

The Dual Approach in the Sunscreen Market: Consumer Behavior Analysis Using PLS-SEM and Product Improvement Using Taguchi Based on the Six Sigma Model

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Abstract—This research investigates the demand for sunscreen products in Ho Chi Minh City, focusing on the factors influencing consumer purchase intentions and the quality improvement of these products. Using Partial Least Squares Structural Equation Modeling (PLS-SEM) and Lean-Six Sigma methodologies, the study explores various aspects such as brand reputation, perceived product quality, and effectiveness of sun protection. The research aims to identify key drivers of consumer behavior and their impact on sunscreen sales, while proposing improvements in product formulations to meet consumer expectations. A survey was conducted with over 500 participants, revealing the importance of perceived usefulness, ease of use, and brand recognition in influencing purchase decisions. Additionally, the study employs the Taguchi method for optimization, improving the sunscreen product by addressing skin irritation issues caused by certain ingredients. The findings suggest that optimizing the concentration of sunscreen components like oxybenzone and octinoxate can significantly enhance product effectiveness while reducing adverse skin reactions. This research contributes valuable insights for businesses in the cosmetics industry, helping to develop high-quality sunscreen products that better meet consumer needs and promote higher sales performance.

Keywords— Sunscreen, PLS-SEM, Taguchi, Lean-Six sigma.

INTRODUCTION

Ho Chi Minh City, located in a tropical climate zone, experiences prolonged hot and humid weather throughout the year. The city's residents are frequently exposed to extreme weather conditions, with temperatures often fluctuating between 35°C and 37°C. The UV index, particularly from 14:00 to 16:00, ranges between 8.7 and 9.6, which can be detrimental to the skin when exposed to direct sunlight. The hottest period occurs from 12:00 to 13:00, when individuals are most at risk from sun exposure. To mitigate the harmful effects of ultraviolet (UV) rays, it is essential for individuals to apply sunscreen, wear protective clothing such as jackets, masks, and gloves.

In this context, sunscreen usage has become an essential measure to protect the skin from UV radiation and prevent skin damage. However, the sunscreen market in Vietnam faces several challenges, including limited consumer awareness, intense competition among brands, and inconsistencies in the effectiveness of sunscreen products across various e-commerce platforms. This study aims to examine the factors influencing consumer purchase intentions and the use of sunscreen while exploring strategies to optimize marketing, improve product quality, and better serve consumer needs in such harsh environmental conditions.

At present, sunscreen is a commonly used product, widely produced and sold on major e-commerce platforms like Shopee, Lazada, and Tiki, with over 2,190 brands available. Among these, La Roche-Posay stands out as the brand with the highest revenue and sales volume. According to recent reports, Shopee leads the market with 75.9% of the sunscreen market share, generating 863.4 billion VND in revenue, followed by Lazada with 20.6% and Tiki with 3.5%. Despite the large revenue figures, the growth and stability of the sunscreen market remain uneven across different product

lines and platforms. This reflects a shift in consumer behavior, with an increasing awareness of the importance of sun protection, yet consumers still struggle to find high-quality sunscreen products that meet their needs.

Table 1. Market Share of E-Commerce Platforms for Sunscreen Products in Vietnam

E-Commerce Platform	Revenue (VND)	Quantity Sold (Units)
Shopee	863.4 billion	4,073,641 units
Lazada	234.9 billion	855,064 units
Tiki	40.0 billion	78,065 units

In table 1 Shopee dominates the market with 75.9% of the total revenue, amounting to 863.4 billion VND, and has sold over 4 million units of sunscreen products. Lazada holds the second-largest market share, accounting for 20.6% of revenue (234.9 billion VND), with over 855,000 units sold. Tiki represents a smaller portion of the market, with only 3.5% of the revenue (40.0 billion VND) and 78,065 units sold. This data highlights the unequal distribution of market share among these platforms, showing a dominance by Shopee in both revenue and sales volume, despite the high demand for sunscreen products during the peak hot season. The variance in sales can be attributed to promotional activities, pricing differences, and platform-specific consumer behavior patterns.

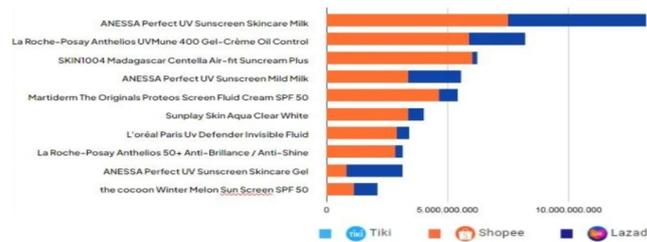


Figure 1. Top 10 best-selling products sales in July 2023

Sales data from July 2023 indicates significant fluctuations in the performance of sunscreen products across e-commerce platforms. For example, the Anessa Perfect UV Sunscreen Skincare Gel saw a 114% increase in sales, while La Roche-Posay Anthelios 50+ Anti-Brilliance experienced a 74% decrease in the same period. Despite a 43% decline in sales, Anessa Perfect UV Sunscreen Skincare Milk remains the best-selling product, outperforming others by a large margin. Additionally, Shopee’s promotional campaigns (e.g., the 7/7 Sale) contributed to a lower price for sunscreen products compared to Lazada, which significantly boosted demand. As a result, Shopee’s sunscreen revenue was double that of Lazada (38.59 billion VND vs. 15.86 billion VND). These results illustrate the market’s volatility and the impact of promotional activities on consumer behavior.

Furthermore, previous research by Diffey (2018) indicates that the primary factor leading to consumer dissatisfaction is the harmful effects of UV radiation, which alters product formulations, causing adverse reactions such as skin irritation. Despite this, research gaps remain in the area of product improvement. There is limited research that combines consumer behavior with product formulation optimization using scientific methods like PLS-SEM and Taguchi. Additionally, there is a lack of in-depth analysis of the effects of individual active ingredients in sunscreens and their interaction with environmental factors such as sweat, water, and high temperatures. Moreover, there is no study focused on optimizing sunscreen formulations to reduce skin irritation while ensuring high levels of protection. Research by Baker et al. (2017) provides insights into natural UV protection mechanisms but leaves gaps in understanding the long-term effects of synthetic ingredients on both the environment and human health, especially when in prolonged contact with skin.

To address these issues, this study focuses on analyzing the factors that influence the purchase and usage intentions of sunscreen in Ho Chi Minh City, where high UV levels are a year-round concern. By applying consumer behavior models such as the Theory of Reasoned Action (TRA) and the Theory of Planned Behavior (TPB), alongside Lean Six Sigma methodologies, this research aims to provide clarity on the key drivers of sunscreen purchases and offer practical solutions for businesses to enhance product quality and improve business strategies.

