



Identification And Evaluation Of Distribution Risk In Food Supply Chain

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Abstract

In the elaborate network of the food deliver chain, distribution stands as a important juncture wherein various risks can appear, probably compromising the best, protection, and integrity of food merchandise. This summary affords a complete review of the identification and evaluation of distribution risks within the food deliver chain.

The primary objective of this take a look at is to elucidate the multifaceted nature of distribution risks and provide insights into powerful danger management strategies. thru a scientific evaluation of literature, this research synthesizes the existing expertise on distribution risks, encompassing factors along with transportation, storage, coping with, and logistics.

Key hazard factors diagnosed consist of temperature fluctuations, contamination, incorrect managing practices, transportation delays, and infrastructural vulnerabilities. those risks can lead to various detrimental effects, along with product spoilage, loss of nutritional fee, foodborne ailments, and reputational harm to meals groups.

Moreover, this observe proposes a complete framework for the evaluation and mitigation of distribution risks within the food deliver chain. The framework integrates qualitative and quantitative chance assessment methodologies, incorporating equipment consisting of hazard evaluation important control points (HACCP), failure mode and results evaluation (FMEA), and probabilistic threat assessment (PRA).

by using imposing proactive threat control measures at every degree of the distribution method, food deliver chain stakeholders can decorate resilience, make certain compliance with regulatory requirements, and protect purchaser fitness and consider. Moreover, leveraging emerging technologies inclusive of block chain, internet of factors (IoT), and predictive analytics can allow real-time tracking and traceability, facilitating fast chance identification and response.

NEED FOR THE STUDY

- Making sure meals safety: Distribution risks can compromise the protection of meals products, leading to infection, spoilage, and foodborne illnesses. by means of understanding and mitigating these dangers, stakeholders can uphold meals protection requirements and defend customer health.
- Preserving Product satisfactory: Distribution dangers, inclusive of temperature fluctuations and mistaken coping with practices, can degrade the great of meals merchandise, affecting their flavor, texture, and dietary price. by dealing with those dangers successfully, groups can preserve product pleasant and meet client expectancies.
- Protective brand popularity: Incidents associated with distribution risks, including product recollects or contamination outbreaks, can damage the popularity of food groups and erode consumer consider. Analyzing and addressing distribution risks can help protect logo reputation and hold consumer self-belief in meals merchandise.
- Compliance with regulations: Regulatory groups impose stringent requirements on food distribution practices to ensure compliance with meals safety requirements and rules. by means of analyzing distribution dangers, agencies can identify regions of non- compliance and implement measures to fulfill regulatory necessities, fending off consequences and legal effects.
- Minimizing economic Losses: Distribution risks can bring about financial losses for meals agencies because of product spoilage, recalls, and supply chain disruptions. by means of proactively coping with those dangers, companies can limit monetary losses and beautify operational efficiency in the deliver chain.
- Enhancing supply Chain Resilience: Distribution risks, including transportation delays and infrastructural vulnerabilities, can disrupt deliver chain operations and impact the well timed delivery of food products. By way of identifying and mitigating these dangers, stakeholders can beautify supply chain resilience and preserve business continuity within the face of unforeseen challenges.
- Facilitating Sustainable Practices: powerful control of distribution risks can make contributions to sustainable food supply chain practices by reducing waste, preserving assets, and minimizing environmental impact. Reading those risks can assist pick out possibilities for development and innovation in sustainable distribution practices.

EVALUATION OF THE BENEFITS AND CHALLENGES

Benefits:

Enhanced Traceability: technologies like block chain allow end- to- end traceability, improving transparency and accountability inside the meals supply chain.

Progressed high-quality manage: actual-time tracking and predictive analytics assist pick out great issues early, decreasing the chance of product remembers and client court cases.

Expanded efficiency: digital answers optimize distribution techniques, streamline stock control, and decrease operational costs, main to extra performance and productivity.

Challenges:

Value of Implementation: Adoption of rising technologies requires substantial investment in infrastructure, software program, and team of workers training, which can be a barrier for smaller businesses.

Information privateness and protection: issues about facts privacy and protection may additionally arise with the gathering and sharing of touchy data across the deliver chain.

Interoperability: Integration and interoperability of various virtual answers and platforms might also pose challenges, specifically in complicated and 48 fragmented supply chains.

