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Abstract: This research identifies suitable indicators and their scale for measuring the sustainability performance of the broiler chicken supply chain, applies the developed measurement system in a specific broiler chicken supply chain, and offers recommendations for improving the sustainability of the broiler chicken supply chain. A total of 15 and 9 indicators were analysed to improve the sustainability performance of the broiler chicken supply chain at the farm and chicken slaughterhouse chain levels, respectively. Analytic hierarchy process was applied to determine the level of importance for the sustainability of each chain (level 1), each dimension (level 2), and each indicator (level 3). The Delphi method was utilised to collect and explain experts' judgements regarding the policies that should be implemented. Measurement results indicate that the total score of the sustainability performance of the broiler chicken supply chain at all levels (small, medium, and large) belongs to the good category.

Keywords: farm chain; chicken slaughterhouse; broiler chicken supply chain; sustainability performance.

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1 Introduction

The huge broiler chicken supply chain in Indonesia involves many actors. Those actors can be differentiated into suppliers of raw materials (vaccines and other drug suppliers, Day Old Chicken (DOC) suppliers- breeders and hatcheries, feed suppliers, and farming equipment suppliers), broiler chicken farmers, collectors or middlemen, slaughterhouses, distributors, traders (traditional market, minimarket, restaurant, and supermarket), and end customers (Oktavera and Andajani, 2013). At the beginning of the chain, breeders and hatcheries produce lots of day-old chickens that are delivered to farms. Once in the farms, day-old chickens are floor-raised on litter (e.g., made from rice hulls) at open structures known as grow-out houses. Chickens are grain-fed, with feed provided by feed suppliers and vaccines from drug suppliers until they reach the targeted weight of the slaughter (around six weeks). Slaughterhouses then collect these mature chickens from farms and turn them into multiple products for wholesalers, which then distribute them to retailers and customers (Solano-Blanco et al., 2020).

In general, broiler chicken farmers in Indonesia consists of individual farmers and multinational corporations. Compared to individual farmers (usually a smallholder), multinational corporation dominates about 80% of broiler chicken farms in Indonesia. These multinational corporations have the technology, resource, and skilled workers; whereas, individual broiler farmers face the problems to acquire day-old chick supply with competitive prices, produce more broiler in their farm, and markets for credit, information, technology are often “missing”, (Patrick, 2004; Jufiardi and Pinagara, 2019).

So, One possible mechanism for improving the smallholders and providing them with the economic benefits is contract farming. This not only has the potential to increase incomes of contracting smallholders but also to have multiplicative effects in the rural and broader economy. Positive evaluations of contract farming generally indicate smallholders either benefit from contracts in terms of enhanced profits or get out of them. There is evidence, however, that contract farming may harm the welfare of smallholders (Patrick, 2004). Eventually, the negative effect of the contract framing can threaten the sustainability of the broiler supply chain. So, to be able to reduce the negative impact of contract farming as well as maintain the sustainability of the broiler chicken supply chain, research is needed to build indicators to measure the level of sustainability which can help policymakers to formulate appropriate policies.

In detail, the explanation about the perspective of the broiler chicken supply chain, the sustainability issues to be solved, and the research approach can be seen in the following sub-section.

1.1 Perspective of broiler chicken supply chain

There are two kinds of farmers, namely, independent farmers and contract farmers, who are also referred to as farmers affiliated with a large company. Independent farmers acquire vaccines and other drugs, DOC, feed, and farming equipment from a spot market. An intermediary, that is, a collector or middleman, operates between independent farmers and traders in a traditional market. The middleman collects broiler chicken from independent farmers and delivers them to traders. Middlemen may sell directly to traditional markets after the chickens are slaughtered in facilities before they are transported to traditional markets (Susanty et al., 2018). Since 1998, most small and medium farms have shifted from independent farming to contract farming systems with large companies; this arrangement is also known as partnership farming or contract broiler farming (Suharno, 2002).

Unlike independent farmers, contract farmers build a relationship with large companies from whom they receive vaccines and other drugs, DOC, feed, and farming equipment from. Contract farmers provide only chicken houses and workers. This partnership scheme aims to support broiler farmers who have limited funds. Once harvest time arrives, the partner farmers give their live broiler chickens to a partner processor or slaughterhouse. Afterwards, the partner processor hands over carcass-shaped chickens to the distributors, who then distribute them to mini-markets, restaurants, and supermarkets (Tatlidil and Aktürk, 2004; Begum, 2005a, 2005b; Goodwin et al., 2005; Simmons et al., 2005). The contract farming system helps the farmers to get more secured input in terms of quantity and quality, access credit facilities, increase their income, learn new skills, obtain technical advice (especially when their large partner companies introduce new technology), reduce the price risk as stated in the contract, and obtain market guarantees (Hedge and Vukina, 2003; Putri and Rondhi, 2020; Nguyen et al., 2011; Barrett et al., 2012; Kumar and Kumar, 2008).

1.2 Sustainability issues to be solved

Despite the advantages of contract farming systems, some social and economic problems exist between farmers and large companies along the broiler chicken supply chain (Singh, 2002; Begum, 2005b; D'Silva et al., 2009; Bengtsson and Seddon, 2013; González-

García et al., 2014; Barrett et al., 2012; Nguyen et al., 2011, Skunca et al., 2018; Tsolakis et al., 2018). Singh (2002) identified some problems related to contract farming systems that can influence the relationship between farmers and large companies. Several problems arise from difficulties in coordinating the production. Moreover, according to Singh (2002), the contract farming system can cause social problems, such as the loss of a farmer's independent status, violation of the terms of agreements, and an imbalance of power between an economically powerful company and the economically weak farmers. Contract broiler farming has been criticised as a business that exploits broiler farmers (Thamizh and Rao, 2009; Nurtini et al., 2017). Eaton and Shepherd (2001) also mentioned that contract farming is more beneficial for the company because it offers a supply of cheap workers (the farmers) and transfers the farming risk to them. In this case, the price of inputs (DOC, feeds, medicines, and vitamins) and output (broiler) is often determined by large companies without transparency. Sometimes, farmers believe that contracts are disadvantageous for them, but they do not have any bargaining power against the partner company. Given the disadvantageous contract, the farmers are unable to apply the proper technology to their farms. As a result, a company suffers losses because the farms become unqualified for broiler chicken production. Conversely, this condition can also cause losses to farmers because they receive a low price. This issue is one of the economic problems of the contract farming system. Based on this condition, the question remains as to whether the contract farming indeed improves the welfare of the farming communities; although some researchers have been proof that the contract farming farmers can get more income than the independent farmers (Wainaina et al., 2012). The research conducted by Putri and Ronny (2020) indicated that some contract farmers in Surakarta can lose as much as 12.5%, if all the production costs are calculated, including worker, chicken house rent, equipment depreciation, water, and electricity, although on the average is profitable. The farmers experience losses, especially those who have a large feed conversion ratio (FCR) deviation compared to the standard. In the long-term, this condition can threaten the sustainability of the relationship between farmers and large companies, and on a broader scale, the broiler chicken supply chain.

The long term sustainability of broiler chicken supply chain are not only threatened by social and economic problems. Environmental issues are increasingly important due to the use of resources (such as energy and water) to intensify broiler meat production. Common environmental problems in the poultry sector include water consumption, energy consumption, feed production, chemical and packaging material usage, wastewater discharge, and waste treatment (Bengtsson and Seddon, 2013; González-García et al., 2014). Livestock buildings and poultry facilities consume energy, given that internal climate adjustment (heating, cooling, ventilation, lighting, and humidity control) and operating production equipment (feeding, sanitation, and egg production) require energy (Baxevanou et al., 2017). Moreover, the manure of animals, carcasses, feathers, and bedding/litter in poultry farms becomes pollutants or emits an odour, thereby affecting the people living in the vicinity of the farms (Kolominskas et al., 2002; Ferket et al., 2002). Odour is a local issue whose impact greatly depends on the subjective perception of a farm's neighbours. Although they generally do not cause any public health concerns, odours can be a strong local problem that is frequently reported by farms' neighbours and thus have a disturbing environmental impact (Gerber et al., 2007). Slaughterhouses have worse sustainability performance than broiler farms

because water is used carelessly in these facilities due to their strict cleaning demands (Berghout et al., 2018).

1.3 Research approach

In short, the problems in broiler chicken supply chain include: social (such as loss of a farmer's independence status), economic (such as a low price received by the farmers), and environmental (such as water and energy consumption and water treatment). They present a huge challenge to sustainable development. To assess the level of sustainability of the broiler chicken supply chain, this research develops a measurement system for assessing the sustainability performance of broiler supply chains. Suitable indicators and their scale for examining sustainability performance of the broiler chicken supply chain will be identified.. Furthermore, this research applies the developed measurement system to a specific broiler chicken supply chain and provides recommendations for improving its sustainability.

According to its purposes, this research considers both sustainability and supply chain issues to incorporate them in the context of the broiler chicken supply chain in Indonesia. This research is part of study on sustainable supply chain management (SSCM). Although the study on SSCM has been of great interest for the last decade in academia and among the practitioners (Hassini et al., 2012), the research on SSCM is still at the development stage (Olga, 2012). Many approaches, such as balanced scorecard (BSC) and its modifications, life cycle assessment (LCA) and its modifications, and fuzzy set approaches, have been proposed as measurement tools for assessing the sustainability of supply chains, including the food supply chain. However, these approaches have been criticised because they do not take all three sustainability aspects (environmental, economic, and social) into consideration and do not incorporate all supply chain members (Ahi and Searcy, 2015; Hassini et al., 2012). Hence, there is a need for more research on developing an appropriate framework for sustainability performance measurements in supply chains based on three different aspects as well as developing suitable indicators and their scale for assessing the sustainability performance of broiler supply chains. This research will contribute to the SSCM literature in terms of a framework for sustainability performance measurement and will extend the methods and tools to determine the current state of sustainability of an entity concerning three sustainability categories. Knowing the current condition of the indicators may assist the broiler chicken supply chain in moving its sustainable performance forward.

