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INDUSTRY 4.0 AND DIGITALIZATION APPLICATIONS IN THE RESTAURANT SECTOR: CONCEPTUAL FRAMEWORK AND FUTURE TRENDS

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Formulation of the problem. This article systematically examines the theoretical foundations, technological components, and application possibilities of Industry 4.0 and digitalization processes in the restaurant sector. *The purpose of the study* is to evaluate, from a conceptual perspective, the impact of these technologies on operational efficiency, service quality, and strategic management in restaurant businesses. *The object of the study* is the organizational, methodological and technological aspects of strengthening internal control systems through the implementation of modern digital technologies and innovative monitoring tools. *Research methods.* Using a descriptive-analytical methodology based on secondary data, regulatory documents, corporate reports, and international assessments, the paper evaluates the extent to which digitalization, automation, data analytics, and continuous control mechanisms have strengthened internal control effectiveness. *The main hypothesis.* It is particularly emphasized that digitalization in the restaurant sector means not only technical renewal, but also a change in the management model, customer relations, and value-creation mechanisms. *Present of the main material.* The analyses show that, in the local higher education environment, the level of digitalization of management and financial models is unevenly distributed, which leads to inefficient allocation of administrative resources, weaker control over teaching quality, and serious financial risks. In particular, financial risks arising from disruptions in system operation have a direct negative impact on universities' budget planning and investment attractiveness. *Originality and practical significance.* The research evaluates the customer service system based on three main stages pre-flight, in-flight, and post-flight processes using system indicators that reflect the degree of customer behavior change. The findings demonstrate that variations in service quality influence not only immediate satisfaction levels, but also passenger flow, repeat travel share, company profitability, and CLV as strategic indicators. *Conclusions and prospects for further research.* The study found that the application of digital technologies, electronic management platforms, and predictive analytics tools makes it possible to minimize administrative costs, optimize resources, and ensure the accessibility of educational services.

Keywords:

restaurant sector, digitalization, industry 4.0, operational efficiency, SWOT analysis.

ІНДУСТРІЯ 4.0 ТА ЗАСТОСУВАННЯ ЦИФРОВІЗАЦІЇ В РЕСТОРАННОМУ СЕКТОРІ: КОНЦЕПТУАЛЬНІ ОСНОВИ ТА МАЙБУТНІ ТЕНДЕНЦІЇ

Постановка проблеми. У цій статті систематично розглядаються теоретичні основи, технологічні компоненти та можливості застосування процесів Індустрії 4.0 та цифровізації в ресторанному секторі. *Метою дослідження* є оцінка з концептуальної точки зору впливу цих технологій на

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операційну ефективність, якість обслуговування та стратегічне управління в ресторанному бізнесі. *Об'єктом дослідження* є організаційні, методологічні та технологічні аспекти посилення систем внутрішнього контролю шляхом впровадження сучасних цифрових технологій та інноваційних інструментів моніторингу. *Методи дослідження*. Використовуючи описово-аналітичну методологію, що базується на вторинних даних, нормативних документах, корпоративних звітах та міжнародних оцінках, у статті оцінюється ступінь, до якої цифровізація, автоматизація, аналітика даних та механізми безперервного контролю посилили ефективність внутрішнього контролю. *Основна гіпотеза*. Особливо підкреслюється, що цифровізація в ресторанному секторі означає не лише технічне оновлення, але й зміну моделі управління, відносин з клієнтами та механізмів створення цінності. *Виклад основного матеріалу*. Аналіз показує, що в вітчизняному середовищі вищої освіти рівень цифровізації управлінських та фінансових моделей розподілений нерівномірно, що призводить до неефективного розподілу адміністративних ресурсів, послаблення контролю за якістю викладання та серйозних фінансових ризиків. Зокрема, фінансові ризики, що виникають через перебої в роботі системи, мають прямий негативний вплив на бюджетне планування та інвестиційну привабливість університетів. *Оригінальність та практична значущість*. Дослідження оцінює систему обслуговування клієнтів на основі трьох основних етапів: передпольотного, під час польоту та післяпольотного процесів, використовуючи системні показники, що відображають ступінь зміни поведінки клієнтів. Результати дослідження демонструють, що варіації в якості обслуговування впливають не лише на рівень негайного задоволення, але й на пасажиропотік, частку повторних поїздок, прибутковість компанії та CLV як стратегічні показники. *Висновки та перспективи подальших досліджень*. Дослідження показало, що застосування цифрових технологій, електронних платформ управління та інструментів прогнозу аналітики дозволяє мінімізувати адміністративні витрати, оптимізувати ресурси та забезпечити доступність освітніх послуг.

