p. 122—135

THE JOURNAL OF INDONESIA SUSTAINABLE DEVELOPMENT PLANNING

VOL. 4 NO. 2 - AUGUST 2023

E-ISSN: 2722-0842 | P-ISSN: 2721-8309

Available online at
journal.pusbindiklatren.bappenas.go.id

Research Paper

Preliminary Analysis of Life Cycle Assessment on Single-Use Plastic Cutlery Set Substitutes in the Catering Industry

Muhammad Ainul Fahmi [1*], Maghfur Rozudin [2], Suci Oktaviani Putri [3], and Jani Raharjo [4]

Padjadjaran University, Bandung, Indonesia [1]
Sepuluh Nopember Institute of Technology, Surabaya, Indonesia [2]
Surabaya State University, Surabaya, Indonesia [3]
Petra Christian University, Surabaya, Indonesia [4]

***) Corresponding author**: *muhammad.ainul.fahml@unpad.ac.id*

Abstract

Single Use Cutlery plastic is an item easily obtained from food catering packages, such as tableware and cutlery sets from the catering industry and is very harmful to the environment. Therefore, this study conducted a Life Cycle Assessment (LCA) analysis to identify the key factors influencing the replacement of single-use cutlery sets within the catering industry. Data collected from the catering industry in Surabaya were processed using SEM PLS modeling. The results showed that the factors Goal and Scope Definition, Life Cycle Inventory, Impact Assessment, and Result Interpretation impact the Life Cycle Assessment of the Catering Industry in Surabaya City as evidenced by all p-values of the inner model being less than 0.05.

Keywords: Life Cycle Assessment; Single Use Plastic Cutlery Set Substitutes; Catering Industry; Structural Equation Model

ARTICLE INFO
Received: April 02, 2023
Received in revised form: June 06, 2023
Accepted: August 24, 2023

doi: 10.46456/jisdep.v4i2.444

THE JOURNAL OF INDONESIA SUSTAINABLE DEVELOPMENT PLANNING
Published by Centre for Planners' Development, Education, and Training (Pusbindiklatren), Ministry of National Development Planning/National Development Planning Agency (Bappenas), Republic of Indonesia

Address: Jalan Proklamasi 70, Central Jakarta, Indonesia 10320
Phone: +62 21 31928280/31928285
Fax: +62 21 31928281
E-mail: journal.pusbindiklatren@bappenas.go.id

Supported by Indonesian Development Planners Association (PPPI)

Please cite this article in APA Style as:
Fahmi, M.A.,Rozudin, M.,Putri, S.O.,& Raharjo, J. (2023). Preliminary Analysis of Life Cycle Assessment on Single Use Plastic Cutlery Set Substitutes in the Catering Industry. *The Journal of Indonesia Sustainable Development Planning, 4*(2), (122—135). https://doi.org/10.46456/jisdep.v4i2.444

1. Introduction

The issue of plastic waste and its environmental impact is a significant global concern (Chae & An, 2018; Potocka et al., 2019). While plastics are widely used due to their convenience, durability, and low cost, the mismanagement of its waste has led to the pollution of land, waterways, and oceans, posing threats to ecosystems and wildlife (Iñiguez et al., 2018; Kwon et al., 2018). Dumping plastic waste into the deep sea or unused land is an unsustainable approach that merely relocates the problem, potentially causing harm to marine life, soil quality, and groundwater (Chae & An, 2018; Zhao et al., 2018). Similarly, exporting plastic waste to less affluent nations as a disposal method raises ethical concerns and fails to address the root problem. Calls for an outright ban on plastics often arise from the pressing need to combat plastic pollution (Blettler et al., 2018; Monteiro et al., 2018). However, it is important to recognize that plastics serve numerous valuable purposes in the daily lives of humans, and a complete ban may not be practical or feasible in many cases. Instead, a more intensive approach is needed to reduce plastic waste and promote responsible plastic management (Jandas et al., 2019; Liu et al., 2023).

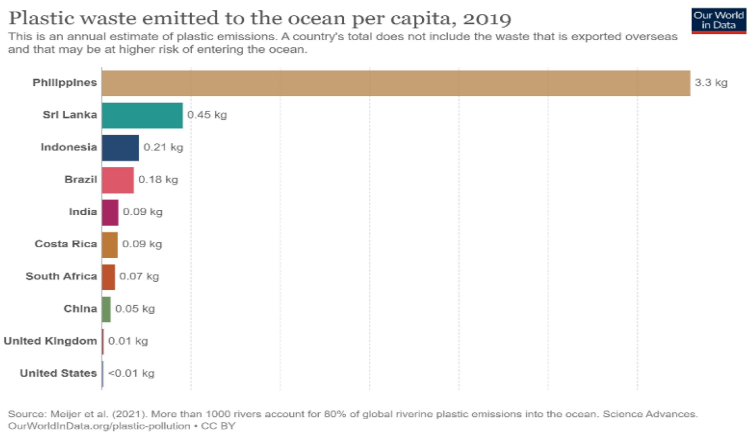

Figure 1. Plastic Waste Emitted to the Ocean per Capita, 2019

Source: (Meijer et al., 2021)

Indonesia deserves recognition for its proactive stance in addressing plastic pollution and its commitment to decreasing its contribution to oceanic plastic waste. Given its substantial role as a contributor to plastic pollution, as shown in Figure 1, the nation must prioritize initiatives to combat this issue and promote sustainable practices (Meijer et al., 2021). The focus on reducing single-use plastic products represents a crucial stride in the right direction. Single-use plastic items, such as cutlery sets and tableware commonly employed in the catering industry, are widespread and substantially contribute to the global plastic waste dilemma, as shown in Table 1 (Organization for Economic Co-operation and Development [OECD], 2019). Therefore, by targeting these specific applications, Indonesia has the potential to wield a significant influence on reducing plastic waste.

