Factors affecting product life cycle in electronic enterprises – evidence from an emerging country

Factores que afectan el ciclo de vida del producto en las empresas electrónicas: evidencia de un país emergente

Fatores que afetam o ciclo de vida do produto em empresas eletrônicas – evidências de um país emergente

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Abstract

Introduction: This paper is the product of the study "Factors affecting product life cycle in electronic enterprises – Evidence from an emerging country" developed at the Electric Power University and National Economics University between 2020 and 2022.

Problem: The electronic manufacturing industry is increasingly developing in emerging markets and integrating into the global economy. The life cycle of electronic products is shorter and requires management.

Objective: The paper aims to study factors that affect the product life cycle in Vietnamese electronic enterprises. The study helps managers in cost management.

Methodology: The paper used a survey of non-probability sampling, and applied regression analysis to examine Vietnamese electronic enterprises. The analysis is done by SPSS and Smart PLS software.

Results: The research results indicate that technology, consumer trends, and R&D are factors affecting product life cycle and post-sale service, and disposal has no impact on electronic products' life cycle. This could be explained by the fact that electronic products are constantly updating and their life cycle is short, that post-sales service does not play a key role, and that waste treatment after sales is not taken seriously by manufacturers, customers, or other related parties.

Conclusion: The results give some meaningful insights for electronics or other enterprises in Vietnam to use effective management of product life cycle.

Originality: The results of this paper provide practical insights into the management of product life cycle and cost management of product life cycle for researchers and managers.

Limitations: The research model should be expanded and the sample size increased to get an overview and greater insight.

Keywords: Product life cycle, product life cycle costing, electronic enterprises.

Resumen

Introducción: Este artículo es producto del estudio "Factores que afectan el ciclo de vida del producto en empresas electrónicas – Evidencia de un país emergente" desarrollado en la Electric Power University y la National Economics University entre 2020 y 2022.

Problema: La industria de fabricación electrónica se está desarrollando cada vez más en los mercados emergentes y se está integrando a la economía global. El ciclo de vida de los productos electrónicos es más corto y requiere gestión.

Objetivo: El documento tiene como objetivo estudiar los factores que afectan el ciclo de vida del producto en las empresas electrónicas vietnamitas. El estudio ayuda a los gerentes en la gestión de costos.

Metodología: El documento utilizó una encuesta de muestreo no probabilístico y aplicó un análisis de regresión para examinar las empresas electrónicas vietnamitas. El análisis se realiza mediante el software SPSS y Smart PLS.

Resultados: Los resultados de la investigación indican que la tecnología, las tendencias de consumo y la I+D son factores que afectan el ciclo de vida del producto y el servicio postventa, y que el desecho no tiene impacto en el ciclo de vida de los productos electrónicos. Esto podría explicarse por el hecho de que los productos electrónicos se actualizan constantemente y su ciclo de vida es corto, que el servicio posventa no juega un papel clave y que el tratamiento de residuos posventa no es tomado en serio por los fabricantes, clientes u otras partes relacionadas.

Conclusión: Los resultados brindan algunas ideas significativas para la electrónica u otras empresas en Vietnam para utilizar una gestión eficaz del ciclo de vida del producto.

Originalidad: los resultados de este documento brindan información práctica sobre la gestión del ciclo de vida del producto y la gestión de costos del ciclo de vida del producto para investigadores y gerentes.

Limitaciones: el modelo de investigación debe ampliarse y aumentar el tamaño de la muestra para obtener una visión general y una mayor comprensión.

Palabras clave: Ciclo de vida del producto, costeo del ciclo de vida del producto, empresas electrónicas.

Resumo

Introdução: Este artigo é produto do estudo "Fatores que afetam o ciclo de vida do produto em empresas eletrônicas – Evidências de um país emergente" desenvolvido na Electric Power University e na National Economics University entre 2020 e 2022.

Problema: A indústria de manufatura eletrônica está se desenvolvendo cada vez mais em mercados emergentes e se integrando à economia global. O ciclo de vida dos produtos eletrônicos é mais curto e exige gerenciamento.

Objetivo: O artigo visa estudar os fatores que afetam o ciclo de vida do produto em empresas eletrônicas vietnamitas. O estudo auxilia os gestores na gestão de custos.

Metodologia: O artigo usou uma pesquisa de amostragem não probabilística e aplicou análise de regressão para examinar empresas eletrônicas vietnamitas. A análise é feita pelos softwares SPSS e Smart PLS.

