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Business Continuity Assessment of the Red Meat Supply Chain in the Greater Amman Municipality: An ISO 22301-Based Case Study

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Abstract

Municipal government supported red meat supply chain management is one of the critical but under-researched elements of urban food security systems. The study proposes a systematic Business Continuity Management (BCM) model to conduct an analysis of the Greater Amman Municipality's (GAM) red meat supply chain using ISO 22301:2019 as a basis. The paper is based on qualitative case study research with primary data gathered by interviewing experienced slaughterhouse management and staff and an examination of the existing GAM risk register. Cases are covered in the research according to six continuity dimensions adapted from ISO 22301 Clause 8: core slaughterhouse operations, food safety inspection, dependencies of external stakeholders, critical assets and utilities, information and documentation infrastructure, and emergency governance and recovery readiness. A revised Failure Mode and Effects Analysis (FMEA) was performed to analyze 10 identified risks and prioritize them using Risk Priority Number (RPN) as the product of the occurrence rate, the difficulty of detection, and their severity. The results show that disease outbreak represents the greatest continuity risk (RPN = 16), before sewage system failure (RPN = 9) and waste accumulation (RPN = 6). While electricity and water supply disruption problems have high severity scores, GAM's current investments in mitigating these have significantly decreased their overall RPN values. This research paper is at Phase 1 of a two-phase research study with Phase 2 being the Business Impact Analysis, dimension-specific continuity strategies development and verification through a simulation. This work adds to the scant literature on municipal food supply chain resilience and illustrates a pragmatic approach to implementing ISO 22301 as an institutional research and practice framework in local government settings.

Keywords

Business continuity management; ISO 22301; red meat supply chain; municipal food security; Failure Mode and Effects Analysis (FMEA)

1. Introduction

Critical municipal supply chain operations play a direct role in keeping essential goods available to the citizens of Jordan, especially basic and essential food products that move daily through markets, inspection points, and distribution channels. Nowadays, with the military conflict between countries the region is experiencing high volatility that threatens these critical operations. When these operations are disrupted, the effect can appear quickly in the form of shortages, delays, waste, or pressure on prices. Public and private organizations are increasingly leaning toward developing Business Continuity Plans to ensure that operations continue smoothly during such events and to prepare for any shock that may arise. Despite this responsibility, the application of formal Business Continuity Management (BCM) frameworks to municipal food operations remains largely absent from both policy practice and academic research. The Research studies Greater Amman Municipality specifically one of the most important supply chains, which is the Red Meat Supply Chain Operation. The research focuses on the current regional context, where many risks can affect demand, prices, and create stress on the flow of essential goods. In this setting, the research aims to examine vulnerable points in the selected municipal supply chain and support the development of more practical and

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resilient continuity planning, with reference to ISO 22301 and its 2024 amendment. identifying and priorities the operational risks that threaten the continuity of GAM's red meat supply chain using a modified Failure Mode and Effect Analysis (FMEA). Then it identifies the critical activities whose disruption would generate unacceptable operational, public health, or legal consequences.

2. Literature Review

2.1 Introduction

This literature review examines the key concepts that support the development of a business continuity and operational resilience framework for red meat supply chain services from a municipal perspective. The review brings together several interconnected areas, including municipal resilience, business continuity planning, process mapping, value stream mapping, process reengineering, waste management, red meat supply chain risks, and risk assessment methodologies. Municipalities play a critical role in maintaining essential public services during disruptions. Their responsibilities often include sanitation, waste management, public health protection, infrastructure support, inspection activities, and food security emergency response.

2.2 Business Continuity and Operational Resilience in Municipalities

The term resilience is increasingly being utilized within the study of public policy to depict how individuals, communities and organizations can adapt, cope, and "bounce back" when faced with external shocks (Shaw 2012). While recent literature has increasingly focused on private sector and community resilience, public sector resilience at the municipal level remains underexplored. The concept of resilience in municipal contexts includes multiple dimensions. Shaw (2012) distinguishes between resilience as "recovery" (returning to pre-disruption states) and "transformation" (adapting to new realities), supporting for the latter's radical framework for innovation. This research also highlights the importance of formal continuity planning frameworks.