Table 1. Single Use Plastics Applications

Time	2019	2020	2021	2022	2023	2024
Plastics applications						
Other	66.315	66.004	66.978	68.725	70.47	72.138
Consumer Products	*46.662*	*46.427*	*47.141*	*48.517*	*49.814*	*51.15*
Transportation	54.431	51.319	53.824	56.272	58.586	60.853
Industrial/machinery	2.683	2.694	2.724	2.788	2.855	2.913
Personal care products	0.027	0.325	0.224	0.156	0.11	0.079
Total	170.118	166.769	170.891	176.458	181.835	187.133

The use of environmentally friendly alternatives to single-use plastic products, such as biodegradable cutlery sets and oxo-biodegradable tableware, is undeniably a pivotal strategy in combatting plastic pollution (Chen et al., 2021; Tan et al., 2021). These alternatives can diminish the ecological impact of plastic waste and pave the way for a more sustainable future (Di et al., 2021; Wei et al., 2022). Biodegradable products are engineered to naturally decompose into non-toxic components over time, typically facilitated by microorganisms. They help alleviate the accumulation of plastic waste in landfills and ecosystems (Moshood, Nawanir, Mahmud, Mohamad, Ahmad, & AbdulGhani, 2022). By using biodegradable cutlery sets and tableware, the reliance on traditional single-use plastics can be reduced, thereby minimizing the long-term environmental consequences (Markowicz & Szymańska-Pulikowska, 2019; Moshood, Nawanir, Mahmud, Mohamad, Ahmad, AbdulGhani, & Kumar, 2022). Conversely, oxo-biodegradable products are conventional plastics modified with additives to expedite their degradation process (Markowicz & Szymańska-Pulikowska, 2019). These additives promote the fragmentation of plastics into smaller pieces, which can subsequently undergo further breakdown through biological or chemical processes. Oxo-biodegradable products are often seen as an intermediate solution that aims to reduce the persistence of plastic waste in the environment (Chiellini & Corti, 2016).

The life-cycle perspective plays a pivotal role in addressing the pressing issue of plastic pollution, as it offers a holistic view of the environmental impacts of various products and their disposal methods. Life-cycle assessment (LCA) methods provide a structured approach to thoroughly evaluate the entire life cycle of a product, including its production, use, and end-of-life stages (Wei et al., 2022). The study by (Sun et al., 2021), underscores the potential environmental benefits of replacing 60% of disposable plastic tableware with reusable or recyclable alternatives, including biodegradable or oxo-biodegradable options. This substitution reduced carbon emissions by an impressive 92%, illustrating the significant positive impact that transitioning away from disposable plastic tableware can have on carbon emissions within this sector. When considering compostable and biodegradable plastic tableware, it is important to highlight their enhanced environmental performance, particularly when properly composted. This is particularly relevant in the catering service sector, where there is often a practice of mixing food waste with disposable tableware. Fieschi and Pretato (2018) stated that composting these materials can lead to favorable environmental outcomes. Furthermore, proper composting enables the organic components of food waste and compostable tableware to naturally break down, contributing to the sustainable circular use of resources.

However, it is important to acknowledge that the environmental performance of diverse tableware options can fluctuate due to various factors, encompassing the materials used, production processes, disposal methods, and the prevalent waste management systems in a given region. This intricacy is exemplified by the study of Blanca-Alcubilla et al. (2018), which adopted a life-cycle perspective to scrutinize plastic products within the catering sector. The study revealed that reusable items contributed more to global warming potential than single-use items, underscoring the multifaceted nature of assessing environmental impacts throughout the life cycle. To effectively address the issue of plastic pollution and to make well-informed decisions, it is imperative to account for various factors. These include the unique contextual aspects, waste management practices, available infrastructure, and the inherent environmental trade-offs associated with different alternatives (Blanca-Alcubilla et al., 2020). Striving for an exhaustive understanding of the life cycle assessment (LCA) ramifications of distinct tableware choices can provide valuable guidance for fostering more sustainable practices within the catering industry and across broader domains (Wei et al., 2022).

In this context, the essence of Life Cycle Assessment (LCA) and its relevance in supporting Sustainable Development Goals (SDGs) has become particularly evident. LCA serves as a potent instrument employed to quantify and assess the environmental consequences associated with the complete life cycle of a product, process, or system, extending from its inception to its end-of-life phase. This holistic approach considers all stages of the value chain, including raw material extraction, production, use, and end-of-life management. Therefore, by evaluating resource use and emissions throughout the life cycle, LCA allows for a more comprehensive understanding of the environmental impacts of a product or process. Life Cycle Assessment is a valuable tool that promotes a systems-based approach to sustainability. It aids businesses and policymakers in making well-informed decisions that contribute to a more sustainable future and align with the attainment of the Sustainable Development Goals (SDGs) (Sala et al., 2019).

This study examined the replacement of single-use tableware or cutlery sets through the lens of life cycle assessment (LCA), considering the pivotal elements of goal and scope definition (GSD), life cycle inventory (LCI), impact assessment (IA), and results interpretation (RI) using a structural equation modeling partial least square (SEM PLS) method (Wei et al., 2022). Structural equation modeling (SEM) is a statistical technique employed to scrutinize relationships between variables and elucidate the causal pathways that connect them. Partial least squares (PLS) represent a specific variant of SEM that proves particularly valuable when dealing with intricate models, limited sample sizes, or non-normally distributed data (Hair et al., 2014). Through the application of SEM PLS, researchers aimed to gauge the ramifications of various variables related to substituting single-use tableware or cutlery sets throughout their life cycle. This comprehensive analysis can aid in assessing the environmental, social, and economic implications associated with different scenarios, ultimately contributing to evaluating their overall sustainability performance (Hair et al., 2017).

The study would likely involve the following steps (Wei et al., 2022):

1. Goal and scope definition (GSD): Clearly define the research objectives, boundaries, and assumptions of the study, such as the functional unit (e.g., number of meals served), system boundaries, and time frame for the analysis.
2. Life cycle inventory (LCI): Collect the inputs (e.g., raw materials, energy) and outputs (e.g., emissions, waste) data associated with each stage of the life cycle of the tableware or cutlery sets. This collection process encompasses details about production, transportation, utilization, and eventual disposal.
3. Impact assessment (IA): Assess the potential environmental, social, and economic impacts of the different life cycle stages using impact assessment methods. This process involves quantifying and characterizing the impacts in categories such as greenhouse gas emissions, energy consumption, water usage, waste generation, and potential human health effects.
4. Results interpretation (RI): Analyse and interpret the impact assessment results to understand the overall sustainability performance of the different scenarios. This includes identifying the key drivers of impact and evaluating trade-offs and synergies between different environmental and social indicators.

