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The Effect of Modernization of Test Equipment, Analyst Competence and Excellent Service on Customer Satisfaction and Its Implications for Customer Loyalty, Center for Standardization of Services for the Chemical, Pharmaceutical and Packaging Industries

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Abstract: The aim of this research is to determine and analyze the influence of modernization of test equipment, analyst competency and excellent service on customer satisfaction and its implications for customer loyalty at the Center for Service Standardization for the Pharmaceutical Chemical and Packaging Industry. This research category uses descriptive methods with a quantitative method approach. The sampling technique used purposive sampling with a total sample of 130 respondents. Data collection uses a questionnaire. The data analysis technique uses Structural Equation Modeling (SEM) analysis which is processed with Smart PLS 4.0. The results of the research prove that the variables of modernization of test equipment, analyst competency and excellent service influence customer satisfaction. Then the variables of analyst competency, excellent service and customer satisfaction influence customer loyalty. Meanwhile, modernization of test equipment has no effect on customer loyalty. Intervening test results prove that modernization of test equipment has no effect on customer loyalty through customer satisfaction. Meanwhile, analyst competency and excellent service influence customer loyalty through customer satisfaction. Likewise, complementary customer satisfaction is able to mediate the influence of analyst competence and excellent service on customer loyalty.

Keyword: Test Equipment Modernization, Analyst Competence, Excellent Service, Customer Satisfaction and Customer Loyalty

INTRODUCTION

The rapid growth of the national industry requires Indonesia to provide high-quality production goods that comply with national and international standards. To ensure this quality, products must undergo quality testing by accredited institutions, which can be carried out by

government or private institutions. Apart from being a requirement for compliance with standards, quality testing is also used as evaluation material for the industry in improving production processes and product development in the future.

Along with the development of science and technology, industrial competition is getting tighter, demanding companies to produce better quality products in order to meet customer expectations. The public's need for products that meet quality standards has opened up opportunities for testing laboratory service providers in Indonesia. The National Accreditation Committee (KAN) notes that there are 1,440 testing laboratories in Indonesia that have been accredited with SNI ISO/IEC 17025 (KAN, 2024). The large number of accredited laboratories creates stiffer competition in providing the best service for customers.

One of the institutions engaged in quality testing is the Center for Standardization of Services in the Chemical, Pharmaceutical and Packaging Industries (BBSPJIKFK), which is a Technical Implementation Unit (UPT) under the Ministry of Industry. BBSPJIKFK has duties in industrial standardization, optimization of industry 4.0 technology, green industry, and services for the chemical, pharmaceutical, and packaging industries (BBSPJIKFK, 2023). The BBSPJIKFK Testing Laboratory has obtained SNI ISO/IEC 17025:2017 certification and is committed to implementing a quality management system that prioritizes customer satisfaction. To face the increasingly fierce competition, BBSPJIKFK implements strategies to improve the quality and accuracy of testing, accelerate services, optimize resources, and develop more competitive marketing strategies.

However, BBSPJIKFK still faces a major challenge in the Minimum Service Standard (SPM) of longer testing times compared to other laboratories. For example, testing for ethylene glycol (EG) and diethylene glycol (DEG) levels at BBSPJIKFK takes 15 days, while other laboratories only take 7-8 days (author's survey, 2024). Therefore, reducing the SPM time is an important step to increase competitiveness and customer satisfaction.

One of the main solutions that can be done is the modernization of test equipment, which allows the testing process to be more efficient and accurate. The use of high-tech equipment, such as high-resolution spectrophotometers, can speed up the analysis process and improve the precision of test results. Previous studies have shown that technological modernization can improve service quality and customer satisfaction in various service sectors, including testing laboratories (Samuel & Farid, 2018; Jintana, 2024; Khan et al., 2022; Mansour et al., 2022; Bacinskas & Kempers, 2020).

In addition to equipment modernization, the competence of laboratory analysts is also an important factor in improving service quality. Competent analysts are not only able to operate modern tools properly but also understand time management in testing and risk management in the use of sophisticated equipment. Human resource competence has been proven to have a significant effect on customer satisfaction in services (Anggraini et al., 2024; Jemmy, 2018; Szewieczek & Karkoszka, 2009).

The data shows that the number of BBSPJIKFK customers fluctuated in the 2017-2024 period. In 2017, the number of customers reached 1,480, but decreased to 547 customers in 2020. However, the trend increased again in 2021 to 697 customers, then to 1,360 customers in 2024 (BBSPJIKFK, 2024). This increase was driven by efforts to modernize equipment, improve analyst competence, and provide excellent service.

In addition, the quality of laboratory services also plays an important role in customer satisfaction. In the context of ISO/IEC 17025:2017, service quality must be guaranteed through good documentation, clear procedures, and routine audits to ensure that services remain up to standard. Studies show that the implementation of the ISO/IEC 17025 quality system can improve transparency and customer satisfaction (Iswahyuningsih et al., 2022).

In the digital era, customers expect faster, easier, and more transparent services. Therefore, the utilization of digital technology is a strategic step in increasing customer

satisfaction. Digitization allows customers to have real-time access to services, data automation processes, and a more effective customer feedback system.

Customer satisfaction plays an intervening role in increasing customer loyalty to BBSPJIKFK. High customer satisfaction encourages customers to continue using laboratory services, which in turn increases the number of customers and laboratory revenue (Saxena, 2017; Wilson & Christella, 2019).

In an effort to increase competitiveness, BBSPJIKFK has launched SIPTENAN (Integrated Customer Information System in Services) in 2023. This system integrates various services ranging from registration, administration, financing, order tracking, to test results. Through SIPTENAN, customers can get faster and more efficient services without having to come directly to the laboratory.

To improve service quality, customer satisfaction, and loyalty, research is needed on the effect of test equipment modernization, analyst competence, and excellent service on customer satisfaction and loyalty to BBSPJIKFK. The results of this study are expected to provide policy recommendations for BBSPJIKFK in improving its competitiveness both nationally and internationally.

