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Towards an Animal Welfare Impact Category: Weighting Indicators in Pig Farming

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Simple Summary: Farm animals such as pigs are often evaluated based on how efficiently they produce food, but their well-being is just as important. Until now, there has been no clear way to include animal welfare—how healthy and comfortable the animals are and how their surroundings impact them—in environmental assessments that help measure the impact of farming. This study presents a framework as a starting point to add animal welfare into what is known as a life cycle assessment, a tool that helps measure the environmental effects of products like meat throughout the entire production chain. By consulting livestock managing experts, the researchers created a scoring system that fairly compares how different parts of pig farming affect animal welfare. This new approach allows decision-makers, farmers, and consumers to see not only the environmental cost of meat production but also the importance of distinct parts of animal welfare consideration based on expert opinion. In the future, this method could be used to design farming systems that are both environmentally friendly and better for animals, thereby helping society make more informed and ethical choices about food.

Abstract: The understanding of sustainability is shifting from that of a purely environmental dimension to one that includes social concerns. Combined with the growing customer interest in livestock husbandry practices, this study investigates the assessment of animal welfare as a socially influenced impact category for the life cycle assessment (LCA) of pig farming. The weighting of animal welfare impacts is based on a quantitative approach using a set of indicators derived from an expert survey using the Analytic Hierarchy Process (AHP). The aim is to develop an easy-to-implement score that translates the characteristics of several animal welfare indicators into a comparable value. To demonstrate the feasibility of the weighting part of the framework, a case study is conducted with nine experts in the fields of animal husbandry, agricultural sciences, and veterinary medicine. The case study results show that the main criteria of single animal observation and feed intake are the most relevant factors, at 30.6%, followed by operation-specific parameters at 23.9% and husbandry conditions at 14.9%. This case study highlights that animal losses (13.9%) significantly influence the impact category, while access to outdoor areas (1.4%) is less important. The overall conclusion is that an animal health-centered approach is preferable when assessing animal welfare.

Keywords: livestock; sustainability; multi-criteria decision analysis; LCA; AHP; sustainable agriculture; impact category; One Health

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1. Introduction

1.1. Background

A significant proportion of greenhouse gas (GHG) emissions in agriculture are caused by livestock in the form of methane and nitrous oxide resulting from enteric fermentation and feed production [1,2], exceeding those of plant-based counterparts [3–5]. Given the urgency of addressing this environmental concern, a life cycle assessment (LCA) is the main tool used to assess the environmental footprint of livestock production [6]. Studies on the LCA of organic agriculture suggest that the environmental impact in terms of common impact categories such as global warming, acidification, and eutrophication [7] often exceeds that of conventional agriculture [8–12]. This lack of understanding is due to lower animal performance in organic livestock systems [10].

However, sustainability goes beyond environmental considerations. It includes social and ethical dimensions, in particular the welfare of animals in the production process, as pointed out by Florindo et al. [13]. The importance of animal welfare has gained attention, reflecting society's growing awareness of the ethical treatment and living conditions of farm animals [14]. Accordingly, the existing LCA framework needs to be extended and adapted to integrate animal welfare to develop a holistic sustainability assessment [11,15]. This aligns with the One Health approach, which emphasizes the interdependence of human, animal, and environmental health [16]. In line with this, in our approach, animal welfare is included as an impact category to represent the social dimension within an LCA framework. Scherer et al. [17] approve of this integration as an external impact. This paper aims to provide a framework for quantifying the social dimension as an impact category for animal welfare, which could extend LCA as a well-defined methodology for the assessment of environmental sustainability. This methodological extension will aid researchers, policymakers, and practitioners in the fields of sustainability, agriculture, and food production.

1.2. Animal Welfare in LCA

This section highlights several areas for further development and the exploration of animal welfare in LCA as they relate to the characteristics of our framework.

The integration of animal welfare into LCA highlights the inclusion of new indicators in the environmental dimension. Consequently, the inclusion of animal welfare as a social dimension in the LCA framework aligns with the goal of achieving a comprehensive sustainability assessment while maintaining internal consistency. With regard to the existing animal welfare assessment, the observed indicators are embedded in different dimensions or reported as individual categories (see Supplementary Material: Table S1 for details) [18]. These indicators are used to examine husbandry conditions and animal health or a combination of both. Lanzoni et al. [18] noted that the determination of the indicators is based on either a quantitative assessment obtained from an on-farm measurement [19] or an estimation made through literature sources or opinions [20]. To ensure the tangibility of the animal welfare assessment, most indicators are normalized and aggregated into a final single score [12,21,22]. This score can be related to a scale or stand alone. For example, Zira et al. [12] developed a score defining *risk pig life days*, while Ziegler et al. [22] used a traffic light system to make animal welfare visually tangible on a scale. Head et al. [23] used survey methods to obtain a score from 1 to 10 for animal welfare, which is displayed via an app, along with other indicators representing, for example, climate or biodiversity concerns. The scores for each impact category are normalized to produce a single overall score. Ruckli et al. [24] considered four sustainability concerns with environmental, economic, social, and animal welfare indicators, and for animal welfare only, 76 indicators are aggregated into six generic animal welfare issues, scored between 0 and 100. In contrast, Castellini et al. [25]

and Rocchi et al. [20] ranked alternative labels with weights calculated using multi-criteria decision analysis (MCDA) methods, including stakeholder opinions, by comparing the calculated indicator values as results without normalization. Bartlett et al. [19] and Zira et al. [12] focused on pigs, with pork being the most consumed meat product globally, followed by chicken and beef [26]. Pork is also the leading meat in terms of environmental impact [27]. Similarly, the framework we have developed is based on the assessment of pigs and pig farming to provide a representative approach to a broader understanding of animal welfare in the context of industrial animal farming alongside environmental assessment. This paper focuses on the pig value chain in Germany, one of the largest pork producers in the world [28].

According to the results of the reviewed studies (see Supplementary Table S1), these studies essentially aim to compare alternatives to the main farming systems, taking into account sustainability concerns. These assessments are based on a specific set of data, which may vary considerably from case to case. Therefore, the applicability of the presented welfare indicators to other cases seems limited. There is a need for a framework to assess animal welfare for each animal species, type of farming, and individual farm structure.

