variable control and significant (p = 5%). This implies that there are significant positive relationships among LCC, LCA, and decision making towards SD. The significant relationship between LCC, LCA, and decision making towards SD is improved by using the value chain as a control variable, where R = 0.919, which supports H3. An increase in the explanatory power of the LCC and LCA integration model is shown if the value chain is a control variable, more than the explanatory power of the LCC and LCA integration model if the value chain is not a control variable. Where, LCC and LCA integration model explanatory power if the value chain as a control variable is 84.5%; while LCC explanatory power is (80.2%) and (73.9%) for LCA. Therefore, LCC and LCA integration increases the explanatory power to interpret changes in the dependent variable.

From the above, the empirical evidence on the validity of the study's hypothesis is supported, where a significant relation between LCC, LCA, and decision making towards SD is found to the extent of 0.468+0.378+0.245+0.248 percent beta values. These empirical results support the study's third hypothesis. To conclude, these results provide empirical evidence that supports this study's hypotheses. First, a significant effect between LCC and decision making towards SD were found. Second, a significant effect between the LCA and decision making towards SD was found, which is consistent with the study second hypothesis. Finally, a significant effect for LCC and LCA integration to make decisions towards SD was found; also, the explanatory integration power increases through the value chain.

6. Discussion

The results of previous literature show that LCC (Animah et al., 2018; Heralova, 2014; Khandelwal et al., 2019) and LCA (Albuquerque et al., 2019, Kamble et al., 2018; Shah and Unnikrishnan, 2018) measure the cost and environmental performance of the activity (Delinchant et al., 2018; Nippala and Vainio, 2019). However, none of these studies discussed the possibility of integrating LCC and LCA on a common basis, except Bierer et al. (2015), which used material flow cost accounting to link LCC and LCA with only a theoretical presentation. Therefore, the central question of this study is whether the integration of LCC and LCA on an appropriate basis for the life cycle framework through the sequence of activities in the value chain supports decision making towards sustainable development (SD).

SD objective is to preserve economic and environmental resources. Therefore, the need for integration between economic and environmental aspects is important.

In developing countries, the problem of waste is emerging as a general phenomenon, an important and challenging problem to deal with, primarily due to the bad practices used to address burning and other factors. These lead to environmental pollution and high treatment costs. In particular, medical waste is different from household waste because of its infectious nature, which leads to the spread of diseases.

Therefore, this study contributes to and extends the LCC and LCA literature in six ways. This study first provides a theoretical framework for the integration of LCC and LCA through the value chain, where all the components derived from the LCC and LCA are considered in a single comprehensive model. Although a number of recent work has been conducted in the same area (e.g., Fan, 2014; Konig and cristo Faro, 2012; Ristimaki et al., 2013; Woon and Lo, 2016), there is an absent linkage that has not been established and needs to be investigated. Second, a field experiment is conducted to demonstrate the validity of integration for effective decision making, especially to achieve the objectives of SD. The case study results show that the integration through the value chain maximizes value by excluding activities that do not add value, such as the transport of waste within the hospital. This integration improves environmental costs and impacts.

Third, the integration of LCC and LCA provides an important starting point to inform about efforts to achieve SD. The analysis shows the cost of each phase and the total cost of MWMS. The results show the importance of the stages of classification, collection, and processing, due to its higher cost. It is clear that the treatment stage, especially burning, dominates most of the total system costs and environmental impacts. Fourth, the results show the cost deviations (Knauer and Möslang, 2018) and the critical areas of environmental impacts for WMS, and the primary sources of these deviations and effects.

Fifth, the LCC and LCA integration framework has proven to be reliable in supporting decision making, particularly towards SD using the results of the field experience. The explanatory power of integration increases through the value chain to interpret the changes in the variables. Where, there is a strong correlation between LCC, LCA and the value chain as independent variables and decision making. This finding can help shed light on ambiguous and contradictory results in the literature. Finally, this work contributes to the extant research on LCC and LCA by providing evidence from Egypt. To the best of our knowledge, no studies have been conducted in Egypt to examine the LCC and LCA integration framework, where our results offer primary evidence Egyptian medical sector.

7. Conclusion

This study examines whether the life cycle costing (LCC) and life cycle assessment (LCA) integration support decision making towards sustainable development (SD), especially in the Egyptian environment. Also, the study explores the establishment of rules for the management of medical care waste, which represents a challenge for the public sector. A framed field experiment with a case study within the Egyptian medical sector was employed. In total, 209 accounting and auditing staff employed in central hospitals in Egypt were interviewed. Our findings show the advantages of integrating LCC and LCA through the value chain, which reduces costs, improve environmental performance, and improve economic and environmental efficiency to make strategic decisions. This demonstrates that integration supports decision making to achieve SD. Besides, the study provides a framework for the integration of LCC and LCA based on the value chain. The results demonstrate the advantages of integrating LCC and LCA through the value chain, which is beneficial for various aspects of cost management and improves environmental performance.

The implications of integration are of primary interest not only to government regulators and management accountants but also to investors, analysts, researchers, and managers. The results of the study leave important implications for all these parts. First, for investors and market analysts, they should take into account the life cycle of the product or service when making their decisions because this integration helps to evaluate all economic and environmental results, such as costs and environmental savings. Therefore, they should make saving predictions cautiously. Secondly, the management accountants must take into account the primary and final processes of the product, when planning the maximum economic and environmental benefits, so they should make effective decisions. Third, government organizations should map economic and environmental development without excessive use of natural resources, and also consider strategic planning and priority setting for SD; therefore, they should develop programs and policies, evaluate existing and alternative systems, and provide a database system similar to the global one. Fourth, for researchers, this study provides evidence that improves the strategic approach of management accounting for the planning of emerging market SD strategies and allows decision-makers to take effective solutions that balance profitability and reduce environmental burdens. Finally, for managers, they must provide incentive programs to motivate employees to achieve specific changes. With the need to involve employees in the process to improve control effectiveness, performance efficiency, and streamline administrative decisions, otherwise, they must provide acceptable justifications for the absence of alternatives that create added value and achieve a competitive advantage.

Our study contributes to the literature by explaining the inconclusive and ambiguous outcome effects of the LCC and LCA integration literature to support decision making towards SD. Evidence of significant relationships, which provide a complete picture, is presented. The results of the study provide some implications for both researchers and professionals. First, for researchers, this study is one of the studies that combine environmental management and accounting perspectives that encourages researchers to exploit this multidisciplinary approach by examining various research topics. Future studies might explore the balanced relationship between economic and environmental efficiency for the public and private sectors. Second, for professionals, it is more beneficial to consider the integration of economic and environmental approaches into strategic planning for governmental or non-governmental organizations. This can help organizations to make decisions based on accurate analysis. The study limited the application of this integration to the medical waste sector without analyse domestic waste. This is mainly due to the severity of these wastes, the possibility of tracking the stages of this system and obtaining officially documented data. Also, due to data availability, our study was limited to large central hospitals. Future research may examine the application of LCC and LCA integration to the private hospitals or other sectors.

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