

INDUSTRIAL INNOVATION

E-ISSN 2964-2442
2026

FOCUS AND SCOPE

- Product and Process Innovation
- Engineering and Industrial Design
- New Product Development
- Technology Application in Industry
- Engineering Experimental Design
- Production Systems Analysis/Design
- Quality Engineering
- Environment Risk Analysis
- Management of Innovation
- Artificial Intelligence in Manufacturing Industries
- Development of Small and Medium Industry

Diterbitkan oleh :
POLITEKNIK ATK
YOGYAKARTA



INDUSTRIAL INNOVATION

ARTICLES

- Evaluating Training Service Quality Using the Fuzzy SERVQUAL Method to Enhance Training Effectiveness at PT. XYZ** 1 - 15
- Evaluation of the Physical and Mechanical Characteristics of Box Leather for Footwear Uppers Based on SNI 0234:2009 and Its Implications for Industrial Ergonomics** 16 - 39
- Physical and Mechanical Characterization of Sheep/Goat Garment Leather According to SNI 4593:2011 with Industrial Ergonomics Considerations** 40 - 55
- Utilization of Digital Collections and Electronic Archives to Support Academic Research at ATK Polytechnic** 56 - 74
- Agradaya's digital transformation journey: Insights from Indonesian agribusiness** 75 - 100



majalah2@politeknikatk.ac.id



e-jurnal.politeknikatk.ac.id



Evaluating Training Service Quality Using the Fuzzy SERVQUAL Method to Enhance Training Effectiveness at PT. XYZ

Tetis Mulyo Ade Januanta^{a*}

^a*BDI Yogyakarta, Yogyakarta, Indonesia*

*adejanuanta@kemenperin.go.id



Evaluating Training Service Quality Using the Fuzzy SERVQUAL Method to Enhance Training Effectiveness at PT. XYZ

Abstract. PT. XYZ, as a work unit under the Ministry of Industry, is responsible for conducting training for industrial human resources. Improving the quality of training services is essential to ensure participant satisfaction. This study aims to analyze service quality using the Fuzzy Servqual method, which combines Fuzzy logic and servqual concepts to objectively measure the gap between customer expectations and perceptions. Data were collected through questionnaires distributed to in-house training participants at PT. XYZ. The results indicate that the service quality has met participants' expectations, with an average positive gap value of 0.061 and a quality (Q) average of 1.014. Based on the Fuzzy Servqual method and Cartesian diagram analysis, four attributes were prioritized for improvement: ease of using the SIDIA information system, ease of contacting PT. XYZ, training meal quality, and communication between instructors/organizers and participants.

Keywords: Service Quality, Fuzzy Servqual, Training, Participant Satisfaction

1. Introduction

Human resource (HR) development has become a critical factor in improving industrial competitiveness amid rapid technological advancement and global market dynamics. Organizations are increasingly required to provide effective training programs to ensure that employees possess the competencies needed to meet industry demands and support organizational performance (Noe, 2020). Training institutions therefore play a strategic role in producing skilled and industry-ready workers through competency-based learning programs.

As a government-affiliated training provider under the Ministry of Industry, PT. XYZ is responsible for delivering vocational and competency-based training programs in several industrial sectors, including footwear, plastics, garments, and furniture. Through in-house, on-site, and blended learning schemes, PT. XYZ seeks to improve workforce competence and support industrial development in Indonesia. The effectiveness of these training programs is strongly



influenced not only by the quality of learning materials and instructors but also by the overall quality of services experienced by participants throughout the training process (Parasuraman et al., 1988).

Service quality has been widely recognized as a determinant of customer satisfaction and organizational performance. According to Parasuraman et al. (1988), service quality is measured through the gap between customer expectations and perceptions of the services received. When perceived performance exceeds expectations, customers tend to report higher satisfaction levels. Conversely, a negative gap indicates dissatisfaction and highlights areas requiring improvement. In the context of training services, participant satisfaction reflects the extent to which training facilities, instructors, administrative services, communication, and supporting infrastructure meet participant expectations (Kotler & Keller, 2016).

Previous studies have demonstrated the effectiveness of the Service Quality (SERVQUAL) model in evaluating service performance across various sectors, including education, healthcare, hospitality, and public services (Zeithaml et al., 2018; Oihu & Tutuhatunewa, 2022). The SERVQUAL framework evaluates service quality through five dimensions: tangibles, reliability, responsiveness, assurance, and empathy. These dimensions provide a comprehensive approach for identifying service attributes that contribute to customer satisfaction or dissatisfaction.

Despite its widespread application, the conventional SERVQUAL method has limitations because respondents often express perceptions and expectations using subjective linguistic judgments. Human assessments are frequently characterized by vagueness and uncertainty, making it difficult to capture service evaluations accurately using crisp numerical values alone (Zadeh, 1965). To address this limitation, researchers have integrated fuzzy logic with SERVQUAL analysis. Fuzzy logic enables the transformation of linguistic assessments into



mathematical representations, thereby reducing ambiguity and improving measurement accuracy (Kusumadewi & Purnomo, 2010).

The integration of fuzzy logic and SERVQUAL, commonly referred to as Fuzzy SERVQUAL, has been successfully applied in various service quality studies. Research by Büyüközkan et al. (2011) demonstrated that Fuzzy SERVQUAL provides a more realistic representation of customer perceptions by incorporating uncertainty into the evaluation process. Similar findings were reported by Awasthi et al. (2011), who showed that fuzzy-based approaches enhance decision-making accuracy in service quality assessment. In training and educational environments, Fuzzy SERVQUAL has proven effective in identifying priority areas for improvement and supporting continuous quality enhancement initiatives (Abdullah, 2006; Teeroovengadum et al., 2019).

Although PT. XYZ routinely collects participant satisfaction data through the SIDIA information system, approximately 15% of participants still report dissatisfaction with the training services provided. Existing evaluations primarily focus on overall satisfaction scores and do not adequately identify specific service attributes that require improvement. Consequently, management faces challenges in determining appropriate corrective actions and allocating resources effectively.

Based on these considerations, this study aims to evaluate the quality of training services provided by PT. XYZ using the Fuzzy SERVQUAL method. Specifically, the study seeks to (1) measure the gap between participant expectations and perceptions across the five SERVQUAL dimensions, (2) determine the overall quality level of training services, and (3) identify priority service attributes requiring improvement through Cartesian diagram analysis. The findings are expected to provide practical recommendations for enhancing training effectiveness and



participant satisfaction while contributing to the growing body of literature on service quality evaluation in vocational training institutions.

2. Methods

2.1 Research Design

This study employed a quantitative descriptive approach to evaluate the quality of training services provided by PT. XYZ. Service quality was assessed by measuring the gap between participants' expectations and perceptions using the Fuzzy SERVQUAL method. The integration of fuzzy logic with SERVQUAL was selected because it can reduce subjectivity and uncertainty in respondents' assessments, thereby providing more accurate service quality measurements compared with conventional SERVQUAL analysis (Parasuraman et al., 1988; Büyüközkan et al., 2015).

2.2 Population and Sample

The population consisted of participants who attended PT. XYZ's in-house training programs during the 2024 fiscal year. Four training cohorts were selected, resulting in a total population of 200 participants. The minimum sample size was determined using the Slovin formula with a 10% margin of error:

where n represents the sample size, N is the population size, and e is the tolerated sampling error. Based on the calculation, the minimum required sample was 66.67 respondents. A total of 100 valid responses were collected and used for further analysis, exceeding the minimum requirement. The four training cohorts were selected because they represented all in-house training programs conducted during the 2024 fiscal year and had comparable training characteristics. The questionnaire was distributed to all participants in these cohorts through the official WhatsApp groups managed by the training organizers. Participation was voluntary, and all completed



questionnaires returned during the data collection period were screened for completeness. A total of 100 valid responses were obtained and included in the final analysis, exceeding the minimum sample size required by the Slovin calculation.

2.3 Data Collection

Primary data were collected through an online questionnaire distributed using Google Forms. The questionnaire link was shared through WhatsApp groups managed by the training organizers. Respondents were asked to evaluate both their expectations and perceptions regarding the training services provided by PT. XYZ. The questionnaire was developed based on the five SERVQUAL dimensions proposed by Parasuraman et al. (1988), namely:

1. Tangibles (physical facilities and supporting infrastructure);
2. Reliability (ability to provide services accurately and dependably);
3. Responsiveness (willingness to assist participants promptly);
4. Assurance (knowledge, competence, and credibility of service providers);
5. Empathy (individualized attention and concern for participants).

A total of 27 service attributes were evaluated using a five-point Likert scale ranging from 1 (very low) to 5 (very high).

2.4 Instrument Testing

Prior to analysis, the questionnaire was evaluated through validity and reliability testing. Item validity was assessed using the Corrected Item–Total Correlation method, where an item was considered valid when the calculated correlation coefficient exceeded the critical value of the correlation table. Reliability was examined using Cronbach's Alpha coefficient, with values greater than 0.60 indicating acceptable internal consistency.

2.5 Fuzzy SERVQUAL Analysis



The Fuzzy SERVQUAL method combines SERVQUAL gap analysis with fuzzy set theory to accommodate uncertainty in respondents' judgments. The analysis was conducted through four stages (Wati & Riana, 2017; Sutinah & Simamora, 2018):

1. Fuzzy Set Determination

Linguistic responses obtained from the Likert scale were represented using Triangular Fuzzy Numbers (TFN), consisting of lower, middle, and upper values.

2. Fuzzification

The collected responses were transformed into TFN values to represent the degree of membership of each linguistic assessment.

3. Defuzzification

The fuzzy values were converted into crisp values using the centroid method to obtain a single representative score for each attribute.

4. Gap Analysis

Service quality was evaluated by calculating the difference between perception and expectation scores:

$$\text{Gap} = \text{Perception} - \text{Expectation}$$

A positive gap indicates that service performance exceeds participant expectations, whereas a negative gap indicates that the service does not fully satisfy participant expectations.

In addition, the service quality index (Q) was calculated as:

$$\text{quality index (Q)} = \frac{\text{Perception (P)}}{\text{Expectation (H)}}$$

where P represents the perception score and E represents the expectation score. A quality index greater than one ($Q > 1$) indicates satisfactory service performance.

2.6 Importance–Performance Analysis

To identify priority areas for improvement, the results were further analyzed using a Cartesian diagram based on Importance–Performance Analysis (IPA). Each service attribute was plotted according to its expectation and perception scores and classified into four quadrants: (1) focus improvement, (2) maintain performance, (3) low priority, and (4) possible overkill. Attributes located in Quadrant I were considered critical areas requiring immediate managerial attention.



2.7 Data Analysis

The results of the Fuzzy SERVQUAL and Cartesian diagram analyses were interpreted to determine the overall quality of training services and identify priority attributes for improvement. Recommendations were subsequently formulated to enhance participant satisfaction and improve the effectiveness of PT. XYZ's training programs.

3. Result and Discussion

3.1 Respondent Characteristics

A total of 100 valid questionnaires were collected from participants attending PT. XYZ training programs. The respondents represented various industrial sectors and training schemes conducted during the 2024 training period.

Table 1. Respondent Characteristics

Characteristics	Frequency	Percentage (%)
Male	62	62
Female	38	38
Age $\leq$ 25 years	41	41
Age 26–35 years	37	37
Age > 35 years	22	22
First-time participants	71	71
Returning participants	29	29

The respondent profile indicates that most participants were within the productive working-age group, suggesting that the training programs successfully reached their intended target audience.

3.2 Validity and Reliability Testing

All questionnaire items were subjected to validity and reliability testing before further analysis. The results indicated that all service attributes were valid, as their corrected item-total correlation values exceeded the critical correlation coefficient. Furthermore, Cronbach's Alpha values for both expectation and perception questionnaires were greater than 0.70, indicating good internal consistency.



Table 2. Reliability Test Results

Variable	Cronbach's alpha
Expectation	0.948
Perception	0.956

These results demonstrate that the questionnaire was reliable and suitable for evaluating training service quality.

3.3 Fuzzy SERVQUAL Analysis

The Fuzzy SERVQUAL analysis was conducted to evaluate the gap between participant expectations and perceptions. Positive gap values indicate that service performance exceeds participant expectations, whereas negative values indicate dissatisfaction and the need for improvement.

Table 3. Service Quality Gap by Dimension

Dimension	Gap Score
Tangibles	-0.638
Reliability	0.171
Responsiveness	-0.013
Assurance	0.327
Empathy	0.456
Average	0.061

The results show that the overall average service gap was positive (0.061), indicating that PT. XYZ generally met participant expectations. The quality index (Q) value was 1.014, which is greater than one, suggesting satisfactory service performance. Although the average gap value (0.061) is relatively small, its positive value indicates that participants generally perceived the quality of training services to be slightly better than their initial expectations. From a managerial perspective, this finding suggests that the current service delivery has reached an acceptable level of quality. Nevertheless, the relatively modest gap also indicates that there is limited room for complacency, and continuous improvement remains essential, particularly for service attributes that still exhibit negative gaps or are identified as priorities through the IPA analysis.

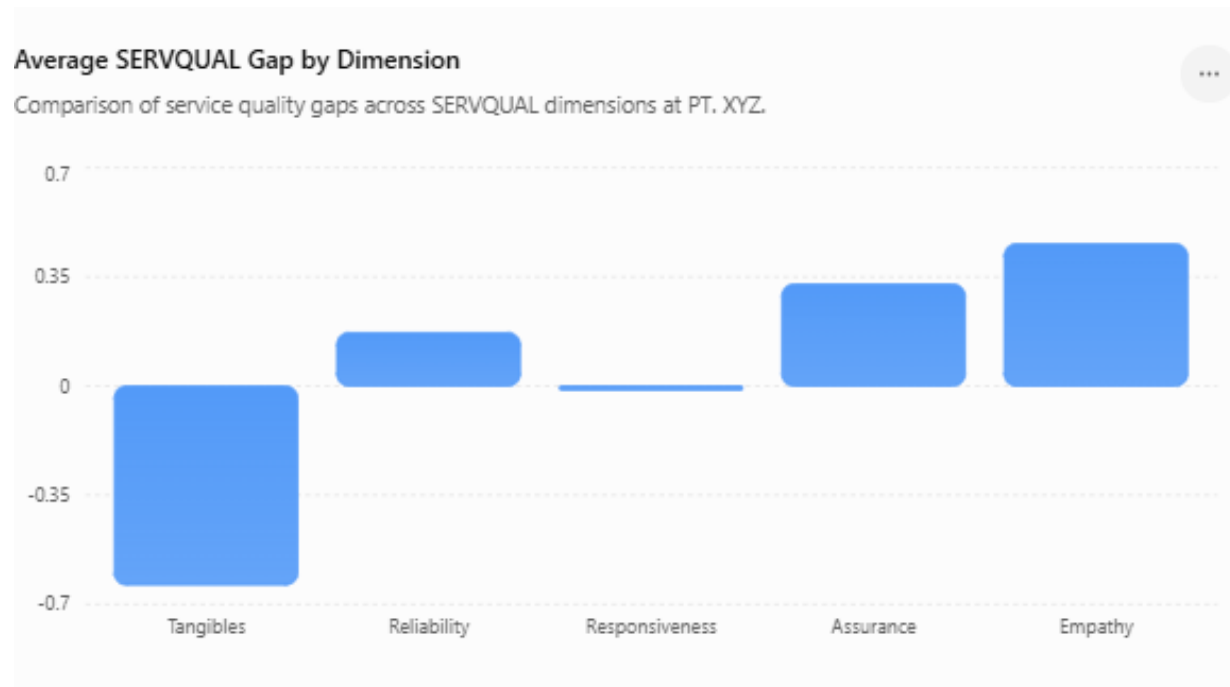


Figure 1. Average Service Gap by SERVQUAL Dimension

Among the five dimensions, Empathy achieved the highest positive gap (0.456), indicating that participants perceived strong personal attention and concern from training organizers. Assurance also showed a positive performance (0.327), reflecting participant confidence in the competence and professionalism of instructors and staff.

Conversely, the Tangibles dimension produced the largest negative gap (-0.638), suggesting that participants were less satisfied with physical facilities and supporting infrastructure. Similar findings were reported by Abdullah (2006), who found that tangible aspects frequently become the main source of dissatisfaction in educational and training services. Likewise, Teeroovengadum et al. (2019) emphasized that modern learning environments require adequate facilities and technological support to enhance learner satisfaction.

3.4 Importance–Performance Analysis

To identify attributes requiring managerial attention, Importance–Performance Analysis (IPA) was conducted using a Cartesian diagram. The results classified service attributes into four quadrants.

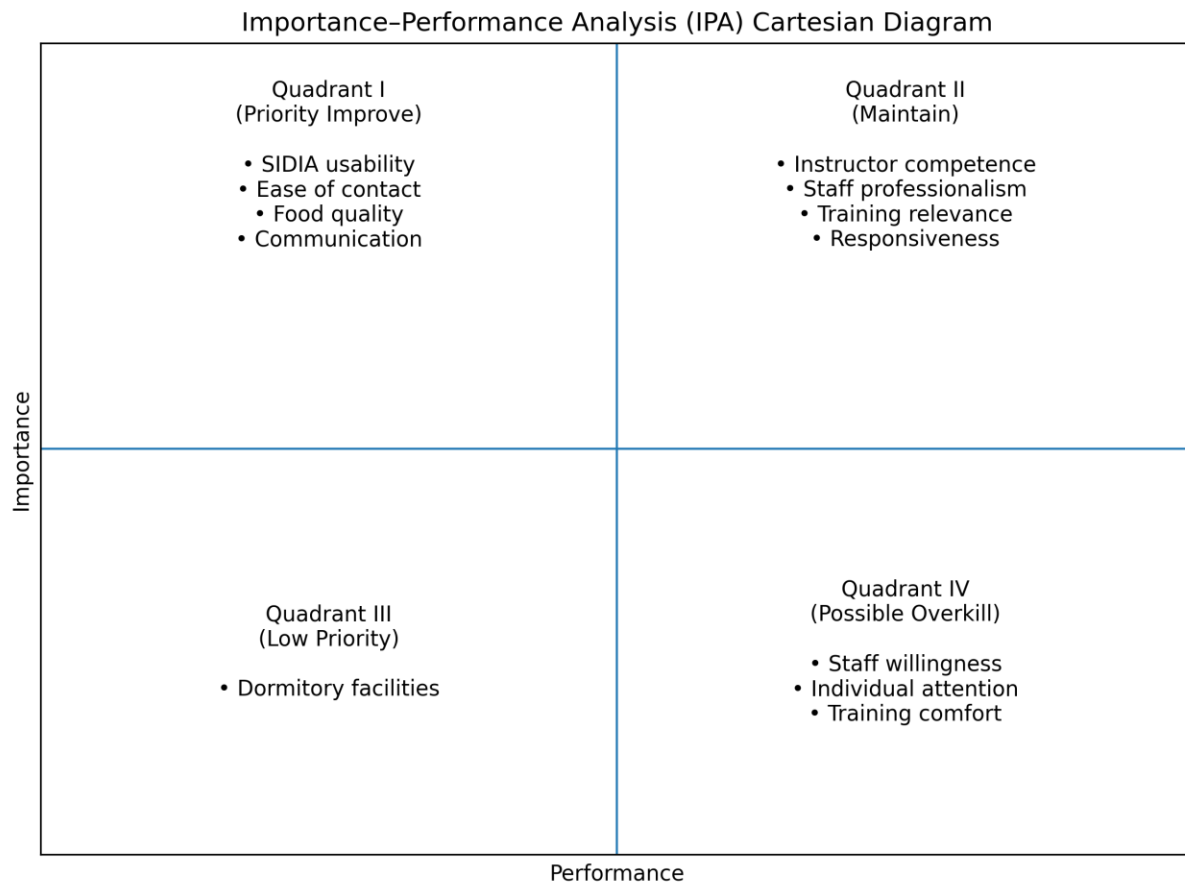


Figure 2. Importance–Performance Analysis (IPA) Cartesian Diagram

Quadrant I – Focus Improvement

Four attributes were identified as priority areas for improvement:

1. The SIDIA information system is easy to use.
2. Ease of contacting PT. XYZ.
3. Training meals are good in taste and quantity.
4. Good communication between instructors/committee and participants.