By applying SEM PLS, the relationship between variables, such as material choices, transportation methods, waste management practices, and environmental impacts within the framework of the life cycle, can be modeled and analysed. This approach can provide valuable insights into the overall sustainability performance and identify strategies for improving tableware or cutlery sets' environmental and social impacts (Hair Jr et al., 2021). Careful consideration of data quality, selection of impact assessment methods, and ensuring that the model accurately reflects the real-world system being studied must be considered when conducting a study using SEM PLS and LCA. Additionally, stakeholder engagement and consultation are important for setting relevant goals and meaningfully interpreting results (Hair & Alamer, 2022; Wei et al., 2022).

2. Methods

This study delved into the analysis of Life Cycle Assessment regarding alternative plastic cutlery sets within the catering industry in Surabaya City. The study framework encompassed key components, namely Goal and Scope Definition (GSD), Life Cycle Inventory (LCI), Impact Assessment (IA), and Result Interpretation (RI). Wei et al. (2022), presented a new synthesis model of analysis of Life Cycle Assessment on plastic cutlery set alternatives in the industry catering in Surabaya City using a structural equation modeling partial least square (SEM PLS), as shown in Figure 2.

A total of four alternative hypotheses related to the relationships between different factors and Life Cycle Assessment (LCA) were formulated as follows:

H1: Goal and Scope Definition (GSD) significantly and positively influences LCA.

H2: Life Cycle Inventory (LCI) significantly and positively influences LCA.

H3: Impact Assessment (IA) significantly and positively influences LCA.

H4: Result Interpretation (RI) significantly and positively influences LCA.

The principal objective of PLS is to establish the significance of the alternative hypothesis, enabling the dismissal of a null hypothesis through the demonstration of substantial t-values. The null hypothesis will be rejected when the t-value surpasses 1.96 (at $p < 0.05$), signifying the presence of an effect between the elements of GSD, LCI, IA, and RI with the components of LCA (Hair Jr et al., 2021).

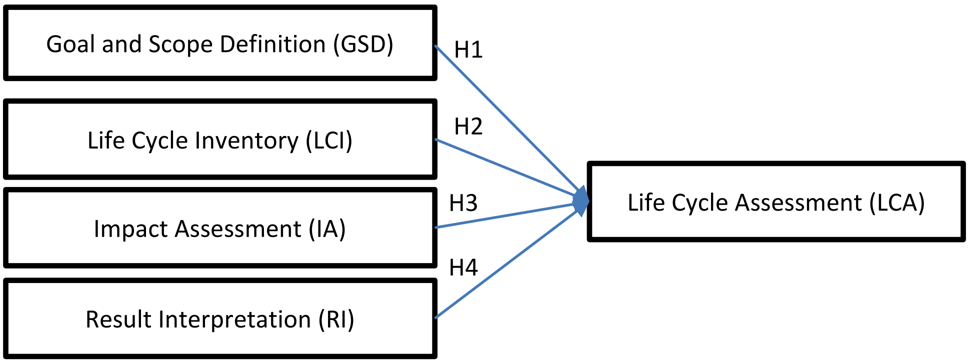

Figure 2. Conceptual Model of Study

A quantitative study was carried out to test these hypotheses, with data collected through closed-ended questionnaires that included alternative responses constructed on a Likert scale (Hair et al., 2017). The Likert scale is a commonly employed tool in surveys used to measure the attitudes and perceptions of respondents on a range of response options. An experiment was carried out through the distribution of questionnaires to all catering industries in the city of Surabaya using a Google form. The selection of samples was conducted using a purposive sampling approach, which involved the withdrawal method using certain criteria. In this case, the criteria for sample selection were catering industries in Surabaya City that had adopted substitutes for single-use plastic cutlery sets. The number of samples to be used in this study is based on (Hair Jr et al., 2021), who explained that the minimum sample size based on the minimum R^2 values starts from 0.1, 0.25, 0.5, and 0.75. These values are for endogenous constructs in Structural Equation Modeling (SEM), with significance levels of 1%, 5%, and 10%, considering the maximum number of constructs in the PLS Path Model. In the context of this study, where there are four PLS paths with an R2 of 0.75 and a significance level of 5%, the minimum required sample size is 33 (Hair et al., 2014).

The collected data were analyzed using the Structural Equation Model (SEM) and Partial Least Squares (PLS) methods. According to preliminary studies, SEM is a statistical technique used to test and model complex relationships between observed and latent variables (Hair et al., 2014; Hair et al., 2017; Hair Jr et al., 2021). Meanwhile, PLS is a variant of SEM beneficial for analyzing models with a smaller sample size or non-normal data distributions (Hair & Alamer, 2022). By utilizing SEM and PLS, the relationships between the GSD, LCI, IA, RI, and LCA variables were determined. These statistical analyses help identify the strength and significance of these relationships and provide insights into the factors influencing LCA in the context of plastic cutlery set alternatives in the catering industry in Surabaya City (Hair Jr et al., 2021; Wei et al., 2022).

Table 2 consists of data from the study by Hair and Alamer (2022), which was processed by SmartPLS 4.0. The data described LCA's analyzed variables, items, indicators, mean, and standard deviation. Furthermore, Tables 3 and 4 were obtained from the values of loading factor and AVE (as convergent validity) and cross-loading (as discriminant validity) using the SmartPLS 4.0 processed data. Table 5 contains alpha and CR values obtained from the reliability values, while Table determined the f-square values. Finally, Table 7 analyzed the hypothesis containing path coefficient, t-value, and p-value values.