Research objectives To identify and assess factors such as brand awareness, perceived usefulness, ease of use, and product quality in relation to consumers' purchase intentions using PLS-SEM. Based on this, propose actionable solutions to improve business performance and customer experience. The study focuses on evaluating the sunscreen purchase intentions of consumers in Ho Chi Minh City, specifically in the context of its hot climate, while identifying behavioral, perceptual, and value-based factors that influence purchase decisions and subsequently improving business effectiveness. The research model can be applied to the sunscreen industry or related sectors, aiming to enhance product quality and business performance.

The structure of the research is as follows: Section 2 discusses Raw Material and Methodology, Section 3 presents the Results, Section 4 covers the Discussion, and Section 5 concludes.

THEORETICAL AND METHODOLOGY

Theoretical and those development

Hypothesis: Perceived Usefulness (PU) Perceived usefulness of sunscreen products refers to an individual's perception and subjective evaluation of the product's effectiveness in providing sun protection and meeting their specific needs. It includes their beliefs and understanding of how well the sunscreen serves its intended purpose and delivers the desired outcomes. This perception considers factors such as the product's ability to protect against harmful ultraviolet (UV) radiation, prevent sunburn and skin damage, and meet user expectations for comfort, ease of use, and compatibility with their skin type. It is a subjective assessment that integrates an individual's knowledge, experience, and personal preferences to determine the overall perception of the sunscreen's usefulness.

Hypothesis: Perceived Ease of Use (PUE) Perceived ease of use of a sunscreen product relates to an individual's subjective evaluation of how easy and convenient it is to use the product. It reflects their beliefs and understanding of the product's user-friendliness and the level of effort required to apply and incorporate it into their skincare routine.

Hypothesis: Expectation (EXP) Expectation of a sunscreen product includes the desired outcomes and benefits that individuals associate with its use. It reflects their anticipated results and the specific advantages they hope to gain from using sunscreen. Expectations are subjective and may vary among individuals based on their needs, preferences, and prior experiences.

Hypothesis: Confirmation (CONF) The confirmation hypothesis refers to whether customers affirm that they have used a sunscreen product. This confirmation may include factors such as usage frequency, purchase frequency, and habitual use of sunscreen products.

Hypothesis: Satisfaction (SAT) Satisfaction with a sunscreen product refers to the overall sense of fulfillment and contentment that individuals experience after using the product. It reflects the extent to which the sunscreen meets or exceeds their expectations, fulfills their specific needs, and delivers the desired benefits and user experience. In other words, satisfaction is a measure of how well the sunscreen aligns with their requirements and provides positive results.

Hypothesis: Attitude (ATT) Attitude toward sunscreen products encompasses an individual's comprehensive evaluation, perception, and inclination toward the product. It reflects their opinions, beliefs, and emotional responses, all of which can shape their behavior and choices regarding sunscreen use. Essentially, attitude toward sunscreen products captures an individual's general

perspective and outlook, playing a crucial role in determining their actions and decisions related to the product.

Hypothesis: Subjective Norms (SN) Subjective norms, in relation to sunscreen products, refer to the social pressure or influence that individuals perceive from others regarding their decision to use the product. It reflects their perception of other people's expectations and opinions concerning sunscreen usage.

Hypothesis: Perceived Control (PC) Perceived control reflects the extent to which consumers feel capable of making informed and rational decisions when choosing to purchase a sunscreen product. This is a crucial factor influencing purchasing behavior, particularly in a market where consumers are presented with an increasing number of choices and must carefully evaluate different brands and products.

Hypothesis: Brand (BR) The brand of a sunscreen product can have a significant impact on consumer perceptions, behavior, and overall market success. Branding serves as a key factor in shaping how consumers perceive and interact with the product.

Hypothesis: Perceived Quality (PQ) Perceived quality of a sunscreen product refers to the subjective evaluation or judgment that consumers make regarding the product's excellence, effectiveness, and overall value. It represents how consumers perceive the sunscreen's ability to fulfill its intended purpose of protecting the skin from harmful UV rays while delivering other desired benefits.

Hypothesis: Purchase Intention (PI) Purchase intention regarding sunscreen products relates to consumers' intention or inclination to buy the product in the near future. It signifies their plan to translate their preference or desire for sunscreen into an actual transaction. Based on these theoretical foundations, the research proposes 11 hypotheses, and the research model is shown in Figure 2.

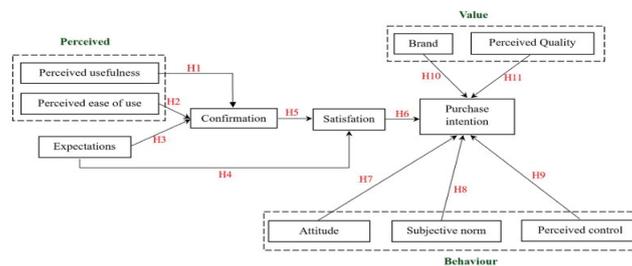


Figure 2. Research Model

Table 2. Scale table for the variable “Perceived usefulness”

Research Factor	Symbol	Observed Variables
Perceived Usefulness	PU	PU1: Protects the skin from sun radiation.
		PU2: Reduces sunburn when exposed to sunlight for long periods.
		PU3: Moisturizes and prevents aging.
Perceived Ease of Use	PE	PE1: Application doesn't take much time.
		PE2: Compact and convenient to carry.
		PE3: Long-lasting reapplication time.
Expectation	EXP	EXP1: Provides good protection against UV rays and long-lasting sun protection.
		EXP2: Non-irritating, gentle on the skin.
		EXP3: Quality from a well-known brand.
Confirmation	CONF	CONF1: Regularly repurchase the product.
		CONF2: Willing to pay monthly.
		CONF3: Tends to buy together with others.
Satisfaction	SAT	SAT1: Price is in proportion to quality.
		SAT2: Easy to buy on e-commerce platforms.
		SAT3: Satisfied with the well-known brand.
Attitude	ATT	ATT1: Interested in sunscreen products.
		ATT2: Using sunscreen is necessary.
		ATT3: Very beneficial for the face.
Subjective Norms	SN	SN1: Friends recommend buying the product.
		SN2: Friends expect regular use.
		SN3: Encourages regular use of whitening products.
Perceived Control	PC	PC1: Carefully consider before buying.
		PC2: Research and buy products suitable for the skin.
		PC3: The decision to buy sunscreen is the right one.
Brand	BR	BR1: Choose products from well-known brands.
		BR2: Trust the quality of well-known brands.
		BR3: Less well-known brands are not reliable.
Perceived Quality	PQ	PQ1: High sun protection factor.
		PQ2: Oil control and non-irritating to the skin.
		PQ3: Effective against water and sweat.
Purchase Intention	PI	PI1: Intends to buy the product in the near future.
		PI2: Intends to buy regularly.
		PI3: Will make an effort to buy the product in the near future.

