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# BULANIK FINE–KINNEY YÖNTEMİYLE OPERASYONEL TEDARİKÇİ RİSKLERİNİN DEĞERLENDİRİLMESİ: FAST-FOOD ZİNCİR RESTORANINDA BİR VAKA ÇALIŞMASI

## *ASSESSMENT OF SUPPLIER-RELATED OPERATIONAL RISKS USING THE FUZZY FINE–KINNEY METHOD: A CASE STUDY IN A FAST-FOOD CHAIN RESTAURANT*

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*Fast-food tedarik zincirleri, Tedarik zinciri risk yönetimi, Tedarikçi riskleri, Bulanık Fine-Kinney yöntemi*

**Keywords**
*Fast-food supply chains, Supply chain risk management, Supplier-related risks, Fuzzy Fine-Kinney method*

**ÖZ**

Fast-food işletmeleri, zamanlama, süreç güvenilirliği ve tedarikçi koordinasyonunun hizmet sürekliliği ile müşteri memnuniyetini belirlediği dinamik ve rekabetçi ortamlarda faaliyet göstermektedir. Bu işletmelerin standartlaştırılmış, sık tekrarlanan ve zaman baskısı altında gerçekleşen teslimat süreçlerine olan bağımlılığı, onları operasyonel aksaklıklara karşı oldukça kırılgan hale getirmektedir. Bu nedenle tedarikçi kaynaklı risklerin erken tespiti, izlenmesi ve önceliklendirilmesi fast-food işletmeleri açısından son derece kritik bir gereklilik olarak öne çıkmaktadır. Bu çalışmada Manisa'da faaliyet gösteren bir fast-food zincir restoranında tedarikçiyle ilişkili operasyonel riskler bulanık Fine–Kinney yöntemiyle değerlendirilerek tedarik zinciri güvenilirliğini artırmaya yönelik kritik risk alanları saha uygulaması üzerinden ortaya konulmuştur. Çalışmada benimsenen yaklaşımla, klasik Fine–Kinney yönteminin sistematik yapısı, uzman görüşlerindeki belirsizlikleri temsil etmeye olanak tanıyan bulanık mantığın esnekliğiyle birleştirilmiş ve dilsel yargıların nicel ifadelere dönüştürülerek ele alınması sağlanmıştır. Tedarik operasyonlarında doğrudan görev alan çalışanlardan elde edilen değerlendirmeler sonucunda teslimat zaman uyuşmazlıkları, soğuk zincir ihlalleri, paketleme ve taşıma hasarları, iletişim yetersizlikleri ve ekipman arızaları en kritik risk faktörleri olarak belirlenmiştir. Bulgular, fast-food tedarik sistemlerinin zamanlama doğruluğu, koordinasyon kalitesi ve süreç tutarlılığına yüksek düzeyde duyarlı olduğunu göstermektedir. Çalışma, bulanık Fine–Kinney yönteminin belirsizlik koşullarında risklerin sistematik biçimde analiz edilmesi ve önceliklendirilmesinde güçlü ve uyarlanabilir bir araç olduğunu ortaya koymakta, ayrıca fast-food sektöründe operasyonel sürekliliğin güçlendirilmesi, tedarikçi performansının izlenmesi ve risk temelli karar süreçlerinin geliştirilmesine yönelik pratik katkılar sunmaktadır.

**ABSTRACT**

Fast-food restaurants operate in dynamic and competitive environments where timing accuracy, process reliability, and supplier coordination determine service continuity and customer satisfaction. Their dependence on standardized, frequently repeated, and time-pressured delivery processes makes them highly vulnerable to operational disruptions. Therefore, the early detection, monitoring, and prioritization of supplier-related risks stand out as a critical necessity for fast-food enterprises. In this study, supplier-related operational risks in a fast-food chain restaurant operating in Manisa, Türkiye, were evaluated using the fuzzy Fine–Kinney method, and critical risk areas aimed at improving supply chain reliability were revealed through a field application. In the adopted approach, the systematic structure of the classical Fine–Kinney method was combined with the flexibility of fuzzy logic, which allows representing uncertainties in expert opinions and enables linguistic judgments to be transformed into quantitative expressions. Based on the evaluations obtained from employees directly involved in supply operations, delivery time mismatches, cold-chain violations, packaging and handling damages, communication deficiencies, and equipment malfunctions were identified as the most critical risk factors. The findings show that fast-food supply systems are highly sensitive to timing accuracy, coordination quality, and process consistency. The study reveals that the fuzzy Fine–Kinney method is a strong and adaptable tool for systematically analyzing and prioritizing risks under uncertainty, and additionally provides practical contributions for strengthening operational continuity, monitoring supplier performance, and improving risk-based decision-making processes in the fast-food sector.

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## 1. Introduction

Supply chains today are positioned not merely as operational structures ensuring the flow of goods and services but as strategic sources of competitive advantage for firms. However, they are increasingly being exposed to unprecedented levels of risk arising from environmental uncertainty, pressures of digital transformation, and rapidly changing consumer demands. These risks extend far beyond physical disruptions or natural disasters, encompassing operational, technological, cyber, organizational, and human-related dimensions that collectively generate systemic fragility throughout the entire supply network (Manuj & Mentzer, 2008; Srivastava & Rogers, 2021). This situation becomes even more critical in the service sector, where the intangible nature of services, the simultaneity of production and consumption, and the necessity of instant customer response reduce the sector's resilience to operational instability (Varzandeh et al., 2016). Indeed, in the post-pandemic period, uncertainties in supply times have directly affected service quality, seriously threatening customer satisfaction and corporate reputation (Wang et al., 2022). Furthermore, the rise in employee turnover, weaknesses in digital infrastructure, fluctuations in supplier performance, and sudden demand shifts have posed significant threats to the operational continuity of service-oriented enterprises (Srivastava & Rogers, 2021). Given this complex risk structure, it is increasingly becoming a managerial necessity for firms operating in the service sector to assess these risks through systematic and holistic analytical approaches.

