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CONCEPTUAL MODEL OF STATE DIGITAL TRACEABILITY IN THE FOOD INDUSTRY IN THE CONTEXT OF ELECTRONIC AND QUICK COMMERCE DEVELOPMENT UKRAINE

Within the framework of the conducted study, the digital transformation processes in the food industry, driven by the rapid development of electronic and quick commerce, were comprehensively analyzed. Based on this analysis, a holistic conceptual model of state digital traceability was developed capable of replacing fragmented regulatory approaches with algorithmic governance logic. The key structural elements of the digital regulatory architecture were systematized, and the unified model «Trek.Food Government» was presented as a central institutional platform that integrates the functions of registration, digital authorization, control, accounting, and incident response. A four-block functional structure of the system was outlined, ensuring end-to-end digital verification of market participants, logistics chains, and product batches, while implementing a new paradigm of behavioral state oversight, where the reputational weight of an actor acquires legally relevant significance. The analytical foundations for transitioning from traditional inspection-based regulation to a risk-oriented model were revealed, wherein automated digital decisions are made based on algorithmically validated deviations recorded at the level of a participant's digital profile, QR-batch, or critical supply chain event. The methodological understanding of state regulatory presence was expanded from a controlling body to an adaptive digital ecosystem that performs profiling, verification, and real-time response based on data integrated with the services «Diia.Business», «Diia.Inspector» and «Diia.Signature». An institutional interaction contour between business, the state, and the consumer was presented, grounded not in formal control, but in digital accountability and transparency through blockchain identification technologies, QR labeling, RFID tracking, smart contracts, and dynamic batch-level digital passports. Institutional and regulatory-technical barriers to system implementation were analyzed, including the legal codification of digital artifacts, interoperability of data formats, and the necessity of deploying a national IoT infrastructure in the food logistics sector. It was substantiated that the proposed model provides the foundation for transitioning from vertically centralized state control to a polycentric, networked, and digitally algorithmized governance system, capable of ensuring not only effective oversight but also fostering trust, safety, and sustainable development of Ukraine's digital food economy.

Key words: digitalization, traceability, food industry, government regulation, e-commerce, fast commerce, QR, RFID, SMART contracts, IoT.

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КОНЦЕПТУАЛЬНА МОДЕЛЬ ДЕРЖАВНОЇ ЦИФРОВОЇ ПРОСТЕЖУВАНОСТІ У ХАРЧОВІЙ ПРОМИСЛОВОСТІ В КОНТЕКСТІ РОЗВИТКУ ЕЛЕКТРОННОЇ ТА ШВИДКОЇ КОМЕРЦІЇ УКРАЇНИ

У межах проведеного дослідження всебічно проаналізовано цифрові трансформаційні процеси у сфері харчової промисловості, зумовлені стрімким розвитком електронної та швидкої комерції, на основі чого сформовано цілісну концептуальну модель державної цифрової простежуваності, здатну замістити фрагментарні регуляторні підходи логікою алгоритмічного управління. Систематизовано ключові структурні елементи цифрової регуляторної архітектури та представлено уніфіковану модель «Трек.Food Government» як центральну інституційну платформу, що об'єднує функції реєстрації, цифрової авторизації, контролю, обліку та інцидентного реагування. Виокремлено чотириблочну функціональну конструкцію системи, яка забезпечує наскрізну цифрову верифікацію суб'єктів ринку, логістичних каналів і партій продукції та реалізує нову парадигму поведінкового державного нагляду, де репутаційна вага суб'єкта набуває юридично релевантного значення. Розкрито аналітичні засади переходу від традиційного інспекційного регулювання до ризик-орієнтованої моделі, в якій автоматизовані цифрові рішення приймаються на підставі алгоритмічно підтверджених відхилень,

зафіксованих на рівні цифрового профілю учасника, QR-партії або критичної події в ланцюгу постачання. Розширено методологічне уявлення про державну регуляторну присутність від органу-контролера до адаптивної цифрової екосистеми, яка здійснює профілювання, верифікацію та реагування в реальному часі на основі даних, інтегрованих із сервісами «Дія.Бізнес», «Дія.Інспектор» та «Дія.Підпис». Представлено інституційний контур взаємодії між бізнесом, державою та споживачем, в основі якого лежить не формальний контроль, а цифрова відповідальність і прозорість через технології блокчейн-ідентифікації, QR-маркування, RFID-трекінгу, SMART-контрактів та партійного динамічного цифрового паспорту. Проаналізовано інституційні та нормативно-технічні бар'єри впровадження системи, зокрема юридичну кодифікацію цифрових артефактів, інтероперабельність форматів даних та необхідність запуску національної IoT-інфраструктури у сфері харчової логістики. Обґрунтовано, що запропонована модель створює підґрунтя для переходу від вертикально централізованого державного контролю до поліцентричного, мережевого й цифрово-алгоритмізованого управління, здатного забезпечити не лише ефективність нагляду, а й умови для довіри, безпеки та сталого розвитку цифрової харчової галузі України.

Ключові слова: цифровізація, простежуваність, харчова галузь, державне регулювання, електронна комерція, швидка комерція, QR, RFID, SMART-контракти, IoT.

Formulation of the problem

In the current context of food market transformation driven by the rapid development of electronic and fast commerce, the issue of ensuring digital traceability in the food industry is gaining strategic importance both for state regulation and for guaranteeing the safety and quality of food products. The shift in consumer behavior toward online sales channels, the emergence of hybrid logistics models, and the growing volume of cross-border trade are creating new challenges for systems of identification, control, and verification of product origin at every stage of its movement. In this context, digital traceability can no longer be viewed solely as an intra-industry or technical mechanism, as it requires a systematic rethinking through the lens of integration with e-commerce platforms, national registries, logistics providers, and state control authorities. International practice demonstrates that effective traceability systems (such as in the EU and South Korea) not only ensure supply chain transparency but also increase trust in domestic producers, promote exports, and strengthen food security. However, in Ukraine, such a model is still in a fragmented implementation stage, which necessitates the development of a comprehensive conceptual architecture for digital traceability capable of uniting governmental, business, and technological interests within the framework of the digital economy.

