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Consideration of Financial and Environmental Concerns in the Life Cycle Costing of Higher Education's Facilities and Services: A Systematic Review of One Decade

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Abstract

The lack of life cycle costing (LCC) studies in higher education is knowledge gap and literature. This paper aimed to review the components that made up the life cycle cost for higher education. This systematic review focused on LCC of Higher Education, where review articles and research articles were collected from Springer-Link, Science-Direct, Scopus, and Google-Scholar online databases. Considering the PRISMA statement and guideline for systematic review in conservation and environmental management. The literature reviewed systematically and bibliometric analysis of co-authorship and concurrence of keywords were analyzed by VOSviewer software. The result shows that there is various studies written about LCC of products, and a deficit of studies in the application of LCC in higher education. Furthermore, there are some studies that used the LCC in construction that were calculated based on the NPV in educational buildings. The most cost element and components were the constructions, operations, maintenances, and demolition. Furthermore, the environmental LCC was used alongside LCA. LCA mostly focused on environmental externalities cost for supporting sustainability. The LCC of higher education is needed to be calculated, involving the total cost of a university as well as construction, operation, safety, externalities, and services costs. However, the education services, facilities and students' costs calculations were not used in the literature. Therefore, it is recommended to establish a comprehensive method to estimate the cost of services and facilities of higher education altogether to contribute in sustainability.

Keywords: Life Cycle Costing, Higher Education, Net Present Value, Method, Service, Cost Data, Sustainability

Introduction

The natural environment has to face various disorders, for example, air, water, soil and noise pollution, global warming, and ozone depletion. Furthermore, anthropogenic interference makes the global environment more fragile, in turn, posing highly dangerous risks for human health (Singh & Singh, 2017). However, a human being still uses natural resources without considering the negative impacts. Therefore, since humans interact with the environment, yielding a very close relationship and mutually affecting each other, the environmental problems caused by irresponsible anthropogenic activities. This study is motivated by the crucial need to understand and optimize the financial and environmental elements of higher education infrastructure and services. Despite universities' important role in sustainable development, there is a noticeable absence of comprehensive life cycle costing (LCC) research in the higher education sector. This study contributes to closing this information gap by conducting a thorough review of the components that comprise the higher education life cycle cost. This study intends to provide significant insights to higher education decision-makers, perhaps leading to more cost-effective and environmentally friendly practices in university operations and management. Consequently, rapid urbanization will affect widespread and adverse impacts on the environment (Peña & Rovira-Val, 2020).

Universities work as facilitators for sustainable development; therefore, universities and their buildings are numerously studied on the diverse aspects of environment and sustainability. For example, energy consumption, carbon footprint, transportation, heating, and cooling systems, and constructions are determined as the hotspots for environmental impacts (Huang et al., 2018). All type of manufacturers and other stockholders are dependent on universities for the skilled workforce demands. Meanwhile communities also demanded from universities to teach their youths and educate the society by intellectual and scientific knowledge (Tasdemir & Gazo, 2020). Higher education is one of the more critical services to produce human capital. The lack of life cycle cost study in higher education is worrying, especially since it designates the cost of higher education.

Education plays a dynamic role in attaining sustainable development goals. Sustainable development demarcates three dimensions: environment, economics, and society. Life cycle assessment (LCA) evaluates environmental impacts (Li et al., 2022; Soni et al., 2016). Life cycle costing assesses the cost of the products or processes during the entire life span, together with LCA (Costa et al., 2019). However, S-LCA is a powerful tool that influences, evaluates, and supports organizations' future and upcoming policies (Kalvani et al., 2022; Sining et al., 2022).

Life cycle assessment is a systematic procedure that assesses a product's lifecycle to analyze the extent of its environmental impact contribution. LCA is a systematic procedure to identify the significant adverse environmental effects of processes and products (Amir Sharaai. Noor, Zalina. Mahmood and Abdul, Halim, Sulaiman, 2014; Muhammad et al., 2019) by measuring the energy and material released into the ecological stream throughout the whole life cycle. LCA has been considered the most vital instrument of the new industrial sectors' environmental management system (Barros et al., 2020). "Life cycle assessment contains four stages: (a) goal & scope definition; (b) life cycle inventory analysis; (c) impact assessment; and (d) interpretation" (Sharaai et al., 2010). The LCA evaluates environmental effects of products or processes over its whole life span; and provides the environmental profile of a system or course based on the appraisal of massive input and output data, and the significant impacts that contribute to the environmental categories: global warming, ozone depletion, eutrophication, eco-toxicity freshwater, and acidification. The LCA study results belong to the quality and credibility data, especially in the stage of LCIA, which will give the expected results for the emission into air, water, and soil (Kaewunruen et al., 2020; Sharaai et al., 2010).

The social life cycle assessment is a social impact estimation methodology. Social life cycle assessment (S-LCA) aimed to measure the socio-economic features of a product or process and to horizontally analyze the negative and positive impacts of the product's whole life cycle on society (Kalvani et al., 2021). Furthermore, it includes the extraction and other procedures of raw resources, industrialization, delivery, usage, maintenance, recycling, and dumping of product wastes (Muhammad et al., 2019). Since the S-LCA deliberates the social impacts that influence and affect the stockholders throughout the product's life cycle (Sharaai et al., 2020), this definition discriminates the S-LCA from the social effects that concentrate on the product or service and involve the company's behavior and socioeconomic standpoint. Additionally, the S-LCA definition is essentially similar to the methodology of the LCA, which emphasizes the environment. At the same time, the S-LCA concentrates on social aspects (Sharaai et al., 2019).

