https://doi.org/10.31436/iiumej.v27i3.4576

Kansei-Based AHP Framework for Feeding Mechanism Concept Selection in Agroindustrial Coconut Deshelling Machine Design

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(Received: 7 July 2026; Accepted: 15 August 2026; Published online: 11 September 2026)

ABSTRACT: Indonesia is one of the world's biggest producers, with an estimated US$2.05 billion in export value for the coconut industry in 2023. However, mechanized deshelling is limited by the non-uniformity of coconut geometry and intensive operator interaction with sharp rotating parts, which may lead to coconut meat breakage, unstable feeding, fatigue, and safety risks. While human-centered agricultural machinery design and multicriteria equipment selection have received increasing attention, integrating user-oriented Kansei criteria with AHP at the pre-prototype concept-selection stage remains limited. This paper develops a Kansei-based Analytic Hierarchy Process (AHP) framework to select the most feasible feeding mechanism concept before detailed design and prototyping. The baseline requirements identified for guidance, clamping, positioning, pushing, rotation control, operator protection, and implementation feasibility were developed into three alternative concepts: V-Guided Mechanical Feeding, Box-Guided Mechanical Feeding, and Assisted Controlled Feeding. Nine experts evaluated seven Kansei criteria, namely Performance, Practicality, Functionality, Durability, Usability, Pleasurability, and Efficiency. All the aggregated pairwise-comparison matrices were consistent (CR $\leq$ 0.10). Box-Guided Mechanical Feeding performed best (0.411) with the baseline weights, and Assisted Controlled Feeding was close behind (0.401). This result indicates a near-tie rather than an outright win. Furthermore, the sensitivity analysis showed that the preferred concept changes when much higher emphasis is placed on functionality or pleasurability. The preferred concept is box-guided for both baseline and performance-oriented conditions. The framework shows a context-dependent trade-off between mechanical control, implementation practicality, and human-centered requirements, providing a transparent basis for concept selection in small- and medium-scale agro-industrial machinery.

ABSTRAK: Indonesia merupakan antara pengeluar kelapa terbesar di dunia, dengan nilai eksport industri kelapa dianggarkan sebanyak AS$2.05 bilion pada tahun 2023. Walau bagaimanapun, proses pengupasan tempurung secara mekanikal masih terhad disebabkan oleh ketidakseragaman geometri kelapa serta keperluan interaksi intensif antara pengendali dengan komponen tajam yang berputar. Keadaan ini boleh mengakibatkan isi kelapa pecah, proses suapan tidak stabil, keletihan pengendali dan risiko keselamatan. Walaupun reka bentuk jentera pertanian berpusatkan manusia dan pemilihan peralatan berasaskan pelbagai kriteria semakin mendapat perhatian, pengintegrasian kriteria Kansei yang berorientasikan pengguna dengan Proses Hierarki Analitik (Analytic Hierarchy Process, AHP) pada peringkat pemilihan konsep sebelum pembangunan prototaip masih terhad. Makalah ini membangunkan kerangka AHP berasaskan Kansei bagi memilih konsep mekanisme suapan yang paling sesuai sebelum peringkat reka bentuk terperinci dan pembangunan prototaip. Keperluan asas yang dikenal pasti merangkumi aspek pemanduan, pengapitan, peletakan, penolakan, kawalan putaran, perlindungan pengendali dan kebolehlaksanaan pelaksanaan. Keperluan ini digunakan untuk membangunkan tiga konsep alternatif, iaitu Suapan Mekanikal Berpandu-V, Suapan Mekanikal Berpandu-Kotak dan Suapan Terkawal Berbantu. Sembilan orang pakar menilai tujuh kriteria Kansei, iaitu Prestasi, Kepraktisan, Kefungsian, Ketahanan, Kebolehgunaan, Keseronokan dan Kecekapan. Semua matriks perbandingan berpasangan yang diagregatkan menunjukkan tahap ketekalan yang boleh diterima (CR ≤ 0.10). Berdasarkan pemberat asas, Suapan Mekanikal Berpandu-Kotak mencatatkan prestasi terbaik (0.411), diikuti rapat oleh Suapan Terkawal Berbantu (0.401). Dapatan ini menunjukkan keputusan yang hampir setara dan bukannya kemenangan mutlak bagi satu konsep. Selain itu, analisis sensitiviti menunjukkan bahawa konsep pilihan berubah apabila penekanan yang jauh lebih tinggi diberikan kepada aspek kefungsian atau keseronokan. Konsep berpandu kotak kekal sebagai pilihan utama dalam keadaan asas dan keadaan yang berorientasikan prestasi. Kerangka ini menunjukkan pertukaran keutamaan yang bergantung pada konteks antara kawalan mekanikal, kepraktisan pelaksanaan dan keperluan berpusatkan manusia, sekaligus menyediakan asas yang telus bagi pemilihan konsep jentera agroindustri berskala kecil dan sederhana.

KEYWORDS: *Coconut Deshelling Machine, Human-oriented, Multicriteria, Optimum solution*

1. INTRODUCTION

The coconut processing industry is a developing sector in Indonesia, supported by abundant raw materials and Indonesia's status as the world's largest coconut producer [1]. In addition, coconuts also have a wide range of economically valuable products in the global market, such as coconut milk and coconut oil [2], [3]. In 2023, Indonesia produced 14.967 million tonnes of coconut in whole-nut equivalent, and the value of coconut exports reached about US$2.047 billion, the International Coconut Community reported [1]. In the industrial context, transforming coconuts into various products involves a long, complex series of processes. One crucial process is deshelling. In this process, the coconut kernel is separated from its shell. The expected result of deshelling is an intact coconut kernel, which facilitates the next process: removing the testa, i.e., the thin brown skin covering the white coconut flesh. The clean coconut kernel will subsequently serve as the main input for various coconut-derived products [4].