Research Methodology

In this study Partial Least Squares Structural Equation Modeling (PLS-SEM) is a statistical technique that is widely used in scientific research and management to analyze and model the relationships between variables. Its primary goal is to create models that encompass both the measurement model and the structural model, allowing for a comprehensive understanding and explanation of the relationships among variables. PLS-SEM employs a range of statistical methods, such as principal component analysis and linear regression, to achieve this objective. By applying PLS-SEM, researchers can determine and assess the strength and direction of relationships between variables. It facilitates the estimation of the impact and effectiveness of independent variables on the dependent variable of interest. This enables researchers to gain insights into how various factors influence the outcomes they are studying. PLS-SEM consists of two interrelated models: the measurement model and the structural model. The measurement model focuses on how the measured variables represent underlying constructs or concepts. On the other hand, the structural model aims to uncover the relationships and connections between these constructs. In PLS-SEM, the measurement model is often referred to as the outer model, while the structural model is known as the inner model. It is worth noting that despite their distinct names, both models operate in a similar manner and complement each other in the analysis. To guide the implementation of PLS-SEM, a flowchart illustrating the algorithm is typically provided. This flowchart outlines the sequential steps and procedures involved in conducting PLS-SEM analysis and serves as a visual representation of the process (Figure 3).

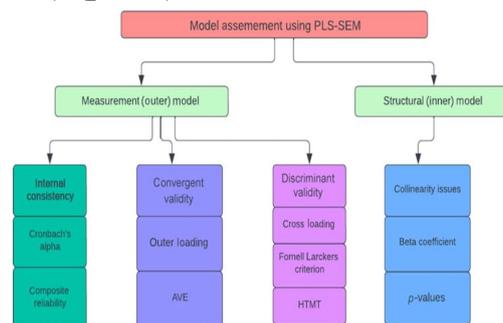


Figure 3. Flowchart of model assessment using PLS-SEM

The present study’s conceptual framework (Fig.) consisted of 11 key variables: Perceived usefulness, Perceived ease of use, Expectations, Confirmation, Satisfaction, Brand, Perceived Quality, Attitude, Subjective norm, Perceived control, Purchase intention. The data collected in this research paper was sent by us with 100 questions with the survey location being Ho Chi Minh City and received 50 responses in return. This set of questions was submitted and revised by 3 leading experts in the cosmetic industry: Dr. Nadim Shaath, Dr. Steven Q. Wang, Dr. Ariel Ostad to collect the set of 33 questions presented in this research paper. This survey questionnaire was distributed to consumers and received a total of 80 500 responses. There are a total of 11 hypotheses, with a combined use of 33 indicators measured on a Likert scale ranging from 1 to 5, as shown in the table below:

Table 3 . Likert Scale

Value	Meaning
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly Agree

The survey findings offer insights into the participant demographics. Among the 500 respondents, the majority (48.2%) fell within the 15 to 25 age range, while a significant proportion (92.6%)

reported an income below 20,000,000 VND. 180 Students comprised 62.40% of the sample, with 62.4% currently pursuing higher education. Additionally, the majority (71.8%) of participants indicated their single marital status (Table 4).

Table 4. Respondents information

Characteristics	Category	Frequency	Percent
Age	15-25	241	48.20%
	26-35	146	29.20%
	36-45	79	15.80%
	46+	34	6.80%
Income	Under 5M VND	161	32.20%
	5-10M VND	213	42.60%
	10-20M VND	89	17.80%
	Above 20M VND	37	7.40%
Education	Higher secondary or less	4	0.80%
	University students	312	62.40%
	Postgraduate	25	5.00%
Occupation	Student	159	31.80%
	Self-employed	279	55.80%
	Job holder	221	44.20%
Marital status	Single	359	71.80%
	Married	141	28.20%

The study uses a quantitative approach that combines foundational theories and modern tools to explore the factors affecting purchase and usage intentions of sunscreen products. The process includes developing a theoretical model, survey design, data collection, and statistical analysis using Structural Equation Modeling (SEM) with Smart PLS 3.3 software. PLS-SEM is used to analyze relationships between variables through techniques like Principal Component Analysis and linear regression. After identifying the impact of key factors, Fishbone diagrams are used to pinpoint root causes, and the Taguchi method is applied for product improvement. The Taguchi method optimizes product quality by using orthogonal arrays and calculating the Signal-to-Noise (S/N) ratio to reduce noise and enhance results.

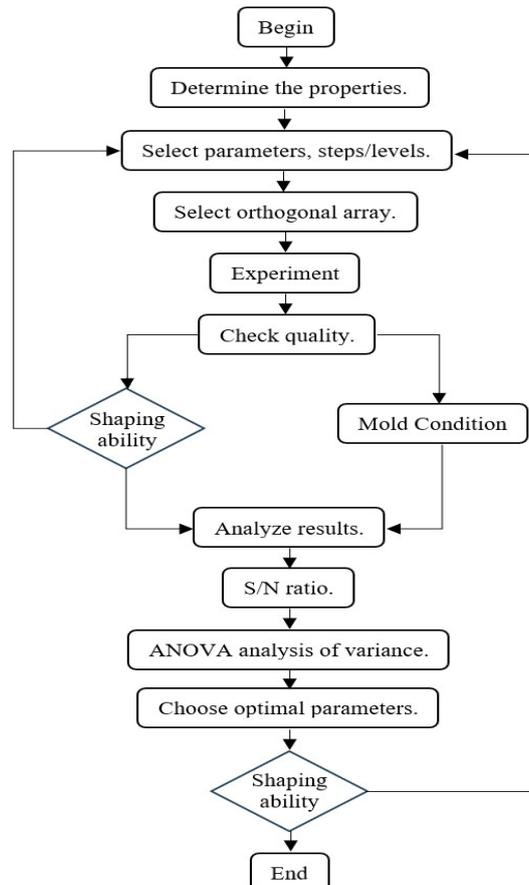


Figure 4. Taguchi optimization flow chart

RESULT

Evaluate the structural model:

Cronbach Alpha (α) is a statistical measure of internal consistency, often used in research. Cronbach's alpha is a widely used statistical method for evaluating the reliability or consistency of a measurement scale or a set of items designed to assess a construct or a latent variable. The concept was first introduced by Lee Cronbach in 1951. The formula for Cronbach's alpha involves the average inter-item correlation and the number of items in the scale.

