Cloud Kitchens and Their Impact on the Restaurant Industry

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Опубліковано	Секція	УДК
30.10.2024	Економіка	338.2:004.8

DOI:https://doi.org/10.5281/zenodo.14650776

Annotation. An analysis of the implementation specifics of the "cloud kitchen" concept as a relevant business model in the restaurant industry, entirely based on food delivery services, has been conducted. This analysis has revealed such advantages of the mentioned concept as reduced production costs, expansion of the customer base, as well as high indicators of organization flexibility and scalability without the need for substantial investments and under conditions of minimal risk during the reorganization of the "cloud kitchen" service. The study included the determination of methods for preparing the general infrastructure for food preparation and the inclusion of food delivery services, as well as the evaluation of quantitative performance indicators, taking into account the working schedules and locations of conventional restaurants that can serve as the basis for the business model. The necessity of forming a methodology for organizing the operation of an information system that manages food preparation and delivery in accordance with changes in target indicators in real-time mode, considering constraints on information channel throughput, computational resources, and the volume of the information repository, has been emphasized. Sets of positions characterizing current trends in the operation of restaurant industry subdivisions organized in accordance with the cloud kitchen business model have been identified, namely: (i) an indicator reflecting how often users turn to online reviews to make decisions about service selection; (ii) an indicator reflecting the software applications customers use to order food online; (iii) a quantitative indicator reflecting ordering food online at discounted prices; (iv) a quantitative indicator reflecting ordering food online according to the chosen brand of food delivery application; (v) a quantitative indicator reflecting ordering food according to the chosen restaurant brand; (vi) a quantitative indicator reflecting the customer's choice of online food delivery application based on online advertising data. Based on quantitative indicators presented in open sources, calculations of such correlation indicators as the Pearson correlation coefficient and the two-tailed p-value of significance were performed, according to which the results of the statistical analysis were interpreted and the level of confidence in the specified results was determined. As a result, methodological recommendations for organizing the effective operation of a cloud kitchen based on statistical analysis of the results of online food delivery services were proposed.

Keywords*:* cloud kitchen, restaurant industry, food delivery service, information system, online applications, Pearson correlation coefficient, two-tailed significance level.

Хмарні кухні та їхній вплив на ресторанну індустрію

Анотація. Проведено аналіз особливостей реалізації концепції «хмарної кухні» як актуальної бізнес-моделі в ресторанному господарстві, повністю заснованої на послугах доставки їжі. Проведений аналіз виявив такі переваги зазначеної концепції, як зниження витрат на виробництво, розширення клієнтської бази, а також високі показники

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гнучкості та масштабованості організації без потреби значних інвестицій та за умов мінімального ризику при реорганізації «хмари». обслуговування кухні. Дослідження включало визначення методів підготовки загальної інфраструктури для приготування їжі та включення служб доставки їжі, а також оцінку кількісних показників ефективності з урахуванням графіків роботи та розташування звичайних ресторанів, які можуть слугувати основою для бізнес-моделі. Обґрунтовано необхідність формування методології організації роботи інформаційної системи управління приготуванням та доставкою їжі відповідно до змін цільових показників у режимі реального часу з урахуванням обмежень на пропускну здатність інформаційного каналу, обчислювальних ресурсів та обсягу інформаційного сховища. , було наголошено. Визначено набори позицій, що характеризують сучасні тенденції функціонування підрозділів ресторанного господарства, організованих за бізнес-моделлю хмарної кухні, а саме: (i) показник, що відображає, як часто користувачі звертаються до онлайн-оглядів для прийняття рішень щодо вибору послуги; (ii) показник, що відображає програми програмного забезпечення, які клієнти використовують для замовлення їжі онлайн; (iii) кількісний показник, що відображає замовлення їжі онлайн за зниженими цінами; (iv) кількісний показник, що відображає онлайн-замовлення їжі відповідно до вибраного бренду програми доставки їжі; (v) кількісний показник, що відображає замовлення страв відповідно до вибраного бренду ресторану; (vi) кількісний показник, що відображає вибір клієнтом програми доставки їжі онлайн на основі даних онлайн-реклами. На основі кількісних показників, наведених у відкритих джерелах, проведено розрахунки таких кореляційних показників, як коефіцієнт кореляції Пірсона та двобічного р-значення значущості, за якими інтерпретовано результати статистичного аналізу та визначено рівень довіри до визначено зазначені результати. У результаті запропоновано методичні рекомендації щодо організації ефективної роботи хмарної кухні на основі статистичного аналізу результатів онлайн-сервісів доставки їжі.