In various coconut industry centers in Indonesia, the deshelling process has been using a deshelling machine [5]. However, the current use of machines still faces several issues, especially in the feeding section, such as the risk of workplace accidents and broken coconuts. This is because coconut sizes are not uniform [6], [7]. In some industries in Indonesia, the main raw material is limited to tall coconut varieties, but their sizes vary widely with age and soil conditions [8]. Moreover, the variability in coconut shell thickness and hardness complicates the mechanical deshelling process for coconut feeding [9].

In addition to issues arising from the coconut material, deshelling problems also stem from the current high level of operator involvement. Operators interact closely with the material and the sharp, moving components of the deshelling machine. The operator must direct, press, and maintain the coconut in the correct position so that it continuously touches the rotary cutter area and is correctly positioned between the rotary and the blade [5]. Therefore, the operator must have high skill and concentration during the deshelling process. Consequently, operator fatigue may cause the process to become unstable and inconsistent. This condition may increase the risk of kernel breakage and workplace accidents. Problems arising from both the coconut material and the operator's side necessitate a better mechanism, especially in feeding the coconut during the deshelling process with this machine. Hence, the feeding problem stems from a combination of the coconut's non-uniform geometry and the need for intense manual control near sharp, moving components, which ultimately affects process stability, kernel integrity, and operator safety.

When designing this feeding mechanism concept, many aspects must be considered. Specifically, this mechanism must ensure the main functions of the existing process, namely guiding, holding, pushing, and maintaining the coconut position relative to the rotary cutter and fixed blade [5]. This requirement is necessitated by the operating sequence, in which the coconut must be continuously positioned and maintained in contact with the cutting zone during deshelling [5]. The selection of the concept should be assessed not only on its technical capabilities but also on its feasibility of implementation. The concept of this feeding mechanism must be applicable and realistic, especially given the condition of the coconut industry in Indonesia, which is mostly small- and medium-scale enterprises [10]. In addition, the new mechanism needs to place the operator at the center of the design process, including safety and comfort. Previous studies on agricultural processing machinery have revealed that human factors and user experience should be considered early in the design rather than only after prototype development [11], [12]. Therefore, in this study, user expectations and impressions are translated into technical design requirements using Kansei Engineering [13].

The decision-making for selecting the feeding mechanism concept must consider multidimensional factors simultaneously. Each alternative concept may have strengths in some factors, but weaknesses in others. A concept may be easier to fabricate and maintain, but it might not sufficiently accommodate the coconut variability in size and operator safety. On the other hand, another concept may improve performance and safety, but it may be difficult to implement because of its mechanical complexity and high investment requirements. Therefore, Kansei Engineering is used to translate the expectations of operators, such as confidence, perceived safety, and ease of use, into explicit evaluation criteria, and AHP structures the trade-offs between these criteria and tests the logical consistency of expert judgments [13], [14], [15]. In current research in agricultural machinery, multicriteria methods are used to compare alternatives. However, such studies are mainly dedicated to the selection of existing machines or developed systems, rather than to human-oriented concept selection before the prototyping phase [16], [17]. Therefore, there is a lack of evidence for a structured concept-stage framework that integrates technical feasibility with operator-oriented Kansei criteria for coconut deshelling feeding mechanisms. Hence, this study aims to develop a Kansei-based AHP framework to select the most feasible feeding mechanism concept for the coconut deshelling machine design as a basis for decision-making before detailed design and prototype development.

2. METHODOLOGY

This research uses the Analytical Hierarchy Process (AHP) integrated with Kansei engineering to select the most feasible feeding mechanism concept for the coconut deshelling machine design. In this case, KE serves as a bridge, translating the operators' expectations into design attributes that, in the context of AHP, serve as criteria. In general, the research proceeds as shown in Fig. 1, which consists of eight stages: identification of design needs through literature review and expert interviews, formulation of alternative concepts, determination of

AHP criteria based on Kansei factors, collection of expert assessments through pairwise comparison, calculation of priority weights and Consistency Ratio (CR), determination of global rankings of alternative concepts, sensitivity analysis, and selection of the best concept.