The threshold for assessing reliability reaches of reliability with all variables giving values greater than 0.7. Composite reliability (CR) - Netemeyer et al. (2003) is a statistical measure used to assess the internal consistency or reliability of a latent construct or composite variable. The internal consistency index of the research model assesses the validity, including both convergent and discriminant validity. The reliability value of the measurement indicators in the research model greater 0.7 and less than or equal 0.9. AVE, or average variance extracted, quantifies the extent to which a construct captures variance relative to measurement error. It measures the proportion of variance in a construct that is accounted for by the observed variables, providing an indication of the construct's reliability and the quality of measurement. AVE values fall within the range of 0 to 1, where higher values indicate a greater proportion of variance explained by the construct. To establish good convergent validity, it is generally accepted that an AVE value of 0.5 or higher is desirable, indicating that the construct accounts for at least 50% of the variance observed in the variables.

Table 5. Composite reliability and convergent validity

Factor	Cronbach's Alpha	Rho_A	CR	AVE
ATT	0.799	0.852	0.861	0.678
BR	0.728	1.490	0.811	0.602
CONF	0.821	0.847	0.893	0.736
EXP	0.776	0.870	0.852	0.661
PC	0.702	0.739	0.814	0.598
PE	0.758	0.773	0.860	0.672
PI	0.826	0.845	0.896	0.741
PU	0.768	0.859	0.860	0.673
PQ	0.803	0.861	0.880	0.710
SAT	0.775	0.801	0.868	0.686
SN	0.765	0.843	0.858	0.672

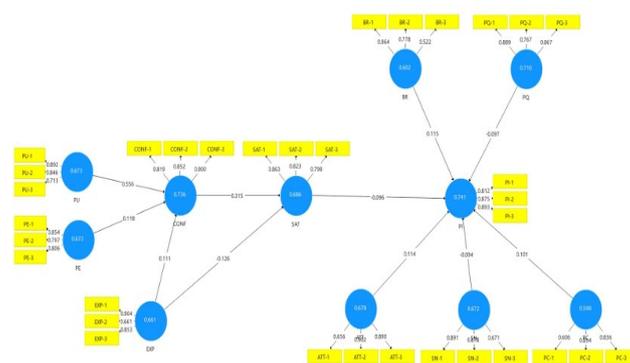


Figure 5. Result of PLS Algorithm

To assess the discrimination accuracy of a measurement model, a common approach is to compare the AVE able and other potential variables. When the AVE coefficient is larger than the remaining correlation coefficients, it indicates a higher level of discrimination accuracy. Convergence can be evaluated using two indices: AVE and AVE. AVE represents the average variance extracted by the indicators, while AVE is the square root of AVE. A high AVE value suggests that a substantial amount of variance in the latent variable is captured by the indicators. Additionally, examining the correlation matrix helps understand the combined relationship between variables. Assessing

convergence also involves considering the average correlation coefficient within a scale compared to the average of the cross-correlation coefficients. A higher average correlation coefficient within the scale indicates a greater amount of shared variation by the latent variable. This implies a stronger relationship between the indicators and the latent construct. By evaluating discrimination accuracy and convergence using these indices and correlation analysis, researchers can gain insights into the quality and reliability of the measurement model and the relationships between variables. The Heterotrait-Monotrait Ratio of Correlation (HTMT), Helenseler et al. (2015) is a statistical measure employed to assess the discriminant validity of latent constructs. It examines the strength of correlations between indicators of different constructs in comparison to correlations between indicators of the same construct. By evaluating the extent to which indicators are more strongly correlated with their own construct (monotrait relationships) rather than with other constructs (heterotrait relationships), the HTMT helps determine the discriminant validity of the constructs.

Table 6. Discrimination accuracy: Fornell–Larcker index

	ATT	BR	CONF	EXP	PC	PE	PI	PU	PQ	SAT	SN
ATT	0.824										
BR	0.083	0.776									
CONF	-0.030	0.083	0.858								
EXP	0.023	-0.043	0.215	0.813							
PC	0.072	0.146	-0.008	0.011	0.773						
PE	0.017	0.030	0.283	-0.052	-0.001	0.820					
PI	0.134	0.134	-0.075	-0.034	0.112	-0.123	0.861				
PU	0.039	0.107	0.615	0.198	0.005	0.308	-0.080	0.820			
PQ	-0.025	0.037	0.078	-0.009	0.076	0.217	-0.121	0.063	0.843		
SAT	0.005	-0.005	0.288	-0.058	-0.030	0.826	-0.124	0.295	0.209	0.828	
SN	-0.014	0.026	0.110	0.095	0.099	0.014	-0.101	0.057	0.139	0.048	0.820

Variance Inflation Factor (VIF) is a statistical measure utilized to evaluate multicollinearity in regression analysis. It determines the degree to which the variance of a predictor variable is inflated as a result of its correlation with other predictor variables in a regression model. VIF is computed for each predictor variable and quantifies the extent to which the variance of that variable increases due to correlations with other predictors. Its purpose is to assess the amount by which the standard error of the estimated regression coefficient is amplified due to multicollinearity. In general, higher VIF values indicate a stronger presence of multicollinearity in a regression model. A VIF value of 1 suggests no multicollinearity, meaning the predictor variable is not correlated with other predictors. On the other hand, VIF values greater than 1 and less than 3 indicate no multicollinearity, with higher values indicating stronger correlations among predictor variables. As a rule of thumb, VIF values above 5 or 10 are often considered indicative of significant multicollinearity, indicating potentially problematic levels of correlation among the predictors. Evaluating VIF values helps researchers identify and address multicollinearity, which can have implications for the reliability and interpretation of regression coefficients in the model.