METHOD

This study uses conclusive research design with a quantitative causal approach. This study aims to test the hypothesis and analyze the effect of test equipment modernization, analyst competence, and excellent service on customer satisfaction and loyalty. The quantitative method was chosen because it can measure the relationship between variables more accurately and objectively.

The population in this study is all customers of the BBSPJIKFK testing and calibration laboratory, with a total of 1,360 customers in 2024. The sampling technique used Disproportionated Stratified Random Sampling, with the minimum sample size calculated based on the approach of Hair et al. (2013), which is 5 times the number of indicators in the questionnaire. With 23 indicators, the minimum sample size required is 115 respondents, but in this study 130 respondents were used.

Data was collected through an online questionnaire distributed via Google Forms, email, and WhatsApp, with the help of the BBSPJIKFK partnership/marketing team. The questionnaire uses a 1-5 Likert scale, where 1 means “strongly disagree” and 5 means “strongly agree”.

This study has independent variables, namely the modernization of test equipment, analyst competence, and excellent service, mediating variables, namely customer satisfaction, and dependent variables, namely customer loyalty.

The data analysis technique used Partial Least Squares Structural Equation Modeling (PLS-SEM) with the help of the Smart PLS 4.0 program. This analysis includes evaluating the measurement model (outer model) for validity and reliability tests, as well as evaluating the structural model (inner model) to test the relationship between variables using R-square, Goodness of Fit (GoF), and hypothesis testing.

Hypothesis testing is done by looking at Path Coefficients, t-value, and p-value. The relationship between variables is considered significant if the t-value > 1.96 or p-value < 0.05 at a significance level of 5%. The results of this study are expected to provide an understanding of the effect of test equipment modernization, analyst competence, and excellent service on customer satisfaction and loyalty BBSPJIKFK.

RESULTS AND DISCUSSION

Results

Modernization of Test Equipment

Modernization is the process of changing people's attitudes and mentality to keep up with the times (KBBI, 2024). In the context of equipment, modernization means updating with more sophisticated technology to improve testing efficiency and accuracy. Everett Rogers' Diffusion of Innovations theory explains how new technologies spread within a population and are adopted gradually (Muliadi & Usman, 2024). Technological innovations in test equipment include the use of more sensitive sensors, advanced analysis software, and non-destructive testing methods, which require laboratories to constantly update their equipment.

In a management perspective, modernization is related to Total Productive Management (TPM) which ensures the effectiveness of equipment with optimal maintenance to reduce operational disruptions (Irsan et al., 2022). From an economic perspective, modernization is in line with Endogenous Growth Theory, where technological innovation is the main driver of economic growth and laboratory productivity efficiency (Chirwa & Odhiambo, 2018).

The benefits of modernizing test equipment include increased accuracy and precision, testing time efficiency, testing capabilities, compliance with the latest regulations, customer satisfaction, and reduced environmental impact (Savelyev, 2020). The dimensions of equipment modernization include technological updates, accuracy and precision, efficiency, and increased productivity.

Analyst competence is an important factor in successful testing. These competencies include general competencies (critical thinking, communication, and cooperation skills), technical competencies (mastery of analytical tools, statistical methods, and technology), and behavioral competencies (integrity, accountability, professionalism, and work ethic) (Tamba, 2021). The dimensions of analyst competence include flexibility, motivation to excel, learning ability, work ethic under pressure, and collaboration.

In this study, modernization is measured through technological renewal, accuracy, efficiency, and productivity, while analyst competence is measured by flexibility, motivation, work ethic, and collaboration. The implementation of equipment modernization and improved analyst competence is expected to increase laboratory efficiency, customer satisfaction, and competitiveness in the testing industry.

Excellent Service

Excellent service is the company's effort to provide the best service to meet customer expectations, both internal and external (Frimayasa, 2017; Rangkuti, 2017). Kotler (2008) in Rachmad et al. (2014) states that service quality can be measured by comparing customer expectations of a service with the actual experience they receive. When services meet or exceed expectations, customers will feel satisfied, which leads to their loyalty to the company.

The company's success in providing optimal services is influenced by various factors. Moenir (2016) revealed that employee awareness of their duties and responsibilities is a crucial aspect in creating quality services. Inefficient work systems and procedures can hamper the delivery of services and reduce customer satisfaction. In addition, unstructured task organization can lead to job overlap or poorly handled tasks. Another influential factor is employee welfare, because insufficient income can reduce work motivation, thus impacting service quality. The availability of adequate facilities and infrastructure is also an important factor in supporting the smooth operation of services.

To improve service quality, companies need to take various strategic steps. One of the main ways is to provide training to employees so that they have the skills to serve customers better. In addition, listening to customer complaints and input is an important step in evaluating and improving service quality. Digitization also plays an important role in improving the efficiency and effectiveness of services. With a digital-based service system, customers can access services more easily and quickly, so that their satisfaction with the company increases. Periodic evaluations of service quality are also needed to ensure standards are maintained. In

addition, rewards for employees who provide the best service can motivate them to continuously improve their performance.

According to Parasuraman et al. in Asnawi (2017), there are five main dimensions of excellent service. The first dimension is tangibles, which includes the physical aspects of service, such as cleanliness, neatness, and ease of access, which can create a positive impression for customers. The second dimension is reliability, which refers to the company's ability to fulfill service promises consistently and on time. Customers expect reliable service and not to experience many obstacles or delays. The third dimension is responsiveness, which is the company's readiness to help customers and provide solutions to their problems. Speed in handling customer complaints or requests can increase customer confidence in the company's services. The fourth dimension is assurance, which reflects the knowledge and expertise of employees in providing services, as well as their friendliness and courtesy in interacting with customers. Employees who have high competence and good attitude will provide a sense of security for customers. The fifth dimension is empathy, which shows the company's concern for the needs and feelings of customers. Paying more attention and listening carefully to customer complaints will make them feel valued.