Regulatory Framework: Regulatory businesses which includes the FDA (meals and Drug management) inside the America and the European meals protection Authority (EFSA) inside the eu have commenced spotting the ability of emerging technologies in food deliver chain control. Rules and standards related to meals safety, traceability, and records safety are evolving to deal with using digital solutions along with block chain and IoT inside the meals industry.

LITERATURE REVIEW

Previous studies on meals deliver chain management, distribution, and hazard evaluation have provided treasured insights into the complexities and demanding situations inherent in ensuring the efficient and dependable shipping of food products to purchasers. Here is a summary of key findings from relevant literature:

Food supply Chain control: studies have highlighted the importance of effective supply chain management practices in enhancing the general performance of the meals deliver chain. This consists of components along with inventory management, demand forecasting, supplier courting control, and logistics optimization. Research has emphasized the want for collaboration and coordination among stakeholders alongside the deliver chain to streamline operations, lessen fees, and improve responsiveness to changing market dynamics.

Distribution challenges: several research have diagnosed numerous demanding situations and complexities related to meals distribution, consisting of transportation constraints, infrastructure barriers, perishability of meals merchandise, and regulatory compliance troubles. 16 research has proven that inefficient distribution practices can lead to delays, disruptions, and increased prices at some point of the supply chain, in the end impacting food availability, high-quality, and affordability for consumers.

Chance assessment in the meals deliver Chain: scholars have recognized the importance of conducting comprehensive threat tests to become aware of and mitigate ability threats to the food supply chain. This includes dangers associated with food protection, first-class manage, supply chain disruptions, and outside factors consisting of natural disasters and geopolitical events. Research have proposed numerous risk assessment frameworks and methodologies to assess the likelihood and effect of various types of risks on the food supply chain, consisting of quantitative and qualitative procedures.

Rising traits and technology: latest literature has highlighted rising tendencies and technologies which have the potential to transform food supply chain control and distribution practices. This consists of improvements in digitalization, data analytics, and net of factors (IoT), block chain era, and artificial intelligence (AI). research has proven that leveraging these technology can decorate visibility, traceability, and transparency in the food supply chain, allowing stakeholders to proactively 17 perceive and mitigate risks at the same time as enhancing operational efficiency and client agree with. So, preceding studies on meals supply chain control, distribution, and threat evaluation have underscored the importance of effective deliver chain control practices, highlighted distribution demanding situations, emphasized the want for comprehensive danger evaluation methodologies, and explored rising tendencies and technologies which have the capacity to reshape the future of the meals supply chain. Building upon these insights, this report ambitions to further check out distribution risks within the meals supply chain and offer actionable hints for stakeholders to strengthen supply chain resilience and ensure the timely delivery of meals merchandise to consumers.

DATA ANALYSIS

1. Hazard identity:

- Organic risks: infection of plants or livestock with pathogens consisting of Salmonella, E. coli, or Listeria.
- Chemical dangers: Presence of pesticide residues or veterinary drug residues in agricultural products.
- Bodily risks: introduction of overseas gadgets like glass, steel, or plastic into harvested plants or livestock feed.
- Environmental dangers: Crop damage or yield discount because of excessive climate occasions, droughts, floods, or soil infection.

Processing and production:

- Biological risks: cross-contamination among raw and processed ingredients, leading to microbial contamination.
- Chemical dangers: Misuse or overuse of food components, preservatives, or processing aids, resulting in chemical dangers.
- Bodily risks: equipment malfunctions, equipment screw ups, or overseas object infection throughout processing. Environmental risks: power deliver disruptions, water scarcity, or air fine troubles affecting production facilities.

Distribution and Transportation:

- Biological dangers: Temperature abuse all through transportation main to microbial growth or spoilage.
- Chemical dangers: publicity to pollution or contaminants at some stage in transit, garage, or dealing with.
- Physical risks: damage to packaging, boxes, or vehicles, inflicting product contamination or leakage.
- Environmental risks: Disruption of transportation routes due to herbal screw.

Warehousing and garage:

- Biological dangers: insufficient temperature control or sanitation practices main to microbial proliferation.
- Chemical dangers: Chemical spills, leaks, or off-gassing from stored merchandise or packaging substances.
- Physical dangers: Structural failures, collapses, or injuries in storage facilities.
- Environmental risks: Pest infestations, mildew increase, or water damage due to poor facility renovation.

