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RESEARCH ARTICLE

Risk assessment in livestock supply chain using the MCDM method: a case of emerging economy

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Abstract

The purpose of the study is to identify and assess the risks related to the livestock supply chain. The major risk related to the livestock supply chain are identified through the comprehensive literature review and finalized with the help of the expert's feedback. Initially, seventeen major livestock supply chain risks are finalized, and these risks are categorized into four major dimensions. Further, analytical hierarchical process (AHP) is used to prioritize these identified major risks based on their severity. Finally, sensitivity analysis is conducted to check the robustness of the risk priorities. The result shows that "input supply risk" is the most significant risk dimension followed by "production risk," "post-harvest risk," and "marketing & price risk." The finding also suggests that "poor quality and under supply of feed and fodder," "lack of proper waste disposal," and "absence of certification for the quality of animals" are the major risks among all seventeen risks. The highest priority risks are input supply risks which require the attention of the livestock supply chain partners. The proposed research framework is used to identify and analyze the livestock supply chain risks. The findings of this research might be beneficial for the farmers and other livestock supply chain stakeholders in developing policies/plans/strategies to control the risk in their livestock supply chain.

Keywords Risk · Risk assessment · Livestock · Supply chain · Analytical hierarchical process (AHP) · Sensitivity analysis

Introduction

The contribution of the agriculture sector to the Indian economy has shown a decline trend in the last three decades from 26.9% in 1990 to 16.2% in 2019 (WDI 2019). However, this sector has great importance in the economy due to its product, market, factors, and foreign exchange contribution (Khan and Ansari 2018). Therefore, the agriculture sector has been an important sector for national policymakers (Muneeb et al. 2021; Kumar et al. 2011). Livestock is a significant contributor to the agriculture sector and approximately a source of income for two-thirds of Indian farm households; additionally, it is a source of domestic fuel and manure (Birthal 2008; Cuéllar and Webber 2008). A compelling feature of livestock farming is that it can be initiated with a little amount of investment and due to its reproducible nature in a short span it can be multiplied many times. Livestock can serve as a backup in the event of crop failure and income shock.

Growing urban population, development of transportation system, increasing supermarket in urban areas, shifting population from low middle income to higher income group, and economic growth are leading to changes in the food

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consumption pattern towards animal food products (Birthal and Taneja 2012). Over the time, per capita consumption of livestock products has significantly increased while the consumption of food grains has declined (Kumar et al. 2014). Demand for livestock products has been growing across the world mainly in low–middle-income countries (LMIC) (Abid et al 2020; Alexandratos and Bruinsma 2012). This increasing demand for livestock products brings prospects for small-scale livestock farmers that can ultimately contribute economic growth and development of the country (Birthal and Taneja 2012). There is the multifaceted role of livestock in farming in rural areas; it acts as a medium of transport and supports the cultivation of the field and provides income support as well (Khan et al. 2013). As compared with crop production, livestock has more power to reduce the poverty (Mellor 2003). According to Abid et al. (2020), livestock is the prime physical capital for rural households. They can sell it at the time of immediate financial need; in addition, it also fulfil the need of daily food consumption and maintaining soil fertility of their agricultural land (Gebremedhin et al. 2004).

The small farmers in India considered livestock as poverty reduction instrument; any mishappening put farmers in a vulnerable situation such as sudden death or any other adverse condition (Chand et al. 2016). The major challenge before the policy planner is to cover the risk to recourse poor livestock farmers. The livestock sector provides livelihood security to poor rural households, but the sector could not reach the real contribution level due to low productivity, unavailability of organized input supply, lack of technology, and involvement of high risk across the supply chain. In developing countries, usually rural small farmers are exposed to various risks and they are unable to access risk management strategies; therefore, their situation is highly susceptible (Chand et al. 2018; Tadesse et al. 2015; Gilligan et al. 2009). Disease epidemics among livestock are the major cause of productivity reduction and sometimes losses of livestock at the mass level (Thornton et al. 2008).

Livestock diseases instigate numerous losses such as the death of the animal, treatment cost, yield loss, and decline in product acceptability (Govindaraj et al. 2021; Charlier et al. 2020). Livestock supply chain effectiveness may be hamper due to the unavailability of input and production risk (Abu Hatab et al. 2021; Adeyemo et al. 2021). The risk related to the livestock supply chain is directly impacts the farmer's income and their investment decision. Some studies have been done to investigate the determinants of risk as well as risk management strategies in the livestock supply chain (Abbas et al. 2022; Adeyonu et al. 2021; Faisal et al. 2021). However, studies on creating a hierarchical structure of livestock risk across the livestock supply are still showing a significant research gap. Understanding of the hierarchical structure of livestock risk enables the stakeholders to know the severity of each risk across the supply chain. Therefore, to deal with these conditions, it is crucial to investigate the livestock supply chain-related risks to reduce their impact on the supply chain and other industry partners. With this objective, we have conducted a literature review and found that there has been limited research to understand the risk and their management in the context of livestock's supply chain. Therefore, this study is conducted to address the issue of risk management for the livestock supply chain. Risk management has four phases: risk identification; risk assessment; risk mitigation; and risk control (Khan et al. 2020, 2021). Risk identification and assessment are the primary and crucial steps of risk management. This study focuses on risk identification and risk assessment for the livestock supply chain and the specific objectives are as follows:

- Identify the major risks related to the livestock supply chain.
- Assessment of the identified risk using the MCDM method
- Provide the risk control measures based on the risk assessment

The above objectives are fulfilled through this study to make the livestock supply chain more resilient. The study significantly contributes to the livestock supply chain and risk management literature, and some major contribution is provided as follows:

- The identified risk related to the livestock supply chain helps the policy planner and government to develop strategies in order to mitigate them for making the livestock supply chain more sustainable.
- The prioritization of the risk in the livestock supply chain enables the managers/farmers to systematically deploy the resources for mitigating the risks in an effective manner.
- The risk assessment framework shows the application of the MCDM method in livestock supply chain management that is easy to implement and logically sound. AHP-based model endorses the assessment of livestock supply chain risks for effective risk management.
- This study addresses the issue of livestock supply chain in the context of developing countries that are more prone to risks in comparison to developed countries.

