Surveying the impact of the coronavirus (COVID-19) on the poultry supply chain: A mixed methods study

Mojtaba Palouj [a,*], Rasool Lavaei Adaryani [b], Amir Alambeigi [b], Maryam Movarej [b], Yahya Safi Sis [b]

[a] Agricultural Planning, Economic and Rural Development Research Institute (APERDRI), Tehran, Iran
[b] Faculty of Agricultural Economics and Development, University of Tehran, Iran

ARTICLE INFO

ABSTRACT

The coronavirus pandemic (COVID-19) has affected all supply chains through severe disruption of logistics activities, production, and markets. This study aimed to survey the impact of the coronavirus on the poultry supply chain using an exploratory sequential mixed design. We first addressed those stages of the poultry supply chain disrupted in an ongoing pandemic, and then elaborated particular disturbances associated with each stage. This study was based on data collected from Iranian poultry industry owners and experts who had sufficient experience in agricultural supply chains as well. As the qualitative phase, the content analysis was conducted to identify the impacts of the coronavirus on the poultry supply chain. The results and conclusions that emerged from the qualitative phase were refined and weighted by the Fuzzy Delphi Method (FDM) and the Fuzzy Analytic Hierarchy Process (FAHP) respectively, in the quantitative phase. The results suggested that the pandemic has further affected the input supply as a stage in the poultry supply chain. This is probably because of the fact that the poultry industry is heavily dependent on inputs' flow. In addition, supply chain governance was seriously impaired due to the persistence of the pandemic. The coronavirus pandemic has significantly affected the stages that are most reliant on transportation. Finally, we found that a part of the disruptions that occur in the downstream of the supply chain is due to the epidemic's direct adverse effects, and another part is due to indirect consequences received from the upstream. Our findings and implications can be useful in decision-making procedures during ongoing epidemics.

1. Introduction

A great number of firms are forced to collaborate together in an uncertain environment in order to achieve their objectives. The supply chain in which most of these firms embedded widely faces a range of risks with different origins (de Oliveira et al., 2019). Risks lead to disruptions in the flow of materials, information, and cash (Ambulkar et al., 2015; Bode et al., 2011), and consequently deteriorate the market and financial performance of the supply chain (Ambulkar et al., 2015; Narasimhan & Talluri, 2009; Nikolopoulos et al., 2020).

Given the efforts addressing the way of managing the risks and disruptions of supply chains, this area has become more important to study (Ivanov, 2020; Queiroz et al., 2020). So far, several exogenous risks such as natural disasters (e.g., earthquakes and epidemics), water scarcity and droughts, demographic challenges, energy prices, and human-made hazards (de Oliveira et al., 2019; Foroozesh et al., 2018; Fusco et al., 2018; Giannakis & Papadopoulos, 2016; Hofmann et al., 2014) have been studied which have a significant effect on the supply chains (Ratten, 2020), and should be covered through innovative insurance tools which take into account also the role of ecosystems' mitigation and climate parameters (Porrini et al., 2019; Valente et al., 2019). Meanwhile, the recent outbreak of the coronavirus disease (COVID-19) originated in December 2019 from Wuhan, China (Cortez & Johnston, 2020; Singh et al., 2020), and then spread quickly worldwide (Li et al., 2020). On March 2, 2021, out of 114,441,348 confirmed COVID-19 cases, 2,538,681 deaths have been reported worldwide (Worldometers, 2021). The spread of infection is still ongoing, so that almost all countries in the world have either reached a peak of the COVID-19 outbreak or are expected to reach it shortly (Tsallis & Tirnakli, 2020).

Coronavirus, as a major risk identified so far, has severely disrupted

---

supply chains (de Sousa Jabbour et al., 2020; Haren & Simchi-Levi, 2020; Queiroz et al., 2020; Richards & Rickard, 2020) which is known as a serious crisis in "breaking many global supply chains" (Ivanov, 2020). Unprecedented effects of the coronavirus on food products and supply chains (Cai & Luo, 2020; Lemke et al., 2020; Paul & Chowdhury, 2020; Richards & Rickard, 2020) are very much related to the geographical location and environmental responses (Ratten, 2020). This is because the governments in different regions have taken various directions, depending on the infection prevalence. Indeed, they have imposed different requirements and restrictions considering the varied effects of the coronavirus on supply chains, such as closing restaurants.

Unlike most crises, coronavirus is a new and ongoing crisis with an uncertain period (He & Harris, 2020; WHO, 2020), which has challenged the future (Ratten, 2020). Accordingly, supply chains are expected to be more seriously exposed to the risks of the coronavirus in the short-term. Although health crises, such as epidemics, are more difficult to understand as they are scarce and unpredictable (Ratten, 2020), the evidence indicates that existing literature on the supply chains risks has been mostly limited to the common risks (Dai & Liu, 2020; Ghadge et al., 2020; Munir et al., 2020; Xie et al., 2020), which can be controlled through interventions (Ratten, 2020). Recently, some scholars have focused on several agri-food supply chains in the context of the coronavirus outbreak (Coluccia et al., 2021; Ivanov, 2020; Nchanji et al., 2021; Paul & Chowdhury, 2020; Singh et al., 2020; Tougeron & Hance, 2021; Wang et al., 2020; Yu et al., 2020); however, there is still no comprehensive understanding of the impacts of this ongoing crisis on supply chains at all stages. This is because of the fact that some impacts of the coronavirus on the food supply chains do not occur immediately. Hence, depending on geographical region (de Paulo Farias & de Araújo, 2020) and firms' vulnerability to shocks (Wang et al., 2020), the coronavirus may have a few gradual impacts on various stages of supply chains, which need to be surveyed. Accordingly, this study aims to address a set of impacts made by the coronavirus on each stage and the whole of the poultry supply chain. The contribution of this study is threefold. Firstly, to address the questions about the thoughts of the business owners (i.e., which of the supply chain operations are more affected by an ongoing outbreak? Or is the supply chain in the downstream vulnerable to the disruption caused by epidemics as often as the upstream? If not, which one is the case?), we survey those operations/mechanisms and stages of the poultry supply chain which have been more affected by the crisis. Secondly, we elaborate the unique disturbances related to the poultry supply chain at each stage. Finally, our research indicates the vulnerable aspects of the supply chain that managers and business owners need to remember in serious shifting situations.

2. Background

2.1. Impact of the coronavirus on supply chains

The risks such as the coronavirus pandemic can disrupt all stages of supply chains (Dev, 2020). This pandemic has intensely affected agri-food supply chains such as fruits, vegetables, fish, poultry, grains, and so on (Dev, 2020; Singh et al., 2020). Coronavirus has led to transportation restrictions as well as population mobility restrictions (Singh et al., 2020). The restrictions mainly disrupt most operations across the supply chain. This is because the supply chain contains processes and stages strongly connected to each other (Mangla et al., 2014, 2015).

Since the population mobility can lead to transmission of infection (Apostolopoulos & Sönmez, 2007; de Paulo Farias & de Araújo, 2020; Tian et al., 2020), the labor shortage is evident in many supply chains (Kumar et al., 2020; Singh et al., 2020). For example, the services provided by truck drivers in supply chains have been dramatically decreased because their relationship with other actors, such as workers, retailers, etc., can result in infection transmission (Lemke et al., 2020).

The transportation restrictions have other devastating consequences, such as delay in delivery, loss of sales, disruption of operations, and price fluctuation (Dev, 2020; Garvey et al., 2015; Paul et al., 2020; Wang et al., 2020). As Wang et al. (2020) argued, for example, imposed transportation restrictions have caused long-lasting market impacts, where a shortage of the hogs to enter the packing stage has led to price fluctuations and has affected the future supply of farmers. These destructive effects are gradually transmitted to the next stages of the supply chain (Wang et al., 2020). In this regard, Kumar et al. (2020) and Dev (2020) pointed out that although the price fluctuations would lead to falling the prices of some agricultural products, consumers still have to pay more. Additionally, input supply and market access are problematic for some agricultural sectors, such as the poultry industry (Dev, 2020). The supply of inputs required for the manufacturing process has been disrupted for various reasons as well as border restrictions and hoarding (Nikolopoulos et al., 2020).

During the coronavirus pandemic, demand for some agri-food products or raw materials has risen suddenly due to panic buying and then has declined for many reasons such as travel restrictions (Nikolopoulos et al., 2020), rumors (Dev, 2020; Kumar et al., 2020), consumers' concern and distrust (Narayanan et al., 2020), and closing the restaurants and hotels (de Paulo Farias & de Araújo, 2020; Richards & Rickard, 2020). As a results, in the early months of the coronavirus outbreak, we could see a significant variation in the price of some agricultural products, such as vegetables and fruits (de Paulo Farias & de Araújo, 2020). It seems that the people have had certain eating habits in their normal life such as pre-epidemic travels; however, during the coronavirus outbreak, these habits have been lost, resulting in a change in demand and price variation. In addition, Dev (2020) and Kumar et al. (2020), for example, argued that with the spread of rumors on social media regarding the transmission of the coronavirus through poultries, the consumption of poultry meat has been decreased. Regardless of rumors, the pandemic has made consumers more concerned about their own food safety. Based on the evidence, in food-serving places, it is expected that touching contaminated surfaces and food containers leads to the spread of infection if the virus is transmitted shortly afterwards via the hands to the mucous membranes of the nose or eyes (Für Risikobewertung, 2020; Galanakis, 2020). Following these concerns about the spread of infection through the food systems, consumers even refuse to order food through online platforms (Narayanan et al., 2020), leading to decreased demand for food. This suggests that safety measures including disinfection of surfaces, keeping working environments clean, food preparation and delivery, and social distancing may need to be taken into consideration across the food supply chain stages, especially the consumption stage to reduce the consumer concerns (Rizou et al., 2020). Besides individual consumers, short-term closure of restaurants and hotels means that a major channel of the food consumption has been lost (Richards & Rickard, 2020); hence, the demand for food is expected to fall as well. Beyond these, the effects of the coronavirus on the economies of countries may result in several undesirable consequences including the rise in the unemployment rate, decline the household income, and the reduction of purchasing power, causing a change in demand for food (de Paulo Farias & de Araújo, 2020; Kumar et al., 2020).

Along with the outbreak of the coronavirus, some businesses related to supply chains have been shut down due to restrictions imposed by the governments and it is difficult to reopen them at the same time. Therefore, different stages of supply chains suffer from irregular practices in the context of the weak links. In such a situation, as Dev (2020) pointed out, in each disrupted supply chain, it is necessary to consider comprehensive mechanisms to form, maintain, and change the ties so that the practices can be properly managed, which are named "governance" (Raynolds, 2004). Likewise, the mechanisms by which the firms manage their ties with others and lead supply chains to be sustainable, are known as the governance mechanisms (Gimenez & Sierra, 2013). They may be set by buyers, producers, and government agencies/Non-Government Organizations (NGOs) (Soundararajan &

Brown, 2016).

Previous studies on the supply chain management have extensively investigated different risks, but studies related to novel coronavirus are just starting to emerge. A study accomplished by Wang et al. (2020) showed that the coronavirus has short-term effects on the supply chain in a way that some effects, such as the consumption effects, disappear in a short time. The price and consumption are immediately affected by the transportation disruptions. Another study by Jallow et al. (2020) indicated that the United Kingdom's infrastructure sector has been affected by the coronavirus outbreak, where the imposed restrictions have weakened team management. Similarly, Cai and Luo (2020) found that the coronavirus has disrupted the supply of inputs. They also showed that the manufacturing supply chain is likely to change in the future. As Richards and Rickard (2020) indicated, the closure of schools, restaurants, and transportation restrictions during the coronavirus outbreak has led to the disruptions in the Canadian fruit and vegetable market. Lu et al. (2020) showed that most of the surveyed companies were unable to operate for various reasons, such as supply chain disruptions and declining the market demand. Coluccia et al. (2021) revealed that during the first wave of the coronavirus, the harvest and production of fresh and perishable products suffered from the pricing risks. However, such risks have not been reported for storable products. In general, previous studies showed that coronavirus has different effects on various aspects of supply chains depending on the conditions, rate of spread, and time. Therefore, there is a need for further studies to provide an in-depth understanding of the effects of this epidemic on the entire supply chain in different contexts.