Along with technological developments, excellent service not only depends on direct interaction between customers and companies, but is also supported by the use of digital technology. Shabani et al. (2022) emphasize that digitization in services can increase the efficiency, effectiveness, and competitiveness of companies. Through digitization, services can be provided more quickly and responsively, for example by providing a user-friendly digital-based service platform. Digital systems also allow customers to place orders or track the status of services independently, which can ultimately reduce waiting times and increase their comfort. In addition, digitization helps to ensure data accuracy and minimize manual errors in the service process. With digital-based services, customers can access services anytime and anywhere, which ultimately increases customer satisfaction with the services provided by the company.

Customer Satisfaction

Customer satisfaction is a major factor in maintaining business continuity, especially in the midst of increasingly fierce competition. Increased customer satisfaction has a positive impact on company loyalty and profitability because satisfied customers tend to make repeat purchases, provide positive recommendations, and build long-term relationships with the company (Tjiptono, 2019). Customer satisfaction occurs when their expectations of a product or service match the experience received. If the product performs better than expected, customers will feel very satisfied, whereas if it does not, customers will feel disappointed (Oliver, 2010; Simon et al., 2016).

Some methods that can be used to measure customer satisfaction include complaints and suggestions systems, mystery shopping, analysis of customers who have stopped, and customer satisfaction surveys (Tjiptono, 2019). Customer satisfaction is also influenced by several factors, such as price, service quality, product quality, emotional factors, and ease of access to products or services (Irawan, 2004 in Roynaldus A. K. Agung et al., 2023). Hatane in Rindy (2022) explains that customer satisfaction can be measured through attributes related to products, services, and purchasing processes.

Customer loyalty is a customer's commitment to continue using a company's products or services even though there are other options. Loyal customers usually make repeat purchases on a regular basis, make recommendations to others, and are not easily tempted to switch to competitors (Batlajery & Alfons, 2019; Simamora & Yusmalinda, 2021). The benefits of customer loyalty for companies include increasing revenue, reducing marketing costs, strengthening reputation, and increasing competitiveness. Factors that contribute to customer

loyalty include service quality, positive experiences, loyalty programs, and good communication with customers (Tjiptono, 2019).

MarkPlus Insight developed four dimensions of customer loyalty, namely transaction, relationship, partnership, and ownership (Thalib, 2014). Transaction measures customer satisfaction in transactions, relationship is related to repeat purchase habits, partnership reflects the level of customer attachment to the product, and ownership shows customer enthusiasm in recommending and defending the brand.

In this study, customer loyalty is measured through the behavior of reusing services and the customer's intention to recommend the service to others (Tjiptono, 2019). High customer satisfaction is expected to increase customer loyalty, which in turn has a positive impact on the company's business growth.

Description of Research Object

The Center for Standardization of Chemical, Pharmaceutical, and Packaging Industry Services (BBSPJIKFK) is an institution under the Industrial Services Policy Standardization Agency (BSKJI), Ministry of Industry, which plays a role in industrial services such as testing, calibration, certification, assistance, and consultancy. Located in East Jakarta, BBSPJIKFK performs various functions, including the implementation of industrial standardization, utilization of industry 4.0 technology, green industry, and testing and certification.

BBSPJIKFK has a vision to accelerate infrastructure development and bureaucratic reform, as well as a mission that includes improving the quality of human resources, strengthening the economy, equitable development, and clean and effective governance.

To increase customer satisfaction and loyalty, BBSPJIKFK has modernized test equipment to ensure more accurate, precise, fast, and productive test results (BBSPJIKFK, 2024). In addition, BBSPJIKFK also improves the competence of analysts, so that they can understand complex test equipment technology, manage time better, and ensure effective communication with equipment providers.

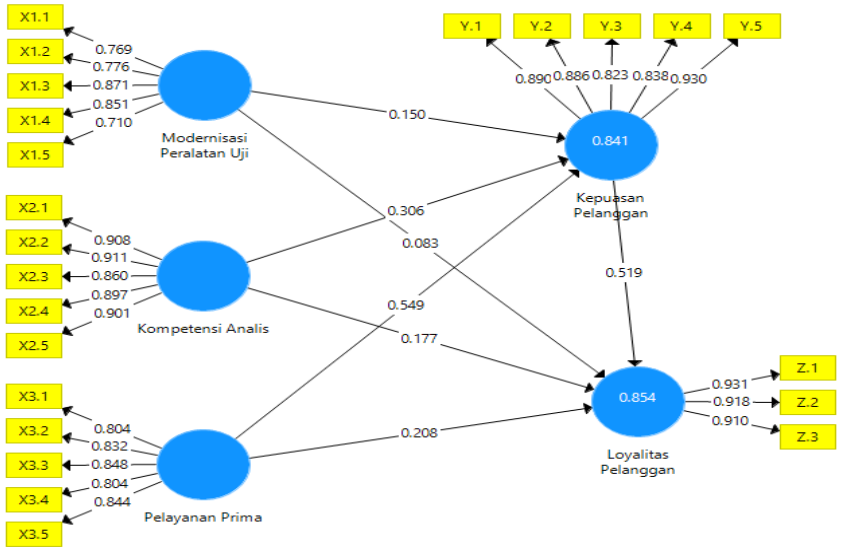
The implementation of ISO/IEC 17025:2017 has become the standard for providing quality, documented, and well-traceable laboratory services. With a combination of test equipment modernization, increased analyst competence, and the implementation of excellent service, BBSPJIKFK hopes to increase customer satisfaction and loyalty to laboratory testing services.

Measurement Model Testing (Outer Model)

Measurement model testing (outer model) is used to determine the specification of the relationship between latent variables and their manifest variables. This test includes convergent validity, discriminant validity, and reliability.

1. Convergent Validity

Convergent validity relates to the principle that the manifest variables of a construct should have a high correlation. The convergent validity test can be seen from the Loading Factor value for each construct indicator, while to assess convergent validity the Loading Factor value must be more than 0.70. In addition, it can also be seen from the Average Variance Extracted (AVE) value which must be greater than 0.5. Based on this criterion, if there is a loading factor <0.70, it will be dropped from the study. The test results using SmartPLS 4.0 software obtained the following indicator results:



Source: PLS 4.0 Processing Results (2025)

Figure 1. SEM-PLS Algorithm Results

For more details, the loading factor test results of each variable will be presented in the following tables.

