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Operational Risk Management in Industrial Dairy Farms: An FMEA-Based Approach

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ABSTRACT

Industrial livestock farms in semi-arid regions face multiple operational risks that can threaten business continuity and productivity. This study aimed to identify and prioritize operational risks in industrial livestock systems using evidence from 50 dairy farms in Mashhad County, north-eastern Iran. We applied a Failure Mode and Effects Analysis (FMEA) approach to develop a risk register and classify risks across major functional domains. Risk priority numbers were then computed based on severity, occurrence, and detectability. Risk scores were elicited through structured expert-based assessments with key farm stakeholders and aggregated to rank risks and highlight high-priority clusters. Results indicate that feed-related volatility (price shocks and quality instability), microclimate control failures (cooling and ventilation disruptions), workforce instability (turnover and skill gaps), and cold-chain disruptions (milk handling and storage reliability) rank among the most critical risks. These risks are not only frequent or severe, but also difficult to detect early, which increases the likelihood of cascading losses through reduced milk yield, herd health complications, and operational downtime. The findings suggest that strengthening preventive management is essential to reduce both the occurrence frequency and the detectability deficiencies of high-priority risks. Key actions include systematic feed-quality monitoring, routine herd health surveillance, and reliability-focused maintenance for cooling, ventilation, and milk-cooling systems. In addition, improving institutional support mechanisms—particularly advisory and extension services, credible and transparent risk-transfer arrangements, and more effective cooperative governance—can enhance implementation capacity and resilience. Overall, the study provides an evidence-based prioritization to guide farm managers and policymakers toward integrated operational risk management in industrial livestock systems operating under semi-arid constraints.

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Introduction

Industrial dairy farming plays a strategic position in Iran's agricultural economy by supporting nutritional security, rural livelihoods, and agro-industrial value chains. As a resource-intensive activity, it provides a steady supply of nutrient-dense products—particularly milk and its derivatives—while generating employment and stabilizing income in rural and peri-urban areas (Górska-Warsewicz et al., 2019; Shahbazi, 2022; Geravandi & Karamifard, 2024; Kitole, 2025; Priyashantha, 2025). However, sustaining productivity in industrial dairy systems increasingly depends on the sector's ability to manage a broad set of risks that affect both farm profitability and continuity, especially under the pressures of climatic stress and market instability (Sahneh et al., 2021; Hashemnia et al., 2022; Shokoohi et al., 2022; Rjili et al., 2023).

Risk exposure in industrial dairy farms is inherently multidimensional, stemming from the interplay of operational, economic, environmental, and institutional factors. At the farm level, feed quality and availability, animal health disorders, labor constraints, and equipment inefficiencies may jointly shape production performance. These operational risks often intersect with economic risks such as input price volatility, delayed payments, and limited access to credit, which can intensify losses by lowering productivity and raising per-unit costs (Finger et al., 2018; Seyedsharifi et al., 2021; Ezadi et al., 2021). In semi-arid environments, climate-related stresses—including heat waves, water scarcity, and increasing weather variability—further intensify vulnerability by affecting feed intake, animal welfare, and production costs (Abbas et al., 2022; Feliciano et al., 2024). Hence, the practical challenge for farm managers and policymakers is not merely identifying individual risks, but understanding which risks should be prioritized given limited resources and constrained adaptive capacity (Hassani et al., 2018).

Prior research has contributed valuable insights into dairy-farm risk management from several angles. Economic and farm management studies have examined decision-making under uncertainty and emphasized productivity–cost trade-offs, including culling and herd replacement strategies, as well as efficiency-oriented pathways such as feed cost control and resource-saving practices (Roustaee et al., 2022; Seyedsharifi et al., 2021; Ezadi et al., 2021). Environmental and animal-health research has documented the impacts of drought, heat stress, and disease on production variability and farm income, highlighting the role of preventive care and early detection in reducing losses (Finger et al., 2018; Abbas et al., 2022; Feliciano et al., 2024; Ferreira et al., 2024). More recently, behavioral and institutional studies have shown that farmers' perceptions, trust in institutions, and access to advisory services and support mechanisms influence adoption of adaptive strategies and resilience-building investments (Alvarez et al., 2021; Riahi & Siadati, 2022; Shantharaju et al., 2024).

Alongside these thematic advances, risk assessment methods in agriculture have evolved toward more structured and decision-oriented frameworks. Failure Mode and Effects Analysis (FMEA) and related approaches have been used to translate expert judgment into comparable risk scores and to prioritize intervention points based on severity, occurrence, and detectability (Zandi et al., 2020; Syarif et al., 2025; Khusna et al., 2025). Such approaches are particularly relevant for farm-level management because they support transparent prioritization under resource constraints and can be linked to actionable preventive and corrective measures.

Despite this progress, empirical evidence remains limited on comprehensive, farm-level risk prioritization that integrates multiple operational domains within a single analytical scheme—especially in semi-arid dairy systems where resource constraints and market uncertainty intersect. Much of the existing work either concentrates on specific risk categories (e.g., prices or climate) or does not provide a structured basis for setting priorities by jointly considering severity, occurrence, and detectability. This limitation matters for agricultural economics and development policy because weak prioritization can reinforce reactive management, misallocation of scarce resources, and ultimately lower resilience.

To address this limitation, evidence from Iranian semi-arid production hubs can clarify which operational risks deserve priority under constrained conditions. Mashhad County in Khorasan Razavi Province offers a relevant empirical setting, as it combines persistent semi-arid pressures—most notably recurrent heat stress and water constraints—with high exposure to input-market instability, largely due to reliance on purchased feed and external inputs. Moreover, the concentration of commercial dairy operations in and around Mashhad raises the economic stakes of operational disruptions, as failures in feeding, cooling and ventilation, herd health management, or milk handling can quickly translate into reduced milk yield, higher veterinary and replacement costs, and operational downtime. Accordingly, focusing on industrial dairy farms in Mashhad County enables this study to generate locally grounded yet policy-relevant evidence on operational risk priorities and to inform more targeted farm management practices and agricultural support interventions aimed at strengthening resilience in Iran's dairy sector.

Therefore, the primary aim of this study is to identify and prioritize operational risks in Iran's industrial dairy farms by applying a structured FMEA approach. The key contribution of this research lies in providing a comprehensive, farm-level risk profile that integrates multiple operational domains, thereby offering actionable insights for targeted risk mitigation and enhancing the resilience of dairy supply chains under resource constraints.

Materials and Methods

The study was conducted in Mashhad County, located in Khorasan Razavi Province in northeastern Iran (Fig. 1). Khorasan Razavi Province has 187,672 purebred, 123,926 crossbred, and 4,221 native cattle, with an estimated annual milk production of 952,009 tons. Within the province, Mashhad County constitutes a major dairy production area, contributing 145,686 tons of milk (28.14% of provincial output) and supporting 87,472 purebred and 53,231 crossbred cattle (Agricultural Jihad Organization of Khorasan Razavi Province, 2023). These figures indicate the regional concentration and economic significance of dairy production in Mashhad, supporting its selection as the study area.