The measurement system for assessing the sustainability performance of broiler supply chains will be tested to farmers and slaughterhouses affiliated with PT Ciomas Adisatwa located in several districts in Central Java Province. This company is a subsidiary of PT Japfa Comfeed, which is one of the two biggest companies in poultry production; the other is PT Charoen Pokphand Indonesia. In 2015, PT Charoen Pokphand Indonesia retained 34% market share in the production of poultry feed and 38% market share in DOC production, whereas PT Japfa Comfeed retained 25% market share in the production of poultry feed and 2% market share in DOC production (Partners, 2017). Central Java Province has the third-largest broiler chicken production in Indonesia after West Java and East Java. The average population of broiler chickens in 2014 to 2018 was 646,568,863 in West Java, 205,558,897 in East Java, and 155,270,554 tails in Central

Java (Central Statistics Agency, 2019). Although Central Java has the third-largest broiler chicken production, interviews with a representative from the Central Java Animal Husbandry and Animal Health Service indicated that this province also faced quite serious problems from 2014 to 2019 in contract farming. During that period, many farmers who affiliated with the large partner companies went bankrupt because their income was not able to cover production costs and capital.

This paper is organised as follows. Following the introduction, Section 2 continues with literature review about the poultry industry and broiler chicken in Indonesia, the measurement for the sustainability of supply chains, and the analytical hierarchy process. Next, the methodology applied in the study is presented in Section 3, followed by the results and discussion in Section 4. Section 5 consists of a conclusion, the implication and limitation of the result as well as future research.

2 Literature review

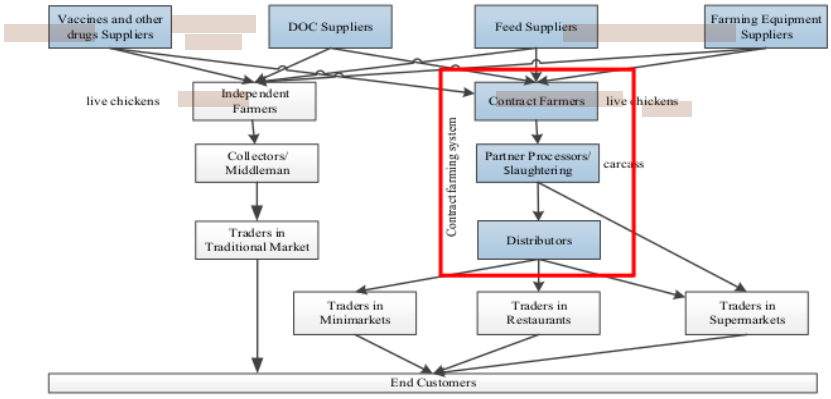
2.1 Poultry industry and broiler chicken in Indone1sia

The poultry industry sector plays an important role in the Indonesian economy. According to the Indonesian Feed Producers Association, this sector provides jobs for 12 million people and has an estimated value of more than 34 billion USD. Furthermore, this sector can supply 65% of Indonesia's animal protein (Wright and Darmawan, 2017). In 2015, five companies had a significant market share in poultry feed production in Indonesia: Charoen Pokphand Indonesia (34%), Japfa Comfeed (25%), Malindo Feedmill (8%), Sierad Produce (5%), CheilJedang (7%), and others (21%). Five companies also had a significant market share in DOC production: Charon Pokhand Indonesia (38%), Japfa Comfeed (22%), Wonokoyo Jaya Corporindo (8%), Malindo Feedmill (7%), Sierad Produce (3%), and others (22%). This finding shows that the Indonesian market is dominated by foreign players (Alonzo, 2016); Charoen Pokhand Indonesia belongs to a Thai group, Malindo is the name for a local operator of the Malaysian-based Leong Hup, and Cheijeang is a Korean corporation that belonged to Samsung until the 1990s (Ferlito, 2018).

Poultry products include native chicken, layer, broiler, duck, and Muscovy duck. Native chickens are specifically used for joint production of meat and eggs. Layers are chicken hens (females) bred to produce table eggs (Ferlito, 2018). Broilers or broiler chickens are the largest part of the poultry population. They were first introduced in Indonesia in the mid-1970s, and new data have been available in official documents since 1984. Broiler chicken farming is generally a commercial business that serves as a specialised and main source of income for particular farmers. Presently, broiler chicken farming is dominated by large companies (Fitriani et al., 2014). An overview of a broiler chicken supply chain in Indonesia is presented in Figure 1. The actors of the broiler chicken supply chain in Indonesia can be differentiated into suppliers of raw materials (vaccines and other drug suppliers, DOC suppliers, feed suppliers, and farming equipment suppliers), independent farmers, contract farmers, collectors or middlemen, partner processors or slaughterhouses, distributors, traders (traditional market, mini-market, restaurant, and supermarket), and end customers (Oktavera and Andajani, 2013).

Since the mid-1970s, the broiler chicken business has grown rapidly. The population of broiler chickens increased at a rate of 35.61% per year between 1980 and 1989. During the 1997–1998 economic crisis, broiler meat production suffered from heavy cuts because of general macroeconomic difficulties experienced by several Asian countries (Saptana and Rusastra, 2001). As the country recovered from this crisis in 1999, production grew rapidly before it slowed down and then stabilised after 2012 (Ferlito, 2018).

Figure 1 Broiler chicken supply chain in Indonesia (see online version for colours)



Source: Oktavera and Andajani (2013)

2.2 *Measurement for the sustainability of supply chains*

A plethora of SCM definitions have been developed in recent years. Evidence also exists of differences between the emphasis and approach of practitioners depending on their functional backgrounds, level of seniority, business sector, and geographical location (Sweeney et al., 2015). According to Leenders and Fearon (2004) and Ambe (2010), supply chain management can be defined as the systemic approach to managing the entire flow of information, materials, and services from raw material suppliers through factories and warehouses to the end customer. Various definitions related to sustainability have also been developed. Berns et al. (2009) claimed that no single established definition for sustainability is available, whereas Johnston et al. (2007) estimated that around 300 definitions of sustainability exist. The Brundtland World Commission report in 1987 presented the most familiar definition of sustainability, stating that sustainability is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (Thomsen, 2013). Sustainability commonly refers to environmental, social, and economic sustainability (Giddings et al., 2002). Barton (2000) and Du Plessis (2000) presented the interconnection among the environmental, social, and economic sectors as sustainable development; in this case, these sectors must have a reasonable level of balance of interactions if the world is to achieve sustainable development. The concept of SSCM was developed on the basis of

the concept of supply chain and sustainable development. SCM is the management of material, information, and capital flow along the supply chain while taking dimensions of sustainable development–that is, economic, social, and environmental–into consideration with final consumers' and stakeholders' requirements (Seuring and Muller, 2008b). In line with Seuring and Muller (2008b), according to Bowen et al., 2001, Farahani et al., 2009, and Peters, 2010, SSCM can be defined as the process of managing supply chain management activities related to environmental, economic, and social problems to improve the long-term economic goals of individual organisations and their supply chains. This three-dimensional concept is also known as the triple bottom line, which refers to decreasing harmful ecological impacts, increasing positive social impacts, and achieving economic sustainability (Saeed and Kersten, 2019). The goal of SSCM is to minimise the supply chain cost or maximise supply chain profits while avoiding adverse effects on the environment and society. Simply put, SSCM enriches the traditional SCM because it considers social and environmental impacts.

Different approaches and levels (regional, industrial, and firm level) have been used as measurement tools for assessing the sustainability of supply chains. These approaches include LCA and its modifications (Andersson, 2000; Nagelaar and van der Vorst, 2001; Arcese et al., 2017; Cucchiella et al., 2014; Wang et al., 2016), farm economic costing (Pretty et al., 2005), food miles (Garnett, 2003), energy accounting in the product life cycle (Dutilh and Kramer, 2000; Carlsson-Kanyama et al., 2003), material flow and energy use of food products (Faist et al., 2001), economically extended material flow analysis (Kytzia et al., 2004), ecological footprints (Gerbens-Leenes et al., 2002; Collins and Fairchild, 2007), mass balance of food sectors (Linstead and Ekins, 2001), sustainability indicators (Yakovleva et al., 2007; Turi et al., 2010), BSC and its modifications (Shafiee et al., 2014; Thanki and Thakkar, 2018), data envelopment analysis (Mirhedayatian et al., 2014), supply chain operations reference model (Bai et al., 2012; Taticchi et al., 2015), and AHP/analytic network process (Agrawal et al., 2016; Büyüközkan and Çifçi, 2012).

Singh et al. (2009) differentiated all measurement tools for assessing sustainability into three types. The first type is a product-related measurement tool, which can be used to identify risks and inefficiencies, such as the use of LCA and its modification, in relation to the material and energy flow of a product or service. The second type is the integrated assessment tool, which can be applied to implement policies or projects through conceptual modelling, multicriterion analysis, risk and uncertainty analysis, or cost–benefit analysis. The third type includes indicators and indices; indicators are used to determine the current state of an entity (organisation, country, etc.) with respect to some sustainability categories, and indices are the result of the standardisation, weighting, and aggregation of the indicators into a single measure or index. The third type of measurement tool is better than the other two because it can consider three sustainability aspects (Hassini et al., 2012; Seuring, 2013) and incorporate several supply chains (Ahi and Searcy, 2015). Table 1 summarises the indicators of supply chain performance on the basis of the environmental, economic, and social dimensions of food, poultry, and broiler supply chain from some authors.