Table 2. Descriptive Analysis Life Cycle Assessment (Variable, Items, Indicator, Mean, and Standard Deviation)

Variable	Items	Indicator	Mean	SD
Goal and Scope Definition (GSD)	GSD1	There is a purpose for using a single-use plastic cutlery set replacement for the LCA process	4,02	0.91
	GSD2	There is a function of replacing single-use plastics cutlery sets with biodegradable cutlery sets or oxo-biodegradable options	4,06	0.824
	GSD3	There is an LCA system that will be used to replace single-use plastics cutlery sets in the catering industry	4,03	0.899
	GSD4	There is a time frame to carry out the LCA concept which will be used to replace single-use plastics cutlery sets in the catering industry	3,98	0.97
	GSD5	There are clear problem limits and assumptions related to the LCA concept that will be used to replace single-use plastics cutlery sets	4	0.893
Life Cycle Inventory (LCI)	LCI1	There is data to determine the raw material from replacing single-use plastic cutlery sets to biodegradable or oxo-biodegradable cutlery sets	4,03	0.916
	LCI2	There is data to find out the energy used during the production process from replacing single-use plastic cutlery sets to biodegradable	4,06	0.865
	LCI3	There is data to find out how much waste can be removed from replacing single-use plastic cutlery sets with biodegradable	4,05	0.825
	LCI4	There is data to find out how much greenhouse gas emissions can be eliminated from replacing single-use plastic cutlery sets with biodegradable or oxo-biodegradable cutlery sets in your catering industry green supply chain practices	4,02	0.853
	LCI5	There is data to find out green supply chain activities from procurement, production, transportation, use to waste management from replacing single-use plastic cutlery sets to biodegradable or oxo-biodegradable cutlery sets in your catering industry green supply chain practices	4,09	0.851
Impact Assessment (IA)	IA1	There is a process of measuring potential influences on environmental aspects	3,99	0.894
	IA2	There is a process of measuring potential influences on social aspects	4,03	0.874
	IA3	There is a process of measuring potential influence on economic aspects	4,14	0.778
	IA4	There is a process of measuring the potential influence on aspects of waste generation	4,15	0.816
	IA5	There is a process of measuring potential influences on aspects of human health effects	4,13	0.836
Result Interpretation (RI)	RI1	There is a process of measuring potential influences on aspects of human health effects	3,94	0.872
	RI2	There is a process of interpreting activities to create alternative scenarios for replacing single-use plastic with biodegradable	3,94	0.917
	RI3	There is a process of identifying driving factors to encourage alternatives to replace single-use plastic with biodegradable	3,88	0.919
	RI4	There is a process of evaluating trade-off factors to encourage alternatives to replacing single-use plastic with biodegradable	3,95	0.93
	RI5	There is a synergy process with environmental and social aspects to encourage alternatives to replace single-use plastic with	4	0.876
Life Cycle Assessment (LCA)	LCA1	There is a Goal and Scope Definition	4,02	0.869
	LCA2	Life Cycle Inventory process	4,01	0.896
	LCA3	Impact Assessment process	4,02	0.889
	LCA4	There is a Result Interpretation	4,05	0.86
	LCA5	There is a process to carry out LCA activities in your catering industry	4,01	0.864

3. Results and Discussions

3.1 Descriptive Analysis

The components of the test used to gauge Life Cycle Assessment (LCA) in the Catering Industry in Surabaya City, show that the perceptions of the respondents are markedly shaped by their level of agreement with the statements provided in the instruments (See Table 2). It is well known that the statement IA4 garners the highest index, indicating that respondents exhibit strong agreement with the assertion, "There is a process of measuring the potential influence on aspects of waste generation." Conversely, the statement with the lowest index is RI3, suggesting that respondents are less aligned with the statement, "There is a process of identifying driving factors to encourage alternatives to replace single-use plastic with biodegradable or oxo-biodegradable cutlery sets."

3.2 Outer Model

The measurement model indicates the capacity of the manifest or observed variables to effectively represent the latent variables under consideration. It is important to note that a loading factor value is ascertained to have high validity when greater than 0.5 (Ghozali & Latan, 2015). The results from the outer measurement model using the PLS analysis tool for each indicator are shown in Table 3.

Table 3. Convergent Validity Life Cycle Assessment (Loadings Factor)

Item	Outload	AVE	Result	Item	Outload	AVE	Result	Item	Outload	AVE	Result
GSD1	0.810			IA1	0.880			LCA1	0.839		
GSD2	0.816			IA2	0.896			LCA2	0.913		
GSD3	0.865	0.710	Supported	IA3	0.891	0.769	Supported	LCA3	0.876	0.772	Supported
GSD4	0.856			IA4	0.831			LCA4	0.893		
GSD5	0.866			IA5	0.827			LCA5	0.872		
LCI1	0.903			RI1	0.789						
LCI2	0.908			RI2	0.800						
LCI3	0.943	0.761	Supported	RI3	0.822	0.763	Supported				
LCI4	0.975			RI4	0.823						
LCI5	0.993			RI5	0.838						

Table 4. Discriminant Validity Life Cycle Assessment (Cross Loadings)

Variable	GSD	LCI	IA	RI	LCA
GSD1	**0.810**	0.465	0.477	0.091	0.156
GSD2	**0.816**	0.401	0.479	0.079	0.092
GSD3	**0.865**	0.413	0.534	0.123	0.165
GSD4	**0.856**	0.434	0.535	0.185	0.244
GSD5	**0.866**	0.462	0.526	0.120	0.203
LCI1	0.314	**0.903**	0.580	0.568	0.735
LCI2	0.319	**0.908**	0.598	0.556	0.752
LCI3	0.443	**0.799**	0.509	0.132	0.133
LCI4	0.475	**0.696**	0.500	0.133	0.170
LCI5	0.493	**0.660**	0.530	0.160	0.181
IA1	0.445	0.628	**0.880**	0.428	0.581
IA2	0.380	0.670	**0.896**	0.536	0.662
IA3	0.633	0.458	**0.691**	0.166	0.246
IA4	0.631	0.416	**0.651**	0.166	0.182
IA5	0.627	0.424	**0.702**	0.132	0.194
RI1	0.133	0.451	0.338	**0.789**	0.588
RI2	0.170	0.593	0.547	**0.800**	0.838
RI3	0.085	0.395	0.296	**0.822**	0.534
RI4	0.107	0.410	0.314	**0.823**	0.535
RI5	0.100	0.418	0.299	**0.838**	0.569
LCA1	0.218	0.565	0.596	0.661	**0.839**
LCA2	0.190	0.651	0.615	0.752	**0.913**
LCA3	0.176	0.736	0.471	0.690	**0.876**
LCA4	0.172	0.713	0.480	0.676	**0.893**
LCA5	0.220	0.631	0.477	0.643	**0.872**

Based on the information provided in the table, it is evident that all measurement items have successfully met the criteria of the outer loading test. These items were considered suitable for measuring each respective latent variable, as they exhibit values for the question indicators exceeding 0.60. Additionally, the average variance extracted (AVE) values for these items surpass the threshold of 0.50.