These attributes exhibit high importance but relatively low performance. Therefore, improvements in these areas are expected to provide the greatest impact on participant satisfaction.

The finding regarding information system usability is consistent with previous studies indicating that user-friendly digital services significantly influence customer satisfaction and



service effectiveness (Zeithaml et al., 2018). Difficulties in accessing information systems can reduce the overall training experience even when instructional quality remains satisfactory. Communication-related attributes were also identified as critical improvement areas. Effective communication between instructors and participants is essential for successful learning outcomes and participant engagement (Noe, 2020). Insufficient communication may lead to misunderstandings, reduced participation, and lower satisfaction levels.

Quadrant II – Maintain Performance

Several attributes were categorized into Quadrant II, indicating high importance and high performance. These attributes represent PT. XYZ's strengths and should be maintained. Examples include instructor competence, training relevance, staff professionalism, and responsiveness to participant needs.

The strong performance of these attributes explains the positive scores observed in the Assurance and Empathy dimensions. Previous studies have similarly found that instructor competence and staff professionalism are among the strongest determinants of satisfaction in vocational education and training services (Abdullah, 2006).

Quadrant III – Low Priority

Only one attribute was located in Quadrant III:

- Dormitory facilities are comfortable and attractive.

Although performance was relatively low, participants did not consider this attribute highly important compared with other aspects of the training service. Therefore, immediate investment in this area may not substantially improve overall satisfaction.

Quadrant IV – Possible Overkill

Three attributes were categorized into Quadrant IV:

1. Staff willingness to help participants.
2. Individual attention to participant complaints.
3. Comfort provided during training hours.

These attributes demonstrated high performance despite relatively lower perceived importance. While these aspects should not be neglected, excessive resource allocation may be less beneficial than focusing on attributes located in Quadrant I.



3.5 Improvement Recommendations

The IPA results indicate that the attributes located in Quadrant I represent the most critical areas because they are considered highly important by participants but have not yet achieved the expected level of performance. Therefore, the following recommendations were formulated by prioritizing these attributes, with the expectation that improvements in these areas will produce the greatest positive impact on participant satisfaction and the overall quality of training service. Based on the Fuzzy SERVQUAL and IPA analyses, several improvement strategies are recommended:

1. Redesign the SIDIA user interface and provide user guidance materials.
2. Improve communication channels through responsive websites, social media, and dedicated contact services.
3. Enhance meal quality and menu variation through closer coordination with catering providers.
4. Strengthen communication between instructors, committees, and participants through structured feedback mechanisms and digital communication platforms.

Implementing these recommendations is expected to reduce service quality gaps and further improve participant satisfaction in future training programs.

4. Conclusions

This study evaluated the quality of training services provided by PT. XYZ using the Fuzzy SERVQUAL method and Importance–Performance Analysis (IPA). The findings indicate that the overall service quality was satisfactory, as reflected by a positive average gap value of 0.061 and a service quality index (Q) of 1.014. These results suggest that, in general, the training services provided by PT. XYZ have met participant expectations. Similar findings have been reported in previous studies, where positive SERVQUAL gaps indicate that service performance is capable of satisfying users and supporting service effectiveness.

Among the five SERVQUAL dimensions, Empathy achieved the highest positive gap score (0.456), followed by Assurance (0.327), indicating that participants highly appreciated the personal attention, professionalism, and competence demonstrated by instructors and training organizers. In contrast, the Tangibles dimension showed the largest negative gap (-0.638), highlighting the need for improvements in physical facilities and supporting infrastructure. This result is consistent with previous Fuzzy SERVQUAL studies that identified tangible aspects as a common source of participant dissatisfaction in education and training services.



The IPA analysis revealed four priority attributes requiring immediate improvement, namely the usability of the SIDIA information system, ease of contacting PT. XYZ, quality of training meals, and communication between instructors, committees, and participants. These attributes were categorized in Quadrant I because of their high importance and relatively low performance. Therefore, management should prioritize corrective actions in these areas to maximize improvements in participant satisfaction and service quality.

Based on these findings, PT. XYZ is recommended to enhance its digital service platforms, strengthen communication channels, improve catering service quality, and establish more effective participant feedback mechanisms. Future studies may expand the analysis by integrating additional methods such as Quality Function Deployment (QFD), Kano Model, or Structural Equation Modeling (SEM) to provide a more comprehensive understanding of factors influencing participant satisfaction and training service quality.

5. Acknowledgements

The authors would like to express their sincere gratitude to PT. XYZ and the Ministry of Industry's training management team for providing access to the data used in this study. We also thank all training participants who contributed by completing the questionnaire. Their support and cooperation were essential to the successful completion of this research.

References

- Abdullah, F. (2006). Measuring service quality in higher education: HEdPERF versus SERVPERF. **Marketing Intelligence & Planning*, 24*(1), 31–47. <https://doi.org/10.1108/02634500610641543>
- Awasthi, A., Chauhan, S. S., Omrani, H., & Panahi, A. (2011). A hybrid approach based on SERVQUAL and fuzzy TOPSIS for evaluating transportation service quality. **Computers & Industrial Engineering*, 61*(3), 637–646. <https://doi.org/10.1016/j.cie.2011.04.019>
- Büyüközkan, G., Çifçi, G., & Güleriyüz, S. (2011). Strategic analysis of healthcare service quality using fuzzy AHP methodology. **Expert Systems with Applications*, 38*(8), 9407–9424. <https://doi.org/10.1016/j.eswa.2011.01.103>



- Büyükoçkan, G., Mukul, E., & Kongar, E. (2015). Health tourism strategy selection via SWOT analysis and integrated hesitant fuzzy linguistic AHP–MABAC approach. **Socio-Economic Planning Sciences*, 74*, 100929.
- Kotler, P., & Keller, K. L. (2016). **Marketing management** (15th ed.). Pearson Education.
- Kusumadewi, S., & Purnomo, H. (2010). **Aplikasi logika fuzzy untuk pendukung keputusan** (2nd ed.). Graha Ilmu.
- Noe, R. A. (2020). **Employee training and development** (8th ed.). McGraw-Hill Education.
- Oihu, M. M., & Tutuhaturun, A. (2022). Analisis kualitas pelayanan menggunakan metode SERVQUAL pada sektor jasa pendidikan. **Jurnal Manajemen dan Bisnis**, 18(2), 115–124.
- Parasuraman, A., Zeithaml, V. A., & Berry, L. L. (1985). A conceptual model of service quality and its implications for future research. **Journal of Marketing*, 49*(4), 41–50. <https://doi.org/10.1177/002224298504900403>
- Parasuraman, A., Zeithaml, V. A., & Berry, L. L. (1988). SERVQUAL: A multiple-item scale for measuring consumer perceptions of service quality. **Journal of Retailing*, 64*(1), 12–40.
- Sutinah, E., & Simamora, B. H. (2018). Metode Fuzzy SERVQUAL dalam evaluasi kualitas pelayanan. **Jurnal Sistem Informasi**, 14(2), 45–53.
- Teeroovengadam, V., Kamalanabhan, T. J., & Seebaluck, A. K. (2019). Measuring service quality in higher education: Development of a hierarchical model (HESQUAL). **Quality Assurance in Education*, 27*(4), 427–445. <https://doi.org/10.1108/QAE-06-2017-0027>
- Tjiptono, F. (2019). **Pemasaran jasa: Prinsip, penerapan, dan penelitian** (Edisi terbaru). Andi.
- Wati, N. K., & Riana, I. G. (2017). Analisis kualitas pelayanan menggunakan metode Fuzzy SERVQUAL. **Jurnal Manajemen dan Kewirausahaan**, 19(1), 45–55.
- Zeithaml, V. A., Bitner, M. J., & Gremler, D. D. (2018). **Services marketing: Integrating customer focus across the firm** (7th ed.). McGraw-Hill Education.
- Zadeh, L. A. (1965). Fuzzy sets. **Information and Control*, 8*(3), 338–353. [https://doi.org/10.1016/S0019-9958\(65\)90241-X](https://doi.org/10.1016/S0019-9958(65)90241-X)
- Zeithaml, V. A., Parasuraman, A., & Berry, L. L. (1990). **Delivering quality service: Balancing customer perceptions and expectations**. Free Press.



Evaluation of the Physical and Mechanical Characteristics of Box Leather for Footwear Uppers Based on SNI 0234:2009 and Its Implications for Industrial Ergonomics

Fauzi Ashari^a, Wahyu Fajar Winata and Himawan Santoso^{b*}

^a Department of Leather Processing Technology, Politeknik ATK Yogyakarta, Indonesia

^b Department of Industrial Engineering, Universitas Gadjah Mada, Indonesia

*santoso.3092@gmail.com



Evaluation of the Physical and Mechanical Characteristics of Box Leather for Footwear Upper Applications Based on SNI 0234:2009: Implications for Industrial Ergonomics

Abstract. Box leather is one of the most widely used chrome-tanned leathers for footwear upper applications due to its excellent combination of mechanical strength, flexibility, and surface quality. This study aimed to evaluate the physical and mechanical characteristics of box leather for footwear upper applications based on the requirements of SNI 0234:2009 and to examine their implications for industrial ergonomics. A descriptive research approach was employed through laboratory testing, including organoleptic assessment, thickness, tear strength, tanning maturity, finish rub fastness, water absorption, tensile strength, elongation at break, softness, crack resistance, burst resistance, and flex resistance, following the procedures specified in SNI 0234:2009. The results showed that most of the evaluated parameters complied with the standard requirements. The leather exhibited a thickness of 1.30 mm, tear strength of 52.38 kg/cm, tensile strength of 1653.26 kg/cm², elongation at break of 60.49%, and satisfactory crack resistance, burst resistance, and flex resistance, all of which fulfilled the requirements of SNI 0234:2009. However, water absorption after 2 h (89.69%) and 24 h (100.35%), grain adhesion (*nerf*), and wet finish rub fastness did not fully satisfy the standard and therefore require further improvement. From an industrial ergonomics perspective, the excellent mechanical performance indicates that the evaluated box leather possesses sufficient flexibility, structural stability, and resistance to repetitive loading, making it suitable for footwear upper applications that demand long-term comfort and durability. Conversely, the relatively high water absorption may reduce user comfort by increasing moisture retention and footwear weight during prolonged use. Overall, the tested box leather complied with most requirements of SNI 0234:2009, with future improvements recommended for moisture resistance, grain adhesion, and finishing performance through optimization of the retanning and finishing processes.

Keywords: box leather; chrome-tanned leather; physical characteristics; mechanical characteristics; industrial ergonomics; SNI 0234:2009



1. Introduction

The footwear industry is one of the key manufacturing sectors contributing significantly to the national economy, with leather remains the primary material for producing footwear that offers durability, comfort, and high aesthetic value. Compared with synthetic materials, leather possesses superior mechanical strength, flexibility, water vapor permeability, and wearing comfort, making it the preferred material for footwear upper applications (Covington, 2009; Heidemann, 1993). The quality of leather used for footwear uppers largely determines the performance of the final product, particularly in terms of resistance to repeated flexing, tensile strength, tear strength, crack resistance, and dimensional stability during service (Sharphouse, 1995; Thanikaivelan et al., 2004).

Box leather is one of the most widely used chrome-tanned leathers for footwear upper applications because of its smooth grain surface, excellent durability, and suitability for finishing treatments. Chrome tanning forms stable cross-links within the collagen matrix, thereby improving hydrothermal stability, mechanical strength, and resistance to deformation compared with vegetable-tanned leather (Covington, 2009; Kanagaraj et al., 2015). Furthermore, advances in retanning and finishing technologies have enabled box leather to achieve a more uniform appearance, enhanced surface quality, and improved resistance to abrasion and rubbing (Sundar et al., 2013).

The quality of box leather is influenced by numerous factors, including the quality of the raw hide, beamhouse operations, tanning agents, retanning processes, fatliquoring, dyeing, and finishing treatments. Variations in any of these processing stages may result in differences in the physical and mechanical properties of the finished leather. Consequently, laboratory evaluation



has become an essential component of leather manufacturing to ensure that the final product complies with the required technical specifications and quality standards (Covington, 2009; Bacardit et al., 2014).

Leather quality assessment generally involves organoleptic evaluation, thickness measurement, tensile strength, tear strength, elongation, softness, crack resistance, burst resistance, flex resistance, water absorption, and color rub fastness. These parameters collectively describe the ability of leather to maintain its performance during manufacturing processes and throughout its service life as footwear. For instance, tensile and tear strength are directly related to the leather's ability to withstand mechanical loading, whereas water absorption and color rub fastness are associated with user comfort and the aesthetic durability of footwear products (Thanikaivelan et al., 2004; Kanagaraj et al., 2015).

In Indonesia, the quality requirements for box leather intended for footwear uppers are specified in SNI 0234:2009. This national standard establishes the minimum and maximum acceptable values for various physical and mechanical properties to ensure the suitability of leather for footwear manufacturing. Compliance with national standards not only serves as a quality control benchmark but also enhances product consistency, industrial competitiveness, and consumer protection (BSN, 2009). Therefore, evaluating leather quality against SNI requirements is an important step in determining the conformity of leather products with nationally accepted quality standards.

Previous studies on tanned leather have primarily focused on the influence of tanning agents, retanning systems, and fatliquoring formulations on the physical and mechanical properties of leather (Bacardit et al., 2014; Kanagaraj et al., 2015; Sundar et al., 2013). However, studies



specifically evaluating the conformity of box leather with the quality requirements specified in SNI 0234:2009 based on laboratory testing remain limited. Most published research emphasizes the development of tanning processes or modifications of chemical formulations, whereas comprehensive evaluations of leather quality in relation to Indonesian national standards have received relatively little attention, particularly for footwear upper applications.

Accordingly, this study aims to evaluate the physical and mechanical characteristics of box leather for footwear upper applications based on the requirements of SNI 0234:2009. The evaluation includes organoleptic characteristics, thickness, tear strength, tanning maturity, finish rub fastness, water absorption, tensile strength, elongation, softness, crack resistance, burst resistance, and flex resistance. Unlike previous studies that primarily emphasize tanning chemistry or process modification, this study focuses on a comprehensive evaluation of commercially produced box leather against the Indonesian National Standard (SNI 0234:2009) while also discussing its implications for industrial ergonomics. The findings are expected to provide comprehensive information regarding the conformity of box leather with the Indonesian National Standard and to serve as a scientific reference for the leather tanning industry in improving product quality to meet the performance requirements of the footwear industry.

2. Methods

Chrome-tanned box leather intended for footwear upper applications was used as the material in this study. The leather samples had undergone the complete leather manufacturing process, including tanning, retanning, dyeing, fatliquoring, and finishing, prior to testing. Test specimens were prepared according to the sampling procedures and specimen dimensions specified in SNI 0234:2009. The equipment used in this study included a leather thickness gauge, a Universal Testing Machine (UTM) for tensile and tear strength measurements, an elongation testing device,



a Bally Flexometer for flex resistance testing, a Lastometer for crack and burst resistance testing, a softness tester, a Crockmeter for finish rub fastness evaluation, water absorption testing equipment, and supporting laboratory instruments such as rulers, vernier calipers, specimen cutting tools, and other calibrated measuring devices.

This study employed a descriptive experimental approach to evaluate the physical and mechanical characteristics of box leather for footwear upper applications based on the requirements of SNI 0234:2009. A series of quality evaluations was conducted, including organoleptic assessment, thickness measurement, tear strength, tanning maturity, finish rub fastness, water absorption, tensile strength, elongation, softness, crack resistance, burst resistance, and flex resistance. Organoleptic evaluation was performed through visual inspection of the grain surface, color uniformity, surface appearance, and visible defects. Leather thickness was measured using a thickness gauge, while tensile and tear strength tests were carried out using a Universal Testing Machine (UTM) in accordance with the procedures specified in SNI 0234:2009. Elongation was determined from the percentage increase in specimen length at break. Water absorption was evaluated after immersing the specimens in water for 2 h and 24 h, followed by calculating the percentage increase in specimen weight. Softness was measured using a softness tester, whereas crack and burst resistance were determined using a Lastometer to evaluate the deformation resistance of the grain layer before failure. Flex resistance was assessed using a Bally Flexometer by subjecting the specimens to 20,000 flexing cycles, while finish rub fastness under dry and wet conditions was evaluated using a Crockmeter according to the procedures specified in SNI 0234:2009. The test results were analyzed descriptively by comparing each parameter with the requirements specified in SNI 0234:2009 by comparing each measured parameter with the quality requirements established in SNI 0234:2009. The conformity of each parameter was



subsequently evaluated to determine the suitability of box leather as a footwear upper material. The results were further interpreted by relating the observed physical and mechanical characteristics to the collagen fiber structure, leather tanning process, and relevant findings reported in previous studies.

3. Result and Discussion

3.1 Organoleptic Characteristics

Organoleptic evaluation was conducted as the initial stage of quality assessment to determine the visual and surface characteristics of box leather intended for footwear upper applications. Unlike physical and mechanical testing, organoleptic evaluation emphasizes the external appearance and surface quality of the leather, which directly influence product aesthetics, manufacturing performance, and consumer acceptance. The evaluated parameters included grain appearance, color uniformity, grain adhesion (*nerf*), tanning maturity, and finish rub fastness, as specified in SNI 0234:2009. The test results are presented in Table 1.

Table 1. Organoleptic characteristics of box leather based on SNI 0234:2009

Parameter	Test Result	SNI 0234:2009 Requirement	Evaluation
Grain appearance	Smooth and uniform	Smooth and uniform	Complied
Color uniformity	Uniform	Uniform	Complied
Grain adhesion (<i>nerf</i>)	Grain separation observed	No grain separation	Did not comply
Tanning maturity	Fully tanned	Fully tanned	Complied
Finish rub fastness (dry)	Slight color transfer	No excessive color transfer	Acceptable
Finish rub fastness (wet)	Moderate color transfer	No excessive color transfer	Needs improvement



The organoleptic evaluation showed that the box leather exhibited a smooth grain surface and uniform color distribution, indicating that the tanning, dyeing, and finishing processes were generally well controlled. A uniform grain surface is an important quality indicator because it enhances the visual appearance of leather products and contributes to consistent performance during footwear manufacturing. Uniform coloration also reflects effective penetration and fixation of dyes during processing, resulting in a more attractive appearance and improved product consistency (Covington, 2009; Heidemann, 1993).