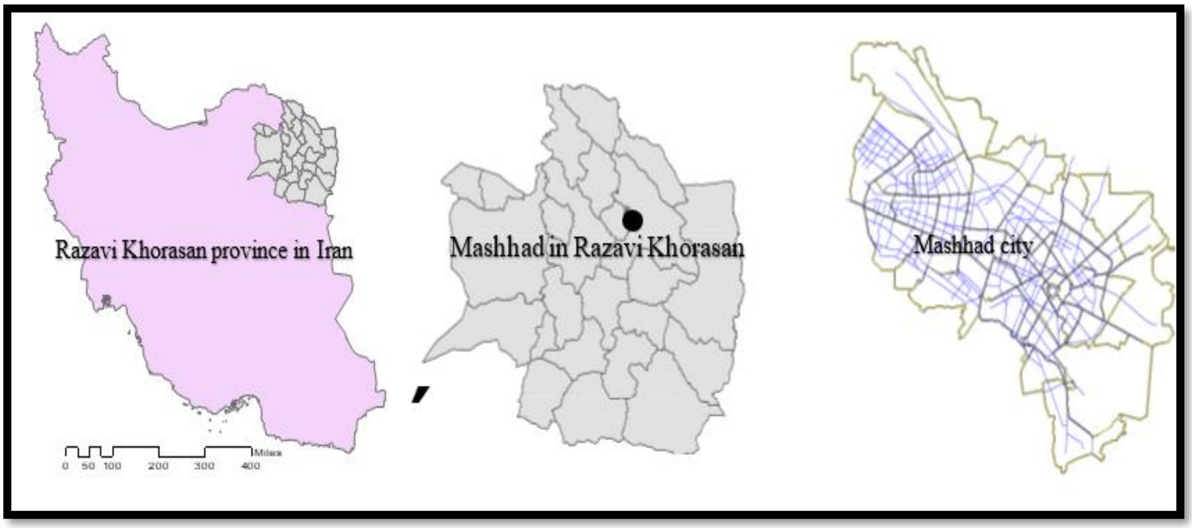

Figure 1: The geographical location of the study area in Razavi Khorasan province, Iran (Firoozzare et al., 2023)

Data were collected in 2024 using a cross-sectional descriptive–analytical design. The industrial dairy farm served as the unit of analysis in this study. A sample of 50 farms was purposefully selected to ensure continuous production activity and the availability of comprehensive operational records. Notably, the sample exhibited a high degree of homogeneity in ownership structure: except for one publicly owned farm, all investigated farms were privately managed. Data collection relied on complementary sources to support subsequent risk prioritization. These included (i) a structured questionnaire administered to a key informant at each farm, and (ii) field-based qualitative inputs from semi-structured interviews and structured observations. Qualitative inputs were used to refine and validate the risk list and to contextualize operational processes. Quantitative scoring was conducted through the structured questionnaire (see Section 2.2 for risk identification and coding details). To standardize expert judgments for the quantitative prioritization stage, the questionnaire was developed based on the finalized risk list. The instrument was refined through review by academic and executive experts to support content validity/ Internal consistency reliability was high (Cronbach's $\alpha = 0.89$). The questionnaire required approximately 60–80 minutes to complete. Key informants were selected based on their operational knowledge and direct familiarity with core farm processes, typically including farm managers, veterinarians, or technical staff involved in production, animal health, and routine operational decision-making. Participation was voluntary, and responses were collected anonymously.

Risk identification, classification, and FMEA-based prioritization

A comprehensive risk register was constructed by synthesizing data from structured questionnaires, semi-structured interviews, and field observations, as detailed in the previous section. Potential risks were initially extracted from existing literature and field evidence. These identified risks were then consolidated and iteratively screened to remove duplicates and merge semantically overlapping items. This process ensured that each retained entry represented a distinct operational vulnerability suitable for quantitative scoring. To ensure traceability throughout the prioritization and reporting stages, each finalized risk was assigned a unique code. The finalized risk register comprised 107 distinct risks. To facilitate domain-level interpretation and reporting, these risks were further classified into nine operational domains: production and feeding operations, procurement and supply chains, disease and herd health management, human resources, infrastructure and facilities, technology and equipment, environmental stressors, institutional framework, and regulatory condition. This classification scheme supports domain-level analysis and enables targeted managerial and policy responses by linking risk priorities to specific operational subsystems, rather than treating the farm as a homogeneous unit.

Risk prioritization was conducted using the Failure Mode and Effects Analysis (FMEA) methodology. The analysis was implemented at the farm-process/failure-mode level, covering key operational processes such as feeding and feed storage, milking, animal health monitoring, housing and ventilation, and routine maintenance. For each risk item, a brief description of the failure mode, plausible causes, expected effects, and existing preventive or detection practices was documented. This documentation aimed to support consistent scoring across farms and respondents and to reduce ambiguity during evaluation. Each risk was assessed across three FMEA dimensions: severity (S), occurrence (O), and detectability (D). Scoring was conducted on a 1–10 scale, where 1 represents the lowest and 10 the highest rating, adhering to established FMEA protocols (Charan et al., 2026). To minimize interpretation variance, precise anchor definitions were used for each dimension:

- Severity reflected the magnitude of operational and economic consequences (including financial loss, production disruption, and quality deterioration).
- Occurrence represented the likelihood of the risk event under current conditions.

Detectability captured the ability to detect or control the risk before substantial impacts materialized. While advanced approaches such as Fuzzy FMEA or AHP can address uncertainty in expert judgments, this study employed a classical FMEA framework. This choice was made to ensure practical applicability and transparency, as classical FMEA, when integrated with a rigorous aggregation process, can effectively manage common FMEA challenges. The use of a structured questionnaire administered to 50 industrial dairy farms allowed for the aggregation of expert judgments across a substantial sample size. This aggregation—specifically the arithmetic mean of raw scores for each dimension (S, O, D)—inherently mitigates individual cognitive biases and reduces the impact of random errors (Foruzanmehr et al., 2020). The Risk Priority Number (RPN) was calculated as RPN = $\bar{S} \times \bar{O} \times \bar{D}$. To ensure reproducibility and clear classification, priority levels (Critical, High, Moderate, Low) were assigned using a percentage-based threshold approach relative to the maximum possible RPN within each operational domain. Risks with RPN >75% of the domain maximum were classified as Critical, 50–75% as High, 25–50% as Moderate, and <25% as Low. Additionally, the standard deviation of scores was calculated for each risk to indicate the level of consensus among experts, thereby enhancing the robustness and interpretability of the prioritization results.

It is important to acknowledge the inherent limitations of the FMEA method, particularly its reliance on expert judgment, which may introduce subjectivity and cognitive biases (e.g., anchoring or recency effects) (Qin et al., 2020; Kurt & Ozilgen, 2013). Furthermore, traditional FMEA assumes independence among risk factors and provides a static snapshot of risk, which may not fully capture dynamic interactions in complex farm systems (Charan et al., 2026; Liu et al., 2019). To mitigate these limitations, this study employed several strategies: (1) the use of standardized anchor definitions for each FMEA dimension to reduce interpretation variance; (2) aggregation of scores across 50 farms to average out individual respondent biases; and (3) triangulation of quantitative FMEA scores with qualitative field observations and semi-structured interviews to validate risk contexts and enhance understanding of the identified risk profile.

Results and Discussion

The distribution of Risk Priority Numbers (RPNs) across functional domains reveals a pronounced concentration of operational risk within specific subsystems of industrial dairy farms. RPN values indicate that feeding and feed procurement, microclimate control and infrastructure reliability, herd health management, and labor-related activities account for the majority of high- and critical-priority risks. These domains consistently rank highest in cumulative risk scores, highlighting their dominant contribution to overall vulnerability in the studied production systems. This pattern suggests that the stability of biologically intensive processes and their supporting physical infrastructure play a decisive role in shaping risk exposure under the semi-arid conditions of Mashhad County. Conversely, domains associated with institutional compliance and routine administrative functions exhibit substantially lower risk scores, indicating a comparatively limited contribution to immediate operational vulnerability at the farm level.

To interpret this pattern, a comprehensive risk inventory comprising 107 operational risks was first established and organized into nine interrelated domains—production, price, damage, technology, labor, credit, institutional, technical, and information—representing the primary channels through which uncertainty affects industrial dairy-farm performance. Risk identification relied on triangulated evidence, meaning that findings were cross-validated using three independent sources: peer-reviewed literature, sectoral reports, and semi-structured interviews with farm managers, veterinarians, and technical staff. Following this identification stage, the preliminary inventory underwent a structured refinement process involving the elimination of duplicate entries, consolidation of conceptually overlapping risks, and expert validation. This process resulted in a final analytical risk register comprising 47 distinct operational risks, which were subsequently subjected to Failure Mode and Effects Analysis. FMEA was then applied to assess each risk along the dimensions of severity, likelihood of occurrence, and detectability, allowing systematic comparison across domains.

