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The Application of Analytical Hierarchy Process (AHP) to Determine Best Cost Efficiency Program: A Case Study of Green Farm Company

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Abstract

Purpose: CV. XYZ as hydroponic agriculture, for years since 2019, producing high-demand crops such as lettuce and spinach. Nevertheless, there has been a decline in revenue that is a result of the inefficiencies in the management of operational costs. Thus, this study aimed to come up with identification and prioritization of cost-efficiency strategies with the intervention of in-depth interviews and Analytical Hierarchy Process (AHP).

Method: A mixed-mode methodology was used. The qualitative in-depth interviews between the Board of Directors were analyzed for the most important triangulated criteria and subcriteria that drive operational efficiency. A quantitative AHP analysis was done to slightly compare these factors.

Results: Technology Levers turned out to be the most influent factor, hybrid farming system was the most feasible alternative, with advantages for offering a balanced system that integrates traditional farming practices with modern technologies for sustainability and efficiency.

Conclusions: Integrating human capital development and technological innovation is imperative for optimal operation efficiency and sustainable growth in the hydroponic agriculture sector.

Limitations: This research is limited by the scope of its data sources and the relatively short evaluation period, which may not fully capture the long-term impacts of the proposed strategies.

Contributions: This conclusion contributes to the field by offering a strategic framework that integrates technological innovation and human resource development for improved agricultural productivity. It provides policymakers, agribusiness leaders, and practitioners with actionable insights into balancing traditional knowledge and digital transformation to address systemic inefficiencies.

Keywords: *Analytical Hierarchy Process (AHP), Cost efficiency, Hydroponic agriculture, Operational optimization.*

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1. Introduction

Food security has become one of the major challenges in the globe today as the population increases and the demand for food rises. Food availability shrinks over time with the rising population. Food demand in developing countries is expected to increase by 60% by 2030 and then double by 2050 (Rozi et al., 2023). Chronic hunger saddles more than 800 million people, while about 2 billion people face weak micronutrient deficiency, and these pose clear public health risks (Jiang, Jamil, Zaman, & Fatima, 2024). Resource limitation, agricultural land conversion, inadequate infrastructure, and competition by imports are some factors that undermine food security (Masum, Abid, Arafat, & Beh, 2020). Indonesia,

the most populous country in the world, frequently suffers from volcanic eruptions and floods. Indonesia's medium-term target for food supply, however, has not been achieved for 2024 at four plus or minus 1 percent, due mainly to external disruptions such as food inflation driven by El Nino and by many of the geopolitical and rising input costs (BPS, 2024).

Recently, the per capita consumption of vegetables in Indonesia has increased significantly in the last few years, mainly due to the rising awareness of healthy food consumption, increased purchasing power, and also due to population growth. This increase in per capita consumption of vegetables from 37,898 thousand rupiah to 57,104 thousand rupiah for the years 2019-2023 portrays the enhancement of the health trend consumed by Indonesians as they become richer and their access to the different varieties of food becomes wider (Alim, 2023). This increased demand does expose domestic production of vegetables in Indonesia to challenges. Although reported production peaked at 15.27 million tonnes in 2022, it suffered a significant loss in 2023 as levels fell to 14.61 million tonnes. The decrease in production, which is accompanied by the rising consumption of vegetables, clearly indicates the decrease in vegetable availability on the domestic market (Dionysopoulou, 2020).

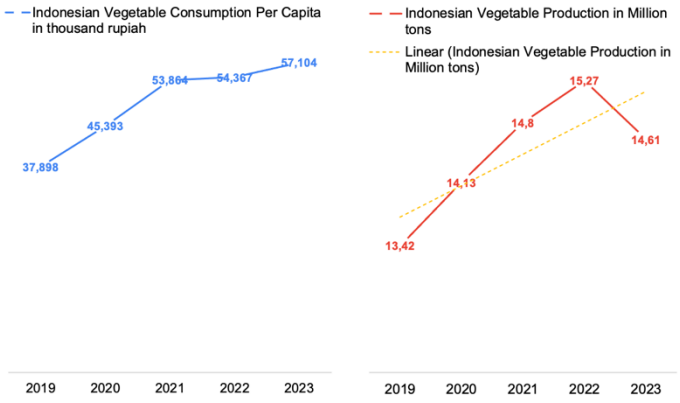

Figure 1. Comparison Between Consumption Vs. Production of vegetables in Indonesia
Source: National Statistics Agency (2024)

Adopting agricultural technology is more than a fad; it has been critically proven throughout history to solve production constraints, as these practices have worked in developed nations in leading to food surpluses, as demonstrated (Campi et al., 2021). In Indonesia, companies like CV. XYZ Green Farm, located in West Java, Indonesia, has endorsed semi-modern systems, for example, closed hydroponics, in which very good quality vegetables are produced adequately and sustainably. The system ensures the continuous available supply across climate variability, such as El Nino. Even though this system is new at CV. XYZ, having been used since 2019, the previous year had a cut of about 70 % of revenues from the company. The demand for vegetables stands stead, which necessitates looking into this setback, for which the management attributes it to less operational cost control. Maintenance of equipment and inefficient means of working with plantation-related problems exacerbated the high production cost, adding to the necessity for an entire resource and strategy review (Gumbo, Margaret, & Chagwesha, 2022). It shows the need for this study into operational efficiency challenges with a specific focus on scalability and improvements in closed farming systems. Thus, using internal evaluations and analytical hierarchy processes, priority determinations will be made for areas needing improving productivity and the availability of resources while offering actionable insights from a growable perspective (Bora, Fanggidae, & Fanggidae, 2023).