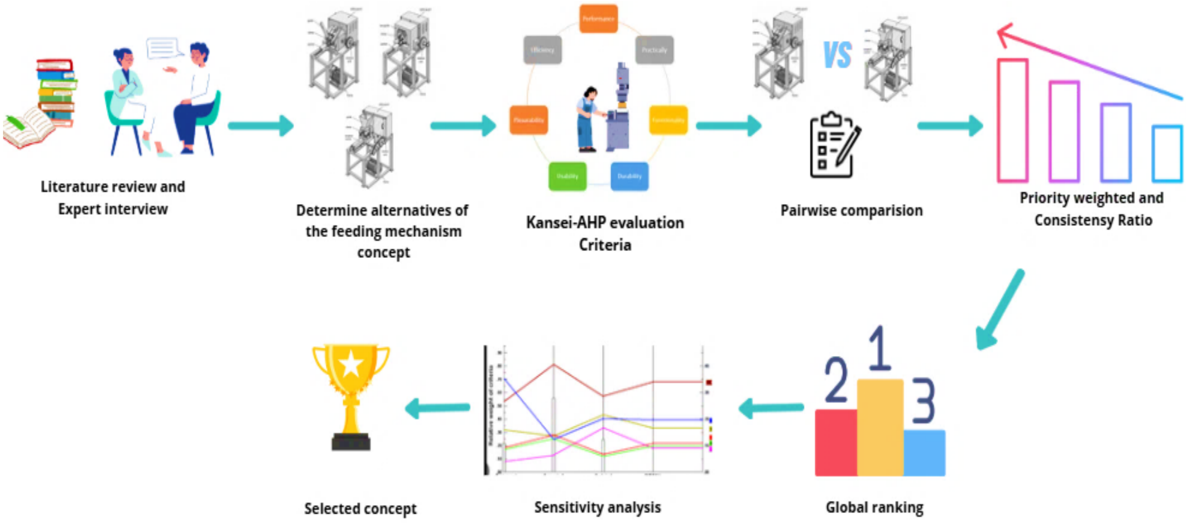


Figure 1. Research framework

2.1. Feeding Mechanism Concept Alternatives

The existing feeding process has five limitations, which form the basis for the alternatives: non-uniform coconuts, unstable positioning, continuous manual force near the cutting zone, absence of self-centering support, and limited control of pushing and rotation. The existing arrangement was considered the baseline functional condition rather than an alternative. Three concepts were considered: simple mechanical guidance, self-centering box guidance, and assisted controlled feeding. These are progressively higher levels of guidance and control.

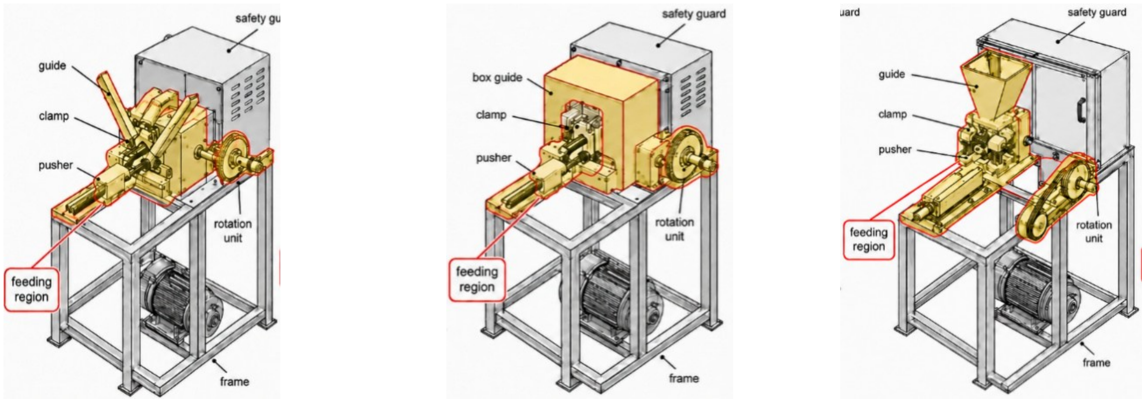
Table 1. Main configuration of the alternative feeding mechanism concept

Task Unit	Alternative Concepts		
	V-guided Mechanical Feeding	Box-guided Mechanical Feeding	Assisted Controlled Feeding
Guiding unit	V-shaped guide rails	Box guide	Funnel guide or box guide with centering block
Clamping unit	Dual-side screw clamp with rubber-lined pads	3-jaw/self-centering holder with free-wheel ball support	Spring-loaded clamp with assisted holding
Adjustment system	Lead screw adjustment	Sliding jaw and locking pin	Telescopic clamp arm
Pushing unit	Rack-and-pinion pusher and linear pusher arm	Rack-and-pinion pusher and linear pusher arm	Screw-drive actuator or assisted pusher
Speed/thrust control	Gear ratio control	Pulley-belt speed reduction	Servo-based or controlled thrust system
Positioning and stopping	V-guide centering and simple adjustable pin stop	Box-guide centering and mechanical end-stop	Limit switch and controlled positioning
Rotation control	Spur-gear drive and pin-lock mechanism	Spur-gear drive and pin-lock mechanism	Chain-sprocket drive with brake or ratchet lock
Frame and safety	Hollow steel frame and full metal guard	Hollow steel frame, adjustable brackets, full metal guard	Integrated frame with sliding or transparent safety shield

This study evaluated three alternative concepts: the V-Guided Mechanical Feeding Concept, Box-Guided Mechanical Feeding Concept, and Assisted Controlled Feeding Concept.

https://doi.org/10.31436/iiumej.v27i3.4576

The V-Guided Mechanical Feeding Concept is the simplest mechanical concept featuring V-shaped guide rails, a dual-sided screw clamp, and a rack-and-pinion pusher. This concept emphasizes ease of fabrication and maintenance. The Box-Guided Mechanical Feeding Concept uses a box guide, a self-centering holder, a free-wheel ball support, a sliding jaw with a locking pin, and a rack-and-pinion pusher. The advantage of this alternative is that it maintains the coconut's positional stability and adapts to variations in material size. Meanwhile, the Assisted Controlled Feeding Concept is a more controlled approach that uses actuators, assisted clamps, controlled-rotation units, and safety guards. This concept emphasizes improved motion control, efficiency, ease of use, and operator protection. Table 1 presents the configurations of the three alternative concepts, and Fig. 2 shows the conceptual designs used in the questionnaire.



(a) (b) (c)

Figure 2. Feeding mechanism concept alternatives: (a) V-guided Mechanical feeding, (b) Box-Guided Mechanical Feeding, and (c) Assisted Controlled Feeding

2.2 Kansei-Based Evaluation Criteria and AHP Hierarchy

Kansei is used to accommodate both the technical aspects and the customer experience in a product [13], [18]. In this case, the product is the feeding mechanism. Kansei factors serve as the main criteria in the AHP structure [15]. Several operational indicators clarify each criterion, but the AHP calculation does not treat these indicators as separate sub-criteria. This approach reduces the burden on respondents and maintains the consistency of expert assessments, without altering the meaning of the operational indicators within each Kansei factor. The criteria used in this study consist of performance, practicality, functionality, durability, usability, pleasurability, and efficiency.