Ключові слова: хмарна кухня, ресторанна індустрія, служба доставки їжі, інформаційна система, онлайн-додатки, коефіцієнт кореляції Пірсона, двосторонній рівень значущості.

Introduction

The emergence and widespread adoption of the "cloud kitchen" (Cloud Kitchen; CK) concept as a business model in the restaurant industry are associated with the growing popularity of food delivery services and the availability of corresponding online platforms, along with the general need to reduce production costs to expand the customer base. According to this concept, the restaurant industry within a CK is organized around food preparation exclusively for delivery to customers, without the need for dining space or guest service staff. Consequently, restaurant operations can be located in the most convenient locations, with delivery services outsourced to third-party providers such as "Bolt Food" or "Glovo" under subcontracting arrangements. This approach offers significant opportunities for increasing the flexibility and scalability of restaurant infrastructure, as well as for implementing experimental approaches without requiring substantial investments and with minimal risk to the industry. This highlights the importance of developing a comprehensive methodology for organizing cloud kitchen services based on a mathematical model and statistical analysis of restaurant industry operations.

As evidenced by scientific research on the implementation of the cloud kitchen concept, there is currently an expansion of the traditional food delivery model through the formation of a unified online platform for corresponding restaurant and food delivery services , regulated by a data processing center presented as a cloud service. The core of the study, therefore, involves determining methods for preparing the general infrastructure for food preparation and integrating food delivery services according to current online platforms, as well as evaluating efficiency metrics that can serve as the basis for optimizing the business model . It is noted that to increase the efficiency of cloud kitchen services, it is necessary to determine the operating hours and locations of traditional restaurants, which handle the primary load during peak hours . This, in turn, necessitates refining effective marketing strategies, including the dissemination of useful information and the implementation of promotional campaigns . While these approaches cover a wide range of tasks to ensure the effective operation of a cloud kitchen, it should be noted that there is still no comprehensive methodology for organizing the information system that manages food preparation and delivery in real-time, considering the constraints on data channel throughput, computational resources, and storage capacity of the corresponding online data processing center platform . This remains an unresolved aspect of the overall research.

Cloud kitchens, also known as virtual kitchens or delivery-only kitchens, are a relatively new phenomenon in the restaurant industry. They do not have physical locations for customer service and focus exclusively on food preparation for delivery. This model has gained significant momentum due to the growing popularity of online food ordering services and changes in consumer habits.

The idea of cloud kitchens arose as a response to the need to optimize costs and increase the efficiency of food delivery. They emerged in large cities with high population density, where real estate is expensive, and the demand for food delivery is constantly growing. Technological innovations such as smart food ordering apps, order management systems, and process automation have contributed to the development of this phenomenon.

Thus, the objective of this study is to develop a comprehensive methodology for organizing the effective operation of a cloud kitchen based on statistical analysis of the performance of online food delivery services and the development of corresponding mathematical models.

1. Problem Statement for the Statistical Analysis of Cloud Kitchen Delivery Service Performance

The core of this research lies in the statistical analysis of the performance of cloud kitchen delivery services. For two sets of positions $A_i:\{a_i^n\}$ and $A_{i'}:\{a_j^n\}$, where $n \in [1; N]$, characterizing current trends in the operation of restaurant industry units organized according to the specified business model, the following correlation indicators are determined: the Pearson Correlation Coefficient (PCC) and the Two-Tailed Significance Level (2TSL), which are mathematically expressed through the functions $\rho_{PCC}(a,b)$ and $p_{2TSL}(a,b)$, respectively. The sets $\{A_i\}$ are formed based on open statistical data derived from anonymous surveys, as presented in relevant professional sources. Correlation indicators are calculated by comparing six positions Zk $A_i:\{a_i^n\}$, where $i \in [1; I]$, formed from the basic sets $A_i^0:\{a_i^k\}$, and $k \in [1; K]$, where $N < K$, excluding data that might indicate outliers. In this study, $K = 150$ and $N = 120$ are calculated for each position $i \in [1; I]$, which, in turn, is defined as $I = 6$ (each position is discussed in detail in the following section).