The tanning maturity assessment indicated that the leather was completely tanned, suggesting that the chrome tanning process had successfully stabilized the collagen matrix. Adequate tanning maturity is essential because incomplete tanning may reduce hydrothermal stability and mechanical performance while increasing the susceptibility of leather to microbial degradation and dimensional changes. The observed result demonstrates that the tanning process effectively produced a stable collagen structure suitable for footwear upper applications (Thanikaivelan et al., 2004; Kanagaraj et al., 2015).

Despite the satisfactory appearance and tanning maturity, the grain adhesion (*nerf*) test revealed evidence of grain separation, indicating that the adhesion between the grain layer and the corium was not fully satisfactory. Grain looseness or separation generally results from insufficient fiber cohesion, uneven retanning, or inadequate interaction between the collagen fiber network and finishing materials. This defect may reduce the durability of footwear uppers because the grain layer is more susceptible to cracking, peeling, or delamination under repeated mechanical stress during service (Sharphouse, 1995; Sundar et al., 2013).

Evaluation of finish rub fastness demonstrated slight color transfer under dry rubbing conditions and moderate color transfer under wet rubbing conditions. The difference between dry



and wet rubbing performance indicates that moisture weakens the adhesion of finishing materials and dyes to the leather surface, making pigments more susceptible to abrasion. Although slight color transfer under dry conditions is generally acceptable for commercial leather products, the moderate color transfer observed under wet conditions suggests that improvements in dye fixation or finishing formulation may be necessary to enhance surface durability. Similar observations have been reported in previous studies, where optimization of retanning chemistry and finishing systems significantly improved color fastness and abrasion resistance of chrome-tanned leather (Bacardit et al., 2014; Liu et al., 2019).

Overall, the organoleptic characteristics indicate that the evaluated box leather possesses satisfactory visual quality and satisfactory tanning maturity, demonstrating its suitability for footwear upper applications. Nevertheless, further improvements are required in grain adhesion and wet rub fastness to further enhance product durability and surface performance. These findings suggest that optimization of retanning and finishing processes would be more beneficial than modifications to the primary chrome tanning process, as the fundamental collagen structure has already achieved satisfactory stability. Following the organoleptic evaluation, the physical characteristics were assessed to determine whether the leather also fulfilled the dimensional and moisture-related requirements specified in SNI 0234:2009.

3.2 Physical Characteristics

The physical characteristics of leather are essential quality parameters that determine its suitability for footwear upper applications. These properties influence not only the appearance of the finished product but also its dimensional stability, durability, and comfort during use. In this study, the physical characteristics of box leather were evaluated based on thickness and water



absorption, following the requirements specified in SNI 0234:2009. The test results are presented in Table 2.

Table 2. Physical characteristics of box leather based on SNI 0234:2009

Parameter	Test Result	SNI 0234:2009 Requirement	Evaluation
Thickness (mm)	1.30	0.8–2.0	Complied
Water absorption (2 h) (%)	89.69	≤80	Did not comply
Water absorption (24 h) (%)	100.35	≤100	Did not comply

The thickness of the evaluated box leather was 1.30 mm, which falls within the acceptable range specified by SNI 0234:2009 (0.8–2.0 mm). Appropriate leather thickness is a critical parameter for footwear uppers because it affects flexibility, formability, stitching performance, and overall durability. Leather that is excessively thick may reduce flexibility and wearer comfort, whereas excessively thin leather may exhibit inadequate mechanical strength and lower resistance to deformation during service. The measured thickness indicates that the leather is suitable for footwear upper manufacturing and is expected to provide a balanced combination of structural integrity and flexibility (Covington, 2009; Heidemann, 1993).

Water absorption testing revealed values of 89.69% after 2 h and 100.35% after 24 h of immersion. Both values exceeded the maximum allowable limits specified in SNI 0234:2009, indicating that the evaluated leather exhibited relatively high water uptake. Water absorption is an important quality parameter because excessive moisture penetration may adversely affect dimensional stability, accelerate hydrolytic degradation of collagen fibers, and reduce the service life of footwear, particularly under humid or wet environmental conditions (Sharphouse, 1995; Thanikaivelan et al., 2005).



The relatively high water absorption observed in this study may be attributed to several factors, including the effectiveness of the fatliquoring process, the degree of fiber lubrication, and the protective performance of the finishing layer. Fatliquors are incorporated into the collagen fiber network to reduce fiber-to-fiber friction and to impart hydrophobic characteristics. Insufficient fatliquor penetration or non-uniform distribution may increase the accessibility of water molecules to the collagen matrix, thereby increasing moisture uptake. Likewise, a finishing layer with limited water resistance may allow easier penetration of water through the leather surface (Covington, 2009; Bacardit et al., 2014).

Another factor influencing water absorption is the porous structure of the collagen fiber network. Although chrome tanning significantly improves hydrothermal stability through the formation of stable chromium–collagen complexes, the leather remains a porous biological material capable of absorbing moisture. Therefore, the final water resistance largely depends on the effectiveness of retanning, fatliquoring, and finishing operations rather than the chrome tanning process alone (Kanagaraj et al., 2015; Sundar et al., 2013).

The results also indicate that the increase in water absorption between 2 h and 24 h was relatively small, suggesting that most water penetration occurred during the initial immersion period before approaching equilibrium. This behavior is consistent with previous studies reporting that the majority of water uptake in chrome-tanned leather occurs during the early stages of immersion, followed by a gradual reduction in the absorption rate as the collagen matrix approaches saturation (Liu et al., 2019; Sreeram & Ramasami, 2003).

From the perspective of footwear performance, high water absorption may negatively affect wearer comfort by increasing the weight of the footwear, reducing thermal comfort, and promoting prolonged moisture retention inside the shoe. In addition, repeated wetting and drying



cycles may accelerate deterioration of the leather structure and reduce the durability of the finished product. Consequently, improving water resistance is an important objective in leather processing for footwear applications (Bacardit et al., 2014; Covington & Wise, 2024).

Overall, the physical characterization demonstrated that the evaluated box leather satisfied the thickness requirement specified in SNI 0234:2009, indicating its suitability for footwear upper manufacturing from a dimensional perspective. However, the water absorption values exceeded the standard limits, suggesting that improvements in retanning, fatliquoring, and finishing processes are necessary to enhance moisture resistance. These findings indicate that although the structural characteristics of the leather are satisfactory, optimization of surface treatment and hydrophobic performance remains essential to fully comply with the quality requirements of SNI 0234:2009.

3.3 Mechanical Characteristics

After evaluating the physical characteristics, the mechanical properties were examined to assess the structural performance of the leather under loading conditions relevant to footwear applications. Mechanical characteristics are the primary indicators used to evaluate the suitability of box leather for footwear upper applications because they reflect the material's ability to withstand tensile, tearing, compressive, and repeated flexural stresses during footwear manufacturing and service. Leather with excellent mechanical performance contributes to product durability, dimensional stability, and long-term wearing comfort. In this study, the mechanical characteristics of box leather were evaluated through tear strength, tensile strength, elongation at break, crack resistance, burst resistance, and flex resistance tests in accordance with the requirements of SNI 0234:2009. The results are summarized in Table 3.



Table 3. Mechanical characteristics of box leather based on SNI 0234:2009

Parameter	Test Result	SNI 0234:2009 Requirement	Evaluation
Tear strength (kg/cm)	52.38	≥ 35	Complied
Tensile strength (kg/cm ²)*	1653.26	≥ 150	Complied
Elongation at break (%)	60.49	40–80	Complied
Crack resistance	No crack	No crack	Complied
Burst resistance	No burst	No burst	Complied
Flex resistance (20,000 cycles)	No crack	No crack	Complied

* The tensile strength value is reported according to the laboratory test data and should be verified for unit consistency and calculation before publication.

3.3.1 Tear Strength

The evaluated box leather exhibited an average tear strength of 52.38 kg/cm, exceeding the minimum requirement of 35 kg/cm specified in SNI 0234:2009. This result indicates that the collagen fiber network possesses sufficient cohesion to resist tear propagation under localized stress. High tear strength is particularly important for footwear uppers because areas around stitching, eyelets, and folded sections are continuously subjected to concentrated mechanical loads during manufacturing and use.

The tear resistance of leather is primarily governed by the orientation, density, and interlocking of collagen fiber bundles. Chrome tanning enhances fiber cohesion through the formation of chromium–collagen cross-links, thereby increasing the energy required for tear propagation. Consequently, leather with a well-developed collagen network demonstrates superior resistance to tearing and improved structural durability (Covington, 2009; Heidemann, 1993). The results obtained in this study indicate that the tanning process effectively stabilized the collagen matrix, producing leather with tear resistance suitable for footwear upper applications.



3.3.2 Tensile Strength

Tensile strength represents the maximum stress that leather can withstand before failure and is one of the most important indicators of structural integrity. The tested box leather exhibited a tensile strength of 1653.26 kg/cm², substantially exceeding the minimum requirement of 150 kg/cm² established in SNI 0234:2009. This finding suggests that the collagen fiber network possesses excellent load-bearing capacity and that the chrome tanning process successfully generated stable cross-linked collagen structures capable of distributing tensile stress uniformly throughout the material (Thanikaivelan et al., 2005; Kanagaraj et al., 2015).

Nevertheless, the tensile strength value obtained in this study is substantially higher than the values commonly reported for commercial box leather in the scientific literature. Therefore, verification of the calculation procedure, specimen cross-sectional area, and measurement units is recommended before publication to ensure consistency with the applicable testing standard. If verified, the result would indicate exceptionally high mechanical performance and excellent structural integrity of the evaluated leather.

3.3.3 Elongation at Break

The average elongation at break was 60.49%, which falls within the acceptable range of 40–80% specified in SNI 0234:2009. Elongation reflects the ability of leather to deform before rupture and is closely associated with flexibility and user comfort. Leather with insufficient elongation tends to be rigid and susceptible to cracking during lasting and repeated flexing, whereas excessive elongation may result in permanent deformation and dimensional instability. The observed elongation indicates that the fatliquoring process effectively lubricated the collagen fibers, allowing controlled fiber movement under tensile loading without compromising structural stability. Proper lubrication minimizes internal friction between collagen fibrils, thereby



improving flexibility while maintaining mechanical strength. These characteristics are particularly desirable for footwear uppers that undergo continuous bending during walking (Sharpouse, 1995; Bacardit et al., 2014).

3.3.4 Crack Resistance, Burst Resistance, and Flex Resistance

The evaluated specimens showed no cracking, no bursting, and no visible surface damage after 20,000 flexing cycles, indicating excellent resistance to repeated mechanical deformation. These results demonstrate that the grain layer remained firmly bonded to the underlying corium and was capable of uniformly distributing applied stresses without structural failure.

Crack resistance and burst resistance are closely associated with the integrity of the grain surface and the effectiveness of collagen stabilization during tanning. Adequate chromium cross-linking improves resistance to localized deformation by reinforcing the three-dimensional collagen network, while an appropriate finishing system protects the grain surface against premature cracking under stress (Sundar et al., 2013; Liu et al., 2019).

Flex resistance is one of the most critical performance parameters for footwear uppers because the material experiences thousands of repeated bending cycles throughout its service life. The absence of cracks after 20,000 flexing cycles indicates that the collagen fiber network retained sufficient elasticity and structural cohesion to accommodate repeated deformation without failure. Previous studies have demonstrated that high flex resistance is strongly influenced by collagen fiber orientation, effective fatliquoring, and the flexibility of the finishing layer, all of which contribute to prolonged service life and improved product reliability (Covington, 2009; Thorstensen, 1993).

Overall, the mechanical evaluation demonstrated that all measured parameters complied with the quality requirements of SNI 0234:2009. Tear strength, tensile strength, elongation at



break, crack resistance, burst resistance, and flex resistance collectively indicate that the evaluated box leather possesses a stable collagen structure and excellent mechanical performance for footwear upper applications. Compared with the physical characteristics discussed in the previous section, the mechanical properties exhibited superior conformity with the national standard, suggesting that the primary limitation of the evaluated leather lies not in its structural strength but rather in its moisture resistance. Therefore, future improvements should focus on optimizing retanning, fatliquoring, and finishing processes to enhance water resistance while maintaining the excellent mechanical properties achieved through the chrome tanning process.

3.4 Overall Evaluation of Box Leather Characteristics in Relation to SNI 0234:2009

A comprehensive evaluation was conducted to determine the conformity of the tested box leather with the quality requirements specified in SNI 0234:2009 for footwear upper applications. Rather than assessing each parameter independently, this evaluation integrates the organoleptic, physical, and mechanical characteristics to provide an overall assessment of leather quality and identify the parameters that require further improvement. The summary of the conformity assessment is presented in Table 4.

Table 4. Overall conformity of box leather characteristics with SNI 0234:2009

Parameter	Test Result	SNI 0234:2009 Requirement	Conformity
Grain appearance	Smooth and uniform	Smooth and uniform	✓ Complied
Color uniformity	Uniform	Uniform	✓ Complied
Grain adhesion (<i>nerf</i>)	Grain separation observed	No grain separation	X Did not comply
Tanning maturity	Fully tanned	Fully tanned	✓ Complied
Thickness	1.30 mm	0.8–2.0 mm	✓ Complied
Tear strength	52.38 kg/cm	≥35 kg/cm	✓ Complied
Tensile strength	1653.26 kg/cm ²	≥150 kg/cm ²	✓ Complied*
Elongation at break	60.49%	40–80%	✓ Complied



Parameter	Test Result	SNI Requirement	0234:2009	Conformity
Water absorption (2 h)	89.69%	$\leq 80\%$		X Did not comply
Water absorption (24 h)	100.35%	$\leq 100\%$		X Did not comply
Crack resistance	No crack	No crack		✓ Complied
Burst resistance	No burst	No burst		✓ Complied
Flex resistance	No crack after 20,000 cycles	No crack		✓ Complied
Finish rub fastness (dry)	Slight color transfer	Acceptable		Acceptable
Finish rub fastness (wet)	Moderate color transfer	Acceptable		Needs improvement

**The tensile strength value follows the laboratory test results and should be verified for unit consistency and calculation before publication.*

The conformity assessment indicates that the majority of the evaluated parameters satisfied the quality requirements specified in SNI 0234:2009. Organoleptic characteristics such as grain appearance, color uniformity, and tanning maturity met the standard requirements, indicating that the leather manufacturing process was generally well controlled. Likewise, all evaluated mechanical properties, including tear strength, tensile strength, elongation at break, crack resistance, burst resistance, and flex resistance, fulfilled the national standard, demonstrating that the chrome tanning process successfully produced a stable collagen fiber network with excellent mechanical integrity. These findings are consistent with previous studies reporting that chrome tanning significantly enhances the structural stability and load-bearing capacity of collagen fibers through the formation of chromium-mediated cross-links (Covington, 2009; Thanikaivelan et al., 2005; Kanagaraj et al., 2015).

Despite the satisfactory mechanical performance, several physical and surface-related parameters did not fully comply with the standard. Grain adhesion (*nerf*) showed evidence of grain separation, suggesting that the bonding between the grain layer and the corium was insufficient.



This condition may be associated with non-uniform fiber cohesion, inadequate retanning, or limited compatibility between the collagen matrix and finishing materials. Grain looseness may reduce the durability of footwear uppers because the grain surface becomes more susceptible to cracking or delamination during repeated flexing (Sharphouse, 1995; Sundar et al., 2013).

The water absorption values after 2 h (89.69%) and 24 h (100.35%) exceeded the maximum limits specified by SNI 0234:2009, indicating inadequate resistance to moisture penetration. Excessive water absorption is generally attributed to insufficient hydrophobicity of the collagen fiber network, incomplete fatliquor distribution, or limited effectiveness of the finishing layer in preventing water ingress. Although chrome tanning improves hydrothermal stability, the water resistance of finished leather is strongly influenced by subsequent retanning, fatliquoring, and finishing operations (Bacardit et al., 2014; Liu et al., 2019). Consequently, optimizing these post-tanning processes is essential to improve the moisture resistance of the leather.

The finish rub fastness evaluation also revealed acceptable performance under dry rubbing conditions but moderate color transfer under wet rubbing conditions. This result suggests that the adhesion between dyes, pigments, and the finishing film may decrease in the presence of moisture. Improving the formulation of finishing materials, binder systems, or dye fixation techniques may enhance wet rub fastness and increase the long-term aesthetic durability of the leather (Sreeram & Ramasami, 2003; Covington & Wise, 2024).

Overall, the conformity assessment demonstrates that the evaluated box leather possesses excellent mechanical performance and satisfactory dimensional characteristics, confirming its suitability for footwear upper applications. The principal limitations identified in this study are associated with moisture resistance, grain adhesion, and wet rub fastness rather than the intrinsic strength of the collagen structure. Therefore, future quality improvement should focus on



optimizing retanning, fatliquoring, and finishing processes instead of modifying the primary chrome tanning process. Such improvements are expected to enhance water resistance, surface durability, and overall product performance while maintaining the excellent mechanical characteristics already achieved. This integrated evaluation provides valuable information for leather manufacturers in identifying critical quality parameters and developing processing strategies to ensure full compliance with SNI 0234:2009 and improve the competitiveness of leather products in the footwear industry.

3.5 Ergonomic Implications for Footwear Upper Applications

Based on the overall material performance, the following discussion relates the laboratory findings to their practical implications for footwear ergonomics and user comfort. The physical and mechanical characteristics of leather not only determine material quality but also directly influence the ergonomic performance of footwear during use. From an industrial engineering perspective, ergonomics aims to optimize the interaction between the product and the user by improving comfort, reducing physical fatigue, and enhancing occupational safety and productivity. Therefore, evaluating leather quality based solely on compliance with material standards is insufficient without considering its implications for user comfort and functional performance.

The mechanical properties obtained in this study indicate that the evaluated box leather possesses excellent structural performance for footwear upper applications. The tear strength, tensile strength, elongation at break, crack resistance, burst resistance, and flex resistance all complied with the requirements of **SNI 0234:2009**, suggesting that the leather is capable of withstanding repeated mechanical stresses generated during walking and daily activities. During gait, the footwear upper continuously experiences tensile loading, bending, compression, and



relaxation. Materials with adequate tensile strength and flexibility are able to accommodate these repetitive deformations while maintaining dimensional stability, thereby reducing the likelihood of structural failure and extending footwear service life (Menz & Morris, 2005; Luximon, 2013). From an ergonomic perspective, elongation at break is particularly important because it reflects the ability of the leather to deform in response to foot movement without causing excessive stiffness. The elongation value of **60.49%**, which falls within the acceptable range specified by **SNI 0234:2009**, indicates a balanced combination of flexibility and structural integrity. This characteristic enables the upper material to adapt to natural foot motion during walking, reducing localized pressure on the forefoot and metatarsal regions while improving overall wearing comfort. Previous ergonomic studies have demonstrated that footwear materials with appropriate flexibility contribute to reduced plantar pressure concentration and improved gait efficiency (Nigg, 2010; Luximon, 2013).