Table 1 Authors, object of the research, and developed indicators of food supply chain and general use

No	*Authors (object of research)*	*Environmental*	*Economic*	*Social*
1	Veleva and Ellenbecker (2001) (general)	• Material used (total [kg] and kg per unit of product) • Energy used (total [kWh] and kWh per unit of product) • Energy from renewables (%) • Tons of CO_2 equivalent • Fresh water consumption (l) • Waste generated before recycling (emissions and solid and liquid waste)	• Costs associated with noncompliance • Rate of employees' suggested improvement in quality, social, and environment, health, and safety performance	• Number of community–company partnerships • Number of employees per unit of product or per dollar sold • Lost w[illegible]days due to injury and illness case rate • Turnover rate or average length of the service of employee (years) • Average hours of employee training per year • Rate of defective products (%) • Rate of customer complaints and returns (number per product sold) • Percentage of products designed for disassembly, reuse, recycling • Percentage of biodegradable packaging
2	Yakovleva et al. (2007) (chicken and potato supply chain)	• Purchase of energy for own consumption per enterprise • Purchase of water for own consumption per enterprise • Cost of sewage and waste disposal per enterprise	• Gross value added per workforce • [illegible] of large enterprises (%) • Import dependency (%)	• Number of employees per enterprise • Average wages per person per year • Female vs. male employment (%)

Table 1 Authors, object of the research, and developed indicators of food supply chain and general use (continued)

No	*Authors (object of research)*	*Environmental*	*Economic*	*Social*
3	Turi et al. (2014) (food supply chain)	• Energy use per unit of production • CO_2 emissions per unit of production • Transport costs per unit of production • Reverse logistics (reduce, reuse, recycle)	• Number of improvement suggestions submitted by employees	• Management levels with specific environmental responsibilities • Number of employees trained/to be trained • Perfect order delivery (percentage) • Product life remaining (percentage) • Number of 'green' products
4	Vaarst et al. (2015) (poultry production)	• Land size • Water use • Pollution and waste management	• Consumption pattern and demand for poultry product • Price of poultry product	• Working conditions and health of individuals (owners or workers) • Fairness of employment contracts • Gender balance • Animal welfare
5	Tan et al. (2015) (general)	• Packaging material reused (kg/unit) • Materials saved from implemented initiatives (kg/kg) • Total energy used (kWh and kWh/unit) • Energy generated by products (kWh)	• Material cost • Energy cost • Cost saved • Operational and capital cost • Net profit margin • Environmental fines and penalties • Innovation and R/D investments • Return on investment • Employee environmental suggestions	• Sustainability reports (number) • Environmentally certified service providers (%) • Sustainability initiatives (number) • Achieved objectives (%) • Labour costs, lost work days • Employee attrition (turnover) rate • Personal protective and safety equipment provision (%)

Table 1 Authors, object of the research, and developed indicators of food supply chain and general use (continued)

No	*Authors (object of research)*	*Environmental*	*Economic*	*Social*
5	Tan et al. (2015) (general)			• Line stops due to safety concerns (%) • Labour productivity • Average hours of sustainability training • Employee training in sustainability (%) • Rate of defective products (%) • Customer complaints (number)
6	Tsolakis et al. (2018) (food supply chain)	*Farming* • Consumption of water Consumption of energy • Ecoproduction practices • Waste management *Processing* • Packaging (materials, quantity) • Consumption of water • Consumption of energy • Waste management	*Farming* • Farm income • Investments *Processing* • Cost of production, material and labour) • Traceability *Retailing* • Utilisation orders, administration cost • Sales	*Farming* • Certification • Farmers' training • Exclusive supplier *Processing* • Staff training • Food safety • Certification *Retailing* • Food safety charity • Traceability • Ethical trading

Table 1 Authors, object of the research, and developed indicators of food supply chain and general use (continued)

No	*Authors (object of research)*	*Environmental*	*Economic*	*Social*
6	Tsolakis et al. (2018) (food supply chain)	*Retailing* • Inventory cycles, inventory management • Defective orders, waste management • Consumption of energy Satisfaction levels (backorders, delays)		
7	Saeed and Kersten (2017) (general)	• Energy efficiency • Material efficiency • Water management • Waste management • Emissions • Land use • Environmental compliance • Supplier assessment	• Social and profitability • Income distribution • Market competitiveness • Sustainability expenditures	• Human rights and anticorruption • Human resources • Health and safety • Training and education • Customer issues • Social compliance

Table 1 indicated that there is no universal consensus or widely accepted sustainable indicators. However, most of the environmental sustainability dimension has indicators related to the input such as consumption of energy, water, material, etc. and the output such as waste, emissions. Similarly, most of the, most of the economic sustainability dimension has indicators related to profitability and income or welfare distribution. Most of the social sustainability related to human rights, human resources, health and safety, and training and education. Given the absence of a consensus on the indicator for measuring sustainability, 17 and 15 initial indicators were chosen for sustainability measurement at the farm and chicken slaughterhouse chain levels, respectively. This selection is based on the most frequently used indicators (such as consumption of energy and water), easily understood by the farmers and management representative of chicken slaughterhouse, quantifiable or can be numerically measured (although it's a qualitative indicators), and the relevant data were available for examining the condition of this indicator. The number of initial indicators was then reduced to 15 and 9 for sustainability

measurement at the farm and chicken slaughterhouse chain levels to accommodate the content validation result.

2.3 AHP

AHP was originally developed by Saaty (1977, 1990, 1995) and is used for multiple-criteria decision-making (MCDM) in uncertain situations. AHP is among the most widely used decision-making approaches in the world today (Singh et al., 2012). Other MCDM methods are technique for order of preference by similarity to ideal solution, simple additive weighting, and preference ranking organisation method for enrichment of evaluations (Tscheikner-Gratl et al., 2017). In the present research, AHP was chosen to assess the relative importance of each chain, dimension (level 2 – environmental, economic, and social), and indicator (level 3). This method was chosen instead of other MCDM methods because it can describe the chain, the three dimensions of sustainability, and its indicators in a hierarchical manner and as a mixture of the quantitative and qualitative indicators proposed by this research. Moreover, this method can translate the opinions of experts into a priority weight for each indicator. In line with this research, AHP was used to assess the relative importance of the indicators of three dimensions of sustainability by many previous authors, such as Yakovieva et al. (2009) for food supply chain, Kara and Köne (2012) for regional environment, Li et al. (2008) and Poveda and Lipsett (2013) for a mining operation, Kumar et al. (2015) for public transportation systems, Anand et al. (2017) for a smart city, Mohammadi and Limaei (2018) for Iranian Caspian forests, Nordin et al. (2018) for a halal warehouse, Ocampo et al. (2015) and Soltani et al. (2019) for manufacturing systems, Ameen and Mourshed (2019) for the urban system, and Arukala et al. (2019) for the construction industry.

AHP primarily comprises several steps (Singh et al., 2012; Sharma and Bhat, 2012; Kumar et al., 2013, 2015; Arukala et al., 2019).

- First, the preliminary problem is discussed to obtain an enriched, conceptual view of the problem and define its objective.
- Second, the hierarchy is structured from the top (the objectives) to the intermediate levels (criteria) to the lowest level (indicators/alternatives).
- Third, a set of pairwise comparison matrices (size $n \times n$) are constructed for each of the lower levels with one matrix for each element in the level immediately above by using Saaty's 9-point scale ranging from 1, which denotes equal importance between elements i and j, to 9, which indicates the absolute importance of element i compared with element j; values of 2, 4, 6, and 8 indicate intermediate values between two adjacent judgements. Then, to conduct pairwise comparison, a questionnaire is designed and distributed among respondents (such as managers, experts, users, etc.). In this case, when activity i compared with j is assigned one of the above numbers, then activity j compared with i is assigned its reciprocal. Moreover, the pairwise comparisons are conducted in terms of preference of one element over the other. $n(n-1)/2$ judgements are required per matrix to develop the set of matrices in step 3; reciprocals are automatically assigned in each pairwise comparison.

- Fourth, after a pairwise comparison matrix is obtained, the next step is to obtain the value of the normalised matrix. The normalised matrix can be obtained by dividing each entry in the column by the sum of entries in a column in the pairwise comparison matrix. The normalised value r_{ij} is calculated by equation (1).

$$r_{ij} = \frac{a_{ij}}{a}, \text{ where } a = \sum_{i=1}^{n} a_{ij} \quad (1)$$

The approximate priority weight (W_1, W_2, …, W_j) for each indicator is obtained by equation (2).

$$W_j = \frac{1}{n} X \sum_{i=1}^{n} a_{ij} \quad (2)$$

- Fifth, consistency index (CI) and consistency ratio (CR) are calculated by using equations (3) and (4), respectively. CR represents judgement consistency

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \quad (3)$$

$$CR = \frac{CI}{RI} \quad (4)$$

where n represents the matrix size, λ_{max} represents the maximum eigenvalue, and RI represents the random index value (the value of RI depends on the size of the matrix). The comparison is acceptable if the CR value less than or equal to 0.10. In some cases, a maximum value of 0.20 may be tolerated. If the CR value is not within this range, then the respondents should study the problem again and revise their judgement (Singh et al., 2012)

- Sixth, the local priority weight of each indicator is transformed into a global priority weight by multiplying local priorities of the indicators by the global priority of their corresponding dimension.

3 Method of the research

3.1 Study area and sample of research

The research object is the broiler chicken supply chain in Central Java Province. The sample of this research comprises 1 chicken slaughterhouse and 30 farmers located in Semarang, Demak, Kudus, Pati, and Rembang District. Among the 30 farmers, 2 were small-scale contract farmers with broiler chickens between 2000 and 5000, 8 were medium-scale contract farmers with broiler chickens between 6000 and 10,000, and 20 were large-scale partner farmers with more than 10,000 broiler chickens.

This research applied nonprobability purposive sampling to select the broiler chicken farmers and the chicken slaughterhouse. Hence, this selection was based on certain characteristics. Broiler chicken farmers who have been affiliated with PT Ciomas Adisatwa for at least a year were chosen. The chicken slaughterhouses of the selected farmers were also included. This research also conducted nonprobability purposive

sampling to choose respondents who filled out the AHP and Delphi questionnaire. These respondents should have sufficient knowledge and experiences regarding the conditions of the broiler chicken supply chain. Three types of respondents were asked to fill out the AHP and Delphi questionnaire; they were the section heads of Veterinary Public Health, a field instructor, and representatives of contract farmers who have been working as breeders for at least 3 years and have extensive knowledge of broiler farming management.