2.2. Poultry supply chain

Evidence shows that consuming a well-balanced diet containing polysaccharides and dietary fiber, vitamins and folate, lipids, and peptides protects the body from harmful diseases, such as the coronavirus (Galanakis, 2020). Therefore, in the era of the coronavirus, the consumption of meat, especially white meat, is recommended as a great source to obtain some of these ingredients and bioactive compounds (Chowdhury et al., 2020).

The consumption of the poultry meat, as one type of white meat, worldwide is predicted to increase with an average growth rate of 0.10% from 2020 to 2022. To meet this increase in consumption, the production is also expected to increase. This change in production could be related to poultry supply chain modernization (OECD/FAO, 2020).

As a modern structure, vertically integrated supply chains have been recently developed in the poultry industry. These supply chains function by using the latest technologies such as modern processing methods (Ariffin & Abas, 2015). They have a potential for the use of modern technologies such as high-pressure processing (Galanakis, 2021) to increase the apparent digestibility of meat. More precisely, the poultry supply chain often follows an integrated system (Pohlmann et al., 2020) in which different stages including the breeding, hatching, feeding, producing, transporting, slaughtering, processing, and distribution are managed by a vertically integrated focal firm, namely integrator (Ariffin & Abas, 2015). Integrators along with other independent partners who act in the poultry industry are known as the poultry supply chain at the national level surrounded by the governance mechanisms (Ariffin & Abas, 2015; Pohlmann et al., 2020).

In the breeding stage, first, the primary breeder firms raise breeding birds for use in breeder farms (parent farms), and second, breeding birds are used to produce eggs for hatching. Subsequently, fertile eggs are controlled for achieving the day-old chicks. After transporting the day-old chicks to the broiler farm, the growers try to raise broiler chickens until preparing the meat for consumption. It should be noted that the feed supply and the feeding of chickens are important in the stage of breeding and broiler farms. Live poultries are transported to the slaughterhouses for slaughtering and processing. Lastly, the poultry meat is distributed to retailers, wholesalers, and restaurants. The surplus

meat is stored in the cold storage (Ariffin & Abas, 2015; Lavaei Adaryani & Palouj, 2019; Pohlmann et al., 2020). Fig. 1 shows the poultry supply chain in more detail.

3. Methodology

3.1. Study design

This study, which employed an exploratory sequential mixed design approach (Creswell & Clark, 2017), was performed to survey the impacts of the coronavirus on the Iranian poultry supply chain. As the qualitative phase, a content analysis was conducted to provide empirical evidence to design the quantitative phase. The results and conclusions that emerged from the qualitative phase were refined and weighted by the Fuzzy Delphi Method (FDM) and the Fuzzy Analytic Hierarchy Process (FAHP) respectively, in the quantitative phase. The proposed research design is shown in Fig. 2.

3.1.1. Qualitative phase

Due to the novelty of the coronavirus (WHO, 2020) and the lack of a significant body of literature on its impacts on the supply chain, we conducted a qualitative survey that consisted of the content analysis. The content analysis, as a research method, focuses on the systematic classification process of coding and identifying the themes to put a subjective interpretation on the content of text data (Hsieh & Shannon, 2005). In this study, we considered this helpful method for analyzing the systematic extraction of the coronavirus impacts on the poultry supply chain.

In order to data collection, online individual semi-structured interviews were conducted with 147 Iranian poultry industry owners and other participants who had sufficient experience in agricultural supply chains. At the beginning of this process, the participants were purposefully invited to express their opinions about several generic questions such as "what effects does the coronavirus have on different poultry supply chain stages, such as input provision, production, sales, etc.?", and then they were involved in deep discussions on the topic. At the same time, along with collecting the data, we started the data analysis using the MAXQDA 12 software. We continued interviewing
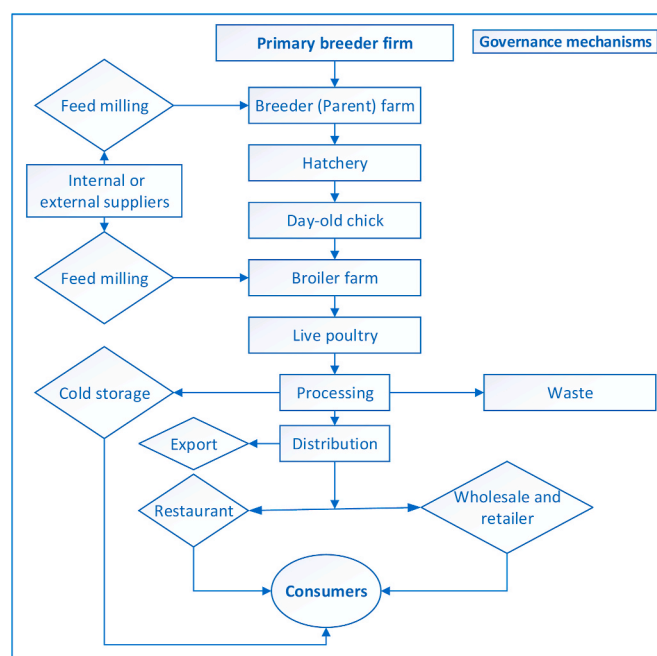

Fig. 1. Poultry supply chain (adapted from Lavaei Adaryani & Palouj, 2019; Pohlmann et al., 2020; Wiedemann et al., 2017 with some modification).
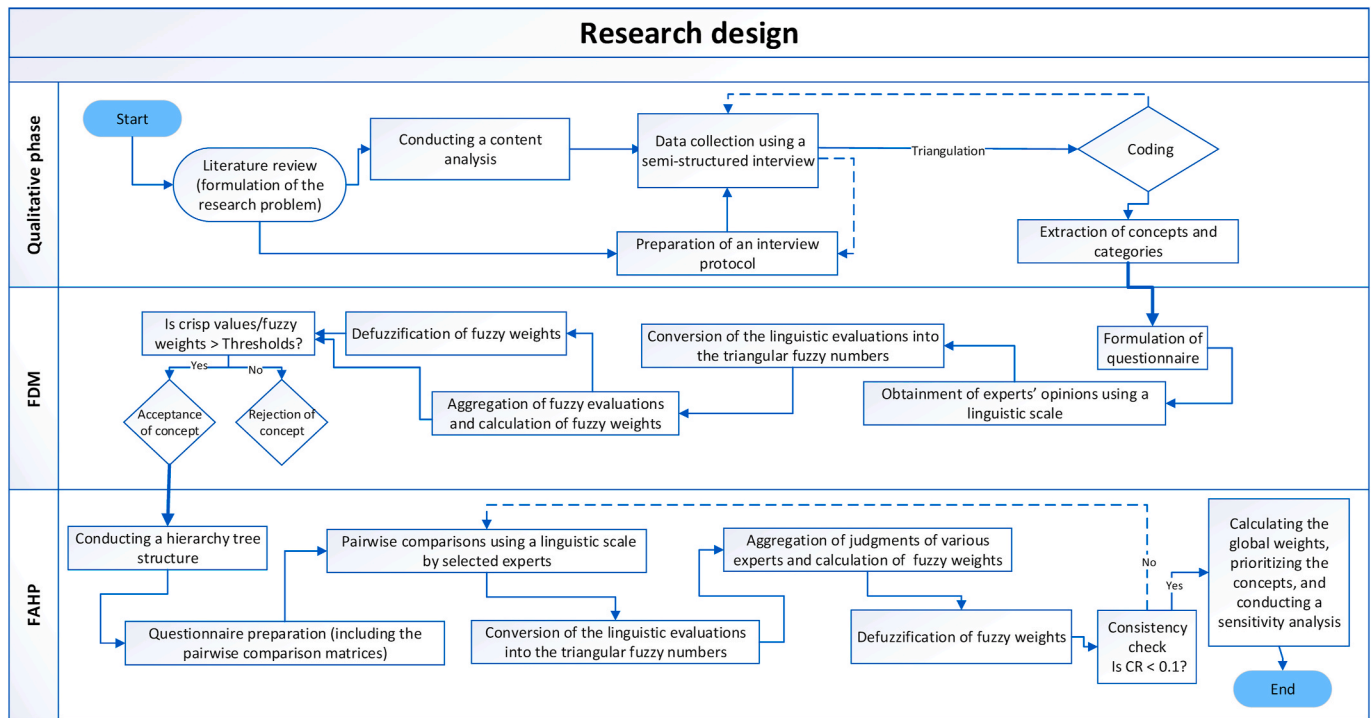
Fig. 2. Flowchart indicating the research design.

new participants until no new information and insights were emerged.

According to Choi et al. (2020), after transcribing each recorded interview, we started line-by-line reading to select the meaning units related to the impacts of the coronavirus. While keeping the core content of the meaning units intact, we condensed them as much as possible. The codes (concepts) were developed by assigning labels to the condensed meaning units (Erlingsson & Brysiewicz, 2017). Finally, with the help of the constant comparative analysis, the codes that described a similar content were assigned to a single category connected to the poultry supply chain stages. To check the validity of the coding, the investigator triangulation (Polit & Beck, 2004) was considered. To do this, the data were analyzed separately and independently by the two first authors. Then, a joint discussion was held to compare the extracted concepts with what the data say, which led to reach an agreement.

3.1.2. Quantitative phase

This study conducted a quantitative step to refine and prioritize the category and concepts that emerged from the qualitative phase. Initially, with the aim of screening, the FDM was used to select solely important concepts in each identified category. Then, the selected categories and concepts were weighted and ranked using the FAHP.

3.1.2.1. Fuzzy Delphi Method (FDM).

Delphi method as a helpful survey technique is widely used to achieve the consensus among experts (Ebrahimi & Bridgelall, 2020; Lee & Hsieh, 2016). To handle the uncertainty in dealing with the traditional Delphi method, the Fuzzy Delphi Method (FDM) was developed by Ishikawa et al. (1993) as an analytical technique. The FDM allows researchers to refine the criteria obtained from the literature or other research procedures by coming to a consensus among experts' opinions (Chang et al., 2011; Ocampo et al., 2018; Singh & Sarkar, 2020). In this study, we employed the FDM to refine the concepts that emerged from the qualitative phase in four steps as follows (Chang et al., 2011; Ebrahimi & Bridgelall, 2020):

In first step, a questionnaire was provided based on the identified concepts from the qualitative phase. 36 experts (decision makers) were invited to assess the importance of each concept on a 7-point Likert scale using linguistic variables described in Table 1. At the second step, the

Table 1
Linguistic variables and corresponding Fuzzy triangular scales indicating relative importance.

Linguistic variable	Fuzzy triangular scale
Very low	(0,0,0.1)
Low	(0,0.1,0.3)
Medium low	(0.1,0.3,0.5)
Medium	(0.3,0.5,0.7)
Medium high	(0.5,0.7,0.9)
High	(0.7,0.9,1.0)
Very high	(0.9,1.0,1.0)

Source (Bouzon et al., 2016).

linguistic evaluations were converted into the fuzzy triangular numbers, as described in Table 1. For example, where an expert chooses "very high", then the fuzzy triangular scale is considered equal to (0.9, 1.0, 1.0).