While there is usually funding for agricultural innovation, developing new ones requires even higher investment in nurturing priority elements. This study shall produce recommendations for CV management. XYZ by shedding light on key elements requiring attention for the improved functioning and growth of the organization. Hence, the study is entitled " The Application of Analytical Hierarchy Process (AHP) to Determine Best Cost Efficiency Program: A Case Study of Green Farm Company."

2. Literature Review

2.1 Theoretical Foundation

The theory of efficiency, as outlined by Farrell (1957), presents a holistic approach to productivity evaluation based on three aspects: technical, allocative, and overall economic efficiency. Technical efficiency defines the extent to which a firm achieves a maximum output from a given set of inputs, thereby indicating how effectively resources are being used in the production process and whether the firm's operation is optimal. Next is allocative efficiency, which measures the extent to which the firm applies its inputs in optimal proportions, depending on their price, aimed at minimum production costs for the same output level, hence optimality in resource allocations (Gumbo et al., 2022). Thus, the two components give rise to economic efficiency, which denotes the fact that firms do not only maximize the output but also do this at the least cost. In effect, it encompasses the fact that the firm is technically efficient and economically efficient, whereby its resources are utilized fully and effectively, thereby giving a basic complete measure and analysis of efficiency in economics and operations research (George, 2021).

2.1.1 Operational Efficiency

Utilization of resources efficiently is more than ever critical for the improvement of company performance; as such, it should be a matter of concern for management (Dalwai & Salehi, 2021; Handoyo, Suharman, K Ghani, & Soedarsono, 2023). Competent operations turn production to lower costs, enlarge profit margins, and improve profitability (Derouiche, Manita, & Muessig, 2021). Studies report that operationally efficient firms outperform their competitors, while inefficiencies impede manufacturing results (Lamourou, Karbout, Zriba, Zoghlami, & Ouessar, 2022). Defensive strategy concentrates on cost efficiency within limited niches (Ingram et al., 2016), while proactive strategy emphasizes creativity and fast-growing market dynamics (Ghofar & Islam, 2015). Optimizing processes, lowering costs, and increasing corporate growth are common operating efficiencies (Tziner & Birati, 1996). Employee behaviors aligned with strategic goals ensure sustained improvement in this respect (Tziner & Birati, 1996).

2.1.2 Hydroponic Farming

Hydroponics is a farming method whereby controlled agricultural conditions are created in an artificial environment without any soil medium in production (Sibanda, 2020). Soil can restrict the farmer on where they can grow the crop; since ideal production requires a certain soil type, the farmer is limited spatially. Farming systems drawn on hydroponics and soilless cultivation using nutrient-rich water offer almost complete control over the growth conditions that lead to more rapid growth, increased yields, and a more efficient use of resources than in traditional systems (Olayemi, 2020). It has added significance in urban locations, making efficient use of ignored places such as rooftops and warehouses, translating into enhanced food security (Barker et al., 2020). Having controlled environments during production also translates into less pesticide use, leading to cleaner and, in many cases, pesticide-free crops, which are the current preferences for health-conscious consumers. " Closed farming systems " such as greenhouses and vertical farming have offered even more sustainability and productivity boosters, correlated with appropriate technology such as LED lighting, automated nutrient delivery, and climate control for creating optimum conditions in which to grow crops throughout the year (Al-Kodmany, 2018). Vertical farming maximizes high land-use intensity by growing crops in stacked layers while solving urban agricultural prisms related to space (Despommier, 2010). These systems also lessen harmful effects on the environment through reduced land degradation, soil erosion, deforestation, and water pollution, as all these impacts are minimized by the diminished use of pesticides and fertilizers (Van Delden et al., 2021). They also enhance urban food security and employment but keep reducing chains of supply, making the food systems more local and resilient (Beacham, Vickers, & Monaghan, 2019).

2.2 Conceptual Framework

2.2.1 Conceptual Framework of the Study

It is, therefore, job mismatch, whereby a mismatch occurs where job skill requirements and job segments are unaligned (Becker, 1985), or employee competence, wherein this factor ensures effective performance (Collins, 2000), or fatigue that drains productivity irrespective of skill status as observed

by Pasupathy and Steege (2011). Attitudes an employee has are also important because positive outlooks ensure even better performance, as stated by Bartel, 2004 for the organization to be well known. Among these is effective supervision that ensures accountability, while the poor give rise to inefficiency (Bridger, 2008). Training and development Improve performance as inadequate programs hinder it (Bertola, 2004)-job security fosters stability and productivity (Bertola, 1990)-well-designed layouts reduce congestion, accidents, and costs (Banjoko, 2002). Technological features include balanced maintenance strategies and combining preventive and predictive methods that their reliable (Sullivan et al., 2007). Research and development (R&D) drives innovation and efficiency (Herring & Roy, 2007), while process management defines and improves different workflows in order to meet customer needs (Forbes & Ahmed, 2010). All these factors double as stimulants to enhance both short-term performance and long-term sustainability in competitive markets (Sooriyamudali, 2020).