3.2 Measurement indicators and scale

The number of indicators for measuring the sustainability of the broiler chicken supply chain at the farm and chicken slaughterhouse levels was reduced from 17 and 9 to 15 and 9, accommodating the content validation result. In this case, a panel of experts who are familiar with the indicators for measuring the sustainability of the broiler chicken supply chain at the farm and chicken slaughterhouse levels was asked to fill out the validation questionnaire. This questionnaire uses a four-point Likert scale (1 = not relevant, 2 = somewhat relevant, 3 = relevant, 4 = very relevant). The panel should determine whether the indicators are relevant for measuring a certain dimension, whether the indicators are relevant for determining the domain of interest, and whether the indicators are relevant for field conditions. Then, the content validity index (CVI) was used to evaluate the validity of the indicators (Lynn, 1996). The CVI value for each indicator was computed as the number of experts giving a rating of either 3 or 4 for that indicator divided by the number of experts, i.e., the proportion in agreement about relevance. For example, an item rated as 'relevant' or 'very relevant' by four out of five judges would have a CVI value of 0.80. Lynn (1986) provided widely cited guidelines for what an acceptable CVI value should be concerning the number of experts. She advocated that with five or fewer experts, the CVI must be 1.00, that is, all experts must agree that the item is content valid.

The calculation results of the CVI for each indicator can be seen in Tables 2 and 3. This research retained only indicators with a CVI value equal to 1 because the validation process uses only three experts. The indicators "average amount of water consumed for one chicken (LF2)" and "frequency of services and material guidance provided by the company to farmers in 1 month (SF5)" had a CVI value of less than 1 (CVI value equal to 0) and were thus deleted from the listed indicators of broiler chicken supply chain at the farm chain. Table 3 shows that all indicators listed in the broiler chicken supply chain at the slaughterhouse level had a CVI equal to 1, which means that none of the indicators listed at the slaughterhouse level should be deleted.

After the content validation process, 15 indicators were used to assess the sustainability of the farm chain, and 9 indicators were utilised to examine the sustainability of the chicken slaughterhouse chain. In the farm chain, the environmental dimension consisted of 1 indicator, the social dimension consisted of 10 indicators, and the economic dimension consisted of 4 indicators. In the chicken slaughterhouse chain, the environmental dimension consisted of 3 indicators, the social dimension consisted of 2 indicators, and the economic dimension consisted of 4 indicators. The proposed indicators that were utilised to examine the sustainability of broiler chickens at both chains were developed following some indicators developed by Veleva and Ellenbecker (2001), Yakovleva (2007), Tan et al. (2015), Saeed and Kersten (2017), and Tsolakis et al. (2018). They were also developed following some indicators developed by the

Minister of Agriculture Regulation No. 13 of 2017 and Law No. 33 of 2014 concerning Halal Product Assurance.

Table 2 Final indicators at the farm chain as the result of the content validation process

No	Indicators	Experts			Number of experts giving a rating of either 3 or 4	CVI
		E1	E2	E3		
Environmental (Yakovleva, 2007; Tsolakis et al., 2018; Saeed and Kersten, 2017)						
1	Average amount of energy consumed for one chicken (LF1)	4	3	4	3	1.00
2	Average amount of water consumed for one chicken (LF2)	2	2	1	0	0.00
Social – (related to partnership in the contract farming system–the farmers and core company; Veleva and Ellenbecker, 2007; Minister of Agriculture Regulation No. 13/2017)						
1	Quality of DOCs supplied by large companies to farmers (SF1)	4	4	4	3	1.00
2	Quality of drugs and vaccines supplied by large companies to farmers (SF2)	4	3	4	3	1.00
3	DOC delivery schedule (SF3)	4	4	3	3	1.00
4	Frequency of technical guidance provided by the company to farmers in one month (SF4)	4	3	4	3	1.00
5	Frequency of services and material guidance provided by the company to farmers in one month (SF5)	2	2	2	0	0.00
6	Conformity between harvest time and contract agreement (SF6)	4	3	4	3	1.00
7	Speed of the response given by the company to the complaints of contract farmers (SF7)	4	4	4	3	1.00
8	Match between selling price and contract agreement (SF8)	4	3	4	3	1.00
9	Match the amount of bonuses as stated in the contract (SF9)	4	4	3	3	1.00
10	Match between the time of payment to the farmer at harvest time with the contract agreement (SF10)	4	3	4	3	1.00
11	Accountability during crop failure (SF11)	4	3	4	3	1.00
Economic (Tsolakis et al., 2018; Saeed and Kersten, 2017; Tan et al., 2015)						
1	Average income earned by farmers for one chicken in one harvest (EF1)	4	3	4	3	1.00
2	Average price of one DOC (EF2)	4	4	4	3	1.00
3	Average feed price for one chicken in one harvest period (EF3)	4	4	4	3	1.00
4	Average price of drugs and vaccines for one chicken in one harvest period (EF4)	4	3	4	3	1.00

E = expert.

Table 3 Final indicators at the slaughterhouse chain as the result of content validation

No	*Indicators*	*Experts*			*The number of experts giving a rating of either 3 or 4*	*The value of CVI*
		E1	*E2*	*E3*		
	Environmental (Yakovleva, 2007; Tsolakis et al., 2018; Saeed and Kersten, 2017; Tan et al., 2015; Turi et al., 2014)					
1	Average amount of water consumed to slaughter one chicken (LS1)	4	3	4	3	1.00
2	Average amount of energy consumed to slaughter one chicken (LS2)	4	4	4	3	1.00
3	Percentage of waste that can be reused and recycled (LS3)	3	4	4	3	1.00
	Social (Yakovleva, 2007; Saeed and Kersten, 2017; Laws of the Republic of Indonesia No. 33/2014 about Halal Product Assurance)					
1	Comparison of male and female workers (SS1)	3	4	4	3	1.00
2	Chicken slaughterhouse already has halal certification from MUI (SS2)	4	4	4	3	1.00
	Economic (Tsolakis et al., 2018; Saeed and Kersten, 2017)					
1	Average of net income per month (ES1)	4	4	4	3	1.00
2	Labour cost per month (ES2)	4	4	4	3	1.00
3	Administration cost per year (ES3)	3	4	4	3	1.00
4	Distribution cost per month (ES4)	4	4	4	3	1.00

E = expert.

Each indicator for measuring the sustainability of farm and chicken slaughterhouse chains applies a five-point Likert scale. Although a higher score indicates a better condition (1 = the worst condition and 5 = the best condition), the five-point Likert scale has a different meaning depending on the condition asked for each indicator. For example, the meaning of values 1–5 for the question related to "the average amount of energy consumed for one chicken" can be explained as follows: 1 = the average amount of energy consumed for one chicken is IDR 526.30 or more; 2 = the average amount of energy consumed for one chicken is more than IDR 355.63 to IDR 526.30; 3 = the average amount of energy consumed for one chicken is more than IDR 184.96 to 355.63; 4 = the average amount of energy consumed for one chicken is more than IDR 14.29 to IDR 184.96; and 5 = the average amount of energy consumed for one chicken is no more than 14.29. The indicators and their scale for farms and chicken slaughterhouses are listed in detail in Tables 4 and 5, respectively. The source of the scale development for each indicator is the result of an observation and a short interview with the contract farmers, the representative of PT Ciomas, and the representative of the chicken slaughterhouse. The scale for each indicator is developed in accordance with previous studies (Yakovleva, 2007; Barana et al., 2014; Bueno et al., 2015).

Table 4 List of indicators and their scale for the farm chains

No	Indicators	Scale				
		1	*2*	*3*	*4*	*5*
	Environmental (Yakovleva, 2007; Tsolakis et al., 2018; Saeed and Kersten, 2017)					
1	Average amount of energy consumed for one chicken (LF1)	$X >$ IDR 526.30	IDR 355.63 < $X \leq$ IDR 526.30	IDR 184.96 < $X \leq$ IDR 355.83	IDR 14.29 < $X \leq$ IDR 184.96	$X \leq$ IDR 14.29
	Social (related to partnership in the contract farming system–the farmers and core company; Veleva and Ellenbecker, 2007; Minister of Agriculture Regulation No. 13/2017)					
2	Quality of DOCs supplied by large companies to farmers (SF1)	Very bad (DOC weighs less than 27 g; DOC is inactive (weak); DOC has no desire to eat)	Bad (DOC weighs less than 27 g; DOC is slightly active; DOC has a low desire to eat)	Adequate (DOC weighs as much as 27 g; DOC active; DOC has enough desire to eat)	Good (DOC weighs more than 27 g; DOC active; DOC has a good desire to eat)	Very good (DOC weighs more than 27 g; DOC is very active; DOC has a good desire to eat and is very stable; does not sleep much)
3	Quality of drugs and vaccines supplied by large companies to farmers (SF2)	Very bad (drugs and vaccines cannot cure sick chickens)	Bad (drugs and vaccines can cure sick chickens, but the time needed for healing is more than 72 h)	Adequate (drugs and vaccines can cure sick chickens, but the time needed for healing is between 48 and 72 h)	Good (drugs and vaccines can cure sick chickens, but the time needed for healing is between 24 and 48 h)	Very good (drugs and vaccines can cure sick chickens, but the time needed for healing is no more than 24 h)
4	DOC delivery schedule (SF3)	More than 48 h	Between 24 and 48 h	Between 12 and 24 h	No more than 12 h	On schedule
5	Frequency of technical guidance provided by the company to farmers in one month (SF4)	Once a month	Twice a month	Thrice a month	Four times a month	Five times a month
6	Conformity between harvest time and contract agreement (SF6)	More than 48 h	Between 24 and 48 h	Between 12 and 24 h	No more than 12 h	On schedule
7	Speed of the company's response to the complaints of contract farmers (SF7)	Very late response (a reply was given several days later)	Late response (a reply was given after 2 h)	Adequate response (a reply was given in 1–2 h)	Quick response (a reply was given in no more than 1 h)	Quick response (a reply was given immediately)

Table 4 List of indicators and their scale for the farm chains (continued)