Third, according to Wu and Fang, 2011 and Bouzon et al. (2016), the fuzzy evaluations were aggregated as follows:

For jth concept importance of the ith expert, the fuzzy number is $\tilde{a}_{ij}$ which could be indicated as follows:

$$\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij}) \text{ for } i = 1, 2, 3, \ldots, n; \quad j = 1, 2, 3, \ldots, m$$

Then, the weight of concept ($a \simeq j$) is calculated as follows:
Where $\tilde{a}_{ij} = (l_j, m_j, u_j)$,

$$l_j = \min(l_{ij}), m_j = \left(\prod_i^n m_{ij} \right)^{1/n}, u_j = \max(u_{ij})$$

Finally, the fuzzy weights $\tilde{w}_i = (l_k, m_k, u_k)$ are defuzzified (crisp) using one defuzzification method. In this paper, we used the center of area (COA) method as follows (Ebrahimi & Bridgelall, 2020):

$$a_j = \frac{l_j + m_j + u_j}{3}$$

Where a_j indicates a crisp number to qualify the aggregated opinion of all experts on jth concept. After calculating the crisp (defuzzified)

numbers for all concepts, we tried to refine them through selecting more important concepts. To this end, we used the two equivalent methods. Based on the first method (Bouzon et al., 2016), we computed a fuzzy triangular number as a threshold which includes the arithmetic mean value of the fuzzy weights for all concepts. This threshold is given below:

$$THRESHOLD = \left(\frac{\sum_{k}^{n}\min(l_{ij})}{n}, \frac{\sum_{k}^{n}\left(\prod_{i}^{n}m_{ij}\right)^{1/n}}{n}, \frac{\sum_{k}^{n}\max(u_{ij})}{n} \right), k$$
$$= 1, 2, 3, \ldots, n.$$

Where k indicates the number of concepts.

The Cronbach's threshold ($\alpha = 0.7$) was considered to assess the concepts regarding their corresponding crisp values (Wu and Fang, 2011). Generally, if the crisp and/or fuzzy triangular numbers of each concept is greater than or equal to the described thresholds, then it is selected as a more important concept. Otherwise, it needs to be rejected.

3.1.2.2. Fuzzy Analytic Hierarchy Process (FAHP). The AHP as a helpful approach to make the best decision based on the set priorities, was first proposed by Saaty (1980). In order to solve multi-criteria decision--making (MCDM) problems, this approach has been widely used by researchers and decision makers in various areas such as technology (Ly et al., 2018), business industries (Govindan et al., 2014; Lee et al., 2008), supply chain (Govindan et al., 2014; Kannan et al., 2013; Mangla et al., 2015), and health and medicine (Lupo, 2016; Singh & Prasher, 2019). The AHP decomposes a problem into its constitutive elements and forms a hierarchical structure from these elements via considering the overall goal (Liu et al., 2020). This structure provides a helpful means to handle the pairwise comparison of the considered elements. The pairwise comparison in the AHP method is made by experts. Nevertheless, they do not often provide precise answers based on the quantitative values, and only focusing on their answers and converting them into the point values may not necessarily lead to reliable results in decision-making process. In such conditions, the FAHP is more efficient than the common AHP through considering the optimism/pessimism rating attitude of experts (Gumus, 2009; Ku et al., 2010). In light of this, we developed a fuzzy AHP model to prioritize those impacts of coronavirus on the poultry supply chain which have been accepted from the FDM stage. A

four-stage procedure was therefore conducted to develop this model as the following:

Firstly, the research problem was decomposed in the form of a hierarchy tree structure. The overall goal, criteria, and sub-criteria were specified at the top-down level, respectively (Fig. 3). Selecting the priorities of the coronavirus impacts on the poultry supply chain was taken into account as the overall goal at the top level of the hierarchical structure. Given this overall goal, different stages of the poultry supply chain (i.e., identified categories), and coronavirus impacts on each stage (i.e., identified concepts) were considered as the criteria and sub-criteria, respectively.

Secondly, based on the overall goal and each criterion, a questionnaire included the pairwise comparison matrices was provided. Then, 18 experts were invited to compare the criteria and sub-criteria by a linguistic scale of importance. Next, linguistic scale was converted into fuzzy triangular numbers according to Table 2. For example, where the judgment of an expert was "very important" regarding the criterion i over criterion j, the corresponding triangular fuzzy numbers were considered equal to (6, 7, 8), and conversely for the criterion j over criterion i were assigned equal to (1/8, 1/5, 1/6). According to Liu et al. (2020), Khan et al. (2019) and Kannan et al. (2013) we used the geometric mean in order to aggregate the judgments of various experts.

Thirdly, we calculated the fuzzy weights of criteria and sub-criteria.

Table 2
Linguistic variables for pairwise comparisons of criteria and sub-criteria.

Linguistic variable	Fuzzy triangular scale	Triangular fuzzy reciprocal scale
Extremely important	(9,9,9)	(1/9, 1/9, 1/9)
Intermediate	(7,8,9)	(1/9, 1/8, 1/7)
Very important	(6,7,8)	(1/8, 1/7, 1/6)
Intermediate	(5,6,7)	(1/7, 1/6, 1/5)
Important	(4,5,6)	(1/6, 1/5, 1/4)
Intermediate	(3,4,5)	(1/5, 1/4, 1/3)
Moderately important	(2,3,4)	(1/4, 1/3, 1/2)
Intermediate	(1,2,3)	(1/3, 1/2, 1)
Equally important	(1,1,1)	(1, 1, 1)

Source: adopted from Ayhan (2013); Emrouznejad and Ho (2017); Kannan et al. (2013).
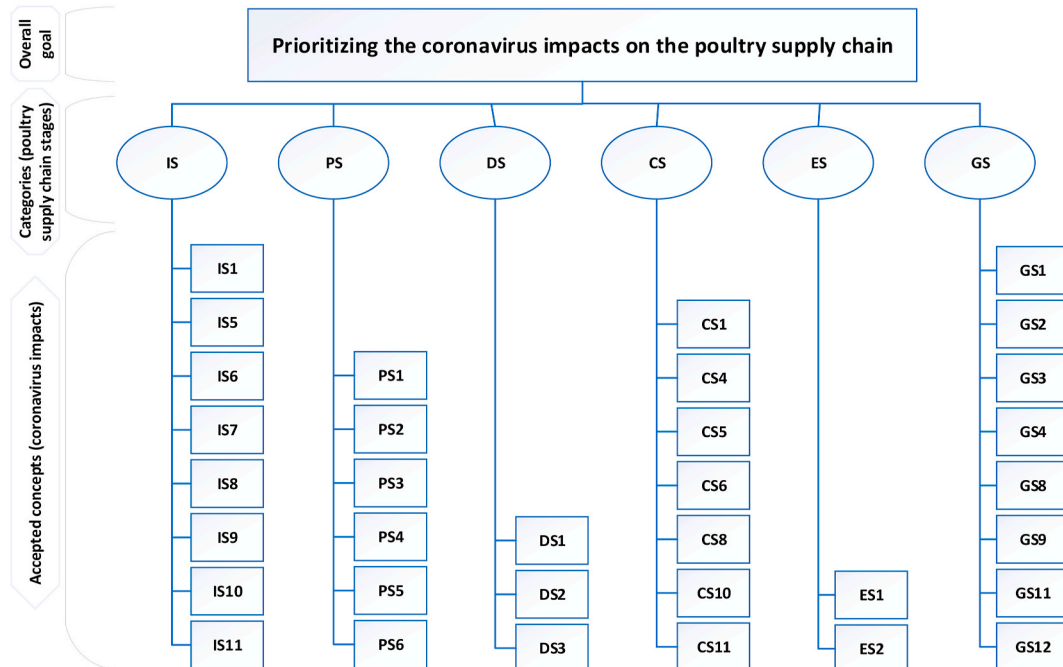

Fig. 3. Hierarchical structure of the problem.

To do this, we used the geometric mean method proposed by Buckley (1985) (Appendix A).

3.1.2.3. Sensitivity analysis. Sensitivity analysis allows researchers to evaluate the priority ranking stability (Vidal et al., 2011) by considering the sequence of changes in the weights of the criteria and sub-criteria (Mangla et al., 2015). Hence, we performed a sensitivity analysis to assess the stability of our decision-making model's components based on the method which has been used by Balusa and Gorai (2019). This method is explained in Appendix B.

4. Findings and discussion

Table 3 indicates the profile of the samples surveyed in different phases of the study. In both phases of the study, most of the respondents were male and married. Of participants, 46.26% were 50 years old or above in the qualitative phase, and most of them were 40–50 years old in various stages of the quantitative phase. Other characteristics of the surveyed samples are illustrated in Table 3.

4.1. Qualitative results

The results of the content analysis, which show different stages of the poultry supply chain affected by the coronavirus along with the disruptions related to each stage, are presented in Table 4. The impacts of the coronavirus on the poultry supply chain are summarized in six categories. Each category has been formed by grouping together those concepts that are related to each other (coronavirus impacts). The first category includes 12 concepts indicating all impacts of the coronavirus related to the supply inputs. The concepts IS5 and IS8, which imply the disruption in the input market, were mostly referred to among all concepts organized into this category. The second category consists of the coronavirus impacts related to the production and processing of the poultry meat. The major content of the interviews related to this

Table 3
Surveyed sample profile in different phases of the study.

| Sample profile | Qualitative phase | | Quantitative phase | | | |
| | | | FDM | | FAHP | |
	n	%	n	%	n	%
Gender						
Male	139	94.56%	25	69.4%	12	66.7%
Female	8	5.44%	11	30.6%	6	33.3%
Age						
<30	4	2.72%	4	11.1%	4	22.2%
30–40	9	6.12%	11	30.6%	2	11.1%
40–50	66	44.90%	12	33.3%	8	44.4%
50 or above	68	46.26%	9	25%	4	22.2%
Experience						
<5	13	8.84%	7	19.4%	5	27.8%
5–10	14	9.52%	10	27.8%	5	27.8%
10–15	55	37.41%	4	11.1%	2	11.1%
15 or above	65	44.22%	15	41.7%	6	33.3%
Occupation						
Faculty member/Researcher	9	6.12%	5	13.9%	5	27.8%
Administration manager	34	23.13%	8	22.2%	5	27.8%
Chief executive officer of integrated supply chains	44	29.93%	11	30.6%	5	27.8%
Poultry industry owner	60	40.82%	12	33.3%	3	16.7%
Relationship status						
Single	25	17.01%	25	69.4%	1	5.6%
Married	122	82.99%	11	30.6%	17	94.4%
Education						
>Academic degree	9	6.12%	5	13.9%	3	16.7%
Bachelor's degree	57	38.78%	14	38.9%	4	22.2%
Master's degree	51	34.69%	9	25%	4	22.2%
Doctoral degree	30	20.41%	8	22.2%	7	38.9%
Total	147	100%	36	100%	18	100%

Table 4
The impacts of the coronavirus on various stages of the poultry supply chain (extracted by using content analysis).

