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Research on Risk Evolution of Online Food Delivery Platforms Based on Fuzzy Cognitive Map

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Abstract. The rapid growth of the online food delivery market in China has led to a range of risk issues, including food safety and delivery transportation risks. This article aims to address these risks by establishing a fuzzy cognitive map for online food delivery platforms (Taking Meituan as an example) and studying the evolutionary characteristics of these risks. Firstly, a risk criteria system is developed considering multiple business scenarios such as online service, consumption activity, offline service and offline management. Secondly, a fuzzy cognitive map is constructed to represent the relations between risk criteria. Finally, the risk feature evolution results are obtained using the iterative algorithm of the fuzzy cognitive map. By analyzing these results, suggestions for risk management in online food delivery platforms are proposed.

Keywords. Online food delivery platform, risk evolution, fuzzy cognitive map

1. Introduction

In recent years, the online food delivery market has developed rapidly. In 2021, China's online food delivery market reached 1 trillion yuan, as reported by the State Information Center, and the user population reached 521 million people in 2022 as reported by the China Internet Network Information Center. While the development of the online food delivery industry has brought convenience to people's lives, it has also given rise to various risk issues, including food safety concerns, rider traffic accidents, environmental risks, and more. Consequently, researchers have directed their attention towards studying risk-related matters pertaining to online food delivery platforms (OFDPs).

Several scholars have investigated the risks associated with OFDPs. Fan et al.[1] focused on platform regulation when examining the risks of OFDPs. Pillai et al.[2] explored the risks from the perspective of customer perception. Wu et al.[3] analyzed the impact of algorithms on platform risk, specifically investigating risk criteria for OFDPs. In another study, Hong et al.[4] examined the influence of perceived food safety risks on consumers' intentions to make online food delivery purchases. Liu and Li[5] delved into the OFDPs’ management strategies to protect restaurant owners and for-hire gig workers.

Furthermore, research efforts have also been dedicated to devising risk assessment methods for OFDPs. An intertemporal utility model is proposed for OFDPs from the

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perspective of behavioral economics[6]. Additionally, the utilization of big data and web-based Decision Support Systems (DSS) has been encouraged for enhancing food safety control[7]. For example, a FoodProfiler mobile app is developed to collect food consumption data directly from users by researchers from Wageningen University[7]. Moreover, the analysis of risk evolution characteristics has been instrumental in facilitating effective risk management. Scholars have utilized fuzzy cognitive maps (FCMs) for conducting risk evolution analysis. For instance, an integrated multi-stage FCM and failure mode and effects analysis were proposed to analyze risks in sequential processes within the food industry[8]. FCM approaches have also been employed to develop an industry 4.0 readiness model[9]. Therefore, this paper aims to study the risk evolution of OFDPs across multiple business scenarios using FCM.

Based on the analysis conducted, two areas require further improvement. Firstly, the risks of OFDPs across multiple business scenarios need to be studied. Secondly, FCM is seldom used in the risk evolution in OFDPs. Therefore, this paper aims to study the risk evolution in OFDPs (Taking Meituan as an example) across various business scenarios using FCM. First, we involve establishing a risk criteria system to multiple business scenarios. Then, we analyze the risk criteria to develop the FCM for OFDPs. Finally, we apply the FCM iterative algorithm to obtain the evolution results of risk, and we conduct an analysis of these findings to propose recommendations for risk management in OFDPs.

2. Construction of FCM for OFDP

2.1. Construction of the Risk Criteria System for OFDP

There are four primary risk criteria based on the business scenario of Meituan, which are: Online service risk C_1, Consumption activity risk C_2, Offline service risk C_3 and Offline management risk C_4. And the overall OFDP risk is denoted as R. Among them, C_1 encompasses risks related to platform network facilities, payment technology, and management, while C_2 focuses on risks that may arise during the consumption process. Similarly, C_3 relates to risks associated with offline services, and C_4 pertains to risks related to social supervision and platform supervision. The risk criteria system of OFDPs is established through a literature analysis method, as presented in Table 1.