Ключові слова:

ресторанний сектор, цифровізація, Індустрія 4.0, операційна ефективність, SWOT-аналіз.

Formulation of the problem. The Fourth Industrial Revolution, Industry 4.0, refers to a profound transformation process encompassing all sectors of the economy. Formed on the basis of the integration of cyber-physical systems, the Internet of Things (IoT), artificial intelligence, big data, and cloud computing, this concept was initially aimed at modernizing the manufacturing sector, but over time it has rapidly spread to service industries, including hospitality and restaurant businesses. In a context where the global food and beverage services market is projected to grow from 2.52 trillion dollars in 2021 to 4.43 trillion dollars by 2028, the strategic importance of digital transformation in this sector has increased even further.

The restaurant sector is, by its nature, a dynamic field facing structural problems such as labour-intensive operational structures, high personnel costs, food waste risk, and the stabilization of service quality. These challenges make the application of Industry 4.0 technologies in this field both necessary and promising. IoT-based smart kitchen systems, AI-powered recommendation algorithms, robotics, blockchain-based supply chain management, and cloud computing platforms are no longer merely theoretical possibilities; they are becoming the reality of modern restaurant business.

The purpose of this article is to systematically examine the theoretical foundations and applied directions of the Industry 4.0 concept in the restaurant sector, to analyze the digital ecosystem framework, and to identify the advantages, challenges, and future development directions brought by these technologies to the sector. The study is based on literature review, conceptual modelling, and SWOT analysis methods. The findings are expected to contribute to the formation of digital strategies for restaurant enterprises, both academically and practically.

Analysis of recent research and publications. The study aims to analyze the structure of customer service in passenger air transportation, identify the dynamics of service quality indicators, and evaluate the economic mechanisms influencing airlines' performance. The research covers 2019–2025 and explores global and regional aviation sector trends, customer behavior models, service system dynamics, and pre-pandemic, pandemic, and post-pandemic operational features. These changes made it possible to consistently analyze the logical relationships between service quality and service transformation processes.

A comprehensive database was used for the research. A significant portion of the information was obtained from ICAO, IATA, and

ACI annual performance reports, as well as from official data published by Heydar Aliyev International Airport, the Azerbaijan State Statistics Committee, and national aviation service reports. Additionally, relevant scientific articles measuring service quality using the SERVQUAL and CASQI models, publications on digital customer experience, and studies on CLV-oriented economic approaches were included from Scopus and Web of Science databases.

Information from regional airlines’ annual reports, airport service quality assessments, and digital service usage at airports enriched the database, enabling a detailed examination of customer experience from functional, emotional, and operational perspectives.

To assess the level of customer service, the following indicators were selected:

OTP (On-Time Performance) – the percentage of flights operated on time

NPS (Net Promoter Score) – customer loyalty index;

CSI (Customer Satisfaction Index) – overall customer satisfaction level;

CASQI-L (Airport Service Quality Index-Landside) – landside service quality indicator;

CLV (Customer Lifetime Value) – the total value a customer brings to a company over their lifetime;

CRM (Customer Relationship Management) – management of customer interactions;

Complaint response time – the time required to respond to customer complaints.

The purpose of the study is to evaluate, from a conceptual perspective, the impact of these technologies on operational efficiency, service quality, and strategic management in restaurant businesses. It is particularly emphasized that digitalization in the restaurant sector means not only technical renewal, but also a change in the management model, customer relations, and value-creation mechanisms.

Presentation of the main research material. Industry 4.0, as the fourth stage of industrial development, refers to the integration of physical systems with digital technologies, data-driven decision-making, and a high level of automation [12, p. 4]. This approach shows that the main distinguishing feature of modern economic systems is not only technological renewal, but also the transition of processes into an interconnected and real-time managed form.

This concept is based on the operation of cyber-physical systems, the Internet of Things, big data, artificial intelligence, and cloud compu-

ting within a unified framework . It is therefore clear that the core of Industry 4.0 is the minimization of the distance between data collection and decision-making.

In the theoretical basis of Industry 4.0, the concepts of “smart manufacturing” and “smart service” occupy an important place [11, p. 510]. This approach is also significant for the restaurant sector, because service efficiency here depends not only on human labour but also on the proper management of information.

Research shows that Industry 4.0 has become not only a transformation concept for manufacturing, but also for service and management sectors [8, p. 3]. This means that digitalization in the restaurant business is not an isolated technological innovation, but part of broader structural change.