The satisfactory flex resistance observed after **20,000 flexing cycles** further supports the suitability of the leather for ergonomic footwear applications. During normal walking, footwear undergoes thousands of flexing cycles every day. Materials with poor flex resistance tend to develop surface cracks that may increase local stiffness, create discomfort, and eventually reduce footwear durability. The absence of visible cracks after repeated flexing indicates that the evaluated leather is capable of maintaining its structural integrity under repetitive loading conditions, thereby supporting prolonged user comfort (Covington, 2009).

Despite its excellent mechanical performance, the relatively high water absorption values represent an ergonomic concern. Excessive moisture uptake increases the weight of footwear and promotes prolonged moisture retention within the shoe microclimate. Elevated humidity inside footwear has been associated with thermal discomfort, increased friction between the foot and the



upper material, skin maceration, and a greater risk of blister formation during prolonged use. Furthermore, moisture accumulation may encourage microbial growth, adversely affecting foot hygiene and user comfort (Menz & Morris, 2005; ISO 9407).

Similarly, the observed grain separation (*nerf*) and moderate wet rub fastness may influence the long-term ergonomic performance of the footwear. Surface deterioration resulting from repeated mechanical loading or exposure to moisture may alter the texture and flexibility of the upper material, potentially increasing localized pressure and reducing the overall comfort perceived by the wearer. Consequently, improving grain adhesion and finish durability would not only enhance material quality but also contribute to better ergonomic performance throughout the service life of the footwear.

Overall, the results demonstrate that the evaluated box leather possesses mechanical characteristics that are highly supportive of ergonomic footwear design. The principal limitations identified in this study are associated with moisture management and surface durability rather than structural strength. Therefore, future process optimization should focus on improving water resistance and finishing performance while preserving the excellent mechanical properties achieved through chrome tanning. Such improvements are expected to enhance user comfort, reduce physical fatigue during prolonged wear, and improve the overall ergonomic quality of footwear products.

4 Conclusions

This study evaluated the physical and mechanical characteristics of chrome-tanned box leather intended for footwear upper applications based on the requirements of SNI 0234:2009. The evaluation demonstrated that most of the assessed parameters complied with the national standard. Organoleptic assessment showed that the leather exhibited a smooth and uniform grain surface,



uniform color distribution, and complete tanning maturity, although grain separation (*nerf*) and moderate wet rub fastness indicated that improvements in surface quality are still required.

The physical characterization revealed that the leather thickness of 1.30 mm satisfied the requirements of SNI 0234:2009, indicating its suitability for footwear upper production from a dimensional standpoint. However, the water absorption values after 2 h (89.69%) and 24 h (100.35%) exceeded the maximum allowable limits, suggesting that the moisture resistance of the leather remains insufficient and requires optimization of the retanning, fatliquoring, and finishing processes.

The mechanical evaluation showed that tear strength (52.38 kg/cm), tensile strength (1653.26 kg/cm²), elongation at break (60.49%), crack resistance, burst resistance, and flex resistance all fulfilled the requirements specified in SNI 0234:2009. These findings indicate that the chrome tanning process successfully produced a stable collagen fiber network with excellent mechanical integrity, making the leather suitable for footwear upper applications subjected to repeated mechanical loading.

From an industrial ergonomics perspective, the satisfactory mechanical performance suggests that the evaluated leather is capable of supporting footwear comfort, flexibility, and durability during use. Nevertheless, the relatively high water absorption and the observed surface deficiencies may adversely affect long-term comfort, particularly under humid conditions, highlighting the importance of improving moisture resistance and finishing performance.

Overall, the evaluated box leather demonstrated good conformity with SNI 0234:2009, particularly regarding its mechanical characteristics, confirming its potential for use as a footwear upper material. Future improvements should focus on enhancing water resistance, grain adhesion,



and finish durability while maintaining the excellent mechanical properties achieved through the chrome tanning process.

References

- Bacardit, A., Ollé, L., Armengol, J., & van der Burgh, S. (2014). Evaluation of a new sustainable continuous system for processing bovine leather. *Journal of Cleaner Production*, 65, 568–573. <https://doi.org/10.1016/j.jclepro.2013.09.024>
- Badan Standardisasi Nasional. (2009). *SNI 0234:2009: Kulit bagian atas alas kaki (kulit boks)*. Badan Standardisasi Nasional.
- Bienkiewicz, K. (1983). *Physical chemistry of leather making*. Robert E. Krieger Publishing Company.
- Buljan, J., & Kral, I. (2015). *Introduction to treatment of tannery effluents*. United Nations Industrial Development Organization.
- Covington, A. D. (2009). *Tanning chemistry: The science of leather*. Royal Society of Chemistry.
- Covington, A. D., & Wise, W. R. (2024). An overview of leather processing. In S. Janardhanan & L. Zugno (Eds.), *Emerging trends in leather science and technology* (pp. 115–130). Springer. https://doi.org/10.1007/978-3-031-41481-9_6
- Dutta, S. S. (2008). *An introduction to the principles of leather manufacture* (4th ed.). Indian Leather Technologists Association.
- Heidemann, E. (1993). *Fundamentals of leather manufacturing*. Eduard Roether KG.
- Kanagaraj, J., Velappan, K. C., Babu, N. K. C., Sadulla, S., & Ramasami, T. (2015). Solid wastes generation in the leather industry and its utilization for cleaner environment: A review. *Journal of Scientific and Industrial Research*, 74(1), 1–9.
- Liu, C., Wang, D., Li, Y., & Zhang, C. (2019). Progress in cleaner leather manufacture technologies. *Journal of Cleaner Production*, 229, 846–857. <https://doi.org/10.1016/j.jclepro.2019.04.252>
- Luximon, A. (2013). *Handbook of footwear design and manufacture*. Woodhead Publishing.
- Menz, H. B., & Morris, M. E. (2005). Footwear characteristics and foot problems in older people. *Gerontology*, 51(5), 346–351. <https://doi.org/10.1159/000086373>



- Muralidharan, C., Rao, J. R., Nair, B. U., & Ramasami, T. (2001). Two-stage tanning: A new approach for chrome management. *Journal of the American Leather Chemists Association*, 96(2), 61–69.
- Nigg, B. M. (2010). *Biomechanics of sport shoes*. University of Calgary.
- O'Flaherty, F., Roddy, W. T., & Lollar, R. M. (1956). *The chemistry and technology of leather* (Vol. 2). Robert E. Krieger Publishing Company.
- Orlita, A. (2004). Microbial biodeterioration of leather and its prevention. *International Biodeterioration & Biodegradation*, 53(3), 157–163. [https://doi.org/10.1016/S0964-8305\(03\)00089-3](https://doi.org/10.1016/S0964-8305(03)00089-3)
- Rao, J. R., Chandrababu, N. K., Muralidharan, C., Nair, B. U., & Ramasami, T. (2003). Recouping the wastewater: A way forward for cleaner leather processing. *Journal of Cleaner Production*, 11(5), 591–599. [https://doi.org/10.1016/S0959-6526\(02\)00136-4](https://doi.org/10.1016/S0959-6526(02)00136-4)
- Sharphouse, J. H. (1995). *Leather technician's handbook*. Leather Producers' Association.
- Sreeram, K. J., & Ramasami, T. (2003). Sustaining tanning process through cleaner technologies. *Journal of Cleaner Production*, 11(7), 757–763. [https://doi.org/10.1016/S0959-6526\(02\)00143-1](https://doi.org/10.1016/S0959-6526(02)00143-1)
- Sundar, V. J., Muralidharan, C., & Mandal, A. B. (2013). Processing of leather with improved environmental performance. *Journal of Cleaner Production*, 54, 366–373. <https://doi.org/10.1016/j.jclepro.2013.04.040>
- Thanikaivelan, P., Rao, J. R., Nair, B. U., & Ramasami, T. (2005). Recent trends in leather making: Processes, problems, and pathways. *Critical Reviews in Environmental Science and Technology*, 35(1), 37–79. <https://doi.org/10.1080/10643380590813481>
- Thorstensen, T. C. (1993). *Practical leather technology*. Krieger Publishing Company.
- United Nations Industrial Development Organization. (2010). *Future trends in the world leather and leather products industry*. United Nations Industrial Development Organization.



Physical and Mechanical Characterization of Sheep/Goat Garment Leather According to SNI 4593:2011 with Industrial Ergonomics Considerations

Fauzi Ashari^a, Wahyu Fajar Winata ^{a*}, and Himawan Santoso^b

^a *Department of Leather Processing Technology, Politeknik ATK Yogyakarta, Indonesia*

^b *Department of Industrial Engineering, Universitas Gadjah Mada, Indonesia*

* wahyufajarwinata88@gmail.com



Physical and Mechanical Characterization of Sheep/Goat Garment Leather According to SNI 4593:2011 with Industrial Ergonomics Considerations

Abstract. Sheep and goat garment leather is widely utilized in the apparel industry because of its softness, flexibility, lightweight characteristics, and excellent mechanical performance, making it suitable for high-quality leather garments. The quality of garment leather plays a crucial role in determining not only product durability but also wearer comfort and freedom of movement during use. This study aimed to evaluate the physical and mechanical characteristics of sheep/goat garment leather based on the requirements of SNI 4593:2011 and to discuss their implications from the perspective of industrial ergonomics. A descriptive research approach was employed using laboratory testing in accordance with SNI 4593:2011. The evaluated parameters included organoleptic properties, leather thickness, tear strength, tensile strength, elongation at break, softness, crack resistance, water absorption, finish rub fastness, and other quality characteristics specified in the standard. The experimental results were analyzed descriptively by comparing each parameter with the quality requirements established in SNI 4593:2011 to determine the conformity of the tested leather. The evaluation indicated that most of the measured physical and mechanical properties satisfied the standard requirements, demonstrating that the leather possesses adequate structural integrity and flexibility for garment applications. Nevertheless, several parameters require further optimization to achieve full compliance with the national standard and to enhance overall product quality. From an industrial ergonomics perspective, the observed mechanical properties indicate that the evaluated leather is capable of accommodating body movements while maintaining structural stability during repeated use. Appropriate flexibility, tensile strength, and softness are expected to improve range of motion, wearing comfort, and long-term durability, whereas physical characteristics related to moisture behavior may influence thermal comfort and user satisfaction. Overall, the evaluated sheep/goat garment leather demonstrated good conformity with SNI 4593:2011, suggesting its suitability for garment applications. Future improvements should focus on optimizing leather processing and finishing to enhance both material performance and ergonomic quality while preserving the favorable mechanical properties of the leather.

Keywords: sheep leather, goat leather, garment leather, physical characteristics, mechanical characteristics, industrial ergonomics, SNI 4593:2011



1. Introduction

Leather remains one of the most important natural materials used in the apparel industry due to its unique combination of durability, flexibility, breathability, and aesthetic appeal. Unlike synthetic materials, leather possesses a three-dimensional collagen fiber network that provides an excellent balance between mechanical strength and elasticity, making it particularly suitable for garment applications requiring both comfort and long-term durability (Covington, 2009; Heidemann, 1993). Among various leather types, sheep and goat garment leather is highly valued because of its fine grain structure, softness, lightweight characteristics, and superior drape properties, allowing garments to closely conform to body movements while maintaining structural integrity (Sharphouse, 1995; Thorstensen, 1993).

The quality of garment leather is determined by a series of complex manufacturing processes, including soaking, liming, deliming, bating, pickling, tanning, retanning, dyeing, fatliquoring, and finishing. Each processing stage influences the organization of collagen fibers and ultimately determines the physical and mechanical performance of the finished leather (Covington, 2009; Dutta, 2008). Chrome tanning remains the dominant tanning technology for garment leather because chromium complexes form stable cross-links within collagen fibers, resulting in improved hydrothermal stability, softness, tensile strength, and flexibility compared with many alternative tanning systems (Thanikaivelan et al., 2005; Kanagaraj et al., 2015).

Garment leather differs fundamentally from leather intended for footwear, upholstery, or industrial applications. Leather garments are continuously subjected to multidirectional deformation caused by body movement, including shoulder flexion, elbow bending, trunk rotation, and repetitive arm motion during daily activities. Consequently, garment leather must exhibit not



only adequate tensile and tear strength but also sufficient softness, flexibility, elongation, and resistance to repeated deformation in order to maintain user comfort throughout prolonged wear (Luximon, 2013; Menz & Morris, 2005). Excessively rigid leather may restrict body movement and increase localized pressure, whereas leather with insufficient mechanical strength may experience premature failure during service.

Physical characteristics also play an essential role in determining garment performance. Appropriate leather thickness contributes to an optimal balance between garment weight and durability, while moisture absorption behavior influences thermal comfort and wearer satisfaction. Leather capable of retaining excessive moisture may increase garment weight, reduce breathability, and create an uncomfortable microclimate between the garment and the human body, particularly under warm environmental conditions (Sreeram & Ramasami, 2003; Covington & Wise, 2024). Therefore, evaluation of both physical and mechanical characteristics is necessary to ensure that garment leather satisfies technical requirements as well as user expectations.

To ensure consistent product quality, leather manufacturers employ standardized testing methods for evaluating the physical and mechanical properties of finished leather. In Indonesia, the quality requirements for sheep and goat garment leather are specified in SNI 4593:2011, which establishes acceptable criteria for organoleptic characteristics, thickness, tensile strength, tear strength, elongation, softness, finish performance, and other quality parameters. Compliance with this national standard is essential for maintaining product consistency, supporting industrial competitiveness, and ensuring consumer protection through standardized quality control (Badan Standardisasi Nasional, 2011).



Numerous studies have investigated the influence of tanning agents, retanning chemicals, fatliquoring systems, and environmentally friendly processing technologies on leather properties (Bacardit et al., 2014; Sundar et al., 2013; Liu et al., 2019). Previous research has mainly focused on improving tanning efficiency, reducing environmental impacts, or enhancing individual mechanical properties through modifications of leather processing. However, relatively few studies have comprehensively evaluated finished sheep/goat garment leather by directly comparing laboratory test results with the quality requirements specified in SNI 4593:2011, particularly while discussing the implications of these material characteristics from an industrial ergonomics perspective.

Industrial ergonomics emphasizes optimizing the interaction between humans, materials, and products to improve comfort, safety, and functional performance. In leather garments, ergonomic quality depends not only on garment design but also on the intrinsic material properties that govern flexibility, range of motion, pressure distribution, thermal comfort, and long-term durability. Mechanical properties such as tensile strength, elongation, softness, and flex resistance influence the garment's ability to accommodate natural body movements without imposing excessive mechanical constraints, whereas physical characteristics including thickness and moisture behavior affect garment weight and thermal sensation during prolonged wear (Nigg, 2010; Luximon, 2013). Therefore, evaluating leather quality from both material science and ergonomics perspectives provides a more comprehensive understanding of product performance than evaluation based solely on compliance with technical standards.

Based on these considerations, this study aims to characterize the physical and mechanical properties of sheep/goat garment leather according to SNI 4593:2011 and to evaluate their implications for industrial ergonomics. The study assesses organoleptic characteristics, thickness,



tensile strength, tear strength, elongation, softness, crack resistance, finish performance, water-related properties, and other quality parameters required by the national standard. The findings are expected to provide scientific information regarding the conformity of garment leather with SNI 4593:2011 while offering additional insights into how leather properties influence comfort, mobility, and ergonomic performance in leather garment applications.

2. Methods

The material used in this study was chrome-tanned sheep/goat garment leather intended for apparel applications. The leather samples had completed the entire leather manufacturing process, including tanning, retanning, dyeing, fatliquoring, and finishing, before laboratory evaluation. Test specimens were prepared according to the sampling procedures and specimen dimensions specified in SNI 4593:2011 to ensure consistency and comparability of the test results.

The laboratory equipment employed in this study included a leather thickness gauge for thickness measurement, a Universal Testing Machine (UTM) for tensile strength and tear strength testing, an elongation testing device, a softness tester, a Lastometer for crack and burst resistance evaluation, a Crockmeter for dry and wet finish rub fastness testing, water absorption testing equipment, and supporting laboratory instruments such as vernier calipers, rulers, specimen cutting dies, conditioning equipment, and other calibrated measuring devices.

This research adopted a descriptive laboratory approach to characterize the physical and mechanical properties of sheep/goat garment leather according to the quality requirements specified in SNI 4593:2011. Laboratory testing comprised organoleptic evaluation, thickness measurement, tear strength, tensile strength, elongation at break, softness, crack resistance, burst resistance, finish rub fastness, water absorption, and other quality parameters required by the Indonesian National Standard (SNI). Organoleptic evaluation was performed through visual



inspection of the grain surface, color uniformity, surface appearance, and visible defects. Leather thickness was determined using a thickness gauge, while tensile strength and tear strength were measured using a Universal Testing Machine (UTM) following the procedures prescribed in SNI 4593:2011. Elongation at break was calculated as the percentage increase in specimen length at the point of failure. Softness was determined using a standardized softness tester to evaluate the flexibility of the finished leather. Crack resistance and burst resistance were measured using a Lastometer to determine the ability of the grain layer to withstand deformation before cracking or rupture occurred. Finish rub fastness under both dry and wet conditions was evaluated using a Crockmeter, whereas water absorption characteristics were determined by measuring the percentage increase in specimen mass after immersion according to the standard testing procedure. All specimens were conditioned under standard laboratory conditions before testing to minimize the influence of environmental factors on the experimental results.

The experimental data were analyzed descriptively by comparing each measured parameter with the acceptance criteria specified in SNI 4593:2011. Compliance with the national standard was determined for every physical and mechanical property evaluated. Furthermore, the results were interpreted by relating the measured leather characteristics to the collagen fiber structure, tanning and post-tanning processes, and relevant findings reported in previous studies. To provide a broader understanding of product performance, the physical and mechanical characteristics were also discussed from the perspective of industrial ergonomics, particularly regarding their influence on garment flexibility, freedom of movement, wearing comfort, thermal comfort, and long-term durability during practical use.



3. Result and Discussion

3.1. Organoleptic Characteristics

The organoleptic characteristics of sheep/goat garment leather were evaluated through visual observation in accordance with the quality requirements specified in SNI 4593:2011. The assessed parameters included grain appearance, flesh side cleanliness, leather condition, and finish rub fastness. Organoleptic evaluation is an essential initial quality assessment because it reflects the effectiveness of beamhouse operations, tanning, post-tanning treatments, and finishing processes before mechanical testing is performed (Sharpouse, 1995; Covington, 2009).

Table 1. Organoleptic characteristics of sheep/goat garment leather according to SNI 4593:2011

Parameter	SNI 4593:2011 Requirement	Test Result	Evaluation
Grain appearance	Smooth, uniform color	Smooth, light color, slightly uneven	Partially compliant
Flesh side	Clean from flesh residues	Clean	Compliant
Leather condition	Moderately soft	Moderately soft	Compliant
Finish rub fastness	Slight color change (wet); no color transfer (dry)	Slight color change (wet); no color transfer (dry)	Compliant

The organoleptic evaluation showed that the sheep/goat garment leather generally exhibited good visual and physical quality. The grain surface was smooth with a light-colored appearance, although slight color unevenness was observed, likely resulting from variations in dye penetration, leather thickness, or local fiber density during dyeing and finishing (Heidemann, 1993). The smooth grain indicates that the collagen fiber structure remained intact throughout beamhouse and tanning operations, reflecting proper processing quality (Covington, 2009). In addition, the flesh side was clean and free from residual connective tissue, demonstrating effective fleshing, which facilitates chemical penetration during tanning and improves manufacturing processes such as cutting and sewing (Dutta, 2008).