2. Materials and Methods

The following definition is proposed for the terms under discussion: The evaluation of animal welfare is predicated on a structured set of indicators. A superior structure is characterized by a set of four main criteria that systematically encompass three to five indicators (bundles of indicators). In accordance with the AHP methodology, the indicators are designated as sub-criteria.

The flowchart in Figure 1 summarizes the main steps in the methodology and application of the framework. The following sections describe the steps shown and their interrelationships in detail while highlighting a structured approach.

2.1. Indicator Assembling

Defining animal welfare remains a considerable challenge due to the inherent complexity of interpreting animal experiences in ways that are accessible to human understanding. Recent advancements in animal welfare science, such as the 2020 update of the Five Domains Model by Mellor et al. [29], emphasize the importance of evaluating both negative and positive affective experiences in animals, including those arising from human–animal interactions. The model broadens welfare assessment beyond biological functioning by systematically considering domains such as nutrition, physical environment, health, behavioral interactions, and mental state. This multidimensional approach underscores that welfare is not merely the absence of suffering but also the presence of opportunities for agency and positive experiences. Effective assessment must therefore rely on observable factors such as behavior, health status, and environmental conditions interpreted through the lens of expert judgment. Notably, welfare can vary significantly between individual animals within a group, making individual-level observation a critical component [30]. This study adopts a pragmatic approach, operationalizing animal welfare through measurable indicators related to health, access to resources, behavior, and the microclimate. The assessment focuses on the on-farm life phase, which constitutes the majority of the animal's lifespan and excludes the slaughter process.

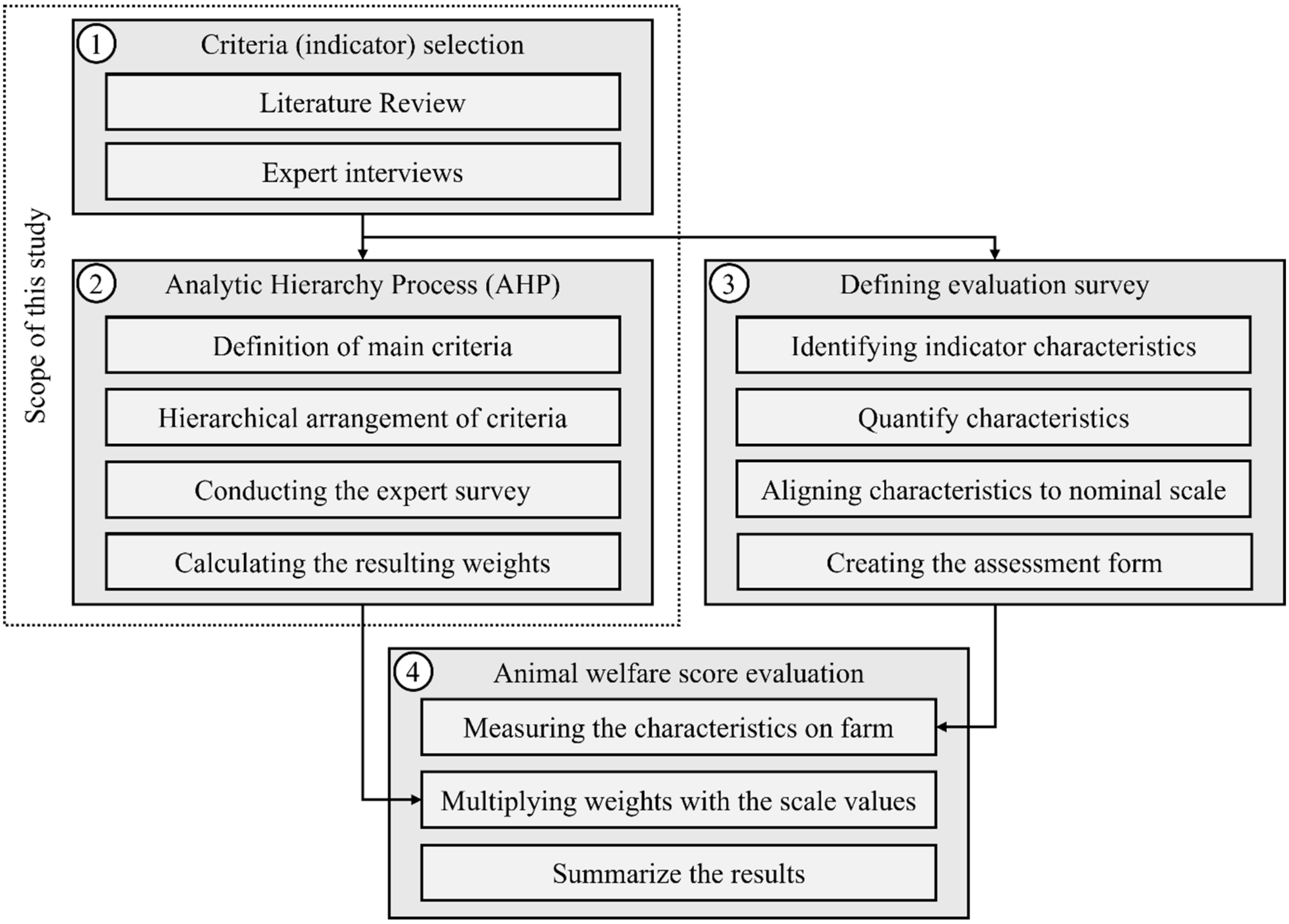

Figure 1. Structure and process of the framework used to retrieve the animal welfare score, with an emphasis on the scope of this study.