The logic of platform economy and ecosystem thinking is also one of the important directions of Industry 4.0 theory [9, p. 180]. This approach shows that enterprises are increasingly moving away from closed business models and creating value through interaction with partners, customers, suppliers, and technology providers.

Approaches related to digital service innovation show that technology enables enterprises not only to improve internal processes, but also to create new service value [10, p. 287]. This confirms that digitalization in the restaurant sector is directly connected to the customer experience.

Examples of Industry 4.0 implementation in enterprises show that, in addition to the technology itself, the form of implementation also has a significant effect on outcomes . This indicates that technology in the restaurant field should be applied not randomly, but purposefully and in stages.

Modern research agendas also give special attention to human-machine interaction, collaborative robots, and decision-support systems [20, p. 326]. It becomes clear that the restaurant model of the future does not eliminate human labour; rather, it complements it with more analytical and supervisory functions.

Systematic literature reviews on Industry 4.0 also emphasize that risks and challenges are part of the theoretical framework [17, p. 1116]. For this reason, successful technology implementation requires not only equipment and software, but also management culture, adaptability, and human capital.

2. Industry 4.0 technologies: IoT, AI, big data, and cloud computing





The main pillars of Industry 4.0 technologies in the restaurant sector are concentrated in the areas of the Internet of Things, artificial intelligence, big data, and cloud computing [1, p. 6]. This shows that the effectiveness of digital transformation depends not on individual tools, but on their integration.

AI-supported IoT systems make it possible in the restaurant environment not only to collect

data from sensors, but also to analyze it and convert it into practical decisions. This means that the smart restaurant model is based not on passive control, but on active management.

The interaction mechanism of Industry 4.0 technologies in the restaurant sector is shown in Figure 1.

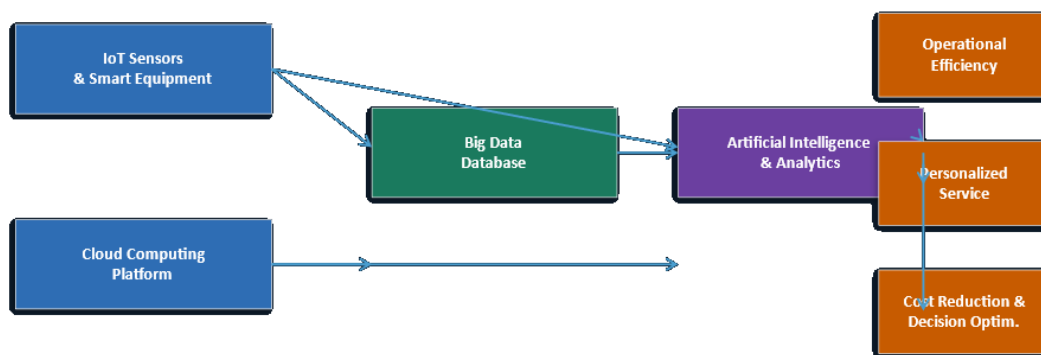


Figure 1 – Interaction mechanism of Industry 4.0 technologies in the restaurant sector
Source: compiled by the authors

Figure 1 conceptually groups the integration of Industry 4.0 technologies in the restaurant sector and their interaction mechanism into four main layers. The IoT sensors, smart devices, and cloud computing platforms acting as the input and infrastructure layer create the fundamental basis for collecting and storing initial data in the restaurant environment. The continuous flow of information from this infrastructure is structured in the data layer, namely in the big data repository, and processed in the analytics layer through artificial intelligence tools. At the end of the technological chain, in the output and outcomes layer, three important strategic advantages for the restaurant business are ensured: operational efficiency, personalized service, and cost reduction and decision optimization. The practical realization of this interaction mechanism depends directly on the implementation of concrete digital solutions that affect customer satisfaction and daily management.

Research in the field of electronic restaurant technologies shows that digital menus, online ordering systems, and smart reservation tools are becoming an integral part of modern restaurant management [3, p. 249]. This indicates that the service model of the sector is increasingly built through digital interfaces.

Analyses of digital transformation in hospitality and tourism show that IoT and mobile

systems increase operational efficiency while also increasing the number of customer contact points [4, p. 7]. Thus, technology strengthens both internal management and external service quality.

Studies on digital supply chain transformation in the food sector show that traceability, transparency, and supply coordination are made more flexible precisely through these technologies. This confirms that technology in the restaurant business is important not only in the service area but also in back-office operations.