The food service sector, by its very nature, embodies a structure characterized by high sensitivity to operational continuity, quality consistency, and customer satisfaction. This fragility becomes even more pronounced in fast-food chains, whose business models are built on service promises that combine high transaction volumes with minimal waiting times, relying heavily on speed and standardization. In such settings, interruptions in the cold chain can jeopardize product quality and food safety, and this challenge becomes more complex in geographically dispersed networks (Cui & Basnet, 2015; Mukucha & Chari, 2022). The requirement for high-frequency and just-in-time deliveries turns supplier operational capability into a strategic determinant, while even minor deviations in timing can adversely affect customer experience (Gunasinghe & Cooray, 2020). Moreover, the inability to maintain packaging standards can lead to fluctuations in product quality, ranging from appearance to taste, ultimately damaging brand perception. In fast-food chains that operate with extensive supplier networks, communication and information flow constitute additional sources of risk, as disruptions in communication can cause operational irregularities in both inventory management and hygiene compliance Considering these dynamics, supply chain risks in fast-food operations should be regarded not merely as logistical challenges but as multidimensional vulnerabilities that threaten the sustainability of service delivery and the overall credibility of the brand.

In the risk assessment literature, a wide range of analytical techniques such as Failure Mode and Effects Analysis (FMEA), Hazard and Operability Studies (HAZOP), and multi-criteria decision-making (MCDM) approaches have been developed to identify, quantify, and prioritize potential hazards across various operational contexts. Among these, the Fine-Kinney method has gained prominence as a practical and structured tool due to its systematic logic, transparency, and ease of implementation. Its core strength lies in its ability to quantify risk levels through clearly defined parameters, enabling organizations to establish objective prioritization in decision-making. Nevertheless, the classical version of the method has been criticized for its inability to adequately capture the ambiguity and subjectivity inherent in expert judgments within complex operational settings. To overcome these limitations, recent research has increasingly integrated fuzzy logic into the Fine-Kinney framework, allowing for a more nuanced representation of uncertainty through linguistic and imprecise data (Çınar et al., 2021; Göker et al., 2022; Kartal & Soyluk, 2023; Över Özçelik et al., 2025). Although these advancements have broadened the method's application in fields such as manufacturing, construction, and occupational safety, its use within service-oriented supply chains, particularly in the food sector, remains limited. In response to this gap, the present study adopts the fuzzy Fine-Kinney method to systematically assess supplier-related operational risks in fast-food operations.

Building upon this foundation, the study further aims to prioritize these risks and to illustrate how the integration of fuzzy set theory enhances the analytical depth of the classical Fine-Kinney approach. By combining the method's structured logic with the flexibility of fuzzy representation, it seeks to provide a more realistic interpretation of expert judgments under uncertainty. This approach makes it possible to analyze operational risks not only as abstract probabilities but as context-bound phenomena shaped by daily managerial and logistical constraints. The study's contribution is threefold. First, it provides a systematic and contextually grounded assessment of supplier-related risks within the fast-food industry, a domain where operational fragility is often overlooked in academic literature. Second, it demonstrates how the integration of fuzzy logic into classical risk analysis enhances interpretive precision and decision-making flexibility in complex service environments. Third, it presents a methodologically rigorous yet practically applicable framework that can serve as a reference model for future risk assessments in service-oriented supply chains. Through this dual focus on methodological refinement and contextual insight, the study aims to contribute to both theoretical advancement and the practical management of operational risks in contemporary service systems.

## 2. Literature

Fine-Kinney is recognized as one of the most widely applied methods in risk assessment because of its systematic structure and ease of implementation. It is particularly prevalent in occupational health and safety, where it is used to prioritize risks in high-hazard settings such as manufacturing plants, construction sites, chemical laboratories, and power stations. For this study, a systematic search was conducted using the keywords "Fine-Kinney," "Fuzzy Fine-Kinney," "Risk Assessment," "Fuzzy Risk Assessment," and "Occupational Risk Analysis" across the Web of Science and Scopus databases, as well as Google Scholar, to capture prevailing trends in the literature. The studies identified through this search were analyzed, and the key findings, along with the dominant directions in the literature, are presented in detail below.

Although the Fine-Kinney method was originally developed to assess occupational health and safety risks, in recent years it has also been employed to evaluate risks across various industries. For instance, Milli et al. (2021) analyzed risks specific to tanning processes in the textile and leather industries using this method and proposed concrete preventive measures for activities identified as high risk. Similarly, Özbakır (2023) applied the Fine-Kinney method in a dairy production facility to evaluate critical risks such as electric shock, explosion, and poisoning, thereby identifying appropriate control measures. In the manufacturing sector, Sianturi et al. (2025) classified 34 distinct hazards in post-welding heat treatment processes within pipe production and developed systematic intervention strategies for each. In the construction industry, Karahan and Aydoğmuş (2023) formulated comprehensive risk control strategies for accident prevention based on the structure provided by the method. In the energy sector, Aslan (2022) examined fire and explosion risks in natural gas plants, identifying them as critical hazard groups and highlighting priority areas requiring emergency intervention. Within logistics, Pajić and Andrejić (2023) investigated occupational safety risks in internal transport processes and identified pedestrian–vehicle collisions as the most critical hazard. Despite its wide spectrum of applications, the use of the Fine-Kinney method in supply chain contexts has remained extremely limited. Indeed, the review revealed only the study by Netro et al. (2018), who classified 118 risks in a chemical industry supply chain and identified critical hazard points across the network.

The literature notes several limitations of the method, including its lack of attention to the interactions among risk parameters, its reliance on fixed numerical values for expert judgments, and its limited capacity to represent uncertainty. The review shows that fuzzy set theory has frequently been adopted to overcome these limitations. One of the earliest contributions in this regard was by Çınar et al. (2021), who applied the fuzzy Fine-Kinney method to analyze port maneuvering risks and demonstrated that interactions between environmental conditions and vessel characteristics could be represented with greater precision. Subsequently, Göker et al. (2022) integrated the method with AN FIS (Adaptive Neuro-Fuzzy Inference System), enhancing the predictive power of the fuzzy Fine-Kinney approach and showing that risk classifications could be supported by artificial intelligence based learning processes. Kartal and Soyluk (2023) developed a revised fuzzy Fine-Kinney model for natural disaster risk management, highlighting the method's adaptability to different scenarios. Likewise, Ceylan (2025) investigated hazards in ship boiler systems within the maritime sector and demonstrated that in automation-intensive environments, the fuzzified approach yields more realistic and applicable results compared to the classical Fine-Kinney method. More recently, Över Özçelik et al. (2025) analyzed occupational health and safety risks in the metal industry using fuzzy Fine-Kinney, showing that the inclusion of intermediate values enhances the sensitivity of assessments. Collectively, these studies illustrate that integrating fuzzy logic into the Fine-Kinney method allows expert judgments and linguistic uncertainties to be modeled more accurately, thereby rendering the method more reliable, flexible, and adaptable across different contexts.