Table 7. Result of VIF

Elements	VIF	Elements	VIF	Elements	VIF
ATT-1	1.622	EXP-3	1.683	PU-2	1.756
ATT-2	1.679	PC-1	1.362	PU-3	1.462
ATT-3	1.931	PC-2	1.420	PQ-1	1.728
BR-1	1.623	PC-3	1.332	PQ-2	1.647
BR-2	1.731	PE-1	1.548	PQ-3	1.842
BR-3	1.262	PE-2	1.463	SAT-1	1.558
CONF-1	1.685	PE-3	1.589	SAT-2	1.633
CONF-2	1.906	PI-1	1.692	SAT-3	1.594
CONF-3	2.035	PI-2	2.041	SN-1	1.725
EXP-1	1.594	PI-3	2.005	SN-2	1.784
EXP-2	1.538	PU-1	1.591	SN-3	1.370

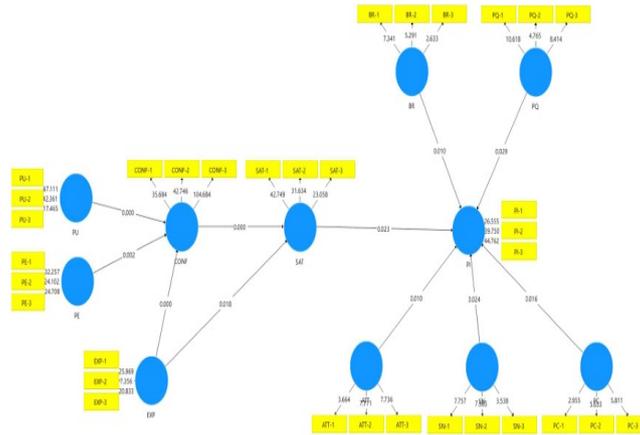


Figure 5. Results of PLS bootstrapping

Through analysis results for all value of variables are less than 0.05. This equally means that all hypothesis is statistically significant. The hypothesis expectation has an impact on Confirmation and Satisfaction. Understandably, people in Ho Chi 12 Minh City have a special interest in the effects and uses that sunscreen brings. Besides, each person has a different skin type, so the expectations and satisfaction level for the product are different. Customer expect more about the quality and effectiveness of sunscreen. In addition, the hypothesis brand and perceived quality are also important factors influencing purchasing decisions. Users tend to use big brands that are well-sold and tested by many experts.

Table 8. Structural analysis of the contrast hypothesis

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics ((O/STDEV))	P Values	Result
ATT → PI	0.114	0.122	0.046	2.498	0.013	Supported
BR → PI	0.115	0.124	0.044	2.595	0.009	Supported
CONF → SAT	0.315	0.317	0.047	6.752	0.000	Supported
EXP → CONF	0.111	0.115	0.030	3.761	0.000	Supported
EXP → SAT	-0.126	-0.129	0.053	2.351	0.019	Supported
PC → PI	0.101	0.110	0.041	2.481	0.013	Supported
PE → CONF	0.118	0.120	0.038	3.060	0.002	Supported
PU → CONF	0.556	0.557	0.040	13.882	0.000	Supported
QUA → PI	-0.097	-0.107	0.044	2.211	0.027	Supported
SAT → PI	-0.096	-0.095	0.042	2.283	0.022	Supported
SN → PI	-0.094	-0.104	0.039	2.389	0.017	Supported

Although all p-value values are less than 0.05, according to the statistical results, the Perceived Quality factor received an average survey result of 1,744, lower than the disagree level of the Likert scale. This proves that most respondents disagreed with the survey question. Thereby showing that the quality of surveyed products does not meet the trust of consumers.

Table 9. T-Value of Perceived Quality

Elements	T-Value
PQ-1	10.618
PQ-2	4.765
PQ-3	8.414

The PLS bootstrapping result with 5000 loops gives the T Value result as shown in the table above. As a result, the value of the PQ-2 factor is much skewed and lower (less than 5) compared to the two factors PQ-1 and PQ-3. This means that the phenomenon of products irritating and clogging pores is a common problem that consumers experience when using sunscreen. To go into the research on the causes of the above situation, we propose the fishbone model to find the causes with 4 main factors: Human, Material, Method, Environment. Our proposed model builds on the principles of building a fishbone diagram by Kaoru Ishikawa that was popularized in 1960.

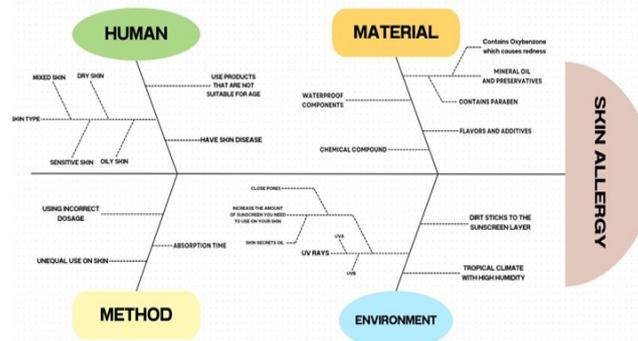


Figure 6. Cause of skin allergy diagram

Each person has different skin types, such as oily, dry, sensitive, or combination skin. Therefore, when applying sunscreen to the skin, it can alter the structure of the sunscreen and result in a greasy or irritating feeling. Depending on the skin type, different types of sunscreen will be suitable and yield different outcomes. It is also possible that our skin may have underlying skin conditions or issues, and using sunscreen when our skin is not ready for it can cause discomfort. These two factors can lead to the skin experiencing greasiness, oiliness, or even irritation after coming into contact with certain components in the sunscreen.

Many products contain oxybenzone at levels exceeding the permitted limit, and this substance can easily cause skin redness and sensitivity. Mineral oil and preservatives, flavor additives, and parabens are ingredients added to sunscreen as additives to make the product smooth, have a pleasant fragrance, and extend the shelf life of the sunscreen. However, excessive amounts of these substances can lead to greasiness, irritation, and many other sunscreens that contain high levels of chemical compounds and water-resistant ingredients can also cause allergic reactions and redness on the skin.

When the skin is exposed to prolonged UV radiation, including UVA and UVB rays, it is necessary to reapply sunscreen after a certain period of time. Failure to cleanse the skin before reapplying sunscreen can lead to clogged pores, excessive sebum on the skin, and a greasy feeling, which may cause skin irritation. Additionally, in cases where sunscreen is not properly stored and allows for dust contamination or when living in a tropical climate with high humidity, the facial skin may also experience greasiness and oiliness after applying sunscreen.

When sunscreen is applied to the face but has not had enough time to absorb into the skin or when it is applied unevenly, it can cause greasiness, oiliness, or excessive frequency of application throughout the day, leading to skin congestion and irritation. Improper use of sunscreen is also a significant factor contributing to allergic reactions on the skin. Applying an excessive amount of sunscreen or exceeding the necessary frequency on the skin can lead to clogged pores and breakouts. Uneven application of sunscreen on different facial areas can result in a thick and inconsistent layer of sunscreen on the face. This reduces the effectiveness of sun protection and can cause skin irritation, redness, itching, or inflammation.