Analysis of recent achievements and publications

In the context of modern research on digital traceability in the supply chains of the food industry, the presented conceptual model of state digital traceability in the food industry of Ukraine stands out as an innovative study that, for the first time, proposes a holistic architecture of digital state regulation in the rapidly developing sphere of electronic and fast commerce. In contrast to existing academic works, which are mainly focused on the technological aspects of individual solutions (Blockchain, RFID, IoT, etc.) or are limited to empirical cases of implementing specific digital tools in production processes, this model integrates the functionality of digital public administration, algorithmic oversight, legally significant digital reputation, and institutional interaction between business, consumer, and the state through a unified integration platform «Trek.Food Government». The analysis of modern publications, particularly the works of Ellahi, Reddy, Charlebois, Lukacs, Verna, Corallo, Mishra, and others, demonstrates scientific interest in the digitalization of food supply chains, but also outlines the limitations of existing approaches in several directions. For example, the study by Ellahi R.M., Wood L.C., Bekhit A.E. [1] provides a systematic review of blockchain solutions in food chains, identifying transparency, safety, and traceability as the main directions, but remains within the technological discourse, not addressing issues of public administration or regulatory implementation. The work of Reddy P., Kurnia S., Tortorella G.L. [2] proposes a five-dimensional model of digital traceability (DFSCT), but does not consider state involvement or integration into national information systems. The comparative study by Charlebois S., Latif N., Ilahi I., Sarker B., Music J., Vezeau J. [3] covers the experience of OECD countries in the field of digital traceability, focusing on regulatory and legal differences, but lacks the component of centralized institutional management or platform-based digital oversight. The work of Lukacs M., Toth F., Horvath R., Solymos G., Alpár B., Varga P., Kertesz I., Gillay Z., Baranyai L., Felfoldi J., et al. [4] demonstrates the possibilities of combining NIRS, IoT, RFID, and blockchain through a specific product case, but is limited to the production point in the chain and does not include comprehensive state interaction or algorithmization of inspection functions. Similarly, the study by Verna E., Genta G., Galetto M. [5] focuses on improving the quality of traceability in the food industry, but points to fragmented implementation of digital tools and cultural unpreparedness for their full-scale application. The work of Corallo A., Paiano R., Guido A.L., et al. [6] presents an IoT framework for transparency in the agri-food chain, but is more of an engineering proposal than a conceptual vision of digital state regulation. The work of Mishra N., Mistry S., Choudhary S., et al. [7] offers blockchain-based solutions in response to food scandals in India, focusing on the technical implementation of QR-codes and decentralized ledgers, but lacks a systematic analysis of regulatory integration or adaptive oversight. Thus, all the analyzed studies form a valuable basis for understanding the technical potential of digital technologies in the field of traceability, but do not go beyond the technological or applied

level. In this context, the proposed conceptual model is the first attempt to create an algorithmized, digitally institutionalized system of state governance that considers the full cycle of digital verification of entities, products, and logistics channels in real time, relying on reputation mechanisms, platform-based interaction, and integration with national services «Diia.Business», «Diia.Inspector», «Diia.Sign». At the same time, this model takes into account the barriers to implementation, including the codification of digital artifacts, the need for a national IoT infrastructure, and the interoperability of digital formats. Therefore, the absence of similar comprehensive solutions in other academic works indicates that this development opens a new paradigm of state presence from a supervisory body to an adaptive digital ecosystem focused on transparency, trust, sustainable development, and effective risk management in the food industry.

Purpose is article

Develop of an architectural conceptual model of digital traceability in the food industry, which integrates state registries, digital e-commerce platforms, logistics systems, and business infrastructure.

Presentation of the main material

For the seamless integration of digital tools and mechanisms (SAP, MES, TMS, POS systems, QR-codes [8], RFID tags [9], Blockchain [10], SMART contracts [10], laboratory systems, digital certification systems, AI analytics, IoT sensors [11], GPS trackers [11], state monitoring systems, integration with «Diia», Big Data [12], open API, and public oversight platforms) into the future state regulation of food industry enterprises in the context of electronic and rapid commerce, it is necessary to develop a unified state digital platform, «Trek.Food Government». This platform will accumulate registration data, digital accounting mechanisms, control, role attribution, and will interact with the «Diia.Business» and «Diia.Inspector» platforms as well as with external state control services in the field of food safety (see Fig. 1).