The life cycle costing (LCC) analyzes the cost of products, services, or processes in the whole life span (Omran et al., 2021; Soni et al., 2016). Furthermore, LCC estimates the cost of all stages: risk, investment, operation, maintenance and demolition (Ma et al., n.d.; Sajid & Bicer, 2021). Finally, the LCC delivers potential facts about the total cost of the product, service, or process throughout the entire life cycle to assist the decision-making process (Liu et al., 2020). The life cycle costing is enormously crucial for facilities management, especially for the higher education institutions, universities, and schools, because those facilities have numerous buildings and related fittings (Kimoto et al., 2013). LCC is a widely used technique in different industries for economic assessment (Peña & Rovira-Val, 2020).

This paper aimed to review the elements and components that made up the life cycle cost for higher education. The literature was reviewed systematically to analyze the LCC studies related to higher education. This paper should answer these questions: what is the current state of the art on LCC for higher education from 2009 to 2020? Which methods are used for the life cycle costing to estimate the overall costs of higher education? Which components and elements are used to calculate LCC in higher education?

Alongside the introduction, the paper is structured as follows: the second part of the paper describes the background, the third part addresses the method used in this review article, the fourth section includes the results and discussions, and the last part delivers the review's conclusion.

Life Cycle Cost (LCC)

Life cycle costing (LCC) is a decision-making tool to estimate the overall cost of a product or service throughout its entire life cycle from production to disposal (Ma et al., 2023). It is a methodology, which systematically estimates economic value throughout the approved scope. LCC is extensively considered as a cost-managing instrument (Zhang et al., 2019). LCC aims to forecast cash flow and to give the assessment of choices for decision-makers

(Samsuddin, 2019). It contains four initial steps: a) definition for analysis, b) problem analysis, c) conducting calculation, and d) result validations and interpretations (RICS, 2016). UNEP has published guidelines for LCC in 2009 and exemplified the different methods in detail. Typically, LCC is used for valuing the cost to economically estimate the effectiveness of a product or process and advise the options; for example, to estimate the effective energy system or product based on its all life cycle costs (Hoogmartens et al., 2014).

The US Department of defense used LCC for the first time in 1933 for the maintenance and operations costs, and in 1981 for the procurement of military goods and equipment to calculate the total cost of products, considering the high costs for warfare equipment like tanks and fighter planes (Hoogmartens et al., 2014). Therefore, it was established by the Department of Defense of the United States by the 1960s. European countries used the LCC method since the 70s as a policy and business decision making tool (Hoogmartens et al., 2014).

Life cycle costing is used to understand the entire life cost of a product and the monetary flow in a targeted product's life cycle. The essential cost is calculated, including the operational, maintenance, and end of life or disposal costs, to give decision-makers suitable options. Therefore, LCC is used continuously as a calculation tool to compare the options. Moreover, LCC defines ISO as "a technique which enables comparative cost assessments to be made over a specified time, taking into account all relevant economic factors both in terms of initial costs and future operational costs." Additionally, LCC has been defined in the ISO 15686 standard as “the cost of an asset or its parts throughout its life cycle, which comprises all stages from construction, operation, and maintenance to end-of-life.” The LCC for buildings include construction, maintenance, operation, and end of life costs (Li et al., 2020).

LCC has three different types: conventional life cycle costing (CLCC), environmental life cycle costing (ELCC), and societal life cycle costing (SLCC). ELCC estimates the economic cost of product or service concerning environmental conservation. The environmental life cycle costing is used simultaneously with the life cycle assessment (LCA) to focus on the environmental externalities cost to support sustainability (Wafa et al., 2022). Studied the three dimension of sustainability Environmental, economic, and social aspects for product sustainability. Therefore, rapid industrial growth causes environmental pollutions and ecological disorders. However, sustainability is considered a priority in today’s world. The environmental life cycle costing is estimated as direct and indirect costs of environmental damages in the entire life cycle of product [58]. Base on Kaewunruen, Sresakoolchai, & Peng (2020) the life cycle cost involves five steps, 1) defining the objective, 2) selecting parameters, 3) collecting data, 4) performing the assessment, and 5) examining the result.

Materials and Methods

This review was conducted based on systematic manners, considering Moher et al. (2009) PRISMA statement “Preferred Reporting Items for Systematic Reviews and Meta-Analyses,” the in-depth guideline, and from the Pullin & Stewart. (2006) “guideline for systematic review in conservation and environmental management” in which three steps for preparing a systematic review were followed: 1) planning a review, 2) conducting a review, and 3) dissemination and reporting of the review. The review also adopted the method used by Matthew, Shuib, Ramachandran, & Afandi, (2019) to analyze which element of the cost was used in the literature. According to Costa et al. (2019), there are no systematic review databases in the environmental field to reduce the bias systematic review in the mentioned subject area.

Planning the Review

Moher et al. (2009) and Pullin & Stewart. (2006) explained that this step defined or developed the research questions. The authors have identified the review questions and established the review protocol. The research questions that have been described by the reviewers to be addressed are as follows:

- What is the current state of art at the life cycle costing in higher education from 2009 to 2020?
- Which methods are used for the life cycle costing to estimate the overall costs of higher education?
- Which elements and components will be used to calculate LCC in higher education?

Conducting the Review

Systematic Literature search

In this step, we have developed a systematic literature search strategy to recognize the related articles. This strategy was tailored to four online databases: Springer Link, Science Direct, Scopus, and Google Scholar. In the review, the protocol revised the search terms in the title, abstract, and keyword to search for "Life Cycle Costing Education," and "Life Cycle Costing Higher Education", and its abbreviation "LCC education" while considering the PRISMA guideline Moher et al. (2009)) for the period from 2009 to 2020. The literature and articles comprised of published and waiting in the press materials. According to Pullin & Stewart. (2006) and Moher et al. (2009) setting the inclusion and exclusion criterion would avoid unnecessary and prolonged list of articles. The sources have been selected based on the inclusion and exclusion criterion. The search mostly focused on mapping the existing literature for LCC in higher education within the environmental science, social science, engineering and economics. The inclusion criterion set included ‘‘life cycle costing’’, ‘‘life cycle economic assessment’’, ‘‘life cycle cost analysis’’, and ‘‘economic cost estimation’’. According to the brief analysis of the articles, the abstracts of the chosen articles were reviewed to focus on the life cycle costing of various products, yielding 137 relevant articles that were included for the review. Duplicated papers, articles dissimilar to the study scope, and articles not written in English, totaling to 111 articles, were excluded from the review. This method would enhance the quality and reliability of the review. The data have been extracted based on a qualitative approach from the articles, which have been chosen for the review. Finally, 58 papers were selected to be intensely reviewed and the data were synthesized to prepare the report for the higher education life cycle costing. Table 1 shows the amount of papers searched from the early mentioned databases and the quantity of inclusion and exclusion strategy.

