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Jurnal Sains dan Aplikasi Keilmuan Teknik Industri (SAKTI) is the official publication of the Industrial Engineering Universitas Ma Chung, with an ISSN of 2829-8519 for print and 2829-8748 for electronic versions. Its logo features water, a gear-shaped sun, and nature, with water symbolizing adaptability and a source of life, the sun representing hope, and nature representing the natural world and its living beings. The journal aims to promote ethical research in industrial engineering and engineering management that is constantly evolving and adaptable, with the goal of benefiting all living things, especially in Indonesia. Within the journal, readers can document their ideas, observations, and experiments related to industrial engineering and sustainable practices. Whether developing new systems or analyzing existing ones, SAKTI aims to be a companion in the pursuit of efficiency, productivity, and environmental responsibility.

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Improving Machine Efficiency at PT PID Ongkowidjojo: OEE and FMEA Analysis Leading to Significant Gains in Primary Stage 3

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Abstract. This study aims to enhance equipment effectiveness in the primary cigarette manufacturing process at PT. PID Ongkowidjojo, focusing on Stage 3, a critical production phase with significant downtime due to equipment failures. Using Overall Equipment Effectiveness (OEE) and Failure Mode and Effects Analysis (FMEA), the research identified nine key failure modes affecting interconnected machines. Based on these findings, targeted improvements were implemented, including scheduled maintenance, real-time monitoring, periodic cleaning, and spare parts inventory management. As a result, the OEE value increased from 50.52% to 56.57%, driven by improvements in Availability (71.07% to 79.22%) and Quality Rate (92% to 93.36%), despite a slight decline in Performance Rate (77.20% to 76.25%). This study highlights the importance of integrating OEE and FMEA methodologies to reduce downtime and address equipment inefficiencies. By tackling the Six Big Losses, particularly equipment failures, this approach offers actionable insights for maintaining operational efficiency and fostering continuous improvement in manufacturing systems.

Keywords: Cigarette primary processing; Equipment effectiveness; Failure Mode and Effect Analysis (FMEA); Six big losses; Overall Equipment Effectiveness (OEE)

1. Introduction

The effectiveness of equipment or machinery is critical in ensuring the smooth operation of production processes. In manufacturing industries, three primary factors often disrupt production: machinery, environment, and human factors, which are interconnected and can influence each other (Triwardani et al., 2017). Addressing these factors is essential to maintaining production efficiency and meeting operational goals.

In the cigarette manufacturing process, production is divided into two key stages: the primary and secondary processes. The primary process involves blending tobacco and cloves into a mixture ready for rolling, serving as the foundation of cigarette production. This stage is crucial as it determines the flavor and quality of the final product (Kurniarso & Azwir, 2014). Inefficiencies or delays in the primary process can disrupt the entire production cycle, emphasizing the need for optimized machine performance.

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Downtime is a critical metric for evaluating machine effectiveness, as non-operational machines result in wasted production time (Exor, 2013). Downtime is categorized into two types: setup and adjustment downtime, which occurs during machine configuration changes, and equipment failure, caused by mechanical breakdowns (Nurwulan & Fikri, 2020). Addressing downtime is essential to improving machine availability and overall production efficiency. Table 1 presents the data on equipment failure time for the primary process.

Table 1 Data on Equipment Failure in the Primary Process

Primary Process	April	May	June	Total
Stage 1	0	0	0	0
Stage 2	0	2.210	1.930	4.140
Stage 3	2.570	4.920	2.405	9.895
Clove	1.301	2.485	2.610	6.396
Total Equipment Failure Time				20.431

Source: Processed Data

Between April and June 2023, the primary cigarette manufacturing process at PT. PID Ongkowidjojo experienced significant downtime, totaling 20,431 minutes. Among the stages, Stage 3 recorded the highest equipment failure time at 9,895 minutes, surpassing Stages 1 and 2. As Stage 3 is the initial stage of the primary process, frequent equipment failures here disrupt downstream production activities and highlight low machine effectiveness.

To address this issue, the study applies Overall Equipment Effectiveness (OEE) and Failure Mode and Effects Analysis (FMEA) methodologies. OEE is a widely recognized tool for evaluating and enhancing machine performance to meet world-class standards (Saw Shu Zhen et al., 2024). Meanwhile, FMEA is a systematic approach to identifying and mitigating potential failure modes, as demonstrated in prior studies (Fadhlullah et al., 2024; Pramono et al., 2024). By integrating these methods, this research aims to reduce equipment downtime, improve machine performance, and provide actionable insights for optimizing the primary cigarette manufacturing process.

2. Methods

The methods to be used to improve the machine effectiveness in Stage 3 of the primary process at PT PID Ongkowidjojo are the Overall Equipment Effectiveness (OEE) and Failure Modes and Effect Analysis (FMEA) methods. The OEE method is employed to measure machine effectiveness based on the factors of Availability, Performance Rate, and Quality Rate, which together yield the OEE value. The OEE value will be analyzed based on the Six Big Losses that have the most significant impact. The most influential factors among the Six Big Losses will be analyzed using the FMEA method, which is expected to minimize downtime in Stage 3 and enhance overall machine effectiveness.

2.1 Overall Equipment Effectivess (OEE)

Overall Equipment Effectiveness (OEE) is a tool used to identify the potential within equipment as well as to identify and track losses (Stamatis, 2010). OEE can be utilized to enhance the effectiveness of machinery or equipment, as well as to empower operators to perform routine activities that also boost productivity and responsibility (Nakajima, 1988). OEE is widely accepted as a tool to measure and evaluate the productivity of production processes.

OEE is divided into three measurement metrics: Availability, Performance, and Quality. The calculation of OEE is done by multiplying the values of equipment availability, work performance, and product quality rate (Pranowo, 2019), as shown in Equation 1.

$$OEE(\%) = Availability \times Performance\ rate \times Quality\ rate \quad (1)$$

2.1.1. Six Big Losses

The Six Big Losses reduce equipment or machinery performance and are categorized into downtime, speed, and defect losses. Downtime losses include breakdowns (unplanned stoppages

due to equipment failure) and setup/adjustment time. Speed losses cover idling and minor stoppages (short production halts) and reduced speed (operating below capacity). Defect losses involve defects in process (production of defective items) and reduced yield (producing fewer good products from raw materials) (Alriva et al., 2015).

2.1.2 Availability

Availability measures the time a machine is available for operation. It is influenced by equipment failure and setup and adjustment losses from the Six Big Losses, meaning it directly impacts downtime losses.

$$Availability = \frac{Loading\ time - Downtime\ Losses}{Loading\ Time} \times 100\% \quad (2)$$

2.1.3 Performance Rate

The performance rate describes the ability of a machine or equipment to produce goods. It is affected by idling and minor stoppage losses and reduced speed, which are two factors from the Six Big Losses.

$$Performance\ Rate = \frac{Processed\ Amount \times Ideal\ Cycletime}{Operating\ time} \times 100\% \quad (3)$$

2.1.4 Quality Rate

The quality rate represents the machine's ability to produce products that meet standards. It is influenced by two types of losses: defects in process and reduced yield (Ariyah, 2022).

$$Quality\ Rate = \frac{Processed\ Amount - Number\ of\ defect}{Processed\ Amount} \times 100\% \quad (4)$$

2.2 Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effects Analysis (FMEA) is utilized as a tool for identifying and eliminating potential failures or damages. The identification of these failures encompasses mechanisms, impacts, likelihoods, prevention strategies, and methods for detection (Nurkertamanda and Wulandari, 2009). The application of FMEA is employed to analyze manufacturing and assembly processes, as well as product design prior to mass production (Wawolumaja and Muis, 2013). To facilitate the FMEA process, a worksheet in the form of a table is utilized. Within it, there is a list of failure modes of the process under analysis, a list of impacts from losses should they occur, S-scale value, O-scale value, D-scale value, calculated RPN value, RPN value category, and preventive actions (Alijoyo, 2017).

3. Results and Discussion

In Figure 1, the tobacco processing process is depicted at stage 3 of the primary process at PT PID Ongkowidjojo. This stage involves several machines: Slicer, Conditioning, Trasher 1, Separator 1, Trasher 2, Separator 2, RC4, Dryer, SILO, interconnected by a conveyor. Tobacco is initially processed through the slicer machine for cutting, then transferred to the conditioning machine for humidification. After humidification, the tobacco undergoes disintegration and separation of Non-Tobacco Related Materials (NTRM) from the tobacco by the trasher and separator machines. The subsequent process involves shredding by the RC4 machine. Once shredded, the tobacco is moved to the dryer machine for drying. Finally, the tobacco is sent to the SILO for blending before being packed into bags and stored. Processed tobacco from stage 3 continues to stage 1 for further refinement processes.

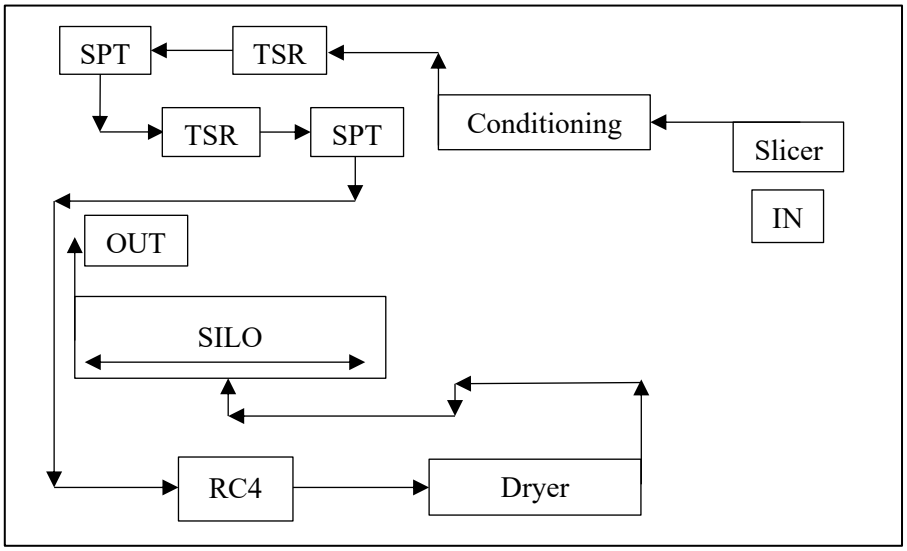

Figure 1 Stage 3 of Tobacco Processing

The tobacco processing stage 3 consists of nine interconnected machines. Therefore, if any one machine experiences a malfunction and stops, it will result in a complete shutdown of all machines. Hence, the machine uptime data collected represents the entirety of stage 3. Table 2 presents the calculation of Overall Equipment Effectiveness (OEE) data before improvement from April to October 2023.

Table 2 The Average OEE Values Before The Improvements

Months	Availability	Performance Rate	Quality Rate	Nilai OEE
April	70.74%	78.16%	93.03%	51.44%
May	71.54%	78.64%	92.81%	52.21%
June	68.96%	74.45%	88.19%	45.28%
July	70.55%	74.94%	90.93%	48.08%
August	73.85%	79.08%	92.36%	53.93%
September	70.92%	78.09%	93.19%	51.61%
October	70.91%	77.06%	93.50%	51.09%
Average	71.07%	77.20%	92.00%	50.52%

The average OEE value for stage 3 from April to October 2023 was 50.52%, with an Availability value of 71.07%, Performance Rate of 77.20%, and Quality Rate of 92.00%. Among the three ratios comprising the OEE, the Availability ratio had the lowest average, at 71.07%. This ratio is influenced by two aspects within the Six Big Losses framework: equipment failure and setup and adjustment. A comparison of these two types of losses is presented below, along with loading time data from April 2023:

$$Equipment\ Failure\ Losses = \frac{Equipment\ Failure\ Time}{Loading\ Time} \times 100\% \quad (5)$$
$$= \frac{2570}{13860} \times 100\%$$
$$= 18.54\%$$

$$Set\ up\ and\ Adjustment = \frac{Set\ up\ and\ Adjustment}{Loading\ Time} \times 100\% \quad (6)$$
$$= \frac{1485}{13860} \times 100\%$$
$$= 10.71\%$$

Based on the above ratio calculations, Equipment failure accounts for the highest loading time, totaling 18.54%. This indicates that 18.54% of the loading time is spent on machine repairs. This figure is higher compared to the time allocated for setup and adjustment, which stands at 10.71%. Therefore, it can be concluded that the Six Big Losses factor most significantly impacting Overall Equipment Effectiveness (OEE) is equipment failure.

Equipment failure occurs when machines break down, halting production entirely. The causes of equipment failure for each machine in stage 3 will be detailed in the Failure Mode and Effects Analysis (FMEA). This FMEA focuses on failure modes that could occur in each machine within stage 3, where each machine represents a tobacco processing process. The FMEA data is based on direct observations in stage 3 and interviews with two experienced machine supervisors and operators.

The FMEA for the tobacco processing machines identifies several potential failures, including malfunctioning limit switches, worn-out or broken knives, hydraulic system issues, incorrect conditioning settings, and electrical supply disturbances. These failures can cause significant operational disruptions, such as ineffective cutting or shredding of tobacco, machine downtime, and improper moisture levels in the tobacco. The analysis highlights the need for regular inspections, timely maintenance, and the availability of spare parts to mitigate these risks. Recommended actions include scheduling regular machine checks, cleaning key areas, lubricating bearings, and conducting inspections by mechanical and electrical teams to ensure optimal machine performance and minimize downtime.