Retail and food service:

- Biological dangers: cross-infection in food practice areas, insufficient hygiene practices.
- Chemical risks: unsuitable use of cleaning retailers, sanitizers, or food contact substances.
- Physical dangers: unintended contamination or tampering of food merchandise on save shelves or in restaurant kitchens.

- Environmental risks: electricity outages, system screw ups, or excessive weather occasions affecting meals provider operations.

Intake:

- Biological dangers: Foodborne illnesses from eating infected food products.
- Chemical dangers: allergies or detrimental outcomes from exposure to allergens or meals components.
- Bodily risks: Choking hazards, foreign item ingestion, or accidents from improperly organized food.
- Environmental dangers: food protection risks associated with domestic food coaching, storage, and dealing with practices.

moreover, outside factors which include supply chain disruptions (e.g., transportation delays, labor shortages), modifications in purchaser options (e.g., demand for natural or locally sourced ingredients), regulatory modifications (e.g., food safety policies, labeling requirements), and international events (e.g., pandemics, trade conflicts, weather change) also can impact the food supply chain and make contributions to various risks at specific degrees.

2. Risk MITIGATION techniques

- Properly Agricultural Practices (gap):
Implement and adhere to whole ideas to ensure safe and sustainable agricultural production.
Train farmers and producers on right soil control, water utilization, pesticide software, and hygiene practices to minimize biological and chemical dangers on the farm level.
Promote incorporated pest control (IPM) strategies to reduce reliance on chemical pesticides and mitigate environmental risks.
- Danger evaluation and crucial control factors (HACCP): broaden and implement HACCP plans to discover, compare, and control food protection dangers for the duration of the food production manner.
Set up essential manipulate factors (CCPs) where preventive measures may be carried out to put off or lessen hazards to suitable stages.
Conduct regular monitoring, verification, and documentation of HACCP processes to ensure compliance and effectiveness.
- Fine management systems (QMS):
Undertake QMS standards consisting of ISO 9001 to set up systematic approaches to first-class warranty and non-stop improvement. Enforce pleasant manage measures at every level of the deliver chain, which include incoming uncooked materials, processing, storage, and distribution.
Conduct ordinary inspections, audits, and nice warranty checks to hold product integrity and consistency.
- Traceability structures:
Put in force traceability systems to track and trace food products for the duration of the deliver chain, from farm to fork. Utilize barcodes, RFID tags, or block chain generation to capture and record key records including product beginning, manufacturing strategies, and transportation routes. Permit actual-time

visibility and transparency to quickly pick out and isolate doubtlessly infected or compromised merchandise inside the event of a food safety incident.

- High-quality assurance Protocols:

Establish pleasant guarantee protocols and standards for dealer qualification, product checking out, and verification of compliance with regulatory necessities.

Collaborate with providers, vendors, and retailers to set up collectively agreed-upon quality standards and performance metrics.

Behavior everyday pleasant audits and inspections to make certain adherence to requirements and identify regions for development.

- Contingency making plans:

Broaden complete contingency plans to count on and respond to emergencies, crises, and supply chain disruptions. Establish clear communicate channels and protocols for reporting and escalating incidents, recollects, or food safety concerns.

Behavior regular drills, simulations, and tabletop physical games to test the effectiveness of contingency plans and make certain preparedness for various eventualities.

- Era answers:

Leverage technology answers which include block chain, net of things (IoT) sensors, and records analytics to beautify transparency, traceability, and real-time tracking of meals products.

Install IoT sensors for temperature tracking, humidity manipulate, and environmental conditions in garage facilities and transportation motors. by using enforcing these danger mitigation strategies and collaborating with stakeholders throughout the meals deliver chain, organizations can beautify meals safety, excellent assurance, and supply chain resilience, thereby decreasing the chance and impact of dangers during the complete manner.

1. IMPLIMENTING MONITORING AND CONTOL MECHANISM IN FOOD SUPPLY CHAIN

- Monitoring Effectiveness of Risk Mitigation Measures: Regularly assess the effectiveness of implemented risk mitigation measures by monitoring key indicators such as incidence of foodborne illnesses, product recalls, quality deviations, and supply chain disruptions.

Establish feedback loops and mechanisms for stakeholders to report incidents, near misses, or observations related to food safety, quality, and supply chain performance.