Research on the role of artificial intelligence in hospitality notes that AI increases both customer satisfaction and operational flexibility through personalized recommendation systems, chatbots, and demand forecasting [13, p. 1308]. This shows that artificial intelligence is not merely a technical tool in the restaurant sector, but also a strategic decision-making mechanism.

Research trends in digital transformation in the service sector show that big data analytics makes services more measurable and predictable. This emphasizes the importance of basing decision-making in restaurant business on data rather than on experience alone.

Digital transformation models in food supply chains show that cloud-based platforms play an important infrastructural role in centralizing and rapidly sharing data. This creates a

particular strategic advantage for multi-branch and dynamic restaurant chains.

3. Digital ecosystem in services: general framework and trends. As a result of digital transformation in the service sector, enterprises are increasingly beginning to operate according to ecosystem logic . This shows that the value of a restaurant enterprise is no longer formed only within itself, but also depends on the digital environment to which it is connected.

Systematic research on digital servitization shows that ecosystem transformation accelerates the shift of service enterprises toward a platform-based collaboration model [9, p. 184]. This explains the growing role of partner networks, delivery platforms, and payment systems in restaurant business.

Contemporary approaches to service-oriented digital innovation emphasize that platformization makes the customer experience more flexible and interconnected [10, p. 291]. Thus, for the restaurant sector, the digital ecosystem is not merely a technical connection, but a unified service experience delivered to the customer.

Bibliometric analyses in the hospitality industry show that the main trends of digital transformation are platform expansion, personalized service, and a multichannel communication model . This explains why mobile ordering, online reservation, and digital loyalty solutions are spreading so rapidly in the restaurant sector.

The general model of the digital ecosystem in the restaurant sector is shown in Figure 2 below.

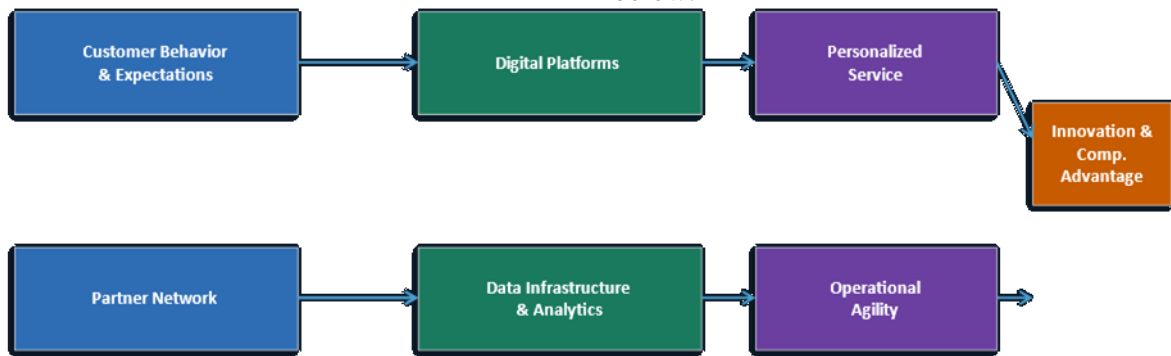


Figure 2 – General model of the digital ecosystem in the restaurant sector. Prepared by the authors
Source: compiled by the authors

The presented Figure reflects the general model of the digital ecosystem in the service sector and the mechanism of interaction among the structural elements of this system. The model consists of four main stages: input factors, platform and infrastructure, output values, and final competitive outcome. In the initial stage, customer behavior, expectations, and the partner network act as input factors, stimulating the formation of digital platforms as well as data infrastructure and analytics. This technological base, in turn, enables personalized services and operational flexibility as output values, resulting in business innovation and strategic competitive advantage. This interaction mechanism of Industry 4.0 technologies in the restaurant sector not only increases enterprise efficiency, but also makes the application of new approaches to management necessary.

Although these advantages raise service quality to a new level, the new challenges and risk factors brought by technological transformation should not be overlooked.

Approaches related to Industry 4.0 development in hotel and restaurant business show that digital solutions intensify customer relations while also creating new dependency and security risks [21, p. 5]. In this respect, technological transition must be accompanied by management responsibility.

4. Industry 4.0 applications in the restaurant sector. Recent studies show that the application of Industry 4.0 and 5.0 technologies in the hospitality and gastronomy industry is characterized by smart kitchens, automated processes, personalized service, and sustainability-oriented solutions. This shows that the restaurant sector is no longer merely digitalizing, but is also approaching a human-centered phase of technological transformation.