Table 1
The Total Number of Searched Papers in the Databases

Database	Total	Included	Excluded
Springer Link	104	50	54
ScienceDirect	88	50	38
Scopus	30	12	18
Google Scholar	27	26	1
Grand Total	248	137	111

Based on Fig1 the literature review framework explains the review conducted based and explained the search strategy in four steps. In the first step the key words has defined, the total article 248 were searched, based on including and excluding the documents the total of 111 article were excluded after reading the title, and 53 more article were excluded after reading the abstract of the articles in step 3, and 58 article were chosen to be reviewed as full text. Finally, in the 4th step total of 10 article were found to integrated for developing calculation components for higher education services and facilities.

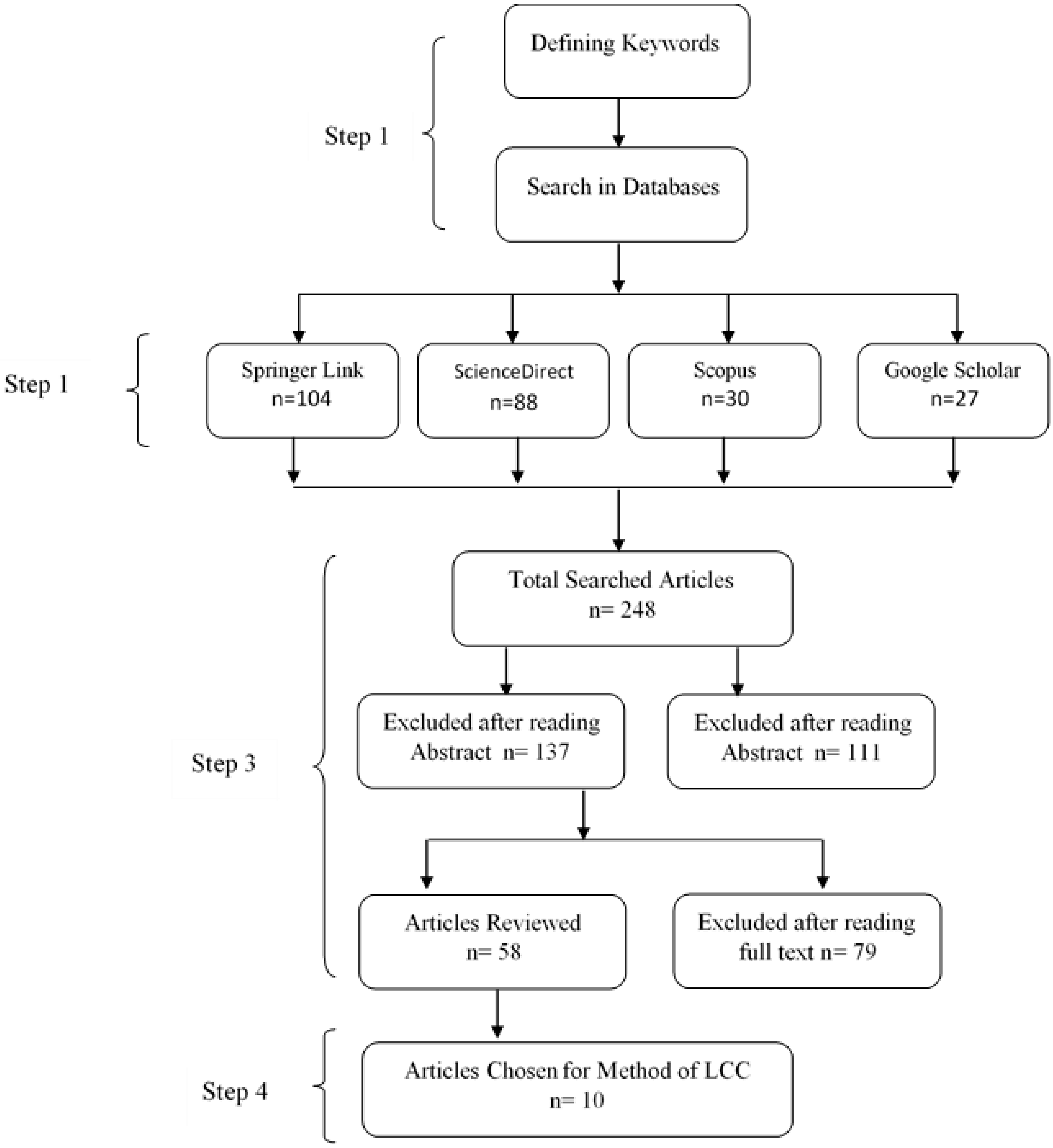

Figure 1: Literature Review Flow Chart

Visual Maps of LCC

According to Van Eck & Waltman (2010) Using the VOSviewer software two visual map were created, the ultimate selection in Mendeley software was exported in RIS format, which was used to generate the visual figures, One is determined by co-authorship, and the other is determined by keyword co-occurrence. Based on Ramos Huarachi, Piekarski, Puglieri, & de Francisco (2020) the setting for VOSviewer program analysing has created in Table 2 as below:

Table 2
Digital Map Settings in the VOSviewer Program

Setting	Visual map of co-authorship	Visual map of co-occurrence
Type of inquiry	Co-authorship	Co-occurrence
Method of counting	Full counting	Full counting
Analyzing units	Authors	Keywords
Minimum number of occurrences	3 occurrences	2 occurrences

Both maps are shown would use an overlay visualization to explain trends to use the pattern of purple, blue, green and yellow colors that vary by years, purple for older years, and yellow for the latter years.