Out of these suggestions aimed at reducing downtime, four were implemented in stage 3 of the primary process at PT PID Ongkowidjojo: regular machine checks, periodic machine cleaning, continuous monitoring during operation, and repairs conducted by vendors. Following the implementation in stage 3, a new OEE value measurement was conducted. Table 3 presents the calculated OEE values from November to January 2024.

Table 3 The Average OEE Values After The Improvements

Months	Availability	Performance Rate	Quality Rate	OEE
November	79.47%	76.44%	94.03%	57.12%
December	77.41%	75.47%	92.63%	54.61%
January 2024	80.78%	76.83%	93.42%	57.97%
Average	79.22%	76.25%	93.36%	56.57%

The average OEE value before improvements was 50.52%, and after the improvements, it increased to 56.57%. The average Availability ratio improved from 71.07% to 79.22%, while the Performance Rate decreased from 77.20% to 76.25%, and the Quality Rate increased from 92% to 93.36%. Based on these comparisons, it can be concluded that the research successfully increased the average Overall Equipment Effectiveness.

The proposals that had the highest impact on improving OEE were regular machine checks and periodic thorough machine cleaning. Previously, machines in stage 3 were only checked when they malfunctioned and required repairs. With the implementation of regular machine checks, operators now inspect machines before use. If any machine issues are detected, repairs can be conducted on the same day or scheduled for weekends. During this implementation, the average downtime decreased compared to before. Furthermore, weekly maintenance also contributed to better operation of the machines in stage 3, thereby increasing machine effectiveness.

4. Conclusions

The study initially identified a low Overall Equipment Effectiveness (OEE) of 50.52% from April to October 2023, primarily due to equipment failure, a key factor among the Six Big Losses. Using Failure Mode and Effect Analysis (FMEA) at stage 3, recommendations were developed, including regular inspections, scheduled repairs, continuous monitoring, thorough cleaning, periodic electrical checks, and maintaining spare parts. Implementation focused on proactive

scheduling of repairs based on real-time observations before production, managed by stage 3 supervisors with the mechanical division.

Following these interventions, OEE for November 2023 to January 2024 increased significantly to 56.57%, alongside improvements in availability (79.22%), performance (76.25%), and quality (93.36%) metrics. This underscores the effectiveness of the implemented strategies in enhancing primary stage 3 processes. Continuous evaluation is crucial to sustain and further improve these gains.

Future research at PT PID Ongkowidjojo should prioritize ongoing maintenance of stage 3 machinery, expanding FMEA application beyond the Six Big Losses to improve OEE, and conducting thorough OEE assessments across all sections to optimize process efficiency. These efforts are essential for enhancing operational effectiveness and productivity in the organization.These recommendations aim to guide future research and support ongoing efforts in improving manufacturing efficiency through effective maintenance and process optimization strategies.

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Optimization of Tobacco Warehouse Temperature to Reduce Defects in Hand-Rolled Kretek Cigarette Products at PT XYZ

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Abstract. The quality of tobacco is a critical component in cigarette production, with moisture content standards ranging from 18% to 19% to prevent production issues caused by tobacco being too dry or too moist. At PT XYZ, a cigarette manufacturing company, storage room temperature was identified as a key factor affecting tobacco moisture content. This study aimed to determine the optimal storage room temperature to maintain tobacco quality using quality control techniques and experimental design. A correlation test revealed a very strong negative relationship (91.812%) between storage room temperature and tobacco moisture content. Using a Completely Randomized Design (CRD) and a one-way ANOVA test, the analysis showed that the storage room temperature significantly impacted moisture content. The optimal temperature for maintaining tobacco quality was found to be 21˚C. These findings underscore the importance of precise temperature control in ensuring tobacco quality, contributing to improved production processes and product consistency in the cigarette industry.

Keywords: Correlation; One-Way ANOVA; Optimization; Warehouse Temperature

1. Introduction

PT XYZ is a cigarette company established in 1946 in East Java, Indonesia. It is known as the oldest producer of hand-rolled kretek cigarettes. The manual rolling process requires workers to meet standards such as weight, diameter, density, and appearance of the cigarettes. The factors that influence the occurrence of defective and damaged products in the production process include human factors, machinery, and raw materials (Suharyanto *et al*., 2022). The main raw material for cigarette production is tobacco. The quality of raw materials is determined by obtaining materials from nature or from suppliers that have been quality-tested (Erdi & Haryanti, 2023). One of the problems with tobacco in PT XYZ was that the moisture content of the tobacco did not meet the established standard. The moisture content that is above or below the standard can cause a decrease in cigarette quality. One of the factors that influences the moisture content of the tobacco at PT XYZ was the temperature of the tobacco storage room.

Therefore, the research was conducted to address the issue of tobacco moisture content due to temperature factors, using quality control techniques and experimental design. Experimental

design involves conducting activities by applying treatments to an object to determine the effect of these treatments on other factors under controlled conditions (Sugiyono, 2012). The research used an experimental design with the One-Way ANOVA method. The Analysis of Variance (ANOVA) is a test that can be used to analyze the differences among more than two independent population groups (Rahmawati & Erina, 2020). ANOVA was used to find the optimal setting level to minimize variation deviations. One-Way ANOVA is an analysis of variance that results from the effect of a single factor (Rahmattulah & Khaerudin, 2020).

2. Method

The research method conducted at PT. XYZ involves specific steps. The data used consists of primary data. Primary data was obtained through field observations, research, and interviews with the Quality Control department. The steps for problem-solving in this research are as follows.

2.1. Correlation Test

The correlation test is used to find evidence of whether there is a correlation between variables, to assess the strength of the relationship between variables, and to gain clarity and certainty about whether the relationship is significant or not (Wulansari, 2019). If the correlation coefficient is close to the value of one, the correlation between the two variables will be stronger (Morris, 2020). The variables tested in this research were warehouse temperature and tobacco moisture content. Correlation analysis is a statistical method used to determine the magnitude that indicates a strong relationship between one variable and another (Uma & Roger, 2016). The formula for the correlation coefficient can be seen in formula (1) to (4).

1. $r = \frac{s_{xy}}{\sqrt{s_{xx} s_{yy}}}$ (1)
2. $s_{xx} = \sum x^2 - (\frac{(\sum x^2)}{\text{Number of data points x}})$ (2)
3. $s_{yy} = \sum y^2 - (\frac{(\sum y^2)}{\text{Number of data points y}})$ (3)
4. $s_{xy} = \sum xy - (\frac{(\sum x)(\sum y)}{\text{Number of data points xy}})$ (4)

2.2. Determining Factors and Levels of Experimental Factors

The factors and levels of experimental factors were determined to identify the factors and levels that would be used for the experiment with the assistance of the Quality Control department of PT. XYZ.

2.3. Creating Randomization and Layout of Completely Randomized Design Experiment

Completely Randomized Design (CRD) is the simplest design among standardized experimental designs (Riadi et al., 2021). The creation of the layout of the CRD experiment begins with determining the number of factors, levels, and replications. Next is the randomization stage. This design is called "randomized" because each experimental unit has an equal chance of receiving a treatment, and it is referred to as "completely" because all treatments planned in the experiment are utilized (Hasdar *et al.*, 2021). Randomization can be done by drawing lots or using random number tables.

2.4. One-Way ANOVA

ANOVA stands for Analysis of Variance, which is a statistical analysis used to test the differences in means among more than two populations. ANOVA that used a single factor is called One-Way ANOVA (Suharjo, 2008). The final result of the ANOVA analysis was the computed F value. This computed F value was then compared with the value in the F table. If the computed F value was greater than the F table value, it could be concluded that the null hypothesis (H0) was rejected and the alternative hypothesis (H1) was accepted, indicating a significant difference in means among all groups. ANOVA calculations were performed using Minitab version 19 application.

2.5. Fisher's Least Significant Difference (LSD) Test

After the ANOVA calculation was performed, it was followed by the Fisher's LSD test. The Fisher's LSD test was used to test the differences among the means of the simplest and most commonly used treatments (Rahmadeni et al., 2019). This test also utilized the Minitab version 19 application.

3. Results and Discussion

3.1. Measurement of Correlation between Warehouse Temperature and Tobacco Moisture Content

Based on the brainstorming conducted with the Quality Control department, one factor that could influence the moisture content of tobacco was identified as the temperature of the tobacco warehouse. Before the research was conducted, it was necessary to provide evidence to determine whether there was a correlation between the warehouse temperature and the tobacco moisture content. Room temperature and tobacco moisture content data in SKT for 30 days is shown in Table 1.

Table 1 Room Temperature and Tobacco Moisture Content in SKT

No	Date	Tobacco Room Temperature (˚C)	Tobacco Moisture Content (%)
1	14 August 2023	30,3 ˚C	17,6%
2	15 August 2023	31,5 ˚C	17%
3	16 August 2023	30,9 ˚C	17,3%
4	18 August 2023	31,7 ˚C	16,9%
5	19 August 2023	31,9 ˚C	16,7%
6	21 August 2023	31,7 ˚C	16,8%
7	22 August 2023	31,8 ˚C	16,9%
8	23 August 2023	32,7 ˚C	15,8%
9	24 August 2023	32,6 ˚C	16,2%
10	25 August 2023	32,4 ˚C	16,6%
11	26 August 2023	32,1˚C	16,7%
12	28 August 2023	32,7˚C	15,9%
13	29 August 2023	32,1˚C	16,8%
14	30 August 2023	32,2˚C	16,8%
15	31 August 2023	32,8˚C	15,5%
16	1 September 2023	30,3˚C	17,4%
17	2 September 2023	30,4˚C	17,2%
18	4 September 2023	31,5˚C	16,9%
19	5 September 2023	31,2˚C	17%
20	6 September 2023	30,9˚C	17,1%
21	7 September 2023	30,5˚C	17,5%
22	8 September 2023	30,6˚C	17,3%
23	9 September 2023	30,4˚C	17,4%
24	11 September 2023	29,6˚C	17,7%
25	12 September 2023	29,4˚C	17,8%
26	13 September 2023	31,5˚C	16,8%
27	14 September 2023	31˚C	17%
28	15 September 2023	31,7˚C	16,5%
29	16 September 2023	30,7˚C	17,1%
30	18 September 2023	31,6˚C	16,7%

Based on Table 1, the correlation between warehouse temperature and tobacco moisture content was calculated. The correlation was as follows:

1. Sxx

$$Sxx = \sum x^2 - \left(\frac{(\sum x)^2}{Number\ of\ data\ point\ x}\right)$$
$$Sxx = \sum 29521{,}61 - \left(\frac{(940{,}7)^2}{30}\right)$$
$$Sxx = 24{,}39367$$

2. Syy

$$Syy = \sum y^2 - \left(\frac{(\sum y)^2}{Number\ of\ data\ point\ y}\right)$$
$$Syy = \sum 8573{,}31 - \left(\frac{(506{,}9)^2}{30}\right)$$
$$Syy = 8{,}389667$$

3. Sxy

$$Sxy = \sum xy - \left(\frac{(\sum x)(\sum y)}{Number\ of\ data\ point\ xy}\right)$$
$$Sxy = \sum 15881{,}56 - \left(\frac{(940{,}7)(506{,}9)}{30}\right)$$
$$Sxy = -13{,}1343$$

4. r

$$r = \frac{Sxy}{\sqrt{Sxx\ Syy}}$$
$$r = \frac{-13{,}1343}{\sqrt{(24{,}39367)(8{,}389667)}}$$
$$r = -0{,}91812$$

Based on the calculation, the value of r was -0.91812 or -91.812%, indicating a negative correlation between warehouse temperature and tobacco moisture content by 91.812% (very strong). The negative correlation indicated that as the temperature of the tobacco storage warehouse increased, the tobacco moisture content decreased.

3.2. Experimental Planning

Experimental planning was carried out as the initial stage or preparation stage in the Experimental Design method. This initial stage was crucial to ensure the smooth execution of the experiment. Several steps were involved in experimental planning, starting from data collection to creating the layout of the experiment using the Completely Randomized Design (CRD) method.

3.3. Determining Experimental Factors

The determination of experimental factors aimed to identify which factors would be used for the experiment. After discussing with the Quality Control department of PT. XYZ, it was found that one factor influencing the moisture content of tobacco was the temperature of the tobacco warehouse. If the temperature of the tobacco storage room rose, the moisture content of the tobacco would decrease, leading to dry tobacco that was difficult to process into cigarettes. Dry tobacco could also cause defects in cigarettes.

3.4. Creating Factor Levels

At this stage, levels or parameters were established for the factors determined in the previous stage. The determination of levels was done with the assistance of the Quality Control department of PT. XYZ. The factor levels that had been established could be seen in Table 2.

Table 2 Experimental Factor Levels

Factor	Levels		
	1	2	3
Warehouse Temperature	18˚ C	21˚ C	24˚ C

From Table 2, it could be seen that there were three levels to be used for the experiment. Each level represented the AC temperature to be used in the experiment to observe its effect on tobacco moisture content. These levels were chosen assuming that if the temperature was too cold or too hot, it would cause a decrease in tobacco moisture content, resulting in dry tobacco. Therefore, the selection of the appropriate temperature level was crucial to maintain the tobacco moisture content according to the company's standard. This research also involved replication six times to ensure the accuracy and precision of the obtained results.