Table 1. The risk criteria system of OFDPs

Primary criteria	Secondary criteria	Meaning of criteria
C_1	Survey and audit risk C_{11}	Checking if a valid food service license is present [1]
	Appraisal mechanism risk C_{12}	Harsh and inflexible "overtime rate" and "Poor feedback rate"[11]
	Rider qualification risk C_{13}	Riders lacking health certificates and weak traffic awareness[11]
	Information leakage risk C_{14}	Customer interests compromised due to information leakage [10]
C_2	Pricing discrimination risk C_{21}	Higher prices for old customers compared to new customers[10]
	False advertising risk C_{22}	A discrepancy between the actual product and its description [5]
	Scheduling algorithm risk C_{23}	Algorithms causing compressed delivery times and forced allocation of orders [3]
	Order commission risk C_{24}	OFDP extracting a higher percentage of commission[5]

Table 1 (Continued). The risk criteria system of OFDPs

Primary criteria	Secondary criteria	Meaning of criteria
C_3	Order timeout or damage risk C_{31}	Order timeouts or damage[2]
	Evaluation distortion risk C_{32}	Untruthful evaluations, deliberate brushing of poor feedback[2]
	food safety risks C_{33}	Food not meeting national safety standards[4]
	Environmental risk C_{34}	Food production environment not meeting hygiene standards, failed sampling, etc. [4]
C_4	Regulatory enforcement risk C_{41}	Lack of timely government supervision means, light platform supervision and punishment [1]
	System imperfection risk C_{42}	Inadequate online food delivery management system [1]
	Complaints and rights protection risk C_{43}	Limited channels for dealing with complaints and defending rights, difficult resolution [1]
	Information asymmetry risk C_{44}	Information asymmetry in OFDP [1]

2.2. FCM Construction for OFDPs

The FCM of OFDPs risks is constructed based on the criteria system outlined in Table 1, as depicted in Figure 1.

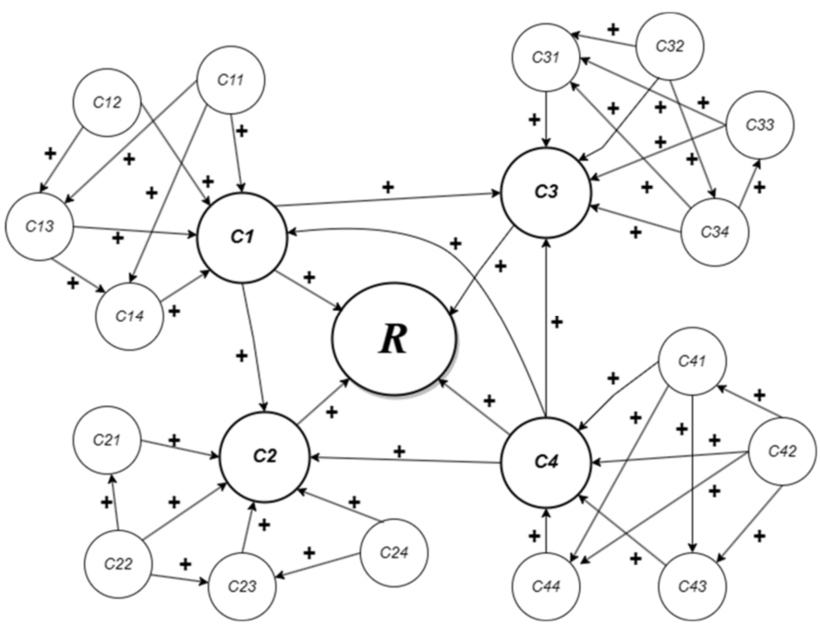

Figure 1. The FCM of OFDP risks

The risk criteria are not entirely independent of each other. For instance, when considering the strictly online service C_1, it diminishes the potential risks associated with consumer activity C_2 and offline service C_3. The precise extent of this correlation is visually depicted in Figure 1, where the symbols "+" and "-" represent positive and negative correlations between the risk criteria, respectively.

3. Analysis of Risk Evolutionary Characteristics for OFDPs

3.1. Risk Evolution Problem Description for OFDPs

OFDPs have a bilateral market structure, which refers to a market structure where buyers and sellers use the services provided by a third-party platform (Taking Meituan as an example) to reach a transaction. In this process, Meituan will charge each party a certain amount of money. The two sides of the transaction refer to merchants and consumers respectively, and Meituan charge the corresponding fees to both sides of the transaction for each order, forming an intertwined background of multiple business scenarios and generating various risks accordingly.

The risk evolution problem for OFDP is described as follows. There are 4 primary criteria $C_i(i = 1,2,3,4)$ and 16 secondary criteria $C_{ij}(i,j = 1,2,\ldots,4)$ as shown in Table 1. The initial state values of criteria are $A_i \in [0,1]$ and $A_{ij} \in [0,1]$, and the FCM is shown in Figure 1.

The calculation procedure of the proposed method is as follows.

Step 1. Obtain the initial state value A_{ij} of criteria C_{ij}. the initial state value A_{ij} of criteria C_{ij} is obtained by experts and shown in Table 2.