Resultados: Os resultados da pesquisa indicam que tecnologia, tendências de consumo e P&D são fatores que afetam o ciclo de vida do produto e o serviço pós-venda, e o descarte não tem impacto no ciclo de vida dos produtos eletrônicos. Isso pode ser explicado pelo fato de que os produtos eletrônicos estão em constante atualização e seu ciclo de vida é curto, o serviço pós-venda não desempenha um papel fundamental e o tratamento de resíduos pós-venda não é levado a sério pelos fabricantes, clientes ou outras partes relacionadas.

Conclusão: Os resultados fornecem alguns insights significativos para empresas de eletrônicos ou outras empresas no Vietnã usarem o gerenciamento eficaz do ciclo de vida do produto.

Originalidade: Os resultados deste artigo fornecem insights práticos sobre o gerenciamento do ciclo de vida do produto e o gerenciamento de custos do ciclo de vida do produto para pesquisadores e gerentes.

Limitações: O modelo de pesquisa deve ser expandido e o tamanho da amostra aumentado para obter uma visão geral e maior percepção.

Palavras-chave: Ciclo de vida do produto, custeio do ciclo de vida do produto, empresas eletrônicas.

1. INTRODUCTION

1.1. Research background

According to the master plan for developing the Vietnamese industry in the vision of 2030, the electronic and information technology industry is estimated to account for 9 - 10% and 12 - 13% of the industry and will meet 65 - 70% and 75 - 80% of the market's demand in 2020 and 2030 respectively [20]. By the year 2030, many devices and technologies will have become digital in the electronic industry. The fiercely competitive market is created by global economic integration that leads to the specialty of

electronic products. This specialty is that electronic products contain high technology and constantly change along with technological advances and new trends; the life cycle of electronic products is becoming shorter and shorter [5]. To help Vietnamese electronic product manufacturers develop and operate at higher productivity, cost management, usage, and optimization become more important and necessary. A cost management tool should be based on the product life cycle that is appropriate for electronic product manufacturers in the current market. At the moment, there are numerous types of research on cost management via product life cycle in different fields such as the construction industry, electrical vehicles, and smartphones….[1, 9, 10, 11]. However, in Vietnam, there are also new topics, such as life cycle costing in brick manufacturers [24].

A significant feature of the competitive market, especially the electronic market, is the life cycle of products becoming shorter and shorter [2]. Hence, enterprises must constantly upgrade their old products and develop new ones. The factors analyzed provide knowledge and benefits of the product life cycle of the electronic industry. The impact of factors including technology, consumer trends, R&D departments, and post-sale service and disposal on the product life cycle is indicated. These enterprises want to save money as well as operate more effectively, so they need to pay more attention to the product life cycle.

1.2. Literature review

Product life cycle costing is emphasized as a method to estimate all the expenses occurring within the life cycle of a product. These costs are related to design, manufacture, use, and disposal. There are many different definitions for life cycle cost methods, but all research agrees that management life cycle costs require tracking the total expenses that occur over the entire lifecycle of a product; from its design until it is withdrawn from the market [2]. In other words, management of costs by product life cycle is also known as management of costs "from the cradle to the grave".

According to Atkinson et al. (2012), the product life cycle could be divided into 3 stages, and the occurring expenses in these three stages could be identified as follows [4]:

The 1st stage: Research, Development, and Engineering (RD&E):

In this RD&E stage, almost all the costs are anticipated *(a large commitment to costs)* [8]. This is because all the design decisions are made before manufacture that almost

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all the costs are anticipated [3]. According to a statistics result provided by Cooper and Slagmulder (2004), 80%-95% of the long-term costs of a product are identified in its designing stage. The survey was designed and developed to see whether allocating the budget according to the product life cycle in the designing stage is successful in controlling the cost over the whole life cycle of the system [14].

The 2nd stage: Manufacturing process:

Manufacturing is the process in which money is spent to buy materials/tools, hire employees/machines, and pay other indirect expenses related to product manufacturing and distribution. In this stage, it is not likely that the expenses could be cut down due to technological decisions since almost all the costs have already been decided in the RD&E stage.