According to Fig. 1, the central functional node of this model is the unified state digital platform for food product traceability, «Trek.Food Government», which accumulates registration data, digital accounting mechanisms, control, role attribution, and interacts with the «Diia.Business» and «Diia.Inspector» platforms as well as external state services. The logic of this system is built according to the principle of digital administrative sequencing, which covers four functional modules: 1) Registration; 2) Authorization; 3) Digital Accounting; 4) Digital Control.
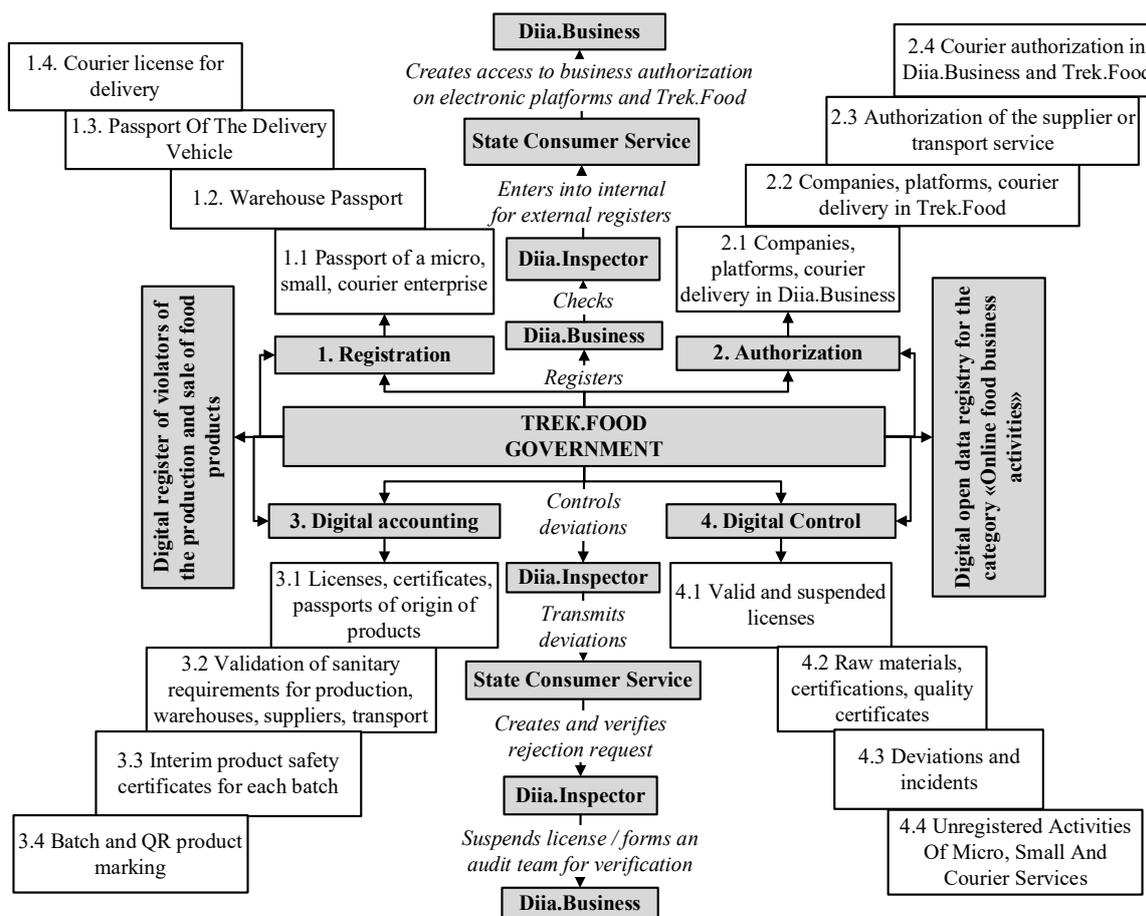

Fig. 1. Functional-procedural model of the «Trek.Food Government» system for registration, integration, accounting, and control of relevant food products in the context of electronic and fast commerce

Source: developed by the author

Each module contains a set of procedures executed both through the public digital services of «Diia» and through automated digital interfaces of executive authorities.

The first «Registration» block is responsible for the digital passporting of micro, small, and medium-sized food enterprises, courier services, warehouses, transport vehicles, and couriers. A key feature is the possibility of data entry into external registries through an authorized state service, enabling the unification of procedures with existing state registries. Importantly, «Diia.Business» serves as the primary system entry interface, where entrepreneurs gain access to electronic platforms and «Trek.Food Government».

The second block, «Authorization», involves confirming the digital status of micro, small, and medium-sized food enterprises, and particularly courier services, couriers, transport service providers, and logistics operators, which is critical for the rapid commerce model where delivery can be carried out by small, non-formalized actors. Authorization serves as a legitimization procedure in the digital domain, transitioning informal businesses into a regulated digital environment without complicating the process. Notably, courier or service confirmation can occur without physical intervention through algorithmic data analysis, significantly reducing the transaction costs of regulation.

The third block, «Digital Accounting», functions as a tool for maintaining registers of licenses, certificates, passports, and the recording of compliance with sanitary requirements. It is linked to digital traceability, implemented through integration with «QR-traceability», certification, smart contracts, and logistics trackers. An innovative element of this block is the creation of batch accounting with «QR-labeling», allowing tracking not only by entities but by each specific batch of goods or deliveries. This solution enables the implementation of the principle of reversible control, particularly when detected deviations automatically trigger procedural investigations or license suspensions.

The fourth block, «Digital Control», includes actions executed through «Diia.Inspector», particularly in the area of automatic license verification, service activity checks, and the creation and verification of digital files and certificates. A unique feature is the possibility of automatic license revocation, meaning violations recorded within the digital system can initiate legally significant administrative decisions without inspection procedures. This logic aligns with the modern «predictive oversight» concept used in leading countries to increase regulatory efficiency while reducing administrative burdens. Additionally, the lower segment of the model includes a mechanism linking activities to sectoral groups, risk categories, and typical violations, enabling the classification of participants by the degree of potential threat or significance, creating a foundation for risk-oriented regulation.

Thus, this system registers, controls, and performs dynamic profiling functions, enabling the state to respond flexibly to changes in market participant behavior. Conceptually, this model represents a governance symbiosis between the «Diia» digital public platforms, digital state control interfaces, and market-generated data. This structure enables a shift from linear regulatory logic to data-driven cybernetic governance, where each administrative action is based on algorithmic conclusions, and each decision is verified, justified, and transparent. Consequently, this model will simplify administrative procedures and transform the approach to state regulation, shifting it from a domain of distrust and constant inspections to a format of algorithmic cooperation where compliant businesses gain faster market access, while violators are automatically detected and blocked by the system without human intervention.