The remaining paper is structured as the "Review of literature" section reviews the livestock supply chain risks; the "Methodology" section explains the research methodology; the "Data analysis" section presents the data and sensitivity

analysis and results; findings are discussed in the "Discussion" section. Implication of the study is given in the "Implications of the study" section, and finally, the "Conclusion" section concludes the study and provides the limitation and scope for the future research.

Review of literature

Livestock experiences a variety of risks and this section deals with the major risk in this sector. Kahan (2008) categorizes risk in livestock farming broadly in (1) production, (2) marketing, (3), financial (4), and institutional and (5) personal/human. Production includes drought-, climate-, and disease-related risk. Financial risk cover issues of loan and cost. Risk regarding demand and supply of Input and products comes under marketing risk. Institutional risks are policy-related issues that have impacts on the livestock supply chain. The last personal and human risks in livestock framing are illness, accident civil unrest, and death. Farm household are either involved in crop production and livestock farming exposed to various market as well as non-market shocks; it may have a long-term and short-term shock that impact yield, animal disease, hailstorm, price, and market availability (Abid et al. 2020). Macroeconomic indicators are directly related with environmental quality (Jahanger et al. 2022). Every year, some parts of India face the heat of drought, and it exposed livestock to the environment and health-related risks (Thornton et al. 2009). For instance, climate changes have a significant impact on the livestock supply chain because frequent changing of the weather negatively affects the productivity of livestock, quality of feed and fodder, the health of the animal, water availability, and reproduction (Polley et al. 2013; Henry et al. 2012 and Chapman et al 2012). Raising temperature due to climate change was exposed to death risk of animals (Nardone et al. 2010). Heat stress and other climate change issues adversely affect the production and productivity of the livestock and supply chain (Cao et al. 2019; Fournel et al. 2017). Furthermore, heat stress affects animal health directly which adversely affect the metabolic and immune system which increase the probability of death of the livestock. Death of the livestock causes severe economic loss to the farmers especially small and medium (Dua 2003). There are direct and indirect implications of climate change on livestock. Health, growth, and reproduction capabilities are directly affected by climatic change while indirect impacts are the implications due to poor quality of feed and fodders growing in the result of adverse weather (Somagond et al. 2022; Wreford and Topp 2020). Probability of morbidity increases with the rise in temperature (Rojas-Downing et al. 2017).

Lack of access to quality feed has been a severe constraint among the livestock farmers and it limits the livestock production LMIC; the absence of quality feed adversely affects the profitability, environment, productivity, nutritional status of the human, food security, and animal health (Balehegn et al. 2020). Increasing input prices is considered one the main risk in the agricultural supply chain including livestock because it limits the ability to adopt the improved variety inputs (Abid, et al. 2020). Fifty percent of the total cost in livestock production is accounted by feed and fodder. Farmers fail to provide quality fodder to their animal in the majority of cases. According to Patel et al. (2011), the lack of quality feed and fodder significantly led to low productivity of livestock. Shortage of animal feed is generally adjusted through low-quality fodder which is unable to lactate the animal or sometimes has an adverse impact on animal reproduction capacity (Lanyasunya et al. 2006). Arable land is continuously declining in India as well as other countries of the world due to the increasing population. Therefore, the availability of land for feed and fodder has been shrunk, which leads to a decline in production. So shortage of feed covers up through the poor quality fodder. Therefore, the availability and cost of feed and fodder become high risk in the livestock sector (Devaki and Senthilkumar 2011). There is a huge gap in supply and demand for feed and fodder in India. The dry fodder is deficit by 21% in 2015 which is expected to increase by 23% in 2025. While green fodder is deficited by 26% which is expected to increase by 40% in 2025. This deficit in fodder is negatively impacted in production and depletion of the livestock productivity (Makkar 2016 and Birthal and Jha 2005).

Disease in an animal is a very severe risk because the expenditure of animal treatment is high; even in the case of small diseases, farmers are unable to pay the treatment amount. In rural areas; it is difficult to bring the animal to the veterinary hospital due to unavailability of hospitals and high transportation costs. Moreover, from an economic point of view, disease occurrence in animals causes a significant economic loss to farmers, particularly during the monsoon season. In the case of India, more than 85% of farmers are small and medium, and are incapable of affording veterinary services (Ravikumar et al. 2007).

In the livestock supply chain, the majority of risks are concern with production due to various factors such as drought, animal disease, and untimely death. The spillover effect of these production risks is observed in price risk (Bishu 2014). Farmers are exposed to climate risk every season and their access to insurance facilities are very limited particularly in a developing country which creates a barrier to transfer the risk to the insurance company. A huge marketing risk is associated with the livestock supply chain because it is required immediate consumption or converting into a non-perishable form. Most of the livestock products are perishable in nature; they need cold storage to maintain the quality of the products;

however, cold storage-embedded supply chain is in the initial stage in India because a high investment is involve in cold storage-based supply chain (Nayak and Bagchi 2022). Another market-related risk in the livestock supply chain is low bargaining power of the small farmer because their marketing surplus is small so they could not bargain in the market (Birthal et al. 2005). Moreover rural market is thin and farmers have to travel to the urban market to sell their livestock product which increases the marketing cost (Pingali et al 2005). In addition, livestock production is not demand driven as per the requirement in urban commercial market standard (Mehta et al. 2007). There is a lack of transport facilities in India (Birthal 2008). Camel milk is the important contributor in the food consumption of the rural community of some parts of country but its production is facing the post-harvest quality and quantity decoration, and risk factor-associated quality and quantity deterioration is still unidentified.

A well-established post-harvest infrastructure is required for sustainable livestock supply chain. India faces the problem of poor infrastructure due to low public and private investment and it is ultimately exposed to marketing risk due to poor processing. Livestock products marketing is characterized by the intervention of the middleman (Singh and Meena 2012) which increase the producers' share in consumers surplus (Ansari and Khan 2018). Middlemen are more inclined towards traders benefit (Gabre-Madhin 2001). Information has been a key determinant for the market participation of farmers because true knowledge enables livestock farmers to take the correct decision in terms of sell and purchase timing, pricing, and market interaction. Poor market information discourages smallholders to participate in the market (Nwafor et al. 2020 and Fafchamps and Hill 2005). Due to lack of information, farmers depend on an informal market channel which increases farmers' dependency on middlemen which ultimately end up with a low piece to the farmers (Masutha and Rogerson 2015). Table 1 represents the various livestock supply chain risk and sub risks.