The 3rd stage: Distribution, waste disposal, and post-sale services:

In this stage, companies have to allocate a budget for the distribution, waste disposal, and post-sale services [4]. All the previous research about a product's life cycle could be divided into three categories based on their approach methods: from the viewpoint of manufacturers, customers/users, or the society/environment. In this research, we focus on clarifying and defining the influence level of four factors including *technology, customer trend, R&D department, post-sale service*, *and disposal* on the life cycle of electronic products. These factors are defined by the three aforementioned approach methods. From the perspective of manufacturers, products in the current market are drastically affected by *technology* as well as input resources of the manufacturing process. There could be a change in the input materials at any time due to resource scarcity [27]. Besides, the fast-paced development of technology has a significant impact on the *trends among customers* and causes many difficulties as well as challenges for enterprises [32,36]. From the perspective of customers/users, the decision of buying is affected by the *initial acquisition cost, operation cost, and maintenance cost* during the retention period [16]. From the perspective of society or environment, the authors consider *social and environmental costs* such as disposal costs or externality costs (which can be referred to as the healthcare cost for people affected by the environmental contamination of the product). Recognition of costs and evaluation of total costs based on product life cycle will provide a framework for managers to manage those expenses effectively [6].

Many cost management tools can provide information to help managers make suitable decisions. Among that, product life cycle costing is a tool facilitating making decisions studied in technological or electrical companies [4,26]. The product life cycle helps to increase procurement effectiveness and encourages extending the planning horizon. Whole life costs include the producer's and consumer's costs. Consumer costs are becoming increasingly important [34, 37]. Besides, management of product life cycle costs provides more comprehensive and transparent total costs.

From the literature review, the management of the product life cycle is mentioned in the technical aspect. The factors that impact the product life cycle are not clear. In each industry, the product life cycle is different and the gap of this study is from the impact factors and industry. According to the literature review and background, the paper has two main objectives: (1) To identify factors affecting the product life cycle in Vietnamese electronic enterprises; (2) To analyze and evaluate factors that influence the product life cycle in Vietnamese electronic enterprises. These objectives help managers in cost management.

The paper is organized as follows: Section 2 identifies hypotheses on the factors affecting the product life cycle. Section 3 presents the research method. Section 4 analyses and discusses the results and the last section gives the conclusion of the study.

2. MATERIALS AND METHODS

2.1. Hypotheses

Technology

The Technology factor is a group of crucial factors to boost enterprises that develop new products. Cao et al.'s research (2009) and Laurindo & Carvalho's research (2005) show that applying new technology in product manufacture can help to reduce production costs and lengthen the product life cycle [10,28]. Applying new product development methods requires enterprises to invest more financial resources including well-qualified workers, machines, and new technology [10,28]. This strategy, however, only benefits enterprises in the long term [28, 31]. Nantes and Lucente (2009) conclude that to meet customers' requirements, the product development process – PDP must be supported by technological advances to make the product different from others available within the market [32]. It also creates advantages for the enterprise while developing products. Moreover, a highly distinctive product combines with innovation

in producing processes that are more likely to be successful [32]. The above discussions lead to the following hypothesis:

H_1: Technology positively influences product life cycle.

Consumer trend

Developing a stable product requires taking all related parties' opinions (including customers' opinions) into consideration. These opinions are valuable because these related parties are engaged in every stage of the product life cycle. Therefore, a comprehensive vision is required to satisfy customers' demands. It reflects marketing on a foundation for the success of a product based on customers' desires [33]. In the current competitive economy, the market constantly changes, customers' demands are also diversified, and enterprises need to change old products to better satisfy customers, or produce new products to catch up with modern trends [36]. Moreover, the time when enterprises face product saturation or recession is an important occasion for them to innovate their product to adapt to the market demands, which also means that the life cycle of old products comes to an end, and the life cycle of a new product starts. Therefore, the trend among customers is also an indispensable factor affecting the product life cycle. Hanna et al (1995) showed that the customer is usually regarded as an inspiration for the development of new products for enterprises [22]. Thoroughly understanding demands and trends among customers is considered an important factor to develop new products successfully [29]. Therefore, the following hypothesis is developed:

H_2: Consumer trend positively impacts product life cycle.

Research and development

Research and development directly affect the product life cycle. According to Debardelaben et al's research (1997), 80% - 85% expense of product life cycle costs is decided in the Research, Development, and Engineering (RD&E) stage [15]. In this RD&E stage, almost all the costs are anticipated [8], as all the design decisions are made before manufacturing the product [3]. A statistical result given by Cooper and Slagmulder (2004) indicates that 80% - 95% long-term cost of a product is identified in its designing stage [14]. The survey was carried out to detect whether using the product life cycle costing method in the designing stage will help to successfully control the cost in the whole system life cycle [14]. Therefore, we find results to confirm the following hypothesis:

H_3: R&D positively influences product life cycle.