No	*Indicators*	*Scale*				
		1	*2*	*3*	*4*	*5*
Social (related to partnership in the contract farming system–the farmers and core company; Veleva and Ellenbecker, 2007; Minister of Agriculture Regulation No. 13/2017)						
8	Match between selling price and contract agreement (SF8)	Very inappropriate (the actual selling price is lower by IDR 10 per kg or more compared with the contract)	Inappropriate (the actual selling price is lower by more than IDR 1 per kg up to IDR 10 per kg compared with the contract)	Adequate (the actual selling price is lower by IDR 1 per kg or less compared with the contract)	Appropriate (the actual selling price is the same as the selling price stated on the contract)	Very appropriate (the actual selling price is higher than the selling price stated on the contract)
9	Match the amount of bonuses as stated in the contract (SF9)	The amount of the bonus is higher by as much as less than 15% compared with the contract provisions	The amount of the bonus is higher by as much as 15% to less than 20% compared with the contract provisions	The amount of the bonus is higher by as much as 20% to less than 25% compared with the contract provisions	The amount of the bonus is higher by as much as 25% to less than 30% compared with the contract provisions	The amount of the bonus is higher by as much as more than 30% compared with the contract provisions
10	Match between the time of payment to the farmer at harvest time with the contract agreement (SF10)	Time of payment realisation is very long, more than 14 days compared with the contract provisions	Time of payment realisation is long, 10 days to less than 14 days compared with the contract provisions	Time of payment realisation is appropriate, 7 days to less than 10 days compared with the contract provisions	Time of payment realisation is quick, 3 days to less than 7 days compared with the contract provisions	Time of payment realisation is very quick, less than 3 days compared with the contract provisions
11	Accountability during crop failure (SF11)	Very dissatisfied; no assistance was provided by core company	Not satisfied; the company provided assistance of IDR 100 per chicken or less	Quite satisfied; the company provides assistance between IDR 100 per chicken and less than IDR 200 per chicken	Satisfied; the company provides assistance between IDR 200 per chicken and less than IDR 300 per chicken	Very satisfied; the company provides assistance of more than IDR 300 per chicken

Table 4 List of indicators and their scale for the farm chains (continued)

No	Indicators	Scale				
		1	*2*	*3*	*4*	*5*
Economic (Tsolakis et al., 2018; Saeed and Kersten, 2017; Tan et al., 2015)						
12	Average income earned by farmers for one chicken in one harvest (EF1)	Less than IDR 2000	IDR 2000 to less than IDR 3000	IDR 3000 less than IDR 4000	IDR 4000 to less than IDR 5000	At least IDR 5000
13	Average price of one DOC (EF2)	At least IDR 8000	IDR 7500 to less than IDR 8000	IDR 7500	IDR 7000 to less than IDR 7500	Less than IDR 7000
14	Average feed price for one chicken in one harvest period (EF3)	At least IDR 30000	IDR 23500 to less than IDR 30000	IDR 20250 to less than IDR 23500	IDR 17000 to less than IDR 20250	Less than IDR 17000
15	Average price of drugs and vaccines for one chicken in one harvest period (EF4)	At least IDR 625	IDR 357.96 to less than IDR 625	IDR 224.43 to less than IDR 357.96	IDR 90.91 to less than IDR 224.43	Less than IDR 90.91

Source of scale: interview with contract farmers

Table 5 List of indicators and the scale for the chicken slaughterhouse chain

No	Indicators	Scale				
		1	*2*	*3*	*4*	*5*
Environmental (Yakovleva, 2007; Tsolakis et al., 2018; Saeed and Kersten, 2017; Tan et al., 2015; Turi et al., 2014)						
1	Average amount of water consumed to slaughter one chicken (LS1)	>157.7905*	154.6960m^3 < $X \leq$ 157.7905 m^3	151.6015 m^3 < $X \leq$ 154.6960 m^3	148.5070 m^3 < $X \leq$ 151.6015 m^3	$X \leq$ 148.5070 m^3
2	Average amount of energy consumed to slaughter one chicken (LS2)	>0.165 KWh**	0.150 KWh < $X \leq$ 0.165 KWh	0.135 KWh < $X \leq$ 0.150 KWh	0.120 KWh < $X \leq$ 0.135 KWh	$X \leq$ 0.120 KWh
3	Percentage of waste that can be reused and recycled (LS3)	X < 70%***	70% ≤ X < 80%	80% ≤ X < 90% 80%	90% ≤ X < 100%	100%

Table 5 List of indicators and the scale for the chicken slaughterhouse chain (continued)

No	Indicators	Scale 1	2	3	4	5
Social (Yakovleva, 2007; Saeed and Kersten, 2017; Laws of the Republic of Indonesia No. 33/2014 about Halal Product Guarantee)						
4	Comparison of male and female workers (SS1)	80% < X ≤ 90% ***	70% < X ≤ 80%	60% < X ≤ 70%	50% < X ≤ 60%	X ≤ 50%
5	Chicken slaughterhouse already has halal certification from MUI (SS2)	Not yet	–	–	–	Already have
Economic (Tsolakis et al., 2018; Saeed and Kersten, 2017)						
6	Average of net income per month (ES1)	Very low (less than IDR 1,119,000,000) ****	Low (IDR 1,119,000,000 to less than IDR 1,360,000,000)	Adequate (1,360,000,000 IDR to less than IDR 1,530,000,000)	High (1,530,000,000 to less than 1,700,000,000)	Very high (more than IDR 1,700,000,000)
7	Labour cost per month (ES2)	Very high (more than IDR 330,000,000) ****	High (IDR 300,000,000 to IDR 330,000,000)	Adequate (IDR 270,000,000 to IDR 300,000,000)	Low (IDR 240,000,000 to IDR 270,000,000)	Very low (less than IDR 240,000,000)
8	Administration cost per year (ES3)	Very high (more than IDR 220,000,000) ****	High (IDR 200,000,000 to IDR 220,000,000)	Adequate (IDR 180,000,000 to IDR 200,000,000)	Low (IDR 160,000,000 to IDR 180,000,000)	Very low (less than IDR 160,000,000)
9	Distribution cost per month (ES4)	Very high (more than IDR 77,000,000) ****	High (IDR 70,000,000 to IDR 77,000,000)	Adequate (IDR 56,000,000 to IDR 70,000,000)	Low (IDR 56,000,000 to IDR 63,000,000)	Very low (less than IDR 56,000,000)

Source of scale: *Barana et al., 2014; **Bueno et al., 2015; ***Yakovleva, 2007; ****interview with the representative of PT Ciomas and the chicken slaughterhouse

3.3 Data collection procedure

Two sources of data, i.e., primary and secondary data, were used in this research. The sources of primary data were the questionnaire results and the interviews with selected broiler chicken farmers, selected representative management of the chicken slaughterhouse, and representatives of the Department of Agriculture in Animal Husbandry in Semarang District. The sources of secondary data were data recorded by the broiler chicken farmers, the chicken slaughterhouse, and the Department of

Agriculture in Animal Husbandry in Semarang District. The secondary data were complementary to the questionnaire results and the personal interviews.

Three types of questionnaires were developed in this research. Two of three questionnaires were developed based on the 15 final indicators to assess the sustainability of the farm chain and on the 9 final indicators to assess the sustainability of the chicken slaughterhouse chain indicators, namely, AHP questionnaire (the first type of questionnaire) and closed-ended questionnaire to measure the current condition of the broiler chicken supply chain at the farm and chicken slaughterhouse levels (the second type of questionnaire). An AHP questionnaire is a closed-ended questionnaire used to compare the level of importance of the sustainability of farms and chicken slaughterhouse chains and the level of importance of each of their dimensions and indicators. The results of this questionnaire indicate the relative weight of the sustainability of each chain and of each dimension and indicator. This questionnaire applies Saaty's nine-point scale (Saaty, 1995). The closed-ended questionnaire that measures the current condition of the broiler chicken supply chain at the farm and slaughterhouse levels applies a five-point Likert scale with different meanings, as shown in Tables 4 and 5. The third type of questionnaire is a Delphi questionnaire, which is a combination of semi-structured and closed-ended questionnaires. It is used to obtain the most reliable consensus of opinion of a group of experts (Linstone and Turoff, 1975). In this research, the Delphi questionnaire is used to obtain the most reliable consensus related to policy to increase the sustainability of the broiler chicken supply chain. The Delphi questionnaire is distributed in several rounds. In the first round, semi-structured questions are used to identify issues related to the proposed policy for increasing the sustainability of the broiler chicken supply chain. On the basis of the information gathered from the first round, the closed-ended questions are used for the second and subsequent rounds. This questionnaire aims to quantify the priority level of the proposed policy on the basis of earlier findings usually by rating or ranking with a five-point Likert scale (1 = not a priority to 5 = essential).

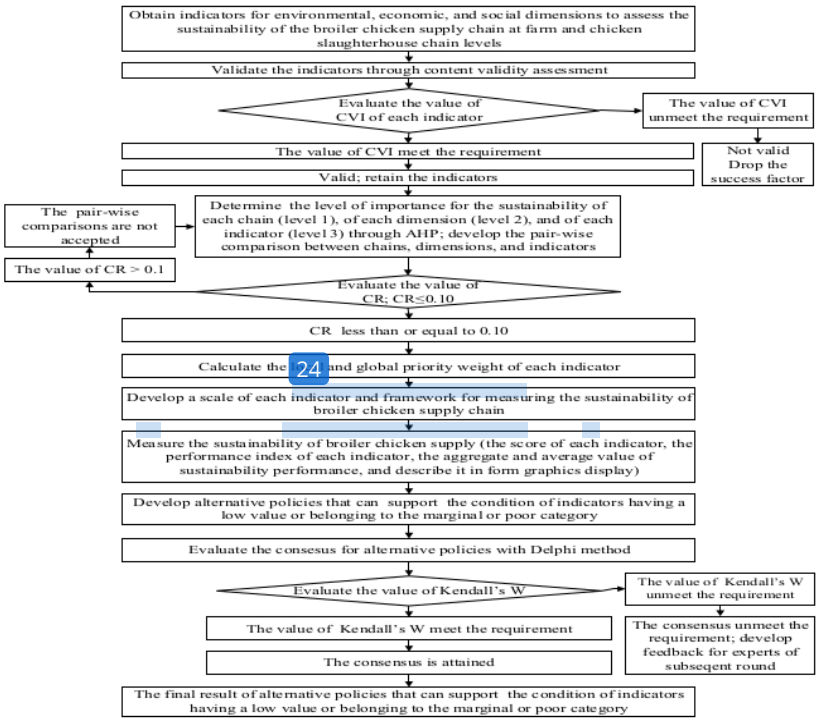
The three copies of the first and third types of questionnaires were distributed to the Department of Agriculture in Animal Husbandry in Semarang District and the representative of the broiler chicken farmers and chicken slaughterhouse. In the Department of Agriculture, one questionnaire was filled out by the section heads of Veterinary Public Health, and the other questionnaire was filled out by the field instructor. Forty copies of the second type of questionnaire were distributed to the selected broiler chicken farmers and representative management of the slaughterhouse; in this questionnaire, they were asked to describe the condition of their farms and slaughterhouse according to the scale of each indicator. Aside from the questionnaire, personal interviews were conducted to further determine the reason each respondent chose a certain value of level importance for each chain, dimension, and indicator, the scale in each indicator, and the priority level of the proposed policy.