- Establishing Key Performance Indicators (KPIs) and Metrics:

Define relevant KPIs and metrics to measure performance in key areas such as:

Compliance with food safety regulations and standards (e.g., percentage of products meeting

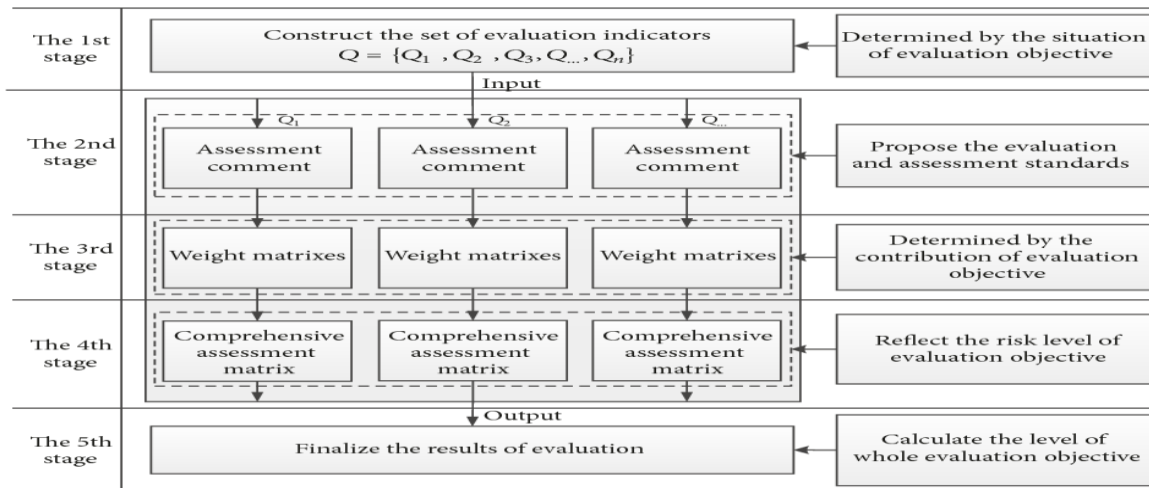


Figure 1. The evaluation steps of FQPM

microbiological criteria).

- Product quality attributes (e.g., sensory evaluation scores, shelf-life stability).
- Supply chain resilience and responsiveness (e.g., lead times, on-time deliveries).
- Set targets and benchmarks for each KPI to track progress and drive continuous improvement efforts.

- Conducting Regular Audits, Inspections, and Reviews: Schedule and conduct regular audits, inspections, and reviews of food production facilities, storage warehouses, transportation vehicles, and retail establishments.

Utilize internal audit teams or third-party auditors to assess compliance with food safety protocols, quality standards, and regulatory requirements. Document findings, observations, and corrective actions taken during audits, and follow up on implementation of corrective and preventive measures.

- Continuous Improvement and Risk Management Review: Foster a culture of continuous improvement by encouraging feedback, participation, and collaboration among stakeholders. Conduct periodic risk management reviews to reassess potential risks, evaluate the effectiveness of existing mitigation measures, and identify emerging threats or vulnerabilities. Incorporate lessons learned from incidents, recalls, or near misses into revised risk mitigation strategies, standard operating procedures, and training programs.

- Utilizing Technology for Monitoring and Control: Implement technology-enabled solutions such as real-time monitoring systems, digital dashboards, and mobile applications to streamline data collection, analysis, and reporting.

Integrate data from various sources across the supply chain (e.g., IoT sensors, ERP systems, traceability platforms) to gain holistic insights into food safety, quality, and supply chain performance.

Leverage predictive analytics and machine learning algorithms to identify potential risks proactively and automate decision-making processes for faster response and resolution.

By implementing robust monitoring and control mechanisms, establishing clear KPIs and metrics, conducting regular audits and reviews, and leveraging technology-enabled solutions, organizations can effectively track the effectiveness of risk mitigation measures, ensure compliance with safety standards, and enhance overall performance and resilience across the food supply chain.