3.5. Creating Randomization and Layout of Completely Randomized Design (CRD) Experiment

The final stage in experimental planning was to create randomization and the layout of the experiment using the Completely Randomized Design method. This research utilized randomization and the layout of the experiment using the CRD method because the data in this experiment were homogeneous and it was assumed that there was no influence of different days on the experiment results. Creating the layout of the CRD experiment began with determining the number of factors, levels, and replications. This determination had been made in the previous stage where this research consisted of one factor, three levels, and six replications. After the factors, levels, and replications had been determined, the next stage was randomization. Through randomization, each experimental unit had an equal chance of receiving a treatment. Randomization could be done by drawing lots or using random number tables. Table 3 showed the layout of the one-factor, three-level, and six-replication experimental design from the randomization results using a random number table.

Table 3 Layout of Completely Randomized Design Experiment with 3 levels and 6 replications

1. 18˚C	2. 21˚C	3. 24˚C
4. 18˚C	5. 21˚C	6. 21˚C
7. 24˚C	8. 21˚C	9. 24˚C
10. 24˚C	11. 18˚C	12. 24˚C
13. 21˚C	14. 18˚C	15. 18˚C
16. 24˚C	17. 18˚C	18. 21˚C

It can be observed that experimental units with numbers 1, 4, 11, 14, 15, and 17 received treatment at 18°C, units with numbers 2, 5, 6, 8, 13, and 18 received treatment at 21°C, and units with numbers 3, 7, 9, 10, 12, and 16 received treatment at 24°C.

3.6. Experiment Execution

The experiment execution phase was carried out according to the previous planning. As per the designated notation, the number of experiments conducted in this study was 18. The experiments were conducted according to the layout of the experiment previously created, as shown in Table 3. The AC temperature in the tobacco warehouse was set according to the level being tested. The experiment began by setting the AC temperature in the tobacco warehouse in the morning according to the experimental level for that day. Subsequently, the tobacco moisture content was checked and recorded regularly at 9 a.m., 12 p.m., and 3 p.m. The recording three times a day aimed to obtain the average tobacco moisture content for that day, resulting in more accurate results.

During the experiment, the tobacco moisture content was checked using a moisture meter. The results of the checks appeared as numerical values and were recorded as testing data. The results of the tobacco moisture content testing for each experiment can be seen in Table 4.

Table 4 Results of Tobacco Moisture Content Testing

Experiment	Tobacco Room Temperature (˚C)	Tobacco Moisture Content (%)			
		09.00 AM	12.00 PM	03.00 PM	Means
1	18˚C	18%	18,5%	18,3%	18,26%
2	21˚C	18,6%	18,4%	18,7%	18,56%
3	24˚C	18,5%	17,8%	17,6%	17,96%
4	18˚C	18,2%	18,5%	18,5%	18,4%
5	21˚C	19%	18,6%	18,7%	18,76%
6	21˚C	18,8%	18,2%	18,4%	18,46%
7	24˚C	18,6%	17,7%	17,9%	18,06%
8	21˚C	18,6%	18,2%	18,4%	18,4%
9	24˚C	18,3%	17,8%	17,9%	18%
10	24˚C	18,5%	17,9%	18%	18,13%
11	18˚C	17,8%	18,3%	18,2%	18,1%
12	24˚C	18,6%	17,8%	17,9%	18,1%
13	21˚C	18,7%	18,4%	18,8%	18,63%
14	18˚C	18,2%	18,6%	18,5%	18,43%
15	18˚C	18%	18,4%	18,2%	18,2%
16	24˚C	18,2%	17,7%	17,9%	17,93%
17	18˚C	18,1%	18,5%	18,4%	18,33%
18	21˚C	18,7%	18,1%	18,3%	18,36%

3.7. Data Processing of Experimental Results

The data obtained from the experiments was analyzed and calculated using ANOVA to determine whether the temperature factor influences tobacco moisture content. After conducting the ANOVA analysis, if the results indicate that there was an effect of the temperature factor on the tobacco moisture content, the Fisher's test would be conducted to determine which levels have a significant effect on tobacco moisture content.

3.8. ANOVA

In this section, hypothesis testing was conducted regarding the average tobacco moisture content factor used in the experiment. The six steps of hypothesis testing used in decision-making in this research was as follows.

1. H0 : There is no effect of warehouse temperature on tobacco moisture content.

   H1 : Warehouse temperature affects tobacco moisture content.
2. α : 0,05 or 5%
3. CR : P-value < α
4. The ANOVA calculation was conducted using Minitab version 19. The ANOVA results for the average moisture content can be seen in Figure 1.

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
suhu	2	0.7452	76.86%	0.7452	0.37262	24.91	0.000
Error	15	0.2244	23.14%	0.2244	0.01496		
Total	17	0.9696	100.00%				

Figure 1 The ANOVA for the average moisture content.

   P-Value : 0
5. Decision : Reject H0, because P-value < α or 0 < 0,05

6. Conclusion : P-value < α, Then \(H_0\) is rejected, meaning that the warehouse temperature has an influence on the tobacco moisture content, and the difference among treatments is highly significant.

Based on the hypothesis testing conducted, it was concluded that the warehouse temperature factor used in the experiment significantly affects the tobacco moisture content. This can be observed from the P-value, which was smaller than 0.01, indicating a highly significant difference. The determination of the value of α depends on the confidence interval to be used, which is 95%. This means that if the confidence interval used is 95%, then the level of error or significance (α) used to find the F-value is 0.05. In this study, a confidence interval of 95% was used, implying that the tolerated level of error was 5%. On the other hand, this also meant that the research results have a 95% chance of being correct.

The determination of the effect of warehouse temperature on tobacco moisture content can also be seen from the calculated F-value and the tabulated F-value. If the calculated F-value is greater than the tabulated F-value, then reject H0. The tabulated F-value is determined using the F-table with the degrees of freedom for treatment being 2 (f1) and the degrees of freedom for error being 15 (f2). The tabulated F-values for degrees of freedom 2 and 15 (f1 = 2 and f2 = 15) at 5% and 1% significance levels are 3.68 and 6.36, respectively. If using the formula in Microsoft Excel, the formula entered would be FINV(α; df1; df2). The main effect plot results can be seen in Figure 2.

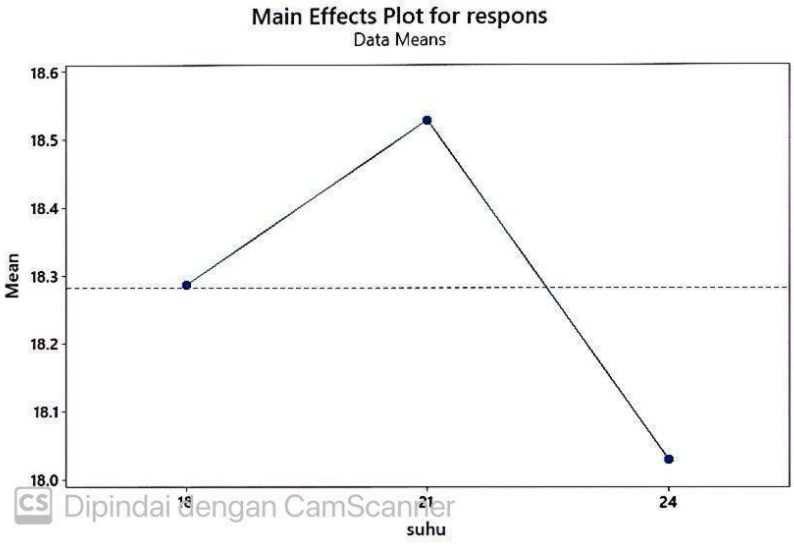

Figure 2 Main Effect Plot of Means

From Figure 2, it can be observed that when the warehouse temperature was 18°C, the average tobacco moisture content was at 18.2867%. Then, when the warehouse temperature rose to 21°C, the average tobacco moisture content also increased to 18.5283%. When the warehouse temperature was further increased to 24°C, the average tobacco moisture content decreased to 18.03%.

3.9. Fishers' Least Significant Difference (LSD) Test

After conducting the ANOVA calculation, the analysis continues with Fisher's LSD test to examine the differences among the simplest and most commonly used treatment means. The confidence interval used in this Fisher's test is 95%. This means that the research results have a 95% chance of being correct. The results of the Fisher's LSD test using Minitab version 19 can be seen in Figure 3.

Fisher Pairwise Comparisons: perlakuan

Grouping Information Using Fisher LSD Method and 95% Confidence

perlakuan	N	Mean	Grouping
2	6	18.5283	A
1	6	18.2817	B
3	6	18.0300	C

Means that do not share a letter are significantly different.

Figure 3 Fisher's Test for Average Moisture Content

Based on Figure 3, it can be observed that all treatments differed significantly. Each treatment had a different letter, indicating a significant difference.

3.10. Determination of Optimal Level Setting

The determination of optimal level settings was conducted using Minitab version 19. The results of the optimal level setting can be seen in Figure 4.

Solution

Solution	suhu	respons Fit	Composite Desirability
1	21	18.5283	0.943333

Figure 4 Optimal Level Setting

Based on Figure 4, it was observed that the most optimal level was the warehouse temperature with an AC setting of 21°C. The Fit Response was determined not based on the "larger the better" or "smaller the better" criteria, but according to the company's standard, which specified a tobacco moisture content of 18% to 19%. Therefore, the middle value of 18.5% was selected. From Table 4, the experimental data results showed that at a temperature level of 21°C, the tobacco moisture content ranged from 18.1% to 19%, indicating that the tobacco moisture content was within the company's standard humidity range of 18% to 19%. Conversely, at a temperature level of 18°C, the tobacco moisture content ranged from 17.8% to 18.6%, indicating that some tobacco moisture content was below the company's standard. Similarly, at a temperature level of 24°C, the tobacco moisture content ranged from 17.6% to 18.6%, indicating that some tobacco moisture content was below the company's standard. Therefore, it was concluded that the most optimal tobacco warehouse temperature was the warehouse with an AC temperature of 21°C.

4. Conclusion

The correlation between tobacco warehouse temperature and tobacco moisture content had the value r of -0.91812 or -91.812%, indicating that the correlation was negatively correlated (very strong). The negative correlation indicated that the higher the tobacco warehouse temperature, the lower the tobacco moisture content. After establishing that there was a correlation between tobacco warehouse temperature and tobacco moisture content, an experiment was conducted using the RAL experimental design method and analyzed using ANOVA and Fisher's LSD test. It was found that the tobacco warehouse temperature significantly affected the tobacco moisture content, and the optimal AC temperature to maintain tobacco quality was 21°C.

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Analisis Faktor Penentu dalam Pemilihan Indekos Mahasiswa di Surabaya (Studi dengan Pendekatan Mixed-Method)

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Abstract. *This study examines the factors influencing students' decisions in selecting boarding houses in Surabaya, an increasingly critical issue as demand for student housing rises post-pandemic. A mixed-method approach was employed, beginning with open-ended questionnaires to identify broad preferences, followed by closed-ended questionnaires to rank key factors. Factor analysis using SPSS revealed three dominant factors: security and environment (33.79%), location and price (22.19%), and facilities (20.47%). Among these, security and environment emerged as the most influential, underscoring the importance of safety and a clean, comfortable setting. Location and price ranked second, with students favoring affordable boarding houses near campuses and essential services. Facilities, including high-speed internet and clean sanitation, also significantly impacted decisions. These findings offer practical insights for boarding house owners to prioritize safety measures, enhance cleanliness, and improve facilities to attract students. While the results align with existing literature on housing preferences, this study is limited by its sample size and focus on Surabaya, which may not generalize to other contexts. Future research could explore additional factors such as parking availability or shared amenities and extend the analysis to other cities for comparative insights. This research contributes to understanding student housing preferences and offers actionable recommendations for managing boarding houses in urban educational hubs.*

Keywords*: Student Housing, Decision Factors, Mixed-Method Analysis, Factor Analysis*

1. Pendahuluan

Surabaya, sebagai salah satu kota pendidikan terbesar di Indonesia, menarik ribuan mahasiswa setiap tahunnya. Sebagian besar mahasiswa ini berasal dari luar kota, sehingga kebutuhan akan tempat tinggal sementara, seperti indekos, menjadi aspek penting dalam pengalaman akademik mereka. Indekos tidak hanya menjadi tempat tinggal tetapi juga berperan dalam mendukung kenyamanan, produktivitas, dan kesejahteraan mahasiswa selama masa studi mereka. Hal ini menjadikan keputusan untuk memilih indekos yang tepat sebagai salah satu langkah strategis bagi mahasiswa.

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Namun, proses memilih indekos sering kali menjadi tantangan. Dengan banyaknya variasi harga, fasilitas, lokasi, dan kondisi lingkungan, mahasiswa sering merasa bingung menentukan pilihan terbaik. Faktor-faktor seperti keamanan, aksesibilitas, kenyamanan lingkungan, dan biaya menjadi pertimbangan utama yang memengaruhi keputusan mereka. Menurut Mandasari (2015), Reza et al. (2023), mahasiswa cenderung memprioritaskan lokasi yang dekat dengan kampus, harga sewa yang terjangkau, dan fasilitas yang memadai. Sementara itu, Hajar et al. (2012), Maulidah (2014), Basamalah et al. (2019) menambahkan bahwa rekomendasi dari teman atau keluarga juga menjadi salah satu faktor signifikan dalam pemilihan indekos.