Table 2. Kansei-based Criteria

Criterion	Operational definition
Performance	Ability of the concept to support stable, smooth, and consistent coconut feeding.
Practicality	Feasibility of implementation, fabrication, adjustment, and use in small- and medium-scale industry.
Functionality	Ability to perform essential feeding functions, including guiding, clamping, positioning, pushing, and rotation control.
Durability	Potential to withstand repeated use, load, vibration, coconut impact, and friction.
Usability	Ease with which operators can understand, operate, and control the mechanism.
Pleasurability	Positive user perception, including confidence, perceived safety, neatness, and comfort.
Efficiency	Ability to reduce feeding time, unnecessary operator movement, and interruption in the process flow.

Table 2 presents the operational definitions of each criterion. The seven criteria were adapted from Kansei literature [13], [15] and recent human-factor design guidance for agricultural processing machinery [11], and refined through literature review and expert interviews to correspond to the identified feeding functions. Before pairwise comparison, experts were presented with their operational definitions to ensure a shared understanding.

Based on the Kansei factor descriptions, Fig. 3 illustrates the AHP hierarchy. The first level is the goal of selecting the most suitable feeding mechanism concept for the coconut deshelling machine. The second level comprises seven Kansei-based criteria, while the third level comprises three alternative feeding mechanisms.

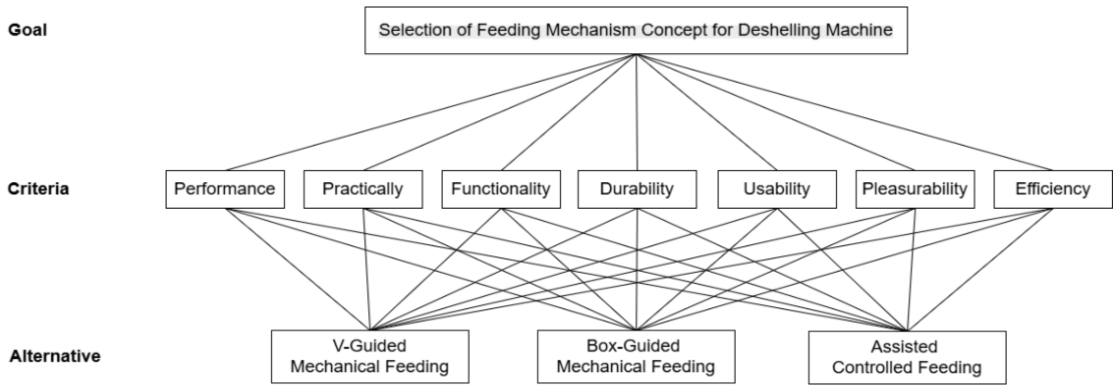


Figure 3. Hierarchy of feeding machine concept for deshelling machine design

2.3 Expert judgment and pairwise comparison

In this study, purposive sampling was used to select 9 experts to evaluate the AHP case. Expert selection was based on their involvement and experience [19] in coconut deshelling, machine maintenance, machine design, production process management, and occupational safety. Experts were contacted individually and invited according to these predefined professional roles. Individuals without relevant direct experience or with incomplete questionnaires were not included. In this study, experts were deliberately selected from practitioners and academics with more than 5 years of experience in their fields. Practitioners include deshelling operators, process supervisors, machine technicians, and GMs, who are managerial personnel. Academics are selected for their expertise in machine design and occupational health and safety. For further details, the expert profiles are available in Table 3.

Table 3. Expert profiles

Expert background	Number	Main contribution
Coconut deshelling operators	2	Practical feeding operation and usability
Deshelling process supervisor	1	Process flow and efficiency
Machine technicians	2	Mechanical feasibility and maintenance
Official Occupational Safety and Health (OSH)	1	General occupational safety risk identification
General manager	1	Feasibility and productivity perspective
Academic expert in machinery design	1	Design logic and technical evaluation
Academic expert in Occupational Safety and Health (OSH)	1	Occupational safety and health perspective

This study involved professional expert judgments on engineering design alternatives. No vulnerable participants or sensitive personal information were involved. All experts were given written information about the purpose of the study, the use of their responses for research and AHP analysis, and the confidentiality of their identities and individual assessments before completing the questionnaire. Participation was voluntary, and providing the information in the questionnaire was considered informed consent to participate. We analyzed and reported individual responses only in the aggregate. Formal institutional ethics/IRB approval was not obtained for this study.

The experts completed pairwise-comparison questionnaires using Saaty's 1-9 scale, as shown in Table 4 [14]. The pairwise comparison assessment is divided into 2 stages: comparisons among the 7 Kansei criteria and comparisons among the 3 concept alternatives for each Kansei criterion. Consequently, the experts completed 42 pairwise comparisons. An example item for criteria comparison was: "In the selection of the feeding mechanism, how important is Functionality compared to Pleasurability?" A sample alternative-comparison-item was: "Which of the two feeding concepts is preferred and with what intensity regarding functionality?" All expert assessments were then combined using the geometric mean to obtain the combined comparison matrix, as this method is suitable for grouping AHP and maintains the matrix's reciprocal property.

Table 4. Saaty scale on pairwise comparison questionnaires

Scale	Interpretation
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values

2.4 Priority Weight, Consistency Ratio, and Global Priority

The pairwise comparison data from experts were converted into a numerical matrix to calculate both the criterion priority weights and the local weights of each alternative [14]. The criteria weights were obtained by normalizing the matrix and calculating the row average Eq. (1):

$$W_j = \frac{1}{n}\sum_{j=1}^{n} \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}} \tag{1}$$

where W_j is the priority weight of criterion j, a_{ij} is the element in the pairwise comparison matrix, and n is the number of criteria.