At the moment, KPMG's efficient operation is indeed a clear outline to cater to every area that needs addressing in hydroponic operations. To begin with, it gives a baseline of an assessing measure of the performance metrics involving energy, water, labor costs, and crop yield along with any area of improvement- clear an opportunity to approach the important cost-saving project . Next were the personalistic methodologies, where organizational processes and the use of technologies would be evaluated for cost-saving opportunities: automation of all tasks such as seeding and watering, optimization of workforce management including training, and outsourcing non-core activities like equipment maintenance (Sarker, Gain, Saha, Mondal, & Ifte, 2024). Identified opportunities for cost savings would be ranked according to potential savings and faster implementation to put a focus on quick wins to generate immediate impact. Application of the above framework to CV. XYZ emphasizes challenges posed by an outdated technique, as it would limit responsiveness to market demand and adoption of new trends in agriculture practice. These issues can be addressed through proactive and systematic strategy measures that provide a solution for existing inefficiencies while laying a foundation for future growth in a highly competitive market (Lee, 2024; Pöhler, Diepold & Wallach, 2024; Wang, 2024; Walter, 2024).

Figure 2: Conceptual Framework
Source: KPMG (2024)

3. Methodology

3.1 Research Design

The directory of research methodology includes mixed methods research paradigm as the third one, which synergizes the positive abilities of the qualitative and quantitative methods (Akimowicz et al., 2018). To study the company's product development process using multiple research approaches, qualitative and quantitative means will be met under mixed methods. In this regard, qualitative means will use in-depth interviews with stakeholders and experts on the efficiency strategy that the company aims to achieve. In the microcosm of quantitative means, digital surveys will be used to collect data across the computerized devices and analyze the data statistically. Triangulation will thus be achieved in a way that shall lead to the greater validity and reliability of findings. As there is cross-referencing of insights from interviews with AHP data from the survey, it guarantees strong conclusions that

accurately represent stakeholder needs and priorities. Such all-inclusive research limits the disadvantages linked to single methodology approaches and allows for more diverse, fruitful, and implementable information.

3.2 Data Collection Methods

3.2.1 In-Depth Interviews

In-depth interviews are qualitative research methods whereby exhaustive individual interviews, either typically one-on-one or in small groups, are organized to gather insights into one's perceptions concerning certain issues, programs, or situations (Boyce & Palena, 2006). For this thesis, the researcher conducted key interviews with targeted members of senior management in the company where one would be able to brainstorm and discuss all the main criteria and sub-criteria for selecting the efficiency program.

3.2.2 Questionnaire

The data are gathered from decision-makers using the analytic hierarchy process (AHP) through a pair comparison matrix. The matrix consists of one matrix assessing key criteria with respect to the optimal decision and four matrices evaluating sub-criteria for each criterion. Part one of the questionnaire deals with comparing criteria and sub-criteria, while part two provides the alternatives for each of these criteria and sub-criteria. This method ensures consistency and accuracy in the comparison matrix (Canco, Kruja, & Iancu, 2021).

3.3 Data Analysis Method

3.3.1 Analytical Hierarchy Process (AHP)

The very first step is to state the problem so that it can be directed precisely to the decision-making process. Some semi-structured interviews are done with our key stakeholders regarding the different aspects of the problem as they are very relevant to identifying the criteria and sub-criteria used. These interviews will primarily derive the criteria and sub-criteria in the arrangement structured into a hierarchical framework following the AHP principles. The qualitative interview data serve to integrate those criteria with the priorities and values of the participants. After the hierarchy setup, the stakeholders move towards a pairwise comparison of the criteria. Each participant is then asked to judge the relatively important criterion against each other, generating pair-wise comparison matrices at each level of the hierarchy. The data's synthesis then becomes subject to the mathematical algorithms of AHP to compute relative weights of criteria and sub-criteria in judgment consistency.

The next step in the analysis is the calculation of priority weights using AHP's eigenvector method to ensure accuracy and reliability. In the end, the weighted criteria will be offered and synthesized to produce a ranking of alternative deal options, thus paving the way for unambiguous decision-making. Thus, Interview-AHP assures, on the one hand, the richness of qualitative insights and, on the other hand, the objectivity and rigor of quantitative analysis to make a robust framework within which complex decisions can be evaluated.