Lebih jauh, studi oleh Paruntu et al. (2021) menemukan bahwa keamanan menjadi faktor utama dalam pemilihan tempat tinggal mahasiswa, terutama di daerah perkotaan yang memiliki tingkat mobilitas tinggi. Selain itu, penelitian oleh Muchlis (2016), Ningrum (2017) mengungkapkan bahwa fasilitas seperti internet cepat dan sanitasi yang baik secara langsung memengaruhi kepuasan mahasiswa terhadap indekos mereka. Studi ini menegaskan pentingnya pendekatan berbasis kebutuhan mahasiswa dalam pengelolaan akomodasi.

Di sisi lain, literatur tentang preferensi mahasiswa di Surabaya masih sangat terbatas. Sementara kota ini terus berkembang sebagai pusat pendidikan tinggi, penelitian lokal yang menggunakan pendekatan kuantitatif dan kualitatif untuk memahami faktor-faktor yang memengaruhi pemilihan indekos mahasiswa belum banyak dilakukan. Studi ini berupaya untuk menjawab kesenjangan tersebut dengan menggunakan metode *mixed-method* untuk memberikan pemahaman yang lebih holistik.

Pendekatan yang digunakan dalam studi ini dimulai dengan eksplorasi preferensi mahasiswa melalui kuesioner terbuka, diikuti oleh analisis faktor untuk menentukan prioritas utama dalam pengambilan keputusan. Analisis ini tidak hanya mengidentifikasi faktor-faktor penting seperti keamanan, fasilitas, dan lokasi, tetapi juga mengeksplorasi hubungan antara variabel-variabel tersebut.

Oleh karena itu, tujuan utama dari studi ini adalah untuk mengidentifikasi dan menganalisis faktor-faktor utama yang memengaruhi keputusan mahasiswa dalam memilih indekos di Surabaya. Hasil studi ini diharapkan dapat memberikan kontribusi praktis bagi pengusaha indekos untuk meningkatkan daya tarik akomodasi mereka serta memperkaya literatur lokal terkait preferensi mahasiswa dalam konteks akomodasi di kota pendidikan.

2. Metode

Penelitian ini dilakukan di Surabaya, dengan memilih sampel mahasiswa dari dua perguruan tinggi yang berbeda di Surabaya. Metode yang digunakan dalam penelitian ini adalah *mixed-method* dengan memberikan pertanyaan terbuka pada kuesioner pilot dan hasil analisis pilot tersebut menjadi kerangka kuesioner untuk penelitian tahap selanjutnya (Creswell, 2018).

Data yang digunakan dalam penelitian adalah data primer. Data diperoleh dari hasil penyebaran kuesioner. Kuesioner dilakukan dalam dua tahap untuk dapat melihat gambaran umum preferensi secara lebih luas. Kuesioner terbuka dilakukan untuk mendapatkan sebanyak-banyaknya aspek preferensi tanpa adanya intervensi ide dari peneliti. Sementara, kuesioner tahap dua dilakukan dalam bentuk peringkatan dan dilakukan dalam rangka mencari faktor kunci dari preferensi-preferensi tersebut. Penelitian ini bersifat eksplanatori dengan mencoba mencari penjelasan lebih lanjut dari hubungan antara preferensi dengan tipe hunian di kalangan mahasiswa (Kumar, 2012). Penelitian ini menggunakan pendekatan grounded theory untuk memperoleh sebuah hasil interpretasi yang berasal dari pandangan responden (Creswell, 2018). Di mana pada pendekatan ini tidak memulai dengan teori. Teori berkembang selama proses penelitian dan dihasilkan dari interaksi terus-menerus antara analisis data, pengumpulan data, dan teori yang dihasilkan. Variabel penelitian yang dihasilkan berasal dari kuesioner yang sudah

disebarkan dan diambil dari 5 faktor dimensi yang dipertimbangkan yang kemudian dijabarkan menjadi 11 variabel, di mana disajikan pada Tabel 1 berikut:

Tabel 1 Variabel Penelitian

Dimensi Faktor	Item Pernyataan	Variabel
Lokasi	Indekos dekat dengan kampus	X_1
	Indekos yang jauh dari kampus	X_2
	Indekos dekat dengan akses yang diperlukan (misalnya fotokopi, warung makan, laundry, mini market)	X_3
	Jarak dari indekos ke kampus terjangkau dengan menggunakan kendaraan/ berjalan kaki	X_4
Keamanan	Tempat kos aman dari pencurian	X_5
Lingkungan	Tempat kos yang nyaman dengan lingkungan yang bersih	X_6
Harga	Harga sewa terjangkau sesuai dengan anggaran yang dimiliki	X_7
	Harga sewa indekos yang jauh dari kampus cenderung murah dibandingkan dengan indekos yang dekat dengan kampus	X_8
Fasilitas	Tersedianya perlengkapan kamar indekos seperti lemari pakaian, tempat tidur, dan lain-lain	X_9
	Tersedianya fasilitas indekos seperti akses internet yang cepat	X_{10}
	Tempat MCK (mandi, cuci, kakus) yang bersih	X_{11}

Selanjutnya dilakukan analisis faktor menggunakan aplikasi SPSS. Langkah awal untuk melakukan analisis faktor adalah dengan menguji validitas dan reliabilitas kuesioner untuk mengetahui apakah data kuesioner yang ada sudah sesuai atau tidak. Pengujian dilakukan untuk mengetahui apakah data kuesioner yang ada tersebut valid dan reliable. Sedangkan pemeriksaan kelayakan data diolah dengan menggunakan analisis faktor yaitu dengan metode *Barlett test of sphericity* serta pengukuran MSA (*Measure of Sampling Adequacy*) dan melihat nilai KMO (*Keiser-Meyem Olkin*).

3. Hasil dan Pembahasan

Penelitian ini menggunakan data hasil kuesioner dengan respondennya merupakan mahasiswa dari dua perguruan tinggi yang berbeda di Surabaya. Untuk mendapatkan data tentang keputusan mahasiswa dalam memilih indekost, langkah awal yang dilakukan adalah dengan menguji validitas dan reliabilitas kuesioner. Uji yang dilakukan menyatakan bahwa kuesioner valid dan reliable dan selanjutnya dilakukan analisis faktor.

Tabel 2 *KMO dan Barletts's Test*

Kaiser-Meyer-Olkin	**Measur of Sampling Adequacy**	0.541
Barlett's Test of Sphericity	Approv. Chi-Square	19.505
	df	10
	Sig.	0.034

Diperoleh hasil uji KMO yang diperoleh sebesar 0.541 yang berarti data cukup untuk dilakukan analisis faktor. Demikian pula pada uji Bartlett nilai sig sebesar 0,034 yang mengindikasikan bahwa korelasi variabel penelitian signifikan.

Tabel 3 *Anit-Image Matrices*

Correlation	Lokasi	Keamanan	Lingkungan	Harga	Fasilitas
Lokasi	0.522[a]	-0.085	0.041	-0.277	-0.145

Keamanan	-0.085	0.557[a]	-0.431	-0.041	-0.146
Lingkungan	0.041	-0.431	0.543[a]	-0.157	-0.022
Harga	-0.277	-0.041	-0.157	0.535[a]	0.120
Fasilitas	-0.145	-0.146	-0.022	0.120	0.512[a]

Measurement System Analysis (MSA) berfungsi untuk memastikan bahwa data yang dikumpulkan adalah valid, maka system pengukurannya juga harus valid. Dengan MSA ini diharapkan kegiatan pengukuran yang akan dilakukan mencerminkan tingkat mutu yang sebenarnya. Nilai MSA pada penelitian ini terletak pada diagonal *Anti-Image Correlations* yang ditandai dengan "a". Pada penelitian ini tidak terdapat variabel yang nilai MSA kurang dari 0,5. Maka penelitian dapat dilanjutkan karena semua variabel memiliki nilai MSA ≥ 0,5.

Tahap selanjutnya pada analisis faktor adalah *Communalities. Communalities* proporsi varian variabel yang dapat dijelaskan oleh faktor. Semakin besar nilai Komunalitasnya, maka semakin besar pula hubungan variabel dengan faktor.

Tabel 4 *Communalities*

	Initial	**Extraction**
Lokasi	1.000	0.773
Keamanan	1.000	0.708
Lingkungan	1.000	0.753
Harga	1.000	0.731
Fasilitas	1.000	0.858

Diketahui pada hasil *Communalities Extraction* diketahui semua faktor mampunyai nilai > 0.5, artinya hubungan antara variabel dengan faktor relatif besar. Sedangkan *Communalities Initial* menggambarkan estimasi varian setiap variabel berdasarkan faktor yang terbentuk. Pada tabel *Communalities* bahwa *Communalities Initial* semua faktor bernilai satu yang artinya varian variabel tersebut dapat dijelaskan oleh faktor-faktor yang terbentuk. Pada hasil yang diperoleh, variabel yang digunakan memperoleh faktor yang baik. Hal ini dikarenakan faktor dapat mewakili keberagaman variabel yang digunakan, hal ini ditandai dengan tingginya hubungan antara variabel dan faktor.

Berdasarkan tabel *Communalities* menunjukkan seberapa besar sebuah variabel dapat menjelaskan faktor-faktor tersebut. Nilai variabel Fasilitas sebesar 0.858 sehingga variabel fasilitas menjelaskan 85,8% faktor pemilihan indekos. Begitu pula dengan variabel lainnya, dimana semuanya >50%, maka dapat disimpulkan bahwa variabel fasilitas, lokasi, keamanan, lingkungan, harga dapat menjelaskan faktor-faktor dalam memilih kos.

Tabel 5 Total *Variance Explained*

Component	**Initial Eigenvalues**		
	Total	**% of Variance**	**Cumulative %**
1	1.690	33.793	33.793
2	1.109	22.189	55.982
3	1.023	20.469	**76.452**
4	0.651	13.028	89.480
5	0.526	10.520	100.000

Untuk mengetahui faktor dominan yang mempengaruhi keputusan mahasiswa dalam memilih indekos, yaitu dengan melihat nilai eigen. Nilai eigen ≥ 1 dapat menjelaskan variabel dengan baik sehingga diikutsertakan dalam pembentukan variabel. Berdasarkan Tabel 5 diperoleh 3 komponen yang nilai eigennya lebih besar sama dengan satu (≥ 1). Ketiga komponen

ini secara berturut-turut diperoleh nilai variansi yaitu: 33.793%, 22.189%, 20.469%, dengan jumlah nilai persentase kumulatif sebesar 76.452% dinilai telah cukup, maka faktor yang dibuat cukup tiga seperti yang terlihat pada kolom *Cumulative %*.

Digunakan rotasi faktor untuk mempermudah interpretasi dalam menentukan item-item apa saja yang masuk dalam suatu faktor. Rotasi faktor yang digunakan dalam penelitian ini adalah rotasi promax yaitu metode rotasi oblique dengan asumsi bahwa faktor-faktornya berkorelasi. Nilai *factor loading* yang digunakan adalah lebih besar dari 0.75 sesuai jumlah sampel yang digunakan yaitu 50.

Tabel 6 *Rotated Component Matrix*

	Component		
	1	**2**	**3**
Lokasi		0.820	
Keamanan	0.814		
Lingkungan	0.864		
Harga		0.766	
Fasilitas			0.918

Berdasarkan Tabel 6, dapat ditentukan item mana yang berkolerasi kuat dengan faktor-faktor yang ada. Faktor pertama terdiri dari X_5, X_6. Faktor kedua terdiri dari variabel X_1, X_2, X_3, X_4, X_7, X_8. Faktor ketiga terdiri dari variabel X_9, X_{10}, X_{11}.Langkah selanjutnya yaitu dengan interpretasi hasil analisis faktor.

Tabel 7 Interpretasi faktor

Faktor	Item Pernyataan	Variabel
Keamanan dan Lingkungan	Tempat kos aman dari pencurian	X_5
	Tempat kos yang nyaman dengan lingkungan yang bersih	X_6
Lokasi dan Harga	Indekos dekat dengan kampus	X_1
	Indekos yang jauh dari kampus	X_2
	Indekos dekat dengan akses yang diperlukan (misalnya fotokopi, warung makan, laundry, mini market)	X_3
	Jarak dari indekos ke kampus terjangkau dengan menggunakan kendaraan/ berjalan kaki	X_4
	Harga sewa terjangkau sesuai dengan anggaran yang dimiliki	X_7
	Harga sewa indekos yang jauh dari kampus cenderung murah dibandingkan dengan indekos yang dekat dengan kampus	X_8
Fasilitas	Tersedianya perlengkapan kamar indekos seperti lemari pakaian, tempat tidur, dan lain-lain	X_9
	Tersedianya fasilitas indekos seperti akses internet yang cepat	X_{10}
	Tempat MCK (mandi, cuci, kakus) yang bersih	X_{11}

Tabel 7 menunjukkan ada 3 faktor keputusan mahasiswa dalam memilih indekos, yang dapat mewakili 11 variabel yang dianalisis. Penamaan faktor-faktornya didasarkan pada variabel-variabel yang dominan. Faktor pertama dinamakan faktor keamanan dan lingkungan. Faktor ini merupakan faktor yang paling mempengaruhi keputusan mahasiswa dalam memilih indekos. Faktor kedua yaitu lokasi dan harga, dan faktor ketiga yaitu fasilitas. Sebagaimana sesuai dengan tabel 6, sesuai dengan klasifikasi tiap komponen (kolom 1, kolom 2, dan kolom 3).