Table 1. Validity Test with Loading Factor

Variable	Indicator	Loading Factor	Description
Modernization of Test Equipment (X_1)	X1.1	**0.769**	Valid
	X1.2	**0.776**	Valid
	X1.3	**0.871**	Valid
	X1.4	**0.851**	Valid
	X1.5	**0.710**	Valid
Analyst Competency (X_2)	X2.1	**0.908**	Valid
	X2.2	**0.911**	Valid
	X2.3	**0.860**	Valid
	X2.4	**0.897**	Valid
	X2.5	**0.901**	Valid
Excellent Service (X_3)	X3.1	**0.804**	Valid
	X3.2	**0.832**	Valid
	X3.3	**0.848**	Valid
	X3.4	**0.804**	Valid
	X3.5	**0.844**	Valid
Customer Satisfaction (Y)	Y.1	**0.890**	Valid
	Y.2	**0.886**	Valid
	Y.3	**0.823**	Valid
	Y.4	**0.838**	Valid
	Y.5	**0.930**	Valid
Customer Loyalty (Z)	Z.1	**0.931**	Valid
	Z.2	**0.918**	Valid
	Z.3	**0.910**	Valid

Source: Data processed using PLS software

The table above provides information on the loading factor value for each manifest variable of Test Equipment Modernization, Analyst Competence, Excellent Service, Customer Satisfaction, and Customer Loyalty. In the table above, it can be seen that the loading factor value of all manifest variables has a positive relationship and the loading factor of the manifest variable is greater than 0.7. These results indicate that the use of these 23 manifest variables is

declared capable of measuring latent variables precisely. Furthermore, the Convergent validity measurement can be presented through the following AVE test results.

Table 2. AVE Test Results

Latent Variables	AVE
Modernization of Test Equipment	**0.636**
Analyst Competency	**0.802**
Excellent Service	**0.683**
Customer Satisfaction	**0.764**
Customer Loyalty	**0.846**

Source: Data processed using PLS software

In the table above, it can be seen that the five latent variables have an AVE value greater than the specified value of 0.5, so that all manifest variables Modernization of Test Equipment, Analyst Competence, Excellent Service, Customer Satisfaction and Customer Loyalty are declared to have met the convergent validity requirements.

2. Discriminant Validity

Discriminant validity relates to the principle that different construct measures (manifest variables) should not be highly correlated with other manifest variables. The discriminant validity test with PLS software can be seen from the cross loading value by comparing the correlation of the indicator with the latent variable, which must be greater than the correlation between the indicator and other latent variables or by comparing the root square of AVE for each construct with the correlation value between constructs in the model. Good discriminant validity is indicated by the root square of AVE for each construct being greater than the correlation between constructs in the model. Based on the test results using SmartPLS 4.0 software, the following results were obtained:

Table 3. Cross Loading Test Results

Indicator	Modernization of Test Equipment	Analyst Competency	Excellent Service	Customer Satisfaction	Customer Loyalty
X1.1	0.769	0.485	0.419	0.501	0.496
X1.2	0.776	0.523	0.532	0.592	0.536
X1.3	0.871	0.654	0.551	0.644	0.665
X1.4	0.851	0.712	0.575	0.654	0.658
X1.5	0.710	0.608	0.386	0.465	0.495
X2.1	0.686	0.908	0.679	0.731	0.751
X2.2	0.680	0.911	0.632	0.696	0.710
X2.3	0.603	0.860	0.663	0.751	0.737
X2.4	0.683	0.897	0.684	0.737	0.721
X2.5	0.715	0.901	0.700	0.798	0.779
X3.1	0.568	0.567	0.804	0.740	0.667
X3.2	0.617	0.736	0.832	0.751	0.739
X3.3	0.466	0.631	0.848	0.710	0.704
X3.4	0.360	0.524	0.804	0.691	0.654
X3.5	0.560	0.636	0.844	0.710	0.728
Y.1	0.580	0.713	0.819	0.890	0.825
Y.2	0.668	0.734	0.752	0.886	0.829
Y.3	0.587	0.682	0.713	0.823	0.742

Indicator	Modernization of Test Equipment	Analyst Competency	Excellent Service	Customer Satisfaction	Customer Loyalty
Y.4	0.633	0.719	0.732	0.838	0.737
Y.5	0.693	0.782	0.793	0.930	0.830
Z.1	0.642	0.750	0.807	0.839	0.931
Z.2	0.703	0.801	0.770	0.819	0.918
Z.3	0.647	0.731	0.757	0.848	0.910

Source: Data processed using PLS software

Based on the data presented in table 4.11 above, it can be seen that each indicator in the research variable has the highest cross-loading value in the variable it forms compared to the cross-loading value in other variables. Based on the results obtained, it can be stated that the indicators used in this study have good discriminant validity in compiling their respective variables.

3. Reliability Test

In addition to the validity test, the construct reliability test is also carried out on the model measurement (outer model) with the aim of proving the accuracy, consistency and precision of the instrument in measuring the construct. In PLS, to measure the reliability of a construct with reflexive indicators, it can be done with a composite reliability test with the provision that if the construct has a composite reliability value greater than 0.7, it can be concluded that the manifest variable has good accuracy, consistency, and precision of the instrument in measuring the construct. The test results using SmartPLS 4.0 software are presented in the following table:

Table 4. Composite Reliability Test Results

Variable	Composite Reliability	*Cronbach's Alpha*	Description
Modernization of Test Equipment	**0.897**	**0.856**	Reliable
Analyst Competency	**0.953**	**0.938**	Reliable
Excellent Service	**0.915**	**0.884**	Reliable
Customer Satisfaction	**0.942**	**0.922**	Reliable
Customer Loyalty	**0.943**	**0.909**	Reliable

Source: Data processed using PLS software

Based on the table above, it can be seen that the Cronbach's alpha and composite reliability values generated by all constructs are very good, namely above 0.70. Therefore, it can be concluded that all construct indicators are reliable or in other words, all manifest variables of the five latent variables are proven to have accuracy, consistency, and precision of the instrument in measuring the construct properly.

