Information technology

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CREATION OF A GLOBAL AI PLATFORM FOR INTERNATIONAL ANIMAL TRANSPORT REGULATIONS: POTENTIAL AND CHALLENGES

Summary. *The study is aimed at establishing an architectural and methodological foundation for a unified global platform based on artificial intelligence technologies, intended to automate compliance in the international transportation of animals. The relevance is determined by a systemic mismatch between the rapid scaling of the Pet Travel market (expected volume — $5.3 billion by 2034) and the inertia of the regulatory infrastructure, which relies on fragmented national prescriptions and heterogeneous control procedures. The objective is to transition from the dominant document-centric paradigm to a data-centric ecosystem in which regulatory requirements and logistical events are represented as formalized entities and relationships governed by knowledge graphs and large language models (LLM). The methodological framework is constructed as a hybrid: a system analysis of regulatory requirements of more than 60 states was conducted, econometric modeling tools were applied to identify factors affecting the probability of refusal of transport, and a synthesis of practice-oriented cases reflecting real scenarios of veterinary and transport support was performed. The results obtained show that the implementation of semantic algorithms for data verification and reconciliation increases the completeness and consistency of compliance checks, which makes it possible to reduce the share of transport refusals by 40–50% and simultaneously decrease biosecurity risks through the early detection of regulatory inconsistencies and* *potentially dangerous deviations in the chain of supporting information. The presented conclusions are relevant for the design and implementation of LegalTech solutions, the activities of veterinary services and logistics operators, as well as for the professional community associated with ensuring animal protection.*

Key words: *AI in logistics, international animal transportation, veterinary compliance, knowledge graphs, regulatory automation, biosecurity, ISO 11784/11785, smart contracts, TRACES, zoonomics.*

Introduction. International mobility of companion animals has evolved from a marginal area into an economically salient segment of global services. The strengthening of the pet humanization trend has driven the sustained inclusion of animals in everyday travel practices: according to estimates, approximately 78% of owners in the United States and European countries take annual trips together with their companion animals. At the same time, the institutional and infrastructural environment of cross-border transport continues to display fragmentation, limited transparency, and heightened operational vulnerability.

The current regulatory landscape is shaped by a multilayered combination of national regimes (USDA in the United States, DEFRA in the United Kingdom), supranational legal prescriptions (EU Regulation No 576/2013), and sectoral corporate standards applied by air carriers (IATA LAR). The lack of a unified digital standard for intersystem data exchange results in a substantial share of transports—up to 15–20%—being complicated by delays, boarding refusals, or the imposition of mandatory quarantine, the cause of which is formal and substantive errors in documentation [1].

The scientific novelty of the study is determined by the substantiation of the architecture of an intelligent verifier (AI-Compliance Engine) oriented not toward the mechanical digitization of paper confirmations, but toward checking the causal-temporal consistency of veterinary events and their logical sequence (vaccination → microchipping → titers) in accordance with dynamically changing requirements of states classified into red and green zones.

The proposed concept is grounded in the hypothesis that the reduction of regulatory uncertainty and the decrease of transaction losses are achievable only through the implementation of a hybrid AI model that combines deterministic mechanisms based on formal rules with probabilistic approaches (LLM) that ensure the interpretation of unstructured and weakly standardized data.

The objective of the work is to develop a conceptual model of a global AI platform capable of harmonizing international requirements and creating conditions for seamless animal transit within end-to-end logistics chains.

Materials and Methods. The methodological framework of the study was formed on the basis of a comprehensive analysis in which the theoretical elaboration of the subject area is coupled with the use of empirical data arrays.

As the source base, first, regulatory and legal materials were used: an analysis was conducted of European Union regulations classified under the EU Animal Health Law, CDC (USA) requirements governing the importation of animals from states classified as high-risk territories, as well as veterinary protocols of the UAE (MOCCAE) and China (GACC). Second, technical documentation was examined, including ISO 11784/11785 standards defining parameters for animal identification, and specifications of the digital systems TRACES (EU) and VEHCS (USA). Third, the empirical block relied on practical materials: the key source was the methodology International rules and logistics of passenger transport of companion animals, which presents algorithmized sequences of actions for more than 60 jurisdictions and summarizes an analysis of real cases of refusals.

Results and Discussion. Macroeconomic analysis records the transition of the animal transport services segment into a mode of accelerated expansion. Even against the backdrop of geopolitical turbulence, demand for animal relocation is characterized by low price elasticity: the priority is the minimization of risks and the assurance of safe movement, which supports willingness to pay for comprehensive services of increased reliability. According to aggregated estimates, by 2034 the total market volume will exceed 5 billion US dollars. At the same time, a structural mismatch persists between the growth rate of demand and the throughput of the currently predominantly analog infrastructure: the dominance of paper document circulation and fragmented verification procedures forms a persistent bottleneck effect in the veterinary control loop, increasing delays, transaction costs, and the probability of operational failures. A graphical interpretation of the forecast market trajectory additionally emphasizes the need for scalable technological transformation and the proactive development of IT solutions capable of supporting growing volumes of checks without degradation in the quality of compliance control [4, 5].