4. Kesimpulan

Berdasarkan hasil dan pembahasan diatas dapat diambil kesimpulan bahwa terdapat tiga faktor yang menjadi keputusan mahasiswa dalam memilih indekos yaitu faktor pertama adalah faktor keamanan dan lingkungan dengan nilai eigen sebesar 1.690% dan varian sebesar 33.793%. Faktor kedua adalah faktor lokasi dan harga dengan nilai eigen sebesar 1.109% dan varian sebesar 22.189%. Serta faktor ketiga adalah faktor fasilitas dengan nilai eigen sebesar 1.023% dan varian sebesar 20.649%. Dengan demikian pengusaha indekos bisa mengusahakan dengan mengedepankan faktor keamanannya dan lingkungan yang nyaman dan bersih. Dan untuk penelitian selanjutnya perlu adanya penelitian lanjutan tentang ketersediaan lahan parkir, mengingat indekos yang dikembangkan adalah untuk mahasiswa yang kebanyakan membawa kendaraan roda 2, terlebih yang membawa kendaraan roda 4.

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Perancangan Website untuk Menangani Keluhan Pelanggan di Industri Sepeda (Analisis Gap Menggunakan WebQual dan IPA)

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Abstrak. Salah satu sektor yang memengaruhi perekonomian Indonesia adalah industri manufaktur, termasuk industri sepeda. PT Insera Sena, sebagai produsen sepeda, menghadapi tantangan dalam menangani data penjualan dan keluhan pelanggan yang tersebar dalam file terpisah, sehingga menyulitkan analisis komparatif. Untuk mengatasi hal ini, studi ini merancang sebuah *website* berbasis metode WebQual yang menganalisis kualitas situs melalui empat dimensi: *usability*, *information quality*, *service interaction quality*, dan *overall impression*. Data diperoleh melalui survei kuesioner kepada divisi International Business menggunakan skala harapan dan persepsi. Analisis dilakukan menggunakan *Gap Analysis* dan *Importance Performance Analysis (IPA)* untuk mengidentifikasi atribut yang perlu diperbaiki. Hasil menunjukkan bahwa dimensi *usability* memiliki gap sebesar -0,47 dan *overall dimension* sebesar -0,99, menunjukkan masih terdapat ketidaksesuaian antara harapan dan persepsi pengguna. Atribut yang menjadi prioritas perbaikan adalah Q1, Q2, Q3, Q4, dan Q23, yang berhubungan dengan kemudahan penggunaan dan tampilan situs. Studi ini memberikan panduan bagi perusahaan untuk meningkatkan kualitas *website* dan kepuasan pelanggan secara efektif.

Kata kunci: Gap Analysis, Industri sepeda, IPA, *Website*, WebQual,

1. Pendahuluan

Industri manufaktur memiliki kontribusi signifikan terhadap pertumbuhan ekonomi Indonesia. Salah satu perusahaan yang bergerak di sektor ini adalah PT Insera Sena, produsen sepeda dengan merek Marin Bikes, yang telah memiliki pelanggan di wilayah Asia hingga Eropa. Dengan cakupan pasar yang luas, perusahaan menghadapi tantangan dalam mengelola data penjualan dan keluhan pelanggan. Data yang terkumpul melalui sistem global sering kali kompleks dan tersebar dalam file Excel terpisah, yang menyebabkan kesulitan dalam melakukan analisis komparasi secara efisien.

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Divisi International Business, yang bertanggung jawab terhadap pengelolaan data ini, memerlukan solusi teknologi yang dapat menyederhanakan pengolahan data tersebut. Salah satu upaya yang dilakukan adalah merancang *website* yang mampu mengintegrasikan data penjualan dan keluhan pelanggan secara efektif. *Website* ini diharapkan mampu memberikan informasi yang lebih komprehensif, seperti hubungan antara jenis kerusakan, waktu produksi, dan penyebab keluhan, sehingga mendukung pengambilan keputusan yang lebih baik.

Dalam era digital saat ini, pemanfaatan teknologi berbasis web untuk pengelolaan data semakin mendominasi berbagai sektor, termasuk manufaktur. Studi oleh Kim *et al.* (2022) menunjukkan bahwa perusahaan yang memanfaatkan teknologi berbasis web untuk analisis data mengalami peningkatan efisiensi hingga 25% dibandingkan dengan metode tradisional. Selain itu, pengembangan *website* yang berorientasi pada pengalaman pengguna menjadi elemen kunci untuk menarik dan mempertahankan pelanggan dalam persaingan global (Nguyen *et al.*, 2023). Oleh karena itu, memastikan kualitas *website* melalui pendekatan yang terstruktur seperti WebQual menjadi sangat relevan.

Metode WebQual, yang dikembangkan oleh Barnes & Vidgen (2002), telah menjadi salah satu alat evaluasi kualitas *website* yang banyak digunakan. Metode ini mencakup empat dimensi utama, yaitu *usability*, *information quality*, *service interaction quality*, dan *overall impression*. Studi terbaru oleh Zhang *et al.* (2023) menekankan bahwa penerapan WebQual tidak hanya membantu mengidentifikasi atribut kritis dalam sebuah *website*, tetapi juga memberikan wawasan strategis untuk meningkatkan pengalaman pengguna. Dalam konteks ini, penggunaan *Gap Analysis* dan *Importance Performance Analysis (IPA)* membantu untuk mengevaluasi kesenjangan antara harapan dan persepsi pengguna, sekaligus menentukan prioritas perbaikan.

Studi ini bertujuan untuk merancang *website* yang sesuai dengan kebutuhan divisi International Business PT Insera Sena, sekaligus mengidentifikasi area perbaikan untuk meningkatkan kualitas situs web. Dengan memanfaatkan pendekatan ini, diharapkan hasil studi dapat memberikan kontribusi signifikan terhadap peningkatan efisiensi operasional dan kepuasan pelanggan perusahaan. Selain itu, temuan studi ini dapat menjadi referensi bagi perusahaan manufaktur lain yang ingin mengoptimalkan pengelolaan data penjualan dan keluhan pelanggan.

2. Metode

Studi ini menggunakan metode difusi dan penerapan ilmu pengetahuan dan teknologi (Iptek) untuk menghasilkan sebuah *website* yang dirancang sesuai kebutuhan divisi International Business PT Insera Sena. Proses studi terdiri dari beberapa tahapan utama, yaitu studi lapangan, studi pustaka, perancangan kuesioner, pengembangan *website*, penyebaran kuesioner persepsi, pengolahan data, dan analisis hasil.

2.1 Studi Lapangan dan Studi Pustaka

Studi diawali dengan pengumpulan data melalui observasi langsung pada divisi International Business PT Insera Sena untuk memahami kebutuhan spesifik perusahaan. Studi pustaka dilakukan dengan mengacu pada studi terdahulu yang relevan terkait metode WebQual dan analisis gap (*Gap Analysis*). Tahapan ini bertujuan untuk memberikan landasan teoritis bagi pengembangan *website*.

2.2 Perancangan dan Penyebaran Kuesioner

Kuesioner yang digunakan dalam studi ini terdiri dari dua jenis: kuesioner harapan dan kuesioner persepsi. Kuesioner harapan disusun berdasarkan dimensi WebQual. *WebQual* merupakan salah satu alat yang digunakan untuk mengevaluasi persepsi pengguna terhadap kualitas situs *web.* Metode ini dikembangkan pada tahun 1998 oleh Stuart Barnes dan Richard Vidgen dan didasarkan pada konsep *Quality Function Deployment (QFD),* yaitu suatu proses dalam pengembangan dan penerapan suatu produk atau jasa berdasarkan konsep “suara pelanggan”. Metode *WebQual* merupakan salah satu metode atau strategi yang paling banyak digunakan dalam menilai kualitas suatu *website* berdasarkan persepsi pengguna akhir (Hamzah *et al.*, 2022).

WebQual merupakan metode yang digunakan untuk menilai kualitas dari suatu situs. *WebQual* sudah mengalami perkembangan dari tahun ke tahun dan versi terakhir *WebQual* adalah *WebQual* 4.0. *WebQual* 4.0 menganalisis kualitas situs dari empat dimensi yaitu *usability, information quality, service interaction quality*, dan *overall impression* (Barnes & Vidgen, 2002). Masing-masing dimensi akan dirinci menjadi 22 pertanyaan. Untuk menilai kualitas dimensi *usability* digunakan 8 pertanyaan, menilai kualitas dimensi *information quality* digunakan 7 pertanyaan, dan menilai kualitas dimensi *service interaction quality* digunakan 7 pertanyaan. Pertanyaan-pertanyaan tersebut dapat dilihat pada tabel 1.

Tabel 1 Dimensi *WebQual* Beserta Pertanyaan

Dimensi	No.	Pertanyaan	Kode Pertanyaan
Usability	1.	*I find the site easy to learn to operate.* (Situs ini mudah untuk dioperasikan)	Q1
	2.	*My interaction with the site is clear and understandable.* (Interaksi dengan situs jelas dan mudah dimengerti)	Q2
	3.	*I find the site easy to navigate.* (Situs memiliki petunjuk yang jelas)	Q3
	4.	*I find the site easy to use.* (Situs mudah digunakan)	Q4
	5.	*The site has an attractive appearance.* (Situs memiliki tampilan yang menarik)	Q5
	6.	*The design is appropriate to the type of site.* (Desain sesuai dengan tipe situsnya)	Q6
	7.	*The site conveys a sense of competency.* (Situs meningkatkan kompetensi atau persaingan)	Q7
	8.	*The site creates a positive experience for me.* (Situs memberikan pengalaman positif)	Q8
Information Quality	1.	*Provides accurate information.* (Menyediakan informasi yang akurat)	Q9
	2.	*Provides believable information.* (Menyediakan informasi yang dapat dipercaya)	Q10
	3.	*Provides timely information.* (Menyediakan informasi yang tepat waktu)	Q11
	4.	*Provides relevant information.* (Menyediakan informasi yang relevan)	Q12
	5.	*Provides easy to understand information.* (Menyediakan informasi yang mudah dimengerti)	Q13
	6.	*Provides information at the right level of detail.* (Menyediakan informasi secara rinci)	Q14
	7.	*Presents the information in an appropriate format.* (Memberikan informasi dalam bentuk yang sesuai)	Q15
Service Interaction Quality	1.	*Has a good reputation.* (Memiliki reputasi yang baik)	Q16
	2.	*It feels safe to complete transactions.'* (Memberikan rasa aman saat melakukan transaksi)	Q17
	3.	*My personal information feels secure.* (Informasi pribadi tersimpan dengan aman)	Q18
	4.	*Creates a sense of personalization.* (Menciptakan kesan personal)	Q19
	5.	*Convey a sense of community.* (Memberikan rasa kebersamaan)	Q20
	6.	*Make it easy to communicate with the organization.* (Memberikan kemudahan untuk berkomunikasi dengan organisasi)	Q21

	7.	*I feel confident that goods/services will be delivered as promised.* (Memberikan rasa yakin barang/pelayanan akan sesuai dengan yang dijanjikan)	Q22
Overall Impression	1.	*My overall view of this website* (Tampilan situs secara keseluruhan baik)	Q23

Sumber : (Syaifullah, 2016)

Kuesioner disebarkan sebanyak dua kali dengan ada perbedaan parameter. Kuesioner pertama merupakan kuesioner harapan responden terhadap *website* yang akan dibuat dengan parameter yang digunakan adalah skala linier dengan keterangan sebagai berikut:
1 : Sangat tidak penting
2 : Tidak penting
3 : Cukup Penting
4 : Penting
5 : Sangat Penting

Kuesioner kedua adalah kuesioner persepsi. Kuesioner persepsi merupakan kuesioner yang berkaitan dengan kepuasan responden terhadap *website* yang sudah dibuat. Parameter yang digunakan adalah skala linier dengan keterangan sebagai berikut:
1 : Sangat tidak puas
2 : Tidak puas
3 : Cukup Puas
4` : Puas
5 : Sangat Puas

Penghitungan rata-rata atribut *Qn* pada masing-masing kuesioner menggunakan rumus:

$$Qn = \frac{\sum(jumlah\ responden\ x\ skor\ skala\ linier)}{total\ responden} \quad (1)$$

Setelah menemukan rata-rata atrbut, langkah selanjutnya adalah menghitung gap dengan rumus

Gap= rata-rata persepsi – rata-rata harapan (2)

2.3 Uji Paired Sample T-Test

Uji *Paired Sample T-Test* merupakan analisis yang dapat digunakan untuk membandingkan rata-rata dua variabel dalam satu grup untuk menguji apakah dua sampel memiliki hubungan atau tidak. Sampel yang berhubungan dapat diartikan sebagai sebuah sampel yang subjeknya sama namun mengalami 2 perlakuan atau pengukuran yang berbeda, yaitu pengukuran sebelum dan sesudah *treatment*. Menurut Sugiyono (2017), *paired sample t-test* merupakan salah satu metode pengujian yang digunakan untuk mengkaji keefektifan perlakuan, ditandai adanya perbedaan rata-rata sesudah diberikan perlakuan. Pedoman pengambilan keputusan dalam uji *paired sample t-test* berdasarkan nilai signifikasi (Sig) adalah sebagai berikut :

- Jika Nilai Signifikasi > 0.05 maka H_0 diterima.
- Jika Nilai Signifikasi < 0.05 maka H_0 ditolak.