Another notable trend in the literature addressing the limitations of the Fine-Kinney method is its integration with multi-criteria decision-making (MCDM) techniques. The rationale for this approach is to compensate for the methodological constraints of Fine-Kinney by supporting the decision-making process with more comprehensive and sensitive methods. For example, Ayvaz et al. (2024) derived criterion weights using Fermatean Fuzzy AHP and prioritized risks through the WASPAS method, further integrating group decisions via the FFWG operator and validated results through sensitivity analyses. Similarly, Wang et al. (2023) extended the Fermatean Fuzzy MARCOS method with prospect theory, incorporating decision-makers' psychological biases and preference intensities into risk rankings, thereby modeling uncertainty more realistically. Fang et al. (2023) applied the CRITIC method to objectively determine criterion weights and then employed the GLDS approach to capture decision-maker attitudes in risk prioritization. Doğan et al. (2022), adopting a slightly different approach, combined fuzzy Fine-Kinney with AHP-based weighting and TOPSIS-based evaluation following the identification of critical hazards, thereby systematically incorporating stakeholder priorities into risk management. Gul et al. (2022) determined control criteria weights using Bayesian BWM and ranked alternatives through fuzzy VIKOR, positioning the selection of preventive measures within a multi-criteria framework. An earlier contribution by Ilbahar et al. (2018) employed Pythagorean Fuzzy AHP to determine parameter weights and a fuzzy inference system to calculate risk values, aiming to overcome the classical method's limitations in representing decision-maker uncertainty. Collectively, these studies have significantly contributed to broadening the methodological scope of the Fine-Kinney method.

This study aims to evaluate operational supplier risks in the context of a fast-food chain restaurant using the fuzzy Fine-Kinney method, thereby providing an original contribution to a field that has been relatively neglected in the literature, both methodologically and sectorally. Addressing uncertainties that threaten operational continuity in supply chains requiring speed, standardization, and high precision, as well as vulnerabilities in supplier relationships, distinguishes this research from previous narrow-scoped approaches. Moreover, the fuzzy approach adopted here not only introduces methodological diversity to academic discussions but also yields practical, decision-supportive outputs for strategic supplier management. Thus, the research simultaneously enhances the sectoral flexibility and generalizability of the Fine-Kinney method while offering an important opening in the literature on supply chain risk analysis under uncertainty.

## 3. Method and Materials

This section outlines the methodological framework and materials used in the study. It describes the fuzzy Fine-Kinney method used to assess supplier-related operational risks, the characteristics of the study group from which expert judgments were obtained, and the specific risks included in the analysis.

### 3. 1. Fine-Kinney Method

Fine-Kinney method is a quantitative risk analysis approach developed by Kinney and Wiruth. In this method, the risk value of a task is calculated by considering the hazard's potential for occurrence, the likelihood of adverse consequences, and the frequency with which the task is performed (Kinney and

Wiruth, 1976). Including the frequency component in the risk assessment process is the key feature that differentiates the Fine-Kinney method from other approaches (Oturakçı and Dağsuyu, 2017). This approach enables a more comprehensive analysis of the realistic effects of risks under practical operating conditions.

The first step in the application of the Fine-Kinney method is the systematic identification of existing or potential risks. At this stage, risks are determined by considering the structure of the process, the technologies employed, critical points in the workflow, and the surrounding environmental conditions. Once the risks have been identified, they are evaluated based on three parameters: Likelihood (L), Exposure Factor (E), and Possible Consequences (C) (Gul et al. 2022; Ayvaz et al. 2024; Över Özçelik et al. 2025). The Likelihood (L) parameter reflects the estimated probability that a hazardous event will occur. The Exposure Factor (E) denotes the frequency with which workers or processes are subjected to the identified hazard, ranging from a value of unity for rare exposure –only a few times per year– to a value of ten for continuous exposure, with interpolation and extrapolation used to assign intermediate values, including zero for no exposure at all. The Possible Consequences (C) parameter captures the potential severity of outcomes should the hazard materialize, extending from minor damage, barely noticeable, assigned a reference value of unity, up to catastrophic outcomes, assigned a value of 100. This parametric configuration enables the simultaneous consideration of probability, exposure frequency, and consequence severity, ensuring that risks are assessed within a quantitative framework and providing a robust basis for comparative analysis across different hazards. The values and explanations associated with these parameters are presented in Table 1.

**Table 1 Parameters and Value Ranges Used in the Fine-Kinney Method**

| Likelihood (P) | Value | Exposure Factor (E) | Value | Possible Consequence (C) | Value |
|---|---|---|---|---|---|
| Might well be expected | 10 | Continuous | 10 | Catastrophe | 100 |
| Quite possible | 6 | Frequent | 6 | Disaster | 40 |
| Unusual but possible | 3 | Occasional | 3 | Very serious | 15 |
| Only remotely possible | 1 | Unusual | 2 | Serious | 7 |
| Conceivable but very unlikely | 0.5 | Rare | 1 | Important | 3 |
| Practically impossible | 0.2 | Very rare | 0.5 | Noticeable | 1 |
| Virtually impossible | 0.1 | Risk Score= P x E x C | | | |

**Source:** Kinney and Wiruth, 1976

After calculating risk scores, the Fine-Kinney method classifies them into quantitative ranges, thereby providing decision-makers with the opportunity to establish operational priorities. This classification is designed to determine the relative weight of a hazard on the system and the level of intervention required. The classification ranges are defined as follows: scores above 400 represent very high risk; scores between 200 and 400 correspond to high risk; scores between 70 and 200 indicate a substantial level of risk; scores between 20 and 70 denote possible risk; and scores below 20 are considered perhaps acceptable (Kinney and Wiruth, 1976). This classification structure allows risk scores to function as a managerial threshold mechanism within decision-support systems. It also establishes a prioritization logic that facilitates the minimization of the highest risks under limited resource conditions.