Building upon this methodological framework, a quantitative assessment was conducted to translate these qualitative judgments into measurable risk scores. To provide a transparent overview of the risk landscape, descriptive statistics were calculated for all identified risks. Table 1 presents the frequency and percentage of risks across four RPN categories (Low, Medium, High, and Critical). As shown, the majority of risks fall into the High category, accounting for 53.20% of the total, followed by Low risks at 21.28%. Notably, 6 risks were classified as Critical, representing 12.76% of the inventory. These critical risks exhibit a mean RPN of 142.19, indicating a severe and highly variable threat to farm operations. The wide standard deviation in the Critical category suggests that while some critical risks are extremely high, others are closer to the threshold, reflecting diverse severity levels within this top tier. Conversely, the Low and Moderate categories show lower mean RPNs (44.00 and 31.50, respectively), confirming their lower priority.

Table 1- Descriptive Statistics of Operational Risks by Priority Category

Category	Frequency (n)	Percentage (%)	Mean RPN	Std. Dev.
Low (< 25%)	10	21.28%	44	35.40
Moderate (25–50\% Max)	6	12.76%	31.50	34.56
High (50–75%)	25	53.20%	46.67	57.21
Critical (> 75%)	6	12.76%	142.19	93.42
Total	47	100.00%		18.45

To determine the most vulnerable operational areas, the mean RPN values were calculated across the nine functional domains. As shown in Table 2, the Production domain exhibits the highest average risk exposure (Mean RPN = 233.00), followed by Credit (Mean RPN = 217.06) and Equipment and Maintenance (Mean RPN = 205.69). This hierarchy indicates that the stability of biologically intensive processes, financial liquidity, and physical infrastructure plays a decisive role in shaping overall vulnerability under the semi-arid conditions of Mashhad County. In contrast, domains related to institutional compliance and routine administrative functions show comparatively lower mean RPNs, suggesting that—while still relevant—they are less critical than production and financial constraints in the current context.

Table 2- Distribution of Operational Risks by RPN Category

Risk Domain	Mean RPN	Std. Dev.	Min	Max
Production	233	54.8	125	274
Price	194.24	152.77	46.22	448.15
Damage	63.4	45.9	31.5	142.19
Human Resource	192.6	106.61	75	312.5
Credit	217.06	95.8	122.67	373.33
Institutional	186.04	78.65	80	268.13
Technical	138.69	61.49	44	244.44
Equipment and Maintenance	205.69	64.04	110	280

Analysis of the full risk register further highlights a small set of individual risks that function as true operational bottlenecks. Increases in feed prices (PRC-50; RPN = 448.15), liquidity shortages in inflationary periods (CR-75; RPN = 373.33), and heat stress during hot seasons (PD-32; RPN = 327.25) consistently emerge as the highest-priority risks. The substantial gaps between these top-tier items and the next-ranked risks confirm the robustness of their prioritization: the ranking is structurally stable and not sensitive to minor variations in expert scoring. This stability strengthens the interpretation that the identified items represent genuine leverage points where operational vulnerability is most acutely concentrated. Figure 2 presents a representative Probability-Impact matrix highlighting key risks and dominant vulnerability patterns.

	Impact 1	Impact 2	Impact 3	Impact 4	Impact 5	Impact 6	Impact 7	Impact 8	Impact 9	Impact 10
Probability 10										
Probability 9						Fluctuation in other feed input costs, Seasonal variability in feed supply costs				
Probability 8				Environmental contamination and legal penalties				Increased production costs		
Probability 7				Loss of capital due to inadequate compensation for damages		Feed spoilage due to improper storage,	Heat stress during hot seasons	Liquidity shortages due to inflationary conditions		
Probability 6					Metabolic disorders from overfeeding	Failure of cooling/storage equipment, Malfunctioning milking machines, Reduced adaptability to changing market or internal conditions, Reduced decision-making and planning accuracy, Animal diseases (e.g., foot-and-mouth disease, mastitis), Labor shortages and high employee turnover, Depreciation of other equipment	Weight loss and weakness due to inadequate nutrition			
Probability 5				Reproductive issues (low fertility, abortion)	Implementation of new laws and regulations					
Probability 4		Natural disasters affecting input supply (Fire and damage)	The ft							
Probability 3					Increased stress and reduced milk yield due to limited movement space					
Probability 2				.		Metabolic disorders from overfeeding				
Probability 1										

Fig. 2- Probability-impact matrix

Taken together, these findings illustrate that economic and environmental uncertainties manifest operationally through their effects on feed management, production routines, and herd-level physiological stress. By organizing risks into well-defined domains and linking them to quantified RPN values, the analysis provides a coherent narrative complement to the tabular results, clearly distinguishing the domains and individual risks with the greatest strategic importance. This integrated perspective forms the basis for the domain-specific prioritization presented in the subsequent sections.

Table 3- Prioritized Production-Related Risks in Industrial Dairy Farms

Risk Code	Risk Description	S	O	D	RPN	Priority
PD-32	Heat stress during hot seasons	8.50	7.00	5.50	327.25	Critical
PD-40	Inadequate ventilation systems	6.50	6.50	6.50	274.63	High
PD-31	Feed spoilage due to improper storage	6.50	6.00	6.50	253.50	High
PD-41	Environmental contamination and legal penalties	7.75	6.50	5.00	251.88	High
PD-42	Reduced production and increased disease due to poor environment	7.00	6.50	5.50	250.25	High
PD-33	Animal diseases (e.g., foot-and-mouth disease, mastitis)	8.00	6.00	5.50	264.00	High
PD-34	Reproductive issues (low fertility, abortion)	7.50	5.50	5.00	206.25	High
PD-35	Weight loss and weakness due to inadequate nutrition	7.50	6.00	5.80	259.19	High
PD-36	Metabolic disorders from overfeeding	5.50	5.50	5.00	151.25	Low
PD-37	Increased stress and reduced milk yield due to limited movement space	5.00	5.00	5.00	125.00	Low
PD-38	Microbial contamination and water salinity	7.00	6.00	4.90	207.81	High

Table 3 presents the prioritized production-related risks, showing that criticalities within this domain are primarily linked to environmental control and animal-performance constraints rather than isolated biological events. Heat stress during hot seasons (PD-32; RPN = 327.25) ranks as the most critical production risk, emphasizing the sensitivity of dairy performance to thermal stress under semi-arid conditions. The high priority assigned to inadequate ventilation systems (PD-40; RPN = 274.63) and poor housing environmental conditions (PD-42; RPN = 250.25) further demonstrates that microclimate deficiencies and housing management represent a major source of production instability. Similarly, Chen et al., (2024) reported that elevated heat stress substantially reduces feed intake, milk yield, and feed efficiency in dairy cows. In line with these findings, Arias et al., (2025) observed that dairy farmers face increased production losses under repeated heat stress events. Seyedsharifi et al., (2024) and Herbut et al., (2018) also highlighted the critical role of temperature and humidity in determining lactation performance, confirming the strong influence of thermal stress on dairy productivity. Furthermore, Bahrami et al., (2025) demonstrated that risks related to production processes and production costs are major economic vulnerabilities that significantly threaten the sustainability of dairy farms.