Dengan hipotesis statistik sebagai berikut :

- $H_0 : \mu 1 = \mu 2$
- $H_1 : \mu 1 \neq \mu 2$

2.4 Gap Analysis

Gap analysis merupakan salah satu metode yang dapat digunakan untuk evaluasi kinerja. Secara harfiah "*gap*" menunjukkan adanya suatu perbedaan antara satu hal dengan hal lainnya. *Gap Analysis* sering digunakan untuk mengukur kualitas pelayanan (*quality of service*). Metode pendekatan ini paling sering digunakan di Amerika Serikat untuk memonitor kualitas pelayanan. Model yang dikembangkan oleh Parasuraman *et al.* (1995) ini memiliki lima kesenjangan, antara lain :

1. *Gap* persepsi manajemen, yaitu adanya perbedaan antara penilaian pelayanan menurut pengguna jasa dan persepsi mengenai harapan pengguna jasa.
2. *Gap* spesifikasi kualitas, yaitu kesenjangan antara persepsi manajemen mengenai harapan pengguna jasa dan spesifikasi kualitas jasa.
3. *Gap* penyampaian pelayanan, yaitu kesenjangan spesifikasi kualitas jasa dan penyampaian jasa (*service delivery*).
4. *Gap* komunikasi pemasaran, yaitu kesenjangan antara penyampaian jasa dan komunikasi eksternal. Ekspektasi pelanggan mengenai kualitas pelayanan dipengaruhi oleh pernyataan yang dibuat oleh perusahaan melalui komunikasi eksternal pemasaran.
5. *Gap* dalam pelayanan yang dirasakan, yaitu perbedaan persepsi antara jasa yang dirasakan dan yang diharapkan oleh pelanggan jika keduanya terbukti sama, maka perusahaan akan memperoleh citra dan dampak positif.

Perhitungan rata-rata skor dilakukan dengan menggunakan rumus:

$$Gap = \text{kualitas yang ada} - \text{kualitas yang diharapkan} \quad (3)$$

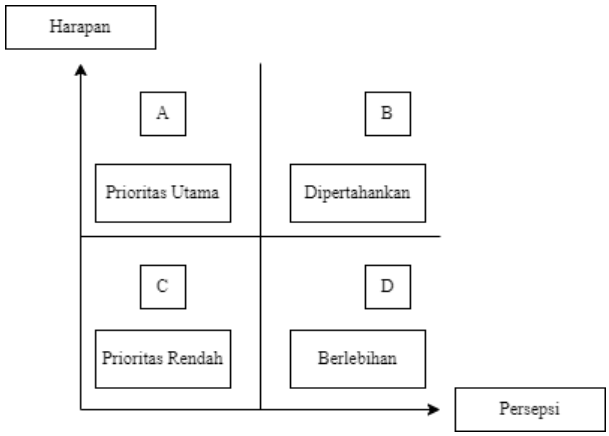
Ketentuan analisis kesenjangan adalah sebagai berikut:

a. Apabila G < 0, maka kualitas kompetensi yang diharapkan lebih tinggi dari pada kualitas kompetensi yang ada. Dengan demikian, perlu diadakan pengembangan untuk meningkatkan kinerja dan kualitas pelayanan.
b. Apabila G > 0, maka kualitas kompetensi yang diharapkan lebih rendah dari pada kualitas kompetensi yang ada. Dengan demikian, pelayanan dapat dikatakan sudah baik.
c. Apabila G = 0, maka kualitas yang diharapkan sama dengan kualitas kompetensi yang ada. Dengan demikian, pelayanan dianggap baik namun tetap perlu ditingkatkan.

2.5 Importance-Performance Analysis (IPA)

Importance-Performance Analysis (IPA) merupakan metode yang dapat digunakan untuk mengetahui kepuasan pelanggan dengan cara mengukur tingkat kepentingan dan tingkat pelaksanaannya. Tingkat kepentingan merupakan seberapa penting atribut tersebut bagi pelanggan, sedangkan tingkat pelaksanaan adalah hasil kinerja yang sudah dilakukan. Hasil dari IPA dimasukkan dalam diagram kartesius untuk mengetahui prioritas dari atribut pelayanan, sehingga akan terlihat mana saja atribut-atribut pelayanan yang perlu untuk diperbaiki dan atribut-atribut mana yang bisa dipertahankan performanya. Keunggulan metode IPA dibanding dengan metode yang lainnya yaitu bentuknya yang sederhana dan dapat membantu mengambil tindakan secara tepat dan cepat dalam mengatasi ketidakpuasan terhadap pelayanan yang diberikan karena menunjukkan atribut kualitas pelayanan yang belum maksimal (Supranto, 2001). Pengukuran IPA diubah menjadi grafik kartesius yang berpusat pada sumbu X dan sumbu Y. Sumbu X adalah nilai rata-rata kinerja dan sumbu Y adalah nilai rata-rata kepentingan. Kemudian kedua sumbu tersebut membentuk dua garis vertikal yang berpotongan dan membagi grafik kartesius menjadi 4 kuadran (Santoso & Alawiyah, 2021).

Pembagian kuadran diagram kartesius pada metode IPA dapat dilihat pada gambar 1.



Gambar 1 Diagram Kartesius

Keterangan:

A = Menunjukkan atribut yang dianggap mempengaruhi kepuasan dan dianggap sangat penting. Namun, pada aktualnya belum sesuai dengan harapan**.**

B = Menunjukkan atribut yang perlu dipertahankan karena sesuai dengan harapan.

C = Menunjukkan atribut yang kurang penting pengaruhnya dan pada aktualnya juga kurang sesuai dengan harapan.

D = Menunjukkan atribut yang kurang penting namun pada aktualnya dianggap sangat memuaskan (berlebihan).

Sumber: (Supranto, 2001)

3. Hasil dan Pembahasan

Kuesioner disebarkan sebanyak dua kali dengan ada perbedaan parameter. Kuesioner pertama merupakan kuesioner harapan responden terhadap *website* yang akan dibuat. Hasil dari kuesioner harapan yang dijadikan acuan dalam pembuatan *website* dapat dilihat pada tabel 3.

Tabel 3 Data Kuesioner Harapan

Dimensi	Pertanyaan	Jumlah responden					Rata-rata
		1	2	3	4	5	
Usability	Q1				3	9	4,75
	Q2				3	9	4,75
	Q3				3	9	4,75
	Q4				3	9	4,75
	Q5			3	4	5	4,17
	Q6			6	3	3	3,75
	Q7			1	4	7	4,50
	Q8				8	4	4,33
Information Quality	Q9				1	11	4,92
	Q10				1	11	4,92
	Q11			1	5	6	4,42
	Q12				3	9	4,75
	Q13				2	10	4,83
	Q14				1	11	4,92
	Q15			1	5	6	4,42
Service Interaction Quality	Q16			1	7	4	4,25
	Q17			1	6	5	4,33
	Q18				5	7	4,58
	Q19			3	6	3	4,00
	Q20			4	5	3	3,92
	Q21			3	5	4	4,08
	Q22				8	4	4,33
Overall Impression	Q23				4	8	4,66

Contoh perhitungan rata-rata atribut Q1: Rata-rata Q1 = $\frac{\Sigma((3 \times 4)+(9 \times 5))}{12}$=4,75

Kuesioner harapan yang disebarkan kepada anggota divisi International Business menghasilkan rata-rata skor untuk masing-masing atribut berdasarkan dimensi WebQual. Data menunjukkan bahwa dimensi *usability* memiliki rata-rata harapan tertinggi, yaitu 4,75, yang mencerminkan pentingnya aspek kemudahan penggunaan *website* bagi pengguna. Selain itu, dimensi *information quality* dan *service interaction quality* juga menunjukkan skor rata-rata yang tinggi, masing-masing sebesar 4,92 dan 4,83. Hal ini menunjukkan bahwa pengguna menginginkan informasi yang akurat dan interaksi layanan yang optimal dari *website*.

Tahap selanjutnya adalah merancang dan membuat *website* berdasarkan hasil kuesioner harapan. Setelah itu, dilakukan penyebaran kuesioner persepsi. Kuesioner persepsi merupakan kuesioner yang berkaitan dengan kepuasan responden terhadap *website* yang sudah dibuat. Hasilnya dapat dilihat pada tabel 4.

Tabel 4 Data Kuesioner Persepsi

Dimensi	Pertanyaan	Jumlah responden					Rata-rata
		1	2	3	4	5	
Usability	Q1		7	4	1		2,50
	Q2			4	3	5	4,08
	Q3	1	2	8	1		2,75
	Q4		7	4	1		2,50
	Q5			3	4	5	4,17
	Q6				2	10	4,83
	Q7				2	10	4,83
	Q8			1	8	3	4,17
Information Quality	Q9					12	5,00
	Q10					12	5,00
	Q11				1	11	4,92
	Q12					12	5,00
Information Quality	Q13					12	5,00
	Q14					12	5,00
	Q15					12	5,00
Service Interaction Quality	Q16			3	8	1	3,83
	Q17				1	11	4,92
	Q18					12	5,00
	Q19					12	5,00
	Q20					12	5,00
	Q21				1	11	4,92
	Q22			1	4	7	4,50
Overall Impression	Q23			4	8		3,67

Contoh perhitungan rata-rata atribut Q1: Rata-rata Q1 = $\frac{\Sigma((7 \times 2)+(4 \times 3)+(1 \times 4))}{12}$=2,50

Hasil menunjukkan bahwa skor rata-rata persepsi untuk dimensi *usability* adalah 3,72, yang masih jauh dari skor harapan. Sementara itu, dimensi *information quality* memiliki skor rata-rata persepsi tertinggi, yaitu 5,00, menunjukkan bahwa *website* telah memenuhi kebutuhan pengguna dalam menyediakan informasi yang akurat dan relevan.

Selanjutnya, dilakukan perhitungan gap antara persepsi dan harapan yang disajikan dalam bentuk tabel seperti yang ada pada tabel 5.

Tabel 5 Tabel Gap Antara Persepsi dan Harapan

Dimensi	Pertanyaan	Rata-rata Persepsi	Rata-rata Harapan	GAP
Usability	Q1	2,50	4,75	-2,25
	Q2	4,08	4,75	-0,67
	Q3	2,75	4,75	-2
	Q4	2,50	4,75	-2,25
	Q5	4,17	4,17	0
	Q6	4,83	3,75	1,08
	Q7	4,83	4,50	0,33
	Q8	4,17	4,33	0,16
Information Quality	Q9	5,00	4,92	0,08
	Q10	5,00	4,92	0,08

	Q11	4,92	4,42	0
	Q12	5,00	4,75	0,25
	Q13	5,00	4,83	0,17
	Q14	5,00	4,92	0,08
	Q15	5,00	4,42	0,58
Service Interaction Quality	Q16	3,83	4,25	-0,42
	Q17	4,92	4,33	0,59
	Q18	5,00	4,58	0,42
	Q19	5,00	4,00	1,00
	Q20	5,00	3,92	1,08
	Q21	4,92	4,08	0,84
	Q22	4,50	4,33	0,17
Overall Impression	Q23	3,67	4,66	-0,99

Contoh perhitungan *gap* atribut Q1: *Gap* Q1= (2,50) – (4,75) = (-2,25)

Hasil analisis menunjukkan bahwa dimensi *usability* dan *overall impression* memiliki gap negatif terbesar, masing-masing sebesar -1,03 dan -0,99. Hal ini menandakan bahwa kedua dimensi tersebut belum memenuhi harapan pengguna. Sebaliknya, dimensi *information quality* memiliki gap positif sebesar +0,08, yang menunjukkan bahwa informasi yang disediakan oleh *website* telah memenuhi atau bahkan melampaui ekspektasi pengguna.

Rendahnya skor pada dimensi *usability* sejalan dengan temuan Zhang *et al.* (2023), yang menunjukkan bahwa *usability* sering menjadi faktor kritis dalam keberhasilan sebuah *website*. Gap negatif yang besar pada dimensi ini mengindikasikan bahwa prototipe *website* membutuhkan perbaikan pada aspek navigasi dan antarmuka pengguna (*user interface*). Hal ini sangat penting, mengingat kemudahan penggunaan merupakan elemen kunci dalam menciptakan pengalaman pengguna yang positif.

Sementara itu, gap positif pada dimensi *information quality* menunjukkan efektivitas pendekatan berbasis data dalam perancangan *website*, sebagaimana ditegaskan oleh Nguyen *et al.* (2023). Informasi yang akurat, relevan, dan mudah dimengerti menjadi keunggulan *website* yang telah memenuhi kebutuhan pengguna. Namun, gap negatif yang signifikan pada dimensi *overall impression* menunjukkan bahwa tampilan visual dan estetika *website* masih memerlukan peningkatan untuk memberikan pengalaman yang lebih memuaskan. Studi lebih lanjut dapat difokuskan pada evaluasi desain visual dan interaksi pengguna untuk memastikan *website* mampu menciptakan kesan yang lebih baik secara keseluruhan.

Setelah melakukan analisis *gap*, tahap berikutnya adalah melakukan uji *paired sample t-test*. Hasil dari uji *paired sample t-test* dapat dilihat pada tabel 6.