Label	Category/concept (coronavirus impacts)	Frequency (reference)	%
	Stage of input supply (IS)		
IS1	Increasing the import restrictions on raw materials due to the increase in the controlling the ports and borders	18	1.533
IS2	Increasing the export restrictions on inputs (raw materials)	4	0.341
IS3	An abrupt rise in the prices of inputs in the global and domestic markets	5	0.426
IS4	Increasing the supply restrictions on foreign currency for imports of inputs	4	0.341
IS5	A limited supply of the inputs due to the storing propensity and the expectation of scarcity in some specific materials and goods	29	2.470
IS6	A limited supply of the inputs due to extending temporary holidays for input supply-related businesses	27	2.300
IS7	Delay in the supply of inputs because of the transportation restrictions	28	2.385
IS8	Reducing hatchery production (obtaining chicks from fertile eggs) because of the market volatility	29	2.470
IS9	Rising the prices of day-old chick and other inputs, such as feed	28	2.385
IS10	Reducing the raising of chicks to produce fertile eggs for hatching (breeder)	18	1.533
IS11	Rising the prices of disinfectants and drugs	17	1.448
IS12	Reducing labor supply and rising wages due to social distancing and work remotely	4	0.341
	Production and processing stage (PS)		
PS1	Increasing the losses of the broiler producer because of the investment failure in capturing the target markets	41	3.492
PS2	Planning and investment restrictions on production process due to the unpredictability of the coronavirus crisis	40	3.407
PS3	Operation restrictions on poultry (broiler) farms due to the closure of most related businesses and the necessity to implement and respect health and safety protocols	36	3.066
PS4	Decreasing the production of poultry meat because of the input shortages	44	3.748
PS5	Closure of traditional broiler farms due to the restrictive health and safety protocols	26	2.215
PS6	Restricting the activity of non-mechanized slaughterhouses to enhance the health and safety of products	22	1.874
PS7	Reducing the use of slaughterhouses' capacity due to the decreased production	5	0.426
PS8	Reducing the expected activities of the slaughterhouses due to a drop in poultry production and its price	7	0.596
	Distribution and selling stage (DS)		
DS1	Disruption in distribution network due to transportation restrictions and market demand changes	25	2.129
DS2	Increasing the transportation costs	17	1.448
DS3	Slump in the price of poultry meat due to the decreased demand	27	2.300
DS4	Increasing the product's (poultry meat) waste due to disruption in the distribution network	5	0.426
	Consumption stage (CS)		
CS1	Decreasing demand for poultry meat because of the animal origins of the coronavirus	16	1.363
CS2	Decreasing demand for poultry meat because of media advertisements about the sensitivity of health and safety protocols	7	0.596
CS3	Decreasing demand for poultry meat because of traditional medicine recommendations concerning the necessity of reducing meat consumption due to its cold nature	6	0.511
CS4	Decreasing demand for poultry meat due to the closure of restaurants and hotels	45	3.833

Table 4 (*continued*)

Label	Category/concept (coronavirus impacts)	Frequency (reference)	%
CS5	Decreasing demand for poultry meat due to travel restrictions and the necessity to stay home	46	3.918
CS6	Decreasing demand for poultry meat due to consumers' distrust to respecting health and safety protocols in the production process	19	1.618
CS7	Decreasing demand for poultry meat due to the rising unemployment rate and reducing consumer purchasing power	6	0.511
CS8	Decreasing demand for poultry meat due to some practices such as self-quarantine and avoiding the face-to-face purchases	40	3.407
CS9	Decreasing demand for poultry meat due to spreading the rumors and misinformation	7	0.596
CS10	Decreasing demand for poultry meat due to changing pattern of the household income allocation (allocation of a major part of the income to purchase health care goods)	29	2.470
CS11	Increasing the tendency to purchase the frozen poultry meat packaged before the coronavirus outbreak	36	3.066
	Export stage (ES)		
ES1	Decreasing the export of poultry meat due to the necessity to implement and respect health and safety protocols	25	2.215
ES2	Decreasing the export of poultry meat due to the restrictions imposed on the ports and borders	26	2.215
	Governance of supply chain (GS)		
GS1	Reducing the focus on establishing an e-platform for buying and selling poultry meat during the quarantine period	44	3.748
GS2	Impossibility to assess the market demand and to stabilize the price of poultry meat due to different waves of the coronavirus outbreak	41	3.492
GS3	Reducing the government support for storage and processing of poultry meat surplus	40	3.407
GS4	Failure of the government and poultry supply chain actors to achieve the market equilibrium	33	2.811
GS5	Failure of the government to achieve macro-goals of the meat production due to lack of accurate vision during the coronavirus crisis	11	0.937
GS6	Increasing the instability of the poultry supply chain due to developing the cross-sectional plans (such as paying cash subsidies instead of non-cash subsidies to the households affected by the coronavirus)	10	0.852
GS7	Decreasing the government's focus on the national broadcasting system to provide required health advice for the consumption of poultry meat	9	0.767
GS8	Impossibility to re-open up different parties of the poultry supply chain at the same time due to the necessity to respect health and safety protocols	45	3.833
GS9	Incapability of the government to support various stages of the poultry supply chain affected by the ongoing pandemic	42	3.578
GS10	Incapability of the government to reestablish the import and export links of the poultry supply chain due to the global outbreak of the coronavirus	11	0.937
GS11	Increasing the restrictions on information flow in the poultry supply chain	31	2.641
GS12	Increasing the restrictions on the flow of material and financial resources in the poultry supply chain	36	3.066
	Total	**1174**	**100**

category was coded at the concept PS4 (3.7%). The third category describes four impacts of the coronavirus on the poultry supply chain where the concept DS3 is identified as the most important concept with the most references (2.3%). The fourth category is related to poultry

meat consumption including 11 concepts. The concepts CS5 and CS4, which show the impacts of the coronavirus on reducing demand, have received the most references among all concepts placed in this category, respectively. The fifth category has two concepts related to the coronavirus impacts on the poultry meat export. Finally, the governance of the supply chain is a category that describes the coronavirus impacts on the overall poultry supply chain. It means that the concepts embedded in this category imply the disruptions, which have challenged the coordination and arrangements of the poultry supply chain practices.

4.2. Quantitative results

4.2.1. FDM results

This study employed FDM to refine the concepts that emerged from the qualitative phase. Table 5 shows the FDM results. Out of 49 impacts of the coronavirus extracted from the qualitative phase, 34 were accepted using the FDM. Based on the threshold value of fuzzification (0.296, 0.701, 0.941) as well as that of defuzzification (0.70), the impacts IS2, IS3, IS4, and IS12 were rejected by experts in the stage of input supply. In the production and processing stage, the impacts PS7 and PS8 failed to reach the thresholds. The FDM calculations of selected or rejected impacts are indicated in Table 5 in more detail.

4.2.2. FAHP results

In order to weigh and prioritize the impacts of the coronavirus accepted by using the FDM, we employed the FAHP method. Fig. 3 indicates the hierarchical structure of the problem. In this section, each stage of the poultry supply chain is analyzed based on the priority of being affected by the coronavirus and then its disturbances are interpreted.

Table 6 shows that the input supply (IS) is the first priority among all stages (categories) of the poultry supply chain affected by the coronavirus. This finding is consistent with Cai and Luo (2020). It suggests that the coronavirus has severely disrupted the upstream of the poultry supply chain (Nikolopoulos et al., 2020). Moreover, it can be transmitted to downstream of the supply chain (Wang et al., 2020) and make it difficult for the supply chain to return to its pre-disturbance state. In this category, the limited supply of the inputs due to the storing propensity and the expectation of scarcity in some specific materials and goods (IS5) comes first (Table 7). When the supply chain actors in the upstream start panic buying the inputs needed for their production process, they indirectly allow the suppliers to hoard raw materials (Nikolopoulos et al., 2020). Delay in the supply of inputs because of the transportation restrictions (IS7) is prioritized next to IS5. We must not forget that transportation restrictions affect the entire supply chain (Jallow et al., 2020). They can initially lead to supply delays (Garvey et al., 2015; Paul et al., 2020) and then damage products gradually (Paul et al., 2020). A limited supply of the inputs due to extending temporary holidays for input supply-related businesses (IS6). As Mangla et al. (2014, 2015) argued, interconnected supply chain activities cause the overall performance of the supply chain to be affected by risks. However, disruptions in input supply-related businesses seem to have more destructive effects, because the effect of the risks is more easily transmitted to downstream of the supply chain. Reducing the hatchery production (obtaining chicks from fertile eggs) because of the market volatility (IS8) ranks fourth. It suggests that the market volatility can prevent suppliers from supplying raw materials. Thus the long-lasting market impacts (Wang et al., 2020) derived by risks would occur sooner. Increasing the import restrictions on raw materials due to the increase in the controlling the ports and borders (IS1) which agrees with Nikolopoulos et al. (2020). Therefore, it can be inferred that in turbulent situations, supply chains, which are not adequately under the control, are more severely disrupted by risks. This is very important for the countries that import raw materials, especially for the poultry industry which is heavily dependent on pandemic-related inputs (Dev, 2020). As Lavaei Adaryani and Palouj (2019) and Financial Tribune (2020)

Table 5
FDM results for screening the impacts of coronavirus on the poultry supply chain.

Impacts	Fuzzy numbers (Fuzzy weights)	Defuzzification	Result	Impacts	Fuzzy numbers (Fuzzy weights)	Defuzzification	Result
IS1	(0.5,0.844,1)	0.781	Accepted	CS3	(0,0.271,0.7)	0.324	Rejected
IS2	(1,0.468,0.9)	0.489	Rejected	CS4	(0.5,0.933,1)	0.811	Accepted
IS3	(0,0.178,0.9)	0.359	Rejected	CS5	(0.5,0.944,1)	0.815	Accepted
IS4	(0,0.226,0.7)	0.309	Rejected	CS6	(0.3,0.880,1)	0.727	Accepted
IS5	(0.5,0.89,1)	0.797	Accepted	CS7	(0,0.328,1)	0.443	Rejected
IS6	(0.5, 0.876,1)	0.792	Accepted	CS8	(0.5,0.936,1)	0.812	Accepted
IS7	(0.3,0.857,1)	0.719	Accepted	CS9	(0,0.310,0.7)	0.337	Rejected
IS8	(0.5,0.902,1)	0.801	Accepted	CS10	(0.3,0.801,1)	0.700	Accepted
IS9	(0.3,0.881,1)	0.727	Accepted	CS11	(0.5,0.950,1)	0.817	Accepted
IS10	(0.3,0.804,1)	0.701	Accepted	ES1	(0.7,0.951,1)	0.884	Accepted
IS11	(0.3,0.8,1)	0.700	Accepted	ES2	(0.3,0.844,1)	0.715	Accepted
IS12	(0,0.140,0.5)	0.213	Rejected	GS1	(0.5,0.936,1)	0.812	Accepted
PS1	(0.5,0.924,1)	0.808	Accepted	GS2	(0.3,0.892,1)	0.731	Accepted
PS2	(0.5,0.912,1)	0.804	Accepted	GS3	(0.5,0.864,1)	0.788	Accepted
PS3	(0.5,0.894,1)	0.798	Accepted	GS4	(0.3,0.842,1)	0.714	Accepted
PS4	(0.5,0.916,1)	0.805	Accepted	GS5	(0,0.463,1)	0.488	Rejected
PS5	(0.3,0.879,1)	0.726	Accepted	GS6	(0,0.427,0.9)	0.442	Rejected
PS6	(0.3,0.868,1)	0.723	Accepted	GS7	(0,0.328,1)	0.443	Rejected
PS7	(0,0.214,0.9)	0.371	Rejected	GS8	(0.5,0.934,1)	0.811	Accepted
PS8	(0,0.217,0.7)	0.306	Rejected	GS9	(0.3,0.9,1)	0.733	Accepted
DS1	(0.7,0.954,1)	0.885	Accepted	GS10	(0,0.298,0.9)	0.399	Rejected
DS2	(0.3,0.803,1)	0.701	Accepted	GS11	(0.5,0.897,1)	0.799	Accepted
DS3	(0.5,0.898,1)	0.799	Accepted	GS12	(0.3,0.808,1)	0.703	Accepted
DS4	(0,0.192,0.7)	0.297	Rejected	*THRESHOLD*	*(0.296, 0.701, 0.941)*		
CS1	(0.3,0.876,1)	0.725	Accepted	*THRESHOLD(α)*		*0.70*	
CS2	(0,0.297,0.7)	0.332	Rejected				

Table 6
Estimated weights of the categories.