3.4 Data processing procedure

Three different methods were used to analyse the data. The data from the first type of questionnaire were examined using AHP (Saaty, 1995). The data from the second type of questionnaire were examined using simple descriptive statistics (statistic mean and simple graphics display). The data from the third type of questionnaire were evaluated using the Delphi method, which was introduced in 1950 by Norman Dalkey for a US-

sponsored military project (Skulmoski et al., 2007), as an iterative process to collect and study the experts' judgement about the policies that should be implemented to improve the sustainability of the broiler chicken supply chain. Graphically, the flow diagram of the research is presented in Figure 2.

Figure 2 Flow diagram of research



4 Results and discussion

4.1 Result of data processing with AHP

In this study, the AHP questionnaire is used to determine the level of importance for the sustainability of each chain (level 1), of each dimension (level 2), and of each indicator (level 3). Graphically, the AHP framework for measuring the sustainable performance of the broiler chicken supply chain is shown in Figure 3.

Data processing with AHP began with the distribution of the pairwise questionnaire to three respondents (the section heads of Veterinary Public Health, the field instructor, and the representatives of contract farmers) to obtain the individual pairwise judgements. An example of the AHP questionnaire for the second level of social dimension at broiler chicken farms is shown in Table 6. Each expert performed pairwise comparison at different levels; thus, 27 pairwise comparison matrices were formed.

Figure 3 AHP framework for measuring the sustainable performance of the broiler chicken supply chain

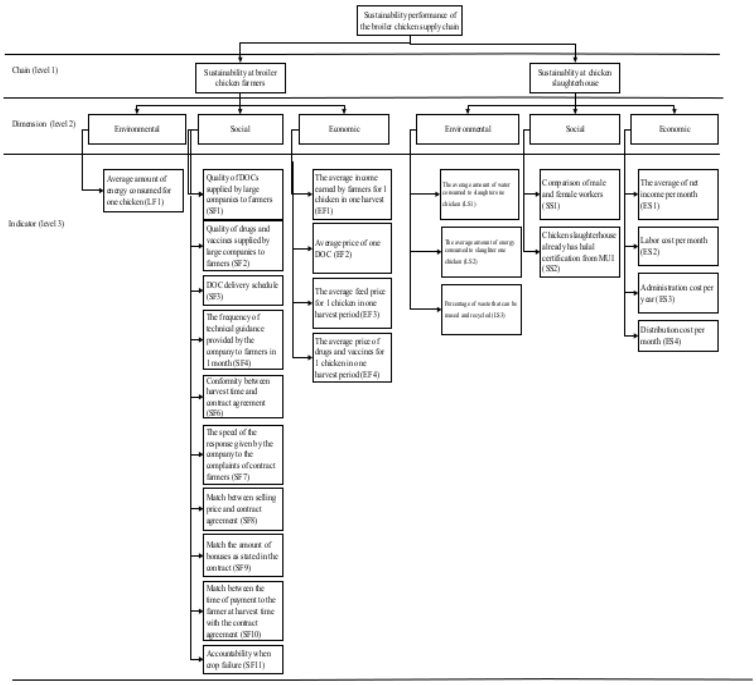


Table 6 Example of the AHP questionnaire for the second level on social dimension at broiler chicken farms

	1 3 5 7 9 9 7 5 3 1	
Quality of DOCs supplied by large companies to farmers (SF1)		Quality of drugs and vaccines supplied by large companies to farmers (SF2)
Quality of DOCs supplied by large companies to farmers (SF1)		DOC delivery schedule (SF3)
Quality of DOCs supplied by large companies to farmers (SF1)		Frequency of technical guidance provided by the company to farmers in one month (SF4)
...		...
Match between the time of payment to the farmer at harvest time with the contract agreement (SF10)		Accountability during crop failure (SF11)

Then, the geometric mean of an individual's judgements was used to avoid the biased attitude of a decision-maker toward a particular alternative and to obtain a single value of the level of importance for the sustainability of each chain, dimension, and indicator. Bias can be reduced to make a consensus, a vote, or a compromise and to separate the model for incorporating the judgements of group members in pairwise comparison matrices (Dryer and Forman, 1992). The result of the geometric means of pairwise comparison to determine the level of importance of the sustainability on each chain (level 1), dimension (level 2), and indicator (level 3) is shown in Tables 7–14.

Table 7 Result of geometric means of pairwise comparison to determine the level of importance of sustainability on each chain (level 1),

Chain (level 1)	*Sustainability at chicken slaughterhouses*	*Sustainability at chicken farms*
Sustainability at chicken slaughterhouses	1.00	0.50
Sustainability at chicken farms	2.10	1.00

Table 8 Result of geometric means of pairwise comparison to determine the level of importance of environmental, social, and economic dimensions on sustainability at chicken farms (level 2)

Dimension (level 2)	*Environmental*	*Social*	*Economic*
Environmental	1.00	1.00	1.00
Social	1.00	1.00	1.00
Economic	1.00	1.00	1.00

Table 9 Result of geometric means of pairwise comparison to determine the level of importance of environmental, social, and economic dimensions on sustainability at the chicken slaughterhouse (level 2)

Dimension (level 2)	*Environmental*	*Social*	*Economic*
Environmental	1.00	0.14	0.14
Social	7.00	1.00	1.00
Economic	7.40	1.00	1.00

Table 10 Result of geometric means of pairwise comparison to determine the level of importance of each indicator on social dimension at chicken farms (level 3)

Indicators (level 3)	*SF1*	*SF2*	*SF3*	*SF4*	*SF6*	*SF7*	*SF8*	*SF9*	*SF10*	*SF11*
SF1	1.00	0.52	0.13	1.00	0.79	2.90	3.66	3.16	1.33	0.41
SF2	1.91	1.00	0.58	1.33	1.36	2.60	1.44	0.55	0.55	0.69
SF3	7.61	1.71	1.00	1.52	1.91	3.66	3.27	0.79	1.52	1.14
SF4	1.00	0.75	0.66	1.00	0.41	0.69	0.46	0.69	0.55	0.52
SF6	1.26	0.74	0.52	2.41	1.00	3.27	1.71	1.44	1.44	1.91
SF7	0.34	0.39	0.27	1.44	0.31	1.00	1.05	0.55	0.79	1.91

Table 10 Result of geometric means of pairwise comparison to determine the level of importance of each indicator on social dimension at chicken farms (level 3) (continued)

Indicators (level 3)	*SF1*	*SF2*	*SF3*	*SF4*	*SF6*	*SF7*	*SF8*	*SF9*	*SF10*	*SF11*
SF8	0.27	0.69	0.31	2.15	0.58	0.95	1.00	0.48	1.00	0.48
SF9	0.32	1.82	1.26	1.44	0.69	1.82	2.08	1.00	1.00	1.00
SF10	0.75	1.82	0.66	1.82	0.69	1.26	1.00	1.00	1.00	0.69
SF11	2.47	1.44	0.87	1.91	0.52	0.52	2.08	1.00	1.44	1.00

Table 11 Result of geometric means of pairwise comparison to determine the level of importance of each indicator on economic dimension at chicken farms (level 3)

Indicators (level 3)	*EF1*	*EF2*	*EF3*	*F*
EF1	1.00	9.00	9.00	9.00
EF2	0.11	1.00	0.79	1.65
EF3	0.11	1.26	1.00	2.60
EF4	0.11	0.61	0.39	1.00

Table 12 Result of geometric means of pairwise comparison to determine the level of importance of each indicator on environmental dimension at the chicken slaughterhouse (level 3)

Indicators (level 3)	*LS1*	*LS2*	*LS3*
LS1	1.00	1.91	1.91
LS2	0.52	1.00	2.76
LS3	0.52	0.36	1.00

Table 13 Result of geometric means of pairwise comparison to determine the level of importance of each indicator on social dimension at the chicken slaughterhouse (level 3)

Indicators (level 3)	*SS1*	*SS2*
SS1	1.00	0.34
SS2	2.92	1.00

Table 14 Result of geometric means of pairwise comparison to determine the level of importance of each indicator on economic dimension at the chicken slaughterhouse (level 3)

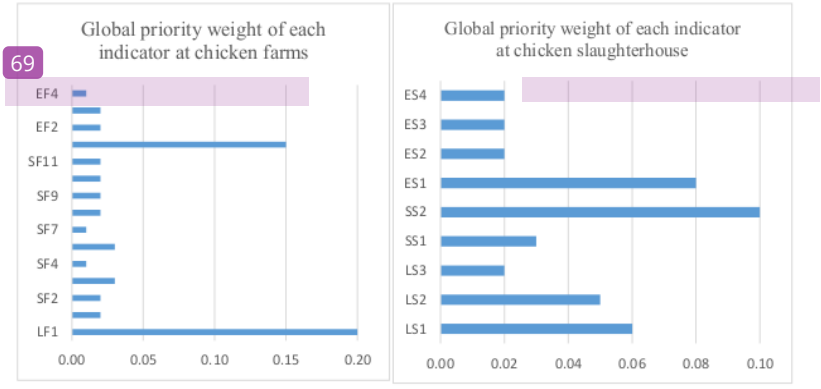
Indicators (level 3)	*ES1*	*ES2*	*ES3*	*ES4*
ES1	1.00	4.33	4.33	4.33
ES2	0.23	1.00	1.19	0.63
ES3	0.23	0.84	1.00	0.79
ES4	0.23	1.59	1.26	1.00

Then, the local priority weight of each chain, dimension, and indicator, the global priority weight of each dimension and indicator, and the CI and CR values are calculated on the basis of the pairwise comparison data by using Equations 1 and 2. The result is shown in Table 15 and Figure 4. All the comparisons are accepted because the CR value is less than or equal to 0.10.