Tabel 6 Hasil Uji *Paired Sample T-Test*

Null Hypothesis	$H_0 : \mu\_difference = 0$
Alternative Hypothesis	$H_1 : \mu\_difference \neq 0$
T-*value*	P-*value*
-0,32	0,754

Dari tabel 6 dapat dilihat bahwa nilai signifikasinya adalah (-0,32) yang artinya nilai signifikasi < 0.05 maka H_0 ditolak dan H_1 diterima. Maka bisa dikatakan bahwa ada gap antara persepsi dan harapan. Berdasarkan tabel 5, maka rata-rata tiap instrumen dikelompokkan berdasarkan dari dimensi masing-masing untuk kemudian dibuat *radar chart*. Dibawah ini merupakan tabel gap dari tiap dimensi.

Tabel 7 Gap Berdasarkan Dimensi

Dimensi	Rata-rata Persepsi	Rata-rata Harapan	GAP
Usability	3,728750	4,468750	-0,740000
Information Quality	4,988571	4,740000	0,248571
Service Interaction Quality	4,738571	4,212857	0,525714
Overall Impression	3,670000	4,660000	0,990000

Perhitungan rata-rata persepsi didapat dengan menggunakan rumus: $\frac{\sum rata-rata\ persepsi}{total\ instrumen}$

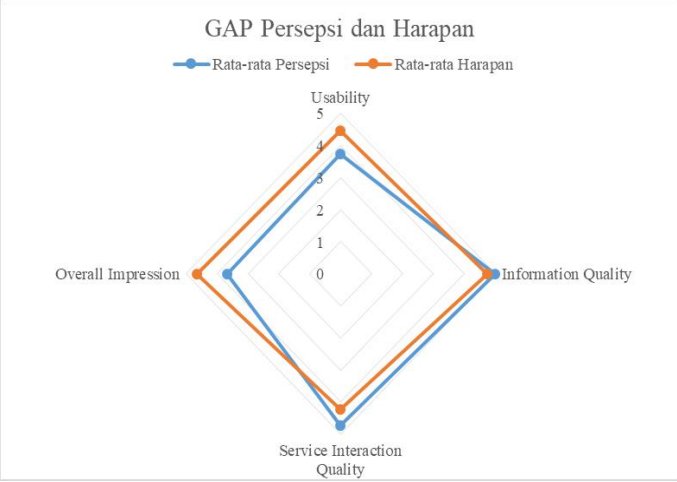
Contoh perhitungan rata-rata persepsi dimensi *usability*

$= \frac{(2{,}50+4{,}08+2{,}75+2{,}50+4{,}17+4{,}83+4{,}83+4{,}17)}{8} = 3{,}72875$

Perhitungan rata-rata harapan didapat dengan menggunakan rumus: $\frac{\sum rata-rata\ harapan}{total\ instrumen}$

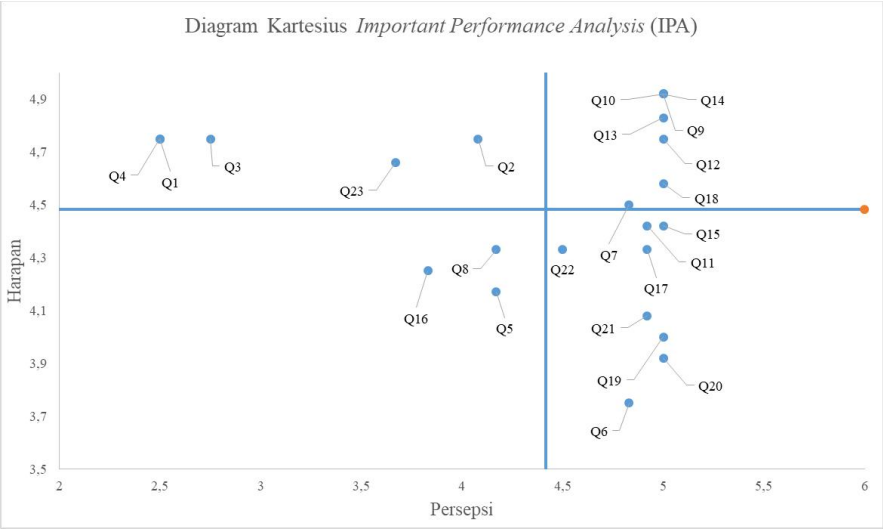
Contoh perhitungan rata-rata harapan dimensi *usability*

$= \frac{(4{,}75+4{,}75+4{,}75+4{,}75+4{,}17+3{,}75+4{,}50+4{,}33)}{8} = 4{,}46875$



Gambar 2 *Gap Analysis* Dalam Bentuk *Radar Chart*

Analisis dalam studi ini dilakukan dengan bantuan metode *Importance Performance Analysis* (IPA). Metode ini dipilih karena membantu mengetahui kepuasan dengan cara mengukur tingkat kepentingan dan tingkat pelaksanaannya. Dalam penerapannya, metode ini menggunakan diagram kartesius. Gambar 3 merupakan diagram kartesius dari 23 instrumen yang ada.



Gambar 3 Diagram Kartesius Metode IPA

Berdasarkan Supranto (2001), maka analisis hasil gambar 3 berdasarkan diagram kartesius adalah sebagai berikut:

Kuadran A merupakan kuadran yang menunjukkan atribut yang dianggap mempengaruhi kepuasan dan dianggap sangat penting. Namun, pada aktualnya belum sesuai dengan harapan. Atribut yang tergolong kuadran A adalah

- Q1 : Situs mudah untuk dioperasikan.
- Q2 : Interaksi dengan situs jelas dan mudah dimengerti
- Q3 : Situs memiliki petunjuk yang jelas.
- Q4 : Situs mudah digunakan.
- Q23 : Tampilan situs secara keseluruhan baik.

Kuadran B merupakan kuadran yang menunjukkan atribut yang perlu dipertahankan karena sesuai dengan harapan. Atribut yang tergolong kuadran B adalah

- Q9 : Menyediakan informasi yang akurat.
- Q10 : Menyediakan informasi yang dapat dipercaya.
- Q12 : Menyediakan informasi yang relevan.
- Q13 : Menyediakan informasi yang mudah dimengerti.
- Q14 : Menyediakan informasi secara rinci.
- Q18 : Informasi pribadi tersimpan dengan aman.

Kuadran C merupakan kuadran yang menunjukkan atribut yang kurang penting pengaruhnya dan pada aktualnya juga kurang sesuai dengan harapan. Atribut yang tergolong kuadran C adalah

- Q5 : Situs memiliki tampilan menarik.
- Q8 : Situs memberikan pengalaman positif.
- Q16 : Memiliki reputasi yang baik.

Kuadran D merupakan kuadran yang menunjukkan atribut yang kurang penting namun pada aktualnya dianggap sangat memuaskan (berlebihan). Atribut yang tergolong kuadran D adalah

- Q6 : Desain sesuai dengan tipe situsnya.
- Q7 : Situs meningkatkan kompetensi atau persaingan.
- Q11 : Menyediakan informasi yang tepat waktu.
- Q15 : Menyediakan informasi dalam bentuk yang sesuai.
- Q17 : Memberikan rasa aman saat melakukan transaksi.
- Q19 : Menciptakan kesan personal.
- Q20 : Memberikan rasa kebersamaan.
- Q21 : Memberikan kemudahan untuk berkomunikasi dengan organisasi.
- Q22 : Memberikan rasa yakin bahwa pelayanan sesuai dengan yang dijanjikan.

Karena berdasarkan teori kuadran A dianggap mempengaruhi kepuasan dan dianggap sangat penting namun pada aktualnya belum sesuai dengan harapan, maka perbaikan difokuskan pada atribut yang terdapat pada kuadran A.

4. Kesimpulan

Studi ini bertujuan untuk merancang sebuah website yang mampu memenuhi kebutuhan divisi International Business PT Insera Sena dalam mengelola data penjualan dan keluhan pelanggan. Berdasarkan analisis menggunakan metode WebQual, ditemukan bahwa kualitas website dapat dievaluasi melalui empat dimensi utama: *usability*, *information quality*, *service interaction quality*, dan *overall impression*. Hasil studi menunjukkan bahwa meskipun beberapa dimensi, seperti *information quality*, telah memenuhi bahkan melampaui ekspektasi pengguna (gap sebesar +0,08), dimensi *usability* dan *overall impression* masih memiliki gap negatif yang signifikan, masing-masing sebesar -1,03 dan -0,99.

Analisis dengan metode *Importance Performance Analysis (IPA)* mengidentifikasi lima atribut prioritas yang membutuhkan perhatian utama, yaitu Q1 (*situs mudah dioperasikan*), Q2 (*interaksi dengan situs jelas dan mudah dimengerti*), Q3 (*situs memiliki petunjuk yang jelas*), Q4 (*situs mudah digunakan*), dan Q23 (*tampilan situs secara keseluruhan baik*). Atribut-atribut ini memiliki pengaruh signifikan terhadap tingkat kepuasan pengguna dan perlu menjadi fokus utama dalam perbaikan website.

Kesimpulan utama dari studi ini adalah pentingnya memperbaiki aspek navigasi dan antarmuka pengguna untuk meningkatkan dimensi *usability*, serta meningkatkan estetika dan kesan visual untuk memperbaiki *overall impression*. Dengan melakukan perbaikan pada atribut-atribut tersebut, website diharapkan dapat memenuhi kebutuhan pengguna secara lebih efektif dan memberikan kontribusi nyata terhadap efisiensi operasional divisi International Business.

Sebagai batasan, studi ini hanya melibatkan responden dari satu divisi perusahaan, sehingga hasilnya belum tentu mencerminkan kebutuhan pengguna dari segmen lain. Studi selanjutnya disarankan untuk memperluas cakupan responden dan mengeksplorasi metode lain untuk meningkatkan pengalaman pengguna, seperti *A/B testing* atau analisis *heatmap* untuk mengevaluasi interaksi pengguna secara lebih mendalam.

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Towards the X-shaped Person, the Next (Industrial) Leader in the Era of Industry 4.0 and Society 5.0

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Abstract. This paper examines the impact on the development of industry and society known as industry 4.0 and society 5.0. Caused by technological and business pressures influenced by the rapid development of digital technology. Industry 4.0 and society 5.0 require the type of person who has digital literacy as well as leadership abilities to lead the industry in an uncertain market situation that can have an impact on disruption. Therefore, to ensure the sustainability of the industry, the type of person who is able to lead the industry through increasing business pressures and strategic environment is needed. This paper evaluates and assesses three shaped of person called I, T, and X on factors related to industrial sustainability, especially in the future due to industry 4.0. The assessment results show that X-shaped person has the highest score of 3.75 compared to I with a score of 1.31 and T with a score of 2.66. This result is specifically influenced by the leadership factor because it has the highest weighting factor of 0.34 for this assessment. This paper proposes an X-shaped person development method both through internal and external programs such as the Leadership Development Program (LDP) or government leadership program held by the National Resilience Institute of the Republic of Indonesia (Lemhannas RI). It is concluded that the X-shaped person is important to be developed for the sustainability and competitiveness of industry today and in the future.

Keywords: X-shaped person, T-shaped person, Industry 4.0, Future industrial leader

1. Introduction

The rapid development of digital technology currently has both positive and negative impacts, especially on industry. The positive impact of current digital technology developments is on increasing efficiency, effectiveness and industrial productivity (Rüßmann et al., 2015). Industries that have adopted advanced (digital) technological developments are known as the 4th industrial revolution or better known as Industry 4.0 (Rüßmann et al., 2015). The term Industry 4.0 was first introduced by the Federal Ministry of Education and Research, Germany at the Hannover Automation Exhibition (Hannover Messe) in 2011 under the name Industry 4.0. This term initially did not refer directly to the 4th industrial revolution, but rather referred to the strategy of developing new technology in the manufacturing industry to provide solutions to megatrends, such as: mass customization, digitalization, very short product life cycles (Rüßmann

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et al., 2015). After that, in 2012 and 2013 the German Government prepared an overview, strategy and scope of Industry 4.0. From here the concept emerged that Industry 4.0 is an evolution of the previous industrial revolution (Kagermann et al., 2013; McKinsey, 2016; Rüßmann et al., 2015; Veile et al., 2019).

The fourth industrial revolution or so-called Industry 4.0 has begun, driven by internet technology applied in production systems or often called Cyber Physical Systems (CPS) or Industrial Internet of Things (IIoT). The information technology used includes and is not limited to big data, programming, networking, human machine interfaces. According to the Boston Consulting Group (BCG) (Rüßmann et al., 2015), information technology that supports Industry 4.0 is known as 9 pillars of advanced technology 1). Big data and analytics, 2). Autonomous robot, 3). Simulation, 4). Horizontal and vertical system integration, 5). Industrial Internet of Things, 6). Cybersecurity, 7). Clouds, 8). Additive manufacturing, and 9). Augmented reality. From the nine pillars of advanced technology that form the basis of Industry 4.0, some of them are actually already used in manufacturing, but Industry 4.0 will change production systems so that isolated cells can be optimized and combined into fully integrated and automated production flow and optimization that generates greater efficiencies and transforms traditional production relationships between suppliers, manufacturers, customers, and between people and machines.