The calculation of the Pearson Correlation Coefficient allows for determining the degree of linear dependence between two variables of the corresponding sets $A_i:\{a_i^n\}$ and $A_{i'}:\{a_i^n\}$. The value of this statistical indicator is measured within the range $\rho_{PCC}(a,b) \in [-1; 1]$, where $\rho_{PCC}(a,b) \to -1$ indicates an inverse relationship, $\rho_{PCC}(a,b) \to 0$ indicates no relationship, and $\rho_{PCC}(a,b) \to 1$ indicates a direct relationship. Within the research framework, the Pearson Correlation Coefficient is characterized by its simplicity in interpreting the results of statistical analysis concerning the direction and strength of the relationship between variables. This provides an opportunity to offer methodological recommendations based on incomplete data sets, which leads to its widespread use in scientific research, particularly in the field of business analytics. Meanwhile, the Two-Tailed Significance Level indicates the probability that the observed correlation between two variables is random. The smaller the value of $p_{2TSL}(a, b)$, the higher the confidence that the observed correlation is not random.

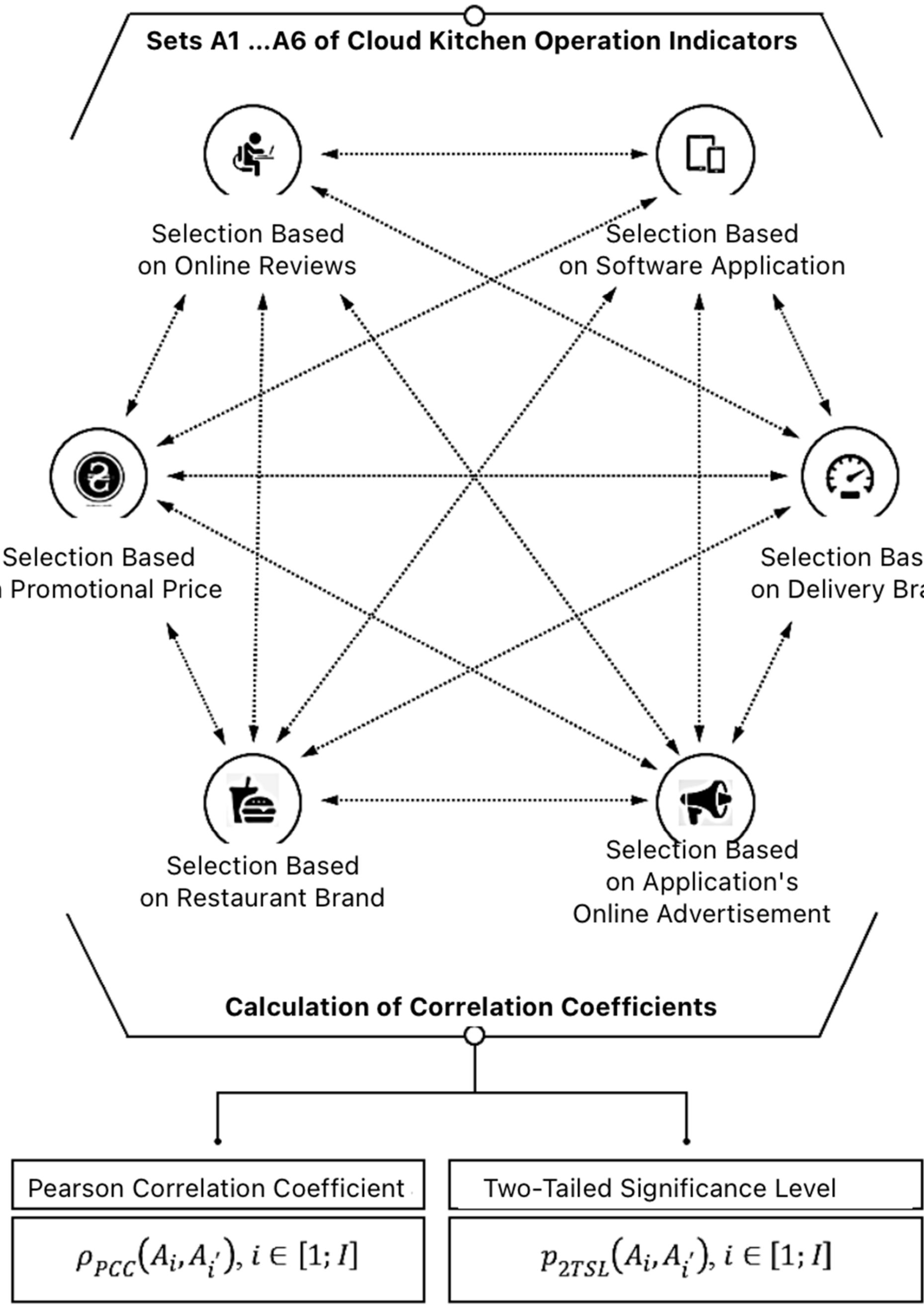

Figure 1. Diagram of Business Analytics for Cloud Kitchen Services Based on Correlation Coefficients

This approach allows for decisions regarding the acceptance of the null hypothesis about the absence of correlation and, thus, helps determine whether the Pearson correlation coefficient results are statistically significant at the level of relevant business analytics.

The set of data between which the correlation is determined includes the following positions (see Figure 1):

A_1: A quantitative indicator showing how often users refer to online reviews when making a decision about service selection (Online Reviews Refer; ORR);

A_2: A quantitative indicator showing the software applications clients use to order food online (Cloud Kitchen Applications; CKA);

A_3: A quantitative indicator showing food orders placed online at promotional prices (Ordering Promotional Food; OPF);

A_4: A quantitative indicator showing food orders placed according to the client-selected online delivery brand (Application Brand Order; ABO);

A_5: A quantitative indicator showing food orders placed according to the client-selected restaurant brand (Restaurant Brand Order; RBO);

A_6: A quantitative indicator showing the client's selection of a food delivery application based on online advertising (Web Ads Application; WAA).