4. Results and discussion

4.1 Result

There why job mismatch applies under human factors when there has been a misalignment regarding skills required in a position and qualifications or preferences of a job seeker; this can be mitigated by improving the job matching process in hiring through the use of skills assessments, structured interviews, and psychometric testing means to ensure that a candidate's skills match the job requirements (Becker, 1985). Competency, too, is a human factor and refers to an employee's being able to apply relevant knowledge, skills, and abilities for effective job function. Regular training sessions, certification programs, and performance evaluations are also crucial for creating and assessing competency in organizational roles (Collins, 2000). Fatigue can affect human productivity in the simplest tasks, affecting both physical and mental performance. To do this, organizations can have regular breaks, limited overtime, and wellness activities, such as sessions on mindfulness and physical activities, which are meant to put up a stress-free life (Pasupathy & Barker, 2012). Employee attitude

plays a large part, too, since having a positive attitude is what helps an organization to run. Organizations can easily have this through recognition programs, feedback channels, and team-building activities to enhance motivation (Bartel, 2004).

One of the most important organizational factors affecting operational efficiency is supervision. With poor supervision, there can be little accountability, along with many loose ends. Leadership training for supervisors, checks, and a strong reporting mechanism must be instituted to allow for proactive resolution (Bridger, 2008). For the most part, moreover, training and development are important considering that ineffectual programs have produced underperformance and ineffectiveness of operations, which meant applying structured on-board training, continuous training programs, and periodic assessments in determining the effectiveness of training (Bertola, 2004). Security of jobs, another organizational factor, augments institutionalization as well as employee loyalty. Policies regarding retention of jobs should be open, development in jobs should be communicated freely, and stability in job roles would encourage good morale among the force (Bertola, 1990). Other areas include optimizing workplace layout, or augmenting layout optimization, as being crucial for a better flow of materials or a reduction in accidents. The following are influential strategies for a layout analysis: visualization techniques for organized workplaces and, of course, safety protocols (Banjoko, 2002).

Organizations also rely on technology factors for their success. Reliability and efficient operational management of equipment are achieved through maintenance, and they include preventive maintenance schedules, predictive technologies, and computerized systems used to monitor maintenance needs (Sullivan et al., 2007). R&D is crucial to energy efficiency improvement and operation improvement. Budgets allocated for R&D, partnerships with research institutions, and sponsorship of innovations will create efficient technologies and practice improvements (Herring & Roy, 2007). Finally, process management tries to optimize customer requirements profitably. Examples of this would include the tools for process improvement, standard operating procedures (SOPs), and continuous monitoring and control system application (Forbes & Ahmed, 2010).

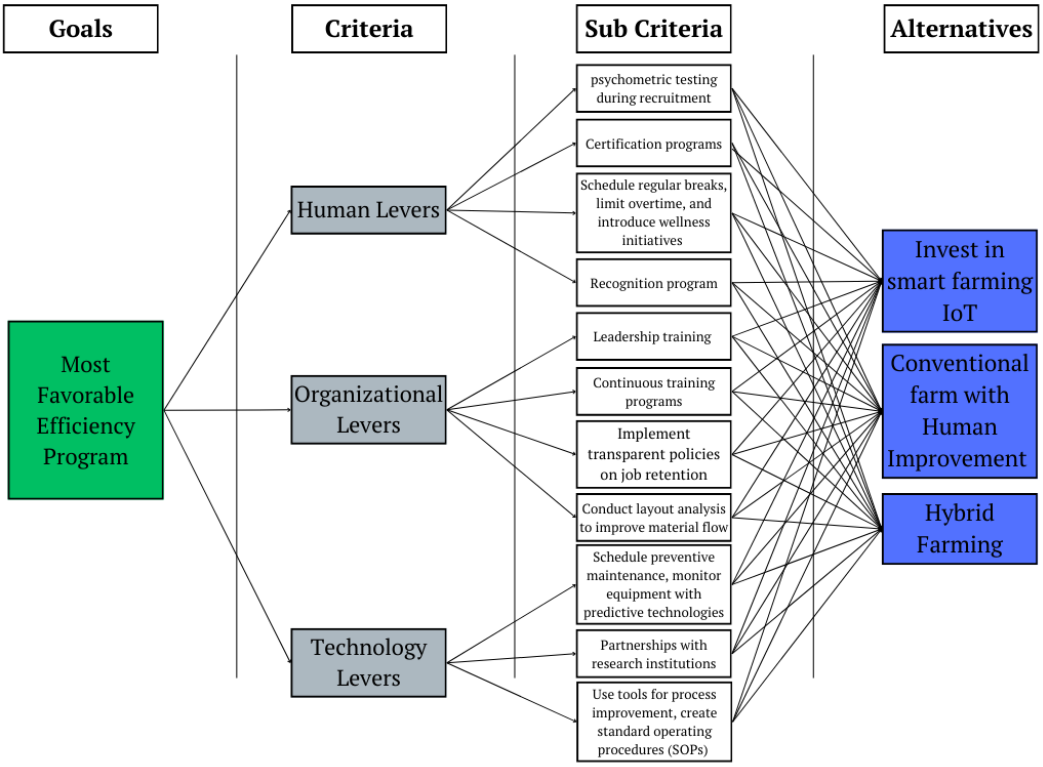

Figure 3: Decision Hierarchy on Selecting the Most Favorable Operational Efficiency Program
Source: Author alayisis (2024)