This distinction is critical for municipalities facing long-term challenges. In distribution contexts, municipal resilience is reflected in the ability of local governments to maintain essential functions, ensure continuity of lifeline services, and effectively coordinate response and recovery efforts (Haraguchi 2020). Business Continuity Planning (BCP) is a critical part of preparedness within disaster risk management. Evidence from the Great East Japan Earthquake shows that absence of BCP led to delays in emergency response and recovery. Therefore, it is essential for ensuring operational continuity and enhancing the resilience of local governments (Prontzas 2025).

Prontzas (2025) introduces the Crisis Management and Resilience Index (CMRI) as the first integrated scientific instrument for assessing local government strategic planning and operational effectiveness in managing crises. The CMRI framework focuses on long-term sustainability and local community resilience, providing municipalities with structured assessment tools. This development represents an important step toward standardizing resilience measurement and enabling comparative analysis across jurisdictions. On the other hand, Haraguchi (2020) applies complex adaptive systems (CAS) theory to analyze Japanese government continuity plans, concluding that effective plans enhance public sector resilience through improved robustness, redundancy, resourcefulness, and rapidity. Simpson et al. (2019) state that drought exposed weakness in revenue models as it is sensitive to decreased water consumption and demonstrated how uncoordinated public and private responses can impact high-reliability service delivery. The research recommends that municipal budgets incorporate resilience qualities including reflectiveness, inclusivity, integration, and flexibility to better withstand future shocks.

2.3 Red Meat Supply Chain Risks

Red meat supply chains are very complex and important multistage systems, yet they can face biological, chemical, and physical hazards that threaten food safety, public health, and economic sustainability (Netherlands Food and Consumer Product Safety Authority 2022).The definition of supply chain uncertainty is "decision-making situations in the supply-chain in which the decision-maker does not know definitely what to decide as he/she is indistinct about the objectives; lacks information about the supply-chain or its environment; lacks information processing capacities; is unable to accurately predict the impact of possible control actions on supply-chain behavior; or lacks effective control actions (non-controllability)" (Managing Supply Chain Risk 2021).

2.4 Process Mapping, VSM, and Waste in Municipality Operations

The use of lean service operations in improving municipal services in Turkey was examined; it demonstrates that systematic waste identification and elimination can significantly enhance service delivery efficiency (Ayrancı and Efe

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2024). It also shows that municipalities adopting lean principles achieved measurable improvements in process cycle times, resource utilization, and citizen satisfaction. A survey about lean applications in the municipal sector, focusing on service supply chain management, reveals that municipalities applying lean principles to service delivery chains achieved improvements in coordination, responsiveness, and resource efficiency. However, the research also identifies challenges including resistance to change, difficulty measuring public service outcomes, and tensions between efficiency and equity objectives (Stentoft Arlbjørn et al. 2011).

Waste in municipal operations takes multiple forms including waiting time, unnecessary movement, overprocessing, defects, excess inventory, underutilized talent, and redundant activities (Paramani et al. 2024). The research analyzes lean service using DMAIC methodology to reduce waste in services, identifying specific waste categories and implementing targeted elimination strategies, demonstrating that systematic waste identification and elimination can reduce service delivery times by 40–50% while improving quality and citizen satisfaction. The integration of waste elimination strategies with business continuity planning remains limited in municipal contexts. However, research suggests that streamlined, waste-free processes are inherently more resilient because they have fewer failure points, require fewer resources to maintain, and can be more easily adapted during disruptions. This connection between process efficiency and resilience represents an important but underexplored dimension of municipal business continuity planning (Suarez Barraza et al. 2009).

2.5 Process Reengineering for Continuity Improvement in Municipalities

Business process reengineering (BPR) represents a more radical approach than gradual process improvement that involves fundamental rethinking and redesigning of processing to achieve huge improvements in critical performance measures.