Dissemination and Reporting of the Review
The outcomes and results of the review, and the inclusion and exclusion were presented qualitatively, and the selected articles were descriptively analyzed. From these 58 papers included for review, 10 papers most interrelated were targeted and analyzed for enhancing the LCC technique for higher education's LCC. The chosen articles mostly used the buildings' LCC in their studies, and thus, the team made some changes to improve the LCC technique for the objects calculated in these papers.

Results and Discussion
The systematic literature search in Springer link, Science Direct, Scopus, and Google scholar databases considered the PRISMA Guideline from the year 2009 to 2020 Moher et al. (2009). Therefore, the answer to the first question found that numerous articles were written on the life cycle costing of different products, especially of the building of educational institutions. However, no article mentioned about the education or higher education services in the literature. The authors mostly calculated the education buildings' life cycle costs in their studies.

Publication trend on LCC in Literature
Goh and Sun (2016) has explained chronologically to estimate the article published on buildings and green buildings by counting the reviewed articles. Table 3 shows the articles, which were reviewed and synthesized based on the scope of the research and product types, and classified based on chronology and scope of research.

Table 3
Chronological Analysis of the Total Numbers of Publications in LCC Based on Subject Area

Years	Publications	Authors	Scope of Research
2009	1	(Lee et al., 2009)	Energy
2010	2	(Al-Karaghouli & Kazmerski, 2010)	Health Clinic PV System
		(Kneifel, 2010)	Energy
2011	2	(Massarutto et al., 2011)	Energy
		(Uygunoğlu & Keçebaş, 2011)	Energy
2012	3	(T. Hong et al., 2012)	School Building Energy
		(C. S. Li & Guo, 2012)	University Building
		(Wang et al., 2012)	School
2013	2	(Ding et al., 2013)	Pavement Maintenance
		(Kimoto et al., 2013)	Education Facilities
2014	4	(Cuéllar-Franca & Azapagic, 2014)	House Stock
		(Bull et al., 2014)	School Building
		(de Jong & Arkesteijn, 2014)	School Building
		(Han et al., 2014)	Building Energy
2015	4	(Seo et al., 2015)	Carbon Liquefaction
		(Galle et al., 2015)	Process
		(Spickova & Myskova, 2015)	Students Residence
		(Tabrizi & Sanguinetti, 2015)	General
			Students Residence
2016	8	(Cartelle Barros et al., 2016)	Power Plant
		(J. Kim et al., 2016)	hydrate inhibitor injection
		(Bengtsson & Kurdve, 2016)	Machining Equipment
		(Ayub. M. F. & Abdul Rashid. K, 2016)	General
		(Goh & Sun, 2016).	Building
		(Corona et al., 2016)	Solar Energy
		(Martinez-Sanchez et al., 2016)	Food Waste Management
		(Erling Salicath, 2016)	Public Assets - School
2017	11	(He et al., 2017)	Electrical Vehicle
		(Sun et al., 2017)	Hydrogen Station
		(Daşdemir et al., 2017)	Pipeline
		(Yang et al., 2017)	Cement Manufacturing
		(Xu et al., 2017)	LID- BMP
		(Haque et al., 2019)	submersible pumps energy
		(Fouche & Crawford, 2017)	Building
		(Biolek et al., 2017)	Construction
		(Max & Mi, 2017)	Energy
		(Bhochhibhoya et al., 2017)	Lodging
		(Trigaux et al., 2017)	Lead refining
2018	5	(Edwards et al., 2018)	municipal food waste
		(L. Huang et al., 2018a)	university dormitories
		(De Menna et al., 2018)	food waste
		(Shan et al., 2018)	Students Well Being in
		(Teshnizi et al., 2018)	Building

			University residential towers
2019	10	(Zhang et al., 2019)	General
		(J. Li et al., 2019)	Solid Waste Management
		(Albuquerque et al., 2019)	Ammonium & Tinplate
		(Lv et al., 2019)	Sanitary ware
		(Xiao et al., 2019)	biogas
		(Lai et al., 2019)	energy
		(Kianian et al., 2019)	Manufacturing Technology
		(Z. Huang et al., 2019)	Residential Building
		(Francini et al., 2019)	Municipal Solid Waste
		(Mahbub & Sharma, 2019)	Water Sources
2020	6	(S. Li et al., 2020)	Building
		(Shea et al., 2020)	University building
		(Liu et al., 2020)	Electricity
		(Xue et al., 2020)	Carbon emissions
		(Barros et al., 2020b)	Campus Building
		(Kaewunruen et al., 2020)	Electricity Generation
			High-speed railway
Total	58		

Based on the literature, (Fig2) quantifies the chronological contribution of the published articles on LCC, specifically for higher education, in different journals according to the year of publication. The year 2017 had the highest contribution with 11 related papers, 2019 with 10 articles, 2016 with 8 papers, the 2020 with 6 articles , 2018 with 5 papers each year, 2015 and 2014 with 4 papers, 2012 with 3 papers, 2010, 2011, and 2013 with 2 papers per each year, and 2009 with one related paper.