To address the issue of discriminant validity for each construct, the next step involves examining the correlation values between constructs in the model, often referred to as cross-loading (Garson, 2016). The results, as shown in Table 4, indicate that all cross-loading values within each of the desired constructs are significantly higher than the cross-loading values with other constructs. This finding supports the conclusion that all indicators are valid, and discriminant validity remains intact. In other words, the measurements effectively distinguish between the intended constructs, reinforcing the validity of the model.

Cronbach alpha and composite reliability scores were used to assess the reliability of each latent construct. This is in addition to the use of the rho value to assure the reliability of the PLS construction score (Dijkstra & Henseler, 2015). It is important to note that both Cronbach alpha and composite reliability need to ideally exceed 0.70 (Hair Jr et al., 2021), while composite reliability is indicated by the rho a value, which should also be 0.70 or higher, as shown in Table 5. Based on the presented Cronbach Alpha and Composite Reliability coefficient values, all of which surpass the 0.70 thresholds, the table unequivocally demonstrates all variables employed in this study exhibit excellent validity and reliability. This suggests that these variables are highly practical and reliable for use in the study.

Table 5. Reliability Test Life Cycle Assessment (α and CR)

Variable	α	CR
GSD	0.902	0.938
LCI	0.783	0.928
IA	0.843	0.971
RI	0.875	0.895
LCA	0.926	0.929

3.3 Inner Model

The Inner Model was used to establish the causal connection between the variables studied with the outcome of the factors shown in Figure 3 and Tables 6-7 (Hair et al., 2017).

Table 6. f-Square Life Cycle Assessment (f-Square and Effect Size)

Correlation	f-Square	Effect Size
GSD -> LCA	0.096	Small
IA -> LCA	0.053	Small
LCI -> LCA	0.366	Large
RI -> LCA	0.581	Large

Table 7. Hypothesis Test Life Cycle Assessment (Path Coefficient, T-Statistics, P-Values)

Hypothesis	Path Coefficient	T statistics	P values
GSD -> LCA	0.196	6.109	0.000
LCI -> LCA	0.463	10.373	0.000
IA -> LCA	0.174	4.951	0.000
RI -> LCA	0.464	11.622	0.000

Based on Figure 3 and Tables 6-7, GSD, LCI, IA, and RI, have a positive and significant influence on LCA. The test results between GSD, LCI, IA, and RI with LCA show path coefficient values of 0.196, 0.463, 0.174, and 0.464, which are close to the +1 value. The T-Statistic values are 6.109, 10.373, 4.951 and 11.622 (>1.96), with f-square values of 0.096, 0.053, 0.366 and 0.581, valued at 0.000 (<0.05).

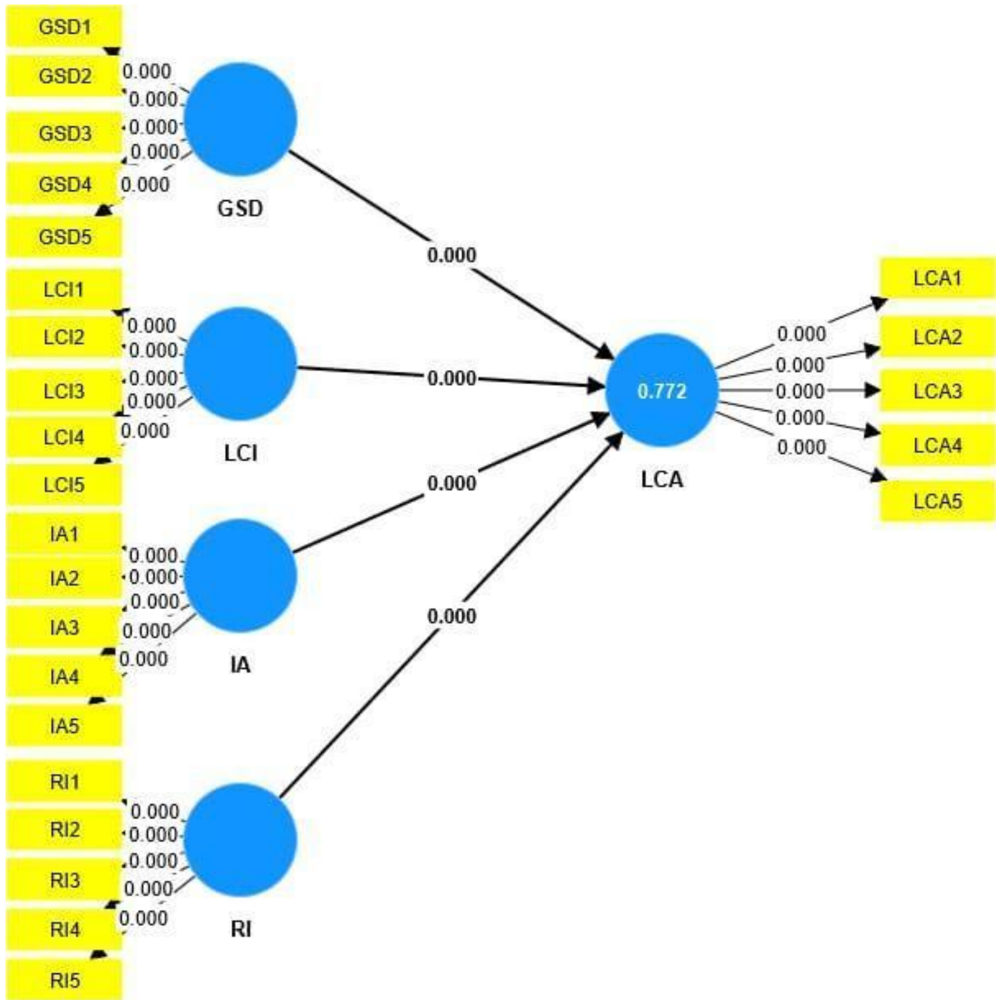

Figure 3. Hypothesis Test Results Life Cycle Assessment (all P-Values <0.05)