Ulinets and Prokhorchuk (2025) suggest that continuity planning processes themselves require radical redesign to achieve effectiveness. Business process restructuring as a strategic anti-crisis tool shows the importance of integrating crisis management with process diagnosis to identify bottlenecks and how digital technologies, innovation, and simulation modeling are crucial for redesigning processes from scratch to ensure sustainability and growth in volatile environments. Yamin et al. (2013) design a BPR model for Makkah Municipality eServices, achieving dramatic reductions in service steps and approvals as they reduced building permit processes from 39 to 13 steps. The research demonstrates that reengineering systems through digital transformation resulted in positive impact in terms of efficiency and customer satisfaction, particularly in a developing country context. Gayialis et al. (2016) develop a BPM system for local governments enabling process modeling, monitoring, simulation, and reengineering. The system facilitates increased efficiency, improved citizen services, and reduced operational costs through systematic process design, benchmarking, redesign, and continuous improvement. Arai and Sun (2013) evaluate BPR effectiveness in Saga Prefecture, Japan, finding that reengineering reduced processing time by approximately 30% through systemized procedures, media conversion from paper to electronics, and improved personal information processing. The research demonstrates significant cost-effectiveness improvements in resident information (41%), national health insurance (32%), and taxation (28%). Kurnia et al. (2022) examine leveraging agile transformation for redesigning local government governance, proposing a new model for disaster-prone areas supported by elite teams with crisis management expertise. The research emphasizes adapting crisis management into integrated digital systems guided by strategic management, morals, and values, with success depending on mindset changes, new bureaucratic culture development, and continuous learning.

2.6 Risk Assessment and Mitigation Methods in Red Meat Supply Chain

A study in Indonesia examined supply chain risks in the meat industry during disruptions. The study aimed to identify risks occurring across the supply chain and used the FMEA, the risk matrix, and proposed several mitigation strategies (Meilina et al. 2020).House of risk, which integrates FMEA with QFD, was used in multiple papers to identify the risks and then come up with mitigation actions (Ibrahim 2022). Fault Tree Analysis (FTA) complements FMEA by graphically representing combinations of failures leading to top-level events (Wahyuni et al. 2025).

In an Austrian pork supply network, a data-driven simulation identified about 30 critical risks that could cause significant supply shortage (Schueller et al. 2022). A risk assessment system using Hazard Analysis of Critical Control Points (HACCP) offers a pathway toward more focused regulatory attention on the highest-risk facilities and processes (Berends and van Knapen 1999).Bogataj et al. (2020) identified the critical risks using FMEA and then used blockchain technology which enabled a traceability system that is decentralized, immutable, transparent, and reliable,

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with real-time data monitoring, enhancing visibility, and fulfilling consumer demand for transparency and quality assurance. They also improved contracts by automation and improved data management.

2.7 Limitations of Existing Evidence

The reviewed literature, while valuable, is constrained by several limitations that restrict the generalizability of its findings.In the municipal operational resilience and business continuity literature, papers address the topic from a general perspective emphasizing service continuity and preparedness without connecting operational resilience to supply chain continuity. BPR studies from Greece (Charalabidis et al. 2023), Japan (Arai and Sun 2013), Spain (Suárez-Barraza 2013), and Saudi Arabia (Yamin et al. 2013) reflect distinct administrative and institutional contexts that limit cross-jurisdictional transferability. Charalabidis et al. (2023) acknowledge the complexity of public sector reengineering due to legal and structural variation across jurisdictions. Most BPR research focuses narrowly on digital transformation, with limited attention to how reengineering supports resilience in terms of efficiency.The red meat supply chain literature, while rich in risk identification, tends to treat assessment and mitigation sequentially and relies on geographically specific datasets. The Dutch study (Berends and van Knapen 1999) acknowledges limited data at certain supply chain stages and restricts its scope to the Netherlands, leaving cross-border stages unaddressed. Another limitation is that supply chain uncertainty remains an unsolved problem (Becker et al. 2004).