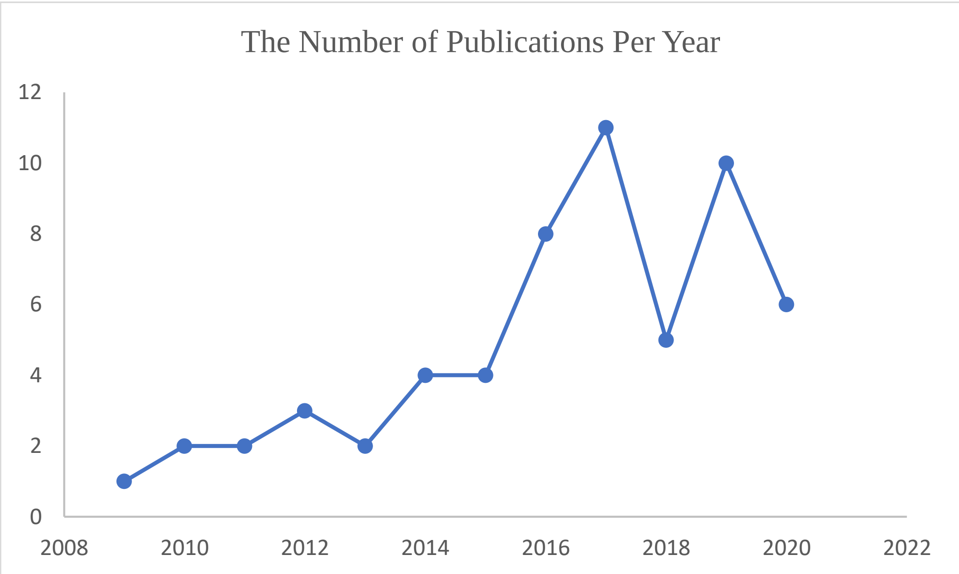

Figure 2. The Chronological contribution of papers by years

Here is still confusion according to the methodology of life cycle costing; no product or service-specific method for life cycle costing was shown. However, there were general guidelines for constructions, such as ISO 15686-5 (Schau et al., 2011). Nevertheless, some of the authors practiced and adopted their methods in line with the life cycle assessment methodology (Cuéllar-Franca & Azapagic, 2014). LCC is a crucial estimation technique that evaluates the cost of product or service throughout the entire life span. It is dependent on authors to use the methods for cost calculations. Some articles utilized the ISO 2006 (ISO, 2006) standards. Others used specific standards for building constructions like the British standards while for bridge construction, BS 5400 was extensively used in Malaysia (Ayub. M. F. & Abdul Rashid. K, 2016). There was no evidence of consensus or a proper method for cost calculation. The most used approach was the net present value (NPV) for calculating the total cost of the products and services. For example, for building's life cycle costing, the NPV estimated the costs in design phases, construction period, maintenance and repair costs, replacement cost, energy cost, and enduring cost (Kneifel, 2010; Li et al., 2020).

LCC itself is a widely confirmed and accepted method in researches involving buildings and other sectors. Applying the LCC, the practitioners must consider the various foundations of uncertainties, like life period, running costs in the future, discount rate, remaining costs and others (Li et al., 2020). Table 4 describes the classifications of life cycle costing in the current literature, which used diverse methods.

Table 4
The Classifications for life cycle costing methods used and techniques

	Life Cycle Cost Used Methods	**Authors**
1	Net Present Value Approach	(Bhochhibhoya et al., 2017; Biolek et al., 2017; Bull et al., 2014; Corona et al., 2016; Daşdemir et al., 2017; Han et al., 2014; Haque et al., 2017, 2019; Huang et al., 2019; Kianian et al., 2019; Lee et al., 2009; Li et al., 2019; Li et al., 2020; Liu et al., 2020; Mahbub & Sharma, 2019; Max & Mi, 2017; Shan et al., 2018; Shea et al., 2020; Spickova & Myskova, 2015; Sun et al., 2017; Teshnizi et al., 2018; Xiao et al., 2019)
2	Using Life Cycle Assessment Approaches	(Barros et al., 2020; Fouche & Crawford, 2017; Hong et al., 2012; Huang et al., 2018; Kaewunruen et al., 2020; Lv et al., 2019; Martinez-Sanchez et al., 2016; Trigaux et al., 2017; Xue et al., 2020; Yang et al., 2017).
3	LCA & NPV	(Bhochhibhoya et al., 2017; Francini et al., 2019; He et al., 2017; Li et al., 2020; Teshnizi et al., 2018; Xiao et al., 2019; Xu et al., 2017).
4	Case Studies	(Albuquerque et al., 2019; Bengtsson & Kurdve, 2016; de Jong & Arkesteijn, 2014; Erling Salicath, 2016; Han et al., 2014; Hong et al., 2012; Hoogmartens, Van Passel, Van Acker, & Dubois, 2014; Kim et al., 2016; Kneifel, 2010; Li & Guo, 2012).
5	LCC as Approach	(De Menna et al., 2018; Fouche & Crawford, 2017; Massarutto et al., 2011; Xue et al., 2020).
6	CBA	(Ding et al., 2013; Huang et al., 2019; Xue et al., 2020).
7	Other	(Al-Karaghouli & Kazmerski, 2010; Cartelle Barros et al., 2016; Cuéllar-Franca & Azapagic, 2014; Edwards et al., 2018; Galle et al., 2015; Kimoto et al., 2013; Seo et al., 2015; Tabrizi & Sanguinetti, 2015; Uygunoğlu & Keçebaş, 2011; Wang et al., 2012; Zhang et al., 2019).

Based on Table 3, most of the studies used the NPV for the life cycle costing. NPV is an investigative index investigates for future investment. However, some of the authors used the life cycle assessment approaches ISO 14040 (ISO, 2006) to calculate the total cost. A small number of authors used the LCA and NPV mixed method to calculate the life cycle cost, several papers used the case study and LCC as a costing approach, and a large number of articles used different methods for their calculations. According to literature, cost-benefit analysis (CBA) was widely used for calculating the cost of the product or process as a decision-making tool (Ding et al., 2013; Hoogmartens et al., 2014; Z. Huang et al., 2019). In some studies, CBA was a valuation method used for life cycle costing (Huang et al., 2019).