Having presented the functional and procedural model of the «Trek.Food Government» system (Fig. 2), we will develop the overall concept of the digital transformation of the state food traceability system in the context of the rapid development of electronic and quick commerce (see Fig. 2).

The presented concept of the digital transformation of the state food traceability system in the context of electronic and rapid commerce (Fig. 2) forms a four-segment configuration centered around «Diia.Business», «Diia.Inspector», «Diia.Signature», and «Trek.Food», embodying the principles of polycentric governance, where key functions are distributed among digital state platforms, logistics nodes, business actors, and consumer interfaces, while management accountability acquires a networked nature.

Structurally, the model is built as a functionally conditioned convergent space where each of the four blocks plays an autonomous yet integrated role in ensuring traceability, namely: The upper segment focuses on the registration of electronic commerce entities, risk labeling through an open reputation system, and the digitalization of production by connecting to «Trek.Food» as the central regulatory hub; The right segment is responsible for intelligent logistics, introducing registers of warehouses, transport vehicles, digital delivery channels, and «QR batch identification» blocks; The lower segment is responsible for technological product traceability through the integration of blockchain infrastructure, HACCP, RFID technologies, verified certificates, and digital product passports. The left segment is responsible for regulating rapid commerce, specifically for the digital recording of courier services, pick-up points, transportation, and compliance with sanitary requirements for mobile distribution. The institutional vertical is integrated into the system via the «Diia» platform, which performs a technical-administrative function and serves as a state trust interface. Through «Diia.Business», electronic legitimization of business operators is implemented; «Diia.Inspector» facilitates remote, intelligent oversight; and «Diia.Signature» provides digital verification of transactions and regulatory documents. As a result, the regulatory infrastructure acquires the characteristics of a dispersed administrative organism, operating through digital algorithms that ensure automated real-time compliance. In comparison with the traditional state control model, which is

based on extensive inspection practices, fragmented licensing, and delayed response, the «Trek.Food Government» system demonstrates the properties of a self-regulating ecosystem, in which each module serves as both a data source and a full unit of accountability, with legally significant digital identity and reputational trace. At the same time, the full-scale implementation of this model requires addressing a range of systemic challenges:
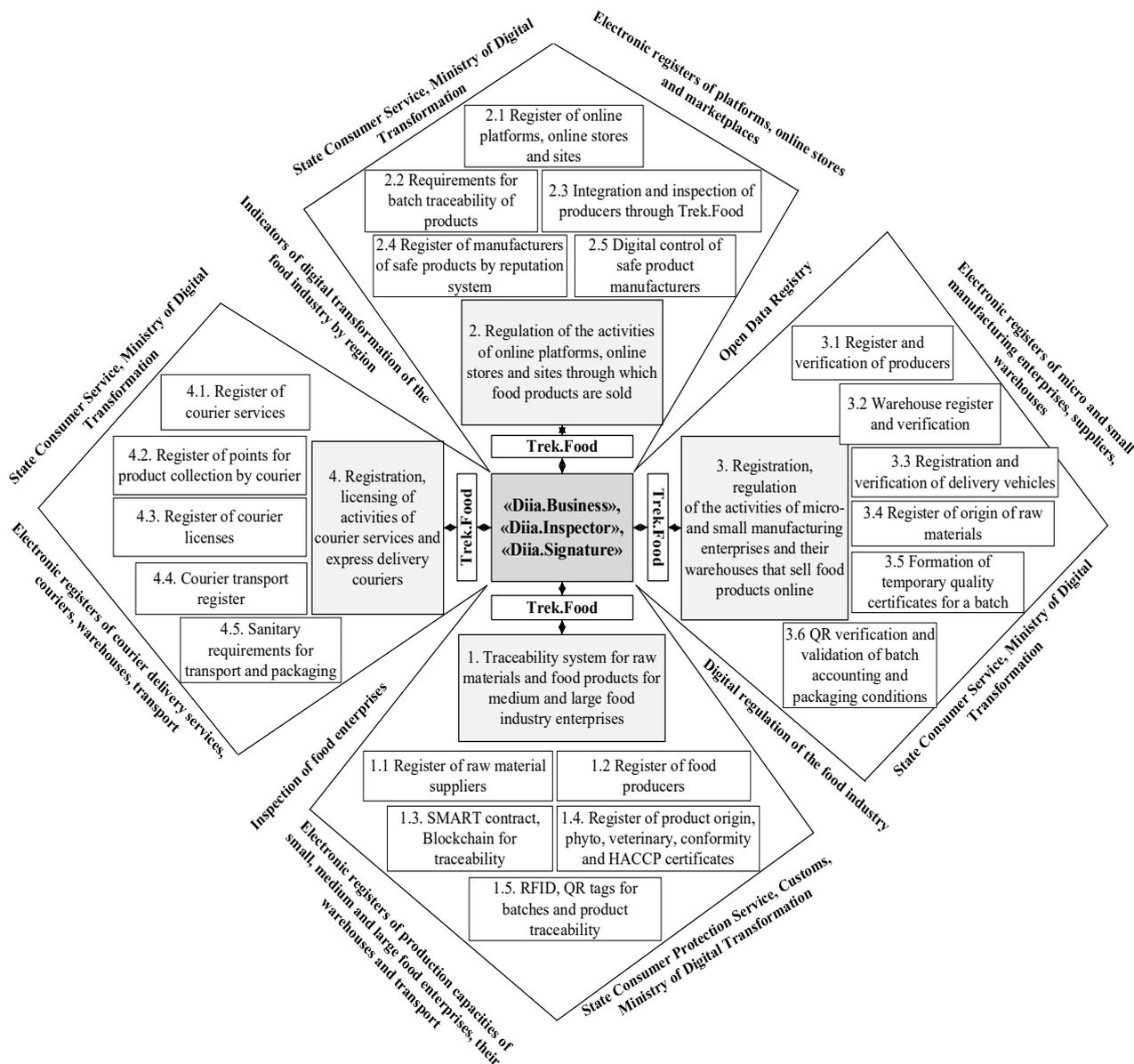

Fig. 2. Concept of digital transformation of the state food product traceability system in the context of electronic and fast commerce

Source: developed by the author

– First, the legal codification of the legal status of digital artifacts such as smart contracts, digital certificates, and blockchain registers is necessary, as without regulatory recognition, their authority will remain declarative.