Table 1. Alternative Criteria and the Reason for Building the Alternative

Current Operational Condition + Integration of IoT systems to monitor and optimize farm operations in real-time.	**Alternative 1** Smart Farming (IoT)	Current Operational Condition + Enhanced traditional greenhouse setup with skill development programs for workers.	**Alternative 2** Conventional Greenhouse with Skill Improvement	Current Operational Condition + Combination of traditional and modern farming techniques to balance efficiency and sustainability.	**Alternative 3** Hybrid Farming

Source: Author data (2024)

4.1.1 Analysis of Pairwise Comparison for Criteria and Sub-Criteria

4.1.1.1 Outcome of Pairwise Comparison for Criteria

This summary presents a survey involving three main criteria with eleven sub-criteria to gather expert opinions. Four respondents filled out an AHP (Analytic Hierarchy Process) paired comparison questionnaire using a scale of 1 to 9, indicating how much one measured element dominates the other. Data processing is conducted through the web-based AHP tool developed by Klause D. Goepel, available at https://bpmsg.com/ahp/ (Goepel, 2018). Results of ranking on the three basic criteria, Organization Levers, Human Levers, and Technology Levers, are given hereunder:

Participant	Human Levers	Organization Levers	Technology Levers	CR_{max}
Group result	28.8%	18.7%	52.5%	0.3%
Handy	9.1%	9.1%	81.8%	0.0%
Ibnu	66.3%	5.8%	27.8%	5.6%
Pratama	12.1%	11.5%	76.4%	0.3%
Fakhri	27.6%	59.5%	12.8%	0.6%

Figure 4: Group Result and Priorities of Individual Participants
Source: Data research (2024)

The results from the AHP analysis have yielded results that show the group weights with Technology Levers receiving the highest weight, which is 52.48%, meaning that the factor most considered in choosing an operational efficiency program was mostly the technology aspect. This shows that technology does play an important role in improving the efficiency of organizations. The Human Lever factor weighs in at 28.77% which shows that the human factor is quite important but still lower in importance to technology in this case. Then we have the Organization Lever factor with the least weightage, which is 18.75%, indicating that the organizational aspect is also taken into consideration but not as the priority after technology and humans in efficiency program selection.

Some variance has been observed in the emphasis that each respondent places on certain priorities. Handy has a very strong toss of the Technology Lever at a whopping 81.82% and nearly none on Human Levers and Organization Levers, each with 9.09%. This speaks to the view of Handy that technology is the most crucial aspect of boosting operational efficiency. On the contrary, the greatest weight assigned by Ibnu was for Human Lever (66.30%), which would benefit more from the human aspect in selecting efficiency programs. Meanwhile, Technology Lever with 27.85% and Organization Lever with 5.85% weight reveal a view that tends to pay attention to human resource roles in successful efficiency programs. Contrarily, Pratama has a view similar to that of Handy by emphasizing Technology Levers (76.41%) and a much smaller weight on Human Levers and Organization Levers (12.10% and 11.49%), showing that technology is also a primary concern for this participant. Meanwhile, Fakhri placed more emphasis on Organization Lever with a weight of 59.54%, indicating that he considers organizational factors as one of the important elements in efficiency improvement. The Human Levers and Technology

Levers had earned smaller weights, 27.64% and 12.83%, indicating, for Fakhri, that the organizational aspect has the most significant impact in terms of program efficiency.

	Cat	Priority	Rank
1	Human Lever	28.8%	2
2	Organization Lever	18.7%	3
3	Technology Lever	52.5%	1

	1	2	3
1	1	1.46	0.58
2	0.69	1	0.34
3	1.73	2.95	1

Figure 5: Consolidated Priorities and Decision Matrix for Criteria
Source: Data research (2024)

The stage involves laying down a foundation for alternatives. Overall, the AHP consensus indicates that, although their priorities differ, Technology Levers are still the most focused point with a weight of 52.48%, closest to Human Levers (28.77%) and also nearer to Organization Levers (18.75%). This indicates that, generally, the group agrees that the most critical thing to consider in selecting the efficiency program is technology despite their differences in priorities, as seen in individual views.

4.1.1.2 Outcome of Pairwise Comparison for Sub-Criteria
The Figure 6. provides a detailed explanation of the paired comparisons conducted for the sub-criteria related to Human Levers:

Participant	psychometric testing	certification programs	introduce wellness initiatives	recognition program	CR_{max}
Group result	**20.3%**	**41.0%**	**19.6%**	**19.2%**	**2.6%**
Handy	9.0%	71.8%	9.6%	9.6%	0.3%
Ibnu	21.3%	16.5%	43.2%	19.0%	4.3%
Pratama	17.4%	52.2%	21.0%	9.4%	6.3%
Fakhri	26.7%	24.5%	8.7%	40.1%	8.9%

Figure 6: AHP Group Result for Sub-criteria of Human Levers
Source: Data research (2024)

Based on the AHP results for the sub-criteria on Human Lever, four (4) respondents had different priorities. Overall, the group's results showed that the Certification Program was the most prioritized sub-criterion, with a weight of 41.02%. Meanwhile, the Psychometric Test ranked lowest, with a weight of 20.26%, indicating that most respondents did not give high priority to this sub-criterion.