Visual Map
Co- Authorship
The number of articles is represented by the size of each circle or frame in the visual maps; for example, the tiny circles or frames means three articles per author; as the circle or frame gets larger, it often showed a high quantity of articles by an author. The circle or frame color depict the typical year of publications; the color of yellow denotes a relatively new theme, while the purple color denotes the oldest. Fig 3 demonstrates the sum of authors who have written at least three publications about LCC is 19. Matthias Finkbeiner published the highest numbers of articles 17, zamagni, alessandra 7, Martínez-Blanco Julia 6, Berger Markus, Inaba Atsushi 4 articles, Sharaai Amir Hamzah and sonnemann, guido 5, berger, markus, inaba, atsushi, kurian, Mathew, matsuno, yasunari, traverso, marzia 4, ciroth, andreas, guinée, jeroen, heijungs, reinout, hunkeler, david, kara, sami, klöpffer, walter, lehmann, annekatrin, reddy, v ratna, ren, jingzheng authors publish at least 3 articles respectively.

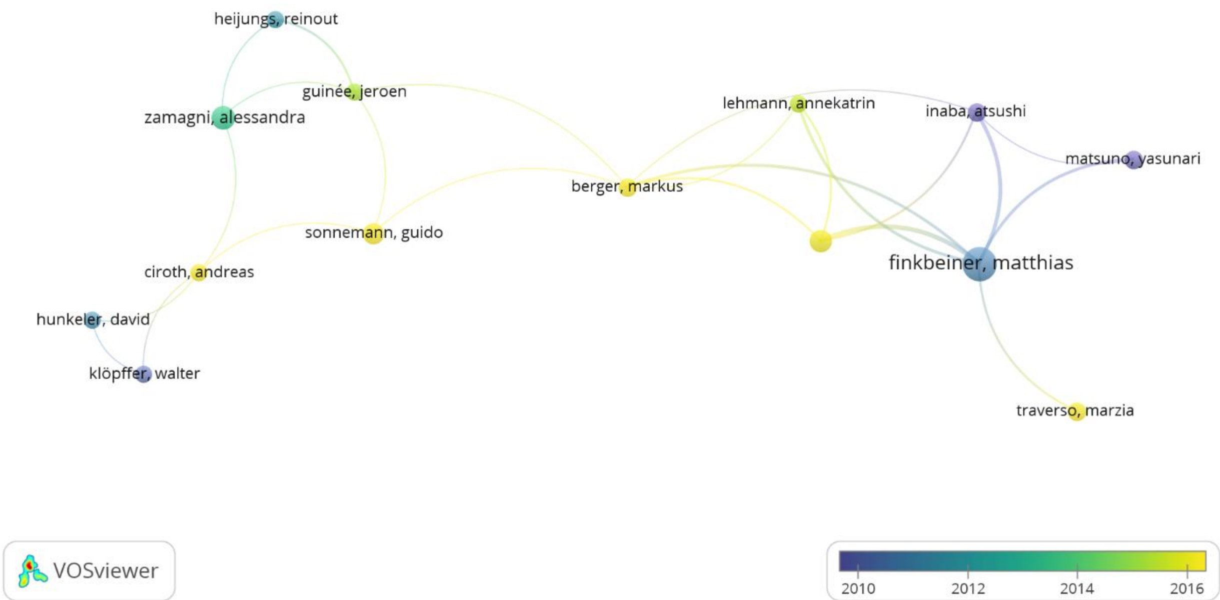

Figure 3: Co-Authorship

The visual map indicate the biggest the circle is the highest of the number co-authorship of publications by authors and the smaller circle is the low number of publications during the period, the smaller circle is at least indicate the 3 article published by authors. Here is strong network among the authors that published the article with co-authors, here is no single author that publish and article in LCC alone. The yellow color is indicate the newest publication and the blue is the eldest of the articles.

Co-Occurrence of keywords

Based on VOSviewer software analyzed in recognize in Figure 4 the 92 keywords by three occurrences. Moreover, the most used key is "Life Cycle Assessment" 24 occurrence followed by "Life Cycle Cost'' 22 and "Life Cycle Costing" 18 occurrences, "LCA" 11 occurrences, "LCC" 10 occurrences, "Life Cycle Costing (LCC)", Sustainability, "Life Cycle Costs, "Education'' 6 occurrences, "Life Cycle Sustainability Assessment'', "Life Cycle Analysis", "energy efficiency" 5 occurrence, and "life-cycle costing" ," life-cycle cost", "life-cycle assessment", "green building" 4 occurrence, and the rest is 3 occurrences respectively. However, eight keywords seem to be very used recently, for example "Green Manufacturing'', "Life Cycle Costing (LCC)'', "Social Life Cycle Assessment'', "Energy'', and "Bioenergy'' were mostly published in recent years in literatures. However, Figure 4 reveal that high number of article were published around 2015 in light green color. However, some keywords are very useful and shows the importance, the net present value is one keyword, which is using for calculating the life cycle costing. The word is sustainability is also used importantly, which have three pillars, economic, social, and environment. Base on life cycle sustainability assessment which is mostly defined by Klöpffer (Costa et al., 2019), the life cycle costing is one important pillar to be studies alongside with LCA and SLCA.