Post sale service and disposal

Effective post-sale service also helps enterprises keep their customers. Many enterprises collaborate to provide their customers with perfect and comprehensive services since they understand that these service packages will bring competitive advantages to their company, and help them to keep loyal customers [35]. As the global market becomes ever-competitive, the market demand increases, and remarkable innovations in technology force enterprises to carefully consider marketing strategies including solutions for product distribution as well as post-sale service provision. Administrators and marketing channel analysts all agree that functions supporting product distribution and post-sale service deserve more attention because they are indispensable stages while packing and catering products for customers [30].

At the end of the product life cycle, if the waste of the product is well handled, there are numerous positive effects on the environment and society. The core mentality of the product lifecycle is reducing burdens caused by the enterprise's business operation to the environment. Effects of the product life cycle are shown through the circular economy [17]. The circular economy includes different stages which hold strong bonds to each other. In this circular economy, the longer the value of products and materials is maintained, the better the situation becomes. Resources are used effectively and waste is reduced. Simultaneously, resources will circulate within the economy until the product lifecycle comes to an end. They will also be reused to create more value. The principle of circular economy is "3R – reduce, reuse, recycle", which means to reduce, reuse, recycle material and energy to turn them into secondary materials [41]. The purpose of this process is to maximize the value related to production and materials that are used in the circular economy [38]. The above discussions lead to the following hypothesis:

H_4: Post-sale service and disposal positively influence product life cycle.

2.2. Research methodology

Learning from previous analysis, the research model is proposed in Figure 1. The conceptual framework has been adopted mainly from the stakeholder theory [18] and resource-based view theory [7]. The stakeholder theory explains the interests of customers affected by the product life cycle and the management of the product life cycle. Customer trends and post-sale service and disposal related to customers and the public are important stakeholders and influences on the product life cycle.

The resource-based view theory is the common theory that relates management tools of companies [25]. Enterprises' resources include all assets, capabilities,

organizational processes, firm attributes, information, knowledge, etc. controlled and used to gain their goals. In this research, technology, and R&D are technical resources that impact on product life cycle and the organization's performance

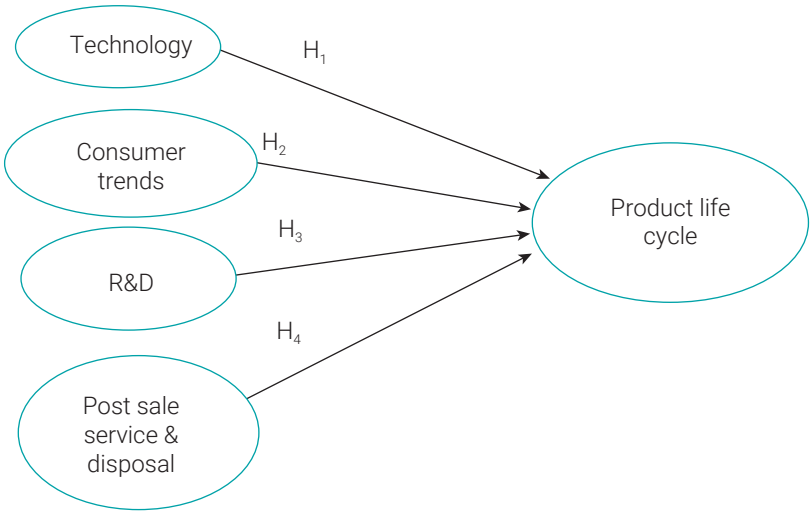

Figure 1. The proposed research model
Source: own work

Independent variables

(1) Technology: Technology (T) is an indispensable factor directly affecting the product life cycle. Three aspects are used to evaluate technology, namely: the complication of manufacturing technology (T1), the budget for technology investment to manufacture products (T2), and hiring well-qualified workers (T3). All Technology scales are measured through the Likert scale from 1 to 5.

(2) Consumer trends: Consumer trends (CT) can also create new trends that may lead to the appearance of brand-new products in the market. Consumer trends are measured by their items, namely: diversified consumer tastes (CT1), a thorough understanding of customers' tastes (CT2), and considering customers as the inspiration for developing new products (CT3). All scales of Consumer trends are measured through the Likert scale from 1 to 5.

(3) R&D: Another principal component of the product life cycle is R&D (RD): Investment cost for R&D (RD1), well-qualified and skilled staff for R&D (RD2), and R&D that thoroughly understands product life cycle (RD3). All scales of R&D are measured through the Likert scale from 1 to 5.