From the literature review of livestock risk across the supply chain, the main four broad dimensions of risk, namely input supply risk, production risk, post-harvest risk, and marketing & price risk, are found. There are very limited studies that examine the risk in the livestock sector, particularly across the complete supply chain in the context of India. It is imperative to analyze the risk by prioritizing it across the livestock supply chain. Prioritizing the risk will enable us to judge the severity of risk in the livestock supply chain. It will be instrumental to get an in-depth understanding of the government to intervene across the livestock supply chain for the development of the livestock sector.

Methodology

The objective of this study is fulfilled through the two-phase methodology. In the first phase, the preliminary risks are identified through the literature review. Further, these identified risks are assessed using a well-known AHP method. The adopted research framework for this study is shown in Fig. 1.

Table 1 Livestock supply chain risk

Major risk in category livestock supply chain	Types of sub risk in livestock supply chain
Input supply risk (SR)	• High cost of feed and fodder (SR1) • Non-availability of medicines during emergency (SR2) • Poor quality and under supply of feed and fodder (SR3) • Absence of certification for quality of animals (SR4)
Production risk (PR)	• Lack of proper living infrastructure (PR1) • Illness/Injury/disability of animal (PR2) • Epidemic attack such a foot and mouth disease (PR3) • Production loss due to drought and flood (PR4) • Theft (PR5)
Post-harvest risk (PH)	• Absence of proper transport infrastructure (PH1) • Absence of cold storage/refrigeration facility (PH2) • Lack of measurement of quality (PH3) • Lack of proper waste disposal (PH4)
Marketing and price risk (MR)	• Lack of discriminatory pricing for quality/graded produce (MR1) • Lack/poor bargaining power (MR2) • Lack of market information (MR3) • Dominance by middlemen (MR4)

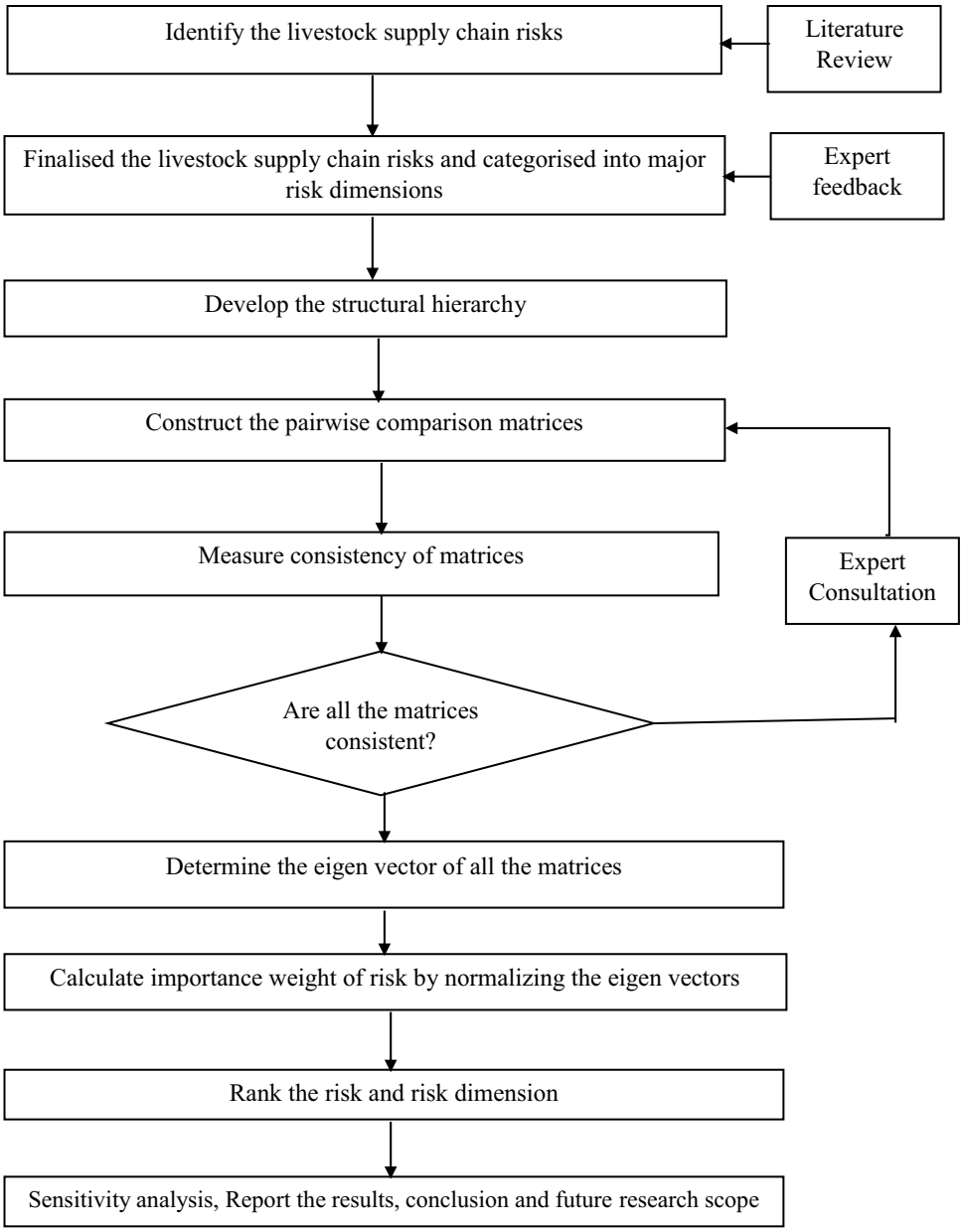

Fig. 1 Propose research framework

Data collection and method

This study is a qualitative research based on expert opinion. The qualitative data has been taken from the panel of experts using the purposive sampling technique; these experts are high-ranked academicians, experienced practitioners, and industry professionals. The expert panel consists of eight members. These experts are selected based on their working experience in the livestock supply chain. The participated expert have more than 10 years of working experience at the manager level. The details of the experts are provided in Table 13 in the Appendix. After the discussion with the experts, seventeen risks are finalized under four broad dimensions of risk.