The leather also exhibited a moderately soft handle and satisfactory finish rub fastness, with only slight color change under wet rubbing and no visible color transfer under dry rubbing, meeting the organoleptic requirements of SNI 4593:2011. These results indicate that chrome tanning, retanning, fatliquoring, and finishing provided adequate fiber lubrication and finish adhesion, contributing to flexibility, durability, and aesthetic quality (Covington, 2009; Thanikaivelan et al., 2005; Sharphouse, 1995). Overall, the leather fulfilled the quality requirements of the standard, with color uniformity remaining the main aspect for improvement. From an industrial ergonomics perspective, the observed softness is expected to enhance wearing comfort by allowing the garment to follow natural body movements while minimizing stiffness and localized pressure. This favorable organoleptic performance provides the basis for evaluating the measurable physical characteristics of the leather, particularly thickness, which further determines garment functionality and user comfort.

3.2. Physical Characteristics

The physical characteristics of garment leather play an important role in determining both product quality and functional performance during use. Among the physical parameters evaluated in this study, leather thickness is considered one of the primary quality indicators because it influences garment weight, flexibility, sewing performance, and wearing comfort. According to SNI 4593:2011, the thickness of sheep/goat garment leather should range from 0.6 to 0.8 mm to provide an appropriate balance between durability and flexibility for garment applications. The thickness measurement results are presented in Table 2.



Table 2. Thickness of sheep/goat garment leather according to SNI 4593:2011

Parameter	SNI 4593:2011 Requirement	Specimen 1	Specimen 2	Average	Evaluation
Thickness (mm)	0.6–0.8 mm	0.70	0.70	0.70	Compliant

The evaluated sheep/goat garment leather had an average thickness of 0.70 mm, which complies with the requirements of SNI 4593:2011. The identical thickness values obtained from both specimens indicate good dimensional uniformity, reflecting effective control of the shaving process during leather manufacturing. Uniform thickness is essential for garment leather because it improves cutting accuracy, sewing performance, and consistency of the final product while promoting even penetration of tanning agents, dyes, and fatliquors, resulting in more homogeneous material properties (Heidemann, 1993; Sharphouse, 1995; Dutta, 2008; Thanikaivelan et al., 2005).

From both material engineering and industrial ergonomics perspectives, the measured thickness provides an appropriate balance between flexibility, lightweight performance, and mechanical durability. Leather within the recommended thickness range offers sufficient strength while remaining soft and flexible enough to follow natural body movements, thereby improving wearer comfort and reducing movement restriction and muscular fatigue during prolonged use (Covington, 2009; Luximon, 2013; Nigg, 2010). Overall, the thickness evaluation confirms that the leather is suitable for garment applications and meets the quality requirements specified in SNI 4593:2011. While thickness contributes significantly to garment performance, the overall serviceability of leather also depends on its mechanical behavior. Therefore, the following section evaluates the mechanical properties that determine the leather's ability to withstand loading during practical use.



3.3. Mechanical Characteristics

The mechanical properties of garment leather determine its ability to withstand tensile, tearing, bending, and repeated deformation during service. In apparel applications, leather is continuously subjected to multidirectional stresses generated by shoulder movement, elbow flexion, trunk rotation, and daily body motion. Therefore, adequate mechanical performance is essential to ensure garment durability while maintaining flexibility and wearer comfort (Covington, 2009; Sharphouse, 1995; Luximon, 2013).

Table 3. Mechanical characteristics of sheep/goat garment leather according to SNI 4593:2011

Parameter	SNI 4593:2011 Requirement	Average Result	Evaluation
Tear strength (N/mm)	≥ 12.5	9.81	Not compliant
Tensile strength (N/mm ²)	≥ 14.0	11.48	Not compliant
Elongation at break (%)	≤ 60	65.50	Not compliant
Softness (mm)	5.0–7.0	5.5	Compliant

The mechanical evaluation showed that the average tear strength (9.81 N/mm) and tensile strength (11.48 N/mm²) were below the minimum requirements of SNI 4593:2011, while the average elongation at break (65.50%) exceeded the maximum allowable limit of 60%. These results indicate that the leather has relatively low resistance to tearing and stretching despite retaining adequate structural integrity. The reduced mechanical performance may be associated with collagen fiber orientation, fiber density, and the effectiveness of retanning and fatliquoring processes, all of which influence fiber cohesion and mechanical behavior (Covington, 2009; Dutta, 2008; Thanikaivelan et al., 2005). Although higher elongation contributes to flexibility, excessive extensibility may reduce dimensional stability and garment fit during prolonged use (Heidemann, 1993).



In contrast, the average softness value of 5.5 mm complied with the requirements of SNI 4593:2011, indicating that the fatliquoring process successfully provided adequate lubrication among collagen fibers to produce a comfortable leather handle (Sharphouse, 1995). Overall, only the softness parameter satisfied the standard, whereas tear strength, tensile strength, and elongation require further process optimization. From an industrial ergonomics perspective, the satisfactory softness enhances flexibility and wearer comfort, but the relatively low strength and excessive elongation may reduce long-term durability and dimensional stability. Therefore, improvements in tanning and post-tanning processes are needed to achieve a better balance between mechanical performance and ergonomic comfort.

3.4. Overall Evaluation Based on SNI 4593:2011

The overall quality evaluation was conducted by comparing all measured organoleptic, physical, and mechanical characteristics of the sheep/goat garment leather with the acceptance criteria specified in SNI 4593:2011. This comprehensive assessment provides an overview of the conformity of the leather with the national standard and identifies the parameters requiring further improvement to enhance product quality.

Table 4. Overall evaluation of sheep/goat garment leather according to SNI 4593:2011

Parameter	Requirement	Result	Evaluation
Grain appearance	Smooth and uniform	Smooth, slightly uneven color	Partially compliant
Flesh side	Clean	Clean	Compliant
Leather condition	Moderately soft	Moderately soft	Compliant
Finish rub fastness	Meets SNI requirement	Meets requirement	Compliant
Thickness	0.6–0.8 mm	0.70 mm	Compliant
Tear strength	≥ 12.5 N/mm	9.81 N/mm	Not compliant
Tensile strength	≥ 14.0 N/mm ²	11.48 N/mm ²	Not compliant
Elongation at break	$\leq 60\%$	65.50%	Not compliant
Softness	5.0–7.0 mm	5.5 mm	Compliant



The evaluation showed that the tested sheep/goat garment leather complied with most of the organoleptic and physical requirements of SNI 4593:2011. The leather exhibited a clean flesh side, moderate softness, satisfactory finish rub fastness, and a uniform thickness of 0.70 mm, indicating effective control of the beamhouse, shaving, and finishing processes (Covington, 2009; Sharphouse, 1995). However, the mechanical properties were less satisfactory, with tear strength and tensile strength below the required limits and elongation at break exceeding the maximum standard. This combination suggests that the collagen fiber network provided good flexibility but insufficient fiber cohesion to withstand higher mechanical stresses (Heidemann, 1993; Thanikaivelan et al., 2005; Dutta, 2008).

Despite these limitations, the leather remains suitable for garment applications where softness, flexibility, and wearer comfort are prioritized over heavy-duty mechanical performance (Luximon, 2013). To achieve full compliance with SNI 4593:2011 and improve product durability, future process optimization should focus on increasing the mechanical integrity of the collagen fiber network through improved retanning formulations, optimized fatliquoring conditions, and better control of finishing processes while preserving the desirable softness and flexibility of the leather.

3.5. Industrial Ergonomics Implications

The ergonomic performance of garment leather depends on achieving an appropriate balance between flexibility, softness, lightweight characteristics, and mechanical durability. The evaluated sheep/goat garment leather demonstrated favorable ergonomic properties, particularly its 0.70 mm thickness and 5.5 mm softness, both of which complied with SNI 4593:2011. These characteristics indicate that the leather is lightweight, flexible, and capable of conforming to body movements, thereby improving wearer comfort, reducing movement restriction, and facilitating garment



manufacturing processes such as cutting and sewing (Covington, 2009; Sharpouse, 1995; Luximon, 2013). In addition, the clean flesh side and satisfactory finish rub fastness further support product quality and user acceptance by maintaining both surface comfort and aesthetic appearance.

However, the ergonomic suitability of the leather is limited by its relatively low tear strength (9.81 N/mm) and tensile strength (11.48 N/mm²), together with an elongation at break (65.50%) exceeding the SNI limit. These results indicate that, although the leather provides good flexibility and mobility, its resistance to repeated mechanical loading in high-stress garment areas such as seams, elbows, and shoulders may be insufficient for prolonged use (Heidemann, 1993; Thorstensen, 1993). Therefore, future optimization should focus on improving collagen fiber cohesion through enhanced retanning and fatliquoring processes to achieve a better balance between mechanical durability and ergonomic comfort. Such improvements are expected to increase the service life of garment leather while maintaining user comfort and supporting its practical application in the apparel industry. (Thanikaivelan et al., 2005; Sundar et al., 2013).

4. Conclusions

This study evaluated the physical and mechanical characteristics of chrome-tanned sheep/goat garment leather according to the requirements of SNI 4593:2011 and discussed their implications from an industrial ergonomics perspective. The results showed that the leather fulfilled the organoleptic requirements and exhibited compliant thickness (0.70 mm) and softness (5.5 mm), indicating good flexibility and suitability for garment applications. However, tear strength (9.81 N/mm), tensile strength (11.48 N/mm²), and elongation at break (65.50%) did not fully satisfy the standard requirements, suggesting that improvements in the tanning and post-tanning processes are still required.



From an industrial ergonomics perspective, the compliant thickness and softness support wearer comfort, flexibility, and freedom of movement, whereas the relatively low mechanical strength may reduce long-term durability in areas subjected to repeated loading. Overall, the evaluated leather demonstrates good potential for garment applications, although further process optimization is recommended to achieve a better balance between mechanical performance and ergonomic comfort while ensuring full compliance with SNI 4593:2011.

References

- Bacardit, A., Ollé, L., Armengol, J., & van der Burgh, S. (2014). Evaluation of a new sustainable continuous system for processing bovine leather. *Journal of Cleaner Production*, 65, 568–573. <https://doi.org/10.1016/j.jclepro.2013.09.024>
- Badan Standardisasi Nasional. (2011). SNI 4593:2011 Kulit jadi untuk jaket domba/kambing. Badan Standardisasi Nasional.
- Covington, A. D. (2009). *Tanning Chemistry: The Science of Leather*. Royal Society of Chemistry.
- Covington, A. D., & Wise, W. R. (2024). An Overview of Leather Processing. In S. Janardhanan & L. Zugno (Eds.), *Emerging Trends in Leather Science and Technology* (pp. 115–130). Springer. https://doi.org/10.1007/978-3-031-41481-9_6
- Dutta, S. S. (2008). *An Introduction to the Principles of Leather Manufacture* (4th ed.). Indian Leather Technologists Association.
- Heidemann, E. (1993). *Fundamentals of Leather Manufacturing*. Eduard Roether KG.
- Kanagaraj, J., Velappan, K. C., Babu, N. K. C., Sadulla, S., & Ramasami, T. (2015). Solid Wastes Generation in the Leather Industry and Its Utilization for Cleaner Environment: A Review. *Journal of Scientific and Industrial Research*, 74(1), 1–9.
- Liu, C., Wang, D., Li, Y., & Zhang, C. (2019). Progress in Cleaner Leather Manufacture Technologies. *Journal of Cleaner Production*, 229, 846–857. <https://doi.org/10.1016/j.jclepro.2019.04.252>
- Luximon, A. (2013). *Handbook of Footwear Design and Manufacture*. Woodhead Publishing.
- Menz, H. B., & Morris, M. E. (2005). Footwear Characteristics and Foot Problems in Older People. *Gerontology*, 51(5), 346–351. <https://doi.org/10.1159/000086373>



- Nigg, B. M. (2010). *Biomechanics of Sport Shoes*. University of Calgary.
- Sharphouse, J. H. (1995). *Leather Technician's Handbook*. Leather Producers' Association.
- Sreeram, K. J., & Ramasami, T. (2003). Sustaining Tanning Process Through Cleaner Technologies. *Journal of Cleaner Production*, 11(7), 757–763. [https://doi.org/10.1016/S0959-6526\(02\)00143-1](https://doi.org/10.1016/S0959-6526(02)00143-1)
- Sundar, V. J., Muralidharan, C., & Mandal, A. B. (2013). Processing of Leather with Improved Environmental Performance. *Journal of Cleaner Production*, 54, 366–373. <https://doi.org/10.1016/j.jclepro.2013.04.040>
- Thanikaivelan, P., Rao, J. R., Nair, B. U., & Ramasami, T. (2005). Recent Trends in Leather Making: Processes, Problems, and Pathways. *Critical Reviews in Environmental Science and Technology*, 35(1), 37–79. <https://doi.org/10.1080/10643380590813481>
- Thorstensen, T. C. (1993). *Practical Leather Technology*. Krieger Publishing Company.



Utilization of Digital Collections and Electronic Archives to Support Academic Research at ATK Polytechnic

Candra Mirawiarsi ^{a*} Tri Rahayu^b

^a *Library Unit, Politeknik ATK Yogyakarta, Ministry of Industry, Yogyakarta, Indonesia*

^b *Archives Unit, Politeknik ATK Yogyakarta, Ministry of Industry, Yogyakarta, Indonesia*

* rahayukumoro@gmail.com



Utilization of Digital Collections and Electronic Archives to Support Academic Research at ATK Polytechnic

Abstract. The advancement of information technology has transformed library and archival services into digital systems that support academic research. This study examines the utilization of digital collections and electronic archives at ATK Polytechnic Yogyakarta, focusing on their roles, benefits, and challenges. A descriptive qualitative approach was employed using observation, interviews, and documentation. The participants consisted of nine undergraduate students and one faculty member selected through purposive sampling. Data were analyzed using the Miles and Huberman interactive model. The findings reveal that digital collections, including e-books, e-journals, institutional repositories, and digital theses, serve as primary scholarly references, while electronic archives provide research data such as reports, policy documents, statistics, and institutional records. These resources improve information accessibility, enhance literature retrieval efficiency, strengthen theoretical foundations, and accelerate research activities. However, limited access to subscription-based journals, incomplete archive digitization, inadequate internet connectivity, and insufficient information retrieval skills remain challenges. Continuous service improvement and digital infrastructure development are essential to enhance research productivity.

Keywords: Digital collections, Electronic archives, Academic research, Library services, Information literacy

1. Introduction

The rapid advancement of information technology in the era of the Fourth Industrial Revolution (Industry 4.0) has fundamentally transformed the way academic institutions manage and disseminate information. Libraries and archival institutions have increasingly adopted digital technologies to improve access to information resources and support education, research, and knowledge creation. Digital libraries provide integrated environments in which information resources can be stored, organized, preserved, retrieved, and accessed through internet-based



platforms without spatial or temporal limitations. Consequently, digital collections have become indispensable components of academic information services, enabling researchers and students to access scholarly materials more efficiently than conventional print-based collections.

Digital collections comprise information resources that are either born digital or converted from print into digital formats, including e-books, electronic journals, institutional repositories, research databases, and other digital learning resources. Previous studies have shown that digital collections improve information accessibility, facilitate literature retrieval, and enhance research productivity by providing timely access to reliable scientific information (Sulistyo-Basuki, 2004; Reitz, 2014). Likewise, digital library services have become essential infrastructures that support evidence-based research and lifelong learning in higher education institutions.

In addition to digital library resources, electronic records constitute another critical component of digital information management. Unlike digital collections that primarily function as reference materials, electronic records preserve authentic evidence of institutional activities, administrative processes, research outputs, and policy implementation. The Regulation of the Head of the National Archives of the Republic of Indonesia (ANRI) No. 15 of 2012 establishes guidelines for managing electronic records throughout their life cycle while emphasizing the principles of authenticity, reliability, integrity, and usability. Duranti and Thibodeau (2006) further argue that electronic records derive their archival value from their connection to organizational transactions, making them reliable primary sources for research and institutional accountability.

The integration of digital collections and electronic records has significantly enhanced academic research by providing broader access to scholarly literature and authentic institutional data. Digital technologies reduce the time required for information retrieval, improve the



efficiency of literature reviews, and strengthen theoretical and empirical analyses through access to diverse and credible information sources. Previous research has consistently reported positive relationships between digital information accessibility and research productivity, highlighting the strategic role of digital information services in higher education.

Despite these developments, empirical studies examining the complementary roles of digital library collections and electronic records remain limited, particularly within vocational higher education institutions. Existing research has predominantly focused on digital libraries or electronic records as separate information systems, while few studies have investigated how these two resources jointly support academic research. This gap is particularly relevant for vocational institutions, where research activities frequently require not only access to current scientific literature but also historical technical documentation, institutional reports, and administrative records that serve as primary research data.

Politeknik ATK Yogyakarta provides an appropriate context for investigating this issue. As a vocational higher education institution specializing in leather, rubber, and plastics technology, it requires comprehensive digital information services to support applied research and innovation. Its academic community relies on various digital resources, including e-books, institutional repositories, subscribed databases such as ACS and Emerald, and electronic archival systems, including the Academic Information System (SIA) and the SRIKANDI electronic records management system. However, several challenges continue to affect the optimal utilization of these resources, including limited access to subscription-based international journals, incomplete digitization of institutional archives, inconsistent internet connectivity, and varying levels of users' information literacy.

Given these circumstances, this study aims to analyze the utilization of digital collections and



electronic records in supporting academic research at Politeknik ATK Yogyakarta. Specifically, the study seeks to identify patterns of resource utilization, examine the factors that facilitate and hinder their use, and evaluate their contribution to academic research activities. The findings are expected to provide practical recommendations for improving digital information services, strengthening institutional digital resource management, and enhancing research productivity within vocational higher education institutions.

2. Methods

This study employed a descriptive qualitative approach to examine the utilization of digital collections and electronic archives in supporting academic research activities at Politeknik ATK Yogyakarta. A qualitative approach was selected because it enables researchers to obtain an in-depth understanding of participants' experiences, perceptions, and opinions regarding the use of digital information resources and electronic archival systems within the academic environment.

The research was conducted at the Library and Archives Unit of Politeknik ATK Yogyakarta. The participants consisted of nine undergraduate students and one faculty member who actively utilized digital collections and electronic archives for academic purposes. These participants were selected using purposive sampling based on their experience in accessing digital library services and institutional electronic archives.

Data were collected through three techniques: interviews, observations, and documentation. Semi-structured interviews were conducted to explore participants' understanding of digital collections and electronic archives, their utilization in academic research, perceived benefits, encountered challenges, and expectations for future service improvements. Observations were carried out to examine the implementation of digital library services, electronic archive management, and user interactions with available digital resources. Documentation was used to



support the findings by reviewing institutional documents, library reports, policies, and other relevant records related to digital collection management and electronic archives.

The collected data were analyzed using the interactive model proposed by Miles, Huberman, and Saldaña (2014), which consists of four stages: data collection, data condensation, data display, and conclusion drawing/verification. During the data condensation stage, interview transcripts and field notes were organized, coded, and categorized according to the research objectives. Subsequently, the data were presented descriptively to identify patterns regarding the utilization of digital collections and electronic archives. Finally, conclusions were drawn through continuous verification to ensure consistency between the collected evidence and the research findings.