The production, bottling, and shipment of sunscreen products can be conducted either entirely within a single facility or partially outsourced. The described manufacturing process utilizes a combination of both approaches, employing full automation. To purify water, a technique called

reverse osmosis is employed. This method involves applying pressure to water and passing it through a semipermeable membrane. Through this process, pure and fresh water is extracted, as the membrane selectively allows water molecules to pass while separating out salts and other impurities. The production process involves procuring ingredients from external suppliers and blending them with purified water based on the final formulation's recipe. This recipe, specifying precise measurements for each ingredient, is documented on a vat sheet. To scale up for commercial production, the measurements are adjusted from the initial 10-gallon recipe used during the development stage to accommodate larger quantities.

The production of plastic containers for the sunscreen is carried out at a blow molding facility, which may be located either within or outside the company. Blow molding is the process used, involving thermoplastics that become pliable when heated and solidify when cooled. Initially, the thermoplastic material is extruded into a tube known as a parison, which is then positioned within an open mold. The mold is subsequently closed around the heated parison, and the bottom of the parison is sealed by pinching it. To shape the container, compressed air is introduced through the top of the parison, causing the softened plastic to expand and conform to the inner walls of the mold. This results in the creation of the desired container shape. After the manufacturing process, the containers are transported to a printing facility where logos and product information are applied. In certain instances, the containers may also undergo a stamping process. Stamping involves impressing a thin metal foil onto the container's surface, typically in the shape of a logo. Once the printing or stamping is complete, the containers are stored until they are ready to be utilized.

To facilitate the filling process, stainless steel tanks with a capacity of up to 1,000 gallons (3,784 liters) are utilized. This operation occurs in a dedicated, sterile room equipped with a conveyor system consisting of multiple incoming tracks. Machine operators oversee the automated process. Containers and caps are transported into the filling room via conveyor tracks. The sunscreen lotion is transferred from the vats through stainless steel piping to a pressure filling machine. This machine inserts a retractable nozzle into each container and precisely fills it with a predetermined quantity of sunscreen lotion. During the production line, the majority of containers are automatically capped. However, certain containers are equipped with pump caps to enable convenient dispensing of the sunscreen. As the containers move past the fill phase, these pump caps necessitate manual assembly by operators.

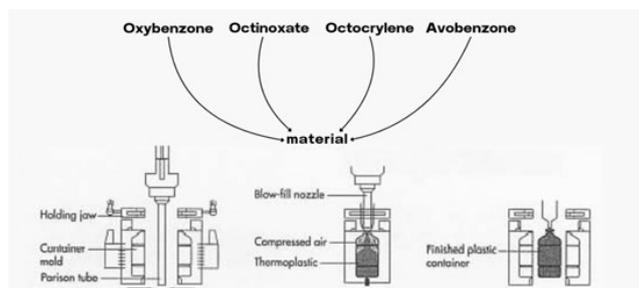


Figure 7. Manufacturing Process

Table 10. Chemicals used in experimental research

Chemicals	Concentration	Unit
Phenoxyethanol	24%	1.1g
Tocopherol acetate	88%	2.3g
Titanium dioxide	25%	3.4g
zinc oxide	25%	1.5g

Table 11. Equipment used in experimental research

Equipment	Model
Ph Tester	PH-101
Heating magnetic stirrer	MH-1
Electric microscale	GF2000
Power supplier	LPS-301
Interfacial tension meter	K9-MKI
Contact angle meter	MODEL 683
Ultrasonic cleaning machine	L-900
Optical microscope	MM-40

Tagich Method

The Taguchi method is considered the best method for optimal implementation of finding optimal conditions in production processing, contributing to improving product quality, production process quality, and productivity. The orthogonal grids in the Taguchi method help reduce noisy parameters in experimental studies to create the best conditions for the experimental parameters of the Taguchi method. In addition, the orthogonal array also creates experimentally balanced levels compared to the Signal to Noise (S/N) index based on the logarithmic formula to improve the optimal level, creating analytical and predictive results. Experimental results are better. The "Signal" value represents the average value of the output level target, and the "Noise" value is the unwanted noise levels. The S/N ratio is calculated for the value used to evaluate the optimization level in the Taguchi experimental study.

Table 12. Options for selection of orthodontic code in taguchi method

Orthogonal	Experimental number	Maximum number of parameters	Levels			
			2	3	4	5
L4	4	3	3			
L8	8	7	7			
L9	9	4		4		
L12	12	11	11			
L16	16	15	15			
L'16	16	5			5	
L18	18	8	1	7		
L25	25	6				6
L27	27	13		13		
L32	32	31	31			
L'32	32	10	1		9	
L36	36	23	11	12		
L'36	36	16	3	13		
L50	50	12	1			11
L54	54	26	1	25		
L64	64	63	63			
L'64	64	21			21	
L81	81	40		40		

Choosing the right and appropriate independent variables in the orthogonal array brings optimal results in the Taguchi method and helps the Taguchi method give better results than other statistical methods. Correct selection of independent variables helps reduce the number of variables. number of experimental evaluations and does not lose any value in the Taguchi experiment, improving the accuracy of Taguchi in performing optimization without being affected by surrounding interference factors. The Taguchi method used in optimizing Injection conditions at the Mold machine is carried out according to the flow chart

In this study, quality engineers at the company applied the Taguchi method to approach and analyze parameters affecting the Injection mold process, optimizing Injection mold conditions to bring about results in reducing production time improving product quality, improving productivity, and enhancing customer satisfaction. Experimental experiments using the Taguchi method are performed in a simple way. However, until now, quality engineers have not really paid attention to and used Taguchi to analyze and optimize the production process.

The experimental model is built based on a parametric diagram with impact parameters such as control parameters and disturbance parameters. The value meets the output of the experimental research model which is Oxybenzone, Octinoxate, Octocrylene, Avobenzone . The value of the control element has a set value. The 4 control parameters are divided in to 2 levels, Factor A has 2 levels with corresponding values of 5%-6%. Factor B has 2 levels corresponding to values in order from level 1 to level 2 which are 5.5%-6.5% . Factor C has 2 levels corresponding to 2 values from level 1 and level 2 are 4, 5. Factor D has 2 levels with values from level 1 to level 2 respectively 2, 3.