Feed spoilage due to improper storage (PD-31; RPN = 253.50) highlights the critical role of post-procurement handling and operational discipline, as losses at this stage propagate through the production system, ultimately constraining animal health status and reducing productivity. In addition, health-related disorders (PD-33; RPN = 264.00) and reproductive problems (PD-34; RPN = 206.25) are ranked among the high-priority risks, underscoring the importance of preventive health surveillance and effective reproductive management for maintaining production efficiency. Similarly, Jensen et al., (2021) demonstrated that health disorders and reproductive inefficiencies substantially intensify operational risk, particularly when they occur alongside environmental stressors. In line with these findings, Borş et al., (2024) reported that compromised animal health conditions are associated with significant declines in milk yield and impaired reproductive performance, with affected cows exhibiting lower conception rates and increased reproductive inefficiencies compared to healthy animals.

Collectively, these results suggest that effective risk mitigation should prioritize thermal stress adaptation, robust microclimate management, and post-procurement operational control, alongside preventive health and reproductive management. Integrating these measures can help buffer industrial dairy farms against both exogenous environmental shocks and endogenous operational vulnerabilities.

Table 4- Prioritized Price-Related Risks in Industrial Dairy Farms

Risk Code	Risk Description	S	O	D	RPN	Priority
PRC-50	Increase in feed prices	9.00	8.00	6.20	448.15	Critical
PRC-51	Fluctuation in other feed input costs	7.50	6.00	6.60	297.00	High
PRC-52	Seasonal variability in feed supply costs	6.50	6.00	6.70	262.50	High
PRC-53	Increase in electricity costs	5.00	5.50	2.30	63.56	Low
PRC-54	Increase in water costs	4.00	6.00	2.00	48.00	Low
PRC-55	Increase in fuel costs	4.20	5.50	2.00	46.22	Low

As shown in Table 4, price-related vulnerability in industrial dairy farms is overwhelmingly driven by feed market dynamics rather than by changes in utility costs. The increase in feed prices (PRC-50; RPN = 448.15) ranks as the most critical risk across the entire register, reflecting its immediate and substantial impact on variable production costs and cash-flow stability. Elevated priority scores for fluctuations in other feed input costs (PRC-51; RPN = 297.00) and seasonal variability in feed supply costs (PRC-52; RPN = 262.50) indicate that exposure is not limited to isolated price shocks but is embedded in persistent and recurrent uncertainty within feed markets. In contrast, increases in electricity, water, and fuel costs (PRC-53–PRC-55) receive comparatively low priority, suggesting that although these inputs contribute to operating expenses, they exert a more limited destabilizing effect on overall farm performance under the conditions examined.

Similarly, Wolf (2012) demonstrated that feed price volatility substantially increases financial risk for dairy producers, with rising feed costs directly reducing profitability and complicating short- and moderate-term financial planning. Casasnovas Oliva & Aldanondo-Ochoa (2014) reported that fluctuations in livestock feed prices significantly affect both short-run and long-run milk production costs, emphasizing the sensitivity of dairy production systems to input price instability. Moreover, cyclical fluctuations in raw milk prices have been documented by Hua et al., (2025), highlighting that both input and output price volatility interact to exacerbate financial instability in dairy operations. These observations are consistent with the dominant ranking of feed-related risks in Table 4, confirming that feed price volatility represents a structural economic stressor rather than a transient market disturbance.

Taken together, these findings suggest that price risks in dairy farming are multifaceted, pervasive, and deeply embedded in market mechanisms, reinforcing the high criticality assigned to feed price volatility and input cost fluctuations in this study's risk prioritization. Effective risk governance should therefore integrate price risk management tools, forward-looking pricing strategies, and financial planning approaches to temper market-driven exposure and improve farm resilience.

Table 5- Damage-Related Risks

Risk Code	Risk Description	S	O	D	RPN	Priority
DR-61	Fire and damage	4.67	2.67	2.67	33.19	Moderate
DR-62	Theft	4.67	3.00	3.33	46.67	High
DR-63	Natural disasters affecting input supply	3.50	3.00	3.00	31.50	Moderate
DR-64	Sudden equipment failure	6.25	6.50	3.50	142.19	Critical

As shown in Table 5, vulnerability within the damage domain is predominantly driven by asset-reliability disruptions rather than episodic hazard events. Sudden equipment failure (DR-64; RPN = 142.19) ranks as the most critical damage-related risk, indicating that unplanned breakdowns can immediately disrupt milk harvesting, storage continuity, and routine farm operations. The relatively high priority assigned to theft (DR-62; RPN = 46.67) further suggests non-negligible exposure to security breaches and direct asset losses, as noted by Riahi & Siadati (2022). In contrast, fire-related damage (DR-61; RPN = 33.19) and natural disasters affecting input supply (DR-63; RPN = 31.50) were assessed at moderate levels, implying that resilience in this domain is more sensitive to preventive maintenance, monitoring discipline, and equipment reliability than to low-frequency external hazards. Similarly, Yamunarani et al., (2024) and Ekhtiyarzadeh et al., (2024) emphasize that challenges associated with mechanization and equipment reliability are key operational constraints in modern dairy farms, significantly influencing production continuity and management efficiency. This alignment suggests that the high ranking of sudden equipment failure in the present study reflects a structural operational vulnerability rather than a sporadic or external hazard. In contrast to less frequent hazards, such as natural disasters, endogenous factors related to equipment maintenance and operational control appear to be the dominant determinants of damage-related risk in industrial dairy farms.

Effective mitigation of damage-related risks should prioritize proactive maintenance, reliability monitoring, and operational oversight. Addressing these endogenous vulnerabilities can substantially reduce downtime and improve resilience, confirming that damage-domain exposure is largely driven by internal operational factors rather than by episodic external shocks.

Table 6- Prioritized Human Resource-Related Risks

Risk Code	Risk Description	S	O	D	RPN	Priority
HR-60	Labor shortages and high employee turnover	8.50	7.50	4.90	312.50	Critical
HR-61	Insufficient staff training and lack of expertise	8.00	7.00	5.10	284.25	High
HR-62	Minor scheduling conflicts	5.50	5.00	3.60	98.50	Low
HR-63	Temporary absenteeism	5.00	5.00	3.00	75.00	Low

Human Resource-related risks emerge as a central source of operational fragility in the studied industrial dairy farms (Table 6). Labor shortages and high employee turnover (HR-60; RPN = 312.50) were ranked at a critical level, reflecting the extent to which staffing discontinuities can disrupt animal-care routines, weaken operational discipline, and compromise hygiene and biosecurity compliance. Insufficient staff training and lack of expertise (HR-61; RPN = 284.25) also received high priority, suggesting that capability gaps amplify the impacts of other stressors by undermining preventive action, monitoring accuracy, and timely response. Similarly, Riahi & Siadati (2022) and Ekhtiyarzadeh et al., (2024) highlighted that limited human skill for operating equipment and machinery constitutes a key challenge in the dairy value chain, reinforcing the importance of targeted training and competency development.

By contrast, lower-ranked risks such as minor scheduling conflicts (HR-62; RPN = 98.50) and temporary absenteeism (HR-63; RPN = 75.00) appear more amenable to routine administrative control, consistent with their comparatively limited contribution to overall operational vulnerability within this domain.

Table 7- Prioritized Credit-Related Risks

Risk Code	Risk Description	S	O	D	RPN	Priority
CR-75	Liquidity shortages due to inflationary conditions	7.00	8.00	6.67	373.33	Critical
CR-76	Loss of financial credibility and bank penalties	7.33	5.00	4.33	158.89	High
CR-77	Loss of capital due to inadequate compensation for damages	7.67	4.00	4.00	122.67	High
CR-78	Reduced profitability and increased debt	6.67	6.00	5.33	213.33	High

Credit-related prioritization shifts analytical attention from exposure to shocks toward the capacity of farms to buffer and absorb disturbances without disrupting core operations (Table 7). Liquidity shortages under inflationary conditions (CR-75; RPN = 373.33) represent the most critical financial constraint, as liquidity tightness directly translates into delayed input procurement, deferred maintenance, and reduced responsiveness during periods of stress. The high ranking of reduced profitability and increasing debt burdens (CR-78; RPN = 213.33) further indicates that vulnerability may accumulate over time through reinforcing financial pressures that limit reinvestment and elevate dependence on external credit. In parallel, loss of financial credibility and associated bank penalties

(CR-76; RPN = 158.89), along with capital erosion due to inadequate compensation for damages (CR-77; RPN = 122.67), underscore the operational implications of repayment capacity and loss-absorption ability. Similarly, Wolf (2012) found that dairy farms experiencing poor financial performance exhibit significant spikes in liquidity and debt repayment stress, with a greater proportion of farms falling below critical liquidity and repayment thresholds during financially weak years. They emphasize that liquidity capacity and debt coverage ratios are central to farm financial resilience, meaning that farms with limited liquidity and repayment ability are more vulnerable to adverse events and cost pressures, consistent with the critical prioritization of liquidity shortages and debt pressures observed in this study. In line with these observations, Karami & Barani (2018) also highlighted that access to credit and effective financial management significantly influence the ability of dairy farms to withstand economic shocks, with limited or mismanaged credit increasing operational vulnerability.