After knowing the criteria weights, the next step is to calculate the Consistency Ratio (CR) [16] to assess the logical consistency of expert judgments. First, the Consistency Index (CI) was computed using Eq. (2), and then CR was calculated using Eq. (3).

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{2}$$

$$CR = \frac{CI}{RI} \tag{3}$$

where $\lambda_{\max}$ is the maximum eigenvalue of the matrix, n is the number of elements compared, RI is the Random Index, based on the number of elements. A CR ≤ 0.10 indicates acceptable consistency, while a higher CR suggests that the judgments need to be revised.

The global priority of each alternative concept was calculated by combining the criteria weights with the local weights of alternatives under each criterion in Eq. (4):

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$$GP_i = \sum_{j=1}^{n} W_j \times LP_{ij} \tag{4}$$

where GP_i is the global priority of alternative i, W_j is the weight of criterion j, LP_{ij} is the local weight of alternative i under criterion j, and n is the total number of criteria. The global priority values were used to rank the alternatives.

2.5 Sensitivity Analysis

Sensitivity analysis was conducted to evaluate the stability of alternative rankings when the weights of the dominant criteria were varied. Following the robustness-testing approach of Manaf et al. [20], the three criteria with the highest baseline weights were varied individually from 0% to 100% in 10% increments, while the remaining criteria were proportionally adjusted to maintain a total weight of 1. The global priority of each alternative was then recalculated to examine whether the selected concept remained stable under different weighting conditions.

3. Result and Discussion

This research aims to select an alternative feeding mechanism concept for the coconut deshelling machine before entering the prototyping stage. The Analytic Hierarchy Process (AHP) method is used and combined with Kansei Engineering. Both approaches are necessary because they involve multidimensional factors that must be considered in selecting the appropriate mechanism. Variability in coconut size and operator involvement can affect process stability, operational efficiency, and workplace safety. With this approach, 9 experts evaluate each alternative through pairwise comparisons, enabling the determination of criterion weights and the global ranking of alternatives in an objective and systematic manner.

Table 5. Consistency Ratio Summary

Matrix	λmax	CI	CR	Status
Criteria	7.7281	0.1213	0.0919	Consistent
Performance	3.0066	0.0033	0.0057	Consistent
Practicality	3.0522	0.0261	0.0450	Consistent
Functionality	3.0038	0.0019	0.0033	Consistent
Durability	3.0106	0.0053	0.0092	Consistent
Usability	3.0017	0.0008	0.0014	Consistent
Pleasurability	3.0649	0.0324	0.0559	Consistent
Efficiency	3.0386	0.0193	0.0333	Consistent

Table 5 reports the maximum eigenvalue (λmax), Consistency Index (CI), and Consistency Ratio (CR) for the criteria matrix and each alternative-comparison matrix. RI = 1.32 was used for the seven-criterion matrix, while RI = 0.58 was used for the three-alternative matrices. The Consistency Ratio (CR) for each criterion's comparison of criteria and alternatives is below the threshold ($CR \leq 0.10$). This indicates that the experts' judgments are logical and consistent. This proves that the obtained priority weights can be reliably used for further analysis [14].

After ensuring an acceptable Consistency Ratio (CR), the next step is to analyze the criterion weights, which reflect the experts' main focus and considerations in selecting the optimal feeding mechanism concept. Fig. 4 shows the distribution of weights for each Kansei-based criterion, with the total value of all criteria set to 1 (100%). From the histogram, the Functionality criterion has the highest weight (0.293), followed by Pleasurability (0.274) and Performance (0.210), indicating the experts' main priorities are the mechanism's ability to perform important functions, operator comfort, and operational stability. These three factors have relatively close values. This indicates that these three factors are considered almost equally important. Together, the weights of these three factors exceed 75%, indicating that they play a dominant role in this AHP model. This also aligns with research by [15], where safety (part of pleasurability in this study) and performance are the two dominant factors in selecting machine design concepts. Other criteria, namely usability, durability, practicality, and efficiency, have lower weights. This phenomenon indicates that, although important, they are considered less decisive than the three dominant criteria. These weight values subsequently serve as the basis for calculating the global priority of alternatives and as a reference for sensitivity analysis, since criteria with higher weights have a greater impact on the ranking of alternatives.