– Second, it is critically important to ensure interoperability between state and private information systems through the standardization of APIs, exchange formats, and identification protocols, particularly regarding integration with international certification platforms.

– Third, a national IoT monitoring infrastructure should be deployed in warehouses, transport hubs, and mobile logistics, which requires technical investments and the development of a new level of digital competence within the regions.

Ultimately, the key issue will remain the establishment of digital accountability through the creation of an algorithmic model for determining liability in cases of inaccurate, missing, or falsified data.

As the next step, we will develop general procedural schemes for implementing digital registration and verification of «Safe Food Enterprises» (Fig. 3), «Safe Warehousing Facilities» (Fig. 4), «Safe Transport Vehicles» (Fig. 5), and a general procedural scheme for implementing digital control of sales, delivery, and incident response (Fig. 6) in the context of electronic and rapid commerce.

According to Fig. 3, the entry channel for the presented procedure of digital registration and verification of «Safe Food Enterprises» consists of three categories of participants: food producers; micro and small producers engaged in the production and online sale of food products; and courier services (only in terms of legal registration) that ensure the rapid delivery of food products.

Thus, the system accounts for the specifics of actors operating within the hybrid conditions of the physical and digital economy, forming an individualized digital registration trajectory according to the participant type. The key entry point into the regulatory environment is the business registration on the state platform «Diia.Business» using standardized forms. At this stage, algorithmic structuring of the initial data is carried out, ensuring its automated transfer for verification in «Diia.Inspector», and subsequently to the State Consumer Service. Thus, the verification of authenticity and legality occurs without direct interaction with an inspector, indicating a shift away from the traditional permit model toward digital legitimization through verified state channels. After confirming the legal status of the entity, its data is automatically entered into the «Legal Registry of Enterprises» (if it had not been previously added), representing a legally significant outcome of the first phase of identification.
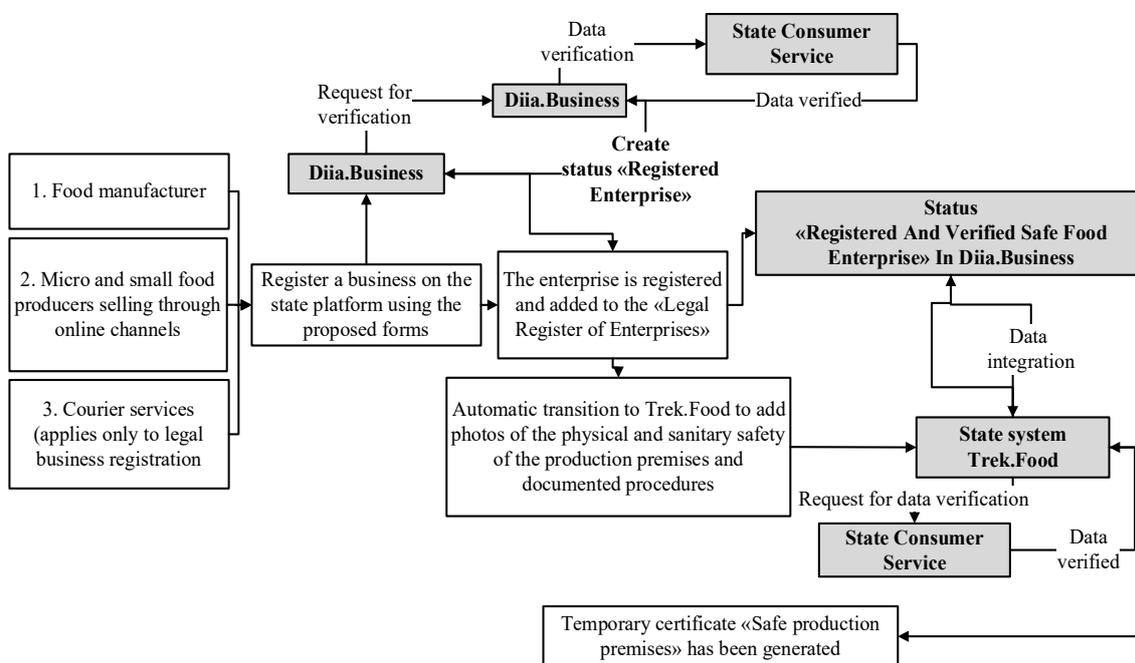

Fig. 3. General procedural scheme for the implementation of digital registration and verification of «Safe Food Enterprises» in the context of electronic and fast commerce

Source: developed by the author

Importantly, the system provides for an immediate transition to the «Trek.Food» digital platform, where the enterprise uploads visual evidence (photos) of the sanitary condition of its premises and procedural documents. This approach confirms the transition from declaration to digital visualization as a new method of compliance verification, significantly increasing transparency and reducing corruption risks. Based on the submitted information, a temporary «Safe Production Facility» certificate is issued, which does not yet guarantee full verification. Its validity is checked upon request from «Trek.Food» to the State Consumer Service, which performs the final data verification. Upon confirmation, the results are integrated into the national system, and the entity receives the status of «Registered and Verified Safe Food Enterprise» within the «Diia.Business» system, establishing both legal status and a marker of digital integrity and compliance within the food supply chain traceability system. An innovative feature of this model is the automatic transition between institutions without the entrepreneur's participation, reducing the regulatory burden on businesses and creating the prerequisites for a new type of service-oriented state. Additionally, the logic of the system's design indicates a bilateral data verification process: from the enterprise (submitted documents and photos) and from the state (cross-checking with the State Consumer Service databases), ensuring systemic reliability of the outcome.