Across all topics, the predominance of qualitative, single-organization case studies with few large-scale comparative studies limits the ability to draw generalizable conclusions or establish causal links between specific interventions and resilience outcomes.

2.8 Research Gap

Based on the reviewed literature, a clear research gap can be identified. Previous studies have examined municipal resilience, business continuity planning, process mapping, value stream mapping, process reengineering, waste management, red meat supply chain risks, and risk assessment methods. However, these topics are usually addressed separately rather than being integrated into one comprehensive framework.

In particular, limited research has focused on halal red meat supply chains from a municipal perspective. Most existing studies discuss general meat supply chains or other meat sectors, while the halal red meat supply chain remains underexplored despite its specific operational, regulatory, and traceability requirements.There is also limited research that connects process improvement tools with business continuity and operational resilience. Process mapping, value stream mapping, and process reengineering are often used to improve efficiency, reduce waste, and redesign services, but they are rarely linked directly to risk identification, continuity planning, and resilience enhancement in municipal food supply chain services.

3. Methodology

3.1 Research Design and Case Study Approach

Our research follows a case study design with qualitative and semi-quantitative analysis to examine business continuity in GAM's red meat supply chain. This approach was selected because the study focuses on a real critical supply chain in Amman and requires understanding the process within its actual operational context (Yin and Campbell 2018). Simulation will later be used to test proposed continuity strategies under realistic disruption scenarios (Dynamics in Supply Chains 2021).

The purpose of this research is not to understand how disruptions may affect the continuity of the red meat supply chain, the stakeholders involved, and the preparation needed to reduce disruption effects. Therefore, the study focuses on identifying major risks, assessing their impact, and linking them to critical activities using VSM and process analysis. The research is guided by ISO 22301 as the main business continuity framework. It is not used for certification, but as a guide to keep the methodology aligned with a recognized international continuity approach.
Data collection depends mainly on interviews with specialists during site visits, supported by the existing GAM risk register. Wider surveys are planned for Phase 2 because the study population is limited and accessible. Using more than one source supports triangulation and strengthens the reliability of qualitative findings (Creswell 2009).

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3.2 Research Model Based on ISO 22301

GAM already uses ISO-based management systems in several areas, including ISO 14001:2015 and ISO 45001:2018 in solid waste treatment operations. Therefore, using ISO 22301 extends an existing management approach rather than introducing a completely new way of thinking (Kilic et al. 2023).

Since the red meat supply chain is a critical operation, ISO 22301 provides a suitable structure because it supports risk identification, business impact analysis, continuity strategies, recovery procedures, and testing. The framework in this study is mainly structured around Clause 8: Operation (ISO 22301:2019). In this research, ISO 22301 is adapted into practical research stages rather than being used for certification. The research stages are shown in Figure 1 below.

3.3 ISO 22301-Based Continuity Assessment Dimensions

A case study dimension means the main continuity area that should be assessed and protected if GAM wants the red meat supply chain to continue during disruption. These dimensions organize the case study before moving to risk identification, FMEA, and Business Impact Analysis.

The following dimensions were selected based on ISO 22301:2019 requirements to prepare for, respond to, and recover from disruption (ISO 22301:2019; Yin and Campbell 2018).

Core Slaughterhouse Operational Continuity

This dimension matches ISO 22301 Clause 8.1 and Clause 8.2, which focus on planning, controlling, and identifying critical activities. It asks which activities must continue and what happens if they stop. BIA supports this by identifying critical activities and the consequences of their disruption over time (Artoonian et al. 2025).
The slaughterhouse is the center of the supply chain, so if this dimension fails, the remaining dimensions will be affected. Any issue in this step may affect food availability for citizens, which makes it a public-facing critical service. Rosales et al. (2020) also show that disruptions at the slaughterhouse stage can affect the rest of the agri-food supply chain.