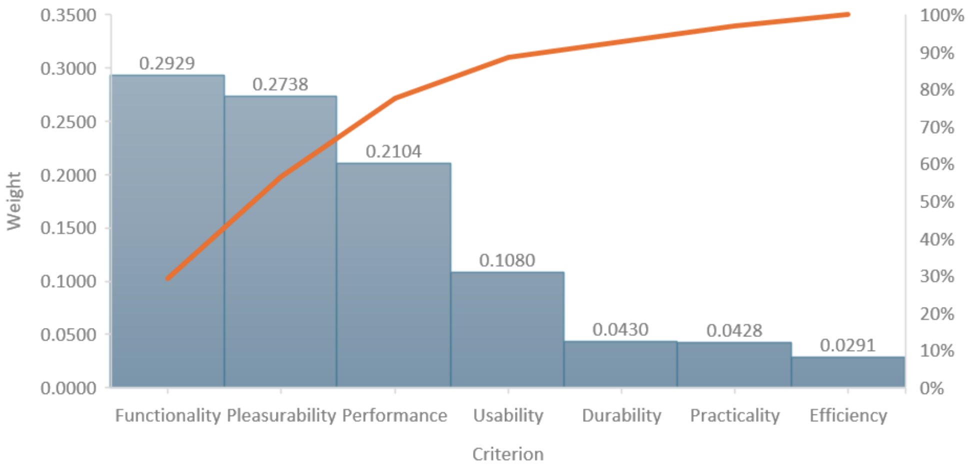


Figure 4. Criteria Weight Histogram

Fig. 5 illustrates the local priority weight values for each feeding mechanism concept across each Kansei criterion. The darker the criterion's color, the greater its weight, and vice versa. A lighter color indicates a lower local priority value. From the image, the three concepts each have advantages, distributing the dominant weights across different criteria. V-Guided Mechanical Feeding has the highest weight in the Practicality criterion (0.614), indicating that this concept excels in ease of implementation and maintenance, but has low weights in Functionality, Durability, and Efficiency (0.09–0.12), showing that its performance and efficiency are quite limited. Conversely, in the Box-Guided Mechanical Feeding concept, the 3 dominant criteria are Usability (0.492), Durability (0.451), and Functionality (0.430). This indicates a balance between mechanical stability and operator comfort. The Assisted Controlled Feeding concept is slightly different, with Pleasurability (0.546) and Efficiency (0.550) as the dominant criteria. This indicates that this concept can provide the operator with safety and comfort at high process speeds. On the other hand, this concept has a low Practicality weight (0.078), indicating higher implementation complexity, especially for small- to medium-sized coconut industries.

These findings are consistent with prior studies on agricultural machinery selection using AHP, which indicate a trade-off between ease of implementation and optimal operational performance. Similarly, recent studies on machinery selection show that multicriteria rankings depend on trade-offs among technical effectiveness, cost, usability, and operational constraints [16], [17]. In addition, [17] found that tractors with greater practical ease or lower mechanical complexity often scored lower on efficiency or sustainability metrics. V-guided, as the simplest concept, is easier to implement but less optimal in terms of function and efficiency. Higher-control concepts, such as Assisted Controlled, are more efficient and provide operator comfort but are mechanically complex. The Box-Guided concept is proposed as the best compromise, balancing mechanical stability, functionality, and operator comfort, in line with recommendations from previous studies that emphasize integrating technical criteria and human factors in the design of agricultural and post-harvest machinery.