Table 15 Local and global priority weight for each chain, dimension, and indicator, and the CI and CR values

Chain (1)	*Dimensions (2)*	*Local weight of dimensions (3)*	*Indicators (4)*	*Local weight of indicators (5)*	*Global weight of indicators according to their dimension (6) = (3) * (5)*	*Global weight of indicators according to their dimension and chain (7) = (1) * (6)*	*CI (8)*	*CR (9)*
	Economy	0.33	EF1	0.74	0.25	0.15	0.03	0.03
			EF2	0.09	0.03	0.02		
			EF3	0.12	0.04	0.02		
			EF4	0.06	0.02	0.01		
Chicken slaughterhouse (0.40)	Environmental	0.33	LS1	0.47	0.16	0.06	0.06	0.10
			LS2	0.35	0.12	0.05		
			LS3	0.18	0.06	0.02		
	Social	0.33	SS1	0.25	0.08	0.03	0.00	0.00
			SS2	0.75	0.25	0.10		
	Economy	0.33	ES1	0.59	0.20	0.08	0.01	0.01
			ES2	0.13	0.04	0.02		
			ES3	0.12	0.04	0.02		
			ES4	0.16	0.05	0.02		

Figure 4 Global priority weight of each indicator (see online version for colours)



The priority weight of sustainability at the farm chain was higher than that at the chicken slaughterhouse chain. At the farm level, the top four indicators are ranked as follows on the basis of the rearranged priority weight in descending order: the average amount of energy consumed for one chicken/LF1 (0.20); the average income earned by farmers for one chicken in one harvest/EF1 (0.15); DOC delivery schedule/SF3 (0.03); and conformity between harvest time and contract agreement/SF6 (0.03). In the chicken slaughterhouse, on basis of the rearranged priority weight in descending order, the top four indicators are ranked as follows: the chicken slaughterhouse already has halal certification from MUI/SS2 (0.10); the average net income per month/ES1 (0.08); the average amount of water consumed by the slaughterhouse for one chicken/LS1 (0.06); and the average amount of energy consumed by the slaughterhouse for one chicken/LS2 (0.05).

4.2 *Result of sustainability measurement*

The aggregate value of the sustainability performance of the broiler supply chain is the sum of the performance index of each indicator, which represents the score of the value of indicators multiplied by the weight of the indicator. In this research, before aggregation, the score value of each indicator was converted to a 1:20 scale, so the measurement scale from 20 to 100 for each indicator can be obtained. This procedure should be conducted to determine the measurement results that can be grouped using the interval value from Trienekens and Hvolby (2000). In this case, according to Trienekens and Hvolby (2000), the measurement result can be grouped into five, namely, poor (score ≤ 40), marginal ($40 <$ score ≤ 50), average ($50 <$ score ≤ 70), good ($70 <$ score ≤ 90), and excellent (score > 90). Trienekens and Hvolby (2000) used this interval value to measure the performance in a supply chain, although they did not apply the concept of sustainability as a framework. Table 16 shows the score of each indicator from small, medium, and large farm chains and the score of each indicator from the chicken slaughterhouse level after the scores are converted to the measurement scale of 20–100. Table 16 also presents the performance index of each indicator (the score value of the indicator multiplied by its priority weight) and the aggregate value of the sustainability performance in the surveyed farm chain.

The calculated aggregate value of sustainability performance in the surveyed farm chain indicates that the aggregate value of the small farm chain (73.90) is lower than those of the medium (77.61) and large (82.48) farm chains. However, Trienekens and Hvolby (2000) showed that all the aggregate values of sustainability belonged to the good category. Figure 5 presents the average score of each dimension (environmental, social, and economic) of small, medium, and large farm chains. The large farm chain has the highest average score for all dimensions. According to Trienekens and Hvolby (2000), the average score of environmental dimension is classified as good for medium and large farm chains and average for small farm chains. The average score of social dimension indicates a good outcome for all the three farm chains. However, the average score of economy dimension belongs to the marginal category for small, medium, and large farm chains. The individual score of each indicator for small, medium, and large farm chains is presented in Table 17 and Figure 6. Most indicators of large farm chains belong to the good category, and only four indicators belong to the marginal category. All these indicators are part of the economic dimensions. A comparison among the indicators in the large farm chain shows that 11 indicators in the medium farm chain belong to the good

category, 1 indicator is under the average category, 2 indicators belong to the marginal category, and 1 indicator (average feed price for one chicken in one harvest period) belongs to the poor category. In the small farm chain, only 7 indicators belong to the good category, 5 indicators belong to the average category, and 3 indicators belong to the marginal category. No indicator is under the poor category. In the chicken slaughterhouse chain, 4 indicators belong to the excellent category, 1 indicator belongs to the good category, 3 indicators belong to the average category, and 1 indicator belongs to the marginal category. Figure 5 shows that almost all the indicators that belong to the large farm chain are located on the outermost line.

Table 16 Score of each indicator, performance index of each indicator, and aggregate value of sustainability performance

				Average score of each indicator (after conversion to the new scale)			*Multiplication between the average score and the weight of each indicator*		
Chain	*Dimension*	*Indicators*	*Weight of indicators*	*Small farm*	*Medium farm*	*Large farm*	*Small farm*	*Medium farm*	*Large farm*
Farm	Environmental	LF1	0.20	60.00	75.00	83.00	12.00	15.00	16.60
	Social	SF1	0.02	70.00	83.00	85.00	1.40	1.66	1.70
		SF2	0.02	70.00	80.00	82.00	1.40	1.60	1.64
		SF3	0.03	80.00	80.00	78.00	2.40	2.40	2.34
		SF4	0.01	80.00	92.50	93.00	0.80	0.93	0.93
		SF6	0.03	80.00	80.00	80.00	2.40	2.40	2.40
		SF7	0.01	80.00	80.00	82.00	0.80	0.80	0.82
		SF8	0.02	80.00	80.00	83.00	1.60	1.60	1.66
		SF9	0.02	80.00	80.00	81.00	1.60	1.60	1.62
		SF10	0.02	80.00	80.00	82.00	1.60	1.60	1.64
		SF11	0.02	60.00	75.00	80.00	1.20	1.50	1.60
	Economy	EF1	0.15	70.00	67.50	86.00	10.50	10.13	12.90
		EF2	0.02	40.00	47.50	42.00	0.80	0.95	0.84
		EF3	0.02	40.00	37.50	53.00	0.80	0.75	1.06
		EF4	0.01	40.00	50.00	53.00	0.40	0.50	0.53
Chicken slaughterhouse *)	Environmental	LS1	0.06	100.00	100.00	100.00	6.00	6.00	6.00
		LS2	0.05	100.00	100.00	100.00	5.00	5.00	5.00
		LS3	0.02	100.00	100.00	100.00	2.00	2.00	2.00
	Social	SS1	0.03	40.00	40.00	40.00	1.20	1.20	1.20
		SS2	0.10	100.00	100.00	100.00	10.00	10.00	10.00
		ES1	0.08	80.00	80.00	80.00	6.40	6.40	6.40
	Economy	ES2	0.02	60.00	60.00	60.00	1.20	1.20	1.20
		ES3	0.02	60.00	60.00	60.00	1.20	1.20	1.20
		ES4	0.02	60.00	60.00	60.00	1.20	1.20	1.20
Total							*73.90*	*77.61*	*82.48*

Figure 5 Average score of each dimension (environmental, social, and economic) for small, medium, and large broiler chicken farm chains (see online version for colours)

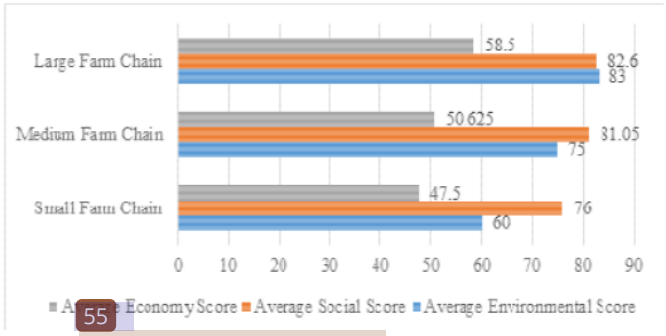
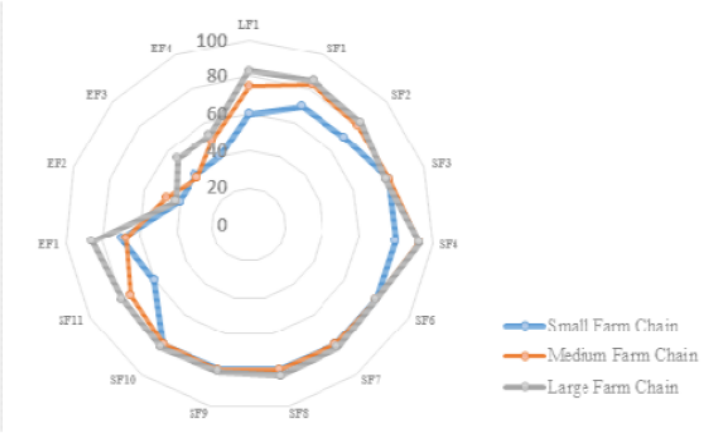


Figure 6 Comparison of the scores of all indicators for small, medium, and large broiler chicken farm chains (see online version for colours)



4.3 Policy recommendation based on the Delphi method

The findings obtained from the sustainability performance measurement were discussed with some experts to find alternative policies that could increase the sustainability level at farms and chicken slaughterhouses. The Delphi method was used to formulate these policies. In this case, the policies were used to solve or improve the condition of indicators that have a low value or belong to the marginal or poor category, such as the price of one DOC (EF2), the average feed price for one chicken in one harvest period (EF3), the average price of drugs and vaccines for one chicken in one harvest period (ES4), and the comparison of male and female workers (SS1).