To enhance the credibility of the study, data triangulation was applied by comparing information obtained from different informants, observation results, and institutional documents. The triangulation process helped ensure the validity and trustworthiness of the research findings by confirming the consistency of information from multiple data sources..

3. Result and Discussion

3.1 Utilization of Digital Collections and Electronic Archives in Academic Research

The findings indicate that lecturers, students, and administrative staff at Politeknik ATK Yogyakarta generally possess a good understanding of digital collections and electronic archives as essential information resources supporting academic activities. Based on the interviews, most respondents described digital collections as information resources stored in digital formats that can be accessed through computers, laptops, smartphones, or other internet-connected devices. Respondents demonstrated their familiarity with various types of digital collections available within the institution, including electronic books (e-books), electronic journals (e-journals), institutional repositories containing students' final projects and lecturers' research outputs, and



online scientific databases. This understanding reflects the increasing awareness of digital information resources among the academic community and forms an important foundation for their effective utilization in research activities.

As shown in Table 1, respondents utilized various digital information resources for different stages of academic research. Each type of digital resource contributes to specific research activities and provides distinct benefits that support information retrieval and research productivity.

As shown in Table 1, respondents utilized various digital information resources for different stages of academic research. Each type of digital resource contributes to specific research activities and provides distinct benefits that support information retrieval and research productivity.

Table 1. Utilization of Digital Collections and Electronic Archives in Academic Research.

Information Resource	Main Utilization	Benefits Identified by Respondents
E-books	Learning materials and theoretical references	Easy access and flexible reading
E-journals	Literature review and recent scientific findings	Updated information and stronger theoretical foundation
Institutional repository	Previous research and final projects	Local scientific references and research continuity
Scientific databases	Retrieval of scholarly literature	Efficient information searching
Electronic archives	Supporting research data and institutional documents	Reliable evidence and secondary research data

Respondents consistently reported that digital collections have become one of the primary sources of scholarly information used throughout the research process. Electronic journals were identified as the most frequently accessed resource because they provide current scientific findings that strengthen literature reviews, theoretical frameworks, and research discussions. In addition, e-books and institutional repositories were widely used to obtain theoretical references and review previous studies relevant to respondents' research topics. Scientific databases such as Google



Scholar, Portal Garuda, SINTA, DOAJ, institutional repositories, and several international databases subscribed to by the institution were also frequently utilized to retrieve academic literature efficiently. The availability of these resources enables researchers to obtain comprehensive and relevant references while reducing the time required for information searching.

The respondents further explained that digital collections are preferred over printed materials because they provide greater accessibility and flexibility. Search functions embedded within digital platforms facilitate rapid information retrieval, while downloadable documents allow users to store and reuse references throughout the research process. These advantages contribute to more efficient literature searching and improve researchers' ability to identify relevant scholarly information. Nevertheless, several respondents acknowledged that printed collections remain valuable, particularly for reading complex materials that require prolonged concentration. This finding suggests that digital collections complement rather than replace conventional printed collections, allowing libraries to accommodate diverse learning preferences and information needs. These findings indicate that participants' experiences reflect broader trends in the adoption of digital information resources within higher education. To better understand these findings, they can be interpreted in light of previous studies on digital library utilization.

The increasing utilization of digital collections observed in this study is consistent with the concept of digital libraries proposed by Brahaj et al. (2013), who defined digital libraries as integrated systems that organize, preserve, and disseminate digital knowledge to facilitate information access. Similarly, Pendit (2008) emphasized that digital libraries should function as an extension of conventional library services by expanding users' access to academic information without eliminating the role of printed collections. Fox and Marchionini (1998) also argued that



digital libraries enhance knowledge discovery by integrating information resources with effective retrieval systems, enabling users to obtain scientific information more efficiently.

The findings further support Calhoun (2014), who highlighted that digital libraries have evolved into strategic infrastructures supporting higher education through integrated access to electronic information resources. Likewise, Xie and Matusiak (2016) explained that digital libraries improve information accessibility by combining digital collections, retrieval technologies, and user-oriented services. In the Indonesian context, Aminullah et al. (2019) reported that the development of digital collections in university libraries significantly improves users' ability to obtain scientific information while supporting educational and research activities. These perspectives reinforce the finding that digital collections have become indispensable resources in academic research at Politeknik ATK Yogyakarta.

In addition to digital collections, respondents indicated that electronic archives have become important sources of secondary data supporting academic research. Electronic archives commonly used by respondents include institutional reports, policy documents, statistical records, administrative documents, and other official records relevant to their research. Respondents emphasized that the availability of these documents in digital formats facilitates data collection because information can be accessed more quickly and efficiently than conventional paper-based archives. Digital access also enables researchers to retrieve documents remotely whenever the records have been published through institutional repositories or official websites. However, respondents acknowledged that access becomes more limited when archival materials have not yet been digitized or remain restricted for administrative reasons.

The interview findings also demonstrate that electronic archives function not only as administrative records but also as valuable research resources. This observation is supported by



previous studies on electronic records management. The utilization of electronic archives identified in this study is closely aligned with the principles of electronic records management. Duranti and Thibodeau (2006) emphasized that electronic records preserve authentic evidence of organizational activities and therefore constitute reliable sources of information for research. Cox (2015) similarly argued that effective records management ensures the authenticity, accessibility, and accountability of institutional records throughout their life cycle. Franks (2013) further explained that electronic records management contributes to organizational memory by facilitating systematic information retrieval and long-term preservation of institutional knowledge. These principles are consistent with the Regulation of the Head of the National Archives of the Republic of Indonesia Number 15 of 2012, which establishes standards for managing electronic records based on authenticity, integrity, reliability, and usability. Furthermore, Law Number 43 of 2007 concerning Libraries emphasizes that libraries are responsible for supporting education, research, preservation, information services, and lifelong learning through the provision of accessible information resources.

Overall, the findings demonstrate that digital collections and electronic archives have become complementary information resources supporting academic research at Politeknik ATK Yogyakarta. Respondents' adequate understanding of digital information resources has encouraged their intensive utilization throughout the research process, from literature searching to data collection. The integration of electronic journals, e-books, institutional repositories, scientific databases, and electronic archives illustrates the growing importance of digital information management in higher education. Consequently, strengthening digital library services and electronic records management will not only improve access to scholarly information but also enhance the effectiveness and quality of academic research conducted within the institution.



3.2 Contributions, Challenges, and Institutional Support for Digital Collections and Electronic Archives

The findings demonstrate that the utilization of digital collections and electronic archives has made substantial contributions to improving academic research activities at Politeknik ATK Yogyakarta. Respondents consistently reported that digital collections facilitate the identification of relevant literature, support the development of theoretical frameworks, enable comparisons with previous studies, and strengthen scientific arguments throughout the research process. At the same time, electronic archives provide reliable institutional documents and secondary data that enhance the credibility and comprehensiveness of research findings. The integration of these digital information resources has therefore improved both the efficiency and quality of academic research conducted by lecturers, students, and administrative staff.

Table 2 summarizes the main contributions, challenges, institutional support, and respondents' recommendations regarding the utilization of digital collections and electronic archives in supporting academic research at Politeknik ATK Yogyakarta.

Table 2. Contributions, Challenges, and Institutional Support for Digital Collections and Electronic Archives.

Aspect	Research Findings
Contributions	Faster information retrieval, improved literature review, stronger theoretical foundation, reliable supporting data
Challenges	Limited access to subscription-based journals, incomplete archive digitization, unstable internet connection, difficulties in selecting search keywords
Institutional Support	Institutional repository, digital collections, information literacy training, electronic resource services
Respondents' Recommendations	Expansion of e-book and e-journal collections, wider database subscriptions, repository improvement, archive digitization, and better internet infrastructure



Almost all respondents acknowledged that digital collections significantly shorten the time required to retrieve scholarly information. Before the implementation of digital library services, literature searches relied primarily on printed collections, requiring users to visit library shelves and manually identify relevant references. In contrast, the availability of digital collections allows researchers to retrieve scientific literature within minutes through integrated search systems and online databases. Respondents also emphasized that electronic journals provide access to recent scientific developments, enabling them to produce more comprehensive literature reviews and better-informed research analyses. Furthermore, the increasing use of institutional repositories facilitates access to previous research conducted within the institution, thereby supporting research continuity and reducing duplication of research topics.

The respondents' experiences consistently demonstrate the practical advantages of digital information resources in academic research. These findings are also consistent with previous studies discussing the role of digital libraries in higher education. These findings support Calhoun (2014), who explained that digital libraries have transformed scholarly communication by providing rapid and integrated access to academic information. Likewise, Xie and Matusiak (2016) argued that digital library services enhance users' ability to discover, retrieve, and manage scholarly information efficiently through integrated digital systems. From an educational perspective, Burbules and Callister (2000) emphasized that information technology enables learners and researchers to access diverse knowledge resources more effectively, thereby improving learning outcomes and research productivity. The experiences reported by respondents in this study confirm the increasingly strategic role of digital collections in supporting academic research within higher education institutions.



Respondents also highlighted the important contribution of electronic archives to research activities. Institutional reports, policy documents, statistical data, and administrative records were frequently used as supporting evidence, particularly in studies requiring official documentation or secondary data. According to the respondents, digital access to institutional archives significantly accelerates data collection and enables researchers to obtain authentic information without relying solely on physical archival materials. This finding reflects the growing importance of electronic records as reliable sources of institutional knowledge and research evidence.

The respondents' perceptions regarding the importance of institutional records also correspond with established concepts in records management literature. The role of electronic archives identified in this study is consistent with the principles of records management proposed by Cox (2015), who emphasized that properly managed records provide reliable evidence for organizational accountability and decision-making. Similarly, Franks (2013) explained that electronic records management improves information accessibility while preserving institutional memory. Millar (2017) further argued that effective archive management depends on the integration of organizational policies, technological infrastructure, and competent human resources to ensure long-term accessibility and preservation of digital records. In the Indonesian context, Sugiarto and Wahyono (2005) emphasized that the transition from conventional to computerized records management requires systematic archive organization and adequate technological support. These perspectives reinforce the importance of continuously improving electronic archive management in higher education institutions.

Despite these positive contributions, respondents identified several challenges that still limit the optimal utilization of digital collections and electronic archives. The most frequently reported constraints include limited access to subscription-based international journals, incomplete



digitization of institutional archives, unstable internet connectivity, and difficulties in selecting appropriate search keywords. Respondents explained that although Google Scholar is commonly used as the initial search platform, identifying relevant scientific literature often requires searching multiple databases such as Portal Garuda, SINTA, DOAJ, institutional repositories, and international databases. They also noted that combining Indonesian and English keywords generally produces more comprehensive search results. Nevertheless, selecting effective search terms remains a challenge for many users, particularly when searching interdisciplinary research topics.

These findings indicate that successful utilization of digital information resources depends not only on the availability of digital collections but also on users' information literacy competencies. Santoso (2021) explained that digital library services should continuously evolve to meet increasingly complex user information needs through effective information management and user-oriented services. Similarly, Wahyuntini and Endarti (2021) reported that digital collections contribute significantly to academic achievement only when supported by users' ability to search, evaluate, and utilize information appropriately. Therefore, improving information literacy is as important as expanding digital collections themselves.

Another challenge concerns the preservation and accessibility of electronic archives. Respondents indicated that not all institutional archives have been digitized, resulting in limited access to certain documents. This finding is consistent with Sari (2008), who emphasized that digital preservation remains a fundamental issue in maintaining long-term accessibility to digital collections. Incomplete digitization may reduce the availability of institutional knowledge and limit researchers' ability to obtain comprehensive supporting evidence. Consequently, sustainable



digitization programs are required to ensure that institutional records remain accessible for future research.

Institutional support emerged as another important factor influencing the utilization of digital collections and electronic archives. Respondents generally expressed positive perceptions of the services provided by the Politeknik ATK Library, particularly the availability of institutional repositories, electronic collections, and information literacy training. According to the respondents, these services have improved their ability to identify appropriate keywords, select suitable databases, and evaluate the credibility of scientific information. These findings indicate that library services contribute not only to information provision but also to the development of users' research competencies.

The role of academic libraries described by the respondents is consistent with Law of the Republic of Indonesia Number 43 of 2007 concerning Libraries, which states that libraries function as institutions supporting education, research, information services, preservation, and lifelong learning. Aminullah et al. (2019) similarly emphasized that continuous development of digital collections enables university libraries to provide more effective information services for academic communities. The findings of this study demonstrate that institutional repositories, electronic information resources, and information literacy programs have become important components in strengthening research capacity at Politeknik ATK Yogyakarta.

Respondents also proposed several recommendations for improving digital information services. These include expanding subscriptions to international electronic journals and e-books relevant to the institution's academic disciplines, increasing access to reputable scientific databases, accelerating the digitization of institutional archives, improving repository functionality through enhanced search features, conducting information literacy training on a regular basis, and



strengthening campus internet infrastructure. These recommendations reflect respondents' expectations that digital library services should continue to evolve in line with the growing demand for accessible, reliable, and high-quality scholarly information.

Overall, the findings indicate that digital collections and electronic archives have become indispensable components of academic research at Politeknik ATK Yogyakarta. Their contributions extend beyond facilitating access to scholarly information by improving research efficiency, strengthening scientific evidence, and supporting knowledge management within the institution. Nevertheless, maximizing these benefits requires continuous institutional commitment to expanding digital collections, improving electronic archive management, strengthening information literacy programs, and enhancing technological infrastructure. Such integrated efforts will ensure the sustainability of digital information services and further strengthen the role of academic libraries and electronic archives in supporting research excellence in higher education.

4. Conclusions

This study demonstrates that digital collections and electronic archives have become strategic information resources in supporting academic research activities at Politeknik ATK Yogyakarta. The findings indicate that lecturers, students, and administrative staff generally possess a good understanding of the functions and characteristics of digital collections and electronic archives. Digital collections, including e-books, electronic journals, institutional repositories, and scientific databases, are widely utilized as primary sources of scholarly information, while electronic archives serve as reliable sources of secondary data and institutional evidence that support research activities.

The utilization of digital collections and electronic archives provides significant benefits for academic research by facilitating faster access to relevant information, strengthening theoretical



foundations, supporting literature reviews, and improving the quality of research analysis. The availability of digital information resources enables researchers to conduct information retrieval more efficiently and flexibly without geographical or time limitations. In addition, the increasing use of institutional repositories and reference management applications reflects the growing adoption of digital technologies in academic research practices at Politeknik ATK Yogyakarta.

Despite these advantages, the study also identified several challenges that limit the optimal utilization of digital information resources. Limited access to subscription-based international journals, incomplete digitization of institutional archives, unstable internet connectivity, and varying levels of information literacy among users remain important issues. These findings suggest that the effectiveness of digital collections and electronic archives depends not only on the availability of digital resources but also on adequate technological infrastructure, systematic information management, and users' competencies in information retrieval.

Therefore, continuous institutional support is required to enhance the role of digital collections and electronic archives in academic research. Efforts to expand subscriptions to electronic resources, accelerate institutional archive digitization, improve repository services, strengthen information literacy programs, and upgrade digital infrastructure are expected to increase the accessibility, effectiveness, and sustainability of digital information services. By implementing these improvements, Politeknik ATK Yogyakarta can further strengthen its digital library and electronic records management systems to support research quality, knowledge dissemination, and institutional development in the digital era.



5. References

- Aminullah, A. M., Iskandar, & Dahlan, M. (2019). Pengembangan koleksi digital dalam membangun perpustakaan digital di Perpustakaan Universitas Islam Negeri Alauddin Makassar. *Libraria: Jurnal Perpustakaan*, 7(2), 183–204.
- Arsip Nasional Republik Indonesia. (2012). *Peraturan Kepala Arsip Nasional Republik Indonesia Nomor 15 Tahun 2012 tentang Pedoman Pengelolaan Arsip Kartografi, Kearsipan Elektronik, dan Tata Rekaman Elektronik*. Arsip Nasional Republik Indonesia.
- Brahaj, A., Razum, M., & Hoxha, J. (2013). Defining digital libraries. In T. Aalberg, M. Dobrev, C. Papatheodorou, G. Tsakonas, & C. Farrugia (Eds.), *Research and Advanced Technology for Digital Libraries (Lecture Notes in Computer Science, Vol. 8092, pp. 23–28)*. Springer. https://doi.org/10.1007/978-3-642-40501-3_3
- Burbules, N. C., & Callister, T. A., Jr. (2000). *Watch IT: The Risks and Promises of Information Technologies for Education*. Westview Press.
- Calhoun, K. (2014). *Exploring Digital Libraries: Foundations, Practice, Prospects*. Facet Publishing.
- Cox, R. J. (2015). *Managing Records as Evidence and Information*. ABC-CLIO.
- Duranti, L., & Thibodeau, K. (2006). The concept of the record: A comparison of the traditional presentation and the digital representation. *Archivaria*, 61, 13–56.
- Fox, E. A., & Marchionini, G. (1998). Toward a worldwide digital library: Introduction. *Communications of the ACM*, 41(4), 28–32. <https://doi.org/10.1145/273227.273229>
- Franks, P. C. (2013). *Records and Information Management*. Neal-Schuman Publishers.
- Millar, L. (2017). *Archives: Principles and Practices (2nd ed.)*. Facet Publishing.



- Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative Data Analysis: A Methods Sourcebook (3rd ed.)*. SAGE Publications.
- Moleong, L. J. (2016). *Metodologi Penelitian Kualitatif (Edisi revisi)*. PT Remaja Rosdakarya.
- Pendit, P. L. (2008). *Perpustakaan Digital: Perspektif Perpustakaan Perguruan Tinggi Indonesia*. CV Sagung Seto.
- Reitz, J. M. (2004). *Dictionary for Library and Information Science*. Libraries Unlimited.
- Republik Indonesia. (2007). *Undang-Undang Republik Indonesia Nomor 43 Tahun 2007 tentang Perpustakaan*. Sekretariat Negara Republik Indonesia.
- Santoso, J. (2021). Kemas ulang informasi koleksi perpustakaan sebagai upaya pemenuhan kebutuhan informasi para pemustaka. *ABDI PUSTAKA: Jurnal Perpustakaan dan Kearsipan*, 1(2), 67–72. <https://doi.org/10.24821/jap.v1i2.5987>
- Sari, D. (2008). *Pelestarian koleksi digital di Perpustakaan Universitas Indonesia (Undergraduate thesis)*. Universitas Indonesia.
- Sugiarto, A., & Wahyono, T. (2005). *Manajemen Kearsipan Modern: Dari Konvensional ke Basis Komputer*. Gava Media.
- Sulistyo-Basuki. (2004). *Pengantar Ilmu Perpustakaan*. Gramedia Pustaka Utama.
- Wahyuntini, S., & Endarti, S. (2021). Tantangan digital dan dinamisasi koleksi dalam pemanfaatan koleksi perpustakaan bagi prestasi belajar mahasiswa. *ABDI PUSTAKA: Jurnal Perpustakaan dan Kearsipan*, 1(1), 15–24.
- Xie, I., & Matusiak, K. K. (2016). *Discover Digital Libraries: Theory and Practice*. Elsevier. <https://doi.org/10.1016/C2014-0-04155-1>
- Yusuf, A. M. (2015). *Metode Penelitian: Kuantitatif, Kualitatif, dan Penelitian Gabungan*. Prenada Media.