With the advent of Industry 4.0, it is expected to optimize and enhance industrial competitiveness by making production operations more effective, efficient, and economical, ultimately benefiting companies. This industrial revolution brings numerous advantages, including the potential to empower individuals and communities by creating new opportunities for social, economic, and personal development. It minimizes the risk of human error, as computer systems exercise full control, ensuring consistent work results. Furthermore, it increases productivity efficiency in production processes, allowing goods to be produced in greater volumes while utilizing fewer resources. Industry 4.0 also ensures data security through cloud computing, facilitates real-time control of sophisticated systems, enhances visibility into the status of goods availability and delivery processes, and reduces supply chain handling costs. These advancements collectively contribute to a more streamlined and competitive industrial landscape.Based on analysis by the Boston Consulting Group (BCG) (Rüßmann et al., 2015), in the manufacturing industry in Germany, there are four areas that benefit from the industrial revolution 4.0: 1) Productivity, 2). Income growth, 3) Employment, and 4) Capital investment. However, Industry 4.0 still has the following challenges 1) Security, 2) Employment, 3) Digital technology literacy, and 4). Competency Transformation.

Therefore, human resource qualifications must be in line with the characteristics of Industry 4.0, especially but not limited to type of industry, management and organization, culture, products and services, technology and factory operations. For this reason, efforts are needed to narrow the gap by improving the qualifications of existing human resources. Traditional human resources are generally classified as I-shaped person, namely specialists in one area of knowledge/skills (Buxton, 2009). Therefore, I-shaped person are no longer relevant to current situations and conditions. Currently, what is needed is a T-shaped person, namely a person who has a balance between technical and managerial abilities (Gibson, 2021; Hammer et al., 2021; Saviano et al., 2016). In fact, due to existing technological developments, more than just one technical ability is needed, more technical abilities are needed with good managerial skills, which is known as Pi, Comb-shaped person (Bassano, 2018; Dekoninck & Bridge, 2023; Veenendaal, 2020).

With the rise of Industry 4.0 and changes in current business pressures that emphasize the use of advanced technology in industry, therefore Industry 4.0 will be a game changer with the consequence that those who cannot adapt will be disrupted (Rüßmann et al., 2015). For this reason, this article will describe the X-shaped person who is able to maintain the sustainability of industrial competitiveness in the future.

2. Methods

This article describes human resources that can maintain the sustainability of industrial competitiveness in the future using exploratory study methods and case studies. The exploratory study method was used because this study is still preliminary in nature with a fairly broad scope with the aim of exploring ideas and understanding in order to gain initial insight (Sitepu, 2020). This method uses qualitative case studies with observations in several best-in-class industries in Indonesia. According to (Sitepu, 2020), this exploratory study method is considered to be most appropriate related to the objective of this study because the objective is to find something as it really is, as a first step in describing X-shaped person more clearly and completely.

For this reason, this studi assesses that X-shaped person are the right type to lead industries in the Industry 4.0 era. An X-shaped person is actually a T-shaped person who has good leadership abilities (Rahman, 2024). This assessment was carried out by comparing the strengths and weaknesses, especially of I, T and X-shaped person in relation to the challenge factors faced as a result of Industry 4.0. The shape and characteristics of type I, T, and X-shaped person are as in Figure 1. The main characteristics are determined by the depth of technical abilities and the breadth of managerial and leadership abilities.

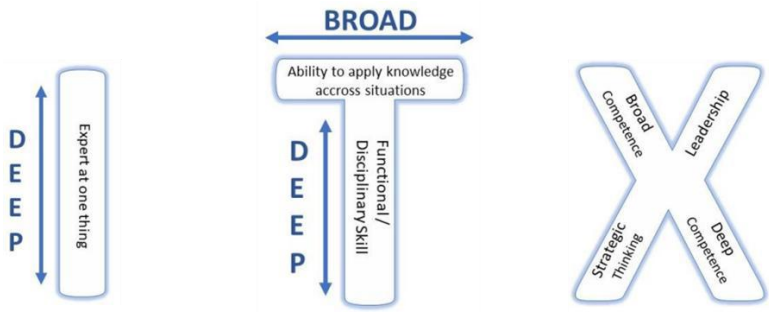

Figure 1. Characteristic of I-shaped, T-shaped, and X-shaped Person (Veenendaal, 2020).

(Rahman, 2024) provides the characteristics of I, T and X-shaped person with consideration factor of expertise, collaboration, innovation, and flexibility as summarized in Table 1.

Table 1. Characteristics of I-shape, T-shaped, and X-shaped person (Rahman, 2024)

Factor	I-Shaped	T-Shaped	X-Shaped
Expertise	Deep in one area, limited elsewhere	Deep in one area, broad in others	Deep in one area, broad in others, plus leadership quality
Collaboration	Low, primarily works within specialty	High, across various disciplines	Very high, excel in leading teams
Innovation	Low, focused on specific domain	High, thanks to interdisciplinary approach	Highest, drives innovation through leadership and collaboration
Flexibility	Low, prefer specialized tasks	High, adaptable to different roles	High, adaptable to leadership and collaborative roles

Therefore, this study intends to understand the strengths and weaknesses of I, T, and X-shaped person through an assessment of factors, other sources may specify different factors, that are considered important for industrial sustainability and competitiveness, namely 1. Digital literacy, 2. Business literacy, 3. Innovation, 4. Culture of Change, and 6. Leadership. These factors are considered important in relation to the industries' ability to face business turmoil.

2.1 Digital Literacy (DL)

Industry 4.0 is an indicator that future industries will be industries that adopt advanced technology, especially IT and digital-based technology. This technology has an impact on society

which is known as society 5.0. (Deguchi et al., 2020; Fukuyama, 2018; *Soc. 5.0*, 2020). Therefore, digital literacy (DL) is very important in the era of Industry 4.0 and Society 5.0 (Deguchi et al., 2020; Fukuyama, 2018; Kagermann et al., 2013; McKinsey, 2016; Rüßmann et al., 2015; Veile et al., 2019). Digital literacy is not only limited to the use of digital technology but also an understanding of the impact of digital technology at large (Martin, 2006). The definition of digital literacy according to (Martin, 2006) is awareness, attitude and ability of individuals to appropriately use digital tools and facilities to identify, access, manage, integrate, evaluate, analyze and synthesize digital resources, construct new knowledge, create media expressions, and communicate with others, in the context of specific life situations, in order to enable constructive social action. Meanwhile, according to UNESCO digital literacy involves the confident and critical use of a full range of digital technologies for information, communication and basic problem-solving in all aspects of life. It is underpinned by basic skills in ICT: the use of computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet. According to Unesco, digital literacy is a very important ability for the future (Law et al., 2018; Unesco, 2006).

2.2 Business Literacy (BL)

The current world situation known as VUCA stands for volatility, uncertainty, complexity, and ambiguity. Currently the new world known as BANI stands for brittle, anxious, non-linear, and incomprehensible. Both VUCA and BANI have an impact on business situations which have become very uncertain with one of the most worrying things being disruption (Baskoro, 2023; de Godoy & Filho, 2021; Evseeva et al., 2022; Murgatrotd, 2024). Therefore, to ensure the sustainability of the industry, business literacy is very important for the industry of the future. According to (Elfandi et al., 2021) in (Rahayu et al., 2023) business literacy is an understanding and ability in the business area. It is the knowledge gained in various ways that encourages people to have an entrepreneurial interest. While (Yaghoubi Farani et al., 2017) defined business literacy as business process knowledge to be used in the decision-making process of business.

2.2.1 Innovation Capability

Innovation is something that will continue to happen and cannot be stopped. Innovation is one way to maintain the sustainability of a company, because if a company does not innovate then the company will be exposed to disruption caused by innovation from competitorsherefore, innovation capability is very important to ensure sustainability and competitiveness. According to (Saunila & Ukko, 2012) in (Narcizo et al., 2017) innovation capability is simply organization's potential to innovate. Actually, there are many definitions of innovation capabilities by several authors (Narcizo et al., 2017). According to (Narcizo et al., 2017) innovation capabilities includes the following aspects: 1. Assets/Organizational Property, 2. Organizational process, and 3. Potential.

2.2.2 Culture Change

Change is the only thing that is certain to happen. Therefore, the ability to accept and encourage change is needed. In Industry, a culture of change is very important so that Industry has resilience and is able to maintain its sustainability and competitiveness. The need of change culture is to help company for transformation journey. Company adaptive culture is actually for the foundation of company transformation such as business transformation, digital transformation etc. (Hollister et al., 2021). Culture according to Hollister et al. 2021 is a shared set of values, beliefs, and norms of behavior.

2.2.3 Leadership

Leadership is needed in industry especially in VUCA and BANI world today and in the future because the leadership function is very important for competitiveness and sustainability (Fletcher et al., 2023; Murgatrotd, 2024; Rath et al., 2021; Schaffer, 2021). This paper consider important leadership functions, among others, include 1. Setting a vision, 2. Creating a strategy, 3.

Managing resources, 4. Driving change, 5. Role model, 6. Etc. One of the important factors of leadership is responsibility, namely towards oneself and others. Therefore, to be able to ensure the sustainability of the industry in the face of existing business and technological pressures, leadership ability and will to responsible is necessary.

3. Results and Discussion

Determining the weight of five factors that are considered important for the current and future industry used to assess people of type I, T, and X is carried out using pairwise comparisons. This method is generally used in assessments using Analytical Hierarchy Process (AHP) (Baskoro et al., 2024). However, determining the weight can also be done through other methods such as using Focus Group Discussion (FGD) by experts. The scale used in determining pairwise comparisons refers to Table 2 (R. W. Saaty, 1987; T. L. Saaty, 1988).

Table 2. Pairwise comparison scale (R. W. Saaty, 1987; T. L. Saaty, 1988)

Importance	Definition	Remark
1	Equal importance	Both elements have similar effect.
3	Weak importance of one over	Experience and judgment strongly favor one element compared to its pair.
5	Essential or strong importance	One element is more important than the other.
7	Demonstrated importance	One element is clearly more important than the other elements.
9	Extreme importance	One element is more important than the other elements
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed. Values between two adjacent judgment values.
Reciprocal	Opposite	Reciprocals for inverse comparison.

The calculation results for determining the weight are as stated in Table 3.

Table 3. Determining priority using pairwise comparisons

Factor	Digital Lit.	Business Lit.	Innovation	Change Culture	Leadership	Priority/ Weight	%
Digital Lit.	1.00	0.33	2.00	1.00	0.33	0.14	13.62
Business Lit.	3.00	1.00	2.00	1.00	1.00	0.26	26.24
Innovation Capability	0.50	0.50	1.00	1.00	0.33	0.11	11.09
Change Culture	1.00	1.00	1.00	1.00	0.33	0.15	14.87
Leadership	3.00	1.00	3.00	3.00	1.00	0.34	34.18
TOTAL	**8.50**	**3.83**	**9.00**	**7.00**	**3.00**	**1.00**	**100**

From the results in Table 3. it can be seen that leadership has the largest priority, namely 34.18% with a weight of 0.34, second place is business literacy 26.24% with a weight of 0.26, and third place is a culture of change 14.87% with a weight of 0.15. This weight indicates the level of importance of factors that influence the sustainability of the industry in the present and future.

The assessment for I, T, and X-shaped person was carried out subjectively by the author based on the author's experience and careful observations over a period of 5 years in national industries that are classified as best-in-class. The result are as shown in table 4.

Table 4. The results of the assessment of I, T, X-shaped person

Factor	Weight Factor (WF)	I-shaped	WF.I	T-shaped	WF.T	X-shaped	WF.X
Digital Lit.	0.14	2	0.28	3	0.42	3	0.42
Business Lit.	0.26	1	0.26	3	0.78	4	1.04
Innovation Cap.	0.11	2.5	0.28	3	0.33	3	0.33
Change culture	0.15	1	0.15	3	0.45	4	0.60
Leadership	0.34	1	0.34	2	0.68	4	1.36
Total	1		1.31		2.66		**3.75**

Note:
- The assessment was carried out subjectively by the author
- Score is 1 to 5

The results of this subjective assessment show that X-shaped person has the highest score, namely 3.75 compared to other type of person. This score is highest compared to T-shaped person with a score of 2.66 and I-shaped person with a score of 1.31. The significant difference in results shows that X-shaped person has a significant influence on factors that impact the sustainability and competitiveness of industry. However, the T-shaped person is actually still relevant to current and future needs as long as the T-shaped person is not in the top leadership position.

The biggest factor that influences the results of this assessment is the leadership abilities of X-shaped person. Therefore, developing human resources to be the X-shaped person can be carried out through a structured, massive and systematic leadership development program (SMT). This effort can be carried out in various ways and methods, including leadership development programs (LDP which are carried out within the organization or carried out outside the organization. Leadership development can also be carried out by joining to leadership development programs carried out by the government such as those carried out by National Resilience Institute of Republic of Indonesia (Lemhannas RI) for short, medium and long term program. The main advantage of the leadership program carried out by Lemhannas RI is the development of national insight and the spirit of nationalism.

As the assessment in Table 4. was carried out subjectively by the author, consequently the results of assessments may be different if it is carried out by different people. Similarly, the weight factors have also been defined subjectively by the author. Therefore, to minimize subjectivity it is recommended to 1) determine the weight factors by several experts in the organization and 2) to carry out the assessment by different experts from different organizations.

4. Conclusions

Based on the results and discussion, it can be concluded that X-shaped person is considered very relevant to be able to lead the industry to attain and maintain sustainability and competitiveness in the future as business pressures and the strategic environment develop. X-shaped person can be developed from T-shaped person by equipping with standard/excellent knowledge and leadership skills. The leadership development can be done internally and/or externally through LDP and or Lemhannas RI program.

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