Table 2. Initial state values of risk criteria for OFDPs

C_{ij}	A_{ij}	C_{ij}	A_{ij}	C_{ij}	A_{ij}	C_{ij}	A_{ij}
C_{11}	0.59	C_{21}	0.39	C_{31}	0.52	C_{41}	0.52
C_{12}	0.58	C_{22}	0.45	C_{32}	0.52	C_{42}	0.41
C_{13}	0.34	C_{23}	0.63	C_{33}	0.88	C_{43}	0.47
C_{14}	0.50	C_{24}	0.51	C_{34}	0.88	C_{44}	0.69

Among them, A_{11}=0.59 indicates that the initial state value of C_{11} is 0.59, and since $A_{ij} \in [0,1]$, the initial state of C_{11} is about medium risk.

Step 2. Obtain the impact intensity matrix of the FCM. The impact intensity matrix W is obtained by experts. Then we have the impact intensity matrix W of the primary criteria C_i on the overall risk R (which is the fifth column of W).

$$W = \begin{bmatrix} 1 & 0.57 & 0.63 & 0 & 0.67 \\ 0 & 1 & 0 & 0 & 0.65 \\ 0 & 0 & 1 & 0 & 0.48 \\ 0.53 & 0.45 & 0.48 & 1 & 0.68 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

The impact intensity matrixes between the secondary criteria and the primary criteria are W_1, W_2, W_3 and W_4.

$$W_1 = \begin{bmatrix} 1 & 0 & 0.44 & 0.76 & 0.40 \\ 0.52 & 1 & 0.63 & 0 & 0.44 \\ 0 & 0 & 1 & 0.39 & 0.48 \\ 0 & 0 & 0 & 1 & 0.38 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad W_2 = \begin{bmatrix} 1 & 0 & 0 & 0 & 0.37 \\ 0.73 & 1 & 0.44 & 0 & 0.41 \\ 0 & 0 & 1 & 0 & 0.67 \\ 0 & 0 & 1 & 1 & 0.66 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\mathbf{W_3} = \begin{bmatrix} 1 & 0.39 & 0.58 & 0.45 & 0.74 \\ 0 & 1 & 0.51 & 0 & 0.38 \\ 0 & 0 & 1 & 0.52 & 0.52 \\ 0 & 0.65 & 0 & 1 & 0.43 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad \mathbf{W_4} = \begin{bmatrix} 1 & 0.59 & 0 & 0 & 0.31 \\ 0 & 1 & 0 & 0 & 0.29 \\ 0.47 & 0.38 & 1 & 0 & 0.58 \\ 0.70 & 0.93 & 0 & 1 & 0.26 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Step 3. Obtain the stable state value of FCM. The stable state values of $\mathrm{A_j}$ are calculated using the iterative algorithm of FCM based on Equations (1) and (2)[9].

$$\mathrm{A_j(k+1)} = \mathrm{f}\Big(\sum_{i=1, i\neq j}^{n} \mathrm{A_i W_{ij}}\Big) \tag{1}$$

$$\mathrm{f}(x) = \frac{1}{1+e^{-\mu x}} \tag{2}$$

Among them, $\mathrm{A_j(k+1)}$ denoted the stable state values of $\mathrm{A_j}$ after a series of $\mathrm{k+1}$ iterations.

(1) The risk evolution between the overall risk R and the primary criteria C_i. Through a series of six iterations, the stable state values of risk criteria are illustrated in Figure 2. As shown in Figure 2, the initial state value is denoted as "IV", the stable state value is denoted as "SV", and the number of iterations is denoted as "N".

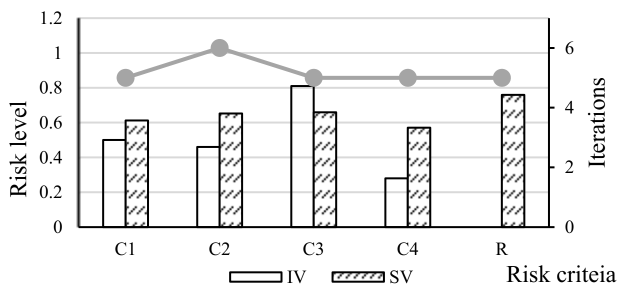

Figure 2. Risk evolution between the overall risk and primary criteria

The criteria currently exerting the greatest influence on the overall risk R are C_3, C_1, C_2, C_4. After 6 iterations, the stable state value of C_3 decreases rapidly, while the stable state values of C_1, C_2, C_4 all keep increasing. Notably, the most substantial increase is observed in the risk value of C_4. Consequently, we propose the following course of action. In the immediate future, we should reduce the risk of C_3 by educating riders about safety practices and intensifying supervision to ensure food safety among online food delivery vendors. In the long term, we should closely monitor the change of C_1, C_2, C_4 by strengthening the qualification audit of online food delivery merchants and optimizing the online ordering system and improving offline management services.