Source: Smart PLS 4.0 Output Results (2023)

3.4 Discussions

Based on the test results, it is evident that Goal and Scope Definition (GSD), Life Cycle Inventory (LCI), Impact Assessment (IA), and Result Interpretation (RI) all exert a positive and significant influence on Life Cycle Assessment (LCA). This is substantiated by the path coefficient values for each of these factors, which are 0.196, 0.463, 0.174, and 0.464, respectively, and are close to the +1 value. Additionally, the T-Statistic values for each path are well above 1.96, namely 6.109, 10.373, 4.951, and 11.622. The f-square values are 0.096, 0.053, 0.366, and 0.581, indicating significant effects, while all p-values are below 0.05, specifically 0.000, signifying statistical significance. The hypotheses H1, H2, H3, and H4 were supported, confirming that Goal and Scope Definition (GSD), Life Cycle Inventory (LCI), Impact Assessment (IA), and Result Interpretation (RI) all have significant and positive effects on Life Cycle Assessment (LCA). These findings align with prior studies (Wei et al., 2022). The finding of this study shows that collaboration between Goal and Scope Definition (GSD), Life Cycle Inventory (LCI), Impact Assessment (IA), and Result Interpretation (RI) encourages the Catering Industry to establish Life Cycle Assessment (LCA).

The novelty of this study lies in creating a conceptual model employing the SEM PLS method, which can serve as a foundation for future research. Based on survey results from the catering industry, this study elucidates that Life Cycle Assessment (LCA) is indeed influenced by four primary factors, namely Goal and Scope Definition (GSD), Life Cycle Inventory (LCI), Impact Assessment (IA), and Result Interpretation (RI). This study marks an initial exploration of applying SEM PLS modeling in LCA analysis, as opposed to previous ones, which had to use laboratory-based methods or use certain measuring devices to measure the level of impact assessment. The result interpretation of the LCA level on a product, including cutlery set products, was determined using a concept that LCA is indeed significantly and positively influenced by 4 factors, namely Goal and Scope Definition (GSD), Life Cycle Inventory (LCI), Impact Assessment (IA), and Result Interpretation (RI).

The goal and scope definition (GSD) of this Life Cycle Assessment (LCA) study is to assess and compare the environmental performance of plastic cutlery and alternative options, specifically focusing on their application within the catering industry. This study aimed to provide insight into the environmental impacts of different tableware materials, thereby assisting stakeholders in making decisions based on sustainability considerations. The main goal and scope are to determine the optimal alternative to plastic tableware while considering the environmental impact of the entire product life cycle (cradle-to-grave). Furthermore, the functional unit (FU) on the goal and scope definition of LCA is used as a reference for comparison between various tableware materials. FU is defined as the request for tableware required to serve 1000 meals, which allows for a consistent evaluation of the environmental impact of each material when used in the context of the catering industry. The goal and scope definition in this LCA study encompasses the entire life cycle of tableware and its alternatives, encompassing the following phases (Wei et al., 2022):

1. Acquisition of raw materials: This stage includes the extraction and processing of raw materials necessary to manufacture tableware.
2. Production of materials and tableware: The manufacturing process involved converting raw materials into finished tableware products.
3. Use and reuse of tableware: The use stage includes the environmental impact of using tableware to serve food, while the reuse stage involves reconsideration.
4. Waste management: The management of waste generated during the life cycle, including disposal, recycling, and other scenarios for the end of life of tableware, is also included.

The goal and scope definition (GSD) in this study adopted a comparative approach, which enabled the assessment of the environmental performance of plastic tableware in contrast to viable alternatives throughout the entire life cycle phase. Therefore, by employing a cradle-to-grave model, the analysis comprehensively covered all phases of the life cycle, encompassing both upstream and downstream processes. An important aspect of this approach is establishing an alternative limitation designed to maintain consistency, such as a set of tableware consisting of a knife, fork, and spoon, which is considered a standard package to be served with food. This standardization ensures a fair and consistent basis for comparing different tableware materials. By conducting LCA studies with predetermined goals and scope definition, this study aimed to provide valuable guidance for the catering industry and other stakeholders. The aim is to assist them in making informed choices regarding tableware materials that exhibit the lowest environmental impact and represent the most sustainable options (Wei et al., 2022).

Life cycle inventories (LCI) in LCA studies were created by collecting data from primary and secondary sources. Primary data is collected directly from the source, while secondary data are obtained from other parties and are available for use in the study. The following is an explanation of the use of primary and secondary data in lifecycle inventories (LCI) (Razza et al., 2015):

1. Primary Data:
    - This data type was used to collect information about the weight of each type of tableware included in a set, such as a set of knives, forks, and spoons. It is used to calculate the environmental impact of using the material in each set of tableware.
    - The direct collection method was used by the research team to weigh each cutlery and get an accurate measurement.

2. Secondary Data:
    - This data type is used to understand material inputs and outputs in various phases of the tableware life cycle, such as raw material acquisition, production, and waste management.
    - It comes from pre-existing sources, such as Environmental Impact Assessment (EIA) reports, scientific research results, previous LCA studies, industry statistics, environmental databases, and other related scientific literature.

In the lifecycle inventories (LCI) stage, data sourced from both primary and secondary sources are leveraged to model material and energy flows throughout the tableware lifecycle, encompassing production to final disposal. This primary and secondary data synthesis enables researchers to compute each tableware type's environmental footprint or impact and its potential alternatives. This calculation hinges on understanding the materials, energy, and processes entailed in the life cycle of each product. It is important to note that the accuracy and validity of the data collected are important factors in the overall quality of the LCA study. Therefore, during the life cycle inventory phase, dedicated efforts should be made to ensure the data used is accurate, reliable, and representative of the real-world conditions of the system under evaluation (Razza et al., 2015).