Inspections and Food Safety Continuity

This dimension is linked to Clause 8.2, Clause 6, and Clause 4 because inspection is a major activity in the food supply chain. Red meat continuity is n
ot only about delivery speed, but also about keeping the process safe, legal, and approved (ISO 22301:2019).
This dimension ensures that red meat is treated as a health-sensitive product, not only a logistics item. If inspection fails or approval is delayed, the disruption can become a public health issue. Trafialek and Kolanowski (2014) also show that FMEA can help identify food safety inspection risks before they become larger public health problems.

External Stakeholder and Approval Continuity

This dimension is driven mainly by Clause 4 because GAM depends on external parties to keep the red meat operation working. Therefore, the study should not only examine the inside of the slaughterhouse, but also the stakeholders and approvals that support the process.

The disruption may occur outside the slaughterhouse but still affect the whole process. For example, supplier delays or approval delays can slow or stop operations, and continuity depends on coordination with external partners and regulatory bodies (Dynamics in Supply Chains 2021).

Critical Assets, Facilities, and Utilities Continuity

This dimension focuses on Clause 7 and Clause 8.3 because the red meat service depends on supporting resources such as facilities, equipment, electricity, water, safety tools, communication systems, and human resources (ISO 22301:2019).This dimension was chosen because the resources behind the process can be as critical as the activity itself. If utilities, buildings, machines, or systems fail, the operation may stop even if the main process is still defined clearly (Pettit et al. 2010).

Information, Documentation and System Continuity

This dimension supports the physical side of the supply chain by focusing on permits, approvals, inspection records, payment records, and reports. If inspection is completed but the record is missing, or if approval cannot be issued because the system is down, the process may still stop or create documentation gaps (ISO 22301:2019).

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Emergency Governance, Communication, and Recovery Readiness
This dimension focuses on how GAM responds when disruption happens, including roles, communication, alternative procedures, incident reports, and recovery actions. It is linked to Clause 5, Clause 8.4, and Clause 8.5, where leadership, continuity procedures, and testing are needed to make the plan useful in a real disruption (ISO 22301:2019; Herbane 2010). Improvement and feedback were kept as part of the assessment instead of being treated as a separate dimension. This is linked to Clauses 9 and 10, which focus on performance evaluation and improvement after the assessment.

Overall, these dimensions help organize the case study and ensure that each risk is linked to a clear continuity area instead of being assessed randomly.

3.4 Study Community / Stakeholders

This section identifies the main stakeholders connected to the red meat supply chain and classifies them based on their power and interest in continuity. This helps determine which stakeholders should be prioritized in interviews and which should be considered indirectly through GAM documents (Iyere and Misopoulos 2022).
The stakeholders were classified into four categories on a stakeholder map based on their influence and interest. This map also helped divide the data collection into two main groups.
Group 1 includes slaughterhouse management and the Veterinary and Inspection Staff, who were prioritized for interviews because they have higher decision-making authority and a stronger understanding of risk impact. Other staff members and external parties will be considered through surveys in Phase 2 because they are highly interested but have less direct authority (Table 1).

Table 1. Study Community and Stakeholder Analysis

Stakeholder Group	Role in the Process	Why They Are Important for the Study
Slaughterhouse management	Supervises the overall slaughterhouse operation and decision-making	They understand the full process, main risks, available resources, and continuity priorities
Operations staff	Handle daily slaughtering, receiving, movement, storage, and handover activities	They know the actual operational problems, delays, bottlenecks, and resource needs
Veterinary and inspection staff	Inspect livestock and meat before and after slaughter	They are critical because inspection affects food safety, approval, rejection, and process flow
Laboratory staff	Conduct required tests when meat samples need further examination	They affect waiting time, approval decisions, and the continuity of safe meat supply
Documentation and control staff	Record quantities, verify documents, issue or track approvals, and follow up process records	They help identify administrative risks, documentation delays, and data accuracy problems
Support services staff	Handle cleaning, disposal, cold storage, equipment, utilities, and facility support	They are important because continuity depends on supporting resources, not only the slaughtering activity
Livestock traders and meat importers	Use the slaughterhouse services and depend on timely processing	They show the effect of delays or disruptions on the supply side and market availability
External government entities	Include related bodies such as the Ministry of Agriculture, JFDA, Customs, and other approval or regulatory bodies	They may affect approvals, inspection requirements, imported meat flow, and regulatory continuity