Various MCDM techniques have been used to prioritize risk, examine critical success factor and sustainability of

Table 2 Standardized comparison scale of nine levels

Definition	Value
Equally important	1
Moderately important	3
Strongly important	5
Very strongly important	7
Extremely important	9
Intermediate values	2, 4, 6, 8

Table 3 The relationship between RI value and count of criterion

N	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	.90	1.12	1.24	1.32	1.41	1.45

supply chain (Agrawal et al. 2022; Singh et al. 2022; Sufiyan et al. 2019). Analytical hierarchical process (AHP), a well-known multi-criteria decision making (MCDM), is used to prioritize the risks. The rationale for using AHP is as follows: (i) it is very easy to implement and (ii) it requires a smaller number of calculations and has high applicability in MCDM processes (Paleie and Lalic 2009; Saaty 2008). Further, the AHP is considered that factors are independent and this study considered the risks are independent. It also effectively handles the inconsistency in human judgment and attributes present in the expert's input (Saaty 1980; Ishizaka and Labib 2009; Shaw et al. 2013). Therefore, AHP is suitable for the prioritization of the risk dimensions and risks. A structured AHP questionnaire is used for the data collection from the eight experts to implement the AHP method. The step-wise process of AHP is provided in the upcoming subsection.

Analytical heretical process

In 1980, Saaty proposed the Analytic hierarchy process (AHP) which is one of the powerful methods to solve the MCDM problems (Saaty 1980). Among the several MCDM methods, AHP is a popular method and widely applied in different fields (Khan et al. 2019). MCDM is devoted to screening, prioritizing the factors/barriers/enablers, or selecting an alternative under usually independent or/and conflicting attributes (Agrawal et al. 2020; Khan et al. 2019; Mannan and Haleem 2017). AHP method is built on three vital stages: (i) hierarchical structure development; (ii), a pair-wise comparison of the factors by the experts and (iii) a synthesis of priorities (Madaan and Mangla 2015). The overall steps of the AHP are provided as follows:

Step 1: Develop the hierarchal structure
The hierarchical structure is developed to organize the factor (in this study risk dimensions) and sub-factors (in this case risks). After the finalization of the hierarchal structure, experts were requested to make pair-wise comparisons among risk demotions as well as risks using a nine-point scale. All pair-wise matrices are developed, and corresponding pair-wise comparisons are delivered to the expert.
Step 2: Establish a pair-wise comparison decision matrix

The second step is the pair-wise comparison of risk dimensions as well as risks to evaluate the relative weight of risk dimension and risk. The risk is pair-wise compared according to their influence and based on the specified risk dimension in the higher level using the nine-point scale shown in Table 2.

Step 3: Compute criteria weight
The criteria (risk dimension) are calculated as using Eq. (1):

$$AW = \lambda_{max} W \tag{1}$$

where A is the priority matrix, W is the importance weight of risk dimension/risk, and $\lambda_{\max}$ is the maximum eigenvalue of matrix A.
Step 4: Calculating the consistency

It is essential for the robust and reliable ranking of the risk that matrix A should be consistent. To measure the consistency of matrix A, a consistency ratio is used. The consistency ratio (CR) is defined as follows:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{2}$$

where CI is the consistency index (CI) and is RI is a random index. The consistency index is calculated using Eq. (3).

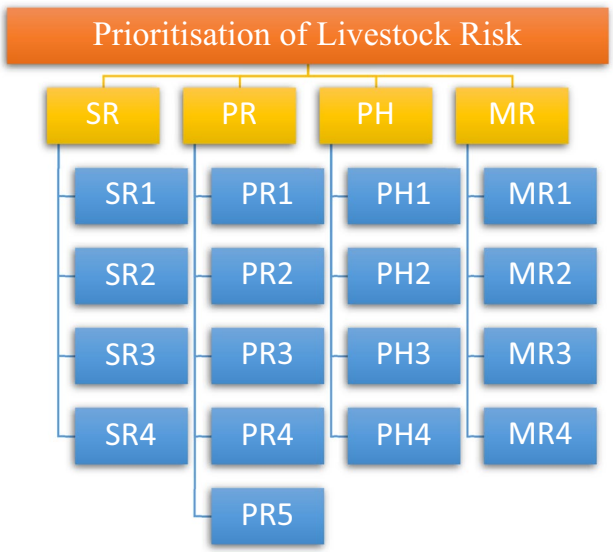

Fig. 2 Hierarchical structure of livestock supply chain risk

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

Further, the value of RI depends on the different count of criteria, and value of RI is demonstrated in Table 3.

If CR is less than 0.10, the result can be acceptable, and experts' input is significantly consistent. Otherwise, we should have returned to step 1 and repeat the process.

Data analysis

The livestock supply chain risks are identified through the extensive literature review of the livestock supply chain, risk management strategies in livestock farming, supply chain management and animal welfare, and validated with expert feedback. Initially, twenty-one risks are identified from the initial literature review. These risks are discussed with the expert team for validation in the Indian context. The experts suggest that four risks are not relevant to the contemporary situation and four are merged into two. Further, two risks are added by the experts in the risk list. In this manner, seventeen risks are finalized. Based on their nature of the risk, these risks are categorized into four broad risk dimensions which are shown in Table 1. Further, a hierarchal structure is developed for the assessment of risk and the same is shown in Fig. 2.

After formulating the hierarchical structure of risks, pairwise assessment matrices are developed using the linguistic evaluation of the experts. The pair-wise matrices are finalized based on the consensus among the experts. The pairwise assessment matrix for the livestock risk dimension is shown in Table 4.