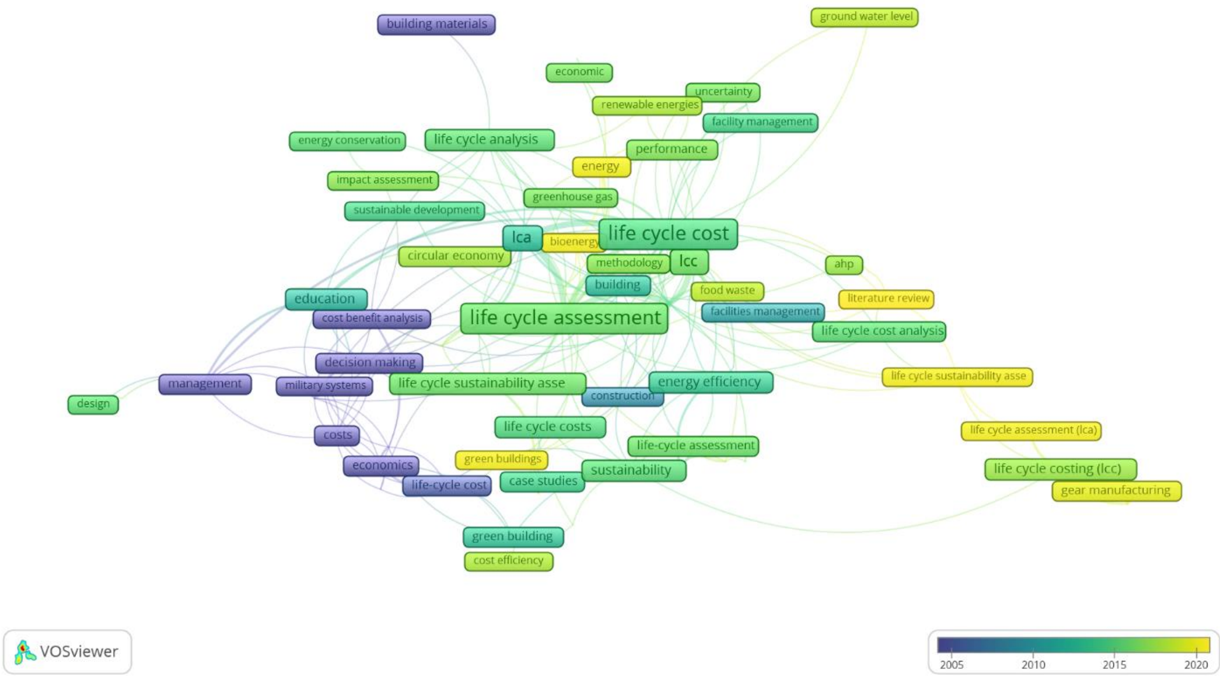

Figure 4: Co-Occurrence of Keywords

This visual map explains the biggest the frame is the highest of the number co-occurrence of keywords and the smaller frame is the low number of keywords' co-occurrence.

Cost Data

While the reviewed articles calculated the life cycle cost using their methods, there were some elements and components that must be calculated based on the nature of the study. According to Han, Srebric and Enache-Pommer, (2014), calculating the life cycle cost of a house or building includes three main phases based on NPV Equation 1: construction, yearly operation, and maintenance costs.

(Eq.1)

$$NPV(i,N) = \sum_{t=1}^{N} \frac{Ct}{(1+r)^t}$$

Where *NPV* is the present value, t is the time of the flow of cash, *N* is the system's life span, *Ct* is net cash flow at the specific time *(t)*, and t and r represent the discount rate.
Huang et al. (2018) calculated the life cycle cost in Fuzhou university town for the university dormitory and did not include the installation instruments in their estimation. While the cost of pre-construction was estimated, the land cost was not included in the calculation process. The LCC was calculated based on Equation 2:

(Eq.2)

$$\text{Ctot} = \sum (Cp + Cc + Co + Cm + Cd + Ce)$$

Where *Ctot* is the total cost, *Cp* is cost of preconstruction, *Cc* is cost of construction, *Co* is cost of operation, Cm is cost of maintenance, *Cd* is cost of demolition or deconstruction and *Ce* is cost of end of life, dealing with wastes of demolition.

Usually, during the preconstruction stage, it is necessary to calculate the cost of design and planning. Furthermore, some studies calculated the constructions' material cost such as bricks, cement, concrete, ceramic, stone, glass, gravel and sand, lime, clay, roof, slag, rubber, PVCs, chemicals, paints, windows, doors, bitumen, textiles, wood, metal, steel, fuel, wood, water, electricity, machinery, and tools, and others [60]. However, in the maintenance stage, the authors calculated the construction materials such as glasses, PVCs, chemicals, paints, windows, doors, bitumen, metal, steel, and wood. Besides that, the phase of operation, including water and electricity, was calculated. Additionally, during the demolition stage, most of the studies calculated the element of the estimated fuel cost (Huang et al., 2018; Huang et al., 2019; Li et al., 2020; Shea et al., 2020; Śnierzyński, Hernes, Bytniewski, Krzywonos, & Sobieska-Karpińska, 2019; Stevanovic, Allacker, & Vermeulen, 2019; Xu et al., 2017)

The cost of the construction phase contained the costs associated to the construction efforts. Operation cost comprised of habitation like water, energy, cleaning, security, management, replacing of equipment, upkeep or maintenance, and reparation costs like installations, sanitary and plumbing (Li et al., 2020). The elements calculated were a composition of components (Galle et al., 2015). The average of the building costs was calculated differently in different studies; however, Bromilow & Pawsey, (1987) calculated the average year of Melbourne University building to be 100 years old. The university buildings were comprised of lecture halls, auditoriums, offices, laboratories, libraries, study rooms, cafeterias, sports complexes, parking areas, residential dormitories, activities halls, and others. Additionally, in some articles, the replacement cost was calculated under the maintenance cost. However, for buildings, the replacement cost was calculated separately because it estimated the entire building replacement cost rather than the facilities replacement cost, and mostly used the

Bromilow and Pawsey. (1987) model of Czech construction's sector for the building's LCC (Biolek et al., 2017).

Anticipated Adjustment in Life Cycle Costing Technique for Higher Education

Practicing life cycle costing in higher education is limited, and no study has used the LCC method for education services. We have found a few studies that estimated the LCC for university buildings (Bromilow & Pawsey, 1987; Huang et al., 2018; Kimoto et al., 2013; Li & Guo, 2012; Xue et al., 2020) , university's accommodation and dormitories (Huang et al., 2018; Teshnizi et al., 2018), and schools (Bull et al., 2014; Erling Salicath, 2016). The lack of studies has encouraged the authors to conduct the current review to adopt a method for life cycle costing in higher education. For university buildings, the LCC is significantly used to recognize and choose the best option of costs based on several strategies, such as energy efficiency and others (Tabrizi & Sanguinetti, 2015). The value of the university facilities is challenging to calculate due to its maintenance and operations rather than commercial assets (Bromilow & Pawsey, 1987). Additionally, Kim, Kim and Lee. (2014) calculated the initial construction, operation and maintenance, and demolition costs.