Structural Model Measurement (Inner Model)

After testing or evaluating the measurement model, if it is fulfilled as shown in the outer model evaluation results, then further testing is carried out on the structural model. The structural model test includes goodness of fit test and hypothesis test (t-test). The goodness of a research model can be shown from the magnitude of the coefficient of determination (R-Square and Q Square), which is a number that shows the magnitude of the variation of the independent variable (exogenous) in influencing the dependent variable (endogenous). The closer to one, the better the model is considered. This study has two structural equations, namely: 1) the effect of modernization of test equipment, analyst competence and excellent

service on customer satisfaction; 2) the effect of modernization of test equipment, analyst competence, excellent service and customer satisfaction on customer loyalty, so that there are two R2 values.

1. Koefisien Determinasi (R^2)

The coefficient of determination (R-Square) is used to measure how much endogenous variables are influenced by other variables. Ghozali (2015) states that an R2 result of 0.67 and above for endogenous latent variables in structural models indicates the effect of exogenous variables (those that influence) on endogenous variables (those that are influenced) as being in the strong category. Meanwhile, if the result is 0.33–0.67, it is in the moderate category, and if the result is 0.19–0.33, it is in the weak category. Based on the data processing that has been carried out using the SmartPLS 4.0 program, the following R-Square values were obtained.

Table 5. Value of the Coefficient of Determination (R2 Test)

Laten Variable	R^2
Customer Satisfaction	0.841
Customer Loyalty	0.854

Source: Data processed using PLS software

Based on the table above, the R-square value from the analysis using SmartPLS software for the customer satisfaction variable is 0.841. This R2 value is in the "strong" category (greater than 0.67). This means that the goodness of model formation from customer satisfaction research can be well explained by the variables of test equipment modernization, analyst competence, and excellent service with a value of 84.1%, while the remaining 15.9% is explained by other variables outside the ones studied. Likewise, for the customer loyalty variable, an r-square of 0.854 was obtained. This R2 value is in the "strong" category (greater than 0.67). This means that the goodness of fit of the customer loyalty model is well explained by the variables of test equipment modernization, analyst competence, excellent service, and customer satisfaction with a value of 85.4%, while 14.6% is explained by other variables not included in the study.

2. Predictif – Relevance (Q^2)

Another test in structural measurement is Q2 predictive relevance, which serves to validate the model. The Q2 predictive result is said to be good if the value is > 0, which indicates that the exogenous latent variable is good (appropriate) as an explanatory variable capable of predicting the endogenous variable. In addition to looking at R-Squares, evaluation of the PLS model can be done with Q2 predictive relevance (Ghozali and Latan, 2015). A Q2 value of > 0 indicates that the model has predictive relevance, while a Q2 value of < 0 indicates that the model has less predictive relevance (Ghozali and Latan, 2015). Q2 values of 0.02, 0.15, and 0.35 can be interpreted as to whether the latent variable predictor has a weak, moderate, or strong influence at the structural level (Ghozali and Latan, 2015).

The predictive relevance value is obtained by the formula:

$$Q^2 = 1 – (1 – R_1^2) (1 – R_2^2) .... (1 – R_n^2)$$

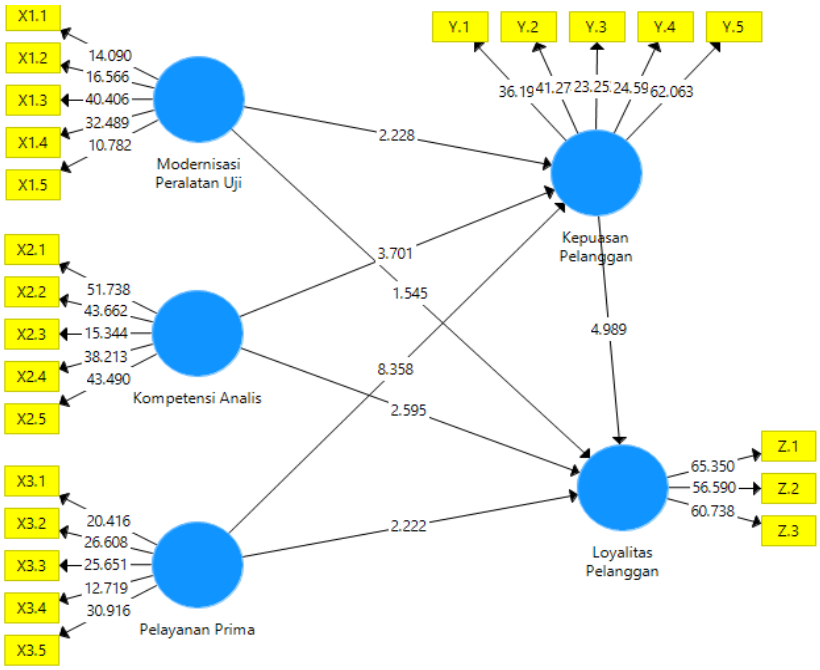
$$Q^2 = 1 – (1 – 0{,}841) (1 – 0{,}854)$$

$$Q^2 = 0{,}977$$

The result of the Q-Square calculation in this study is 0.977 > 0, indicating that the model has predictive relevance. This is because 97.7% of the exogenous variables, namely the modernization of test equipment, analyst competence, excellent service, and customer satisfaction in this study, are suitable for explaining the endogenous variable, namely customer loyalty. With this result, it is concluded that this model has relevant predictive value.

Hypothesis Test Results

Based on the data processing that has been carried out, the results can be used to answer the hypothesis in this study. The hypothesis test in this study was carried out by looking at the T-Statistics value. The research hypothesis can be declared accepted if the t-statistic value > 1.96 t-table. The following presents the bootstrapping test results to obtain the t-statistic value of the relationship between variables.