Category (criterion)	Sorted weights
IS	0.3453
GS	0.3423
PS	0.1226
CS	0.0982
ES	0.0519
DS	0.0396
Consistency check	λ_{max} = 6.4599, CI = 0.09198, RI = 1.26, CR = 0.07

reported, Iran imports approximately 80% of the raw materials needed for the manufacturing of poultry feed (mainly corn) per year. Finally, rising the prices of day-old chick and other inputs, such as feed (IS9), reducing the raising of chicks to produce fertile eggs for hatching (breeder) (IS10), and rising the prices of disinfectants and drugs (IS11) are ranked next to IS1, respectively. Previous studies (Dev, 2020; Garvey et al., 2015; Kumar et al., 2020; Paul et al., 2020; Wang et al., 2020) have also confirmed that price fluctuations, as well as disruption of operations, are the consequences of risks such as the coronavirus. Because of these consequences, supply chains may be exposed to various losses, such as loss of sale, in downstream part.

The governance of the supply chain (GS) is prioritized next to the input supply (IS), implying that the coronavirus has affected the ability of actors to manage their relations with others in the supply chain (Gimenez & Sierra, 2013). In this stage (category), the impossibility to assess the market demand and to stabilize the price of poultry meat due to different waves of the coronavirus outbreak (GS2) holds first rank. As Dev (2020) has acknowledged, during the coronavirus outbreak, the market access opportunities have been decreased for poultry farmers. This is because the coronavirus outbreak is highly unpredictable compared to almost all other risks, such as earthquakes, it would therefore be more destructive (de Oliveira et al., 2019). Reducing the focus on establishing an e-platform for buying and selling poultry meat during the quarantine period (GS1) holds second. During the pandemic, some consumers are concerned about ordering food through online platforms (Narayanan et al., 2020), where these platforms receive more attention than physical purchasing. However, the government is likely

to fail to develop them due to a focus on the medical sector instead of supply chain management. Impossibility to re-open up different parties of the poultry supply chain simultaneously due to necessity to respect health and safety protocols (GS8) comes third. This means that only some businesses related to the supply chain can be reopened (Lemke et al., 2020), which results in performance deterioration. In fact, due to the absence of some partners in the supply chain, actors cannot receive the necessary links to stabilize their operations. Reducing the government support for storage and processing of poultry meat surplus (GS3), the failure of the government and poultry supply chain actors to achieve the market equilibrium (GS4), and the incapability of the government to support various stages of the poultry supply chain affected by the ongoing pandemic (GS9) are all prioritized next to GS8, respectively. This suggests that the poultry market disruptions cannot be controlled through the cooperation of the government and supply chain actors partly due to the indirect effects of the coronavirus on the input supply and partly because of the direct effects of the epidemic on the consumption. Such disruptions, which have long-lasting impacts on the market (Wang et al., 2020), are as the result of the prolonged outbreak of the epidemic (Tsallis & Tirnakli, 2020). Thus, unknown epidemics are posed as serious risks for the supply chain governance. Increasing the restrictions on information flow in the poultry supply chain (GS11) and increasing the restrictions on the flow of material and financial resources in the poultry supply chain (GS12) come at last, respectively.

The production and processing stage (PS) as the third stage affected by the coronavirus (Coluccia et al., 2021), is prioritized next to the governance of the supply chain (GS). In this stage, increasing the losses of the broiler producer because of the investment failure in capturing the target markets (PS1) and operation restrictions on the poultry (broiler) farms due to the closure of most related businesses and the necessity to implement and respect health and safety protocols (PS3) come first and second in the priority list, respectively. In addition, decreasing the production of poultry meat because of the input shortages (PS4) holds third rank. These suggest that shocks caused by the closure of the input supply-related businesses could affect the production-related businesses (Paul et al., 2020; Wang et al., 2020; Cai & Luo, 2020), and then lead to decrease the returns on investment through poultry farmers' failure to access the target markets. Planning and investment restrictions on production process due to the unpredictability of the coronavirus crisis

Table 7
Local and global weights and ranking for all categories and concepts.

Category (criterion)	weights	Impact (concept or sub-criterion)	Sorted Relative weights	Global weights	Global rank	Consistency check
IS	0.3453	IS5	0.2719	0.0939	2	λ_{max} = 9.01814, CI = 0.14545
		IS7	0.2172	0.0750	3	RI = 1.41, CR = 0.10
		IS6	0.2019	0.0697	4	
		IS8	0.0975	0.0337	11	
		IS1	0.0885	0.0306	12	
		IS9	0.0556	0.0192	17	
		IS10	0.0362	0.0125	22	
		IS11	0.0312	0.0108	27	
PS	0.1226	PS1	0.4217	0.0517		λ_{max} = 8.98798, CI = 0.14114
		PS3	0.2477	0.0304	13	RI = 1.41, CR = 0.10
		PS4	0.1420	0.0174	19	
		PS2	0.0948	0.0116	24	
		PS5	0.0557	0.0068	29	
		PS6	0.0380	0.0047	31	
DS	0.0396	DS3	0.6379	0.0253	14	λ_{max} = 6.52951, CI = 0.1059
		DS1	0.2759	0.0109	26	RI = 1.26, CR = 0.08
		DS2	0.0861	0.0034	34	
CS	0.0982	CS4	0.3597	0.0353	10	λ_{max} = 7.62343, CI = 0.10391
		CS8	0.1936	0.0190	18	RI = 1.36, CR = 0.076
		CS5	0.1572	0.0154	20	
		CS6	0.1511	0.0148	21	
		CS10	0.0538	0.0053	30	
		CS11	0.0398	0.0039	33	
		CS1	0.0447	0.0044	32	
ES	0.0519	ES1	0.8305	0.0431	9	λ_{max} = 2, CI = 0
		ES2	0.1695	0.0088	28	RI = 0, CR = 0
GS	0.3423	GS2	0.2985	0.1022	1	λ_{max} = 3.05746, CI = 0.02873
		GS1	0.1957	0.0670	5	RI = 0.52, CR = 0.055
		GS8	0.1654	0.0566	6	
		GS3	0.1532	0.0525	7	
		GS4	0.0606	0.0207	15	
		GS9	0.0600	0.0205	16	
		GS11	0.0342	0.0117	23	
		GS12	0.0325	0.0111	25	

(PS2) ranks fourth. This agrees with the study by Ratten (2020) which emphasizes that the coronavirus crisis is unpredictable. The closure of traditional broiler farms due to the restrictive health and safety protocols (PS5) is prioritized next to PS2. Restricting the activity of non-mechanized slaughterhouses to enhance the health and safety of products (PS6) comes at last. This shows that unlike common risks, controlling the epidemics affecting supply chains requires constant planning and decision-making by health authorities (de Paulo Farias & de Araújo, 2020).

The consumption stage (CS) as the fourth stage affected by the coronavirus, is prioritized next to the production and processing stage (PS). It is not surprising because some impacts of the coronavirus, such as impacts on consumption, are likely to be smoothed out in a short time (Wang et al., 2020). It represents that the outbreak of the epidemic initially leads to a decrease in demand (Kumar et al., 2020; Lu et al., 2020; Narayanan et al., 2020; Nchanji et al., 2021; Nikolopoulos et al., 2020) for the poultry meat, but it does not last for the long-term (Wiedemann et al., 2017). In this stage, decreasing demand for poultry meat due to the closure of restaurants and hotels (CS4) is at the top ranking, a finding supported by previous studies (de Paulo Farias & de Araújo, 2020; Richards & Rickard, 2020). More precisely, as Richards and Rickard (2020) pointed out, the closure of restaurants, as one of the major customers of poultry meat, significantly reduces demand. Decreasing demand for the poultry meat due to some practices such as self-quarantine and avoiding the face-to-face purchases (CS8) occupies second place next to CS4. In this regard, Narayanan et al. (2020) pointed out that the consumers avoid not only face-to-face but also online purchasing. Decreasing demand for the poultry meat due to travel restrictions and the necessity to stay home (CS5) holds third rank. Also, decreasing demand for poultry meat due to consumers' distrust to respecting health and safety protocols in the production process (CS6) and decreasing demand for poultry meat due to changing pattern of the

household income allocation (allocation of a major part of the income to purchase health care goods) (CS10) are prioritized next to CS5, respectively. Previous studies (de Paulo Farias & de Araújo, 2020; Kumar et al., 2020) have confirmed that the coronavirus has undesirable consequences including the rise in the unemployment rate, decline the household income, and the reduction of purchasing power, which lead to a change in demand for food. On this basis, consumers are expected to devote their limited income to purchasing more essential goods. Finally, increasing the tendency to purchase the frozen poultry meat packaged before the coronavirus outbreak (CS11), and decreasing demand for poultry meat because of the animal origins of the coronavirus (CS1) hold the last place in the priority list, respectively. These suggest that in a pandemic, consumers' distrust (Narayanan et al., 2020) and rumors (Dev, 2020; Kumar et al., 2020) are important factors that affect demand for products.

The export stage (ES), and distribution and selling stage (DS) are prioritized as the last stages of the poultry supply chain affected by the coronavirus, a finding that is consistent with the results of Tougeron and Hance (2021). In the export stage, decreasing the export of poultry meat due to the necessity to implement and respect health and safety protocols (ES1), and decreasing the export of poultry meat due to the restrictions imposed on the ports and borders (ES2) come first and second in the priority list, respectively. These suggest that the restrictions made due to the coronavirus outbreak not only disrupt supply chains in upstream but also in downstream (Nikolopoulos et al., 2020). Finally, in the distribution and selling stage, the slump in the price of poultry meat due to the decreased demand (DS3) comes first. Fluctuations in demand, especially in the early months of the coronavirus outbreak, have severely affected food prices (Dev, 2020; Nikolopoulos et al., 2020). Therefore, in order to balance the market, managers should pay attention to the day-to-day fluctuations in demand at the very beginning of the epidemics. Disruption in distribution network due to transportation

restrictions and market demand changes (DS1), and increasing the transportation costs (DS2) hold second and third places in this stage, respectively. Because of the importance of transportation across all stages of supply chains, its disruptions can lead to the problems that ultimately challenge the market (Paul et al., 2020).

4.2.3. Sensitivity analysis

Table 8 shows the sensitivity analysis on the results of the FAHP. For six uncertainty values (i.e., α = 0, 0.2, 0.4, 0.6, 0.8, and 1) in three decision-making attitudes (optimistic (λ = 1), pessimistic (λ = 0), and neutral (λ = 0.5)), the results indicate that the rank of all stages (categories) of the poultry supply chain except IS and GS remains unchanged. Given λ = 0, IS is at the top ranking under four different values of uncertainty (α = 0.4, 0.6, 0.8, and 1). This is true for λ = 0.5 (α = 0, 0.4, 0.8, and 1); however, regarding λ = 1, the rank of GS is at the top under various uncertainty values including 0.2, 0.6, 0.8, and 1. As a result, based on different combinations of λ and α values, IS occupies the highest rank for more times, and therefore is more stable than GS.

Similarly, a sensitivity analysis on the concepts (sub-criteria) was performed based on different λ and α values. Fig. 4 indicates that where λ equals 1, the rank of concepts is slightly stable while changing the α values. This is somewhat true for λ = 0. It is observed that with changes in the values of α and λ, GS2 and IS5 occupy the first and second priorities, respectively. The ranking of the concepts was significantly altered by changing α from zero to 0.2, where λ is equal to 0.5.