Welfare initiatives are the second priority sub-criterion, with a weight of 19.57%. This reflects the importance of strategies that support employee well-being in improving their performance and productivity. Finally, the Award Program is seen as a fairly important sub-criterion, with a weight of 19.15%, but not as large as the certification and welfare programs.

In this case, the psychometric test was the least prioritized sub-criterion by respondents, with a relatively lower weight than the other sub-criteria. Thus, although each strategy has an important role, respondents tend to prioritize competency development through certification, improving employee welfare, and giving rewards as the main steps in improving the human factor in the organization.

Consolidated Priorities

Consistency Ratio CR: 2.6%

	Cat	Priority	Rank
1	psychometric testing	20.3%	2
2	certification programs	41.0%	1
3	introduce wellness initiatives	19.6%	3
4	recognition program	19.2%	4

Consolidated Decision Matrix

Aggregation of individual judgments for 4 Participant(s)

	1	2	3	4
1	1	0.69	0.76	1.00
2	1.46	1	2.55	2.43
3	1.32	0.39	1	0.90
4	1.00	0.41	1.11	1

Figure 7: Consolidated Priorities and Decision Matrix for Sub-criteria of Human Levers
Source: Data research (2024)

With a consistency ratio of 2.6%, the Consolidation Priorities and Consolidated Decision Matrix showed that the Certification Program (41.0%) was the most preferred sub-criterion, followed by the Psychometric Test (20.3%), which took second place. The Wellbeing Initiative (19.6%) ranked third, while the Rewards Program (19.2%) took the last position, as illustrated in the Consolidated Decision Matrix.

This Consolidated Decision Matrix shows an aggregation of individual assessments of four participants, with the highest score for the Certification Program getting a weight of 1.00 in first place for Respondent 4, while the Psychometric Test is getting the highest weight for Respondent 1 (0.76). The Wellbeing Initiative received a weight of 1.00 by Respondent 4 and the Award Program showed a variation in priority, with the highest weight by Respondent 1 (0.69).

The Figure 8. Provides a detailed account of the pairwise comparison conducted for the sub-criteria associated with Organization Levers:

Participant	leadership training	continuous training programs	Implement transparent policies	Conduct layout analysis	CR_{max}
Group result	**15.0%**	**50.1%**	**13.3%**	**21.7%**	**1.1%**
Handy	13.5%	64.9%	6.4%	15.2%	5.6%
Ibnu	17.3%	53.1%	16.3%	13.3%	8.9%
Pratama	15.1%	55.1%	16.7%	13.1%	9.3%
Fakhri	9.9%	22.9%	12.4%	54.7%	5.5%

Figure 8: AHP Group Result for Sub-criteria of Organizational Levers
Source: Data research (2024)

Three respondents considered the continuous training program the most important sub-criterion, while one respondent was the most concerned about conducting layout analysis related to the company's objectives. For this category, the sub-criterion that respondents did not prioritize the least was the implementation of transparent policies.

Consolidated Priorities

Consistency Ratio CR: 1.1%

	Cat	Priority	Rank
1	leadership training	15.0%	3
2	continuous training programs	50.1%	1
3	Implement transparent policies	13.3%	4
4	Conduct layout analysis	21.7%	2

Consolidated Decision Matrix

Aggregation of individual judgments for 4 Participant(s)

	1	2	3	4
1	1	0.35	0.93	0.71
2	2.83	1	4.68	2.18
3	1.07	0.21	1	0.61
4	1.41	0.46	1.63	1

Figure 9. Consolidated Priorities and Decision Matrix for Sub-criteria of Organizational Levers
Source: Data research (2024)

With a consistency ratio of 1.1%, the Consolidation Priority and Consolidated Decision Matrix show that the continuous training program sub-criterion (50.1%) is the most preferred sub-criterion, followed by conduct layout analysis (21.7%) in second place, and implementing transparent policies (13.3%) ranking last, as illustrated in Figure 4.5.

The Figure 10, provides a detailed account of the pairwise comparison conducted for the sub-criteria associated with Technology Levers:

Participant	Invest monitor equipment with predictive tech	partnerships with research institutions	create new standard operating procedures	CR_{max}
Group result	**55.9%**	**24.9%**	**19.1%**	**1.6%**
Handy	73.2%	13.0%	13.8%	0.4%
Ibnu	55.0%	24.0%	21.0%	1.9%
Pratama	71.7%	6.6%	21.7%	3.9%
Fakhri	13.9%	77.3%	8.8%	5.6%

Figure 10. AHP Group Result for Sub-criteria of Technology Levers
Source: Data research (2024)

Three (3) respondents considered Investing in monitor equipment with predictive tech the most important sub-criterion, while one respondent was the most concerned about Partnering with a research institution to achieve the company's goals. For this category, the least prioritized sub-criterion by respondents was creating new standard operating procedures (SOP).