The set of assessment indicators, as hierarchically arranged in Figure 2, is defined and verified through qualitative expert interviews based on a literature review, which represents Step 1 in Figure 1. The following section contains detailed information regarding the experts' academic backgrounds, additional knowledge, and professional experience. Further explanation of the characteristics of the indicators and their possible measurability can be found in Table A1. There is an overlap with the indicators identified in other studies that consider the welfare of pigs in the context of LCA, as shown in the literature review in the Supplementary Materials (Table S1). With regard to the main criterion of husbandry conditions, most of the assigned indicator characteristics are objectively measurable, and the lower limits are regulation-specific and defined by German law. Regarding the indicator floor, there are not many possible floor types for pig houses, such as concrete or rubber slatted floors, and their advantages and disadvantages are clear. In addition, the characteristics of these indicators differ among farming systems and provide an opportunity to differentiate on a factual level. The main criterion of feed intake includes indicators that contribute to the welfare of the animal by meeting basic needs such as drinking and eating [31]. Failure to meet these needs can lead to stress and increased incidence of disease [32]. The main criterion of operation-specific parameters supports the rating of the health of the animal group by providing indicators that act as a warning signal when deviations occur. These indicators, such as the percentage of animal losses, are recorded by default and represent quantifiable parameters derived by farm management. Finally, the completely animal-centered indicators of the main criterion of single animal observation should be evaluated by examining and observing the animals as individuals, increasing the difficulty of measurement by introducing mainly subjective measurement. However, while increasing the difficulty, these indicators help to include concrete animal-related factors, such as external integrity, to assess the state of stress in groups of animals [33]. Almost all the indicators presented in Table A2 are in line with the literature, with the exception of daily weight gain and lactation period. Daily weight gain was emphasized by the experts interviewed in order to obtain an overview of the group of animals, especially in case of deviations, from which differences can be deducted. The lactation period is an important indicator of piglet health in terms of future weight gain and lifespan [34]. In Europe, the lower limit of the lactation period is defined by law depending on the farming system [35].

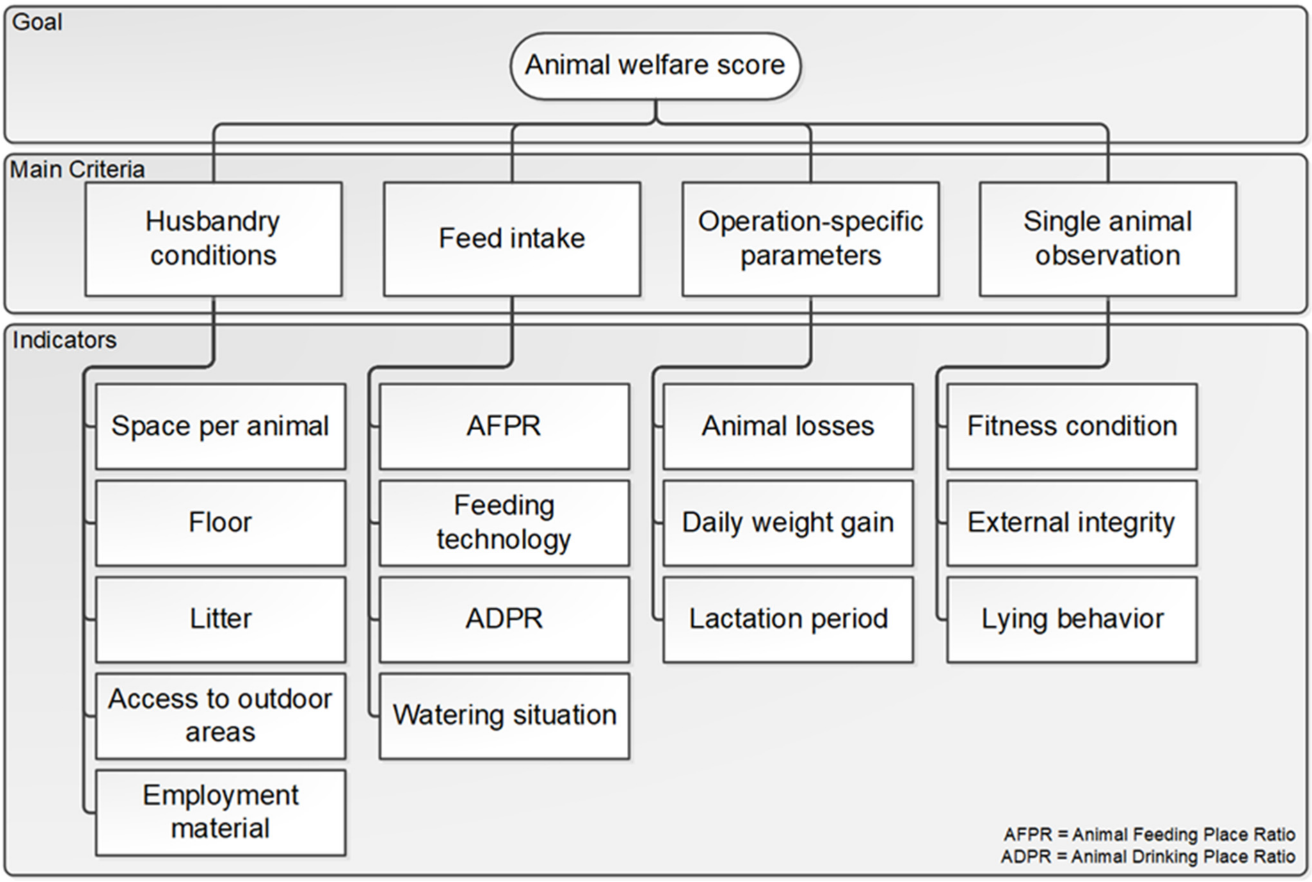

Figure 2. Hierarchical criteria-based structure for the goal of animal welfare assessment in pigs, based on Saaty [36].

2.2. Framework Description

Drawing on the methodology for calculating environmental impacts in a Life Cycle Impact Assessment (LCIA), we develop a synthetic model for an impact assessment that includes animal welfare as an impact category. The framework described in this paper, shown as a flowchart in Figure 1, uses MCDA methods to address the underlying aggregation and weighting process, which represents Step 2 in Figure 1. Ultimately, the developed framework proposes a metric for conducting impact assessments that results in a numerical value, which is standardized with the unit Animal Welfare Equivalent and quantifies the impact category of animal welfare as a result of Step 4 in Figure 1. The main advantage of the presented approach is the tangibility of the scale on which the animal welfare score can be classified. The involvement of pig husbandry and animal health experts in the decision-making process forms the basis of the assessment framework presented. In order to develop an impact category, indicators are needed to define the animal welfare characteristics, as identified in Section 2.1 and shown in Step 1 of Figure 1. The relationships and dependencies between the characteristics of these indicators and their impact categories in the context of LCIA in relation to the presented animal welfare impact category are structured in Figure 3.