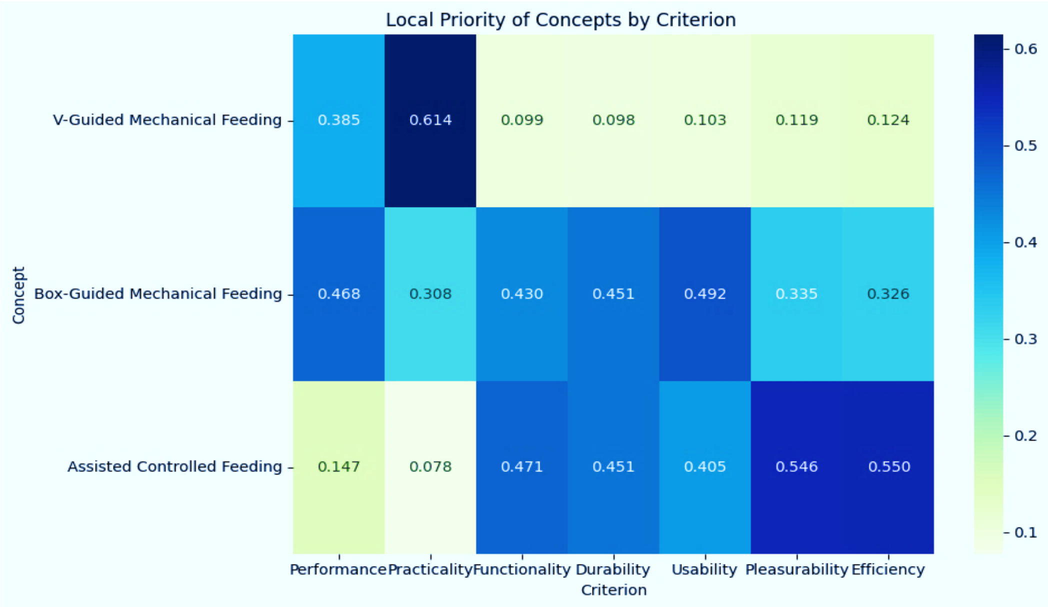


Figure 5. Concepts Local Priority by Criterion Heatmap

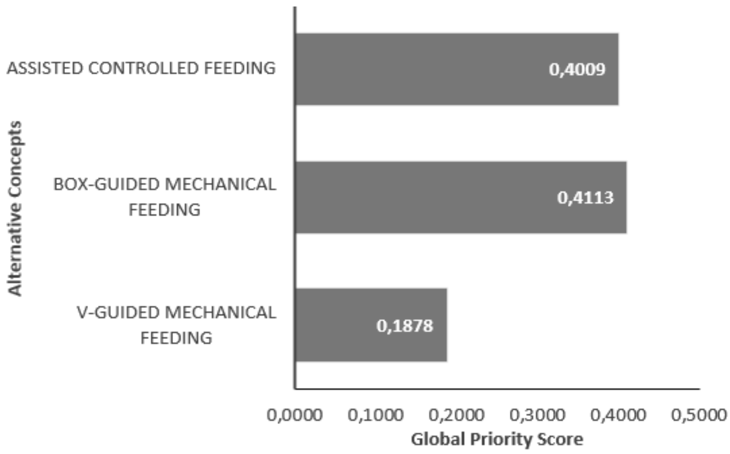
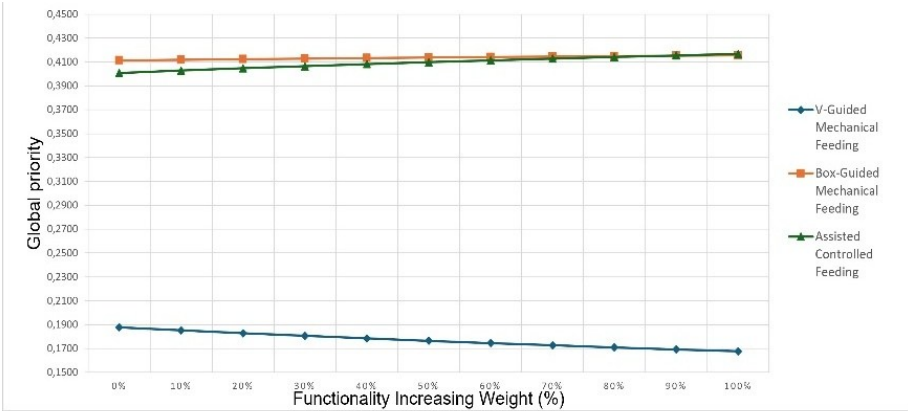
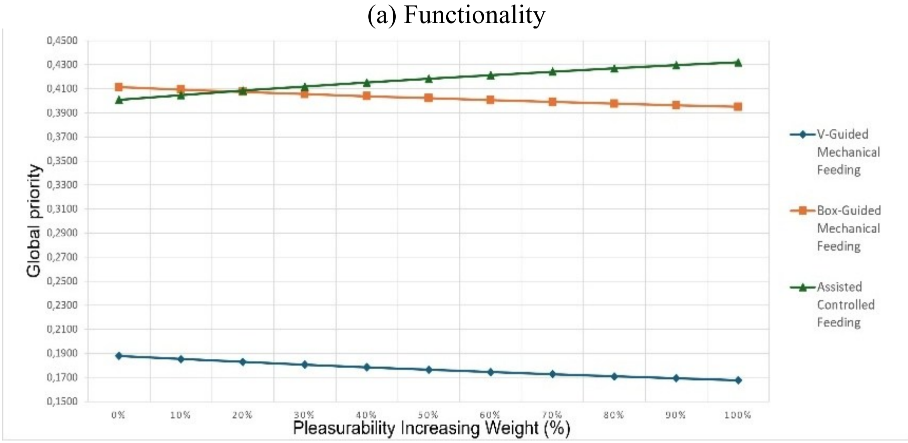


Figure 6. Global Priority Alternatives Diagram

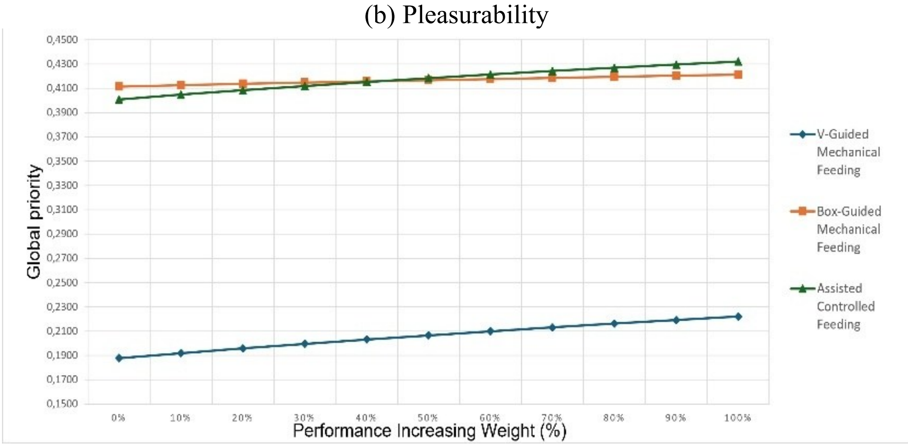
After determining the local priority for each concept in each criterion, the next step is to analyze the global priority to determine the global ranking of the feeding mechanism concept alternatives. Global Priority integrates criteria and local weights for each alternative, providing a comprehensive picture of which concept is most worthy of selection. Fig. 6 shows the global priority values. The Box-Guided Mechanical Feeding concept receives the highest global priority (0.411), followed by Assisted Controlled Feeding (0.401) and V-Guided Mechanical Feeding (0.188). The 0.010 difference between the two highest-ranked concepts is very small and should not be interpreted as an absolute winner. Box-Guided is the baseline preferred concept under the original criterion weights, while the Assisted Controlled concept remains practically competitive and may be selected when the target industry has more financial, technical, and maintenance capability. Meanwhile, V-Guided has the lowest value because it is simpler but less optimal overall. V-Guided remains the simplest alternative but is less competitive overall because of its lower functionality, durability, and efficiency priorities. Some prior literature has also reported similar results. The agricultural and post-harvest machines chosen balance performance and ease of use, avoiding options that are too simple or too complex [15].



(a) Functionality



(b) Pleasurability



(c) Performance

Figure 7. Sensitivity analysis of global priorities under varying weights of the three dominant Kansei criteria

A sensitivity study assessed the robustness of the selected feeding mechanism concept to variations in the main Kansei criteria. The study focused on the three most heavily weighted criteria, which together account for more than 75% of the overall criteria weight: Functionality, Pleasurability, and Performance, as shown in Fig 4 above. This technique is similar to robustness testing in AHP-based decision models, where sensitivity analysis is performed to assess whether the final ranking is stable under variations in the relative importance of criteria

https://doi.org/10.31436/iiumej.v27i3.4576

[20]. In this study, each dominant criterion was varied from 0% to 100%, and the other criteria were proportionally adjusted to ensure the total weight remained 1. Figure 7 shows the results (a, b, and c).