Consolidated Priorities

Consistency Ratio CR: 1.6%

	Cat	Priority	Rank
1	Invest monitor equipment with predictive tech	55.9%	1
2	partnerships with research institutions	24.9%	2
3	create new standard operating procedures (SOP	19.1%	3

Consolidated Decision Matrix

Aggregation of individual judgments for 4 Participant(s)

	1	2	3
1	1	1.98	3.31
2	0.50	1	1.15
3	0.30	0.87	1

Figure 11. Consolidated Priorities and Decision Matrix for Sub-criteria of Technology Levers
Source: Data research (2024)

With a consistency ratio of 1.6%, the Consolidation Priority and Consolidated Decision Matrix show that the Sub-criterion of investing in monitor equipment with predictive tech (55.9%) is the most preferred sub-criterion, followed by partnership with research institutions (24.9%) in second place, and creating new standard operating procedures (SOP) (19.1%) ranking last. To get a more comprehensive

overview of the relative importance of each sub-criterion, the following figure illustrates the decision hierarchy with consolidated priorities on the criteria and sub-criteria:

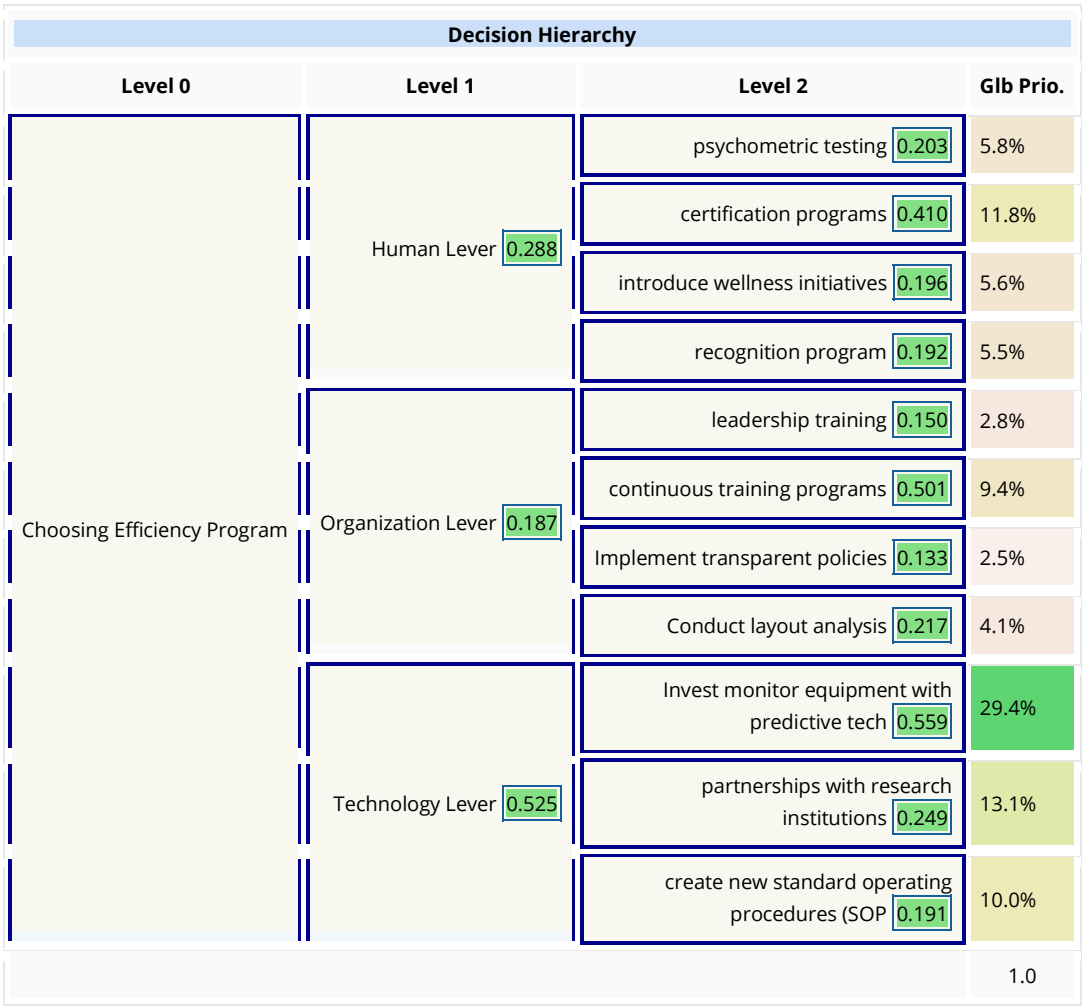

Figure 12. Relative Weights of Criteria and Sub-Criteria with Respect to the Goal
Source: Data research (2024)

Based on the research findings, it can be seen that there are a total of four (4) sub-criteria that emerge as the most important:

1. Invest in monitor equipment with predictive tech 29.4%;
2. Partnerships with research institutions for 13.2%;
3. Certification programs 11.8%; and
4. Create new standard operating procedures (SOP) 10.0%.