For an animal welfare assessment, the individual indicators that make up the Life Cycle Inventory (LCI) need to be measured, weighted, and aggregated to obtain the final score. In the framework presented, the starting point for the required aggregation methodology, namely, the Analytic Hierarchy Process (AHP), is a hierarchically structured set of criteria, which is assembled in Section 2.1 and shown in Figure 2. The corresponding step in the framework is Step 2 (Figure 1). Four main criteria and 15 sub-criteria (indicators) have been identified for the assessment of animal welfare. The hierarchical structure provides criteria-related bundles of indicators arranged as sub-criteria. Each main criterion groups together the corresponding sub-criteria. The application of the AHP methodology starts with the weighting of the sets of indicators against each other. For these pairwise comparisons, the criteria levels and corresponding indicators can be arranged in the structure of matrices. By conducting a survey, the pairwise comparisons are transformed using the AHP, resulting in a percentage weight for each indicator. This widely used method helps to reveal the relative importance, measured as the weight of the hierarchical elements. AHP is a versatile MCDA technique for weighting summable attributes and evaluating alternatives systematically and in a hierarchical structure, as introduced by Saaty [36]. Saaty [36] recommends that the separation shown in Figure 2 creates four relatively homogeneous sets of elements with respect to the common attribute in order to avoid significant errors. Furthermore, grouping is performed because it is hardly possible for respondents to weight all 15 indicators against each other and to consider all further weightings in each decision in order to achieve consistency. Saaty [36] sets the dimensional limit for a bundle of indicators at nine. The main criterion of husbandry conditions combines five indicators, feed intake combines four, and the two persistent main criteria combine three-dimensional indicator matrices. When answering the questionnaire, each respondent successively compares the indicators of the sub-criteria in pairs separated by the main criteria, and then the main criteria are compared in pairs. The weighting of the compared indicators follows the specific scheme of an absolute scale—originally nine importance values and their reciprocals. These values reflect the intensity of the importance of the indicators in relation to each other, as chosen by the respondents editing the survey. In this study, the AHP is applied by consulting nine field experts to complete an online survey that provides a three-level scale of equal importance (1), strong importance (5), and extreme importance (9), as well as their reciprocals. This scale differs from the traditional AHP scale of nine levels. This practical procedural choice is necessary in order to disaggregate the comparisons and thus encourage evaluators to provide more discrete responses. This and other deviations from the traditional AHP scale have been proposed and extensively discussed in the literature [37–42]. In summary, deviating from the well-researched and proven, although sometimes criticized, fundamental scale requires additional consideration and analysis. Consequently, a critical ratio (CR) threshold of 0.1 may indicate, but not reflect, inconsistencies in judgement. For further information on the execution, we refer to the Supplementary Materials (S2).

To demonstrate the feasibility of the approach outlined in the last two stages of Step 2 (Figure 1), a validation run is carried out with nine field experts. Therefore, the application of the AHP methodology described above is carried out by means of a questionnaire. By answering this questionnaire, experts rate the different indicators against each other on the given scale. This requires a basic common understanding of the characteristics of the indicators and their measurability. Prior to the start of the questionnaire, these basic explanations were given to prepare the editors, as shown in Table A1, along with possible characteristics. An online survey was carried out to obtain the experts' assessments. Therefore, experts in pig production and animal health were contacted in August and September 2023. A total of nine completed surveys were collected. The group of respondents consisted of three pig farmers, three agricultural scientists, two agricultural consultants specializing in pig production, and one large animal veterinarian. Finally, an individually weighted set of criteria is obtained for each expert. However, a single set of criteria weightings must be determined for the concept presented. This is achieved by aggregating the individual comparison matrices into a single comparison matrix. The aggregation is performed using the geometric mean. The geometric mean is chosen because it has a proven track record in group judgments [43,44]. After aggregation, the weights obtained add up to one across all indicators, providing the basis for score aggregation as the characterization model of the impact category, as shown in Figure 3.

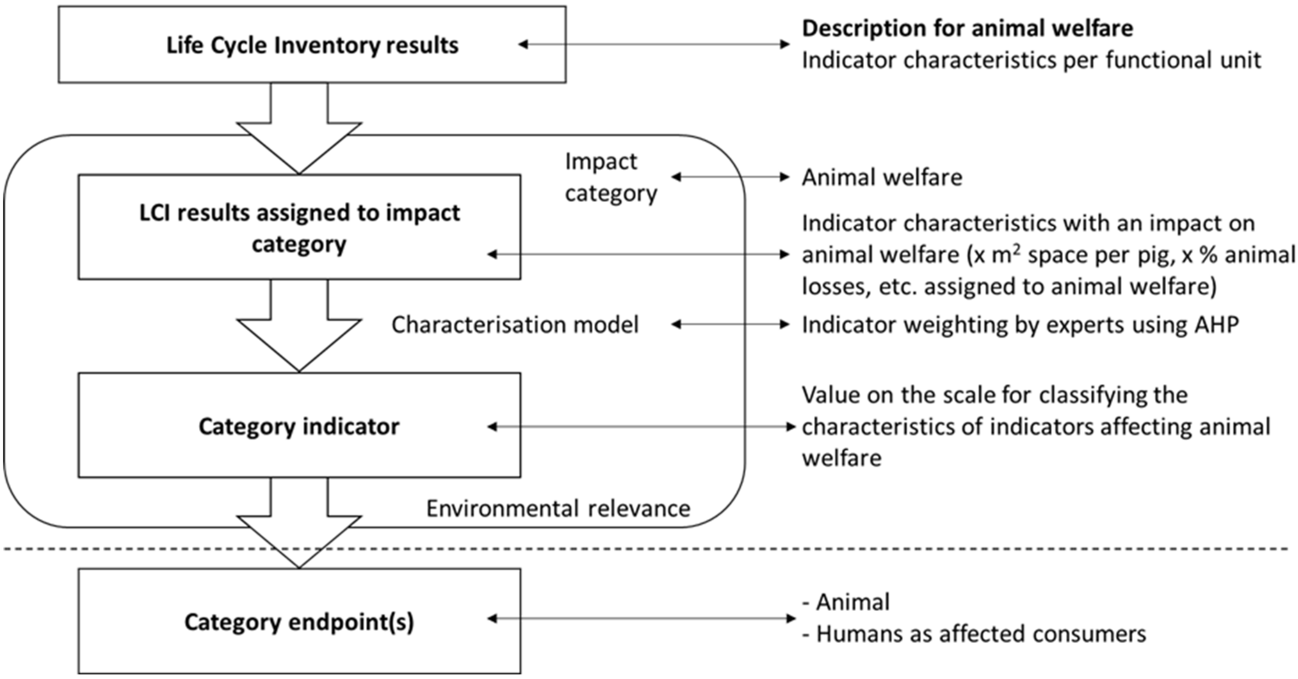

Figure 3. Concept for the implementation of animal welfare as an impact category based on ISO 14044 [45].