Environmental impact assessment (IA) through life cycle modeling, often facilitated by GaBi software, constitutes a prevalent approach in LCA studies. GaBi (Global Approach to Biological Systems) software is one of the leading LCA software used to analyze and assess a product's or system's environmental impact from a life cycle perspective. This method unravels and assesses the material flow across every phase of the tableware life cycle, from production to ultimate disposal. Environmental impact quantification is executed using the CML (Centrum voor Milieukunde) method 2001-Jan.2016. This method stands among several environmental impact assessment techniques and typically encompasses an array of distinct environmental impact categories. By gauging environmental impacts across multiple categories, LCA studies can provide a more exhaustive portrayal of the environmental implications associated with each alternative. Below are the 11 environmental impact categories examined in this study using the CML method 2001-Jan.2016 (Wei et al., 2022):

1. GWP 100: Global Warming Potential, measures the impact of greenhouse gases on climate change.
2. AP: Acidification Potential, assesses the impact of increasing environmental acidity.
3. EP: Eutrophication Potential, measures the impact of excessive nutrient release and causing eutrophication problems in waters.
4. ODP: Ozone Depletion Potential, measures the impact on stratospheric ozone layer depletion.
5. ADP Element: Abiotic Depletion Potential of natural elements, examines the depletion of non-organic natural resources.
6. Fossil ADP: Fossil energy depletion potential, evaluates the impact on fossil energy resource depletion.
7. FAETP inf.: Photo-oxidation formation potential of organic matter, assesses the photo-oxidation pollutant formation.
8. HTP inf.: Hydrocarbon formation potential measures the hydrocarbon formation.
9. MAETP inf.: Potential formation of strong acid compounds, assesses the formation of strong acid compounds.
10. POCP: Expanded photo-oxidant ozone formation potential, examines the photo-oxidant ozone formation at the ground level.
11. TETP inf.: Potential for the formation of oxygen compounds, measures the impact of the formation of oxygen compounds.

Following calculation of environmental impact data within each category, the ensuing step involves result interpretation (RI). This process culminates in drawing conclusions and offering recommendations based on the environmental impact analysis of each available alternative. These insights serve as valuable reference points for decision-makers when selecting the most sustainable tableware materials, ones that minimize environmental impact. The interpretation of findings from this LCA study empowers stakeholders, including the catering industry, to make more environmentally responsible decisions, aligning their practices with sustainability principles and responsible resource management (Wei et al., 2022).

Conclusions

Based on the results and discussions presented in the hypothesis testing chapter, several conclusions were drawn from this study. The study involved testing four hypotheses, and all four were valid. Furthermore, the conceptual model of the study identified four factors, named Goal and Scope Definition (GSD), Life Cycle Inventory (LCI), Impact Assessment (IA), and Result Interpretation (RI). These factors significantly and positively influenced the Life Cycle Assessment (LCA) of single-use cutlery set substitutes in the catering industry.

These results highlighted the importance of integrating Life Cycle Assessment into the business practices of the catering industry to replace single-use tableware or cutlery sets. By incorporating LCA concepts and implementing the four factors mentioned, catering businesses effectively reduced waste, minimized their environmental impact, and enhanced their overall Life Cycle Assessment performance. through the replacement of single-use cutlery sets in the catering industry.

These findings offered a robust basis for the catering industry to adopt and enhance the implementation of Life Cycle Assessment concepts. Further study was recommended to explore how these strategies influenced long-term Life Cycle Assessment and how are optimized for maximum impact.

Overall, this study underscored the significance of Life Cycle Assessment practices for addressing social, environmental, and economic aspects. By embracing LCA, the catering businesses contributed to sustainable development and improved their overall environmental performance, which aligned with their operations with principles of sustainability and responsible resource management.

Limitation

This study serves as an introductory examination of the substitution of single-use tableware, or cutlery sets through the application of Life Cycle Assessment principles, which was only carried out in the catering industry in Surabaya. Future study needs to be carried out with a wider range of respondents, such as in Indonesia or around the world.

Reference

Blanca-Alcubilla, G., Bala, A., de Castro, N., Colomé, R., & Fullana-i-Palmer, P. (2020). Is the reusable tableware the best option? Analysis of the aviation catering sector with a life cycle approach. *Science of the Total Environment*, *708*. https://doi.org/10.1016/j.scitotenv.2019.135121

Blanca-Alcubilla, G., Bala, A., Hermira, J. I., De-Castro, N., Chavarri, R., Perales, R., Barredo, I., & Fullana-I-palmer, P. (2018). Tackling international airline catering waste management: Life zero cabin waste project. state of the art and first steps. *Detritus*, *3*(September), 159–166. https://doi.org/10.31025/2611-4135/2018.13698

Blettler, M. C. M., Abrial, E., Khan, F. R., Sivri, N., & Espinola, L. A. (2018). Freshwater plastic pollution: Recognizing research biases and identifying knowledge gaps. *Water Research*, *143*, 416–424. https://doi.org/10.1016/j.watres.2018.06.015

Chae, Y., & An, Y. J. (2018). Current research trends on plastic pollution and ecological impacts on the soil ecosystem: A review. *Environmental Pollution*, *31*, 387–395. https://doi.org/10.1016/j.envpol.2018.05.008

Chen, Y., Awasthi, A. K., Wei, F., Tan, Q., & Li, J. (2021). Single-use plastics: Production, usage, disposal, and adverse impacts. In *Science of the Total Environmen*t, *752*. https://doi.org/10.1016/j.scitotenv.2020.141772

Chiellini, E., & Corti, A. (2016). *Oxo-biodegradable Plastics:* Who they are and to what they serve—present status and future perspectives. In M. A. AlMa'adeed & I. Krupa (Eds.), *Polyolefin compounds and materials* (1st ed., pp. 341–354). https://doi.org/10.1007/978-3-319-25982-6_14

Di, J., Reck, B. K., Miatto, A., & Graedel, T. E. (2021). United States plastics: Large flows, short lifetimes, and negligible recycling. *Resources, Conservation and Recycling*, *167*. https://doi.org/10.1016/j.resconrec.2021.105440

Dijkstra, T. K., & Henseler, J. (2015). Consistent partial least squares path modeling. *Management Information Systems Research Center, University of Minnesota*, *39*(2), 297–316.