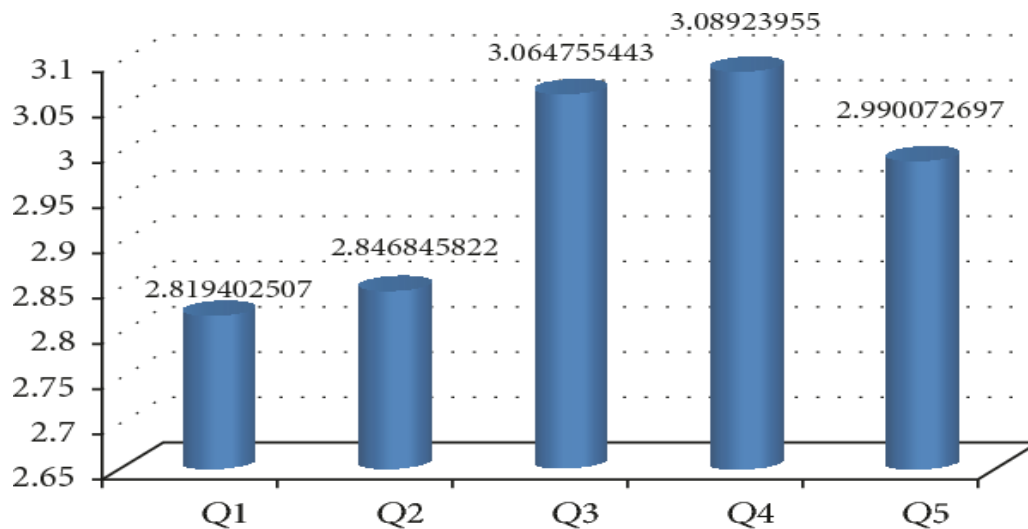


Figure 2: Food quality risk levels of evaluation objects.

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Risk evaluation indicators	Frequency	Comment	P ₁	P ₂	P ₃	P ₄	P ₅
Production and processing risk Q ₂							
Illegal use of additives Q ₂₁			58	202	303	245	90
Contamination with foreign matter Q ₂₂			84	218	323	211	62
Inability to wash a food product clean Q ₂₃			86	254	343	151	64
Presence of detergent residue Q ₂₄			76	208	307	229	78
Pathogen contamination Q ₂₅			42	180	275	255	146
Microbial contamination Q ₂₆			40	212	301	239	106
Uncertified processing equipment Q ₂₇			58	208	313	241	78
Nonstandardized processing personnel operation Q ₂₈			64	220	321	233	60
Insufficient processing environment Q ₂₉			60	212	299	249	78
Insufficient processing equipment Q ₂₁₀			78	244	325	209	42
Inappropriate packaging Q ₂₁₁			218	280	247	113	40
Insufficient packaging quality Q ₂₁₂			224	268	241	121	44
Uncertified packaging logo Q ₂₁₃			156	206	305	151	80
Insufficient assurance of personnel health Q ₂₁₄			158	256	255	163	66
Quality inspection risk Q ₂₁₅			166	212	251	179	90
Insufficient storage process Q ₂₁₆			192	216	319	97	74

Table 3: Assessment comment of evaluation objective Q₂.

OVERVIEW OF REGULATORY REQUIREMENTS AND STANDARDS

Food safety Modernization Act (FSMA) (usa):

FSMA sets forth policies governing the safe transportation of food products, which includes requirements for temperature manipulate, sanitation, and training of employees. Key provisions encompass the Sanitary Transportation of Human and Animal food (STF) rule, which establishes criteria for the sanitary transportation of food products to prevent infection and make certain meals safety.

Correct Distribution exercise (GDP) guidelines (eu):

GDP recommendations outline principles and necessities for the distribution of medicinal merchandise for human use, together with temperature manipulate, storage situations, and

documentation. Whilst GDP pointers specifically target pharmaceutical distribution, they serve as a reference for quality practices in meals distribution and transportation.

International agency for Standardization (ISO) requirements:

ISO standards including ISO 22000 (food protection control structures) and ISO 9001 (great management structures) provide frameworks for implementing meals safety and quality management practices all through the supply chain. ISO 22000 mainly addresses the management of meals protection hazards in the meals supply chain, which includes transportation and distribution.

Discussion OF STAKEHOLDER ROLES

Regulatory necessities and standards governing food distribution and transportation play a critical position in making sure the protection, quality, and integrity of meals products for the duration of the supply chain. Even as compliance with those rules presents challenges for enterprise stakeholders, adopting exceptional practices and leveraging assist from

Authorities companies, industry institutions, and global corporations can help mitigate dangers and decorate meals safety and safety in distribution. Collaborative efforts between stakeholders are critical to cope with compliance demanding situations, sell continuous development, and protect public health.

Government companies:

Government organizations which include the FDA, USDA (u.s. department of Agriculture), and ecu fee play a key function in establishing and imposing regulatory necessities for meals distribution and transportation. They conduct inspections, problem steering documents, and implement compliance with rules to defend public fitness and ensure food protection.