Based on the results above, it is proven that these four sub-criteria have a dominant influence, accounting for 64.3% of the total 100% of the sub-criteria in the selection process of the best efficiency program in CV. XYZ. Judging from this, decision-makers, especially the Person in Charge (PIC), must prioritize these four sub-criteria when determining the most effective investment in operational efficiency. This strategic approach will ensure the selection of program efficiency in accordance with the company's capabilities and the problems faced by the company. In contrast, the lowest priority sub-criterion was Leadership Training (2.8%), which showed that this was the least chosen priority by the participants. Next is Psychometric Testing (5.8%), which gets a low priority weight compared to several other sub-criteria. Introduce Wellness Initiatives (5.6%) and Recognition Program (5.5%) have almost the same weight and are in the order of low priority. Continuous Training Programs (9.4%) received a slightly higher priority but were still in the category of sub-criteria with medium priority.

4.1.1.3 The Outcome of Pairwise Comparison for Sub-Criteria with Alternative

Based on the previous process, the second questionnaire was given to the same group of participants or experts who assessed the initial questionnaire. During this phase, the paired comparison method is used to determine the importance of each criterion. Next, rankings for various factors related to the alternative are assessed, and these rankings are then multiplied by the weights of their respective criteria. This process generates a priority index for alternatives, which serves as an indicator of how well each alternative aligns with various sub-criteria.

Participant	Hybrid Farming System	Conventional Farming with Skill Improvement	Smart farming (IoT)	CR_{max}
Group result	37.4%	33.8%	28.8%	2.5%
Handy	22.8%	40.3%	36.9%	9.8%
Ibnu	54.0%	18.9%	27.1%	5.6%
Pratama	51.5%	26.2%	22.3%	9.8%
Fakhri	28.7%	50.7%	20.6%	8.0%

Figure 13. Alternatives by Participants

Research results reveal varying preferences among participants for the three farming system alternatives: Hybrid Farming System, Conventional Farming with Skill Improvement, and Smart Farming (IoT). On a group level, the Hybrid Farming System emerged as the top preference, receiving a weighted score of 37.4%, followed by Conventional Farming with Skill Improvement at 33.8% and Smart Farming (IoT) at 28.8%, with a CRmax of 2.5%, indicating high consistency in the group's judgments. It suggests that while the group collectively leaned towards the Hybrid Farming System, individual preferences showed variability, with some participants emphasizing skill improvement or IoT adoption. This indicates the importance of tailoring strategies to address diverse priorities within stakeholder groups while maintaining consistency in the decision-making process.

4.1.2 Discussion on Criteria and Sub-criteria Weights

The Analytical Hierarchy Process (AHP) analysis highlights the prioritization of criteria and sub-criteria critical for operational efficiency in CV. XYZ. Among the three main criteria, Technology Levers emerged as the most significant, receiving a weight of 52.5%. This indicates that the adoption and optimization of technology play a pivotal role in addressing operational challenges. Sub-criteria within this category, such as "Invest in monitoring equipment with predictive technology" (55.9%), were identified as the highest priority, emphasizing the importance of leveraging technology for predictive maintenance and operational efficiency.

Human Levers, with a weight of 28.8%, were the second most important criterion. Within this category, "Certification programs" (41%) were prioritized, reflecting the critical need for employee skill development to enhance productivity and reduce inefficiencies. Other sub-criteria, such as "Introduce wellness initiatives" and "Recognition programs," were given moderate importance, underscoring the role of employee well-being and motivation.

The Organizational Levers criterion, with a weight of 18.7%, ranked lowest, but "Continuous training programs" (50.1%) within this category were emphasized. This suggests that while organizational factors are less prioritized overall, structured and continuous employee training is still crucial for improving operational efficiency. The prioritization of sub-criteria and their corresponding weights offers actionable insights into which aspects should be addressed immediately to maximize cost efficiency and operational performance.

4.2 Business Solution

The Hybrid Farming System, with the highest weight of 37.4%, is identified as the most suitable solution for addressing operational inefficiencies at CV. XYZ. This alternative balances traditional and modern

farming techniques, combining sustainable practices with advanced technologies. The Conventional Farming with Skill Improvement alternative, which ranked second with a weight of 33.8%, focuses on improving workforce skills and operational processes within a traditional farming framework. Finally, the Smart Farming (IoT) alternative, with a weight of 28.8%, emphasizes leveraging IoT technologies to enhance precision and efficiency in farming operations.

5. Conclusion

The results highlight the importance of leveraging technology to address inefficiencies. Key priorities include investing in predictive maintenance tools and establishing partnerships with research institutions to drive innovation. Alongside technological improvements, enhancing human capital through certification programs, wellness initiatives, and continuous training emerged as vital for improving workforce productivity and morale. Organizational factors, though less prioritized, also play a supporting role in ensuring sustained operational improvements.

The most suitable alternative was a hybrid farming system, offering a balanced approach that integrates traditional farming methods with modern technologies for sustainability and efficiency. Conventional farming with a focus on skill improvement and smart farming utilizing IoT solutions were also recognized as viable strategies, each addressing specific aspects of operational challenges.

Limitations and Future Study

This research is limited by the scope of its data sources and the relatively short evaluation period, which may not fully capture the long-term impacts of the proposed strategies. Future studies should consider longitudinal analyses and broader stakeholder engagement, including government agencies and smallholder farmers, to validate the scalability and sustainability of the hybrid approach in diverse agricultural contexts.

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