Figure 1 presents the forecast of the global market volume for animal transport services.

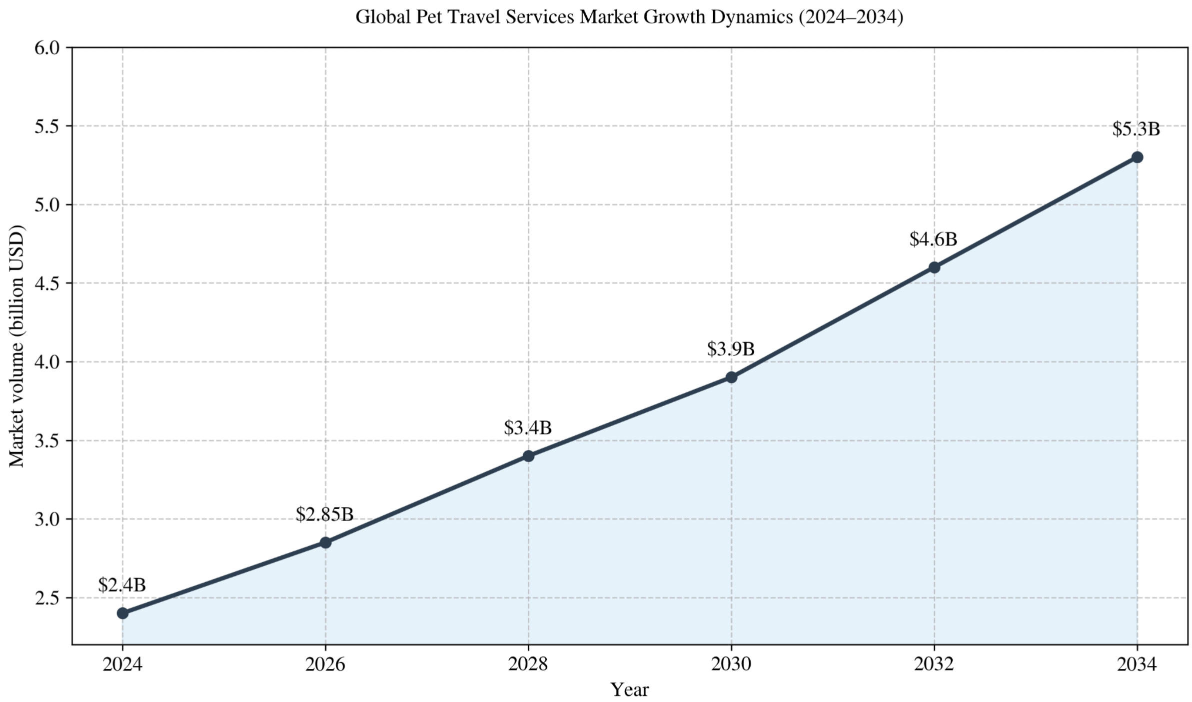

Fig. 1. Forecast of the global market volume for animal transport services (2024–2034)

Source: compiled by the author based on [4, 5]

The acceleration of market development is associated not only with an increase in the number of transports, but also with the growing complexity of logistics configurations. When direct air travel predominated in the earlier period, control procedures were largely structured around a single border-crossing point. Under current conditions, against the backdrop of the closure of certain airspaces and the influence of geopolitical factors, transport chains are acquiring a multimodal character (a road segment in combination with air and ferry legs). Such a movement trajectory requires coordination and temporal synchronization of veterinary documents with the requirements not only of the destination country, but also of transit jurisdictions, which increases the sensitivity of the entire procedure to formal discrepancies and errors in document attributes.

A significant constraint of the sector remains the high frequency of refusals at border crossing and cases of mandatory placement of animals in quarantine. Analysis of TRACES (EU) data and USDA APHIS reporting indicates that the predominant set of violations is driven not by the actual health status of animals, but by defects of an administrative and documentary nature. The author's practical methodology additionally confirms the dominance of the human factor as the primary root cause of failures: errors made by private veterinary professionals during documentation, as well as insufficient awareness among airline staff regarding applicable rules and restrictions, become of critical importance.

For greater clarity, Figure 2 reflects the structure of causes of non-compliance in cross-border movement of animals.