In order to calculate the animal welfare score in Step 4 (see Figure 1), Step 3, which is outside the scope of our framework, must be carried out. In Step 3, a five-point nominal scale, representing the category indicator in Figure 3, is introduced to rate the characteristics of the indicators. The five levels range from poor (1) to good (5) for each indicator, thus defining the scale that the evaluator can use for assessment on the farm under consideration. This scale has to be assigned to the characteristics by indicator according to expert interviews and based on a literature review. An example of the application of Step 3 is shown in Table 1 for the indicator space per animal, based on a classification developed by major German food retailers [46]. Based on a classification that refers to the same nominal scale for each indicator, a survey for the on-farm assessment has to be formulated. When the LCI is carried out on the farm in Step 4, a scale value is assigned to each indicator. These indicator-specific values for the farm under consideration are multiplied by the indicator weights (from the AHP in Step 2) using the weighted sum method and result in the animal welfare equivalent. Following the assessment, in relation to a functional unit within the boundaries of the considered systems, the unit for the impact category animal welfare has to be the animal welfare equivalent per kilogram live weight pig of the specific farm or housing section. In order to interpret this impact category indicator value, the nominal scale or category indicator of the characteristic evaluation and its definition must be taken into account. This scale determines the result, as the weighting from the AHP adds up to one when the indicators are combined. Thus, in relation to the definition of the nominal scale, the lower the score, the lower the welfare of the animal examined, and vice versa. Finally, the animal welfare score is an integer value between one and five, related to the functional unit of the study, which constitutes the animal welfare impact category.

Table 1. Exemplary scale to evaluate characteristics of the indicator space per animal for pigs weighing 50–110 kg [46].

Indicator: Space per Animal (50–110 kg)	Measurement by Characteristic (Minimum Indoor Area)
1	0.75 m^2
2	0.825 m^2
3	1.05 m^2
4	1.5 m^2
5	<110 kg: 1.3 m^2; 1 m^2 (outside) >110 kg: 1.5 m^2; 1.2 m^2 (outside)

3. Results

The development of the framework carried out in this paper focuses on the validation of its applicability in weighting the evaluated indicators with AHP, which represents Step 2 (Figure 1), leading to the following results: The starting point is an AHP-based survey with a pre-selected set of indicators in the example of pig farming. Then, following the AHP method described in Section 2.2, the priorities within the hierarchy are derived. The indicator percentages are obtained by multiplying the raw AHP priorities of each indicator by the share of the top-level main criterion, shown in brackets. The extent of the influences is visualized using a Sankey diagram in Figure 4, which is intended to make the weighting more tangible. For the numeric display of the results, we refer to Figure A1. The expert judgement with AHP shows that the overarching criteria of feed intake and single animal observation are the most highly rated. The priority of husbandry conditions is the least derived at 14.9%. This difference may be due to the fact that the high-priority criteria include indicators that directly influence the welfare of the animal in the context of feed intake and observation of the animal itself. The higher priority given to these criteria therefore highlights the importance of an animal-centered approach.

The Sankey diagram in Figure 4 emphasizes that the indicators with the highest priority are animal losses and fitness condition. The weight of animal losses as an indicator stands out, taking into account the rating of the associated main criterion of operation-specific parameters, which is significantly lower than that of the highest rated criteria. When validating the selection of indicators from the reviewed literature with expert interviews, the selection of animal losses as an indicator for the set under consideration was particularly supported. The interviewed experts have determined that the percentage of animal losses in a husbandry section exceeding a certain number is an essential indicator that animal health is affected, which is in line with the findings of Dolman et al. [47]. After animal losses, another highly weighted indicator is fitness condition, which is hierarchically related to single animal observation. Considering all indicators in its branch, fitness condition attracts attention with its individual weight. According to the explanation accompanying the survey (see Table A1), the fitness condition indicator is intended to record the observed fitness level of the animals captured via the established body condition score [48]. By providing data for an animal health-centered view, these two indicators define the focus of an animal welfare assessment using the framework.