(4) Post-sale service and disposal: Post-sale service and disposal factors include several indicators: Green products make the product life cycle last longer (PS1), reusing, reproducing, and recycling products can minimize their side effects on the environment (PS2), and good management of post-sale service could also be relevant for product distribution (PS3). All scales of Post-sale service and disposal are measured through the Likert scale from 1 to 5.

Dependent variables

Product life cycle (PLC): This factor is measured by the following indicators: sales revenue, sales volume, and time for the growth stage [19, 40]. The scales measure the existence of products in three stages [4].

Sample sizes

There are numerous methods for identifying the optimal sample size. According to Tho's research (2013), the optimal sample size in multiple linear regression (MLR) can be defined by the formula: "$n \geq 50 + 8p$". In this formula, n is the optimal necessary sample size, and p is the number of dependent variables in the model [38]. According to Hair et al's research (2017), the sample size may be under 100 [21]. The optimal sample size must be ten times the number of paths in the researched model [21].

We sent the research survey via Email/Zalo/Facebook and some other channels which can conveniently attach the link to the research survey created by Google Forms. This survey was carried out from March 2021 to August 2021. In this survey, 167 forms were filled out. A non-probability sampling method, which is convenient sampling, was used for this survey.

We filtered the collected data and got 134 qualified responding data used for analysis using SPSS, the Smart-PLS software. 134 responses are more than the optimal number of samples required in the aforementioned research. However, to make this research more reliable, the number of samples should be much more than the optimal number of samples required.

3. RESULTS

SPSS and SmartPLS tools were used to analyze the data. SPSS was applied to clear data and run basic statistics. SmartPLS was applied to evaluate the effects of different elements in the research model. This tool is regularly used to assess complex

linear structure models with a high level of accuracy. Furthermore, data does not need to meet the normally distributed standard.

Descriptive statistics

Almost all the companies participating in this research are small and medium-sized enterprises (SMEs). Table 1 indicates that the largest proportion of enterprises accounted for within the sample are associated companies, the remainder are joint-stock companies, private enterprises, limited liability companies, and state-owned enterprises.

Table 1. Classification of companies by type of businesses

Time	Amount	%
Joint stock company, limited liability company	39	29%
Associated company	61	46%
Private enterprises	28	21%
State owned enterprises	6	4%
Total	**134**	**100%**

Source: own work

Table 2 shows that enterprises manufacturing communication equipment account for the largest proportion of the electronics manufacturing industry in Vietnam.

Table 2. Classification of companies in electronic industry

Products	Amount	%
Electronic component	33	25%
Computer & computer peripheral device	19	14%
Communications Equipment	59	44%
Consumer electronic	15	11%
Other electronic products	8	6%
Total	**134**	**100%**

Source: own work

Regression analysis

We cleaned the collected data and got 134 qualified responding data which can be used for analysis using SPSS software and SmartPLS. Table 3 shows the factors' indicators and KMO's test.

Table 3. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.802
Bartlett's Test of Sphericity	Approx. Chi-Square	744.677
	df	66
	Sig.	0.000

Source: own work

All factors' indicators were included during the EFA analysis. Qualified indicators for PLS-SEM analysis included Technology (T), Consumer trend (CT), and R&D department and operation (RD) for independent variables.

Table 4. Rotated Component Matrix

	1	2	3	4
CT1	0.880			
CT2	0.831			
CT3	0.829			
T2		0.844		
T1		0.837		
T3		0.780		
RD2			0.858	
RD1			0.798	
RD3			0.750	
PS2				0.838
PS3				0.772
PS1				0.656

Source: own work

Pearson's correlation measures the relationship between dependent and independent variables. Table 5 shows the result of the correlation of the variables of the research model. Post-sale service and disposal (PS) are excluded according to the analysis indicators of Pearson's correlation.

Table 5. Pearson Correlations

		F_T	F_RD	F_CT	F_PS	F_PLC
F_T	Pearson Correlation	1	.400**	.605**	.097	.571**
	Sig. (2-tailed)		.000	.000	.263	.000
	N	134	134	134	134	134
F_RD	Pearson Correlation	.400**	1	.464**	.136	.549**
	Sig. (2-tailed)	.000		.000	.118	.000
	N	134	134	134	134	134
F_CT	Pearson Correlation	.605**	.464**	1	.103	.594**
	Sig. (2-tailed)	.000	.000		.236	.000
	N	134	134	134	134	134
F_PS	Pearson Correlation	.097	.136	.103	1	.027
	Sig. (2-tailed)	.263	.118	.236		.760
	N	134	134	134	134	134
F_PLC	Pearson Correlation	.571**	.549**	.594**	.027	1
	Sig. (2-tailed)	.000	.000	.000	.760	.000
	N	134	134	134	134	134

Source: own work

The post-sale service and disposal (PS) have a significance that is higher than 0.05 (0.76) in Table 5. This result indicates that there is no correlation between Post-sale service and disposal (PS) and Product life cycle (PLC). In Table 7, the Outer loading indicators of Post-sale service are excluded.