3.5 Data Collection Methods

Due to restricted timing and employee availability, this phase depended only on interviews with experienced employees and management. Five experienced employees reviewed the 49 risks in the municipality risk register and selected the 10 risks most relevant to the red meat supply chain. They then rated the risks based on impact and probability. This reflects purposive sampling, where participants are selected because of their direct knowledge of the research topic (Creswell 2009).

One issue during this stage was that each participant assessed risks from their own departmental perspective. Although an FMEA rating guide was provided, participants explained that risks may have different types of impact, such as financial, operational, public safety, service continuity, or stakeholder satisfaction impacts.Therefore, the numerical scores were supported by qualitative explanations to make sure the final risk assessment reflected both the assigned ratings and the practical reasoning behind them. This is consistent with applied FMEA practice, where numbers alone may not fully explain the operational context (Liu et al. 2013).

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Figure 1. Red Meat Supply Chain Stakeholder Map

3.6 Risk Identification

After GAM considered the business continuity implications of a potential Strait of Hormuz closure, meetings were held with executives and management to discuss direct and indirect risks that may affect municipal operations. The result was 49 risks covering natural hazards, regional instability, local instability, supply shortages, and diseases.

For this research, the GAM risk register was refined into 10 main direct risks for the red meat supply chain. These risks were generalized based on the slaughterhouse manager's request to make them more inclusive and operationally relevant (Artoonian et al. 2025).The result was 10 direct risks, meaning risks that can immediately disrupt the red meat supply chain without depending on another event.

3.7 Risk Assessment Using FMEA

After selecting the 10 main risks, a modified FMEA approach was used to assess and prioritize them. FMEA helps identify failure modes, evaluate their effects, and rank them based on risk level (Aleksic et al. 2022).

The final scores combined the numerical ratings with the interview comments to reflect the real impact on continuity. The final risk priority score was calculated using Probability x Detection x Impact, where higher scores indicate risks that need greater attention in the business continuity plan (Liu et al. 2013).

3.8 Business Impact Analysis

Following the FMEA, a Business Impact Analysis will be completed in Phase 2 to identify the operational consequences of disruption and the maximum time each critical activity can be interrupted before consequences become unacceptable (ISO 22301:2019; Artoonian et al. 2025).

Critical activities will be identified by linking the affected processes of the main risks with VSM, critical path analysis, and interview findings. An activity will be considered critical if its interruption may cause public health risk, legal violation, halt in supply, or unrecoverable operational gap.

For each critical activity, Phase 2 will define MTPD, RTO, and MBCO. These parameters show how long the activity can stop, how fast it should be restored, and the minimum service level that must continue during disruption.

3.9 Business Continuity Strategies

Business continuity strategies will be developed after the BIA. The aim is to protect critical activities, maintain the MBCO, and recover within the required timeframe, following ISO 22301 Clause 8.3 (ISO 22301:2019). The strategies will be linked to the six continuity dimensions and prioritized based on the risks with the highest RPN and shortest MTPD. Both preventive and recovery-oriented strategies will be considered.

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Finally, the strategies will be tested through simulation and evaluated by GAM management, which supports ISO 22301 Clause 8.5 on exercise programs (ISO 22301:2019).

4. Results and Discussion

4.1 FMEA Results

This section presents the FMEA results, while the BIA, continuity strategies, and simulation testing will be discussed in Phase 2 based on the risk priorities shown here (Table 2).