Next, we will examine the general procedural scheme for implementing digital registration and verification of «Safe Warehousing Facilities» in the context of electronic and rapid commerce (see Fig. 4).

Following the example shown in Fig. 3, the subsequent general procedural scheme for implementing digital registration and verification of «Safe Warehousing Facilities» in the context of electronic and rapid commerce (Fig. 4) is carried out.
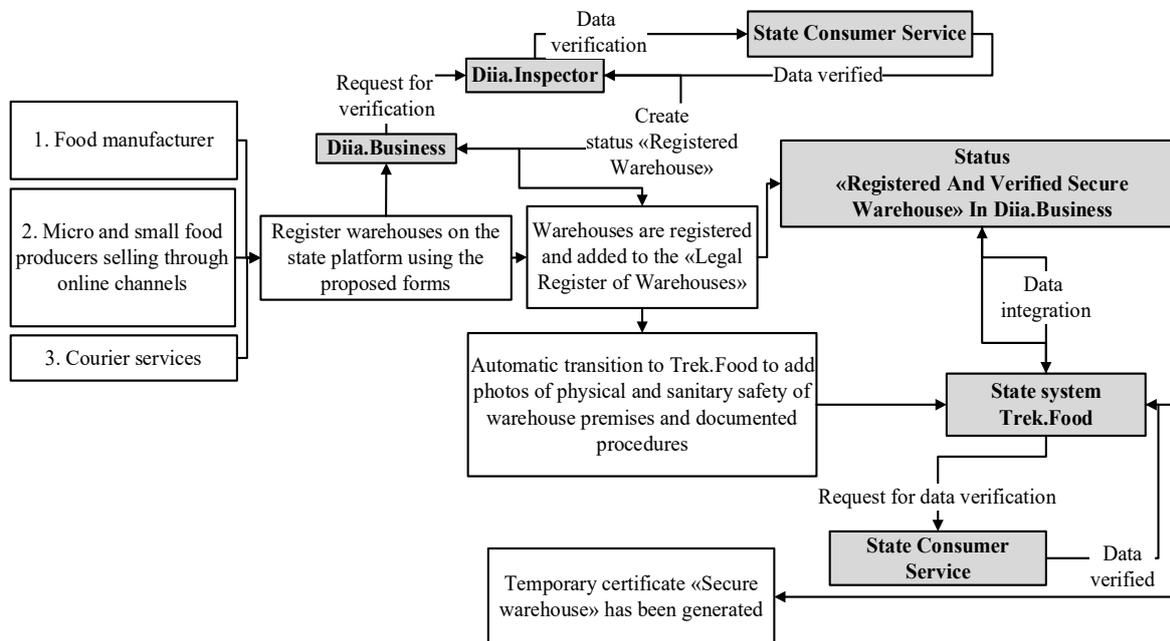

Fig. 4. General procedural scheme for the implementation of digital registration and verification of «Safe Warehouse Facilities» in the context of electronic and fast commerce

Source: developed by the author

However, for verification photo-control, the following parameters are analyzed: the location for storing raw materials, the location for storing finished products, the presence of temperature, humidity, and airtightness control systems, documented batch accounting to ensure traceability, and data from logistics enterprises involved in transportation.

Following the example shown in Fig. 3, the subsequent general procedural scheme for implementing digital registration and verification of a «Safe Transport Vehicle» in the context of electronic and rapid commerce (Fig. 5) is carried out. However, for verification photo-control, the following parameters are subject to analysis: the external condition of the vehicle and its internal compartments, the type of transport vehicle, sanitary condition, compliance with food transportation requirements, the presence of temperature, humidity, and airtightness sensors, the presence of GPS traceability systems, or a contract with the transport owner company (if it is an external carrier).

In the absence of a verified business entity status, this indicates that the enterprise has either unconfirmed safety data or existing violations, which primarily allows for a preliminary conclusion not to engage with this enterprise.

An additional element that will provide more detailed evidence of safety violations in the production, storage, or transportation of products will be the «enterprise rating system», which will be formed according to the number of product-related incidents recorded via the QR-code feedback mechanism (Fig. 6).

Let us consider the general procedural scheme for implementing digital control of sales, delivery, and incident response in the context of electronic and rapid commerce (see Fig. 6).

According to Fig. 6, the presented general procedure demonstrates the algorithmic transition from the registration function to the function of adaptive regulatory oversight, in which the state not only records the status of enterprises but also responds to behavioral anomalies detected directly within the delivery chain. The central element of the scheme is the digital trace of each product package, recorded through the assignment of a QR-code within the «Trek.Food» system. Each order is recorded as a digital transaction linked to a specific batch, package, transport, and supplier.