Research on Industry 4.0 applications in the food industry shows that sensor-based monitoring systems create significant efficiency in monitoring temperature, reducing waste, and accurately managing inventory [16, p. 7]. This



confirms that technology provides measurable economic benefits in restaurant operations.

5. Strategic effects of digitalization and the SWOT approach. The general map of digital transformation in the hospitality industry shows that digital strategies have now become a core

tool for market position, customer relations, and operational flexibility. This indicates that technology in restaurant business is not an extra advantage, but a condition of competition.

The SWOT analysis of digitalization in the restaurant sector is shown in Figure 3 below.



Figure 3 – SWOT analysis of digitalization in the restaurant sector

Source: compiled by the authors

Figure 3 presents a large-scale SWOT analysis aimed at evaluating the internal and external environmental factors of the digitalization process in the restaurant sector. In the strengths (S) block, internal advantages such as reduced operational costs, minimized food waste, real-time inventory tracking, and personalized customer service are highlighted. However, in the weaknesses (W) section, internal limitations such as high initial investment costs, lack of qualified personnel, and cybersecurity vulnerabilities are noted. In the external environment context, digitalization offers restaurants competitive advantage, blockchain-based transparent supply chains, and AI-based demand forecasting as new opportunities (O), while also exposing them to serious threats (T), such as rapid technological obsolescence, privacy requirements, and financial risks caused by system disruptions. This strategic picture proves that to benefit fully from digitalization, its internal strengths must be transformed directly into consumer behavior and service quality.

Research on digitalization in hospitality and tourism shows that mobile ordering, online reservation, and digital payment systems change the customer experience while accelerating decision-making processes [4, p. 11]. This indicates

that digital tools affect both market behavior and internal management at the same time.

Studies on the forms of applying digital technologies in production and service processes show that, for successful transformation, the sequence of implementation is as important as the technological choice itself. The conclusion is that SWOT analysis is useful not only for assessing the current situation, but also for determining implementation priorities.

Conclusion and prospects for further research. As a result of the analysis, Industry 4.0 technologies for the restaurant sector represent not merely a technological innovation tool, but also the foundation of a fundamental business model transformation. The synchronized application of technologies such as IoT, artificial intelligence, big data, cloud computing, robotics, and blockchain increases operational efficiency, deepens customer satisfaction, strengthens food safety, and ensures the sustainability of competitive advantage.

Based on the literature review and conceptual analysis, several important conclusions have been reached. First, within the logic of the digital ecosystem of Industry 4.0, restaurant enterprises are moving away from a monolithic operating model toward a platform-oriented, data-driven, and network-based management model. Second,



the integration of IoT, artificial intelligence, big data, and cloud computing transforms reactive management into proactive decision-making. Instead of intervening after a problem arises, the system diagnoses the problem in advance and offers a solution. Third, in a digital ecosystem, value is created not only through the enterprise's internal resources, but through the interaction of platforms, partner networks, data flows, and customer behavior. Fourth, the SWOT analysis shows that although the benefits of digital transformation are clear, high initial investment requirements, lack of qualified staff, cybersecurity risks, and institutional resistance are the main barriers to this transformation in the sector.

It is recommended that restaurant enterprises implement digital transformation within a unified strategy, in a phased and prioritized sequence. Before technology adoption, it is necessary to assess the digital readiness of existing operational processes — that is, a digital maturity audit should be the essential first step. In this phase, technologies with the highest return potential should be prioritized, including IoT-based inventory management, AI-supported demand forecasting, and cloud-based operational integration.

Investment in human resources is an integral part of this process. If technology adoption is not carried out in parallel with the development of employees' digital skills, the full potential of the system cannot be realized. In this regard, in-house training programs, joint skill-development initiatives with technology partners, and the formation of a digital culture at all management levels are among the key priorities.

To preserve customer trust, special attention should be paid to data privacy. Ensuring the principle of transparency in the collection, processing, and use of customer behavior data guarantees both legal compliance and long-term brand reputation. The application of blockchain-based supply chain traceability also strengthens compliance with food safety standards and corporate accountability to customers.

From a theoretical perspective, this study is based on literature review and conceptual modelling. Future research should place particular emphasis on empirical studies measuring, through quantitative methods, the actual level of application of Industry 4.0 technologies in the restaurant sector in Azerbaijan. In addition, comparative studies examining the application possibilities of the Industry 5.0 concept – the human-centered automation paradigm – in the

restaurant sector may also be considered a promising direction.

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