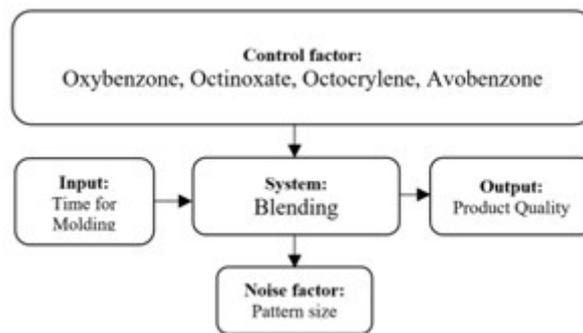


Figure 8. Parameter diagram

Oxybenzone is a widely accepted sunscreen ingredient that provides protection against both UVB and UVA rays. The permissible concentration of oxybenzone in sunscreen products varies depending on the country. In the United States and Canada, concentrations of oxybenzone up to 6% are allowed. Australia, New Zealand, European Union member countries, and most Asian countries permit a maximum concentration of 10%, with the exception of Japan, which restricts it to 5%. For our enhanced product model, we suggest two value ranges for the oxybenzone concentration: 5% to 6%. This range falls within the allowable limits set by various regulatory bodies. It's important to comply with the specific regulations and guidelines of the target market when formulating sunscreen products containing oxybenzone. The proposed allowable concentrations of Octinoxate for the new product are 5.5% - 6.5%. Octinoxate, also known as Octyl Methoxycinnamate, is an ester cinnamate derived from Methoxycinnamic Acid and Ethylhexanol. It is commonly used in sunscreen and skincare products to protect the skin from the harmful effects of UVB and UVA rays. The mechanism of action of Octinoxate involves absorbing UVB and UVA rays, which allows it to accumulate in the outermost layer of the epidermis. By doing so, it helps prevent cell and DNA damage by reducing the expression of the protein after UV exposure. Additionally, Octinoxate increases the skin's tolerance to UV rays, thereby reducing the risk of sunburn, DNA changes, and skin damage. The U.S. Food and Drug Administration (FDA) has provided recommendations regarding the use of Octinoxate. They suggest that products containing Octinoxate should have a concentration below 7.5%. In the case of the new product being proposed, the allowable concentrations fall within the range of 5.5% - 6.5%. Octocrylene is an organic compound that belongs to the Benzophenone family. It is a liquid, viscous, and colorless substance that can dissolve in oil. Octocrylene is a chemical sunscreen ingredient that is soluble in oil. Its primary function is to protect the skin from the harmful effects of UVB rays and to some extent, UVA II rays, with its maximum absorption occurring at 304 nm. Octocrylene is commonly used in sunscreen products, skincare items, and personal care products, with a permissible concentration of no more than 10-12%. The recommended concentration of Octocrylene in cosmetics is 5%. In this

improved product, we propose two permissible levels for this ingredient, which are 4% - 5%. In skincare cosmetics, Octocrylene acts as a stabilizing agent while also providing sun protection. Manufacturers incorporate Octocrylene into their sunscreen formulations because of its ability to neutralize and reflect UV rays present in sunlight. Avobenzone is a chemical compound found in sunscreen that helps shield the skin from harmful UVA rays by absorbing them. Unlike other chemical sunscreen ingredients like titanium dioxide and zinc, which rest on the surface of the skin and reflect sunlight, Avobenzone absorbs the rays. In terms of toxicity, Avobenzone in sunscreen is generally considered safe, but it degrades quickly when exposed to sunlight. When used alone, Avobenzone provides approximately 30 minutes of protection upon sun exposure. As a result, many chemical sunscreen products incorporate Avobenzone to safeguard against UVA rays, but manufacturers often need to include additional chemicals like octocrylene to extend the sunscreen's effectiveness beyond 30 minutes. Avobenzone is among the various sunscreen ingredients currently undergoing further safety testing under the supervision of the U.S. Food and Drug Administration (FDA). In the United States, it can be utilized as an over-the-counter sunscreen with an activity level of up to 3%. Its maximum allowable concentration extends to 5% in the European Union, where it has been used since 1978 (FDA approval was granted in 1996). This study proposes an optimal improvement level for Avobenzone of 2% - 3%.

Table 13. Control factor and Levels

No.	Description	Level 1	Level 2
A	Oxybenzone	5	6
B	Octinoxate	5.5	6.5
C	Octocrylene	4	5
D	Avobenzone	2	3

Table 14. Analysis of variable forr SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Oxybenzone	1	0.31180	0.31180	0.31180	6.90	0.079
Octinoxate	1	0.14243	0.14243	0.14243	3.15	0.174
Octocrylene	1	0.13743	0.13743	0.13743	3.04	0.180
Avobenzone	1	0.01902	0.01902	0.01902	0.42	0.563
Residual Error	3	0.13562	0.13562	0.04521		
Total	7	0.74630				

Table 15. Response Table for Signal to Noise Ratios

Level	Oxybenzone	Octinoxate	Octocrylene	Avobenzone
1	-39.17	-39.11	-39.10	-39.02
2	-38.77	-38.84	-38.84	-38.92
Delta	0.39	0.27	0.26	0.10
Rank	1	2	3	4

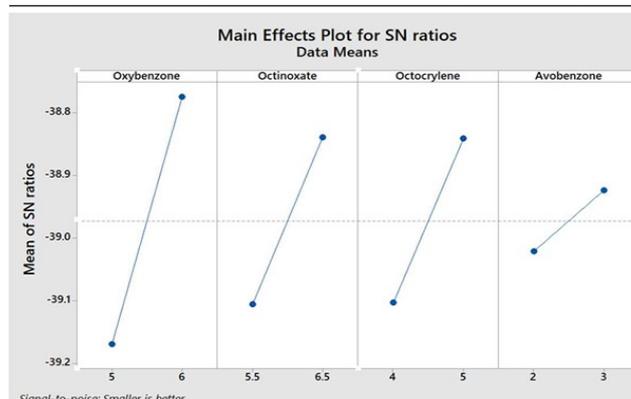


Figure 9. Main Effects Plot for SN ratios

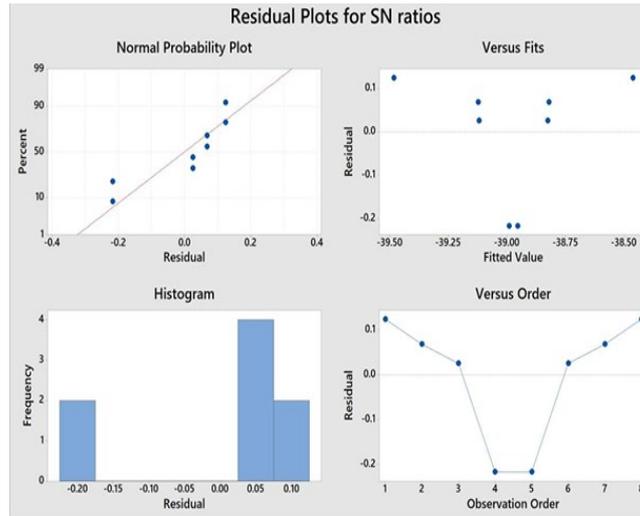


Figure 10. Residual Plots for SN ratios
Table 16. Analysis of Variance for Mean

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Oxybenzone	1	33.008	33.008	33.008	6.76	0.080
Octinoxate	1	14.445	14.445	14.445	14.445	14.445
Octocrylene	1	15.820	15.820	15.820	3.24	0.170
Avobenzone	1	1.758	1.758	1.758	0.36	0.591
Residual Error	3	14.648	14.648	4.883		
Total	7	79.680				