In contrast to price-driven exposures such as feed cost volatility, which reflect external market shocks, the patterns identified in credit-related risks here highlight endogenous financial vulnerabilities that stem from operational performance and capital structure. This underscores the importance of short-term liquidity management, prudent debt oversight, and strong financial discipline as key determinants of resilience in industrial dairy systems.

Table 8- Prioritized Institutional-Related Risks

Risk Code	Risk Description	S	O	D	RPN	Priority
IN-79	Implementation of new laws and regulations	5.33	5.00	3.00	80.00	Moderate
IN-80	Reduced product quality and legal penalties	7.00	6.00	5.00	210.00	High
IN-81	Imposition of regulatory restrictions	7.50	6.50	5.50	268.13	High

Table 8 shows that vulnerability associated with institutional risks in industrial dairy farms is driven more by farms' capacity to comply with quality assurance, documentation, and regulatory procedures than by the mere introduction of new laws. Regulatory restrictions (IN-81; RPN = 268.13) and reduced product quality penalties (IN-80; RPN = 210.00) were assigned high criticality, indicating that lapses in procedural discipline, record-keeping, and compliance routines can quickly lead to operational disruptions and financial losses. In contrast, implementing new laws and regulations (IN-79; RPN = 80.00) received a moderate priority score, suggesting that the volatility of policy itself is less destabilizing than the farms' ability to maintain consistent compliance. Similarly, Karami & Barani (2018) emphasize the role of government policies, regulatory enforcement, and product quality standards in shaping operational resilience in dairy farms. This indicates that institutional risks in industrial dairy farms are largely operational in nature, stemming from compliance performance, procedural discipline, and the ability to align production practices with regulatory requirements, consistent with the prioritization observed in Table 8.

The technical and equipment/maintenance-related risk domains are treated separately to provide a clear analytical distinction between systemic operational vulnerabilities and physical asset reliability issues. Technical risks (Table 9) primarily capture deficiencies in managerial decision-making, planning accuracy, resource allocation, and overall operational discipline. These factors influence farm performance indirectly, manifesting as economic losses, reduced productivity, or limited adaptability, rather than causing immediate operational stoppages. In contrast, equipment and maintenance-related risks (Table 10) directly affect the continuity of production processes and post-harvest handling through physical failures or malfunctions. This distinction ensures that prioritization reflects the different pathways through which these risk categories influence industrial dairy farm performance and supports targeted mitigation strategies for each domain.

Table 9. Prioritized Technical Risks

Risk Code	Risk Description	S	O	D	RPN	Priority
TE-82	Tractor depreciation	5.00	4.33	4.33	93.89	Moderate
TE-83	Depreciation of other equipment	4.33	3.67	3.67	58.26	Low
TE-84	Increased financial loss and reduced resource management transparency	6.00	5.33	5.00	160.00	High
TE-85	Reduced profitability and productivity	7.33	6.67	5.00	244.44	High
TE-86	Economic losses	7.33	6.33	4.67	216.74	High
TE-87	Loss of market opportunities and income reduction	6.33	4.67	2.67	78.81	Moderate
TE-88	Increased production costs	4.00	3.67	3.00	44.00	Low
TE-89	Reduced operational transparency and lost development opportunities	6.33	5.00	4.67	147.78	High
TE-90	Exposure to sudden crises due to poor risk anticipation	6.67	6.00	4.33	173.33	High
TE-91	Reduced decision-making and planning accuracy	6.33	6.00	4.67	177.33	High
TE-92	Reduced adaptability to changing market or internal conditions	5.67	5.33	4.33	130.96	Moderate

Technical risks summarized in Table 9 primarily capture performance losses arising from deficiencies in operational efficiency, managerial discipline, and planning capacity rather than from physical asset failure alone. High-priority items—most notably reduced profitability and productivity (TE-85; RPN = 244.44) and broader economic losses (TE-86; RPN = 216.74)—indicate that technical weaknesses manifest directly as economic vulnerability. In addition, elevated priority assigned to poor risk anticipation (TE-90; RPN = 173.33) and reduced decision-making and planning accuracy (TE-91; RPN = 177.33) highlights the importance of forecasting routines, preparedness discipline, and decision-support practices as central leverage points within this domain. By contrast, asset depreciation items such as tractor depreciation (TE-82; RPN = 93.89) and depreciation of other equipment (TE-83; RPN = 58.26) were assigned moderate to low priority, suggesting that long-term capital wear is less destabilizing than deficiencies in planning, coordination, and execution. Similarly, Tosun (2025) reported that dairy farms with stronger managerial practices—including improved feeding schedules, health routines, and housing conditions—demonstrated significantly higher technical efficiency, reinforcing the present finding that deficiencies in planning and operational control (e.g., TE-90 and TE-91) are key determinants of performance. In line with this, Dubey et al., (2025) observed that multiple management factors, including feed quality and environmental control, significantly affect technical efficiency, aligning with the high priority of economic and managerial technical risks in Table 10.

A broader review by Müller et al., (2017) emphasizes that managerial discipline and input optimization are central to achieving technical efficiency, supporting the notion that planning accuracy and decision support are critical for reducing technical vulnerabilities. Furthermore, Karbasi et al., (2015) showed that improving education, feeding management, and resource allocation can enhance technical efficiency, consistent with the high weighting of planning and transparency risks (TE-89, TE-90) in the present study. Dagistan et al., (2022) also highlighted that inefficient input use and poor managerial practices contribute substantially to technical inefficiencies, confirming that economic and operational vulnerabilities are tightly linked to managerial competence.

Collectively, these findings indicate that mitigating technical risks in industrial dairy farms should extend beyond routine asset replacement toward strengthening monitoring systems, enhancing planning consistency, and improving managerial follow-through. Operational improvements in these areas are critical for reducing economic losses, enhancing productivity, and increasing resilience to both internal and external stressors.

Table 10. Equipment and Maintenance-Related Risks

Risk Code	Risk Description	S	O	D	RPN	Priority
EM-70	Malfunctioning milking machines	8.00	7.00	5.00	280.00	Critical
EM-71	Failure of cooling/storage equipment	7.50	6.50	5.00	243.75	High
EM-72	Inadequate maintenance schedules	7.00	6.00	4.50	189.00	High
EM-73	Minor equipment wear and tear	5.50	5.00	4.00	110.00	Low

Equipment and maintenance-related risks (Table 10) underscore the operational significance of reliability in core production and post-harvest processes. Malfunctioning milking machines (EM-70; RPN = 280.00) were ranked as critical, reflecting their immediate impact on milk harvesting continuity and quality. High priority assigned to failures in cooling and storage equipment (EM-71; RPN = 243.75) and inadequate maintenance schedules (EM-72; RPN = 189.00) highlights that cold-chain integrity and preventive maintenance practices are key controllable factors influencing downstream losses. In contrast, minor equipment wear and tear (EM-73; RPN = 110.00) received low priority, suggesting that routine inspection and timely servicing are generally sufficient to manage these issues.