Consequently, there is no method to calculate higher education life cycle costing, which comprehensively includes the total cost of higher education, building, services and operations. Therefore, it is imperative to develop some indicators for education services and facilities, especially the university's assets, such as university buildings, libraries, laboratories, auditoriums, classrooms, dormitories, cafeterias, and offices. Furthermore, it is necessary to calculate the cost of the services provided by universities.

Additionally, Kimoto, Yoshizaki and Ikeda. (2013) explained that LCC was delineated in three stages as follows: preliminary costs are the primary and initial expenditures, yearly costs are the cost calculated for twelve months, considering that the yearly cost is the same every year, and incidental costs are estimated in periodic manners. Moreover, they calculated the education facilities based on university outline as ground product (m^2), floor area (m^2), number of teachers and staff, number of students and number of buildings. However, the repainting and renovation cost was estimated in the maintenance cost, yet eventually, these elements and components were estimated separately for university buildings (Kimoto et al., 2013). Based on BS ISO 15686-5, Ayub & Abdul Rashid. (2016) have divided the life cycle costing process into three main phases: input of the data, conversion, and output, Shan, Melina and Yang. (2018) have calculated the tutorial classroom in Singapore. Table 5 shows the components and elements for the education life cycle cost, which comprehensively explains the education cost. Some of the authors calculated the different elements and components based on their own nature of research.

Table 5
Elements Calculated for Building, Especially for Education Building in the Literature

Elements	**Domain**	**Components Calculated**	**(Huang et al., 2018)**	**(Kimoto et al., 2013)**	**(Śnierzyński, et *al.*, 2019)**	**Cuéllar-Franca & Azapagic, 2014)**	**(Li et al., 2020)**	***(Xu et al., 2017)***	**(Huang *et al.*, 2019)**	**(Bromilow & Pawsey, 1987)**	**(Bromilow & Pawsey, 1987)**	**(Bromilow & Pawsev. 1987)**
	Preconstruction	Plan, design		√					√	√		√
Construction	Construction	Wages	√		√	√		√	√	√		√
		Transportation	√					√		√		
		Energy		√		√	√	√	√		√	√
		Raw Materials		√				√	√	√		√
Operation	Maintenance	Maintenance		√	√	√		√	√	√	√	√
		Renovation & Replacement		√		√	√			√		√
		Labor cost				√		√	√		√	
		Energy	√								√	√
	Consumption	Water			√		√				√	
		Electricity	√	√	√				√	√	√	
		Waste	√		√		√			√		√
		Salaries			√							√
Demolition	Demolition	Demolition	√					√				
		Labor	√			√		√	√			
		Energy	√			√						
		transportation							√			
		Recycling				√						
		Landfilling	√			√				√		
Safety & Externalities	Costs related to safety	Fire Safety		√		√	√			√		

	Pollutions	Air pollution						√			
		Water pollution			√			√			
		Soil pollution						√			
Services	Staff cost	Salary,			√		√			√	√
		Utility cost	√			√	√		√	√	
		Room service cost	√							√	√
	Lab Cost	Laboratory fittings								√	
Student Costs	Facilities costs	Tuition fee			√						
		Transportation		√							
		Communication				√					

Based on Table 5, the literature shows that in the context of higher education, there is no comprehensive method identified to calculate higher education LCC, which would have included the all elements and components of higher education. We have determined some elements calculated in other LCC studies for education facilities especially buildings as it was needed to calculate the overall costs of higher education. However, in Table 4, different articles focused on some components which were calculated in their studies, but there was no article that calculated all the components in higher education facilities and services. The next studies should calculate the higher education life cycle costing other than the components and elements listed in Table 4, including the risk mitigation, building safety and externalities, insurance and staff retirement, lab and chemicals risks in laboratory, and stationary costs.

Conclusion

LCC is most useful tool contributing in Life cycle sustainability assessment. Higher education is one of the important services to produce graduates who will contribute to the communities as human capitals. Therefore, the LCC is a vital management tool to estimate the cost of products or services during the entire life span. Furthermore, two visual maps were created to characterize the authors and keywords based on research patterns. In this regard, 77 authors have written and published three articles on Life Cycle Costing, with Mathias Finkbeiner the highest publication 32 on top, the altman, douglas g, liberati, alessandro, moher, david, tetzlaff, Jennifer leading the way with 10 articles each. Based on VOSviewer software analyzed in recognize the 75 keywords by three occurrences were analyzed, the most used key is “Life Cycle Assessment” 34 occurrence followed by “Life Cycle Costing” and “Life Cycle Cost’’ 23 occurrence, “LCA” 15 occurrence, “LCC” 12 occurrence, and “Life Cycle Costing (LCC)” 8 occurrence.

Based on the findings, there were numerous life cycle costing studies in the literature on the products. However, there has yet a study on the higher education services. Some studies calculated the higher education facilities, especially the dormitories and building life cycle cost. However, the education services and facilities calculations were not used in the literature related to the LCC of higher education. Based on the review of methods, there was no comprehensive method used for the higher education or other services. Hence, it is important to adopt a method for the higher education life cycle costing. Consequently, we aimed to adopt the methods that used the existing calculations in the literature. According to the literature search, there were some articles that calculated the university residential or non-residential buildings' LCC using different elements in their studies. Finally, based on this review, finding a specific method required for the higher education life cycle costing would involve modification and development of the method in combination with the building life cycle elements and components, such as facilities, services, operations, constructions, lab facilities, safety, and student costs to insure the sustainability of higher education services in sustainable manners.

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