Source: Data processed using PLS software

Figure 2. Bootstrapping Test Results

The following is the result of the hypothesis test obtained in this study through the inner model test.

Table 6. Hypothesis Test Results

Hypothesis	Effect	Path Coefficient	T-Statistic	*P-values*	Decision
Direct Influence					
H1	Modernization of Test Equipment -> Customer Satisfaction	0.150	2.228	**0.026**	Accepted
H2	Analyst Competency -> Customer Satisfaction	0.306	3.701	**0.000**	Accepted
H3	Excellent Service -> Customer Satisfaction	0.549	8.358	**0.000**	Accepted
H4	Modernization of Test Equipment -> Customer Loyalty	0.083	1.545	**0.123**	Rejected
H5	Analyst Competency -> Customer Loyalty	0.177	2.595	**0.010**	Accepted
H6	Excellent Service -> Customer Loyalty	0.208	2.222	**0.027**	Accepted
H7	Customer Satisfaction -> Customer Loyalty	0.519	4.989	**0.000**	Accepted
Indirect Effect					

H8	Modernization of Test Equipment -> Customer Satisfaction -> Customer Loyalty	0.078	1.893	**0.059**	Rejected
H9	Analyst Competence -> Customer Satisfaction -> Customer Loyalty	0.159	3.115	**0.002**	Accepted
H10	Excellent Service -> Customer Satisfaction -> Customer Loyalty	0.285	4.182	**0.000**	Accepted

Source: Processed data (2025)

In this study, there are 7 direct effect hypotheses with detailed test results as follows:

H1: Modernization of Test Equipment Affects Customer Satisfaction

Hypothesis 1 explains the direct effect of test equipment modernization on customer satisfaction. By looking at the results of data processing in the table above, a path coefficient of 0.150 is obtained with a t-statistic value of 2.228 > 1.96 and a p-value of 0.026 < 0.05, thus H1 is accepted, meaning that the test equipment modernization variable has a significant effect on the customer satisfaction variable in the BBSPJIKFK testing laboratory.

H2: Analyst Competence Affects Customer Satisfaction

Hypothesis 2 explains the direct effect of analyst competence on customer satisfaction. By looking at the results of data processing in the table above, a path coefficient of 0.306 is obtained with a t-stat value = 3.701 > 1.96 and p-values of 0.000 < 0.05 so that H2 is accepted, this means that the analyst competence variable has a significant effect on the customer satisfaction variable in the BBSPJIKFK testing laboratory.

H3: Excellent Service Affects Customer Satisfaction

Hypothesis 3 explains the direct effect of excellent service on customer satisfaction. By looking at the results of data processing in the table above, a path coefficient of 0.549 is obtained with a t-stat value = 8.358 > 1.96 and p-values of 0.000 < 0.05 so that H3 is accepted, this means that the excellent service variable has a significant effect on the customer satisfaction variable in the BBSPJIKFK testing laboratory.

H4: Modernization of Test Equipment Affects Customer Loyalty

Hypothesis 4 explains the direct effect of test equipment modernization on customer loyalty. By looking at the results of data processing in the table above, a path coefficient of 0.083 is obtained with a t-stat value = 1.545 < 1.96 and a p-value of 0.123 > 0.05, thus rejecting H4. This means that the test equipment modernization variable has no effect on the customer loyalty variable in the BBSPJIKFK testing laboratory.

H5: Analyst Competence Affects Customer Loyalty

Hypothesis 5 explains the direct effect of analyst competence on customer loyalty. By looking at the results of data processing in the table above, a path coefficient of 0.177 is obtained with a t-stat value = 2.595 > 1.96 and a p-value of 0.010 < 0.05 so that H5 is accepted, this means that the analyst competence variable has a significant effect on the customer loyalty variable in the BBSPJIKFK testing laboratory.

H6: Excellent Service Affects Customer Loyalty

Hypothesis 6 explains the direct effect of excellent service on customer loyalty. By looking at the results of data processing in the table above, a path coefficient of 0.208 is obtained with a t-stat value = 2.222 > 1.96 and a p-value of 0.027 < 0.05, so H6 is accepted, this means that the excellent service variable has a significant effect on the customer loyalty variable in the BBSPJIKFK testing laboratory.

H7: Customer Satisfaction Affects Customer Loyalty

Hypothesis 7 explains the direct effect of customer satisfaction on customer loyalty. By

looking at the results of data processing in the table above, a path coefficient of 0.519 is obtained with a t-statistic value of 4.989 > 1.96 and a p-value of 0.000 < 0.05 so that H7 is accepted, this means that the customer satisfaction variable has a significant effect on the customer loyalty variable in the BBSPJIKFK testing laboratory.

Intervening or mediation occurs when the third mediator variable intervenes between two other related constructs. More precisely, changes in the exogenous construct cause changes in the mediator variable, which in turn result in changes in the endogenous construct in the PLS path model. Thus, the mediator variable regulates the nature (i.e., the underlying mechanism or process) of the relationship between the two constructs. Furthermore, testing the mediation effect in the analysis using PLS uses the procedure developed by Baron and Kenny (1998, in Ghozali and Latan, 2016) where the effect of the mediation variable on the endogenous variable is significant at a t-statistic > 1.96, then the mediation variable is proven to mediate the effect of the exogenous variable on the endogenous variable. In this study, there are 3 hypotheses of indirect influence with the following test results:

H8: The Effect of Test Equipment Modernization on Customer Loyalty through Customer Satisfaction

Hypothesis 8 explains the effect of customer satisfaction in mediating the modernization of test equipment on customer loyalty. By looking at the results of data processing in the table above, a path coefficient of 0.078 is obtained with a t-stat value = 1.893 < 1.96 and a p-value of 0.059 > 0.05 so that H8 is rejected, this means that the test equipment modernization variable has no effect on customer loyalty through customer satisfaction. This shows that customer satisfaction is unable to mediate (no mediation) the effect of test equipment modernization on customer loyalty in BBSPJIKFK testing laboratories.