Table 4 Pair-wise assessment matrix for livestock risks dimensions

Risk dimensions	SR	PR	PH	MR	Weight	Rank
SR	1	2	2	3	0.407	1
PR	1/2	1	2	4	0.305	2
PH	1/2	1/2	1	3	0.199	3
MR	1/3	1/4	1/3	1	0.089	4
CR value = 0.049						

Table 5 Pair-wise assessment matrix for input supply risks

Supply Risk	SR1	SR2	SR3	SR4	Weight	Rank
SR1	1	1/3	1/4	1/2	0.095	4
SR2	3	1	1/2	1/2	0.201	3
SR3	4	2	1	3	0.469	1
SR4	2	2	1/3	1	0.236	2
CR value = 0.065						

Table 6 Pair-wise assessment matrix for production risks

Production risk	PR1	PR2	PR3	PR4	PR5	Weight	Risk
PR1	1	1/2	1/3	1/3	1	0.094	4
PR2	2	1	1	1/2	3	0.202	2
PR3	3	1	1	1/4	2	0.183	3
PR4	3	2	4	1	5	0.44	1
PR5	1	1/3	1/2	1/5	1	0.082	5
CR value = 0.034							

Table 7 Pair-wise Assessment Matrix for post-harvest risk

Post-harvest risk	PH1	PH 2	PH 3	PH 4	Weight	Rank
PH 1	1	1/2	1/3	3	0.182	3
PH 2	2	1	2	2	0.376	1
PH 3	3	1/2	1	4	0.342	2
PH 4	1/3	1/2	1/2	1	0.101	4
CR value = 0.089						

Table 8 Pair-wise assessment matrix for marketing & price risk

Market risk	MR1	MR2	MR3	MR4	Weight	Rank
MR1	1	1/2	1/4	1/3	0.10	4
MR2	2	1	1/2	1/2	0.185	3
MR3	4	2	1	1	0.37	1
MR4	3	2	1	1	0.345	2
CR value = 0.004						

Table 9 Final rank of livestock risks

Risk Dimension	Weight	Risk	Local weight	Local rank	Global weight	Global rank
SR	0.407	SR1	0.095	4	0.0387	9
		SR2	0.201	3	0.0818	4
		SR3	0.469	1	0.1909	1
		SR4	0.236	2	0.0961	3
PR	0.305	PR1	0.094	4	0.0287	13
		PR2	0.202	2	0.0616	7
		PR3	0.183	3	0.0558	8
		PR4	0.440	1	0.1342	2
		PR5	0.082	5	0.0250	14
PH	0.199	PH 1	0.182	3	0.0362	10
		PH 2	0.376	1	0.0748	5
		PH 3	0.342	2	0.0681	6
		PH 4	0.101	4	0.0201	15
MR	0.089	MR1	0.100	4	0.0089	17
		MR2	0.185	3	0.0165	16
		MR3	0.370	1	0.0329	11
		MR4	0.345	2	0.0307	12

Table 10 Preference weights for sensitivity analysis of the major risk dimension

Risk dimensions		Values of preference weights								
	Normal	S1	S2	S3	S4	S5	S6	S7	S8	S9
SR	0.407	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
PR	0.305	0.463	0.412	0.360	0.309	0.257	0.206	0.154	0.103	0.051
PH	0.199	0.302	0.269	0.235	0.201	0.168	0.134	0.101	0.067	0.034
MR	0.089	0.135	0.120	0.105	0.090	0.075	0.060	0.045	0.030	0.015
SUM	1	1	1	1	1	1	1	1	1	1

Table 11 Relative weights of risks by sensitivity analysis for scenario 1 to scenario 9

Risks	Normal	S1	S2	S3	S4	S5	S6	S7	S8	S9
SR1	0.039	0.010	0.019	0.029	0.038	0.048	0.057	0.067	0.076	0.086
SR2	0.082	0.020	0.040	0.060	0.080	0.101	0.121	0.141	0.161	0.181
SR3	0.191	0.047	0.094	0.141	0.188	0.235	0.281	0.328	0.375	0.422
SR4	0.096	0.024	0.047	0.071	0.094	0.118	0.142	0.165	0.189	0.212
PR1	0.029	0.044	0.039	0.034	0.029	0.024	0.019	0.015	0.010	0.005
PR2	0.062	0.094	0.083	0.073	0.062	0.052	0.042	0.031	0.021	0.010
PR3	0.056	0.085	0.075	0.066	0.056	0.047	0.038	0.028	0.019	0.009
PR4	0.134	0.204	0.181	0.158	0.136	0.113	0.091	0.068	0.045	0.023
PR5	0.025	0.038	0.034	0.030	0.025	0.021	0.017	0.013	0.008	0.004
PH 1	0.036	0.055	0.049	0.043	0.037	0.031	0.024	0.018	0.012	0.006
PH 2	0.075	0.114	0.101	0.088	0.076	0.063	0.050	0.038	0.025	0.013
PH 3	0.068	0.103	0.092	0.080	0.069	0.057	0.046	0.034	0.023	0.011
PH 4	0.020	0.031	0.027	0.024	0.020	0.017	0.014	0.010	0.007	0.003
MR1	0.009	0.014	0.012	0.011	0.009	0.008	0.006	0.005	0.003	0.002
MR2	0.016	0.025	0.022	0.019	0.017	0.014	0.011	0.008	0.006	0.003
MR3	0.033	0.050	0.044	0.039	0.033	0.028	0.022	0.017	0.011	0.006
MR4	0.031	0.047	0.041	0.036	0.031	0.026	0.021	0.016	0.010	0.005

Similar to the risk dimensions, the pair-wise comparison matrix is also developed for the input supply risk, production risks, post-harvest risks and market risk using the expert's feedback and shown in Tables 5, 6, 7, and 8 respectively.

Finally, local and global weights have been assessed for each risk through the AHP method. The local weight of each risk is provided in the pair-wise assessment matrix in Table 9. Based on the weight of risk dimensions and risk, the global weight of each risk is calculated by multiplying the local weight with the weight of the corresponding risk. The weight of the risk refers to the severity of the risk in the livestock supply chain. The higher value of the importance