Similarly, Yamunarani et al., (2024) emphasizes that equipment reliability, particularly in milking and refrigeration systems, is a critical determinant of operational efficiency and product quality in modern dairy farms. In line with this, Riahi & Siadati (2022) reported that preventive maintenance and systematic monitoring significantly reduce downtime and improve continuity of milk collection and storage. Consistent with these findings, Younesi et al., (2025) highlighted that mechanical and infrastructural issues, including malfunctioning milking systems, inadequate cooling devices, and poor maintenance planning, are major sources of technical risk—supporting the present study's conclusion on the critical role of equipment reliability and facility design in overall vulnerability. The alignment of these studies with the present findings suggests that the high ranking of EM70 to EM72 reflects structural operational vulnerabilities rather than sporadic or minor equipment failures. Proactive maintenance, early fault detection, and disciplined adherence to equipment schedules emerge as essential strategies for minimizing operational disruptions and sustaining productivity in industrial dairy systems.

In light of the prioritization results, the most critical vulnerabilities converge around heat stress (PD-32), feed price volatility (PRC-50), liquidity constraints (CR-75), and equipment reliability (DR-64). The analysis indicates that mitigating heat stress is closely associated with improvements in cooling efficiency within milking parlors and resting areas, where enhanced fogging and ventilation capacity are directly linked to reductions in heat-related productivity losses. Likewise, stabilizing feed supply through structured contractual arrangements and diversification of sourcing channels appears strongly connected to greater cost predictability and reduced exposure to supply-chain disruptions.

Financial resilience emerges as another pivotal dimension, as liquidity planning and disciplined debt management are closely tied to the farm's capacity to absorb economic shocks and avoid deferred maintenance. In parallel, the prevention of equipment-related disruptions is consistently associated with systematic preventive maintenance protocols and early fault detection practices, particularly in cooling and milking systems, thereby reducing operational downtime and safeguarding product quality.

Taken together, these findings underscore that resilience in industrial dairy systems is primarily shaped by targeted improvements in thermal management, feed security, financial stability, and equipment reliability. Rather than representing isolated control points, these domains function as leverage nodes within an interconnected risk structure, where interventions in high-impact areas generate cascading stabilizing effects across production, health, and financial performance. Such an integrated perspective provides a structured basis for optimizing resource allocation and reducing systemic operational vulnerability.

Conclusion

This study developed and applied an integrated FMEA-based analytical framework to systematically identify, classify, and prioritize 107 operational risks in industrial dairy farms in Mashhad County. Following the refinement of the initial risk inventory through the elimination of duplicate and conceptually overlapping items, the final FMEA-based prioritization was conducted on

47 distinct operational risks. The results reveal a clear concentration of high-criticality risks within the economic–financial and environmental–operational domains, with feed price inflation, inflation-driven liquidity constraints, and seasonal heat stress emerging as the most critical threats due to their compounded severity, recurrence, and limited early detectability.

A central analytical insight of this study is the structural role of low detectability as a systemic vulnerability factor. Several risks attain critical status not only because of their intrinsic severity, but also because weak monitoring systems, fragmented information flows, and delayed managerial responses allow impacts to accumulate before corrective action is initiated. This shifts risk exposure from isolated operational failures toward a broader governance and management-capacity challenge.

Beyond risk ranking, the proposed framework contributes a structured, replicable, and transferable methodology for farm-level risk profiling that integrates technical, economic, and organizational dimensions of vulnerability. As such, it provides a practical decision-support tool for more targeted allocation of managerial attention and policy resources, particularly in semi-arid, inflation-prone, and resource-constrained production systems. On this basis, the following policy and management recommendations are proposed, incorporating specific implementation pathways and cost-benefit considerations:

Inflation-Indexed Credit Mechanisms: Financial institutions, in coordination with the Ministry of Agriculture Jihad, should deploy inflation-indexed working capital facilities for high-risk farms to preserve purchasing power during price shocks. These facilities must be designed with conditional disbursement mechanisms that enforce feed quality standards and supplier diversification, preventing crisis-driven quality degradation. Although implementing dynamic pricing indices requires administrative overhead, the long-term economic benefit of preventing systemic supply-chain collapse far outweighs the costs, ensuring greater financial stability for the sector.

Multi-tiered Infrastructure Adaptation Strategies for Heat-Stress Vulnerability: Public-private partnerships and local cooperatives should facilitate a tiered climate-adaptation support package that combines concessional finance with technical assistance for ventilation and cooling systems. Targeting criteria must be rule-based, relying on heat-exposure indices and herd size to ensure efficient resource allocation. The upfront capital investment in infrastructure is justified by the substantial return on investment through reduced mortality rates and stabilized milk yields, making these adaptation measures economically sustainable.

Integrated Governance for Monitoring and Early-Warning Systems: The Veterinary Organization, in collaboration with IT service providers, should institutionalize standardized monitoring architectures supported by interoperable farm–cooperative dashboards. By integrating climatic, animal-health, and market indicators into predefined action thresholds, stakeholders can significantly reduce detection-to-response delays. The marginal cost of implementing such digital monitoring architectures is negligible compared with the potential financial devastation of undetected disease outbreaks or market shocks, making it a high-value intervention.

Coordinated Procurement and Risk Sharing: Farmer cooperatives and insurance companies should strengthen procurement platforms to pool demand, diversify sourcing channels, and stabilize access to critical inputs under volatile conditions. Coupling procurement coordination with formal risk-sharing instruments—such as contingency reserves and mutual insurance mechanisms—can reduce cascading operational disruptions. This collective approach not only reduces individual farm exposure to price spikes but also lowers transaction costs associated with individual risk management, creating a more stable operational environment.

To further enrich policy guidance and deepen the understanding of mitigation effectiveness, future research could employ stochastic simulation models. Such models could support detailed cost-benefit analyses of proposed risk management strategies and provide more robust quantitative evidence for decision-making.

Author Contributions

Ali Mollaei Jaghargh was responsible for the investigation, data collection, and writing the original draft. Ali Firoozzare contributed to the conceptualization and methodology, and provided ongoing guidance, supervision, and project administration throughout the research process. Nazanin Yousefian was responsible for the final writing, and editing of the manuscript.

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Ethical considerations

The authors avoided data fabrication, falsification, plagiarism, and misconduct.

Conflict of interest

The author declares no conflict of interest.

REFERENCES

1. Abbas, Q., Han, J., Bakhsh, K., Ullah, R., Kousar, R., Adeel, A., & Akhtar, A. (2022). Adaptation to climate change risks among dairy farmers in Punjab, Pakistan. Land Use Policy, 119, 106184. https://doi.org/10.1016/j.landusepol.2022.106184.
2. Agricultural Jihad Organization of Khorasan Razavi Province. (2023). Statistical Yearbook of Agriculture, Iran.
3. Alvarez, A., García-Cornejo, B., Pérez-Méndez, J. A., & Roibás, D. (2021). Value-Creating Strategies in Dairy Farm Entrepreneurship: A Case Study in Northern Spain. Animals, 11(5). https://doi.org/10.3390/ani11051396.
4. Arias, R. A., Heinsohn, J., Keim, J. P., Pinto, R., & Bombal, E. (2025). Perception of Chilean dairy farmers facing the growing heat stress events in the country. Austral Journal of Veterinary Sciences, 57(1), e5704. https://doi.org/10.4206/ajvs.57.04.
5. Borş, A., Borş, S.I., Floriștean, V.C. (2024). Mastitis impact on high-yielding dairy farm's reproduction and net present value. Frontiers in Veterinary Science, 10, 1345782. https://doi.org/10.3389/fvets.2023.1345782.
6. Bahrami, M., Yazdani, A.R., Yeganeh Badrabadi, Ha. (2025). Effective factors on reducing economic risk of dairy cattle farms in Gorgan. Journal of Ruminant Research, 13(3), 19-32. (in Persian with English abstract).
7. Casasnovas-Oliva, V. L., & Aldanondo-Ochoa, A. M. (2014). Feed prices and production costs on Spanish dairy farms. Spanish Journal of Agricultural Research, 12(2), 291-304. https://doi.org/10.5424/sjar/2014122-4890.
8. Charan, K.V., Singh, M., Redhu, S. Soni, G. (2026). A framework for automating failure modes and effects analysis (FMEA) using large language models (LLMs) and retrieval-augmented generation (RAG). Int J Syst Assur Eng Manag, 17, 1495–1509. https://doi.org/10.1007/s13198-026-03171-6.
9. Chen, L., Thorup, V., Kudahl, A., & Østergaard, S. (2024). Effects of heat stress on feed intake, milk yield, milk composition, and feed efficiency in dairy cows: A meta-analysis. Journal of Dairy Science, 107(5), 3207-3218. https://doi.org/10.3168/jds.2023-24059.
10. Dagistan, E., Ozdemir, T., & Korkmaz, H. (2022). Technical inefficiencies in Eastern Mediterranean dairy farms: Causes and solutions. Journal of Dairy Science & Technology, 12(3), 145–160.