H9: The Effect of Analyst Competence on Customer Loyalty through Customer Satisfaction

Hypothesis 9 explains the effect of customer satisfaction in mediating analyst competence on customer loyalty. By looking at the results of data processing in the table above, a path coefficient of 0.159 was obtained with a t-statistic value of 3.115 > 1.96 and a p-value of 0.002 < 0.05, so H9 is accepted. This means that the analyst competence variable has a significant effect on customer loyalty through customer satisfaction. This shows that customer satisfaction successfully and significantly mediates the effect of analyst competence on customer loyalty at the BBSPJIKFK testing laboratory.

H10: The Effect of Excellent Service on Customer Loyalty through Customer Satisfaction

Hypothesis 10 explains the effect of customer satisfaction in mediating excellent service on customer loyalty. By looking at the results of data processing in the table above, a path coefficient of 0.285 is obtained with a t-statistic value of 4.182 > 1.96 and a p-value of 0.000 < 0.05, thus H10 is accepted, meaning that the excellent service variable has a significant effect on customer loyalty through customer satisfaction. This shows that customer satisfaction successfully and significantly mediates the effect of excellent service on customer loyalty at the BBSPJIKFK testing laboratory.

Discussion

The Effect of Test Equipment Modernization on Customer Satisfaction

The modernization of laboratory testing equipment technology plays an important role in improving operational efficiency and customer satisfaction. The results show that the modernization of testing equipment has a positive and significant effect on customer satisfaction at BBSPJIKFK, in line with research by Oktapia and Faisal (2022) and Nurhikmah and Fasa (2024), which confirms that technological progress and digital transformation increase customer satisfaction.

The application of modern test equipment makes test results more accurate, precise, and fast, thus speeding up service time and reducing customer waiting time. Data shows that of the 123 test groups, 119 groups have used modern equipment, while 4 groups still use manual equipment. Meanwhile, calibration laboratories still fully use manual equipment for 99 test groups.

This modernization allows laboratories to provide test results that are more efficient and in line with customer expectations, support service development, and increase testing productivity. Therefore, BBSPJIKFK needs to continue updating technology to take advantage of the latest innovations, to ensure better accuracy, speed, and efficiency of testing in the future.

The Influence of Analyst Competence on Customer Satisfaction

Analyst competence includes the knowledge, skills, and professional attitude required to carry out tasks in a testing laboratory. The results show that analyst competence has a positive and significant effect on customer satisfaction at BBSPJIKFK, in line with the research of Tamba (2021) and Widyastuti et al. (2020), which states that the competence of employees and tutors affects customer satisfaction.

Customers give a positive response to the ability of analysts to operate modern technology, work professionally, and complete tests on time. Competent analysts can improve the precision, productivity, and quality of testing and calibration results, which are the main factors in maintaining customer satisfaction.

BBSPJIKFK needs to continue to adapt to technological developments and improve the competence of analysts through training and skills development in order to compete with other laboratories. Optimizing the use of technology in the laboratory industry also contributes to increasing the efficiency, productivity, and competitiveness of BBSPJIKFK in the testing services industry.

The Effect of Excellent Service on Customer Satisfaction

Excellent service is the maximum effort made by an organization to ensure that customers are satisfied with the service provided. The results show that excellent service has a positive and significant effect on customer satisfaction at BBSPJIKFK, in line with the research of Pane and Lubis (2024), Subawa and Sulistyawati (2020), Hidayat et al. (2015), Haryono (2017), and Rasyid (2017), who emphasized that service quality has a direct impact on customer satisfaction.

Descriptive analysis shows that customers are very satisfied with the friendliness of BBSPJIKFK services, the clarity of information regarding service time and costs, and the reliability in completing testing and calibration according to the promised schedule. BBSPJIKFK continues to strive to provide excellent service based on clear standards, so that there is a common understanding between customers and service providers.

These service standards benefit customers by providing a guarantee of service quality, while for BBSPJIKFK, these standards serve as a tool for communication, performance measurement, and monitoring and evaluation. In addition, the customer feedback mechanism in the service standards helps BBSPJIKFK understand customer needs and continuously improve service quality on an ongoing basis.

The Effect of Test Equipment Modernization on Customer Loyalty

Test equipment modernization reflects the acceptance of technological innovations, such as the use of more sensitive sensors, advanced data analysis software, and non-destructive testing techniques. However, the results show that the modernization of test equipment has no significant effect on customer loyalty at BBSPJIKFK. This is in line with the research of Rahman et al. (2021) which states that innovation does not always have an impact on customer

loyalty, but contradicts the research of Harshini et al. (2024) and Rasyid (2017) which states that the utilization of technology can increase customer loyalty.

This lack of influence is due to the high level of competition in the testing laboratory industry, where customers have many alternative services that offer lower costs, faster test results, or other advantages. Although the modernization of test equipment improves accuracy and efficiency, customers consider cost factors, reliability of results, and speed of service more when choosing a laboratory.

Customer loyalty can only be increased if the modernization of test equipment at BBSPJIKFK is able to produce more accurate, faster, more precise, and more efficient test results than competitors. Therefore, further investment in more competitive modern test equipment is needed to increase competitiveness and maintain customer loyalty.

The Influence of Analyst Competence on Customer Loyalty

Analyst competence includes the knowledge, skills, and professional attitude required in laboratory testing. The results show that analyst competence has a positive and significant effect on customer loyalty at BBSPJIKFK, in line with the research of Widyastuti & Sutrisno (2020) and Jati (2009), which states that workforce competence affects customer loyalty.

The higher the competence of the analyst, the more likely it is that customers will return to use BBSPJIKFK services. Analysts who have flexibility, work ethic, and the ability to collaborate in a team are able to improve the productivity, quantity, and quality of testing services. This competence includes an understanding of laboratory procedures, basic testing techniques, equipment calibration, and skills in analyzing data and solving problems.

However, there is currently an imbalance in the level of analyst competence, with most having mastered test methods and equipment operations, while others still rely on specific analysts for specific parameter testing. Therefore, a larger budget allocation for education and training is needed so that all analysts have equal competence.