5. Conclusion and implications

Undoubtedly, all supply chains are disrupted by epidemic outbreaks. In this study, we first addressed those stages of the poultry supply chain disrupted by an ongoing pandemic and then particularly elaborated disruptions associated with each stage. Therefore, our study contributes to the supply chain management literature by exploring a set of supply chain operations and stages disrupted by the coronavirus. This study also advances relevant literature by addressing unique disturbances in each identified stage of an important and vulnerable supply chain (i.e., poultry supply chain). Lastly, our study is significant because it identifies vulnerable aspects of the supply chain by examining specific risk situations. Our conclusions and remarks are as follows:

- The input supply as a stage of the poultry supply chain in the context of a developing country is more severely disrupted by the epidemic outbreak. Thus, a part of the disruptions that occur in the downstream of the supply chain is due to the epidemic's direct adverse effects, and another part is due to the indirect consequences received from the upstream.
- The poultry supply chain governance has been severely disrupted due to ongoing waves of the epidemic outbreaks of novel coronavirus. This suggests that collaborations and interactions at the macro level have been severely affected and other relevant supply chains are likely to be at risk.
- Although the epidemic outbreak has reduced poultry meat consumption, it is not very significant; because this is controlled by some short-term events such as rumors, panic buying, closing the restaurants and hotels, etc., which are certainly not stable.
- Since epidemic outbreaks directly lead to transportation disruptions, the stages of supply chains that are more transportation-dependent such as distribution and input supply are more likely to be affected by epidemics of infectious disease.

Our results are important for the supply chain managers and business owners, particularly in the food supply chains, because it allows them to identify the vulnerable stages in their own supply chain and then make appropriate decisions if the epidemic outbreak or even similar situations persist. This study also has practical implications that will be of interest to the government officials and policy-makers. Generally, our study

Table 8
Changes in relative weight and rank of the poultry supply chain stages (criteria) related to the impacts of the coronavirus by sensitivity analysis.

Criterion	Normal	λ = 0						λ = 0.5						λ = 1					
		α = 0	α = 0.2	α = 0.4	α = 0.6	α = 0.8	α = 1	α = 0	α = 0.2	α = 0.4	α = 0.6	α = 0.8	α = 1	α = 0	α = 0.2	α = 0.4	α = 0.6	α = 0.8	α = 1
IS	0.34532 (1)	0.33518 (2)	0.34279 (2)	0.35746 (1)	0.35377 (1)	0.34817 (1)	0.40048 (1)	0.34809 (1)	0.33988 (2)	0.35394 (1)	0.34305 (2)	0.34511 (1)	0.34809 (1)	0.35277 (1)	0.33762 (2)	0.35117 (1)	0.33117 (2)	0.34296 (2)	0.34555 (2)
PS	0.12262 (3)	0.11978 (3)	0.12529 (3)	0.13039 (3)	0.13016 (3)	0.12793 (3)	0.12798 (3)	0.12307 (3)	0.12869 (3)	0.12751 (3)	0.12312 (3)	0.12313 (3)	0.12307 (3)	0.12607 (3)	0.13111 (3)	0.12523 (3)	0.11658 (3)	0.12006 (3)	0.11938 (3)
DS	0.03963 (6)	0.03727 (6)	0.03953 (6)	0.04305 (6)	0.04568 (6)	0.04327 (6)	0.03846 (6)	0.03990 (6)	0.04017 (6)	0.04132 (6)	0.03991 (6)	0.03992 (6)	0.03990 (6)	0.04257 (6)	0.04054 (6)	0.03998 (6)	0.03519 (6)	0.03786 (6)	0.03745 (6)
CS	0.09823 (4)	0.09826 (4)	0.10002 (4)	0.10702 (4)	0.10044 (4)	0.09989 (4)	0.09754 (4)	0.09832 (4)	0.09907 (4)	0.10604 (4)	0.09908 (4)	0.09878 (4)	0.09832 (4)	0.09918 (4)	0.09829 (4)	0.10515 (4)	0.09712 (4)	0.09761 (4)	0.09689 (4)
ES	0.05188 (5)	0.04455 (5)	0.04754 (5)	0.05293 (5)	0.06062 (5)	0.05215 (5)	0.04764 (5)	0.05296 (5)	0.04686 (5)	0.05245 (5)	0.05115 (5)	0.05190 (5)	0.05296 (5)	0.05955 (5)	0.04630 (5)	0.05201 (5)	0.04281 (5)	0.05146 (5)	0.05239 (5)
GS	0.34232 (2)	0.36496 (1)	0.34484 (1)	0.30915 (2)	0.30933 (2)	0.32859 (2)	0.28790 (2)	0.33767 (2)	0.34532 (1)	0.31874 (2)	0.34369 (1)	0.34116 (2)	0.33767 (2)	0.31985 (2)	0.34613 (1)	0.32646 (2)	0.37712 (1)	0.35005 (1)	0.34834 (1)

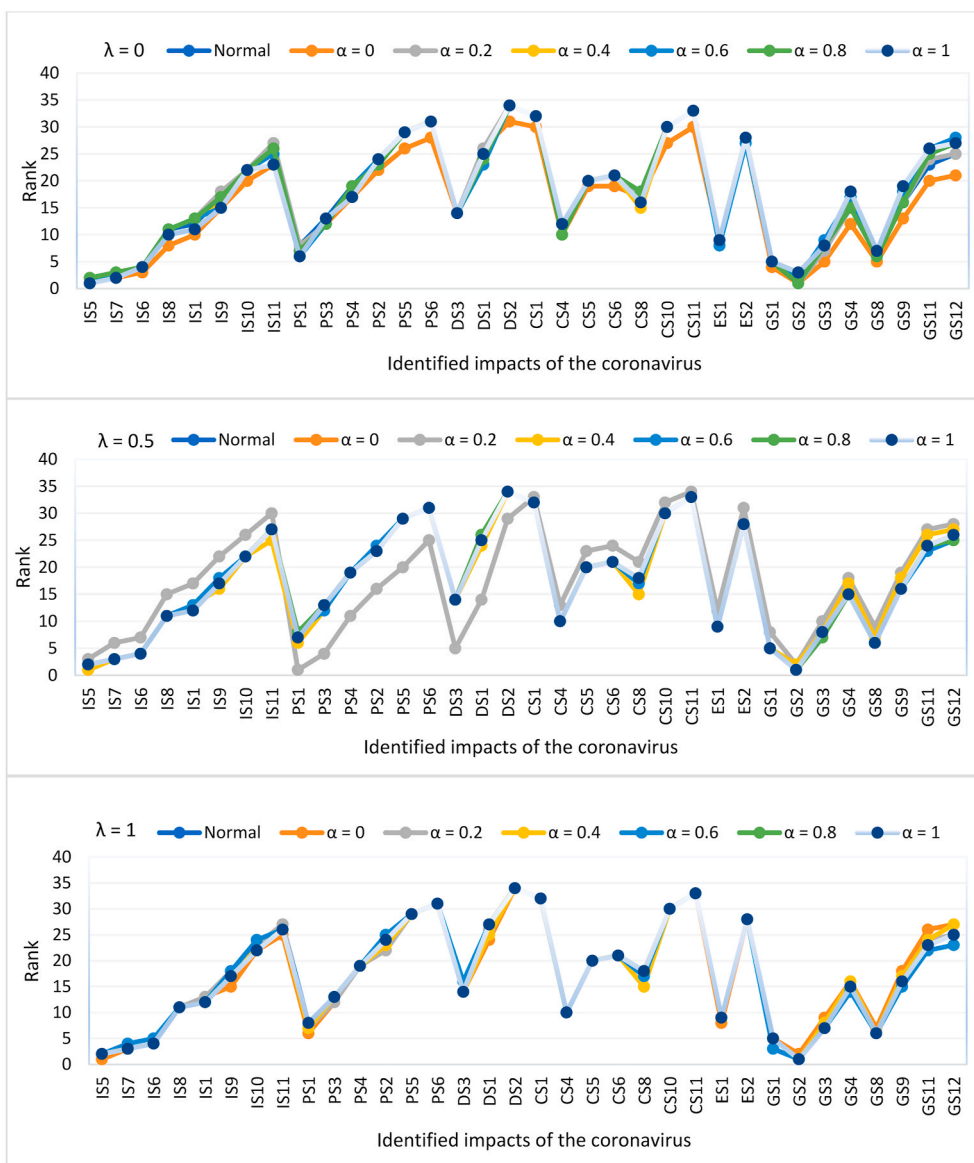(1), (2), (3), (4), (5), and (6) refer to criteria ranks.

Fig. 4. Changes in the rank (priority) of the identified impacts of the coronavirus on the poultry supply chain (sub-criteria) by sensitivity analysis.

provides several practical implications as follows:

Based on the results, managers need to put more effort into the upstream management of the supply chain to avoid disruptions in the downstream. Since the supply of inputs has been disrupted due to transportation and import restrictions, and the expectation of scarcity in some specific materials and goods, managers may interact with multiple suppliers in close distance proximity, possibly adopting sustainable transportation routing decision, inspired to both economic and environmental dynamics (Micale et al., 2019). Also, actors who work in R&D units of supply chains should be encouraged to seek alternatives for imported raw materials required to produce poultry feed. It is suggested that required raw materials would be provided through the contract farming, wherein domestic preferred farmers commit to producing raw materials and the managers commit to purchasing them (Ragasa et al., 2018). Generally, agri-food supply chains that are biologically more sensitive to the flow of feed inputs should consider a combination of the above-mentioned implications.

According to the results, government officials should consider the dependence of the parties on each other when deciding to re-open the businesses embedded in the supply chain. Since the market has been severely affected by the epidemic outbreak, the government should

balance it by storing the surplus produced poultry meats, while supporting the producers. Similarly, the government's interventions and supports seem to be helpful to balance the market during epidemic outbreaks. Lastly, efforts should be made to dispel the rumors about the role of food in the transmission of infection using capabilities of the communication media.

In order to decrease the effects of the coronavirus on food consumption, particularly poultry meat, it is necessary to consider the facilities required for the development of products' processing and packaging and the use of cold storage capacities. This would prevent the spread of infection and would increase the consumer trust during the epidemic outbreak. This is especially important in the context of developing countries, which should be considered across the whole poultry supply chain (not integrators).

As with any study, this one is not without limitation. This survey was conducted based on data collected from Iran as a developing country. Therefore, the results are specifically applicable for the developing countries. This is because the impacts of the coronavirus outbreak in developed countries are dissimilar to developing countries due to the state of infrastructure, culture, access to technology, etc. In addition, coronavirus as an ongoing and unknown crisis has diverse impacts on

various supply chains depending on the situation that the impacts may change after each wave. It is therefore important to interpret the results of this study, which is related solely to a period of the disease outbreak, with caution. Future research may focus on data from developed countries to provide further insights into the impact of this epidemic on different supply chains.

CRediT authorship contribution statement

Mojtaba Palouj: Conceptualization, Supervision, Project administration. **Rasool Lavaei Adaryani:** Methodology, Software, Formal analysis, Investigation, Writing – review & editing. **Amir Alambeigi:** Investigation, Writing – review & editing, Funding acquisition. **Maryam Movarej:** Methodology, Software, Conceptualization, Funding acquisition. **Yahya Safi Sis:** Conceptualization, Formal analysis, Funding acquisition.

Declaration of competing interest

We have no conflicts of interest to disclose.

Appendix A

According to Buckley's (1985) method, $\widetilde{D} = [\widetilde{a}_{ij}]$ as a fuzzy pairwise comparison matrix, where $\widetilde{a}_{ij}$ is the relative importance of a_i over a_j, is set as follows:

$$\widetilde{D} = \begin{bmatrix} (1,1,1) & \widetilde{a}_{12} & \dots & \widetilde{a}_{1n} \\ \widetilde{a}_{21} & (1,1,1) & \dots & \widetilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{a}_{n1} & \widetilde{a}_{n2} & \dots & (1,1,1) \end{bmatrix}$$

Where $\widetilde{a}_{ij} \times \widetilde{a}_{ji} \approx 1$, $\widetilde{a}_{ij} \cong \frac{w_i}{w_j}$, i, j = 1, 2, …, n.