Fieschi, M., & Pretato, U. (2018). Role of compostable tableware in food service and waste management. A life cycle assessment study. *Waste Management*, *73*, 14–25. https://doi.org/10.1016/j.wasman.2017.11.036

Garson, G. D. (2016). *Partial least squares: Regression and structural equation models.* Statistical Associates Publisher.

Ghozali, I., & Latan, H. (2015). *Partial least squares konsep, teknik dan aplikasi menggunakan program smartpls 3.0 untuk penelitian empiris.* Badan Penerbit Universitas Diponegoro.

Hair, J., & Alamer, A. (2022). Partial least squares structural equation modeling (PLS-SEM) in second language and education research_ Guidelines using an applied example. *Research Methods in Applied Linguistics*, *1*(3). https://doi.org/10.1016/j.rmal.2022.100027

Hair, J. F. J., Hult, G. T. M., Ringle, C., & Sarstedt, M. (2017). *A primer on partial least squares structural equation modeling (PLS-SEM).* Sage Publishing.

Hair, J. F., Sarstedt, M., Hopkins, L., & Kuppelwieser, V. G. (2014). Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research. *European Business Review*, *26*(2), 106–121. https://doi.org/10.1108/EBR-10-2013-0128

Hair Jr, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., Danks, N. P., & Ray, S. (2021). *Partial least squares structural equation modeling (PLS-SEM) using R: A workbook.* Springer Nature. https://library.oapen.org/handle/20.500.12657/51463

Iñiguez, M. E., Conesa, J. A., & Fullana, A. (2018). Recyclability of four types of plastics exposed to UV irradiation in a marine environment. *Waste Management*, *79*, 339–345. https://doi.org/10.1016/j.wasman.2018.08.006

Jandas, P. J., Prabakaran, K., Mohanty, S., & Nayak, S. K. (2019). Evaluation of biodegradability of disposable product prepared from poly (lactic acid) under accelerated conditions. *Polymer Degradation and Stability*, *164*, 46–54. https://doi.org/10.1016/j.polymdegradstab.2019.04.004

Kwon, B. G., Chung, S. Y., Park, S. S., & Saido, K. (2018). Qualitative assessment to determine internal and external factors influencing the origin of styrene oligomers pollution by polystyrene plastic in coastal marine environments. *Environmental Pollution*, *234*, 167–173. https://doi.org/10.1016/j.envpol.2017.11.046

Liu, K., Tan, Q., Yu, J., & Wang, M. (2023). A global perspective on e-waste recycling. *Circular Economy*, *2*(1), Article 100028. https://doi.org/10.1016/j.cec.2023.100028

Markowicz, F., & Szymańska-Pulikowska, A. (2019). Analysis of the possibility of environmental pollution by composted biodegradable and oxobiodegradable plastics. *Geosciences (Switzerland)*, *9*(11). https://doi.org/10.3390/geosciences9110460

Meijer, L. J., van Emmerik, T., van der Ent, R., Schmidt, C., & Lebreton, L. (2021). More than 1000 rivers account for 80% of global riverine plastic emissions into the ocean. *Science Advances*, *7*(18). https://doi.org/10.1126/sciadv.aaz5803

Monteiro, R. C. P., Ivar do Sul, J. A., & Costa, M. F. (2018). Plastic pollution in islands of the Atlantic Ocean. *Environmental Pollution*, *238*, 103–110. https://doi.org/10.1016/j.envpol.2018.01.096

Moshood, T. D., Nawanir, G., Mahmud, F., Mohamad, F., Ahmad, M. H., & AbdulGhani, A. (2022). Biodegradable plastic applications towards sustainability: A recent innovations in the green product.

Cleaner Engineering and Technology, *6*. https://doi.org/10.1016/j.clet.2022.100404

Moshood, T. D., Nawanir, G., Mahmud, F., Mohamad, F., Ahmad, M. H., AbdulGhani, A., & Kumar, S. (2022). Green product innovation: A means towards achieving global sustainable product within biodegradable plastic industry. *Journal of Cleaner Production*, *363*. https://doi.org/10.1016/j.jclepro.2022.132506

Organization for Economic Co-operation and Development. (2019). *The methodology to derive secondary plastic volumes is explained in the Annex to the OECD Global Plastics Outlook.* https://Stats.Oecd.Org/Viewhtml.Aspx?Datasetcode=PLASTIC_USE_V2_3&lang=en#.

Potocka, M., Bayer, R. C., & Potocki, M. (2019). Plastic pollution affects American lobsters, Homarus americanus. *Marine Pollution Bulletin*, *138*, 545–548. https://doi.org/10.1016/j.marpolbul.2018.12.017

Razza, F., Innocenti, F. D., Dobon, A., Aliaga, C., Sanchez, C., & Hortal, M. (2015). Environmental profile of a bio-based and biodegradable foamed packaging prototype in comparison with the current benchmark. *Journal of Cleaner Production*, *102*, 493–500. https://doi.org/10.1016/j.jclepro.2015.04.033

Sala S, Benini L, Beylot A, Castellani V, Cerutti A, Corrado S, Crenna E, Diaconu E, Sanyé-Mengual E, & Secchi. (2019). *Consumption and Consumer Footprint: methodology and results Indicators and assessment of the environmental impact of European consumption*. European Commission. https://doi.org/10.2760/98570

Sun, Q., Yi, A. L., & Ni, H. G. (2021). Evaluating scenarios for carbon reduction using different tableware in China. *Science of the Total Environment*, *791*. https://doi.org/10.1016/j.scitotenv.2021.148279

Tan, W., Cui, D., & Xi, B. (2021). Moving policy and regulation forward for single-use plastic alternatives. *Frontiers of Environmental Science and Engineering*, *15*(3). https://doi.org/10.1007/s11783-021-1423-5

Wei, F., Tan, Q., Dong, K., & Li, J. (2022). Revealing the feasibility and environmental benefits of replacing disposable plastic tableware in aviation catering: An AHP-LCA integrated study. *Resources, Conservation and Recycling*, *187*. https://doi.org/10.1016/j.resconrec.2022.106615

Zhao, Y. B., Lv, X. D., & Ni, H. G. (2018). Solvent-based separation and recycling of waste plastics: A review. *Chemosphere*, *209*, 707–720. https://doi.org/10.1016/j.chemosphere.2018.06.095