Despite its structured formulation, the Fine-Kinney method is not without limitations. The most significant limitation is its reliance on subjective expert judgment in assigning values to the parameters of likelihood, exposure, and consequence, which can lead to variability in assessing identical hazards and reduce reproducibility across applications (Birgören, 2017). This limitation introduces epistemic uncertainty that may undermine the reliability of the risk classification process. To overcome this issue, the method has been adapted using fuzzy set theory, which systematically represents imprecise or linguistically expressed expert evaluations through fuzzy numbers and membership functions. The incorporation of fuzzy logic mitigates subjectivity and provides a more consistent treatment of uncertainty, thereby enhancing the robustness and credibility of the overall risk assessment process (Gul & Celik, 2018; Satici and Mete, 2023; Ayvaz et al., 2024).

## 3. 2. Fuzzy Fine-Kinney Method

The Fuzzy Fine-Kinney method is an extension of the classical Fine-Kinney framework that incorporates fuzzy set theory into the risk assessment process. Its primary aim is to address the imprecision and subjectivity inherent in expert evaluations when assigning parameter values. Rather than relying on fixed numerical scores, the Fuzzy Fine-Kinney method employs fuzzy numbers and membership functions to represent linguistic terms such as "lower (l)," "modal(m)," or "upper(u)," thereby enabling a more realistic modeling of human judgment under uncertainty. In this approach, the three parameters –Likelihood, Exposure, and Possible Consequences– are expressed as fuzzy variables, each defined by appropriate membership functions, typically triangular or trapezoidal in form. Expert judgments articulated through linguistic scales are mapped onto these fuzzy sets, and risk scores are derived through fuzzy arithmetic operations. A defuzzification procedure is then applied to translate the fuzzy risk values into crisp outputs that can be compared with established thresholds, thereby supporting decision-making (Satici and Mete, 2023). This process maintains the structured logic of the original Fine-Kinney method while integrating vagueness and uncertainty into the evaluation.

In this study, the fuzzification process was performed using the triangular fuzzy number sets developed by Oturakçı and Dağsuyu (2017) through the Mamdani min–max approach. Triangular fuzzy numbers were preferred because they provide a balanced combination of analytical simplicity and expressive capacity in representing uncertainty. Each number is defined by three parameters that enable linguistic expert judgments to be translated into quantitative values without losing interpretive clarity. Their computational efficiency and straightforward defuzzification process make them particularly suitable for operational risk analyses that rely on human evaluations rather than objective measurements. Accordingly, these triangular sets were employed to represent each Fine-Kinney parameter within the fuzzy framework, enabling expert judgments to be systematically transformed into computational values. The fuzzy scale for the Likelihood (P) parameter, along with its corresponding triangular representations, is presented in Table 2.

**Table 2 Triangular Fuzzy Numbers for Likelihood Parameter**

| Linguistic terms | Likelihood (P) | Fuzzy numbers |
|---|---|---|
| MW | Might well be expected | (6,10,10) |
| QP | Quite possible | (3,6,10) |
| UB | Unusual but possible | (1,3,6) |
| OR | Only remotely possible | (0.5,1,3) |
| CV | Conceivable but very unlikely | (0.2,0.5,1) |
| PI | Practically impossible | (0.1,0.2,0.5) |
| VI | Virtually impossible | (0,0.1,0.2) |

The representation of likelihood introduces the probability dimension of risk assessment. However, a comprehensive assessment also requires considering how often hazards occur in practice. To capture this dimension, the fuzzification procedure was extended to the Exposure Factor (E) parameter, as shown in Table 3.

**Table 3 Triangular Fuzzy Numbers for Exposure Factor Parameter**

| Linguistic terms | Exposure Factor (E) | Fuzzy numbers |
|---|---|---|
| C | Continuous | (6, 10, 10) |
| F | Frequent | (3, 6, 10) |
| O | Occasional | (2, 3, 6) |
| U | Unusual | (1, 2, 3) |
| R | Rare | (0.5, 1, 2) |
| VR | Very rare | (0, 0.5, 1) |

The inclusion of exposure frequency adds the temporal perspective of risk, complementing the probability dimension. However, even frequent and probable hazards vary greatly in their potential impact. Therefore, the final step of the fuzzification process addresses the Possible Consequences (C) parameter, the results of which are displayed in Table 4.

**Table 4 Triangular Fuzzy Numbers for Possible Consequence Parameter**

| Linguistic terms | Possible Consequence (C) | Fuzzy numbers |
|---|---|---|
| Ca | Catastrophe | (40, 100, 100) |
| D | Disaster | (15, 40, 100) |
| VS | Very serious | (7, 15, 40) |
| S | Serious | (3, 7, 15) |
| I | Important | (1, 3, 7) |
| N | Noticeable | (0, 1, 3) |

With the fuzzification of likelihood, exposure, and consequences completed, the fuzzy Fine-Kinney procedure advances to the stage of calculating overall risk values. At this point, the three fuzzy parameters are aggregated through fuzzy arithmetic operations, producing triangular fuzzy risk scores that preserve the uncertainty embedded in expert evaluations. Because such scores cannot be directly interpreted in managerial practice, a defuzzification process is required to obtain crisp outputs.

In this study, the center of gravity method was applied, yielding a single representative value for each identified risk. These defuzzified values were then compared against the classical Fine-Kinney risk thresholds (e.g., very high, high, substantial, possible, or acceptable), which serve as decision rules for prioritization. In this way, the method retains the structured logic and interpretability of the original Fine-Kinney approach while extending its analytical depth by systematically incorporating vagueness and uncertainty into the evaluation process.

### 3.3. Study Group

The application of this study was conducted in a fast-food chain restaurant operating in Manisa, Türkiye. The analysis focused on supplier-related processes, where operational risks are particularly critical given the sector's reliance on speed, standardization, and uninterrupted service. Data were obtained from five expert participants directly involved in the restaurant's supply operations. These participants assessed the identified risks following the procedural steps of the fuzzy Fine-Kinney method, providing informed judgments that guided the fuzzification and prioritization process. To ensure analytical consistency and preserve participant anonymity, the contributors were coded as P1–P5 throughout the evaluation process.