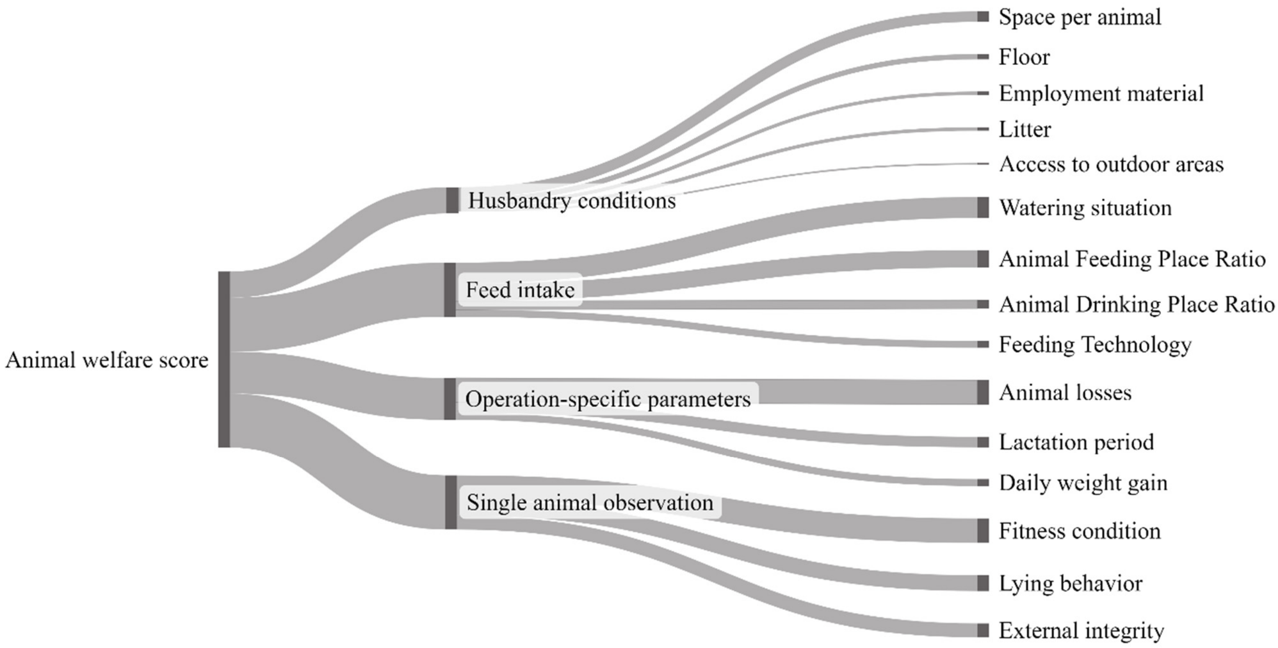

Figure 4. Visualization of the influence of the weights in a Sankey diagram based on the results of the AHP application.

Looking more closely at the high weighting of the fitness condition indicator, the associated main criterion, single animal observation, must be considered as the highest rated criterion. Obviously, it transmits its highest overall influence to its indicators when the weights are transferred. Because of this decisive influence, further analysis of the weights is carried out within the hierarchical branches. The second most important criterion is feed intake, which includes the watering situation and the animal–feeding place ratio (AFPR) as indicators with much higher weights than the other two indicators. Following the expert interviews to compile the set of indicators, high priority was given to health concerns. The watering situation is critical to maintaining animal health due to the susceptibility to contamination, particularly in terms of access to water. For example, different drinking troughs provide different levels of access to water. The watering situation and the animal–feeding place ratio contribute to the accessibility of basic needs. The interruption or disruption of access causes stress for the animals and can lead to health problems.

In terms of husbandry conditions, the space per animal indicator stands out by being somewhat distant from the other indicators with a high share. Furthermore, access to outdoor areas is the least preferred indicator for animal welfare in general. The observed difference is indeed surprising, as it does not correspond to the socially accepted view of animal welfare, which typically envisages animals living on green pastures and in more natural, spacious conditions [49].

To emphasize the importance of the parameter that reflects the quality of the calculations, the CR is visualized in Figure A1. The CR of almost all matrices is below the 10% limit, indicating good consistency across the paired comparisons made by respondents [36]. The CR of the single animal observation bundle exceeds this limit but is only slightly above the limit. This bundle of indicators exhibits some interdependencies in the experts' perceptions that can cause this effect. Furthermore, the small number of indicators increases the influence of an inconsistent response.

In conclusion, the framework gives priority to an animal health perspective. In addition, significant differences in the weighting of indicators within the main criteria branches emphasize the importance of certain indicators over others.

4. Discussion

4.1. Main Results

The framework presented provides an approach to integrating animal welfare into LCA. The development of an animal welfare impact category is part of this approach. What distinguishes our approach is the use of AHP to individually assess and weight the indicators and to guide them toward the improvement of key aspects of animal welfare. In contrast to the literature review (see Appendix A), which mainly compares the welfare characteristics of different labeled farming systems, we propose a different focus when comparing developments on a farm. The inclusion of animal welfare as an impact category within LCA is consistent with this farm-centered approach, which supports more in-depth assessments. The derived animal welfare equivalent is a valuable representation that reflects the actual state of the farm in terms of animal welfare. As with environmental LCA results, the assessment does not end with the score but can be used as a basis for improvement. The quantifiability of the animal welfare assessment, expressed as a score from bad to good, enables both farm managers and consumers to recognize and adjust their practices accordingly. In addition, this approach can be applied to specific areas within livestock production. For example, it is possible to focus on specific parts of the farm, such as the insemination unit or the weaning area. In such cases, if the database is large enough, the results can be aligned with a more specific functional unit of the LCA study, providing more insights than can be obtained when considering the whole farm.

With regard to the evaluation of animal welfare, the individual weighting of the indicators brings a new approach to the consideration of animal welfare in the context of LCA. Most of the approaches found in the literature do not consider weighting. Nevertheless, similar to the presented approach, Zira et al. [50] applied AHP with an expert survey. Thus, the AHP application differs from our approach, as it is applied to weight the subcategories in a social LCA framework, while the assigned indicators are equally weighted [50]. Furthermore, Bartlett et al. [19] used the Welfare Quality® score for pigs as the technical basis and integrated the four Welfare Quality® principles of good feeding, good housing, good health, and appropriate behavior with randomly selected weights. Both studies focused on the inclusion of different scores in animal welfare assessment. While Zira et al. [50] focused on the social LCA inclusion of animal welfare and animals as stakeholders by calculating several social indices, Bartlett et al. [19] introduced a welfare cost approach to include animal welfare. Both processed the original animal-related measurements and parameters with multiple other influencing values to develop the resulting indicator values. Compared to these approaches, the present approach does not transform the welfare assessment results based on indicators and multiple calculation steps into higher scores. Instead, it focuses on a relatively straightforward synthesis of the different welfare indicators into a final score. This synthesis does not take into account any further evaluation of the range of indicators beyond transferring the characteristics of the indicators to a scale. The aim is to produce an easily implemented assessment that translates the characteristics of the indicator into a comparable value while maintaining a direct link to the original indicators.

4.2. Methodology

Beyond the main findings, a closer look at the underlying methodology reveals some notable challenges and shortcomings in the practical application of this approach. One of the main challenges, but also one of the main strengths, is the selection of indicators that comprehensively capture the different facets of animal welfare. Experts disagree on which aspects should be considered, and the definition of animal welfare itself is a subject of ongoing debate. A hierarchical categorization based on key criteria has been used to address these disagreements. The key criteria are intended to explain the general areas in which animal welfare can be assessed. This approach is beneficial, but it is clear that a more comprehensive and rigorous methodology can be developed. Further refinement can be achieved by conducting multiple iterations of the AHP surveys to identify the most critical top-level criteria and their underlying indicators. This process may result in the elimination of certain indicators that prove to have insignificant impacts or importance. The challenge of this refinement is to establish a cut-off criterion. Once indicators have been selected through these iterative processes, the next step is to assign appropriate weights. In summary, the framework presented offers an innovative perspective on animal welfare in the context of LCA but also highlights its complexity. Reaching a consensus on the essential indicators and their relative importance remains a key challenge in this evolving field of research.