Thus, the study is based on determining the correlation coefficients ρ_{PCC} and p_{2TSL} for the complete set of pairs $(A_i, A_{i'})$, where $i \neq i'$.

2. Calculation of Correlation Coefficients within the Framework of Business Analytics for Cloud Kitchen Online Services

In the first stage of the study, it is proposed to calculate the correlation coefficients ρ_{PCC} and p_{2TSL} for all possible pairs of quantitative indicators A_1, which indicate the influence of online reviews when making service selection decisions for a specific "cloud kitchen" service.

Table 1

Results of the Calculation of Correlation Coefficients for the Set of Indicators A_1

		CKA	OPF	ABO	RBO	WAA
ORR	ρ_{PCC}	– 0,01	– 0,02	– 0,65	0,11	0,69
	p_{2TSL}	0,93	0,79	0	0,22	0

Table 1 denotes the relevant indicator as ORR, with the other indicators being CKA, OPF, ABO, RBO, and WAA. The results of the statistical analysis indicate an inverse relationship between the ORR indicator and the ABO indicator, and a direct relationship between the ORR indicator and the WAA indicator, according to Pearson's correlation coefficient with the highest statistical confidence based on the two-tailed significance level. On the level of formulating methodological recommendations, it can be noted that:

Online reviews for making decisions about selecting a "cloud kitchen" service significantly impact the disruption of user loyalty to well-known brands.

The influence of online reviews in making decisions about selecting a "cloud kitchen" service can be enhanced through the establishment of online advertising.

Table 2

Results of the correlation coefficient calculation for the set of indicators A_2

		ORR	OPF	ABO	RBO	WAA
CKA	ρ_{PCC}	– 0,01	0,08	0,1	0,01	0,9
	p_{2TSL}	0,93	0,39	0,29	0,89	0,33

In the second stage, the corresponding procedure is conducted for the indicator that denotes the software applications users employ to order relevant services (CKA indicator). The results of the statistical analysis (Table 2) indicate a direct relationship between the CKA indicator and the WAA indicator according to Pearson's correlation coefficient, suggesting the influence of advertising on the choice of software application. However, it is worth noting a low level of confidence based on the two-tailed significance level, meaning that the aforementioned conclusion requires additional validation at the expert assessment level.