### 3.4. Supplier-Related Operational Risks

As part of the case study, ten supplier-related risks were assessed using the fuzzy Fine-Kinney method. These risks were identified in consultation with the restaurant's managers and represent operational vulnerabilities that may disrupt continuity, efficiency, and quality in fast food supply processes. The risks cover a broad range of supplier-related issues, including delivery, product quality, handling, hygiene, and coordination. Specifically, they comprise delivery delays resulting from suppliers' failure to meet agreed timelines; incorrect or incomplete deliveries where orders arrive with missing or erroneous items; and cold chain violations due to improper transportation or storage conditions. In addition, inconsistencies in material quality and damages arising from inadequate packaging or handling were included, as such problems directly affect product integrity. The scope was further extended to cover non-compliance with hygiene and food safety standards, as well as low flexibility in emergency situations, such as sudden demand surges or product recalls. Finally, communication and coordination deficiencies between the restaurant and its suppliers, mismatches in delivery timing that coincide with peak operational hours, and vehicle or equipment malfunctions occurring during delivery were also considered. Together, these ten risks provide a comprehensive representation of supplier-related challenges in the fast-food sector and serve as the empirical basis for the fuzzy Fine-Kinney evaluation conducted in this study. These risks are listed in Table 5.

**Table 5 Supplier-Related Risks Assessment Through the Fuzzy Fine-Kinney Method**

| Risks | Scope | Code |
|---|---|---|
| Delivery Delays | Failure of the supplier to deliver orders within the agreed time frame. | R1 |
| Incorrect or Incomplete Deliveries | Orders arriving with missing or erroneous items that disrupt operational flow. | R2 |
| Cold Chain Violations | Products being transported or stored without maintaining appropriate temperature conditions. | R3 |
| Inconsistencies in Material Quality | Variations in the quality standards of delivered materials, affecting product uniformity. | R4 |
| Packaging and Handling Damages | Physical damage to products due to inadequate packaging or mishandling during transport. | R5 |
| Non-Compliance with Hygiene and Food Safety Standards | Supplier's failure to adhere to required hygiene, sanitation, or food safety regulations. | R6 |
| Low Flexibility in Emergency Supply Situations | Inability to respond effectively to sudden demand fluctuations, product recalls, or supply disruptions. | R7 |
| Communication and Coordination Deficiencies | Lack of timely and accurate information exchange between the restaurant and suppliers. | R8 |
| Delivery Time Mismatches | Deliveries coincide with peak operational hours, causing workflow interruptions. | R9 |
| Vehicle or Equipment Malfunctions during Delivery | Technical failures or capacity limitations of delivery vehicles or equipment. | R10 |

## 3.5. Procedural Flow

The methodological procedure followed a four-step structure: risk identification, parameter fuzzification, defuzzification of aggregated scores, and risk classification according to Fine-Kinney thresholds. Figure 1 presents the overall flow of the study, illustrating how the four stages connect within the fuzzy Fine-Kinney procedure.

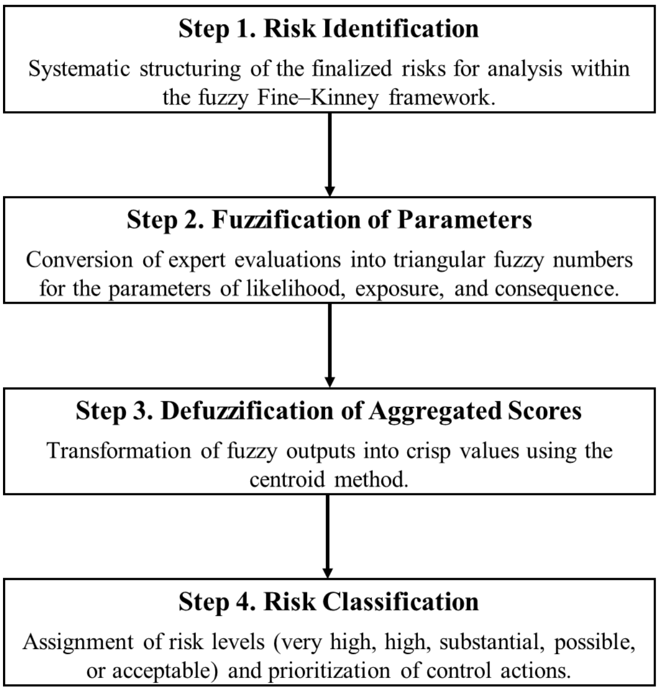


**Figure 1 Procedural Flow of the Fuzzy Fine-Kinney Risk Assessment Process**

The four-stage structure of the fuzzy Fine-Kinney process reflects the systematic logic of the study's methodological flow. In the first stage, potential operational risks were identified through an extensive review of the literature and refined through consultations with supply chain managers, ensuring that the final list of risks accurately reflects the realities of fast-food supplier operations. In the second stage, these risks were evaluated by experts using linguistic expressions defined for the parameters of Likelihood, Exposure, and Possible Consequences. The linguistic terms were then converted into triangular fuzzy numbers according to the membership functions adopted in this study, allowing expert opinions to be expressed in a quantitative form without losing their qualitative meaning. In the third stage, the aggregated fuzzy risk scores were transformed into crisp values through the centroid (center-of-gravity) defuzzification method, providing comparable outputs for all coded risks. In the final stage, the defuzzified scores were classified based on Fine-Kinney's threshold ranges, assigning each risk to its corresponding level (very high, high, substantial, possible, or acceptable) and guiding the prioritization of preventive and corrective actions accordingly.

### 3.6. Ethical Considerations

This study was conducted in accordance with established ethical research principles and was formally approved by the Scientific Research Ethics Committee in the Social and Human Sciences at Alanya Alaaddin Keykubat University (Decision No: 2025/15, dated 10 September 2025). Participation was voluntary, and all participants were informed in advance about the purpose of the research and the confidentiality of the collected data. Every stage of the study—from data gathering to interpretation—was conducted with respect for participants' professional integrity and privacy.