(2) The risk evolution between C_1, C_2, C_3, C_4 and the secondary criteria.

Through a series of iterations, the stable state values are illustrated in Figure 3. As shown in Figure 3, the initial state value is denoted as "IV", the stable state value is denoted as "SV", and the number of iterations is denoted as "N".

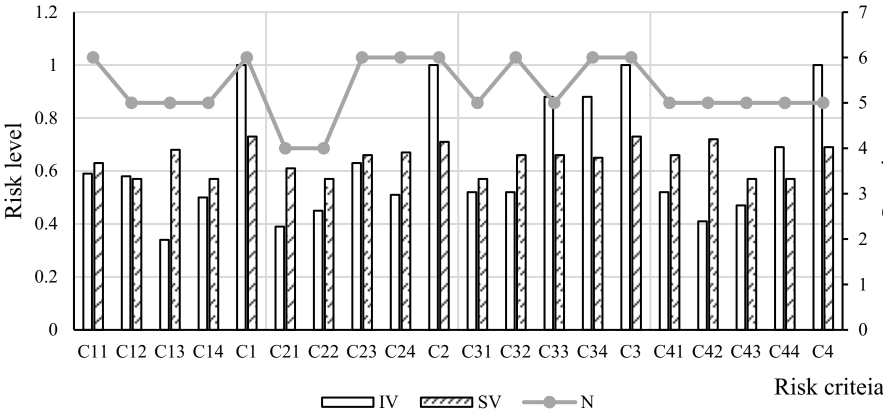

Figure 3. Risk evolution between primary criteria and secondary criteria

Initially, the criteria C_{11} and C_{12} have a significant impact on C_1. However, after reaching a stable state through data iteration, the risk value of C_{12} decreases, while the risk values of C_{11}, C_{13} and C_{14} all increase. Notably, C_{13} exhibits the fastest growth in risk value. Therefore, we recommend the following actions. At this stage, it is crucial to closely reduce the risk values of C_{11} and C_{12} by regular inspections of business licenses for online food delivery shops and improving the merchant assessment mechanism. In the future, particular measures should be implemented to reduce the risk of C_{13}, such as conducting regular health examinations for delivery riders and providing traffic safety education.

Initially, the criterion C_{23} has a significant impact on C_2. After reaching a stable state through data iteration, the risk values of C_{21}, C_{22}, C_{23} and C_{24} all increase. Notably, C_{23} and C_{24} have the highest risk values. Therefore, it is crucial to prioritize the risk situation of C_{23} currently and the risk situation of both C_{23} and C_{24} in the future. To mitigate these risks, it is recommended to implement measures such as optimizing scheduling algorithms and employing differentiated commission collection strategies.

Initially, the criteria C_{33} and C_{34} have a significant impact on C_3. After reaching a stable state through data iteration, the risk values of C_{31} and C_{32} gradually decrease, while the risk values of C_{33} and C_{34} increase. In the stable state, C_{32} and C_{33} pose the highest risks. Hence, it is crucial to prioritize monitoring the risk situation of C_{31} and C_{32} presently, as well as the risk situation of C_{32} and C_{33} in the future. Implementing measures such as standardizing product reviews and strengthening platform supervision will effectively mitigate these risks.

Initially, the criteria C_{41} and C_{44} have a significant impact on C_4. After reaching a stable state through data iteration, the risk value of C_{44} gradually decreases, while the risk values of C_{41}, C_{42}, and C_{43} increase. In the stable state, the risk values of C_{41} and C_{42} are the highest. Therefore, we should focus on the risk situation of C_{41} and C_{44} at present and the risk situation of C_{41} and C_{42} in the future. To mitigate these risks, it is crucial to implement measures such as conducting regular inspections of takeaway merchants, ensuring seamless complaint channels, and imposing stringent penalties on any illicit activities.

4. Conclusions

This paper employs FCM to examine the factors that influence the risks associated with OFDPs. Our analysis highlights two crucial criteria, namely Consumer Activities Risk and Offline Management Risk, which significantly impact OFDP risks. To mitigate these risks, we propose several measures. First, OFDPs should enhance the qualification audit process for both merchants and takeaway riders. Second, stricter supervision of food safety and hygiene should be implemented. Third, the development of a humanized order scheduling algorithm is essential. Additionally, establishing efficient complaint channels and offering preferential activities can contribute to risk reduction. These measures serve a dual purpose: they effectively regulate the behavior of merchants and the delivery process of takeaway riders while simultaneously reducing perceived consumer risk and enhancing customer loyalty.

Acknowledgments

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