The indicator weightings were derived via the Analytic Hierarchy Process (AHP) using a structured survey of nine domain experts. While this offers a transparent and repeatable mechanism, it is subject to the composition of the expert group, which, in this study, leaned toward practical pig production expertise. As such, the results may reflect implicit industry priorities. We recommend that future applications broaden the expert base to include more ethologists and animal welfare scientists to balance the perspectives.

Given the additional challenges of the proposed framework, particularly the adaptation of the importance scale proposed by Saaty [36] for the survey, the implementation of a fuzzy approach can be suggested. The fuzzy AHP method allows for paired comparisons based on vague, fuzzy ratings [51]. Furthermore, the method allows for the quantification of weak priorities and incomparability, allowing the decision-maker to remain unaware of their preferences. In particular, when considering animal behavior and welfare, such uncertainties arise due to the subjective perception of some parameters. In addition to this potential mechanism for coping with uncertainties, the choice of the MCDA methodology involved represents another possibility for improvement. According to Cinelli et al. [52], the selection of appropriate MCDA methods for each decision problem is challenging. Considering this research, it may be of significant importance to review alternative appropriate MCDA methods that could be assigned to the presented framework. By way of example, an extension may include further preference ranking or outranking methods, such as the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [53] and the Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) [54].

The selected indicators in this framework are limited to those for which standardized on-farm data collection is feasible and consistent across farming systems. As a result, more subjective or behaviorally nuanced indicators—such as affective state or the quality of enrichment use—were not prioritized. While this allows for comparability and implementation in real-world contexts, it inevitably narrows the scope of the welfare picture. We recognize that such constraints can introduce bias toward production-relevant metrics and suggest that future adaptations incorporate complementary qualitative assessments or fuzzy logic systems.

In completing the assessment that must follow the current study, it is essential to ensure that the characteristics of the indicators are consistent with the nominal scale. The entire classification system is relevant, as it provides the basis for calculating the animal welfare score of the system being assessed. The characteristics must be assigned to the scale in a way that ensures that they are detectable, visible, distinguishable, and, when possible, numerically determinable. To this end, the classification shall be based on an appropriate number of expert judgements.

5. Conclusions

The assessment of animal welfare is undoubtedly a contentious and multifaceted issue that requires careful consideration. The framework presented in this study takes a novel approach by identifying a set of hierarchically structured indicators and weighting them using expert judgement to provide a comprehensive assessment of welfare considerations. Single animal observation and feed intake are the main criteria that significantly influence the underlying indicators. Influenced by its assigned main criterion, single animal observation, the fitness condition indicator is one of the highest rated indicators. However, another indicator that attracts attention receives almost the same weight, namely animal losses, which underlines the overall finding that an animal health-centered approach is preferred when assessing animal welfare. These retrieved indicators should then be translated into numerical values, giving them a level of quantifiability not commonly found in the literature reviewed. One of the distinctive aspects of our methodology is its commitment to maintaining the validity of these measurements. This not only distinguishes it but also underlines its practicality for practitioners and, ultimately, consumers throughout the livestock value chain. To overlook this dimension when conducting environmental assessments in the livestock sector would be to miss a crucial component of sustainability. We acknowledge that translating the multidimensional concept of animal welfare into a single numerical score entails reductionist compromises. While this format is useful for comparability and integration into broader LCA models, it may obscure important qualitative nuances. Transparency in score composition and maintaining traceability to individual indicators are therefore central principles of the presented framework.

Our framework aims to realize the vision of a holistic sustainability assessment by introducing a new impact category that incorporates animal welfare into the LCA framework. In doing so, it paves the way for a more comprehensive assessment of sustainability in the livestock sector, where both environmental and social factors are given their due importance. The impact category is explained using a score based on an equivalent, which serves as a means of summarizing the overall results of this category. This score must be classified and interpreted in relation to the other LCA results in order to obtain a holistic sustainability assessment. Once an animal welfare score has been calculated, it is essential to have a methodology in place for evaluating the different categories under consideration and consolidating them into a final score. This approach should encompass all the results and provide a qualitative assessment of their interrelationships. In this sense, the integration of animal welfare into LCA also supports the One Health approach, which emphasizes the interconnection among human, animal, and environmental health [16]. This implementation is in line with van der Werf et al. [11], who emphasized the importance of including social aspects in the LCA of the livestock industry in order to increase the robustness of the assessment.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su17104677/s1, Table S1: Review of animal welfare based on [9,12,17–25,33,40,43,47,50,55–70]. Document S2: AHP execution [40,43,68–70].

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Abbreviations

The following abbreviations are used in this manuscript:

LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
AHP	Analytic Hierarchy Process
MCDA	Multi-Criteria Decision Analysis
CR	Critical Ratio
AFPR	Animal–Feeding Place Ratio
ADPR	Animal–Drinking Place Ratio

Appendix A

Table A1. Assignment of the 15 indicators to the four main criteria with explanations of the indicators' features and their possible measurability.

Main Criterion	Indicator	Explanation	Measurability
Husbandry conditions	Space per animal	Average area per animal per farming section.	easily measurable factor (m^2) the legal standard is specified
	Access to outdoor areas	Presence of an outlet.	easy to measure (presence yes/no) area not decisive
	Floor	Soil conditions per section.	easily measurable factor (type, material) a classification of whether compatibility with the respective development stage of the animals is sought
	Litter	Presence of straw.	easily measurable (presence yes/no) the legal standard for sows enables species-typical behavior
	Employment material	Nature of the material, such as a stationary chain or a loose object. Edibility and accessibility.	easily measurable (type, edibility yes/no) differences in materials legal standard as a minimum assessment
Feed intake	Animal–feeding place ratio (AFPR)	Ratio of usable feeding places to the average number of animals per section of housing.	easily measurable (#:#) at the same time, accessibility is a decisive criterion for inclusion
	Feeding technology	Eating is facilitated by built-in technology.	easily measurable (type, species) ad libitum, liquid, solid, etc. possible evaluation according to the species-appropriateness of the feeding method
	Animal–drinking place ratio (ADPR)	Ratio of usable drinking places to the average number of animals per section of housing.	easily measurable (#:#) at the same time, accessibility is a decisive criterion for inclusion
	Drinking situation	Water absorption is facilitated by installed technology.	easily measurable (type, species) accessibility, cleanliness, species appropriateness