Improving analyst competence is also an important requirement in the face of test equipment modernization, so that testing can be done faster, more accurately, and with more precision. With better competence, BBSPJIKFK can increase customer loyalty through more reliable and professional services.

The Effect of Excellent Service on Customer Loyalty

Excellent service is the best service provided to customers based on established standards and procedures. The results show that excellent service has a positive and significant effect on customer loyalty at BBSPJIKFK, supporting the research of Subawa & Sulistyawati (2020), Jati (2009), Hidayat et al. (2015), and Rasyid (2017), who state that service quality has a direct impact on customer loyalty.

Customers who are satisfied with BBSPJIKFK services tend to return to use laboratory services and recommend them to colleagues. Therefore, BBSPJIKFK needs to improve its responsiveness in responding to customer complaints and optimize digital access, such as websites to monitor testing progress.

To increase customer loyalty, service quality must be improved at all stages of service, from registration, testing, to the issuance of Test Result Reports (LHU). In addition, support from other divisions, such as the procurement of chemicals and consumables, is also important to avoid testing delays that can affect customer satisfaction. With more efficient and responsive service, customer loyalty to BBSPJIKFK can continue to be improved.

The Influence of Customer Satisfaction on Customer Loyalty

Customer satisfaction occurs when customer needs and expectations are properly met. The results show that customer satisfaction has a positive and significant effect on customer

loyalty at BBSPJIKFK, supporting the research of Pradana & Ahmad (2023) and Rasyid (2017), which states that customer satisfaction contributes to increased loyalty.

Customers who are satisfied with BBSPJIKFK services tend to continue using laboratory services repeatedly. Factors that increase customer satisfaction include modernization of test equipment, competence of analysts in operating modern equipment, and excellent service which includes ease of digital access, timeliness of test results, and responsiveness to customer complaints.

However, customer satisfaction can decrease if there are delays in service, especially when customers make complaints but they are not immediately handled due to personnel limitations. Therefore, BBSPJIKFK needs to ensure that there is a work system in place that allows other officers to handle the duties of colleagues who are not on duty, so that testing results are still completed on schedule. By maintaining and improving customer satisfaction, customer loyalty to BBSPJIKFK's testing and calibration services can be maintained.

The Effect of Test Equipment Modernization on Customer Loyalty Through or Mediated by Customer Satisfaction

Customer satisfaction is a key factor in business success and plays a role in building a harmonious relationship between the company and the customer. However, the results of the study show that test equipment modernization has no effect on customer loyalty, either directly or through customer satisfaction as a mediating variable. In other words, the level of customer satisfaction does not change the effect of test equipment modernization on customer loyalty.

Although the modernization of test equipment improves the accuracy, speed, and efficiency of services, this is not enough to maintain customer loyalty. The challenge for BBSPJIKFK is how to ensure that this modernization is well socialized to customers, so that they really feel the benefits. In addition, competition with other testing laboratories that are able to provide faster and more efficient services is also a factor that influences customer loyalty.

Customers are more focused on timely test results as promised by the service, not on the technology used. Therefore, modernization must be optimized in daily operations so that it can provide real added value for customers. Thus, BBSPJIKFK needs to ensure that modernization is effective, efficient, and relevant to customer demands and the testing laboratory industry competition.

The Influence of Analyst Competence on Customer Loyalty Through or Mediated by Customer Satisfaction

The competence of analyst officers plays an important role in creating customer satisfaction, which ultimately has an impact on customer loyalty to BBSPJIKFK testing laboratory services. The results showed that analyst competence has a significant effect on customer loyalty through customer satisfaction as a mediating variable.

The analysis shows that customer satisfaction mediates partially (partial mediation) and is complementary, meaning that both the direct and indirect effects of analyst competence on customer loyalty have the same direction, which is positive and significant. Customers who are satisfied with the analyst's expertise in operating modern equipment, reading and analyzing data, and drawing conclusions from test results are more likely to remain loyal to BBSPJIKFK services.

This finding emphasizes the importance of improving analyst competence through continuous training, especially in the use of modern laboratory equipment and data analysis, to increase customer satisfaction and loyalty to the BBSPJIKFK laboratory.

The Effect of Excellent Service on Customer Loyalty Through or Mediated by Customer Satisfaction

Excellent service aims to provide the best service to customers to create satisfaction and a memorable experience. The implementation of excellent service includes a professional attitude, concern for customers, quick response to complaints, and utilization of technology to improve customer comfort.

The results showed that excellent service has a significant effect on customer loyalty through customer satisfaction as a mediating variable. Customer satisfaction is proven to mediate partially (partial mediation) and is complementary, where both the direct and indirect effects of excellent service on customer loyalty have the same direction, which is positive and significant.

Customers who are satisfied with friendly, responsive, and professional service tend to have higher loyalty to the BBSPJIKFK testing laboratory. Therefore, all employees at BBSPJIKFK must continue to improve the quality of service by being polite, understanding customer needs, giving full attention, and providing the right information and services. With optimal service excellence, customer satisfaction and loyalty can continue to increase.

CONCLUSION

The results showed that the modernization of test equipment, analyst competence, and excellent service have a positive and significant effect on customer satisfaction at BBSPJIKFK. Customers feel more satisfied when testing and calibration services are carried out with precise modern equipment, highly competent analysts, and responsive and professional excellent service.

However, the modernization of test equipment has no effect on customer loyalty because customers are more focused on accurate and timely test results than on the technology used. On the other hand, analyst competence and excellent service have a significant effect on customer loyalty, both directly and through customer satisfaction as a mediating variable.

The advice for BBSPJIKFK is to continue modernizing test equipment by considering the efficiency of maintenance costs and improving analyst competence so as to be able to operate modern equipment to the maximum. In addition, digital services need to be improved, especially in website accessibility and online communication, so that customers can more easily monitor the service process. Improving the quality of excellent service through ease of access, fast response, and the application of digital technology is expected to increase customer satisfaction and loyalty to BBSPJIKFK services.

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