Thus, the starting point becomes the customer's order placed via an online platform or mobile application, to which the manufacturer assigns a batch-specific unique identifier and applies final product labeling, ensuring traceability and enabling tracking of the entire product supply lifecycle from the place of production to the moment the customer opens the packaging. After the product is dispatched using verified transportation compliant with sanitary requirements, the key moment occurs when the end consumer receives the order and, using a QR-code, verifies the product's authenticity,

quality, and compliance. If no incidents are identified upon receipt of the order, the transaction is completed successfully, which automatically forms a positive reputational trace of the enterprise within the «Trek.Food» system.
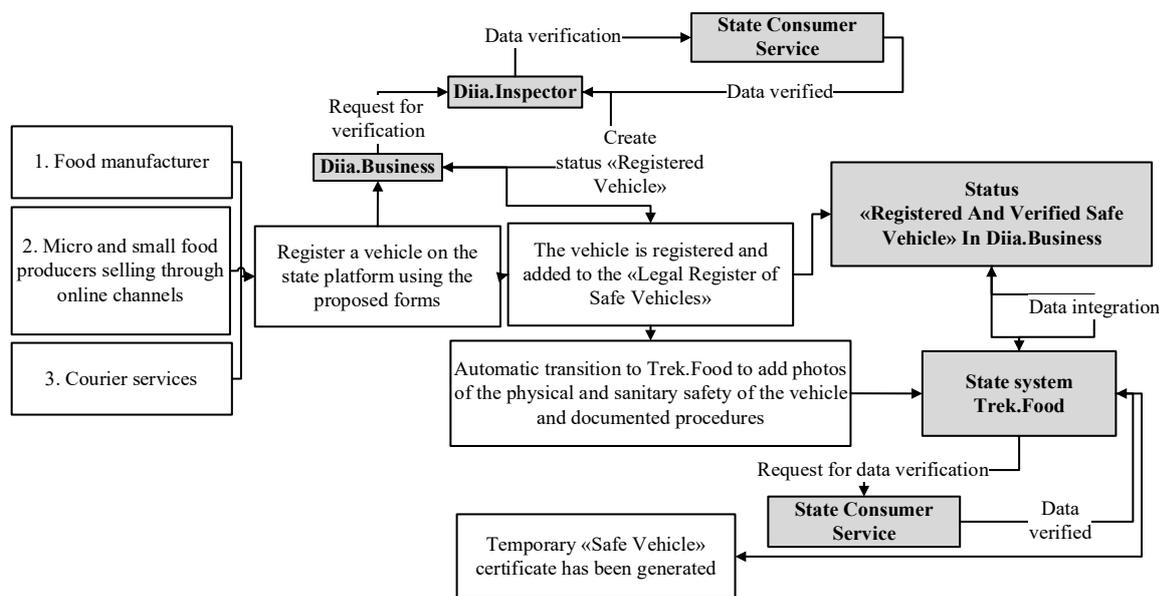
Fig. 5. General procedural scheme for the implementation of digital registration and verification of a «Safe Vehicle» in the context of electronic and fast commerce

Source: developed by the author

However, in a negative scenario where the customer identifies an incident (such as unsafe packaging, damage, or signs of counterfeiting), they scan the «QR-code», activating the incident response procedure within the «Trek.Food» framework. The system logs the event, identifies the enterprise, batch, delivery route, and other delivery parameters, and then transmits a digital report to the State Consumer Service. This mechanism serves as an example of a consumer-triggered regulatory approach where the initiative comes not from an inspector but from the customer, significantly increasing the speed and objectivity of the response.

The system then transitions to adaptive scenario-based regulation, where it is confirmed that the incident is related to minor factors that can be improved through corrective actions.

However, if the incident concerns a hazardous factor (health/safety), a comprehensive audit of production, warehouses, transportation, and packaging is conducted, ensuring proportional state intervention by involving inspections according to the risk level of the incident rather than a formal schedule. In cases of systematic violations, the «Trek.Food» system records the accumulation of negative reputational assessments, after which the system automatically restricts the enterprise's functionality and changes its status in «Diia.Business» to «unverified enterprise», or initiates a license revocation procedure. This process transforms reputation into an active regulatory instrument, where digital reputational weight carries not only an image-related but also a legal force, fundamentally shifting the regulatory model from formal to behavioral oversight.

A distinctive feature of this model is that each incident is considered in the context of batch-specific labeling, a specific transaction, rather than the general profile of the enterprise, ensuring high precision in state response, avoiding collective liability, and allowing the rapid isolation of problematic segments without halting the entire business operation.