Table 3

Results of the correlation coefficient calculation for the set of indicators A_3

		ORR	CKA	ABO	RBO	WAA
OPF	ρ_{PCC}	– 0,02	0,08	– 0,3	0,04	0,28
	p_{2TSL}	0,8	0,39	0,001	0,68	0,002

In the third stage, the corresponding procedure is conducted for the indicator that denotes the increase in online food orders at discounted promotional prices (OPF indicator). Unfortunately, for all categories, the Pearson correlation coefficient is relatively low (Table 3), making it impossible to formulate methodological recommendations.

Table 4

Results of the correlation coefficient calculation for the set of indicators A_4

		ORR	CKA	OPF	RBO	WAA
ABO	ρ_{PCC}	– 0,65	– 0,1	– 0,3	– 0,04	– 0,9
	p_{2TSL}	0	0,29	0	0,65	0

In the fourth stage, the corresponding procedure is conducted for the indicator that denotes food orders according to the brand of online delivery chosen by the client (ABO indicator). The results of the statistical analysis indicate an inverse relationship between the ABO indicator and the ORR indicator, as well as with the WAA indicator according to Pearson's correlation coefficient with the highest statistical confidence based on the two-tailed significance level (Table 4). The high level of inverse correlation $\rho_{PCC}(A_1; A_4) = -0,65$ was discussed earlier, while the value $\rho_{PCC}(A_1; A_4) = -0,9$ indicates that online advertising, with each additional hryvnia invested in the advertising budget, increases the number of sales through any cloud kitchen, any brand, or any cuisine (specifically the dishes), algebraically, as it were, "grows," and this is relevant to the cloud kitchens of restaurants.

Table 5

Results of the correlation coefficient calculation for the set of indicators A_5

		ORR	CKA	OPF	ABO	WAA
RBO	ρ_{PCC}	0,11	0,01	– 0,04	– 0.04	0,06
	p_{2TSL}	0,22	0,9	0,68	0,65	0,5

In the fifth stage, the corresponding procedure is conducted for the indicator that denotes food orders according to the brand of the restaurant chosen by the client (RBO indicator). Unfortunately, for all categories, the Pearson correlation coefficient is relatively low (Table 5), making it impossible to formulate methodological recommendations.

Thus, the statistical analysis highlighted the promotion of one's own food delivery brand through the establishment of a system for distributing online reviews and advertising software applications, based on which cloud kitchen services are implemented.

The prospects for the development of cloud kitchens look promising. Technological innovations, such as food delivery drones and robot chefs, may further enhance the efficiency and convenience of cloud kitchens. The growing popularity of healthy eating and eco-friendly products also opens up new opportunities for the development of this market segment.

Cloud kitchens are an important innovation in the restaurant industry, significantly impacting business models and consumer habits. They offer economic advantages and new opportunities for development but also face several challenges. The future of cloud kitchens looks promising, and their continued development will significantly influence the restaurant business.

In 2024, cloud kitchens remain one of the most discussed and significant trends in the restaurant industry. The COVID-19 pandemic has significantly altered consumer habits, pushing most people to use online food ordering services. This change remains relevant in 2024, as many consumers continue to prefer the convenience and speed of food delivery to their homes or offices.

The relevance of cloud kitchens in 2024 is driven by their ability to adapt to modern market demands and consumer needs. They continue to revolutionize the restaurant industry by offering economically efficient and technologically advanced food delivery solutions. Their impact on the industry will continue to grow, as they provide new opportunities for business development and meeting the needs of modern consumers.

Conclusions

As a result of the conducted research, the features of organizing the efficient operation of a "cloud kitchen" based on statistical analysis of the performance of online food delivery services were analyzed.

In the course of the study, the following were conducted:

The identification of sets of positions that characterize current trends in the operation of restaurant divisions organized according to the cloud kitchen business model

The calculation of such correlation indicators as Pearson's correlation coefficient and the two-tailed significance level, based on which the results of the statistical analysis were interpreted and the level of confidence in the given results was determined.

The statistical analysis provided an opportunity to formulate methodological recommendations for promoting new cloud kitchen services.

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