For each criterion i in the fuzzy pairwise comparison matrix, the fuzzy geometric mean $(\widetilde{r})$ is given as in the following:

$$\widetilde{r} = \left(\prod_i^n \widetilde{a}_{ij} \right)^{1/n} \text{ or } \widetilde{r} = \sqrt[n]{\widetilde{a}_{i1} \times \widetilde{a}_{i2} \times \dots \times \widetilde{a}_{in}}$$

Then the fuzzy weights $(\widetilde{w}_i)$ for each criterion i is computed as follows:

$$\widetilde{w}_i = \widetilde{r}_i \times \left(\widetilde{r}_1 + \widetilde{r}_2 + \dots + \widetilde{r}_n \right)^{-1}$$

Where $\widetilde{r}_k = (l_k, m_k, u_k)$, $(\widetilde{r}_k)^{-1} = (\frac{1}{u_k}, \frac{1}{m_k}, \frac{1}{l_k})$

Finally, the defuzzification of fuzzy weights $\widetilde{w}_i = (l_k, m_k, u_k)$ are defuzzified using the center of area (COA) method as just described earlier.

We calculated the global weight of each sub-criteria by multiplying its defuzzified weight (relative weight) with the defuzzified weight of its related criterion (i.e., poultry supply chain stage).

Forth, as the final stage, consistency check of each pairwise comparison matrix was considered. To calculate the consistency ratio (CR), we computed the largest eigenvalue (λ_{max}) for each pairwise comparison matrix of order n. We calculated the consistency index (CI) as follows:

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

Finally, we calculated the consistency ratio by the formulae:

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

Where the RI is a random index dependent on the size of the matrices and it is found according to Table 9 (Saaty, 2000). CR value less than or equal to 0.1 were taken as positive evidence to indicate reasonable consistency in the pairwise comparison matrices.

Appendix B

According to Balusa and Gorai (2019), first, we specified the lower and upper bound of the fuzzy numbers regarding to α-cut values as follows (Balusa & Gorai, 2019; Gorai et al., 2015):

$$\overline{x}_\alpha = \left[x - \alpha, \quad x + \alpha \right]; \frac{1}{\overline{x}_\alpha} = \left[\frac{1}{x+\alpha}, \quad \frac{1}{x-\alpha} \right]$$

Table 9
Values of the random index (RI).

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49

Where α indicates uncertainty in the range of 0–1 (1 show the most uncertainty). According to Balusa and Gorai (2019), we considered α with value varying from 0 to 1 with 0.2 as increment (i.e., 0, 0.2, 0.4, 0.6, 0.8, and 1). Also, $\bar{x}_\alpha$ represents the judgment of the experts based on the linguistic variable in Table 1 (for example, where the judgment of an expert was the strong importance of criterion *i* over criterion *j*, $\bar{x}_{0.2}$ specified equals [3.8, 4.2].

Second, after formulating the fuzzy pairwise comparison matrices for each set of criteria and sub-criteria by above formula, we converted these fuzzy pairwise comparison matrices into crisp pairwise comparison matrices as follows:

$$a_{ij}^\alpha = \lambda a_{iju}^\alpha + (1-\lambda)a_{ijl}^\alpha$$

Where a_{ijl}^α and a_{iju}^α are defuzzified (crisp) values that represent the lower and upper bound of relative importance value a_{ij}, respectively. In addition, λ indicates the decision-making attitude, accepting any values ranging from 0 to 1. In line with Balusa & Gorai's (2019) recommendation, we choice λ equal to 1, 0, and 0.5 for optimistic, pessimistic, and neutral conditions, respectively. That is, the crisp pairwise comparison matrices relevant to each fuzzy pairwise comparison matrix were formulated for three values of λ. In summary, we computed weights of criteria and sub-criteria included in the crisp pairwise comparison matrices obtained by combining a six-value set of α and three values of λ. Changes in these weights provided information to understand the stability of priority ranking.

References

Ambulkar, S., Blackhurst, J., & Grawe, S. (2015). Firm's resilience to supply chain disruptions: Scale development and empirical examination. *Journal of Operations Management, 33*, 111–122.

Apostolopoulos, Y., & Sönmez, S. (2007). Tracing the diffusion of infectious diseases in the transport sector. In *Population mobility and infectious disease* (pp. 131–156). Springer.

Ariffin, A., & Abas, Z. (2015). Literature ratified knowledge based view of poultry supply chain integration concept. *Journal Teknologi (Sciences & Engineering), 77*(27), 35–39. https://pdfs.semanticscholar.org/757b/8846df29ebab7a0d36fe0a82082a754e3f2d.pdf.

Ayhan, M. B. (2013). *A fuzzy AHP approach for supplier selection problem: A case study in a gear motor company*. ArXiv Preprint ArXiv:1311.2886.

Balusa, B. C., & Gorai, A. K. (2019). Sensitivity analysis of fuzzy-analytic hierarchical process (FAHP) decision-making model in selection of underground metal mining method. *Journal of Sustainable Mining, 18*(1), 8–17.

Bode, C., Wagner, S. M., Petersen, K. J., & Ellram, L. M. (2011). Understanding responses to supply chain disruptions: Insights from information processing and resource dependence perspectives. *Academy of Management Journal, 54*(4), 833–856.

Bouzon, M., Govindan, K., Rodriguez, C. M. T., & Campos, L. M. S. (2016). Identification and analysis of reverse logistics barriers using fuzzy Delphi method and AHP. *Resources, Conservation and Recycling, 108*, 182–197.

Buckley, J. J. (1985). Fuzzy hierarchical analysis. *Fuzzy Sets and Systems, 17*(3), 233–247.

Cai, M., & Luo, J. (2020). Influence of COVID-19 on manufacturing industry and corresponding countermeasures from supply chain perspective. *Journal of Shanghai Jiaotong University, 25*(4), 409–416.

Chang, P.-L., Hsu, C.-W., & Chang, P.-C. (2011). Fuzzy Delphi method for evaluating hydrogen production technologies. *International Journal of Hydrogen Energy, 36*(21), 14172–14179.

Choi, S., Yang, E. C. L., & Tabari, S. (2020). Solo dining in Chinese restaurants: A mixed-method study in Macao. *International Journal of Hospitality Management, 90*, Article 102628.

Chowdhury, M. A., Hossain, N., Kashem, M. A., Shahid, M. A., & Alam, A. (2020). Immune response in COVID-19: A review. *Journal of Infection and Public Health, 13* (11), 1619–1629.

Coluccia, B., Agnusdei, G. P., Miglietta, P. P., & De Leo, F. (2021). Effects of COVID-19 on the Italian agri-food supply and value chains. *Food Control, 123*(107839), 1–11.

Cortez, R. M., & Johnston, W. J. (2020). The Coronavirus crisis in B2B settings: Crisis uniqueness and managerial implications based on social exchange theory. *Industrial Marketing Management, 88*, 125–135.

Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Sage publications.

Dai, M., & Liu, L. (2020). Risk assessment of agricultural supermarket supply chain in big data environment. *Sustainable Computing: Informatics and Systems, 28*, Article 100420.

Dev, S. M. (2020). Addressing COVID-19 impacts on agriculture, food security, and livelihoods in India. In *IFPRI book chapters, in: COVID-19 and global food security (p. Chapter 7, 33-35)*. International Food Policy Research Institute (IFPRI).

Ebrahimi, S., & Bridgelall, R. (2020). A fuzzy Delphi analytic hierarchy model to rank factors influencing public transit mode choice: A case study. *Research in Transportation Business & Management*, 100496.

Emrouznejad, A., & Ho, W. (2017). *Fuzzy analytic hierarchy process*. CRC Press.

Erlingsson, C., & Brysiewicz, P. (2017). A hands-on guide to doing content analysis. *African Journal of Emergency Medicine, 7*(3), 93–99.

Financial Tribune. (2020). *Rise in animal feed imports*. https://financialtribune.com/articles/domestic-economy/103068/rise-in-animal-feed-imports.

Foroozesh, N., Tavakkoli-Moghaddam, R., & Mousavi, S. M. (2018). Sustainable-supplier selection for manufacturing services: A failure mode and effects analysis model based on interval-valued fuzzy group decision-making. *International Journal of Advanced Manufacturing Technology, 95*(9–12), 3609–3629.

Fusco, G., Miglietta, P. P., Porrini, D., & others. (2018). How drought affects agricultural insurance policies: The case of Italy. *Journal of Sustainable Development, 11*(1).

Galanakis, C. M. (2020). The food systems in the era of the Coronavirus (COVID-19) pandemic crisis. *Foods, 9*(4), 523.

Galanakis, C. M. (2021). Functionality of food components and emerging technologies. *Foods, 10*(1), 128.

Garvey, M. D., Carnovale, S., & Yeniyurt, S. (2015). An analytical framework for supply network risk propagation: A bayesian network approach. *European Journal of Operational Research, 243*(2), 618–627.

Ghadge, A., van der Werf, S., Kara, M. E., Goswami, M., Kumar, P., & Bourlakis, M. (2020). Modelling the impact of climate change risk on bioethanol supply chains. *Technological Forecasting and Social Change, 160*, Article 120227.

Giannakis, M., & Papadopoulos, T. (2016). Supply chain sustainability: A risk management approach. *International Journal of Production Economics, 171*, 455–470.

Gimenez, C., & Sierra, V. (2013). Sustainable supply chains: Governance mechanisms to greening suppliers. *Journal of Business Ethics, 116*(1), 189–203.

Gorai, A. K., Upadhyay, A., Tuluri, F., Goyal, P., Tchounwou, P. B., & others. (2015). An innovative approach for determination of air quality health index. *The Science of the Total Environment, 533*, 495–505.

Govindan, K., Kaliyan, M., Kannan, D., & Haq, A. N. (2014). Barriers analysis for green supply chain management implementation in Indian industries using analytic hierarchy process. *International Journal of Production Economics, 147*, 555–568.

Gumus, A. T. (2009). Evaluation of hazardous waste transportation firms by using a two step fuzzy-AHP and TOPSIS methodology. *Expert Systems with Applications, 36*(2), 4067–4074.

Haren, P., & Simchi-Levi, D. (2020). How Coronavirus could impact the global supply chain by mid-March. *Harvard Business Review, 28*. https://hbr.org/2020/02/how-coronavirus-could-impact-the-global-supply-chain-by-mid-march.

He, H., & Harris, L. (2020). The impact of covid-19 pandemic on corporate social responsibility and marketing philosophy. *Journal of Business Research, 116*, 176–182.

Hofmann, H., Busse, C., Bode, C., & Henke, M. (2014). Sustainability-related supply chain risks: Conceptualization and management. *Business Strategy and the Environment, 23*(3), 160–172.

Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research, 15*(9), 1277–1288.

Ishikawa, A., Amagasa, M., Shiga, T., Tomizawa, G., Tatsuta, R., & Mieno, H. (1993). The max-min Delphi method and fuzzy Delphi method via fuzzy integration. *Fuzzy Sets and Systems, 55*(3), 241–253.

Ivanov, D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. *Transportation Research Part E: Logistics and Transportation Review, 136*, Article 101922.

Jallow, H., Renukappa, S., & Suresh, S. (2020). The impact of COVID-19 outbreak on United Kingdom infrastructure sector. Smart and Sustainable Built Environment. https://doi.org/10.1108/SASBE-05-2020-0068.

Kannan, D., Khodaverdi, R., Olfat, L., Jafarian, A., & Diabat, A. (2013). Integrated fuzzy multi criteria decision making method and multi-objective programming approach for supplier selection and order allocation in a green supply chain. *Journal of Cleaner Production, 47*, 355–367.