Evaluate the validity and reliability of variables.

The result, after running PLS Algorithm for the first time, shows that on the scale of reliability, the variation of Average Variance Extracted (AVE) of the post-sale service and disposal (PS) variable could not reach the standard as AVE = 0.307<0.5; the Cronbach's Alpha indicator = 0.638 < 0.75. The P-value of the correlation between Post-sale service and disposal (PS) and Product life cycle (PLC) does not meet the standard (p=0.949). Using the results of Table 5 and running the PLS Algorithm and the first time Bootstrapping, the Post-sale service and disposal (PS) were excluded in the running PLS Algorithm and the second time Bootstrapping. The independent variables are Technology, Consumer trend, and R&D. The Construct Reliability and Validity of the three variables are confirmed with AVEs > 0.5 and Cronbach's Alpha > 0.75. The outer loadings of three variables are presented in Table 6.

Table 6. Constructs and indicators of the model

Constructs and indicators	Cronbach's Alpha	Loading PLS-SEM	Mean	Std.
Technology (T) *Cronbach's Alpha = 0.847*				
Complex manufacturing technology results in products with a longer life cycle (T1)	0.763	0.902	3.87	1.107
High technology investment costs create products with a longer life cycle (T2)	0.750	0.894	4.04	0.969
Using more skilled workers produces products with a longer life cycle (T3)	0.847	0.835	3.99	1.121
Consumer trend (CT) *Cronbach's Alpha = 0.906*				
The higher the customer's tastes, the longer the product life cycle (CT1)	0.850	0.920	4.06	1.046
Understanding the needs of customers, the product life cycle will be longer (CT2)	0.856	0.923	4.20	0.964
Customers are the source of ideas for new product development (CT3)	0.888	0.909	4.28	1.007
Research and development (RD) *Cronbach's Alpha = 0.784*				
High investment costs for research, and development, enabling the R&D department to promote efficiency (RD1)	0.709	0.835	3.69	0.871
With qualified and skilled staff, the R&D department operates effectively (RD2)	0.686	0.821	3.89	0.847
R&D department knowledgeable about product life cycle (RD3)	0.729	0.852	3.79	0.974
Post sale service and disposal (PS) *Cronbach's Alpha = 0.642*				
Producing "green" products make the product life cycle longer (PS1)	0.649	N/A after running EFA	3.57	0.699
Products designed to be reused or recycled can reduce the product's life cycle impact on the environment (PS2)	0.384		3.86	0.824
Good management of "post or after-sale service" is useful for the distribution stage of the product life cycle (PS3)	0.555		4.20	0.754
Product life cycle (PLC) *Cronbach's Alpha = 0.785*				
The higher the product sales, the longer the product life cycle (PLC1)	0.742	0.817	4.56	0.699
The higher the number of sales, the longer the product life cycle (PLC2)	0.668	0.857	4.44	0.863
The longer the growth stage, the longer the product life cycle (PLC3)	0.708	0.854	4.19	1.020

Source: own work

After eliminating the variable of Post-sale service and disposal (PS), we started running PLS Algorithm for the second time, and this time the result shows that all the scales in the research are reliable, which could be indicated by the fact that the Cronbach's Alpha indicator is between $0.75< \alpha < 0.95$, and the composite reliability (CR) is between $0.85 < CR < 0.95$. In the reflective measurement model, the reliability

and validity of the construct are assessed according to the processing procedure. The main statistical criteria are included in Table 7.

Table 7. Construct Reliability and Validity after running PLS Algorithm for the 2nd time

	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Technology	0.850	0.909	0.770
Consumer trend	0.906	0.941	0.710
R&D	0.787	0.874	0.699
Product life cycle	0.796	0.880	0.710

Source: own work

The Outer Loadings of all the indicators are all > 0.7, which means all the observing variables converge into all the notions of the scale. Besides, the research result also shows that all the AVE indicators - Average Variance Extracted > 0.5, so the authors can make the conclusion that all the scales reach the required convergence level.