Enterprise associations:

Industry institutions including the international affiliation for food safety (IAFP) and the global meals safety network (IFSN) provide resources, training, and guidance to help groups navigate regulatory requirements and put in force first-rate practices. They facilitate expertise sharing, collaboration, and networking among stakeholders within the meals enterprise.

Global agencies:

International organizations together with the sector fitness agency (WHO) and the meals and Agriculture employer (FAO) of the United nations work to harmonize meals protection requirements, sell first- class practices, and facilitate worldwide cooperation in addressing meals protection and protection challenges. They expand tips, provide technical help, and support ability-constructing projects to bolster meals 52 systems and enhance regulatory compliance global.

RECOMMENDATIONS FOR ENHANCING DISTRIBUTION RISK MANAGEMENT PRACTICES

Spend money on generation solutions: Put into effect advanced technology which include IoT sensors, block chain, and predictive analytics to decorate visibility, traceability, and actual- time monitoring skills throughout the deliver chain. these technologies enable proactive risk management and facilitate timely intervention to mitigate capacity distribution risks.

Fortify Collaboration and conversation: Foster collaboration and communicate amongst supply chain companions, which include manufacturers, vendors, stores, and logistics providers. set up obvious communication channels, proportion relevant facts and statistics, and collaborate on risk evaluation, mitigation strategies, and contingency planning to cope with distribution risks effectively.

Increase complete threat management strategies: Develop comprehensive risk management techniques that embody preventive measures, responsive techniques, and contingency plans to deal with a extensive

range of distribution dangers. Recall elements including temperature control, infection prevention, deliver chain disruptions, and regulatory compliance in risk evaluation and mitigation efforts.

Prioritize education and schooling: Spend money on education and schooling applications to beautify the know-how and abilities of employees involved in food distribution and transportation. Offer education on food safety protocols, first-class manipulate measures, regulatory compliance necessities, and high-quality fifty four practices for handling and transporting food merchandise properly.

Behavior normal Audits and tests: Put in force regular audits, tests, and inspections of distribution facilities, transportation cars, and approaches to identify capacity risks and ensure compliance with regulatory requirements and enterprise exceptional practices. Address any identified gaps or deficiencies directly to limit the danger of distribution associated troubles.

Sell dealer range and Resilience: Diversify the dealer base and establish relationships with multiple providers throughout distinct regions or nations to reduce dependency on a single source of supply. Develop resilience in the deliver chain with the aid of figuring out opportunity providers, establishing backup plans, and proactively managing provider dangers.

SUGGESTIONS FOR FUTURE RESEARCH DIRECTIONS

Effect of emerging technology: Explore the effect of rising technologies such as artificial intelligence, robotics, and self-sufficient motors on distribution chance control in the food deliver chain. Look into the potential advantages, demanding situations, and implications of adopting those technology for reinforcing meals safety, efficiency, and resilience.

Deliver Chain Resilience and adaptableness: Check out strategies for reinforcing supply chain resilience and flexibility to mitigate the impact of outside disruptions, along with natural failures, geopolitical events, and public health crises, on meals distribution. Have a look at the effectiveness of resilience-constructing measures and contingency making plans in ensuring business continuity and minimizing disruption risks.

Client choices and expectancies: Examine customer choices, behaviors, and expectations concerning meals protection, exceptional, and transparency in the distribution process. Explore the position of patron consider, perceptions, and verbal exchange in shaping buying choices and emblem loyalty, and identify possibilities for enhancing purchaser self-belief through stronger distribution risk control practices.

Regulatory Compliance and requirements: Evaluate the effectiveness of regulatory frameworks and industry requirements in governing meals distribution and fifty six transportation. Verify the alignment among regulatory necessities and enterprise practices, discover areas for improvement, and advocate recommendations for enhancing regulatory compliance and harmonization to make certain consistent meals protection requirements across the supply chain.

Sustainability and Environmental effect: Look into the environmental impact of food distribution sports and discover sustainable practices and technology for reducing carbon emissions, minimizing food waste, and optimizing aid usage within the distribution method. Observe the intersection of distribution chance control and sustainability dreams to promote environmentally accountable practices in the meals deliver chain.

By means of enforcing these hints and exploring future studies directions, stakeholders can enhance distribution hazard control practices, improve supply chain resilience, and make certain the secure and efficient distribution of food products to customers whilst addressing rising challenges and possibilities in the evolving panorama of the meals supply chain.

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