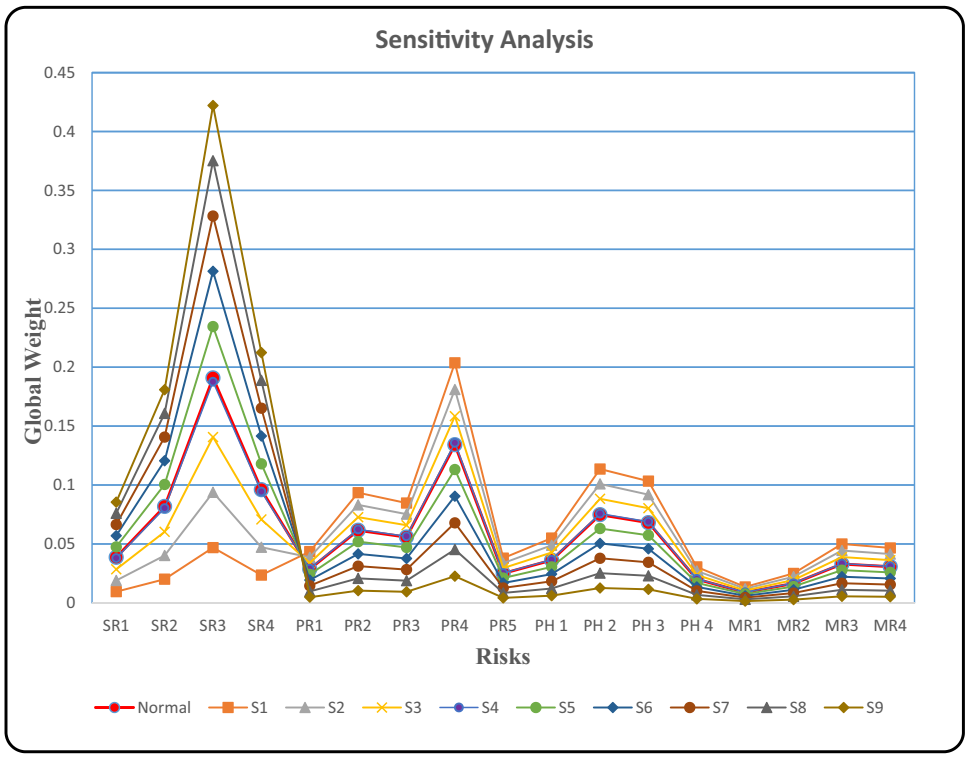

Fig. 3 Sensitivity analysis of livestock supply chain risk by their global weights

Table 12 Global rank of livestock supply chain risk as per sensitivity analysis for S1 to S9

Risks	Normal	S1	S2	S3	S4	S5	S6	S7	S8	S9
SR1	9	17	16	14	9	8	5	5	4	4
SR2	4	15	11	8	4	4	3	3	3	3
SR3	1	8	3	2	1	1	1	1	1	1
SR4	3	14	8	6	3	2	2	2	2	2
PR1	13	10	12	12	13	13	13	13	13	13
PR2	7	4	5	5	7	7	8	8	8	8
PR3	8	5	6	7	8	9	9	9	9	9
PR4	2	1	1	1	2	3	4	4	5	5
PR5	14	11	13	13	14	14	14	14	14	14
PH 1	10	6	7	9	10	10	10	10	10	10
PH 2	5	2	2	3	5	5	6	6	6	6
PH 3	6	3	4	4	6	6	7	7	7	7
PH 4	15	12	14	15	15	15	15	15	15	15
MR1	17	16	17	17	17	17	17	17	17	17
MR2	16	13	15	16	16	16	16	16	16	16
MR3	11	7	9	10	11	11	11	11	11	11
MR4	12	9	10	11	12	12	12	12	12	12

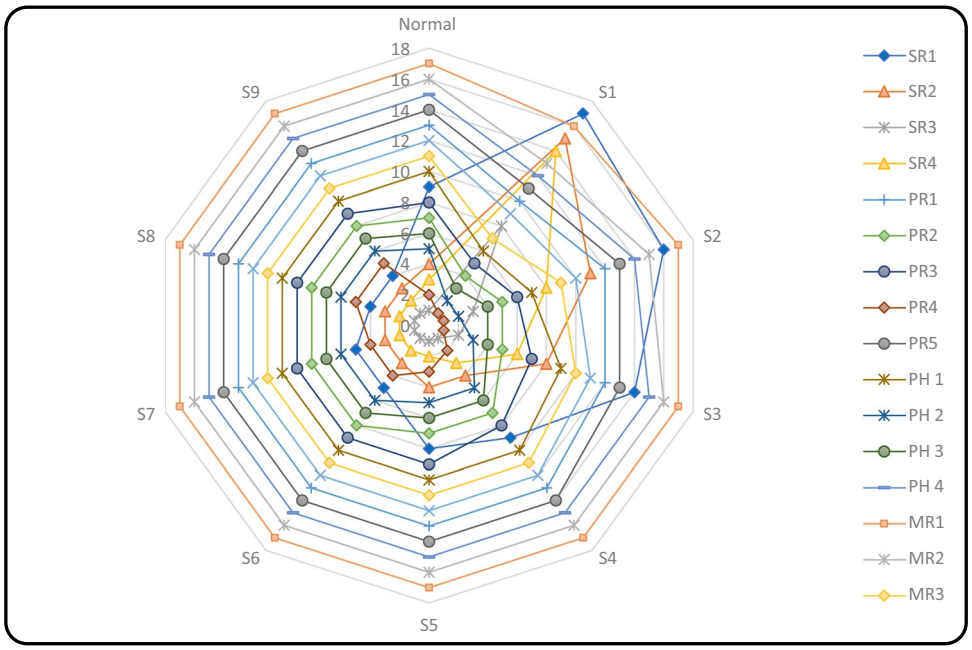

Fig. 4 Sensitivity analysis of livestock supply chain risk by rank

weight of any risk can be interpreted as a high potential to disrupt the livestock supply chain. It should be noted that the global weight refers importance of the risks among all the identified risks (in this case among seventeen risks), while the local weight infers the importance of the risk among the specific dimension. As per the value of the local and global weight, the risks are locally and globally ranked. All calculated values are presented in Table 9.

Sensitivity analysis

For robustness and reliability, a sensitivity analysis is also performed because in MCDM analyses, the results might be influenced by data imprecision, vagueness, and subjective judgment of experts (Govindan et al. 2014). Some studies show that small variations in weights may change the final ranking. Therefore, it is necessary to assess the robustness of the ranking obtained. In order to test the result's

robustness, a sensitivity analysis should be performed (Mangla et al. 2017; Asjad and Khan 2017). In this study, supply risk (SR) was prioritized as the first among the identified risk dimensions (refer to Table 9). Therefore, it was chosen first for sensitivity analysis by varying the weight. The weight of supply risk was varied from 0.1 to 0.9 with increments of 0.1 and create nine scenarios (S1 to S9). At the same time, corresponding fluctuations in the weights of the other dimensions were also made. These changes are in the weight of all risk dimensions are shown in Table 10.