The sensitivity study indicated that the ranking of alternatives was fairly robust, while some changes occurred under certain weighting conditions. In the Functionality sensitivity case in Fig 7a, Box-Guided Mechanical Feeding remained the top-ranked concept across Functionality weights from 0% to 40%. However, when the Functionality weight reached 50% or higher, Assisted Controlled Feeding became the first-ranked concept. The highest-ranked concept is context-dependent. This crossover confirms, as shown in the graph, that Assisted Controlled becomes more attractive as decision makers attach very high importance to controlled pushing, clamping, positioning, and rotation. Box-Guided remains the baseline preferred option at the original Functionality weight of 0.293.

The same tendency was observed in the Pleasurability sensitivity scenario in Fig 7b. Box-Guided Mechanical Feeding was the best-ranked alternative when Pleasurability was weighted between 0% and 30%. However, Assisted Controlled Feeding became dominant when the Pleasurability weight was 40% or higher. Consequently, Assisted Controlled may be preferred when perceived safety, operator confidence, comfort, and control dominate the decision, although its higher mechanical complexity and lower practicality remain an important implementation constraint for small- and medium-scale enterprises.

However, the Performance sensitivity case in Fig. 7c provided greater support for Box-Guided Mechanical Feeding. Box-Guided Mechanical Feeding was still the preferred concept at a Performance weight of 20% and above. Assisted Controlled Feeding was dominant only when the Performance weight was very low (0–10%). This indicates that Box-Guided Mechanical Feeding is more strongly correlated with reliable, smooth, and consistent coconut feeding performance. The result supports Box-Guided for performance-oriented and baseline decision conditions, but does not rule out Assisted Controlled as a viable option for different strategic priorities.

Table 6. Sensitivity Analysis Scenario and Selected Concept Result

Scenario	Weight adjustment	Selected concept	Interpretation
Baseline	Original weights	Box-Guided Mechanical Feeding (baseline-preferred)	Top-ranked under baseline weights, but near-tied with Assisted Controlled.
Functionality sensitivity	Functionality varied from 0% to 100% at 10% intervals	Box-Guided at 0–40%; Assisted Controlled at ≥50%	Ranking changes when functionality receives very high emphasis.
Pleasurability sensitivity	Pleasurability varied from 0% to 100% at 10% intervals	Box-Guided at 0–30%; Assisted Controlled at ≥40%	Ranking is sensitive to operator comfort and perceived safety.
Performance sensitivity	Performance varied from 0% to 100% at 10% intervals	Assisted Controlled at 0–10%; Box-Guided at ≥20%	Box-Guided is supported under baseline and performance-oriented conditions.

The sensitivity analysis indicates that Box-Guided Mechanical Feeding is the preferred compromise under the baseline weights, but the choice between Box-Guided and Assisted Controlled is not absolute. Box-Guided is preferred with the original weights and moderate changes in the dominant criteria, while Assisted Controlled becomes top-ranked with greater weight on Functionality or Pleasurability. On the other hand, V-Guided Mechanical Feeding was not selected in any sensitivity case because its simplicity and practicality did not outweigh its poor functionality, performance, and efficiency. For medium-scale enterprises with conventional fabrication and limited maintenance capability, Box-Guided offers a viable path to more stable feeding and less manual intervention. However, higher-level enterprises with larger automation budgets and stronger control-system capability may choose Assisted Controlled to prioritize operator comfort, perceived safety, and motion control.

4. CONCLUSIONS

The research shows that a Kansei-based AHP framework can be used in the conceptual design of the feeding mechanism before detailed design by integrating technical requirements with operator-oriented considerations. In the baseline expert priorities, the preferred compromise feeding mechanism for implementation in medium-scale coconut agroindustry is the Box-Guided Mechanical Feeding, which combines mechanical guidance and self-centering capability with lower implementation complexity than the assisted-control alternative. However, the tight baseline ranking and the sensitivity analysis suggest that Assisted Controlled Feeding is also a feasible option and can become more attractive when more weight is given to overall functionality, operator confidence, perceived safety, or process efficiency. Therefore, the decision is more about context than a hunt for the universally best mechanism. Importantly, the favored Box-Guided concept directly addresses the original design challenges by reducing dependence on continuous manual holding and repositioning, improving repeatability in accommodating non-uniform coconut sizes, and increasing separation between the operator and the cutting interface. These anticipated benefits may reduce conditions associated with fatigue, kernel breakage, and accident exposure. This can be demonstrated following experimental verification on the physical prototype in the subsequent stage. The framework can be extended to other decisions in agro-industrial machinery where technical performance, implementation feasibility, and human factors must be considered simultaneously. The next step should be to develop and test a validated design through prototype development, mechanical performance testing, ergonomic assessment, and safety evaluation under actual coconut deshelling conditions.

ACKNOWLEDGEMENT

The authors would like to thank Universitas Gadjah Mada for partially funding this research through the Final Assignment Recognition Program (Program Rekognisi Tugas Akhir, RTA), under Assignment Letter No. 5286/UN1.P1/PT.01.03/2024, and the Center for Higher Education Funding of Indonesia for providing a scholarship to the first author. The authors also extend their sincere gratitude to all experts who participated in this study for their willingness, time, professional judgment, and valuable insights during the AHP assessment. Their contributions provided essential input to this research. The authors also acknowledge using generative AI solely to assist in creating visually engaging representations and polishing the manuscript's language. The authors reviewed, revised, and validated all final visualizations, scientific content, data analyses, interpretations, and conclusions.

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