Agradaya's digital transformation journey: Insights from Indonesian agribusiness

William Ben Gunawan^{ab*}

^aINTI International University, Nilai, Negeri Sembilan, 71800, Malaysia

^bAsia Cyber University, Pasar Minggu, Jakarta, 12550, Indonesia

*wbwilliambenwb@gmail.com



Agradaya's digital transformation journey: Insights from Indonesian agribusiness

Abstract. This study explores the strategic digital transformation of Agradaya, an Indonesian small and medium-sized enterprise (SME) committed to ethical sourcing and social impact in the agricultural sector. Operating in contexts characterized by low productivity and limited market access, Agradaya utilizes digital platforms to connect smallholder farmers directly with consumers, thereby bypassing intermediaries and promoting fair trade practices. The study identifies key strategic drivers of this transformation, including evolving digital market dynamics, technological advancements, supportive government policies, and the firm's embedded social mission. Using an integrated strategic analysis framework, comprising PESTEL, Porter's Five Forces, SWOT, VRIO, Value Chain, Competitive Profile Matrix, Grand Strategy Matrix, and Ansoff Matrix, the research highlights Agradaya's core strengths in farmer empowerment and agri-social branding, while also addressing challenges related to logistics, funding constraints, and impact measurement. The findings emphasize the firm's dual orientation toward commercial sustainability and social value creation, and underscore the importance of a stewardship-driven organizational culture in fostering resilience and long-term growth. This case provides practical and theoretical insights for social enterprises undertaking digital transformation in emerging agricultural economies.

Keywords: digital transformation, social enterprise, agriculture, strategic management

1. Introduction

The agricultural sector in Indonesia forms a critical pillar of the national economy, yet it grapples with persistent challenges, including suboptimal production levels, limited market access, and the escalating impacts of climate change. Smallholder farmers, particularly in regions like Yogyakarta, Sleman, and the Menoreh Hills, face significant hurdles in connecting with urban markets and efficient logistics systems. This often forces them into disadvantageous arrangements with middlemen, leading to diminished profits and a lack of transparency in the product supply chain (JICA, 2014; Tracextech, 2025; Susanawati et al., 2021). In response to these systemic



issues, there has been an increasing emphasis on modernization and innovation within the agricultural industry. Digital transformation has emerged as a crucial strategic imperative, offering viable solutions to these long-standing problems by empowering farmers with enhanced access to information, resources, and broader markets (Sargani et al., 2025). The imperative to accelerate digital transformation in agriculture is paramount for enabling farmers and small and medium-sized enterprises (SMEs) to significantly boost their productivity, cultivate resilience, and secure a competitive advantage within the rapidly evolving digital economy.

Agradaya, an Indonesian SME established in 2014 and based in Sleman, Yogyakarta, stands as a pertinent case study in this transformative landscape. Agradaya's online platform directly connects consumers with natural and artisan herbs and spices, which are sourced directly from smallholder farmers in the Menoreh Hills region. By embracing digital agriculture, Agradaya leverages technology not only to enhance agricultural production but also to champion sustainability. Founded as a social enterprise, Agradaya's initial goal was to create a direct sourcing model that bypassed intermediaries, thereby securing better prices for farmers and improving supply chain visibility. This commitment extended to developing sustainable agricultural value chains through the promotion of natural and artisan products and the implementation of community-based agroforestry initiatives. Through its adherence to ethical trade practices and its profound emphasis on local livelihood enhancement, Agradaya has meticulously constructed a traceable, farmer-centric distribution model. This model simultaneously safeguards environmental integrity and stimulates rural economic growth, establishing fundamental approaches to ethical sourcing, social empowerment, and sustainability since its inception (Maulinda, 2019; Rahmaningrum et al., 2024).

The strategic transformation of Agradaya is predominantly driven by its digital initiatives and



a proactive cultivation of an innovative organizational culture. For technological integration to be truly effective, it must be harmonized with robust people development. Consequently, Agradaya invests significantly in training and supporting its farmers, ensuring that they can effectively utilize the provided technology.

Digital transformation in the agricultural sector is often positioned as a solution to stagnating productivity and limited market access. Agradaya, as a social enterprise focusing on local herbal commodities, has emerged as a pioneer in integrating social narratives with digital technology. Strategies such as the use of e-commerce platforms and storytelling approaches for products represent downstream interventions that have successfully expanded market reach while strengthening brand image. However, these achievements remain partial and have yet to reach a systemic transformation from upstream to downstream. Viewed through the framework of Westerman et al. (2014), digital transformation should involve a deep restructuring across three core pillars: customer experience, operational processes, and business models. In this context, Agradaya has indeed introduced innovations in customer experience and parts of its business model, but tends to overlook the optimization of internal processes. The absence of an Enterprise Resource Planning (ERP) system, lack of analytical dashboards for production monitoring, and minimal use of precision technologies in upstream activities indicate that Agradaya remains in a stage of shallow digitalization, which risks hindering the scalability and sustainability of its transformation efforts.

This study aims to critically examine the efficacy of Agradaya's corporate strategy and its broader agricultural impact within the Indonesian market. Specifically, it evaluates the drivers of its digital transformation, assesses the outcomes of its collaborations with local farmers, and explores the resulting opportunities and challenges. Furthermore, the research investigates the



long-term sustainability of Agradaya's business model in the context of the wider Indonesian agricultural industry.

2. Methods

This research employs a qualitative case study approach to analyze Agradaya's strategic digital transformation. The primary data for this study is derived from the "Agradaya Strategic Management" report, which details the company's background, strategic drivers, formulated strategies, and challenges. The report itself synthesizes existing company information, public data, and relevant academic and industry publications. The analytical framework integrates several well-established strategic management tools in line with the research by Gunawan (2024), including PESTEL Analysis to evaluate macro-environmental forces (Political, Economic, Social, Technological, Environmental, Legal); Porter's Five Forces to assess competitive intensity (threat of new entrants, buyer power, supplier power, threat of substitutes, and rivalry); SWOT Analysis to identify internal strengths and weaknesses and external opportunities and threats; the VRIO Framework (Barney's Framework) to determine valuable, rare, inimitable, and organized resources and capabilities; Value Chain Analysis to disaggregate primary and support activities; a Competitive Profile Matrix (CPM) to compare Agradaya against key competitors; the Grand Strategy Matrix to identify appropriate strategic directions; and the Ansoff Matrix to analyze growth strategies in terms of market penetration, market development, product development, and diversification.

The methodology also includes an assessment of monitoring and control mechanisms, proposing specific metrics and frequencies for various strategic areas. Challenges in strategy implementation, particularly concerning funding, demonstrating social impact, and upscaling through a Resource-Based View (RBV) lens, are critically examined. The theoretical



underpinnings for understanding social entrepreneurship and stewardship culture are drawn from existing literature (Adro & Fernandes, 2021; Bacq & Eddleston, 2016; Zahra, 2021; Zahra et al., 2008). The reliance on a single internal report as the primary data source means that the findings are specific to the Agradaya case. While robust in its internal analysis, the generalizability of the findings may be limited without further empirical data collection, such as interviews with company stakeholders or additional quantitative performance data. However, the comprehensive application of established strategic frameworks allows for an in-depth understanding of Agradaya's unique position and strategic responses within the Indonesian agricultural context.

3. Result and Discussion

3.1. Formulating and Implementing Strategies

From a sociological perspective, Agradaya's digital transformation also faces serious challenges in the form of a digital divide among its partner farmers. Most of these farmers are located in areas with limited digital infrastructure, including unstable internet connectivity and inadequate technological devices. This situation poses the risk of creating new forms of exclusion behind the narrative of inclusion, where technology strengthens those who are already prepared while leaving behind those who are not. Without a well-planned digital inclusion strategy, such as digital literacy training, affordable device subsidies, and the provision of technology access at the community level, digital transformation may actually widen structural gaps between innovation hubs and grassroots producers. As a social enterprise, Agradaya must recognize that digital success is not solely determined by user interfaces but also by sustainable systems of knowledge and institutional values. A transformation that relies heavily on the founder's charismatic narrative is inherently fragile and not replicable. In line with Hess and Ostrom's (2007) concept of the knowledge commons, social enterprises should aim to build a technological ecosystem that not



only connects producers with consumers but also empowers producers as autonomous and resilient digital subjects. Therefore, this study not only aims to appreciate Agradaya's achievements but also to offer a critique of the limitations and risks inherent in its digital approach, which remains insufficiently inclusive and strategic, as examined through theoretical lenses such as the digital transformation model, dynamic capabilities, and the concept of digital justice.

The analysis of Agradaya's level of digital transformation based on three key dimensions, as presented in Table 1, reveals uneven progress across the fundamental aspects of digital transformation.

Table 1. The Level of Agradaya's Digital Transformation Based on the McKinsey Model

Dimension of Digital Transformation	Current Status of Agradaya	Remarks
Customer Experience	Fairly mature (e-commerce & storytelling)	Needs expansion of distribution channels and improved UI/UX
Internal Processes	Low (minimal operational automation)	No ERP system or performance dashboard in place
Business Model	Innovative (farmer disintermediation)	Not yet flexible for global scalability

Agradaya's social entrepreneurial mission is unequivocally centered on fostering self-sustaining village economies, a vision deeply congruent with established social entrepreneurship theory (Adro & Fernandes, 2021). The explicit positioning of farmers at the core of its business architecture demonstrates an exceptional alignment between its stated mission and operational execution. This integration is not merely rhetorical; it profoundly influences the organization's strategic direction and is a distinctive source of competitive advantage. By prioritizing the economic empowerment and well-being of smallholder farmers, Agradaya cultivates a unique value proposition that resonates strongly with conscious consumers and differentiates itself from conventional agricultural businesses. This deeply embedded social mission provides a clear ethical



compass for the organization, guiding decisions from sourcing to market, and thus building strong brand loyalty and stakeholder trust.

Beyond confirming this mission–operation alignment, the configuration speaks to a central debate in social-entrepreneurship research: how ventures sustain the dual pursuit of social and commercial value without succumbing to mission drift. Saebi et al. (2019) argue that such hybridity is best examined across multiple levels of analysis, with a venture's competitive advantage often emerging from—rather than despite—the tension between its social and economic logics. Agradaya substantiates this proposition, as its farmer-centric mission functions not as a constraint on competitiveness but as its very source; yet the same body of work cautions that founder-dependent, weakly institutionalised hybrids remain prone to instability as they scale—a risk this study later documents in Agradaya's governance and reconfiguration weaknesses.

The macro-environmental forces, as outlined in Table 2, significantly shape Agradaya's strategic landscape, predominantly offering a favorable external environment for its operations and growth, contingent upon its adaptability and innovative capacity. Agradaya's reputation as a provider of high-quality, safe, and ethically produced goods. Collectively, these PESTEL factors create a largely conducive environment for Agradaya's growth, provided the company continues to strategically leverage these external forces and innovate proactively. Agradaya's reputation as a provider of high-quality, safe, and ethically produced goods. Collectively, these PESTEL factors create a largely conducive environment for Agradaya's growth, provided the company continues to strategically leverage these external forces and innovate proactively. In summary, while Agradaya faces notable competition and the omnipresent threat of substitutes, its unique farmer-centric model and ethical sourcing practices significantly mitigate supplier power and provide a buffer against new entrants, enabling it to navigate a competitive landscape.



Table 2. PESTEL Analysis of Agradaya's Business Model

Factor	Impact on Agradaya
Political	The government pushes for Agriculture 4.0 and SME digitization.
Economic	Increasing demand for health-conscious, traceable products.
Social	Wellness and sustainability trends shape consumer behavior.
Technological	Rise of digital supply chains and mobile-based agriplatforms.
Environmental	Need for sustainable, organic, low-waste farming practices.
Legal	Food certification regulations (BPOM, Halal MUI) guide

Table 3. Porter's Five Forces Analysis of Agradaya

Force	Evaluation of Agradaya
New Entrants	Moderate threat; digital access lowers entry barriers, but certifications and farmer ties provide some defense.
Buyer Power	Medium; niche consumers value quality but have many herbal options.
Supplier Power	Low, direct, and loyal relationships with farmers reduce risks.
Substitutes	Moderate; many alternatives exist (mass-market supplements, other herbs).
Rivalry	High competition with both local herbal brands and global wellness imports.

Read together, the PESTEL and Porter's Five Forces analyses form the external evidentiary base for the SWOT that follows, rather than standing as separate exercises. The macro-level forces they identify—state-backed Agriculture 4.0 and SME digitalisation, rising demand for traceable wellness goods, and the diffusion of mobile agri-platforms—map directly onto the Opportunities quadrant, while intense rivalry and the threat of substitutes recur as external Threats. Agradaya's low supplier power, itself a product of its direct farmer ties, is the industry-structural expression of the farmer-trust Strength identified internally. Synthesised in this way, the two external tools show that Agradaya competes in a structurally attractive yet contestable arena in which advantage rests on relational and reputational assets rather than on scale or cost—consistent with recent evidence that SME competitiveness in digitalising value chains increasingly hinges on intangible, relationship-based resources (Verhoef et al., 2021).

Table 4 provides a comprehensive internal and external evaluation of Agradaya's strategic position. Agradaya's core strengths are formidable and constitute significant competitive



advantages. Deep farmer trust, cultivated through equitable partnerships and direct sourcing, ensures a stable and high-quality supply chain. Its certified, premium product line appeals to discerning consumers. Crucially, a strong brand story rooted in social impact and ethical practices creates a powerful emotional connection with customers, fostering loyalty and advocacy. These strengths collectively reinforce its market position and differentiate it from competitors. Despite its strengths, Agradaya faces notable weaknesses. Its logistics infrastructure is currently limited for large-scale international exports, restricting its global market reach and potential for significant revenue diversification. Furthermore, the inherent lack of robust digital infrastructure in many rural areas poses a challenge to fully realize the potential of its digital transformation strategy for all farmer partners. A significant dependency on the founder's leadership vision, while currently a strength, also represents a potential single point of failure if succession planning or leadership transition is not adequately addressed.

Agradaya has significant opportunities for expansion and growth. Entering export markets in ASEAN and the European Union, where demand for ethically sourced and natural products is high, presents a substantial avenue for revenue growth. Strategic partnerships with wellness influencers can amplify its brand message and reach new customer segments. These opportunities leverage its existing strengths and align with global market trends. External threats include the unpredictable impact of climate change on herb yields, which could disrupt its supply chain and affect product availability. More aggressive market entry by large, established herbal players poses a significant competitive threat, as they possess greater resources for marketing, distribution, and pricing strategies. Agradaya must proactively develop contingency plans and maintain its competitive differentiation to mitigate these risks. Overall, Agradaya possesses strong internal capabilities that can be leveraged to seize external opportunities. However, addressing its logistical limitations and



dependence on founder vision, while preparing for climate impacts and intense competition, will be critical for sustained success.

Table 4. SWOT Analysis of Agradaya

Strengths	Weaknesses
Farmer trust and ethical sourcing.	Limited logistics for large-scale exports.
Certified, premium product line.	Lack of digital infrastructure in rural areas.
Strong brand story.	Dependence on the founder's leadership vision.
Opportunities	Threats
Export to ASEAN and European Union markets.	Climate change is affecting herb yields.
Partnering with wellness influencers.	Aggressive market entry by big herbal players.

Agradaya's success in integrating social values with economic activities cannot be separated from the strength of its founder's personal vision. Its charismatic and intuitive approach has served as the main driver of innovation and the mobilization of farming communities. However, from the perspective of modern strategic management, a high dependency on a central figure creates a form of centralized dependency that poses significant risks to the organization's long-term sustainability. An overly informal management structure with minimal systematization can hinder the institutionalization of values and the replication of its business model in broader contexts. A strategy that is solely based on the founder's vision tends to produce an organically structured organization that is difficult to standardize. This is evident in Agradaya, which has yet to adopt performance-based management tools such as the Balanced Scorecard, an essential instrument for assessing success across more complex and integrated dimensions, not only from a financial perspective, but also in terms of farmer satisfaction, internal process efficiency, and organizational learning. The absence of measurable indicators makes it difficult to evaluate Agradaya's achievements systematically and to audit its performance transparently, whether for internal decision-making or external accountability.



Furthermore, the Dynamic Capabilities framework (Teece, 2007), which consists of sensing, seizing, and reconfiguring, suggests that while Agradaya excels in identifying opportunities (sensing), it lacks sufficient institutional capacity to quickly capitalize on those opportunities (seizing), and to reconfigure its assets and internal structure to remain adaptive to market changes (reconfiguring). In this regard, weak organizational structure and limited research and development-based innovation capabilities represent real obstacles to achieving sustainable competitiveness. Therefore, Agradaya's management strategy stands at a crossroads between value-based success and the need for more systemic institutional renewal. Without a shift toward an organization that is both agile and structured, Agradaya risks becoming a socially inspiring yet stagnant enterprise, locally impactful, but unable to grow sustainably or compete within a global context. The analysis of Agradaya's strategic capability dimensions, as presented in Table 5, indicates that the organization's capacity to respond to digital market dynamics remains at varying levels.

Table 5. Analysis of Agradaya's Strategic Capability Dimensions

Strategic Capability Dimension	Agradaya's Current Condition	Strategic Implications
Sensing	High (identifying opportunities in the digital herbal market)	Requires stronger market research
Seizing	Moderate (limited product development)	Needs innovation driven by R&D and external collaboration
Reconfiguring	Low (internal structure not yet adaptive)	Organizational restructuring is necessary

The table analyzing Agradaya's strategic capability dimensions illustrates that the organization's ability to respond to changes and seize opportunities in the digital market remains unbalanced across the three core dimensions. In the sensing dimension, Agradaya demonstrates a high capacity to identify opportunities, particularly in the digital herbal market. However, this



strength is not yet supported by robust and structured market research, which limits its potential to make data-driven strategic decisions. In terms of seizing, Agradaya is at a moderate level, with product development efforts still limited. This indicates the need for stronger innovation, driven by research and development (R&D) as well as strategic collaboration. Meanwhile, the reconfiguring dimension reveals the most critical weakness, as Agradaya's internal structure remains insufficiently adaptive to external dynamics. Therefore, institutional reform is essential for the company to transform sustainably and remain competitive in an evolving market landscape.

These capability gaps warrant interpretation against recent digital-transformation theory rather than description alone. Warner and Wäger (2019) show that digital transformation is not a discrete technological event but a continuous process of strategic renewal enabled by dynamic capabilities; from this vantage, Agradaya's uneven sensing–seizing–reconfiguring profile explains why its digitalisation has advanced at the customer-experience layer while upstream processes remain unautomated. Vial (2019) likewise frames digital transformation as a reconfiguration of value-creation paths through digital technologies that is contingent on enabling organisational structures—precisely the structures Agradaya has yet to build. Read through these lenses, Agradaya's condition reflects not a shortage of digital tools but a shortfall in the second-order, reconfiguring capabilities needed to convert opportunity-sensing into institutionalised advantage. Framing the firm's core challenge as capability-building rather than technology adoption constitutes this study's principal contribution to digital-transformation research in social-enterprise settings.