It is evident that from Table 10, the weights and rankings of each risk are also changed as the weights of the risk dimensions are varied. The weights of each risk in different scenarios (S1,….S9) are shown in Table 11. It is apparent from Table 11 that the weight of the supply risk is varied from 0.1 to 0.4, and the fluctuations in the importance weight of risk are high and after that becomes less varied. The weight of risks in different scenarios (S1, … S9) is shown in Fig. 3. Based on the weights obtained in nine scenarios, the rank of each risk is evaluated and shown in Table 12. The initial scenario (S1 to S4) shows the rank fluctuation of the risks and after that, the rank is the same or slightly changed. The rank of each risk is presented with the help web diagram and shown in Fig. 4.

Discussion

The result of the AHP method shows the priority order of risk dimensions as input supply risk > production risk > post-harvest Risk > market and price risk. The global ranking of each risk is determined based on their corresponding global importance weights. Further, the result of the AHP was discussed with the expert's panel to get further insights to mitigate the consequence of the livestock supply chain risks, which in turn will advance the livestock supply chain robustness, and hence improve the performances. The high priority risk needs immediate attention of the livestock stakeholder to control these risks for the effective and efficient management of the livestock supply chain.

The input supply risk (SR) has the highest priority among the identified risk dimensions. Akcaoz and Ozkan (2005) and McDermott et al. (2010) also come to the same conclusion that input risk in terms of cost and availability is among the biggest risk across the supply chain. Some other studies also find that lack of access to input due to high cost and unavailability is the severe risk in livestock supply chain (Abu Hatab et al. 2021; and Salman et al. 2010). Thus, there is a need to focus to manage input supply risk (SR) and putting serious effort to mitigate this risk by the farmers, policy planners, and farm managers. Under the input supply risk (SR), the priority order of the risk is as follows: "high cost of feed and fodder" > "non-availability of medicines during emergency" > "poor quality and undersupply of feed and fodder" > "absence of certification for the quality of animals." The highest priority risk is the "high cost of feed and fodder" which could be reduced through the increasing area under cultivation as well as productivity by using an advanced variety of feed/fodder. Further, the supply chain of feed/fodder should be efficiently managed through improved supply chain techniques. The next risk "non-availability of medicines during emergency" is one of the major concern in case of the livestock supply chain. Veterinary services should be available at the doorstep of the farmers. Subsidized medicine should be provided to the farmers and intervention of village-level para-vets should be improved. Further, "poor quality and undersupply of feed and fodder" have rank third, which could be reduced through procuring high-quality feed/fodder. In addition, standardization should be established for feed and fodder. District/ block level agricultural officer should ensure the organized input supply at each block. Apart from this, farmers should select the supplier of the feed/fodder based on quality rather than cost. The next risk is "absence of certification for the quality of animals" which are a significant risk for the livestock supply chain. Before the selling of animals in the market, a seller should have a health fitness certificate from certified veterinary practitioners.

The next highest risk dimension is the "production risk" among the identified risk dimensions, under the "production risk" the priority of the risk is as follows: "lack of proper living infrastructure" > "illness/Injury/disability of animal" > epidemic attack such as foot and mouth disease" > "production loss due to drought and flood" > "theft." Previous studies also express that production risk which includes the disease and climatic risk are among the top risk category across the livestock supply chain (Govindaraj et al. 2021; Adeyemo et al. 2021; Cao et al. 2019; Nardone et al. 2010; Meuwissen et al. 2001). Government should focus on environmental quality (Rafei et al. 2022; Chen et al. 2022). The highest priority risk is the "lack of proper living infrastructure" which is the major concern of livestock in developing countries like India. However, Central and state governments have various schemes such as a national livestock mission, a national program for dairy development and animal husbandry infrastructure development fund. There is a need to make the farmers aware of these schemes to develop the living infrastructure for the livestock. The next risk is "illness/Injury/disability of

animal" that adversely affect the livestock productivity, which has a spillover effect on farmers' income. Furthermore, this risk can be mitigated through providing veterinary facilities and regular assessment of animal health. In this row, the next risk is "epidemic attack such as foot and mouth disease" which have had been a major problem for the livestock supply chain. These epidemic attacks could be controlled through the proper vaccination and hygienic environment. Frequently, a quarterly village level vaccination drive should be arranged by the district veterinary department. The next risk is production loss due to drought and flood" that is a natural risk. There should be an effective and efficient information communication arrangement so the farmers could be timely aware of the disasters. In addition, proactive measures such as vacant the place could be done in order to reduce the negative consequences. The least significant risk among the production risk category is "theft" that could be controlled through proper security of the farm shed and traceability.

The third most significant risk dimension is "post-harvest risk" with an importance weight of 0.199. Under the risks related to the "post-harvest risk" dimension, the priority order is: "absence of proper transport infrastructure" > "absence of cold storage/refrigeration facility" > "lack of measurement of quality" > "lack of proper waste disposal." Godde et al. (2021) and Rajeb (2018) also concluded that transportation and storage infrastructure is the severe challenges across the livestock supply chain. The unavailability of proper transport availability and infrastructure are obstacles for the livestock supply chain specifically in the rural areas. The production takes place in rural areas and the consumption market is available in an urban area; therefore, transport has great importance, and the lack of proper transport infrastructure creates a major challenge for efficient livestock supply chain management. In order to mitigate this risk, the government should develop better rural–urban connectivity in terms of transport. A specific amount of fuel should be provided at a subsidized rate to the farming community.

The next significant risk is the "lack of cold storage/refrigeration facility" which creates a big threat to the quality of the final product of the livestock industry. Livestock product generally has a low shelf-life; therefore, quality of the product deteriorates starts deteriorating after some time. This risk can be controlled by building a large-scale cold storage that could be used for the livestock industry. In addition, refrigerator equipped vehicles should be used for transportation. The next place in terms of risk under post-harvest risk is occupied by lack of measurement of quality. Framers should be aware of national and international quality standards. The least significant risk is the "lack of proper waste disposal" that could be controlled through the development of effective solid waste disposal practices such as water treatment and solid waste management. Waste disposal treatment is important from a sustainable development point of view.