Distinguishment evaluation

The discriminant price was assessed using the Fornell-Larcker criteria and the HTMT coefficient. The below results show that all scales have discriminatory values, with both HTMT indexes less than 1, the highest value being 0.937. We concluded that although the scales are correlated, they are still distinct from each other, and there is no middle-concept phenomenon. Tables 8 and 9 show that all diagonal values (square root of AVEs) are higher than other values in the corresponding columns (cross-loadings), therefore, the discriminant validity is verified.

Table 8. Discriminant Validity

	Consumer trend	Product life cycle	R&D	Technology
Consumer trend	0.918			
Product life cycle	0.575	0.843		
R&D	0.466	0.590	0.836	
Technology	0.581	0.586	0.411	0.878

Source: own work

Table 9. Heterotrait-Monotrait Ratio (HTMT)

	Consumer trend	Product life cycle	R&D	Technology
Consumer trend				
Product life cycle	0.675			
R&D	0.541	0.733		
Technology	0.661	0.709	0.494	

Source: own work

Evaluation of multicollinearity problem within the model

To evaluate the multicollinearity phenomenon, the VIF indicator < 3 is considered an ideal situation since at this point, the multicollinearity phenomenon never happen. However, the VIF indicator <5 is also acceptable, but when this indicator >=5, the multicollinearity phenomenon is much more likely to happen. Table 10 shows that the multicollinearity phenomenon almost never happens, and the VIF indicator of Consumer trends regarding the product life cycle is acceptable because it is still under 5.

Table 10. Inner VIF Values

	Consumer trend	Product life cycle	R&D	Technology
Consumer trend		1.666		
Product life cycle				
R&D		1.328		
Technology		1.570		

Source: own work

The direct impact level of different factors

Evaluate R^2 (Coefficient of Determination)

According to Cohen et al. (2003) and Cohen (1988), the model is good when the R^2 value is greater than 0.26 for endogenous latent variables [12,13]. The results show that Technology, Consumer trends, and R&D explain 52.3% of the Product life cycle in electronic product manufacturing companies [12,13].

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Path Coefficient (f^2) evaluation

According to Hair et al. (2017), path coefficient (f^2) with a value of $0.02 \leq f^2 < 0.15$ is a small effect; $0.15 < f^2 \leq 0.35$ is the medium effect [21]. According to Table 11, R&D and Technology have a small impact on the Product life cycle (0.054 and 0.091, respectively), while, Consumer trend has a larger impact (0.137).

Table 11. f Square

	Consumer trend	Product life cycle	R&D	Technology
Consumer trend		0.137		
Product life cycle				
R&D department		0.054		
Technology		0.091		

Source: own work

Figure 2 summarizes path coefficients in the structure model with three independent variables.

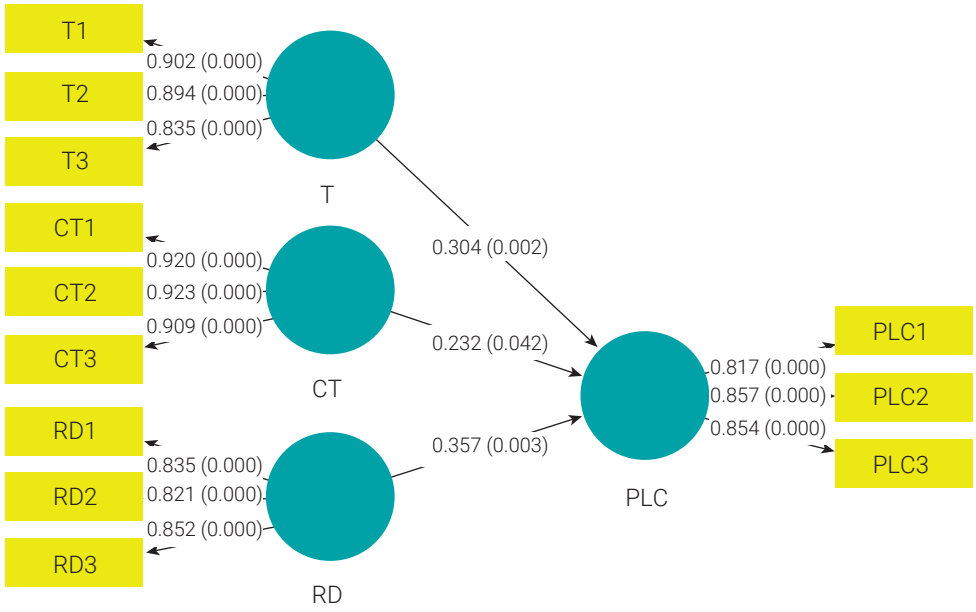

Figure 2. Path coefficients in the structure model
Source: own work

Running the bootstrapping procedure gave detailed results of the structural model [21].