11. Dubey, P., Singh, R., & Kumar, S. (2025). Management practices and technical efficiency in dairy farms. Scientific Reports, 15(1), 1124. https://doi.org/10.1038/s41598-025-14597-6.
12. Ezadi, T., Zare Mehrjerdi, M.R., Amirtaimoori, S., Mehrabi Boshr Abadi, H., Naghavi, S. (2022). Evaluation of Efficiency and Prioritization of Resilience and Efficiency Criteria of Dairy Industrial Farms in Kerman. Res Anim Prod, 13(36), 163-171. https://doi.org/10.52547/rap.13.36.163. (in Persian with English abstract).
13. Ekhtiyarzadeh, Mohammad Hassan., Rahimian, Mehdi., Gholamrezai, Saeed., & Aref Nejad, Mohsen.
14. (2024). Challenges of the Dairy Cow Value Production Chain in Iran. *Space Economy and Rural Development*, *13* (47), 59-74. http//doi.org/10.61186/serd.13.1.1. (in Persian with English abstract).
15. Feliciano, R. J., Guzmán-Luna, P., Hospido, A., & Membré, J. (2024). A multicriteria assessment of food safety measures for a large dairy farm in hot weather conditions. Microbial Risk Analysis, 27-28, 100312. https://doi.org/10.1016/j.mran.2024.100312.
16. Ferreira, J.S., Baccili, C.C., Nemoto, B.S., Vieira, FK., Sviercoski, L.M., Ienk, T., Pagno, J.T., Gomes, V. (2024). Biosecurity practices in the dairy farms of southern Brazil. Front Vet Sci, 11, 1326688. https://doi.org/10.3389/fvets.2024.1326688.
17. Finger, R., Dalhaus, T., Allendorf, J., & Hirsch, S. (2018). Determinants of downside risk exposure of dairy farms. European Review of Agricultural Economics, 45(4), 641-674. https://doi.org/10.1093/erae/jby012.
18. Firoozzare, A., Ghazanfari, S., & Yousefian, N. (2023). Designing and analyzing the motivational risk profile of healthy food and agricultural products purchase. Journal of Cleaner Production, 432, 139693. https://doi.org/10.1016/j.jclepro.2023.139693.
19. Geravandi, S., & Karamifard, F. (2024). Analyzing Impact Components' Digital Empowering on Intelligence Business Case study: Management of Dairy farms in Kermanshah Province. Iranian Journal of Agricultural Economics and Development Research, 55(1), 1-14. https://doi.org/ 10.22059/ijaedr.2021.322304.669032. (in Persian with English abstract).
20. Górska-Warsewicz, H., Rejman, K., Laskowski, W., & Czeczotko, M. (2019). Milk and Dairy Products and Their Nutritional Contribution to the Average Polish Diet. Nutrients, 11(8), 1771. https://doi.org/10.3390/nu11081771.
21. Foruzanmehr, M., Khashei siuki, A., Najafi mood, M.H., Khozeymehnezhad, H. (2020). Application of Fuzzy and FEMA Modified Methods in Risk Assessment of Man-Made Threats in Water Systems. Disaster Prev. Manag. Know, 10 (3), 240-250. (in Persian with English abstract).
22. Hashemnia, M., Kalantari, K., Asadi, A. & Ganjkhanlou, M. (2023). Defining the optimal strategy(s) to improve the position of traditional livestock keepers in the red meat supply chain (Case study: the southwestern skirt of Zagros). Iranian Journal of Agricultural Economics and Development Research, 54(1), 221-239. doi: 10.22059/ijaedr.2022.335979.669125. (in Persian with English abstract).
23. Hassani, L., Daneshvar-Kakhki, M., Sabuhi-Sabooni, M., Ghanbari, G., & Fantke, P. (2018). Quantification of energy and environmental aspects of iranian dairy farms based on optimal nutrition. In Proceedings of 189th The IIER International Conference (pp. 6-11) http://iraj.in/journal/IJASEAT/paper_detail.php?paper_id=14309.
24. Herbut, P., Angrecka, S. & Walczak, J. (2018). Environmental parameters to assessing of heat stress in dairy cattle—a review. Int J Biometeorol, 62, 2089–2097. https://doi.org/10.1007/s00484-018-1629-9.
25. Hua, J., Ma, C., Kang, Y., & Jia, Y. (2025). Why is dairy production so difficult to stabilize? Research on the micro-mechanism and transformation mechanism of cyclical fluctuations of raw milk prices in China. Frontiers in Sustainable Food Systems, 9, 1655741. https://doi.org/10.3389/fsufs.2025.1655741.
26. Karami, A., & Barani, N. (2018). The role of agricultural bank credits in the prosperity of livestock activities in the Qarqari district of Hirmand city. Agricultural Economics Research, 10. 2.
27. Karbasi, A., Rahimi, M., & Ghorbani, R. (2015). Impact of managerial practices and input optimization on technical efficiency of dairy farms. Journal of Agricultural Economics Studies, 4(1), 13–25. (In persian)
28. Khusna, A., Muzayyanah, M. A. U., Kusumastuti, T. A., & Putra, A.R.S. (2025). Comprehensive analysis of supply chain risk in the goat milk industry in east java: Scor-fmea approach. Adv. Anim. Vet. Sci, 13(2), 217-230.
29. Kitole, F.A. (2025). Impact of dairy farming extension programs on smallholder livestock keepers' welfare among Maasai communities in Arusha, Tanzania. Preventive Veterinary Medicine, 239, 106511. https://doi.org/10.1016/j.prevetmed.2025.106511.