Khan, A. A., Shameem, M., Kumar, R. R., Hussain, S., & Yan, X. (2019). Fuzzy AHP based prioritization and taxonomy of software process improvement success factors in global software development. *Applied Soft Computing, 83*, Article 105648.

Ku, C.-Y., Chang, C.-T., & Ho, H.-P. (2010). Global supplier selection using fuzzy analytic hierarchy process and fuzzy goal programming. *Quality and Quantity, 44*(4), 623–640.

Kumar, S., Maheshwari, V., Prabhu, J., Prasanna, M., Jayalakshmi, P., Suganya, P., … Jothikumar, R. (2020). Social economic impact of COVID-19 outbreak in India. *International Journal of Pervasive Computing and Communications, 16*(4), 309–319.

Lavaei Adaryani, R., & Palouj, M. (2019). *Problem analysis the structure and process of poultry value chain towards its improving* (Unpublished).

Lee, A. H. I., Chen, W.-C., & Chang, C.-J. (2008). A fuzzy AHP and BSC approach for evaluating performance of IT department in the manufacturing industry in Taiwan. *Expert Systems with Applications, 34*(1), 96–107.

Lee, T. H., & Hsieh, H.-P. (2016). Indicators of sustainable tourism: A case study from a taiwan's wetland. *Ecological Indicators, 67*, 779–787.

Lemke, M. K., Apostolopoulos, Y., & Sönmez, S. (2020). A novel COVID-19 based truck driver syndemic? Implications for public health, safety, and vital supply chains. *American Journal of Industrial Medicine, 63*(8), 659–662.

Li, Q., Guan, X., Wu, P., Wang, X., Zhou, L., Tong, Y., … others. (2020). Early transmission dynamics in Wuhan, China, of novel Coronavirus–infected pneumonia. *New England Journal of Medicine, 382*, 1199–1207.

Liu, Y., Eckert, C. M., & Earl, C. (2020). A review of fuzzy AHP methods for decision-making with subjective judgements. *Expert Systems with Applications*, Article 113738.

Lupo, T. (2016). A fuzzy framework to evaluate service quality in the healthcare industry: An empirical case of public hospital service evaluation in Sicily. *Applied Soft Computing, 40*, 468–478.

Lu, Y., Wu, J., Peng, J., & Lu, L. (2020). The perceived impact of the covid-19 epidemic: Evidence from a sample of 4807 SMEs in sichuan province, China. *Environmental Hazards, 19*(4), 1–18.

Ly, P. T. M., Lai, W.-H., Hsu, C.-W., & Shih, F.-Y. (2018). Fuzzy AHP analysis of internet of things (IoT) in enterprises. *Technological Forecasting and Social Change, 136*, 1–13.

Mangla, S. K., Kumar, P., & Barua, M. K. (2014). A flexible decision framework for building risk mitigation strategies in green supply chain using SAP–LAP and IRP approaches. *Global Journal of Flexible Systems Management, 15*(3), 203–218.

Mangla, S. K., Kumar, P., & Barua, M. K. (2015). Risk analysis in green supply chain using fuzzy AHP approach: A case study. *Resources, Conservation and Recycling, 104*, 375–390.

Micale, R., Marannano, G., Giallanza, A., Miglietta, P. P., Agnusdei, G. P., & La Scalia, G. (2019). Sustainable vehicle routing based on firefly algorithm and TOPSIS methodology. *Sustainable Futures, 1*, Article 100001.

Munir, M., Jajja, M. S. S., Chatha, K. A., & Farooq, S. (2020). Supply chain risk management and operational performance: The enabling role of supply chain integration. *International Journal of Production Economics, 227*, Article 107667.

Narasimhan, R., & Talluri, S. (2009). Perspectives on risk management in supply chains. *Journal of Operations Management, 27*(2), 114–118.

Narayanan, L., Pandit, M., Basu, S., Karmakar, A., Bidhan, V., Kumar, H., & Brar, K. (2020). *Impact of lockdown due to COVID-19 outbreak: Lifestyle changes and public health concerns in India*.

Nchanji, E. B., Lutomia, C. K., Chirwa, R., Templer, N., Rubyogo, J. C., & Onyango, P. (2021). Immediate impacts of CoV-19 pandemic on bean value chain in selected countries in sub-Saharan Africa. *Agricultural Systems, 188*, 103034.

Nikolopoulos, K., Punia, S., Schäfers, A., Tsinopoulos, C., & Vasilakis, C. (2020). Forecasting and planning during a pandemic: COVID-19 growth rates, supply chain disruptions, and governmental decisions. *European Journal of Operational Research, 290*(1), 99–115.

Ocampo, L., Ebisa, J. A., Ombe, J., & Escoto, M. G. (2018). Sustainable ecotourism indicators with fuzzy Delphi method–A Philippine perspective. *Ecological Indicators, 93*, 874–888.

Oecd/FAO. (2020). *OECD-FAO agricultural outlook*. https://doi.org/10.1787/agr-outl-data-en

de Oliveira, F. N., Leiras, A., & Ceryno, P. (2019). Environmental risk management in supply chains: A taxonomy, a framework and future research avenues. *Journal of Cleaner Production, 232*, 1257–1271.

Paul, S. K., & Chowdhury, P. (2020). A production recovery plan in manufacturing supply chains for a high-demand item during COVID-19. *International Journal of Physical Distribution & Logistics Management, 51*(2), 104–125.

Paul, S., Kabir, G., Ali, S. M., & Zhang, G. (2020). Examining transportation disruption risk in supply chains: A case study from Bangladeshi pharmaceutical industry. *Research in Transportation Business & Management,* Article 100485.

de Paulo Farias, D., & de Araújo, F. F. (2020). Will COVID-19 affect food supply in distribution centers of Brazilian regions affected by the pandemic? *Trends in Food Science & Technology, 103*, 361–366.

Pohlmann, C. R., Scavarda, A. J., Alves, M. B., & Korzenowski, A. L. (2020). The role of the focal company in sustainable development goals: A Brazilian food poultry supply chain case study. *Journal of Cleaner Production, 245*(118798), 1–13.

Polit, D. F., & Beck, C. T. (2004). *Nursing research: Principles and methods*. Lippincott Williams & Wilkins.

Porrini, D., Fusco, G., & Miglietta, P. P. (2019). Post-adversities recovery and profitability: The case of Italian farmers. *International Journal of Environmental Research and Public Health, 16*(17), 3189.

Queiroz, M. M., Ivanov, D., Dolgui, A., & Wamba, S. F. (2020). Impacts of epidemic outbreaks on supply chains: Mapping a research agenda amid the COVID-19 pandemic through a structured literature review. *Annals of Operations Research*, 1–38.

Ragasa, C., Lambrecht, I., & Kufoalor, D. S. (2018). Limitations of contract farming as a pro-poor strategy: The case of maize outgrower schemes in upper west Ghana. *World Development, 102*, 30–56.

Ratten, V. (2020). Coronavirus and international business: An entrepreneurial ecosystem perspective. *Thunderbird International Business Review, 62*(5), 629–634.

Raynolds, L. T. (2004). The globalization of organic agro-food networks. *World Development, 32*(5), 725–743.

Richards, T. J., & Rickard, B. (2020). COVID-19 impact on fruit and vegetable markets. *Canadian Journal of Agricultural Economics/Revue Canadienne d'agroeconomie, 68*(2), 189–194. https://doi.org/10.1111/cjag.12231

Rizou, M., Galanakis, I. M., Aldawoud, T. M. S., & Galanakis, C. M. (2020). Safety of foods, food supply chain and environment within the COVID-19 pandemic. *Trends in Food Science & Technology, 102*, 293–299.

Für Risikobewertung, B. (2020). Can the new type of Coronavirus be transmitted via food and objects. https://www.bfr.bund.de/cm/349/can-the-new-type-of-Coronavirus-be-transmitted-via-food-and-objects.pdf.

Saaty, T. L. (1980). *The analytic hierarchy process*. New York, NY, USA: McGrawHill international.

Saaty, T. L. (2000). *Fundamentals of decision making and priority theory with the analytic hierarchy process* (Vol. 6). RWS publications.

Singh, S., Kumar, R., Panchal, R., & Tiwari, M. K. (2020). Impact of COVID-19 on logistics systems and disruptions in food supply chain. *International Journal of Production Research*, 1–16.

Singh, A., & Prasher, A. (2019). Measuring healthcare service quality from patients' perspective: Using fuzzy AHP application. *Total Quality Management and Business Excellence, 30*(3–4), 284–300.

Singh, P. K., & Sarkar, P. (2020). A framework based on fuzzy Delphi and dematel for sustainable product development: A case of Indian automotive industry. *Journal of Cleaner Production, 246*, 118991.

Soundararajan, V., & Brown, J. A. (2016). Voluntary governance mechanisms in global supply chains: Beyond CSR to a stakeholder utility perspective. *Journal of Business Ethics, 134*(1), 83–102.

de Sousa Jabbour, A. B. L., Jabbour, C. J. C., Hingley, M., Vilalta-Perdomo, E. L., Ramsden, G., & Twigg, D. (2020). Sustainability of supply chains in the wake of the coronavirus (COVID-19/SARS-CoV-2) pandemic: Lessons and trends. *Modern Supply Chain Research and Applications*, 1–10.

Tian, H., Li, Y., Liu, Y., Kraemer, M. U. G., Chen, B., Cai, J., Li, B., Xu, B., Yang, Q., Yang, P., & others. (2020). *Early evaluation of Wuhan City travel restrictions in response to the 2019 novel Coronavirus outbreak*. Medrxiv.

Tougeron, K., & Hance, T. (2021). Impact of the COVID-19 pandemic on apple orchards in Europe. *Agricultural Systems*, 103097.

Tsallis, C., & Tirnakli, U. (2020). Predicting COVID-19 peaks around the world. *Frontiers in Physics, 8*, 217.

Valente, D., Miglietta, P. P., Porrini, D., Pasimeni, M. R., Zurlini, G., & Petrosillo, I. (2019). A first analysis on the need to integrate ecological aspects into financial insurance. *Ecological Modelling, 392*, 117–127.

Vidal, L.-A., Marle, F., & Bocquet, J.-C. (2011). Using a Delphi process and the analytic hierarchy process (AHP) to evaluate the complexity of projects. *Expert Systems with Applications, 38*(5), 5388–5405.

Wang, Y., Wang, J., & Wang, X. (2020). COVID-19, supply chain disruption and China's hog market: A dynamic analysis. *China Agricultural Economic Review, 12*(3), 427–443.

WHO. (2020). Coronavirus disease (COVID-19) outbreak. https://www.who.int.

Wiedemann, S. G., McGahan, E. J., & Murphy, C. M. (2017). Resource use and environmental impacts from Australian chicken meat production. *Journal of Cleaner Production, 140*, 675e684. https://www.sciencedirect.com/science/article/pii/S0959652616307636.

Worldometers. (2021). Coronavirus update. https://www.worldometers.info/Coronavirus/?utm_campaign=homeAdvegas1?%22.

Wu, C.-H., & Fang, W.-C. (2011). Combining the Fuzzy Analytic Hierarchy Process and the fuzzy Delphi method for developing critical competences of electronic commerce professional managers. *Quality and Quantity, 45*(4), 751–768.

Xie, X., Yang, Y., Gu, J., & Zhou, Z. (2020). Research on the contagion effect of associated credit risk in supply chain based on dual-channel financing mechanism. *Environmental Research*, Article 109356.

Yu, X., Liu, C., Wang, H., & Feil, J.-H. (2020). The impact of COVID-19 on food prices in China: Evidence of four major food products from beijing, shandong and hubei provinces. *China Agricultural Economic Review, 12*(3), 445–458.