Table 17. Response Table for Means

Level	Oxybenzone	Octinoxate	Octocrylene	Avobenzone
1	90.75	90.06	90.13	89.19
2	86.69	87.38	87.31	88.25
Delta	4.06	2.69	2.81	0.94
Rank	1	3	2	4

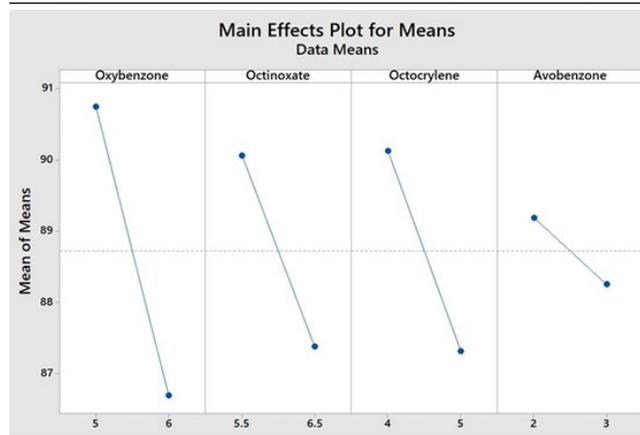


Figure 11. Main Effects Plot for Means

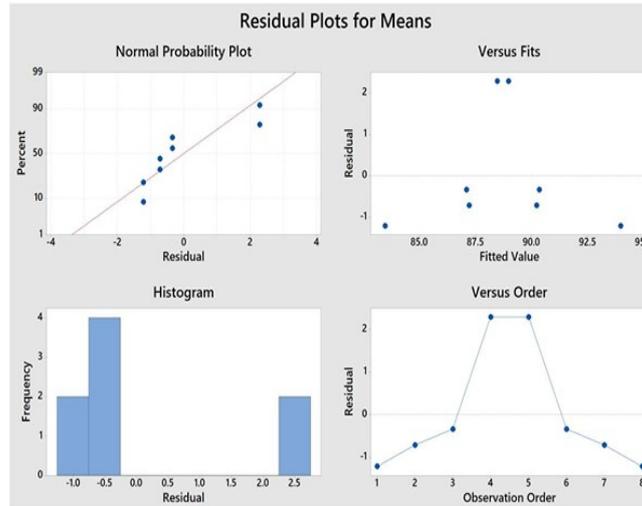


Figure 12. Residual Plots for Means

Table 18. Optimal design

No	Description	Level	Value
A	Oxybenzone	1	5
B	Octinoxate	1	5.5
C	Octocrylene	1	4
D	Avobenzone	1	2

This research article presents the development and implementation of a sunscreen product line based on measurement results and user surveys. It introduces a novel and distinct approach compared to current practices. The authors employ a cause-and-effect diagram to identify key factors in the experimental study. They then utilize a model to determine 466 process parameters for designing Taguchi experiments. Following the design of a new sunscreen product line with allowable concentrations of its components, considerable improvements are observed in product quality. There is a notable reduction in irritation and pore clogging, while maintaining the product's sun protection effectiveness. As a result, customer satisfaction is significantly enhanced.

The market offers a wide range of sunscreen products, but some of them contain ingredients that are not suitable for sensitive skin. Consequently, users who experience skin irritation do not repurchase these products, resulting in a decline in sunscreen sales. To tackle this problem, an enhanced product line has been introduced, specifically designed to minimize skin irritation by reducing the concentration of harmful ingredients, while still ensuring effective sun protection. This product line is the central focus and receives the highest production priority, aiming to improve user experience and achieve desired business results for the company.

Table 19. Comparing the effectiveness of the old product versus the optimal product.

	OLD PRODUCT	OPTIMAL PRODUCT
DEGREE OF SKIN ALLERGY	80%	35%
SUN PROTECTION ABILITY	70%	70%
BUSINESS EFFICIENCY	60%	85%

The sun protection effectiveness remains unchanged before and after, both at a rate of 70%. The level of skin irritation for the new product (80%) is significantly lower compared to the old product (35%). Additionally, the business effectiveness for the optimized new product (85%) increases by 25% compared to the same period of the old product (60%).

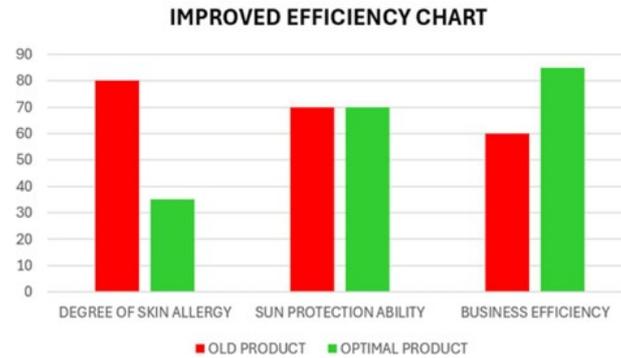


Figure 13. Comparing the effectiveness of the old product versus the optimal product.

Discussion and Conclusion

Sunscreen plays a crucial role in protecting the skin against harmful UV rays emitted by the sun. Its usage can effectively shield the skin from both UVB and UVA rays, thereby reducing the risk of sunburn, preventing skin damage, and minimizing the chances of dermatological issues like skin cancer and premature aging caused by sun exposure. The proposed research model (Figure 3) evaluates various aspects of individuals' underlying values that influence their intention to use sunscreen in Ho Chi Minh City. This evaluation is done through the application of structural relationships and models. The model's parameters assess the suitability and complexity of the proposed framework. The Theory of Reasoned Action (TRA) and the Theory of Planned Behavior (TPB) serve as the referenced and applied models in this study. This research holds significant importance in enhancing our understanding of the crucial measurement factors associated with sunscreen products. The survey results, obtained from the measurement of variables within the research model, demonstrate a p-value < 0.05 , indicating their validity. These findings aid in identifying the factors impacting sales revenue. The research outcomes also highlight the need for improvements in product lines to enhance the consumer experience. Furthermore, the study incorporates the Taguchi method for optimization, leading to the development of more effective products. These improvement results support suppliers in creating new products and boosting business revenue.

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