During manuscript preparation, generative artificial intelligence (DeepL) was used solely as a translation support tool. The analytical design, interpretation of findings, and all substantive arguments were entirely developed by the author. The use of AI tools was limited to facilitating the translation process and did not affect the scientific reasoning, originality, or methodological decisions of the research.

## 4. Application and Findings

In the initial phase of the analysis, the linguistic evaluations provided by the participants were compiled to establish the study's qualitative dataset. The participants were employees directly involved in supply-related operations and had first-hand experience with the practical challenges of the process. Each participant evaluated the ten risks associated with suppliers using the linguistic scales defined for the Fine-Kinney parameters of Likelihood (L), Exposure (E), and Possible Consequences (C). Their assessments capture how these operational risks were perceived within the daily flow of the restaurant's activities and provided the empirical basis for the subsequent stages of analysis. The linguistic evaluations of all participants are presented collectively in Table 6.

**Table 6 Linguistic Evaluations of Supplier-Related Risks Provided by the Expert Participants**

| Risks | P1 | | | P2 | | | P3 | | | P4 | | | P5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P | E | C | P | E | C | P | E | C | P | E | C | P | E | C |
| **R1** | PI | R | S | CV | U | I | PI | R | S | MW | F | I | OR | R | I |
| **R2** | CV | R | I | CV | U | I | CV | R | S | CV | R | I | PI | VR | I |
| **R3** | UB | F | VS | CV | U | VS | UB | F | S | UB | F | I | OR | O | I |
| **R4** | CV | U | VS | OR | O | S | CV | R | S | CV | R | N | OR | O | S |
| **R5** | UB | O | S | CV | U | S | UB | O | S | QP | O | S | UB | F | S |
| **R6** | PI | U | S | PI | R | S | CV | R | VS | PI | R | I | OR | O | S |
| **R7** | OR | R | S | OR | O | VS | CV | U | S | QP | O | S | OR | O | S |
| **R8** | QP | F | S | UB | O | VS | QP | F | S | CV | U | I | OR | O | S |
| **R9** | MW | C | D | UB | F | D | QP | F | S | UB | F | I | OR | O | S |
| **R10** | MW | C | S | OR | U | S | QP | F | S | OR | O | I | UB | O | S |

Following the compilation of linguistic data, the evaluations were converted into triangular fuzzy numbers in line with the fuzzy scale adopted in this study. Each linguistic term used by the participants for the parameters of Likelihood, Exposure, and Possible Consequences was matched with its corresponding triangular representation. To obtain a unified, consensus-based assessment, the mean values of the triangular numbers provided by all participants were calculated. This process produced an aggregated fuzzy assessment table that summarizes the collective assessment of supplier-related risks and serves as the basis for the subsequent computational steps. The resulting aggregated fuzzy evaluations are presented in Table 7.

**Table 7 Aggregated Fuzzy Evaluations of Supplier-Related Risks**

| Risks | P | | | E | | | C | | |
|---|---|---|---|---|---|---|---|---|---|
| | l | m | u | l | m | u | l | m | u |
| **R1** | 1.38 | 2.38 | 3.00 | 1.10 | 2.20 | 3.80 | 1.80 | 4.60 | 10.20 |
| **R2** | 0.18 | 0.44 | 0.90 | 0.50 | 1.10 | 2.00 | 1.40 | 3.80 | 8.60 |
| **R3** | 0.74 | 2.10 | 4.40 | 2.40 | 4.60 | 7.80 | 3.80 | 8.60 | 21.80 |
| **R4** | 0.32 | 0.70 | 1.80 | 1.20 | 2.00 | 3.80 | 3.20 | 7.40 | 17.60 |
| **R5** | 1.24 | 3.10 | 5.80 | 2.00 | 3.40 | 6.20 | 3.00 | 7.00 | 15.00 |
| **R6** | 0.20 | 0.42 | 1.10 | 0.90 | 1.60 | 3.00 | 3.40 | 7.80 | 18.40 |
| **R7** | 0.94 | 1.90 | 4.00 | 1.50 | 2.40 | 4.60 | 3.80 | 8.60 | 20.00 |
| **R8** | 1.54 | 3.30 | 6.00 | 2.20 | 4.00 | 7.00 | 3.40 | 7.80 | 18.40 |
| **R9** | 2.30 | 4.60 | 7.00 | 3.40 | 6.20 | 9.20 | 7.40 | 19.40 | 47.40 |
| **R10** | 2.20 | 4.20 | 6.40 | 2.80 | 4.80 | 7.00 | 2.60 | 6.20 | 13.40 |

Building on the aggregated fuzzy assessments presented in Table 7, the next step focused on calculating fuzzy risk scores for each identified risk. In accordance with the Fine-Kinney methodology, the aggregated fuzzy mean values of Likelihood (P), Exposure (E), and Consequence (C) were multiplied to obtain a fuzzy risk value for each case. This step enabled the determination of each risk's overall magnitude under conditions of uncertainty. The fuzzy risk scores were then defuzzified using the centroid (center-of-gravity) method to derive crisp numerical values that could be compared directly. Based on the defuzzified scores, all risks were classified according to Fine-Kinney threshold ranges, allowing their relative severity to be clearly distinguished. The defuzzified scores and corresponding classifications are presented in Table 8.

**Table 8 Risk Scores and Classification**

| Risks | Fuzzy Score | | | Defuzzified Score | Risk Classification |
|---|---|---|---|---|---|
| | *l* | *m* | *u* | | |
| **R1** | 2.73 | 24.09 | 116.28 | 47.70 | Possible risk |
| **R2** | 0.13 | 1.84 | 15.48 | 5.82 | Acceptable risk |
| **R3** | 6.75 | 83.08 | 748.18 | 279.33 | High risk |
| **R4** | 1.23 | 10.36 | 120.38 | 43.99 | Possible risk |
| **R5** | 7.44 | 73.78 | 539.40 | 206.87 | High risk |
| **R6** | 0.61 | 5.24 | 60.72 | 22.19 | Possible risk |
| **R7** | 5.36 | 39.22 | 368.00 | 137.52 | Indicate substantial risk |
| **R8** | 11.52 | 102.96 | 772.80 | 295.76 | High risk |
| **R9** | 57.87 | 553.29 | 3052.56 | 1221.24 | Very high risk |
| **R10** | 16.02 | 124.99 | 600.32 | 247.11 | High risk |