Conclusions

Within the scope of the research, a conceptual model of state digital traceability in the food industry was developed as a response to the transformation of the food sector under conditions of electronic and rapid commerce. The designed architecture of the «Trek.Food Government» system is based on the principles of data-driven governance, algorithmic verification, and integration with public digital platforms («Diia.Business», «Diia.Inspector», «Diia.Signature»), ensuring end-to-end interaction between state registries, business structures, and logistics operators. The proposed four functional blocks (registration, authorization, digital accounting, digital control) will enable end-to-end traceability, automated safety verification, and real-time incident response. Functionally, this model envisions the application of digital identity, the participant's reputational profile, an incident response mechanism, and behavioral control, allowing a transition from inspection-based logic to preventive, risk-oriented regulation using SMART-contract tools, QR technologies, Blockchain identification and digital verification procedures.
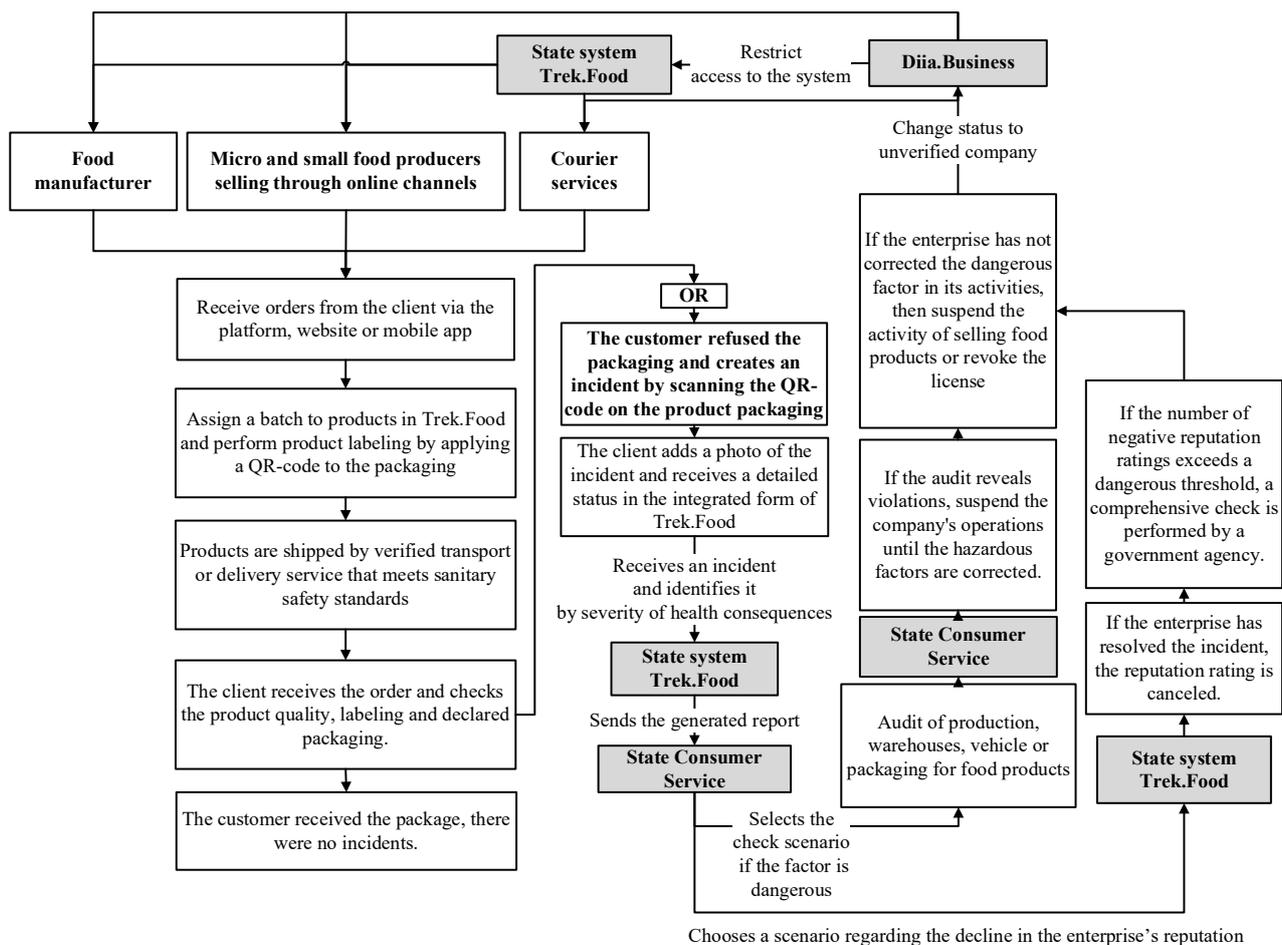
Fig. 6. General procedural scheme for the implementation of digital control of sales, delivery and incident response in the context of electronic and fast commerce

Source: developed by the author

References

1. Ellahi R.M., Wood L.C., Bekhit A.E. (2024). Blockchain-Driven Food Supply Chains: A Systematic Review for Unexplored Opportunities. *Applied Sciences*. Vol. 14 (19). DOI: https://doi.org/10.3390/app14198944

2. Reddy P., Kurnia S., Tortorella G.L. (2022). Digital Food Supply Chain Traceability Framework. *Proceedings*. Vol. 82 (1). DOI: https://doi.org/10.3390/proceedings202208200

3. Charlebois S., Latif N., Ilahi I., Sarker B., Music J., Vezeau J. (2024). Digital Traceability in Agri-Food Supply Chains: A Comparative Analysis of OECD Member Countries. *Foods*. Vol. 13 (7). DOI: https://doi.org/10.3390/foods13071075

4. Lukacs M., Toth F., Horvath R., Solymos G., Alpár B., Varga P., Kertesz I., Gillay Z., Baranyai L., Felfoldi J., et al. (2025). Advanced Digital Solutions for Food Traceability: Enhancing Origin, Quality, and Safety Through NIRS, RFID, Blockchain and IoT. *Journal of Sensor and Actuator Networks*. Vol. 14 (1). DOI: https://doi.org/10.3390/jsan14010021

5. Verna E., Genta G., Galetto M. (2025). Enhanced Food Quality by Digital Traceability in Food Processing Industry. *Food Engineering Reviews*. Vol. 17, pp. 359–383. DOI: https://doi.org/10.1007/s12393-024-09392-4

6. Corallo A., Paiano R., Guido A.L., et al. (2018). Intelligent Monitoring Internet of Things Based System for Agri-Food Value Chain Traceability and Transparency: A Framework Proposed. *IEEE Workshop on Environmental, Energy, and Structural Monitoring Systems (EESMS)*. pp. 1–6. DOI: https://doi.org/10.1109/EESMS.2018.8405814

7. Mishra N., Mistry S., Choudhary S., et al. (2020). Food Traceability System Using Blockchain and QR Code. *IC-BCT* 2019. *Springer Nature Link Singapore*. pp. 33–43. DOI: https://doi.org/10.1007/978-981-15-4542-9_4

8. Official page GS1. What is a QR Code? Available at: https://www.gs1us.org/upcs-barcodes-prefixes/what-is-a-qr-code

9. Official page GS1. What Is RFID Technology, and How Does It Work? Available at: https://www.supplychain.gs1us.org/rfid

10. Official page IBM. What are smart contracts on blockchain? Available at: https://www.ibm.com/think/topics/smart-contracts

11. Official page IBM. What is the Internet of Things (IoT)? Available at: https://www.ibm.com/think/topics/internet-of-things

12. Official page IBM. What is big data analytics? Available at: https://www.ibm.com/think/topics/big-data-analytics