Table 17 Scores of all indicators for small, medium, and large broiler chicken farm chains

Indicator	*Small farm chain*		*Medium farm chain*		*Medium farm chain*	
LF1	60.00	Average	75.00	Good	83.00	Good
SF1	70.00	Average	83.00	Good	85.00	Good
SF2	70.00	Average	80.00	Good	82.00	Good
SF3	80.00	Good	80.00	Good	78.00	Good
SF4	80.00	Good	92.50	Good	93.00	Good
SF6	80.00	Good	80.00	Good	80.00	Good
SF7	80.00	Good	80.00	Good	82.00	Good
SF8	80.00	Good	80.00	Good	83.00	Good
SF9	80.00	Good	80.00	Good	81.00	Good
SF10	80.00	Good	80.00	Good	82.00	Good
SF11	60.00	Average	75.00	Good	80.00	Good
EF1	70.00	Average	67.50	Average	86.00	Good
EF2	40.00	Marginal	47.50	Marginal	42.00	Marginal
EF3	40.00	Marginal	37.50	Poor	53.00	Marginal
EF4	40.00	Marginal	50.00	Marginal	53.00	Marginal

The Delphi study was administered in four rounds. In the first round, semi-structured questions were distributed to the experts to identify some proposed policies related to indicators that have a low value or belong to the marginal or poor category. Briefly, several proposed policy resulted from the first round:

i supervise DOC selling prices from breeding farms, which is controlled by only a few players such as Charoen Pokphand, Japfa, Wonokoyo, Malindo, Manggis, and Samsung (POL1)

ii review the effectiveness of the implementation of the Minister of Agriculture Regulation No. 32/2017 concerning the main quota system for imported DOC to balance the domestic broiler market (POL2)

iii provide associations and organisations that can accommodate the aspirations and complaints of contract farmers in running a partnership and improve the bargaining position of farmers compared with the core company (POL3)

iv provide subsidies for domestic development of vaccines and medicines so they can be purchased by farmers at a more affordable price (POL4)

v control the price of vaccines and medicines for farmers (POL5)

vi require manufacturing companies to practice continuous innovation in using domestic raw materials to ensure a cheaper feed price (POL6)

vii require manufacturers to practice continuous innovations to produce good-quality feed by using a more modern production system (POL7)

viii issue government regulations related to the composition of male and female workers (POL8)

ix ask feed manufacturers to give equal opportunities to women and hire them for suitable tasks (POL9).

Then, on the basis of the proposed policies gathered from the first round, close-ended questions were used for the second and subsequent rounds. The results for the second, third, and fourth rounds are summarised in Table 18.

Table 18 Second, third, and fourth rounds of the Delphi method

	Round 2				*Round 3*				*Round 4*			
	E 1	*E2*	*E3*	*Mean*	*E1*	*E2*	*E3*	*Mean*	*E1*	*E2*	*E 3*	*Mean*
POL1	4	5	3	4.000	4	5	4	4.33	4	5	4	4.33
POL2	5	5	4	4.667	5	5	4	4.67	5	5	4	4.67
POL3	5	4	4	4.333	5	5	4	4.67	5	5	4	4.67
POL4	5	4	5	4.667	5	4	4	4.33	5	4	4	4.33
POL5	4	2	4	3.333								
POL6	5	4	4	4.333	5	4	4	4.33	5	4	4	4.33
POL7	5	4	4	4.333	5	4	4	4.33	5	4	4	4.33
POL8	2	4	2	2.667								
POL9	4	4	4	4.000	4	4	4	4.00	4	4	4	4.00
	N			9	N			7	N			7
	Kendall's W[a]			0.231	Kendall's W[a]			0.452	Kendall's W[a]			0.755
	Chi-square			4.160	Chi-square			6.333	Chi-square			10.571
	df			2	df			2	df			2
	Asymp. sig.			0.125	Asymp. sig.			0.042	Asymp. sig.			0.005

E = expert.

A review of the data from round 2 shows that any policy with an average rating of 4.0 or higher would be regarded as an important alternative policy; policies with a low rating would be excluded from the list. In round 2, the alternative policies are to control the price of vaccines and medicines to farmers (POL5) and for the government to issue regulations on the composition of male and female workers (POL8), both of which have an average value of less than 3. Consequently, the two alternative policies were excluded from the list and from the questionnaire given to the experts in the second round. Table 18 also shows the result of Kendall's coefficient of concordance (Kendall's W) test for the second, third, and fourth rounds. The Delphi method should be further used in the second round because the Kendall's W in the second-round is 0.231 or less than 0.5. Kendall's W represents the level of consensus between the participants (Habibi et al., 2014), and it ranges from 0 to 1, indicating the degree of consensus reached by the panel. A Kendall's W of more than 0.7 indicates a strong consensus; a Kendall's W of 0.5 corresponds to a moderate consensus; and a Kendall's W of less than 0.3 denotes a weak consensus (Habibi et al., 2014). The third-round questionnaire was designed on the basis of the seven remaining alternative policies and distributed to the experts. In the

third round, all alternative policies had an average value of above 4, thereby indicating that all the remaining policies were necessary to improve low-value indicators. The Kendall's W in the second round is still less than 0.5 (i.e., 0.452). Therefore, the Delphi method should be used further in the fourth round. In the fourth round, all alternative policies had an average value of above 4. When the Kendall's W is more than 0.5 (i.e., 0.755), the use of the Delphi method can be stopped. The final alternative policies according to their rank are as follows:

i review the effectiveness of the implementation of the Ministry of Agriculture Regulation No. 32/2017 (POL2)

ii provide associations and organisations that can accommodate the aspirations and complaints of contract farmers in running a partnership and improve the bargaining position of farmers relative to that of large companies (POL3)

iii monitor DOC selling prices from breeding farms, which are controlled by only a few players (POL1)

iv provide subsidies for the domestic development of vaccines and medicines (POL4)

v require manufacturers to practice continuous innovation in using domestic raw materials to ensure a cheaper feed price (POL6)

vi require manufacturers to practice continuous innovation to produce good-quality feed by using a more modern production system (POL7)

vii ask feed manufacturers to give equal opportunities to women and hire them for suitable tasks (POL9).

5 Conclusion

This research aimed to identify the suitable indicators and their scale for measuring the sustainability performance of the broiler chicken supply chain. It also attempted to apply the developed measurement system in a specific broiler chicken supply chain and formulate recommendations to improve the sustainability of the broiler chicken supply chain. After the content validation process, this study identified 15 and 9 indicators that belong to environmental, social, and economic dimensions to measure the sustainability performance at farms and chicken slaughterhouses, respectively. Measurement results revealed that the total score of the sustainability performance at all levels of the broiler chicken supply chain (small, medium, and large) indicates a good category, although the total score of the broiler chicken supply chain with a large farm is higher than that of the broiler chicken supply chain with small and medium farms. Efforts to increase sustainability performance focused on low-value indicators that belong to a marginal category, i.e., the price of one DOC, the average feed price for one chicken in one harvest period, the average price of drugs and vaccines for one chicken in one harvest period, and the comparison between male and female workers at a chicken slaughterhouse.

The price of DOC and the average prices of feed, drugs, and vaccines depend on the contract between a large company and contract farmers. These factors are important and should be considered by large companies because these factors can determine the satisfaction level of contract farmers, who tend to maintain their partnership or business

relationship when they feel satisfied with such companies. These factors are also essential for the survival of contract broiler farmers because their survival depends on profitability. Previous studies described the majority of the costs of DOC, feed, drugs, and vaccines for broiler chickens. Fixed and variable costs contribute 7.54% and 92.45%, respectively. The variable costs include chicks (29.5%), feed (45.48%), and interest on working capital (10.37%), while medicine and veterinary charges and electricity account for 8.17% and 1.3% of the total cost, respectively. On the basis of the cost structure of broiler chicken farms, electricity cost is another important expense that should be determined to ensure good sustainability performance at a farm chain. Although electricity cost is dependent on technology and housing systems, this expense belongs to the five ranks that contribute to variable costs. In our study, the importance of electricity cost for sustainability performance was described based on the rearranged priority weight in descending order. This finding suggests that the average amount of energy consumed is the most important factor at a farm chain to achieve sustainability in the environmental dimension.

This research has some implications for increasing broiler chicken sustainability. Contract farming dominates national broiler production in Indonesia, providing advantages not only for farmers but also for large companies. As such, the government or policymakers should focus on minimising the conditions that likely damage the relationship between contract farmers and large companies. The government should also maintain the stability of the costs of DOC, feed, drugs, and vaccines because most of the costs negatively affect the profitability of farmers. Several alternatives include subsidy provisions and trade regulations on DOC imports. The government should also conduct further research on drugs and vaccines so that they can be produced locally and delivered to contract farmers at reasonable prices. From an academic point of view, this research has a significant theoretical implication on the sustainability literature. The primary contribution of this research is the development of a robust framework for measuring sustainability performance in the broiler chicken supply chain. The proposed framework can help researchers derive new ideas to develop other frameworks and to refine, extend, and enhance this framework. This framework offers an excellent opportunity for scholars to conduct tests in other broiler chicken supply chains.

This study has several limitations. First, not all contract farmers who have formed partnerships with PT Ciomas Adisatwa were included in the study sample; only 30 contract farmers and 1 chicken slaughterhouse located in Central Java were considered. The limited sample of this research can cause bias to our results because of the condition of the surveyed contract farmers and chicken slaughterhouse. Second, the broiler chicken supply chain is the object of the study, which focuses only on the farm and chicken slaughterhouse levels. This study excludes consumers as part of the measurement of the sustainability level of the broiler chicken supply chain. Given this limitation, future research should increase the sample size of not only contract farmers who are connected with PT Ciomas Adisatwa but also of those who are connected with other large companies. Future research should also compare the level of sustainability performance between contract farmers and independent farmers and between regions. Moreover, future studies should enhance the measurement of the sustainability of the broiler chicken supply chain by including other factors related to consumers and other participating actors, such as governments.

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