Table 2: Failure Mode and Effects Analysis (FMEA) for GAM Red Meat Supply Chain

Processes Affected	Failure Mode	Failure Cause	Failure Effect	O (1–5)	D (1–5)	S (1–5)	RPN	Actions to Reduce Occurrence of Failure
Slaughterhouse Operations / Inspection / Waste Disposal / Transportation	**Disease Outbreak**	Contaminated meat, weak early detection, or infected livestock entering the supply chain, wrong transportation and refrigeration	Slaughtering may be stopped, meat may be rejected, and public health risk may increase	**2**	**2**	**4**	**16**	Strengthen ante-mortem inspection protocols; implement rapid testing kits; train staff on disease detection; establish quarantine procedures
Slaughterhouse Operations / Sanitation	**Sewage System Failure**	Sewage blockage, overflow, drainage failure, or wastewater system malfunction	Hygiene and sanitation conditions may be affected, creating health and operational risks	**3**	**1**	**3**	**9**	Schedule regular drain inspections; maintain emergency plumber contacts; install overflow alarms
Slaughterhouse Operations / Sanitation	**Waste Accumulation**	Delay in waste removal, contractor failure, poor handling of condemned meat, or lack of disposal capacity due to unexpected extra waste	Waste accumulation, odor, contamination risk, environmental hazard, may affect employee safety, and operational delays may occur	**2**	**1**	**3**	**6**	Establish secondary waste contractor agreements; implement daily waste monitoring; set up on-site temporary storage contingency
Slaughterhouse Operations / Transportation	**Border Crossing Closure**	Border closure, regional instability, import restrictions, or transportation disruption	Livestock or meat supply may decrease, causing shortage or delay in supply availability	**1**	**1**	**5**	**5**	Diversify livestock suppliers domestically; maintain strategic buffer stock; develop regional supplier network
Slaughterhouse Operations	**Fire Hazard**	Electrical fault, unsafe storage, equipment overheating, or human error	Operations may stop, equipment may be damaged, and employee safety may be affected	**1**	**1**	**5**	**5**	Install fire detection and suppression systems; conduct regular fire drills; enforce electrical safety inspections; maintain fire extinguishers
Data Entry / Registration / Payment Process	**Database Loss**	System crash, cyber issue, backup failure, human error, or server failure	Inspection records, supplier data, and operational	**1**	**1**	**5**	**5**	Implement automated daily backups to cloud and off-site servers; establish data

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Processes Affected	Failure Mode	Failure Cause	Failure Effect	O (1–5)	D (1–5)	S (1–5)	RPN	Actions to Reduce Occurrence of Failure
			documentation may be lost or delayed					recovery plan; conduct regular backup testing
Slaughterhouse Operations / Inspection / Registration / Payment Process	**Electricity Disruption**	Grid power outage or unstable electricity supply (common in Jordan)	Refrigeration, lighting, machinery, and daily operations may be disrupted	**2**	**1**	**2**	**4**	Install backup generators; use UPS systems for critical equipment; develop power outage SOPs
Slaughterhouse Operations / Sanitation	**Water Supply Disruption**	Water network interruption (common in Jordan), low water pressure, pump failure	Cleaning, washing, sanitation, and hygiene processes may be affected, causing operational delays	**2**	**1**	**2**	**4**	Install water storage tanks; establish backup water supply contracts; implement water pressure monitoring systems
Registration / Payment Process	**Internet Loss**	Internet service provider outage, router/network failure, or communication infrastructure issue	Digital communication, reporting, and access to online systems may be delayed	**2**	**1**	**2**	**4**	Subscribe to secondary ISP; use mobile data as backup; maintain offline-capable systems for critical operations
Slaughterhouse Operations	**Machinery Breakdown**	Lack of preventive maintenance, spare part shortage, equipment aging, or sudden mechanical failure	Slaughtering or handling activities may be delayed or stopped	**2**	**1**	**2**	**4**	Implement preventive maintenance schedule; maintain critical spare parts inventory; train backup operators
Data Entry / Registration / Payment Process	**System Breakdown**	Software failure, server issue, user error, or poor system maintenance	Approvals, documentation, coordination, and reporting may be delayed	**3**	**1**	**1**	**3**	Establish IT support SLA; maintain manual backup procedures; schedule regular system maintenance windows