Risk classification was performed according to the Fine-Kinney methodology, which evaluates defuzzified scores within predefined threshold ranges. As presented in Table 8, the results reveal a clear distribution of supplier-related risks across different severity levels. The highest defuzzified score was observed for R9 (Delivery Time Mismatches), which was classified as a very high risk with a value of 1221.24. R3 (Cold Chain Violations), R5 (Packaging and Handling Damages), R8 (Communication and Coordination Deficiencies), and R10 (Vehicle or Equipment Malfunctions) were all categorized as high risks, with scores ranging between 206.87 and 295.76. R7 (Low Flexibility in Emergency Supply Situations) fell into the substantial risk category, with a score of 137.52. R1 (Delivery Delays), R4 (Inconsistencies in Material Quality), and R6 (Non-Compliance with Hygiene and Food Safety

Standards) were identified as possible risks, each receiving a score below 70. Finally, R2 (Incorrect or Incomplete Deliveries) was classified as acceptable with a score of 5.82.

## Conclusion

This study applied the fuzzy Fine-Kinney method to assess supplier-related operational risks in a fast-food chain restaurant operating in Manisa, Türkiye. The case analysis provided a detailed understanding of how daily supply processes are exposed to uncertainty and how such risks can be systematically prioritized under real operational conditions. The results showed that delivery time mismatches, cold-chain violations, packaging and handling damages, communication deficiencies, and equipment malfunctions represented the most critical risk factors. These findings indicate that the operational structure of fast-food supply chains is highly sensitive to timing accuracy, coordination quality, and process reliability.

From a methodological perspective, the fuzzy Fine-Kinney approach provided a structured and quantitative framework capable of capturing the inherent uncertainty in expert evaluations. In line with previous studies that have applied or refined the method in different fields such as maritime operations (Çınar et al., 2021), adaptive neuro-fuzzy inference systems (Göker et al., 2022), disaster risk management (Kartal and Soyluk, 2023), and occupational safety in manufacturing (Över Özçelik et al., 2025), the integration of fuzzy logic has enabled an increase in both the interpretive capacity and flexibility of the original Fine-Kinney framework. The fuzzy adaptation further allowed the inclusion of linguistic judgments, reflecting the experiential insights of employees who directly deal with supplier-related challenges in their daily work. This adaptability becomes highly valuable in fast-paced service environments characterized by rapid decision cycles and minimal tolerance for operational delays. By transforming qualitative expert opinions into quantifiable expressions, the method provided a systematic and transparent basis for prioritizing supplier-related risks within the fast-food supply context.

The practical application of this framework revealed a differentiated structure of supplier-related risks within the operational environment of fast-food chains. Among the ten risks evaluated, delivery time mismatches (R9) emerged as the most critical, followed by high-level risks associated with cold chain violations (R3), packaging and handling damages (R5), communication and coordination deficiencies (R8), and vehicle or equipment malfunctions (R10). These findings point to the predominance of operational and logistical disruptions over purely supplier-related or quality-based concerns. In the context of fast-food operations, where service continuity and product freshness depend on tightly synchronized processes, even minor deviations in timing, coordination, or temperature control can quickly escalate into system-wide inefficiencies.

Building on these findings, the study also offers managerial implications for the design of supplier management strategies in fast-food operations. High-risk areas such as delivery timing, cold-chain management, and equipment reliability call for dynamic scheduling mechanisms, real-time temperature and vehicle monitoring systems, and preventive maintenance programs. Moreover, communication deficiencies identified in the case point to the necessity of standardized coordination protocols between suppliers and stores to ensure consistent information flow and reduce uncertainty in order fulfillment. Implementing these measures can strengthen operational resilience and improve the reliability of service delivery.

Beyond the operational level, the findings also suggest that effective supplier risk management in fast-food chains requires an integrated governance perspective. Establishing clear performance standards, conducting regular supplier audits, and implementing incentive-based evaluation systems could strengthen accountability across the supply network. Collaboration mechanisms such as joint contingency planning and shared digital tracking platforms may also enhance responsiveness to disruptions and improve transparency in information exchange. Furthermore, developing supplier relationship programs that emphasize mutual learning and process improvement can foster long-term trust and reduce the recurrence of high-impact risks.

Despite its methodological and contextual contributions, this study has several limitations that should be acknowledged. The analysis was conducted within a single fast-food chain restaurant, which naturally restricts the generalizability of the findings. Although the case provides valuable insights into supplier-related risks in fast-food operations, variations in organizational structure, supplier networks, or geographic conditions may yield different outcomes. Additionally, the assessment relied on expert judgments from employees directly involved in supply processes, which may have introduced subjective bias despite the use of fuzzy logic to minimize such effects. Future studies could expand the research by incorporating multiple cases across different service sectors or by integrating complementary decision-making methods to validate and extend the robustness of the results.

Nevertheless, this case study extends the applicability of the fuzzy Fine-Kinney method beyond its conventional industrial applications by demonstrating its relevance to service-sector risk assessment. Future research may apply the same approach to multi-unit or regional fast-food networks, enabling comparative analysis of supply-related vulnerabilities across different scales and operational configurations. Integrating fuzzy Fine-Kinney with multi-criteria decision-making or simulation-based modeling could further enhance its diagnostic capacity for complex service systems where human factors and time sensitivity intersect.