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Table 12a. Results and hypotheses testing done by SmartPLS software

	Original Sample (O)	T Statistics (|O/STDEV|)	P Values
H_1: Technology positively influences product life cycle	0.304	3.071	0.002
H_2: Consumer trend positively impacts product life cycle	0.232	2.035	0.042
H_3: R&D positively influences product life cycle	0.357	3.013	0.003

Source: own work

Table 12b. Results and hypotheses testing by SPSS software

	β	t-Value	P Values	Results
H_1: Technology positively influences product life cycle	0.278	3.503	0.001	Confirmed
H_2: Consumer trend positively impacts product life cycle	0.314	4.376	0.000	Confirmed
H_3: R&D positively influences product life cycle	0.288	3.507	0.001	Confirmed
H_4: Post sale service and disposal positively influences product life cycle	-0.073	-1.155	0.250	Not confirmed

Source: own work

The results in Table 12a, and Table 12b show that hypotheses H_1, H_2, and H_3 are accepted, while hypothesis H4 is rejected because the indicators of EFA and Pearson's correlation do not meet the standards. Technology, Consumer trend, and R&D have a positive effect on the Product life cycle. This finding is similar to the results of Nantes & Lucente (2009), Hanna et al. (1995), and Cooper & Slagmulders (2004) [14, 22, 32]. Those are several related studies.

Hypothesis H_4: Post-sale service and disposal positively influence product life cycle is not confirmed. This indicates no interest in Post-sale service and disposal of products in electronic enterprises in Vietnam. Paolo Gaiardelli & Sergio Cavalieri (2008) indicated that the Post sale service affects the whole product life cycle. Post or after-sale service is a positive impact on product development [42]. There is no confirmation of hypothesis H4, which proposes that enterprises should examine their manager's and staff's awareness of recycling, reusing, and green production.

4. DISCUSSION AND CONCLUSIONS

The electronic manufacturing industry is a growing industry in Vietnam. Electronic products and their life cycles have also become popular study areas. In this study, we generalize the theoretical contents related to the product life cycle and the factors affecting the product life cycle gathered from published research, namely, Technology, consumer trends, R&D, post-sale service and disposal. Through hypothesis testing using SPSS and Smart PLS software, the research results show that the factors affecting product lifecycle are technology, consumer trends, and R&D.

The R&D department and operation are very important and have the highest weight in the research model (Table 12a). It is relevant to the weight of the cost of the whole product life cycle [4]. Electronic enterprises should spend time and money significantly in the R&D department and operation. It helps to effectively manage the product life cycle and develop products. The technology is an apparent aspect of the 4.0 technology era. R&D development needs modern and relevant technology. Technology of electronic enterprises relates to as enterprises' strategy. Electronic enterprises should innovate the technology of manufacturing. Customer trends have a relationship with the product life cycle that indicates the significant impact from the customer aspect. Manufacturing arises from customer needs and services them. Therefore, managers' minds and designers' ideas should be infused with an understanding of customers.

Post-sale service does not play a key role, and the waste treatment after sales is not taken seriously by manufacturers, customers, or other related parties. However, post-sale service and disposal are identified as important elements of product life cycle [41]. It is changing positively and strategically in managers' awareness and the government of state agency of waste treatment after the distributions. Waste treatment after distribution of electronic products should consider sustainability due to their harmful effects on the environment. The results give some meaningful insights for Vietnamese electronics or other enterprises in Vietnam to use effective management of the product life cycles. It also provides practical insight into the management of product life cycles for researchers and managers.

For future research, some suggestions are raised from the limitations of this paper: The medium number of samples, the research methodology, re-confirmation of Hypothesis 4, and control variables. The scope of this paper is in Vietnamese SMEs, larger electronic enterprises in Vietnam will be added to the population and the sample size will be expanded. This helps researchers that have a larger sample to confirm more hypotheses. The R^2 of the model is 52% which proves the medium fit of the research model. More samples may push the R^2 higher. The case study is relevant

towards collecting qualitative data on the product life cycle. In the research model, control variables should be added and studied: the enterprises' size (sales, number of employees), operation year, sex of top management, age of top management, and regulations. We can develop the research model with control variables and evaluate their impact of them on the product life cycle. The operation performance can add to examining the relationship between the product life cycle and the operation performance. In this paper, the post-sale service does not give a significant impact on the product life cycle. It means that more samples or added scales are needed to re-confirm Hypothesis 4.

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