The table includes O, D, S, and RPN columns, representing Occurrence, Detection, Severity, and Risk Priority Number. Occurrence and Severity were rated from 1 to 5, where 1 is the lowest and 5 is the highest. Detection was also rated from 1 to 5, but 1 means easy to detect and 5 means difficult to detect. Therefore, risks with higher occurrence, higher severity, and lower detectability receive higher RPN values (Table 3).

Table 3: RPN Risk Legend

RPN Risk Legend
High Risk (≥ 15)
Medium-High Risk (8–14)
Medium Risk (5–7)
Low Risk (1–4)

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4.2 Discussion

The FMEA was used to prioritize the risks affecting the red meat supply chain. RPN was calculated as the product of occurrence, detection difficulty, and severity. Most risks had a detection score of 1 because they can be detected quickly, except for risks where the issue may not appear in the early stages.

Based on the results, disease outbreak was the highest ranked risk with an RPN of 16. It is critical because it has a detection score of 2, since an animal may appear healthy during slaughter, but contamination or bacteria may only be detected after refrigeration, even with inspection procedures in place.

The severity is high because zoonotic diseases can affect inspectors, workers, and transportation staff (CDC 2024). If the disease is discovered after slaughtering or during refrigeration, the meat cannot be treated as normal waste and requires special disposal, sanitation, and investigation. Fortunately, the risk is rare because the slaughterhouse already applies preventive inspection measures before animals enter the process.

The second highest RPN is sewage system failure. Interviews showed that the sewage system fails around once or twice monthly and is usually solved within 1-2 hours. However, the slaughterhouse uses around 600 m^3 of water daily for cleaning, washing, and sanitizing, so even a short failure can interrupt hygiene-related operations and affect continuity.

Waste accumulation is different because its impact is not only operational. It also affects sanitation, employee comfort, environmental safety, community impact, and cost. Interview findings showed that rejected or diseased meat requires additional chemical treatment before disposal to prevent misuse.

Although this step is important for safety, it creates odor, extra cost, and an unhealthy working environment. Even though GAM uses two large trucks to transport accumulated waste, the process still requires labor and effort. Therefore, waste accumulation should be managed through faster disposal and more environmentally responsible treatment methods.

Other risks, such as electricity disruption, water supply disruption, and internet loss, have high severity but lower RPN values because GAM already has contingency plans for them. For example, the slaughterhouse has extra water tanks, underground water storage, and an additional water flow from GAM. Therefore, these risks are serious, but current mitigation measures reduce their priority compared to risks that are repeated or harder to control.

5. Conclusion

This study provides a structured BCM assessment of GAM's red meat supply chain using ISO 22301:2019. Through expert interviews, FMEA, and a six-dimension continuity framework, the research identifies the main vulnerabilities in the supply chain and provides a basis for formal continuity strategies.

Disease outbreak was identified as the highest-priority risk (RPN = 16), followed by sewage system failure (RPN = 9) and waste accumulation (RPN = 6). Risks such as electricity, water, and internet disruption had lower RPN values because GAM already has mitigation measures for these utilities.

The study also shows that informal contingency planning can reduce risk priority even before a formal BCMS is fully implemented. The six continuity dimensions ensure that the assessment goes beyond daily operations and covers food safety, external dependencies, resources, documentation, and emergency governance. This study has limitations. Data collection was limited to five experienced employees due to time and availability constraints, and wider stakeholder surveys are still planned for Phase 2. Also, BIA, continuity strategies, and simulation testing are not yet completed, so the current findings should be understood as initial risk prioritization rather than a full continuity plan.

Phase 2 will develop continuity strategies for the highest-priority risks and test them through simulation with GAM management. This will provide the operational detail needed to move from research-based assessment toward a more formal BCMS implementation.

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