Table A1. *Cont.*

Main Criterion	Indicator	Explanation	Measurability
Operation-specific parameters	Animal losses	This factor should be recorded in a posture section.	easily measurable (%) sow planner fattening pigs, piglets (born alive, <8 kg), piglet rearing (8–30 kg)
	Daily weight gain	This factor is intended to record posture-specific deviations with comparable basic criteria.	easily measurable (weight in kg) define deviations based on feed intake and performance
	Lactation period	This factor is intended to determine the duration of the piglets' intake of the mothers' milk.	easy to measure (duration in weeks)
Single animal observation	Fitness condition	This factor is intended to record the external fitness level of the animals.	difficult to measure (body condition score, subjective) classification from 1 to 5 activity, reactions, weight
	External integrity	This factor is intended to reflect semi-annual monitoring.	difficult to measure (subjective) skin (wounds)
	Lying behavior	This factor should allow conclusions to be drawn about the well-being associated with each section of the husbandry.	difficult to measure (abnormalities, subjective) show clear abnormalities (cluster vs. total isolation)

= Number.

Table A2. Identified indicators for the presented framework and their appearance in the assessed literature.

Main Criteria	Indicators	Bartlett et al. [19]	Bonneau et al. [9]	Dolman et al. [47]	Röös et al. [55]	Ruckli et al. [24]	Scherer et al. [17]	Zira et al. [12]
Husbandry conditions	Space per animal	x				x	x	x
	Floor	x				x		x
	Litter	x				x		x
	Access to outdoor areas	x			x	x	x	x
	Employment material	x	x			x		x
Feed intake	Animal–feeding place ratio	x	x					
	Feeding technology	x	x					
	Animal–drinking place ratio	x	x			x		
	Watering situation	x	x			x		
Operation-specific parameters	Animal losses		x	x		x		x
	Daily weight gain							
	Lactation period					x		
Single animal observation	Fitness condition	x						
	External integrity	x				x		x
	Lying behavior	x						

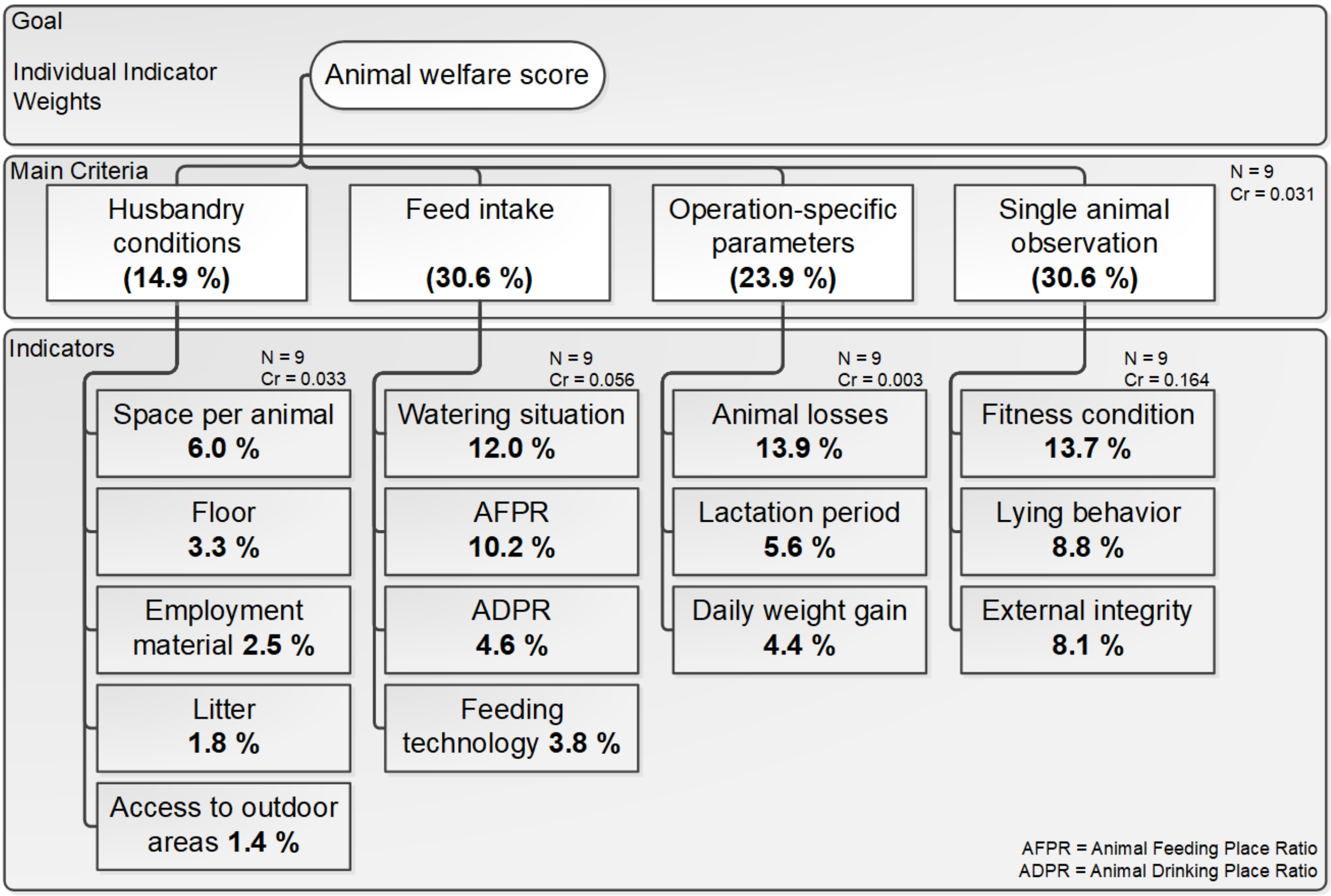

Figure A1. Individual indicator weights derived using the AHP survey.

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