30. Kurt, L., & Ozilgen, S. (2013). Failure mode and effect analysis for dairy product manufacturing: Practical safety improvement action plan with cases from Turkey. Safety Science, 55, 195-206. https://doi.org/10.1016/j.ssci.2013.01.009.
31. Liu, H., Chen, X., Duan, C., & Wang, Y. (2019). Failure mode and effect analysis using multi-criteria decision making methods: A systematic literature review. Computers & Industrial Engineering, 135, 881-897. https://doi.org/10.1016/j.cie.2019.06.055.
32. Müller, K., Schmid, H., & Weber, A. (2017). Technical efficiency in dairy farms: A systematic review. Journal of Dairy Science, 100(5), 4110–4125. https://doi.org/10.3168/jds.2016-12123.
33. Priyashantha, H. (2025). World dairy system sustainability: A milk quality perspective. Frontiers in Sustainable Resource Management, 4, 1572962. https://doi.org/10.3389/fsrma.2025.1572962.
34. Qin, J., Xi, Y., & Pedrycz, W. (2020). Failure mode and effects analysis (FMEA) for risk assessment based on interval type-2 fuzzy evidential reasoning method. Applied Soft Computing, 89, 106134. https://doi.org/10.1016/j.asoc.2020.106134.
35. Riahi., V. & siadati., S. (2022). Risk management of livestock activity in rural areas of Golpayegan county. Economic Geography Research, 3(7), 1-19. (In persian)
36. Rjili, H., Muñoz-Ulecia, E., Bernués, A., Jaouad, M., & Martin-Collado, D. (2023). Evolution of pastoral livestock farming on arid rangelands in the last 15 years. Animal, 17(4), 100748. https://doi.org/10.1016/j.animal.2023.100748.
37. Roustaee, R., Rafiee, H., Ghodsi, D., Omidvar, N., Hosseini, H., & Toorang, F. (2022). Challenges and Obstacles to Dairy Consumption in Iran from Stakeholders' Perspectives Using a Food System Approach. Sustainability, 15(16), 12568. https://doi.org/10.3390/su151612568.
38. Sahneh. R., Sahneh, B., & Khajeh Shahkoohi, A. (2022). The Role of Small Livestock Units in Sustainable Livelihood of Rural Households (Case study: Villages of Aq Qala County). Geography and Development, 20 (67), 142-167. http://dx.doi.org/10.22111/J10.22111.2022.6913. (in Persian with English abstract).
39. Seyedsharifi, R., Amiri, S., Hedayat evrigh, N., Seif davati, J., & Yelchi, T. (2021). Investigating profit maximization in dairy cow herds toward production system optimization. Journal of Animal Science, 31(3), 27-39. https://doi.org/10.22034/AS.2021.39086.1563. (in Persian with English abstract).
40. Shahbazi, H. (2021). The optimal budget of Milk Generic advertising: an application of different allocation methods. Iranian Journal of Agricultural Economics and Development Research, 52(4), 643-662. doi: 10.22059/ijaedr.2021.285992.668791. (in Persian with English abstract).
41. Shantharaju, A., Islam, M. A., Kath, J. M., Mushtaq, S., Muniyappa, A., & Singh-Peterson, L. (2024). Understanding Constraints and Enablers of Climate Risk Management Strategies: Evidence from Smallholder Dairy Farmers in Regional South India. Sustainability, 16(5), 2018. https://doi.org/10.3390/su16052018.
42. Shokoohi, Z., Bakhshoudeh, M., & Asgari, M. (2022). Subsidies Reform and the Efficiency of Dairy Farms in Iran: A Comprehensive Evaluation. Iranian Journal of Economic Studies, 10(2), 391-410. https://doi.org/ 10.22099/ijes.2022.40872.1757.
43. Syarif, M., Jais, I. R. M., Maflahah, I., & Ihsannudin, I. (2025). Risk Evaluation in Corn Supply Chain with FMEA Approach: Challenges and Opportunities for Supply Efficiency. International Journal of Industrial Engineering, 36(1), 181-194.
44. Tosun, H. (2025). Operational management and technical efficiency in Turkish dairy farms. Journal of Veterinary and Animal Management Studies, 18(2), 45–59. https://ejournals.epublishing.ekt.gr/index.php/jhvms/article/view/38618.
45. Wolf, C.A. (2012). Dairy farmer use of price risk management tools. Journal of Dairy Science, 95(7), 4176-4183. https://doi.org/10.3168/jds.2011-5219.
46. Younesi, A., & Karimi, K. (2025). Designing a welfare model for cows in industrial dairy farms of Pakdasht county. Journal of Animal Production, 27 (2), 207-221. https://doi.org/10.22059/jap.2025.367154.623766.
47. Yamunarani, T., Bharathkumar, R., Jeevitha, V., Jagadeesh, S., (2024). Advancements and challenges in automatic milking systems: A comprehensive review. J Instrum Control Eng. 12(2):26
48. Zandi, P., Rahmani, M., Khanian, M., & Mosavi, A. (2020). Agricultural Risk Management Using Fuzzy TOPSIS Analytical Hierarchy Process (AHP) and Failure Mode and Effects Analysis (FMEA). Agriculture, 10(11), 504. https://doi.org/10.3390/agriculture10110504.

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مدیریت ریسک‌های عملیاتی در واحدهای صنعتی پرورش گاو شیری: رویکردی مبتنی بر FMEA

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تاب‌آوری، تغییرپذیری اقلیمی، مشهد، عدم‌قطعیت.

چکیده

دامداری‌های صنعتی در مناطق نیمه‌خشک با ریسک‌های عملیاتی متعددی مواجه‌اند که می‌تواند تداوم کسب‌وکار و بهره‌وری آن‌ها را تهدید کند. هدف از این مطالعه، شناسایی و اولویت‌بندی ریسک‌های عملیاتی در نظام‌های دامداری صنعتی با استفاده از شواهد به‌دست‌آمده از ۵۰ واحد پرورش گاو شیری در شهرستان مشهد واقع در شمال شرقی ایران است. برای این منظور، رویکرد تجزیه‌وتحلیل حالت و اثرات خطا (FMEA) به‌منظور تدوین یک فهرست ثبت ریسک و طبقه‌بندی ریسک‌ها در حوزه‌های عملکردی اصلی به کار گرفته شد. سپس، اعداد اولویت ریسک بر اساس سه شاخص شدت، وقوع و قابلیت تشخیص محاسبه گردید. نمرات ریسک از طریق ارزیابی‌های ساختاریافته مبتنی بر نظر کارشناسان با حضور ذی‌نفعان کلیدی واحدها استخراج شد و به‌منظور رتبه‌بندی مخاطرات و برجسته‌سازی خوشه‌های با اولویت بالا، تجمیع گردید. نتایج نشان می‌دهد که نوسانات مرتبط با خوراک دام (شوک‌های قیمتی و ناپایداری کیفیت)، نقص در کنترل ریزاقلیم (اختلال در سیستم‌های سرمایش و تهویه)، بی‌ثباتی نیروی کار (جابه‌جایی کارکنان و شکاف مهارتی) و اختلال در زنجیره سرد (قابلیت اطمینان در جابه‌جایی و نگهداری شیر) در زمره بحرانی‌ترین ریسک‌ها قرار دارند. این ریسک‌ها نه‌تنها مکرر یا شدید هستند، بلکه تشخیص زودهنگام آن‌ها نیز دشوار است؛ امری که احتمال وقوع زیان‌های پی‌درپی را از طریق کاهش تولید شیر، عوارض مرتبط با سلامت گله و توقف عملیات، افزایش می‌دهد. یافته‌ها حاکی از آن است که تقویت مدیریت پیشگیرانه به‌منظور کاهش تواتر وقوع و رفع کاستی‌های مربوط به قابلیت تشخیص در ریسک‌های دارای اولویت بالا، امری ضروری است. اقدامات کلیدی در این زمینه شامل پایش سیستماتیک کیفیت خوراک، مراقبت و ارزیابی مستمر سلامت گله، و همچنین نگهداری و تعمیرات مبتنی بر قابلیت اطمینان برای سیستم‌های سرمایشی، تهویه و خنک‌کننده شیر است. افزون بر این، بهبود سازوکارهای حمایتی نهادی - به‌ویژه خدمات مشاوره‌ای و ترویجی، ترتیبات معتبر و شفاف انتقال ریسک و حکمرانی کارآمدتر تعاونی‌ها- می‌تواند ظرفیت اجرایی و تاب‌آوری را ارتقا بخشد. در مجموع، این مطالعه یک اولویت‌بندی مبتنی بر شواهد را ارائه می‌دهد تا مدیران واحدها و سیاست‌گذاران را به‌سوی مدیریت یکپارچه ریسک‌های عملیاتی در واحدهای صنعتی پرورش گاو شیری تحت محدودیت‌های مناطق نیمه‌خشک هدایت نماید.

استناد:

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