The "market and price risk" is the least priority risk among broader risk dimensions. Under the "market and price risk" dimension, the risk priority order are as follows; "lack of discriminatory pricing for quality/graded produce" > "lack/poor bargaining power" > "lack of market information" > "dominance by middlemen." The most severe risk is the "lack of discriminatory pricing for quality/graded produce" which could be controlled through the established mechanism to set the fair market prices for the livestock product. The farmers generally operate in a highly competitive business environment, and entry and exit from the market are easy, therefore each producer has low bargaining power. The next risk is the "poor bargaining power" that could be controlled through effective market policies for the livestock industry. The next risk is "lack of market information" this is the biggest problem for the farmers; however, there are various online platform available which provides price information. In addition, risk could be mitigated through effective communication among the livestock supply chain partners and market players. Furthermore, IT support can also act as a tool to provide credible information about the market to the various stakeholder of the livestock. The least significant risk is the "dominance by middlemen" which could be a major issue for the livestock farmer. This risk could be reduced by creating a direct marketing channel and providing training about the direct access of the market. Further, various government initiatives have also reduced the influence of the middlemen.

Implications of the study

Policy implications

The findings of the research show that several risks exist in the livestock supply chain that needs to be mitigated in order to make the supply chain resilient. The findings show feed and poor quality of fodder is one of the biggest risk in livestock supply chain As most of the farmers in developing countries are uneducated, the government should conduct a program to create awareness about the role of feeder on animal health. Further, the subsidies should be provided for the

good quality fodder and ensure the availability of the fodder in the market at an affordable price. The government need to set a minimum level of criteria for the feeder through certifications in order to control the production and distribution of poor-quality feeders. In addition, the production loss due to drought and flood is another issue for the livestock supply chain partners is significant. Therefore, there is a need to develop an effective transportation and communication network so that correct information about disasters could be reached timely to supply chain partners and consequently they could move their animals to a safer place. Animal health is also a major concern for the livestock supply chain partners. The livestock supply chain partner needs to set a village level veterinary department where the health check of animals could be done at regular intervals. For instance, prior to the purchase and sale, the health certificate of the animal should be mandatory. In addition to this, emergency services should also provide in the government veterinary hospitals to provide health support to animals.

Managerial implications

The managers of livestock supply chain need to address the risk that are emerges across the supply chain in order to make their supply chain sustainable. Through the identified risks, managers could formulate the mitigation strategies for controlling the risks. Further, the prioritization of the risks helps the managers to better utilization of their resources by focusing on the higher priority risks firstly. For instance, they could transfer the risk to the insurance company by acquiring insurance for animals. The prioritization of the risk dimensions also assists the managers to look at the department which is more prone to risks and develop the strategies on time to overcome them. In addition to this, supply chain managers need to create an awareness program about national and international quality standards, so that, supply chain partners could maintain the quality. This study also suggests the lack of infrastructure is another risk for the producer that need to address. The propose framework is also utilized for the assessment of risks by a manager for their livestock supply chain. A better assessment helps the manager to track the progress of the risk management plan.

Conclusion

The objective of this study is to examine the risks in the livestock supply chain in emerging economies context. In order to meet this objective, two-phase methodology is applied. In the first phase, the significant risks are identified through the literature review. After that, these risks are validated by the experts and finalized as per the context of emerging economies, they suggested total seventeen risks which are categorized into four major dimensions for effective risk assessment. Furthermore, using the AHP, the risk dimensions and risk are prioritized as per their severity. The highest priority risks are input supply risks which require the attention of the livestock supply chain partners. Further, sensitivity analysis is conducted to check the robustness of the adopted model. The result of sensitivity analysis confirms that the ranking of the risk is robust. The findings of this study were discussed with the expert's panel, who provided some useful recommendations to control the critical risks. This research finding might be beneficial for the farmers and other livestock stakeholders while analyzing the livestock risks for developing policies/plans/strategies to control their consequences.

This study also has some limitations that will address in future studies. The primary limitation of this study that the risks are identified through the literature review and there is a chance to overlook some relevant risks. This limitation can be removed through more extensive review in future studies. Additionally, the risks are assessed through the expert input that could be biased as per their belief and working organization. The biasness could be resolved through integrating the fuzzy or grey theory with the AHP method. Further, this study is conducted in a developing country so the generalization of the finding are limited. We have only focused on the two phases of risk management rather than addressing the holistic risk management approach. In order to overcome these limitations, this study could be validated through the data collection from multiple countries including developed countries. This study could be extended to case study using other risk assessment methods. The other MCDM methods such as analytical network process (ANP), best worst method (BWM), fuzzy BWM and technique for order of preference by similarity to ideal solution (TOPSIS), and base criteria Method (BCM) can be also applied for the assessment of the risks. Additionally, some other risk assessment techniques are fault tree analysis (FTA), failure effect mode analysis (FEMA), and Bayesian network. A survey-based research taking behavioral, pshychological, and sociodemographic variable may also provide the in-depth understanding of broad- and subcategory-wise risk across the livestock supply chain. In future, this study could also be extended by addressing the risk mitigation strategies for effective risk management.

Appendix

Table 13 Experts profile

S. no	Designation/position	Education	Expertise area	Working experience (in years)
1	Livestock supply chain manager	MBA	Livestock supply chain management	16
2	Operations manager	Master of Engineeirng	Operations	12
3	Risk manager	M.Tech	Supply chain	11
4	General manager	MBA	Marketing	13
5	Strategic manager	M.Tech	Strategy	18
6	Professor	PhD	Supply chain	30
7	Academia	PhD	Food supply chain management	11
8	Academia	PhD	Risk management	10

Author contribution Waseem Khan: conceptualization, literature review and validation Shahbaz Khan: methodology, formal analysis and validation, Aruna Dhamija: literature and discussion. Mohammad Haseeb: investigation and writing. Saghir Ahmad Ansari: review and editing.

Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval Not applicable.

Consent to Participate Not applicable.

Consent to publish Not applicable.

Conflicting interests The authors declare no competing interests.

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