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## GENİŞLETİLMİŞ ÖZET

Fast-food işletmeleri, hız, standardizasyon ve süreç sürekliliği üzerine inşa edilmiş operasyonel yapıları nedeniyle, tedarik zincirinde meydana gelen en küçük aksaklıktan dahi doğrudan etkilenmektedir. Bu durum, fast-food tedarik zincirlerinde zamanlama doğruluğunu, süreç güvenilirliğini ve tedarikçi koordinasyonunu hizmet kalitesinin ve müşteri memnuniyetinin belirleyici unsurları haline getirmektedir. Dolayısıyla, tedarikçi kaynaklı risklerin erken tespiti, izlenmesi ve önceliklendirilmesi, fast-food İşletmelerinde operasyonel sürdürülebilirliğin sağlanması açısından stratejik bir yönetim gereksinimi olarak ortaya çıkmaktadır. Bu gereksinimden hareketle çalışmada fast-food sektöründe çoğunlukla göz ardı edilen tedarikçi tabanlı operasyonel riskler derinlemesine incelenmiş ve bu risklerin sistematik biçimde değerlendirilmesine yönelik analitik bir yaklaşım geliştirilmiştir. Bu kapsamda, Manisa ilinde faaliyet gösteren bir zincir restoran örneğinde, tedarikçi kaynaklı operasyonel riskler bulanık Fine-Kinney yöntemi kullanılarak analiz edilmiştir. Fine–Kinney yöntemi, tedarikçi kaynaklı operasyonel risklerin nicel olarak değerlendirilmesini sağlamak ve uzman yargılarında kaçınılmaz biçimde bulunan belirsizliği analitik biçimde modele dâhil edebilmek amacıyla benimsenmiştir. Klasik Fine–Kinney yaklaşımı, risklerin olasılık (L), maruziyet (E) ve olası sonuç (C) parametreleri üzerinden sistematik biçimde puanlanmasına olanak tanıyan yapılandırılmış bir çerçeve sunmakla birlikte nitel yargıların içerdiği belirsizlik düzeyini temsil etmede sınırlılıklar taşımaktadır. Bu çalışmada, söz konusu sınırlılığı aşmak ve uzman değerlendirmelerini daha gerçekçi biçimde modele yansıtmak amacıyla Fine–Kinney yöntemi bulanık mantık yaklaşımıyla bütünleştirilerek yeniden yapılandırılmıştır. Bu kapsamda, katılımcıların olasılık, maruziyet ve sonuç parametrelerine ilişkin dilsel değerlendirmeleri bulanık sayılar aracılığıyla ifade edilerek farklı uzman görüşleri ortak bir bulanık küme mantığı altında birleştirilmiştir. Belirsizliğin temsilinde ise kavramsal açıklık sağlaması ve hesaplama sürecine pratiklik kazandırması nedeniyle üçgensel bulanık sayılar (triangular fuzzy numbers) tercih edilmiştir. Her bir parametre, alt (l), orta (m) ve üst (u) değerlerden oluşan üyelik fonksiyonlarıyla modellenmiş; elde edilen bulanık risk değerleri ağırlık merkezine dayalı durulaştırma (centroid defuzzification) yöntemiyle tekil sayısal skorlara dönüştürülmüştür. Böylece, uzman değerlendirmelerindeki belirsizlik analitik biçimde işlenmiş, farklı risk faktörleri arasındaki karşılaştırılabilirlik güçlendirilmiş ve yöntemin yorumlama güvenilirliği artırılmıştır. Uygulama aşamasında, ilgili işletmenin tedarik operasyonlarında görev yapan beş uzman katılımcıdan geliştirilen bulanık Fine–Kinney modeline uygun biçimde veri toplanmış ve analiz süreci yürütülmüştür. Bu doğrultuda, katılımcıların tedarikçi ilişkilerinden kaynaklanan on temel risk faktörüne yönelik olasılık (L), maruziyet (E) ve olası sonuç (C) parametreleri hakkındaki dilsel değerlendirmeleri toplanarak bulanık sayılar aracılığıyla modellenmiştir. Analiz sonucunda en kritik operasyonel risk, 1221,24 puanla çok yüksek risk olarak tanımlanan teslimat zaman uyuşmazlıkları (R9) olmuştur. Bu bulgu, fast-food operasyonlarının zaman hassasiyetinin tedarik zinciri risklerini nasıl büyütebileceğini göstermektedir. Soğuk zincir ihlalleri (R3), paketleme ve taşıma hasarları (R5), iletişim ve koordinasyon eksiklikleri (R8) ile araç veya ekipman arızaları (R10) yüksek risk kategorisinde yer almış ve lojistik sürekliliğin kırılgan yönlerini ortaya koymuştur. Acil durum esnekliğinin düşüklüğü (R7) önemli risk grubunda değerlendirilirken; teslimat gecikmeleri (R1), malzeme kalitesinde tutarsızlıklar (R4) ve hijyen standartlarına uyumsuzluk (R6) olasılık dâhilinde risk düzeyinde sınıflandırılmıştır. Buna karşılık hatalı veya eksik teslimatlar (R2) 5,82 puan ile kabul edilebilir risk sınırında kalmıştır. Çalışmada elde edilen bulgular, fast-food tedarik zincirlerinin zamanlama doğruluğu, koordinasyon kalitesi ve süreç tutarlılığına son derece duyarlı olduğuna işaret etmektedir. Özellikle teslimat süreçlerinde yaşanan zaman uyuşmazlıklarının, soğuk zincir bütünlüğü ve ekipman güvenilirliğiyle birlikte hizmet sürekliliği üzerinde belirleyici bir etkiye sahip olması oldukça dikkat çekicidir. Bu sonuçlar, tedarikçi kaynaklı risklerin sadece lojistik süreçlerden ibaret olmadığını, içsel bilgi akışı ve operasyonel planlama hatalarından da beslenebildiğini göstermektedir. Bu nedenle fast-food tedarik zincirlerinde risk yönetiminin, hizmet kalitesi ve marka güvenilirliğiyle doğrudan ilişkili stratejik bir yönetim alanı olarak ele alınması büyük önem arz etmektedir. Tedarikçi performansının düzenli olarak izlenmesi, teslimat planlamasının dijital sistemlerle senkronize edilmesi, soğuk zincir bütünlüğünün gerçek zamanlı olarak takip edilmesi ve önleyici bakım uygulamalarının yaygınlaştırılmasıyla risk yönetimi daha proaktif, veri temelli ve sürdürülebilir bir yapıya dönüştürülebilir. Çalışma, bulanık Fine–Kinney yönteminin hizmet sektöründeki uygulanabilirliğini ortaya koyarak literatürü yöntemsel ve bağlamsal düzeyde zenginleştirmektedir. Ancak analiz tek bir işletme örneğiyle sınırlı olduğundan sonuçların genellenebilmesi için farklı bölgelerde ve daha geniş örneklemlerle desteklenmesi gerekmektedir.