The application of the VRIO framework to Agradaya's key competencies, as shown in Table 6, reveals its core sources of sustainable competitive advantage (SCA). Agradaya's competitive positioning is anchored in two sources of sustainable competitive advantage (SCA) and one



temporary advantage identified through VRIO analysis. Its Farmer Empowerment Model constitutes a strong SCA as it is valuable in ensuring consistent supply, high-quality inputs, and meaningful social impact; rare due to its deep, ethical partnerships with smallholder farmers; inimitable because of the time, trust, and relational capital required; and well-organized within its operational and social mission, forming the foundation of its ethical sourcing and supply chain integrity. Similarly, its Agri-Social Brand Identity represents a powerful SCA, as it is valuable in resonating with conscious consumers, rare among authentic social enterprises, and highly inimitable given the genuine narrative and trust it embodies, while being consistently organized across all brand touchpoints to foster loyalty and emotional connection. In contrast, Traceable, Certified Herbs provide only a temporary competitive advantage: although valuable and somewhat rare due to the cost and complexity of certification, they are not fully inimitable, as competitors can eventually replicate such standards over time. Overall, the VRIO analysis highlights the need for Agradaya to continuously strengthen its social innovation and brand authenticity to sustain long-term differentiation as certification-based advantages become more commonplace.

Table 6. VRIO Analysis of Agradaya

Capability	Valuable	Rare	Inimitable	Organized	Result
Farmer Empowerment Model	✓	✓	✓	✓	Sustainable Advantage
Traceable, Certified Herbs	✓	✓	X	✓	Temporary Advantage
Agri-Social Brand Identity	✓	✓	✓	✓	Sustainable Advantage

A detailed examination of Agradaya's value chain reveals how each activity contributes to both its competitive advantage and social mission. In inbound logistics, the company's direct,



ethical sourcing model eliminates middlemen and fosters trust-based relationships with smallholder farmers, ensuring high-quality raw materials, fair pricing, and strong supply chain integrity. Its operations combine traditional manual processing with semi-industrial techniques for drying and packaging, preserving artisanal quality while enabling scalable growth and maintaining its premium positioning. In outbound logistics, Agradaya leverages digital platforms to reach domestic consumers and actively pursues international export partnerships, bypassing inefficient intermediaries and enabling a direct-to-consumer approach that enhances responsiveness and customer feedback loops.

In marketing and sales, Agradaya emphasizes wellness-driven content and Instagram storytelling to communicate its product authenticity, social impact, and health orientation, thereby building emotional connections, brand loyalty, and advocacy. Supporting these primary activities are robust initiatives such as farmer training programs, community development efforts, and strategic NGO partnerships, all of which strengthen rural livelihoods while enhancing product quality and sustainability. Together, these interconnected activities reflect a value chain that seamlessly integrates commercial viability with social impact, reinforcing Agradaya's distinctive and resilient market position.

Considered jointly, the VRIO and Value Chain analyses explain Agradaya's competitive advantage more completely than either does alone. VRIO identifies what the advantage consists of—the Farmer Empowerment Model and the Agri-Social Brand Identity as sources of sustainable advantage—while the Value Chain locates where that advantage is produced and defended: in inbound logistics (ethical direct sourcing), operations (artisanal-to-semi-industrial processing), and marketing (wellness storytelling). Notably, the two resources VRIO classifies as sustainable are precisely those embedded across several mutually reinforcing value-chain activities, whereas



the merely temporary advantage of certified herbs is confined to a single, replicable activity. This linkage indicates that Agradaya's advantage is systemic rather than attribute-based, echoing the resource-based view that competitive advantage is most durable when valuable resources are woven into interdependent organisational routines rather than held as discrete assets (Zahra, 2021).

The CPM (Table 7) provides a focused competitive assessment against other Indonesian social enterprises that share similar values of ethical sourcing, direct rural community trade, and impactful missions, rather than against large corporations or generic e-commerce platforms. The chosen competitors (Javara Indonesia, Krakakoa, and Du'Anyam) provide a relevant benchmark. The analysis reveals that Agradaya demonstrates strong performance across critical success factors, achieving high scores in brand differentiation, product certification & quality, farmer or community empowerment, and innovation (product & storytelling). Its scores in these areas are competitive with, and in some cases equal to, its peers. However, Agradaya's "Market Reach & Export Access" is notably lower than Javara and Krakakoa, indicating an area for strategic improvement. Despite this, its overall score remains competitive, confirming a solid strategic foundation rooted in its brand and social impact. This suggests that while Agradaya excels in its core ethical and social aspects, expanding its market footprint, particularly internationally, is a key area for future strategic focus to match the reach of some of its more established peers.

Table 7. Competitive Profile Matrix of Agradaya

Strategic Factor	Agradaya	Javara	Krakakoa	Du'Anyam
Brand Differentiation	4	4	4	4
Product Certification & Quality	4	4	4	3
Farmer or Community Empowerment	4	4	4	4
Market Reach & Export Access	2	4	3	3



Innovation (Product & Storytelling)	4	3	3	4
Digital Integration	3	3	4	3
Total Score	21/24	22/24	22/24	21/24

Agradaya's strategic positioning within Quadrant I of the Grand Strategy Matrix (Figure 1), characterized by high market growth and a strong competitive position, indicates that the company is well-situated for aggressive growth strategies. In this quadrant, companies should leverage their inherent strengths and market advantages to consolidate and expand their position. The recommended strategies for Agradaya include:

- a. **Market Development:** This involves expanding into new geographic markets (e.g., ASEAN and European Union as identified in SWOT and Ansoff analyses) and targeting new customer segments. Agradaya can leverage its existing products and strong brand story to enter these new territories.
- b. **Market Penetration:** Increasing sales of existing products within existing markets through enhanced marketing, distribution, and competitive pricing.
- c. **Product Development:** Innovating to create new products or significantly improving existing ones to meet evolving consumer needs and maintain a competitive edge. This could involve diversifying its herb and spice offerings or developing new product formats (e.g., ready-to-use mixes).
- d. **Forward Integration:** Gaining greater control over its distribution channels, potentially by establishing its own retail outlets (digital or physical) or strengthening direct-to-consumer models.
- e. **Backward Integration:** While Agradaya already has strong direct farmer relationships, further strengthening this control over raw material sourcing can ensure consistent quality and supply.



- f. Related Diversification: Venturing into new businesses that are strategically related to its current core competencies, such as related agricultural products or wellness services.

The Ansoff Matrix provides a valuable framework for understanding Agradaya's growth strategies, articulating how the company intends to expand its market presence and product offerings.

- a. Market Penetration: Agradaya's market penetration strategy is focused on increasing the sales of its existing organic herb products within its current Indonesian market. This can be achieved by intensifying its presence on existing e-commerce platforms through enhanced digital marketing campaigns targeting domestic health-conscious consumers. Furthermore, exploring partnerships with local health food stores and cafes could expand its physical distribution channels within Indonesia. The overarching objective is to deepen market share for its established product lines among its existing customer base, leveraging brand loyalty and product quality.
- b. Market Development: This strategy involves Agradaya taking its existing, certified organic herb products into new geographical markets or targeting new customer segments. A prime example is Agradaya's deliberate focus on exporting its products through ASEAN trade networks and specifically targeting Indonesian diaspora communities abroad. This approach shrewdly leverages its established product quality and compelling brand story to reach new customer bases beyond Indonesia's borders, unlocking significant avenues for international growth. This demonstrates a strategic recognition of the export potential for its unique, ethically sourced products.

3.2. Challenges in Implementing Formulated Strategies

Agradaya's commitment to sustainable local resource management through farmer



partnerships (Maulinda, 2019) exemplifies core principles of social entrepreneurship. This field is characterized by innovative practices designed to generate social value within both commercial and non-profit sectors, emphasizing groundbreaking approaches to enhance value creation (Adro and Fernandes, 2021). Agradaya specifically addresses the pervasive issue of low market prices for spice agricultural products by improving the supply chain and eliminating direct, unmediated sales (Maulinda, 2019). However, the implementation of its formulated strategies is not without significant challenges.

Challenges to Maintain a Source of Funding

Agradaya consistently faces obstacles in securing and maintaining adequate funding, which significantly constrains its capacity for operational growth and innovation. As a social enterprise, it must navigate the dual imperative of financial sustainability and social impact. To overcome these limitations, Agradaya must adopt a highly proactive and diversified approach to resource management. Firstly, a thorough investigation of all potential funding sources is imperative, ensuring alignment with its strategic goals and social mission. This extends beyond traditional grants to include impact investments, crowdfunding initiatives, strategic corporate partnerships, and even revenue diversification strategies that can generate additional internal capital. Demonstrating a clear return on investment, both financial and social, becomes critical for attracting and retaining diverse funders. Secondly, Agradaya should actively engage in strategic networking. Participation in relevant conferences, industry workshops, and community events offers invaluable opportunities to connect with potential funders, collaborators, and mentors. These interactions can open doors to new capital, foster knowledge sharing, and create synergistic partnerships that enhance operational capacity and amplify social impact (Fraser, 2024). Building a robust network of supporters and advocates can provide not only financial resources but also



valuable expertise, mentorship, and access to broader markets.

Challenges of Demonstrating Social Impact and Return on Investment

One of the most profound challenges for Agradaya is effectively quantifying and communicating its social impact and return on investment (ROI) to diverse stakeholders, particularly funders. Funders increasingly demand concrete evidence of effectiveness before allocating resources, creating a significant pressure point for social enterprises like Agradaya. The inherent complexity of measuring intangible social benefits often leads to frustration among Agradaya's leadership, who, despite their deep commitment to the mission, struggle to articulate its multifaceted value in quantifiable terms that resonate with financial metrics. To address this critical challenge, Agradaya must prioritize the development of precise metrics and robust evaluation mechanisms from the very inception of its programs. This necessitates a shift from retrospective reporting to prospective impact planning. The systematic application of methodologies such as logic models is highly recommended. Logic models provide a structured framework for explicitly outlining program objectives, planned activities, anticipated outputs (e.g., number of farmers trained), and expected outcomes (e.g., increase in farmer income, improvement in environmental practices, enhanced community well-being). This structured approach enhances clarity and ensures alignment with stakeholder expectations regarding measurable impact (Van De Ven et al., 2023). This anticipatory method not only facilitates a clearer demonstration of impact but also inherently improves overall program design and implementation. By defining success metrics upfront, Agradaya can ensure that its interventions are strategically designed to achieve demonstrable results. Furthermore, this approach promotes transparency and accountability in its operations, building greater trust with funders and beneficiaries alike. The ability to articulate impact using credible data and narratives will be crucial for sustained funding and scaling its social



mission.

Challenges in Upscaling Social Impact by Resource-Based View Implementation

The Resource-Based View (RBV) theory posits that a firm's sustained competitive advantage is derived from the effective utilization of its unique and valuable resources (Zahra, 2021). Agradaya implicitly adopts this approach, particularly through its collaborative model with small-scale farmers to cultivate raw materials. By training these farmers to meet high national and international standards for quality and natural ingredients, Agradaya secures a steady supply of premium raw materials, mitigating distribution issues and establishing a distinct competitive advantage (Rahmaningrum et al., 2024). However, Agradaya faces considerable challenges in acquiring additional resources and further developing its internal capabilities to truly upscale its social impact. To overcome this, it must strategically leverage its existing resources and foster an organizational culture that promotes synergy and continuous improvement. We propose that a strong organizational culture is essential for effectively utilizing skills and resources to maximize social impact within a social enterprise.

Research suggests that a "stewardship culture" can serve as an invaluable resource for entrepreneurial firms (Zahra et al., 2008). A stewardship culture, in this context, is defined as one that actively promotes teamwork, fosters accountability among employees, and cultivates a profound sense of shared purpose. This culture enables social entrepreneurs to forge deep emotional bonds with their mission, translating into higher commitment and sustained effort. Bacq and Eddleston (2016) empirically demonstrated how social enterprises with a strong stewardship focus can significantly enhance their social outcomes. Their findings indicate that an employee-centered stewardship culture helps enterprises effectively counteract challenges related to securing government support and generating income, making them more resilient and adaptive. Conversely,



an entrepreneur-centered stewardship culture amplifies the positive impact of government support and income generation on social outcomes. Therefore, for Agradaya to successfully upscale its social impact, it must intentionally cultivate a collaborative culture that instills positive behaviors, empowers employees, and deeply aligns their individual efforts with the overarching social mission, thereby unlocking the full potential of its resource base.

Limitations

This study relies on documentary evidence as its primary data source and therefore does not include primary empirical validation through interviews or surveys. While the integrated use of multiple strategic management frameworks provides analytical triangulation and enhances the rigor of the strategic assessment, the findings should be interpreted within the context of a document-based case study. Future research is encouraged to incorporate interviews with Agradaya's management, employees, partner farmers, and other stakeholders, together with longitudinal organizational performance data, to further validate and refine the strategic recommendations proposed in this study.

4. Conclusions

Agradaya stands as a compelling exemplar of how an Indonesian small and medium enterprise (SME) can strategically leverage digital tools, integrate profound social value, and cultivate ethical branding to achieve transformative growth. Through its distinctive model of direct farmer partnerships and specialized product creation, the company has demonstrated remarkable capacity for growth while steadfastly preserving its core values of social empowerment and sustainability. Despite facing persistent challenges related to funding scarcity and infrastructure limitations, Agradaya's clear strategic direction, coupled with the robust trust it has cultivated among its stakeholders, positions it favorably for long-term growth and continuous innovation within the



dynamic Indonesian agricultural landscape.

The recommendations for Agradaya are multifaceted, aiming to amplify its social presence and fortify its operational and market capabilities. Diversifying funding sources and refining social impact assessment methodologies are critical steps to ensure financial sustainability and effective communication of its value proposition to investors and beneficiaries alike. Crucially, the strategic adoption and integration of digital tools are envisioned to significantly enhance both its market share, by reaching broader consumer bases, and its supply chain operations, by improving efficiency and traceability from farm to consumer. Furthermore, cultivating a stewardship culture that empowers high-performing employees is paramount. This internal focus will enable Agradaya to build organizational resilience, foster a spirit of continuous internal innovation, and ultimately drive more sustainable growth that is deeply aligned with its foundational mission of farmer empowerment. By systematically addressing these strategic imperatives, Agradaya can solidify its leadership as a pioneering social enterprise at the nexus of agriculture and digital transformation in Indonesia.

Agradaya can no longer rely solely on its social narrative and unique products as its main sources of competitive advantage in an increasingly complex digital ecosystem. To strengthen its position as a digitally driven social enterprise, Agradaya must transform into an organization supported by integrated systems and data. Technological reinforcement should span the entire value chain from upstream (farmer data, IoT implementation), midstream (logistics and production automation), to downstream (omnichannel platforms and AI-powered CRM). In parallel, the organizational structure must evolve from dependence on a central figure to a function-based collective system. A socially oriented Enterprise Architecture approach can serve as a strategic foundation for aligning processes, structures, and information systems with Agradaya's social



mission and growth objectives. This transformation will better equip Agradaya to face disruption, expand its social impact, and compete globally while maintaining its identity as a community-based enterprise.

References

- Adro, F. D., & Fernandes, C. (2021). Social entrepreneurship and social innovation: looking inside the box and moving out of it. *Innovation: The European Journal of Social Science Research*, 35(4), 704–730. <https://doi.org/10.1080/13511610.2020.1870441>
- Bacq, S., & Eddleston, K. A. (2016). A Resource-Based View of Social Entrepreneurship: How Stewardship Culture Benefits Scale of Social Impact. *Journal of Business Ethics*, 152(3), 589–611. <https://doi.org/10.1007/s10551-016-3317-1>
- Fraser, M. (2024, February 15). 4 Great ways networking can help grow your social enterprise. International Social Enterprise Observatory. <https://iseo.scot/2023/11/17/ways-networking-grows-nyour-social-enterprise/>
- Gunawan, W. B. (2024). Matching stage strategy development of PT Alam Sutera Realty Tbk: Diversification as key strategy for business sustainability. *Review of Management, Accounting, and Business Studies*, 5(2), 96-108. <https://doi.org/10.38043/revenue.v5i2.5649>
- Hess, C., & Ostrom, E. (2006). *Understanding Knowledge as a Commons: From Theory to Practice*. The MIT Press. <https://doi.org/10.7551/mitpress/6980.001.0001>
- Maulinda, K. (2019). Proses pengembangan Social Enterprise Agriculture: Studi biografi pada Agradaya. *Jurnal Studi Pemuda*, 7(2), 133. <https://doi.org/10.22146/studipemudaugm.40114>
- Rahmaningrum, A. S., Setyawan, B. E., & Utami, W. (2024). Analisis Resource-Based View dan Lifestyle Segmentation pada Perusahaan Sociopreneurship: Studi Kasus CV. Agradaya. *Jurnal Ekonomi Manajemen Dan Akuntansi*, 2(1).



<https://doi.org/10.23917/determinasi.v2i1.186>

Saebi, T., Foss, N. J., & Linder, S. (2019). Social entrepreneurship research: Past achievements and future promises. *Journal of Management*, 45(1), 70–95.

<https://doi.org/10.1177/0149206318793196>

Sargani, G. R., Wang, B., Leghari, S. J., & Ruan, J. (2025). Is Digital Transformation the Key to Agricultural Strength? A Novel Approach to Productivity and Supply Chain Resilience. *Smart Agricultural Technology*, 100838. <https://doi.org/10.1016/j.atech.2025.100838>

Susanawati, Y. T. N., Fauzan, M., & Sharifuddin, J. (2021). Supply chain management of red chili based on the food supply chain network in Yogyakarta, Indonesia. *IConARD 2021*. <https://doi.org/10.1051/e3sconf/202131601010>

Teece, D. J. (2007). Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal*, 28(13), 1319-1350. <https://doi.org/10.1002/smj.640>

Van De Ven, M., Reining, S., & Batenburg, R. (2023). Key performance indicators for business models: a systematic review and catalog. *Information Systems and e-Business Management*, 21(3), 753–794. <https://doi.org/10.1007/s10257-023-00650-2>

Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Qi Dong, J., Fabian, N., & Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, 122, 889–901. <https://doi.org/10.1016/j.jbusres.2019.09.022>

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, 28(2), 118–144. <https://doi.org/10.1016/j.jsis.2019.01.003>

Warner, K. S. R., & Wäger, M. (2019). Building dynamic capabilities for digital transformation:



An ongoing process of strategic renewal. *Long Range Planning*, 52(3), 326–349.

<https://doi.org/10.1016/j.lrp.2018.12.001>

Westerman, G., Bonnet, D., & McAfee, A. (2014). *Leading digital: Turning technology into business transformation*. Harvard Business Press.

Zahra, S. A. (2021). The Resource-Based View, Resourcefulness, and Resource Management in Startup Firms: A proposed research agenda. *Journal of Management*, 47(7), 1841–1860.

<https://doi.org/10.1177/01492063211018505>

Zahra, S. A., Hayton, J. C., & Salvato, C. (2008). Culture of family commitment and strategic flexibility: the moderating effect of stewardship. *Entrepreneurship Theory and Practice*, 32(6), 1035–1054. <https://doi.org/10.1111/j.1540-6520.2008.00271.x>