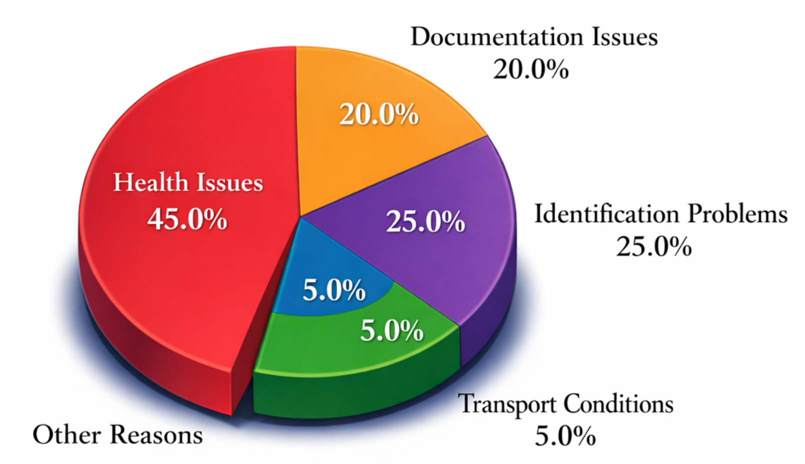

Fig. 2. Structure of reasons for non-compliance in transboundary movement of animals

Source: compiled by the author based on [1, 6]

The data presented in Figure 2 indicate that approximately 45% of problems in the international animal transport chain are attributable to documentation defects. This ratio empirically supports the hypothesis of high effectiveness of preliminary automated verification based on AI: shifting the main burden of identifying formal inconsistencies to the pre-transit stage can substantially unload border-veterinary control circuits and reduce the stressfulness of the procedure arising from refusals, delays, and forced additional inspections.

When designing a global platform, the central constraint is the task of harmonizing normatively heterogeneous requirements, since the international space is in fact stratified by epizootic zones, and the regimes of movement between them exhibit pronounced asymmetry. The consequence is a multiplicity of compliance logics dependent on the direction of movement, the status of the country of origin, transit jurisdictions, and the nature of supporting veterinary events. On the basis of practical materials from the methodology of A. Veselovskaya and relevant international regulations, a requirements matrix for key routes was formed, intended to identify conflicts and formalize parameters subject to machine interpretation within a unified data-oriented architecture.

Table 1 presents the results of comparing matrices of veterinary requirements for key export destinations.

Table 1

Comparative matrix of veterinary requirements for key export destinations

Requirement	European Union (EU)	USA (CDC High-Risk)	UAE (MOCCAE)	China
Microchip	ISO 11784/11785. Must be implanted before vaccination.	ISO compatible. Implanted before vaccination.	ISO 11784/11785.	ISO 11784/11785.
Rabies vaccination	Minimum 21 days. 1-year and 3-year vaccines are recognized (but primary is 1 year).	Minimum 28 days (for primary). Strict age control (>6 months).	Minimum 21 days. Manufacturer is strictly controlled.	2 vaccinations with an interval of 30 days.
Antibody titers	Quarantine 3 months after blood sampling.	Mandatory. No quarantine, but reservation in ACF is required.	Mandatory. Quarantine is not required, entry immediately.	Mandatory. Level ≥ 0.5 IU/ml.
Specific treatments	Echinococcosis (24-120 h) for Finland, Ireland, Malta.	Not required federally, but recommended.	Treatment against external and internal parasites (14 days).	Treatment against external and internal parasites.
Health certificate	EU Health Cert	CDC Import	Import Permit +	State certificate

	(valid for 10 days).	Form + State certificate.	Health Cert (valid for 5 days).	(F5a).
Key risk	Vaccination cancellation if the chip is implanted later.	Entry refusal without a reservation in ACF (Animal Care Facility).	Deportation in the absence of an Import Permit.	Mandatory quarantine in case of errors in titers.

Source: compiled by the author based on [3, 7]

The substantive logic of the table demonstrates the fundamental labor intensity of algorithmizing compliance checks, because an identical set of veterinary events can generate different regulatory trajectories depending on the destination jurisdiction. An illustrative example is provided by the results of serological testing for antibodies: in a number of destinations (in particular, the UAE), immediate entry is permissible provided that the established formal conditions are met, whereas for the European Union a deferred admission is applied, providing the completion of a three-month period after obtaining titers. Consequently, the platform logic should rely on a dynamic rules graph capable of recalculating the regulatory route depending on the destination country, the country of origin, and contextual attributes, including the origin of the vaccine and the admissibility of a specific product in a given jurisdiction. In terms of digital design, this means the need to form an adaptive pathway of the logistics process in which the sequence of actions and control points is not set statically, but is derived from the set of applicable norms [16, 17].

To implement such a model, the use of a knowledge graph is proposed as the basic representation of normative reality. Traditional relational repositories (SQL), optimized for a tabular structure and rigidly defined schemas, prove to be of limited suitability when working with multilevel, context-dependent, and frequently changing veterinary rules. By contrast, the graph paradigm provides natural modeling of hierarchies, exceptions, and dependencies, making it possible to store not only facts, but also their normative-logical links. Within the proposed architecture, graph nodes are interpreted as key entities of the domain (for example, Country, Vaccine, Animal species), whereas edges reflect rules and relationships of a normative nature (permits, requires, prohibits), including conditions of applicability, temporal parameters, and permissible sequences of veterinary events. This approach makes it possible to represent regulatory requirements as a computable structure suitable for automated inference and continuous updating when legal regimes change (see Fig. 3).

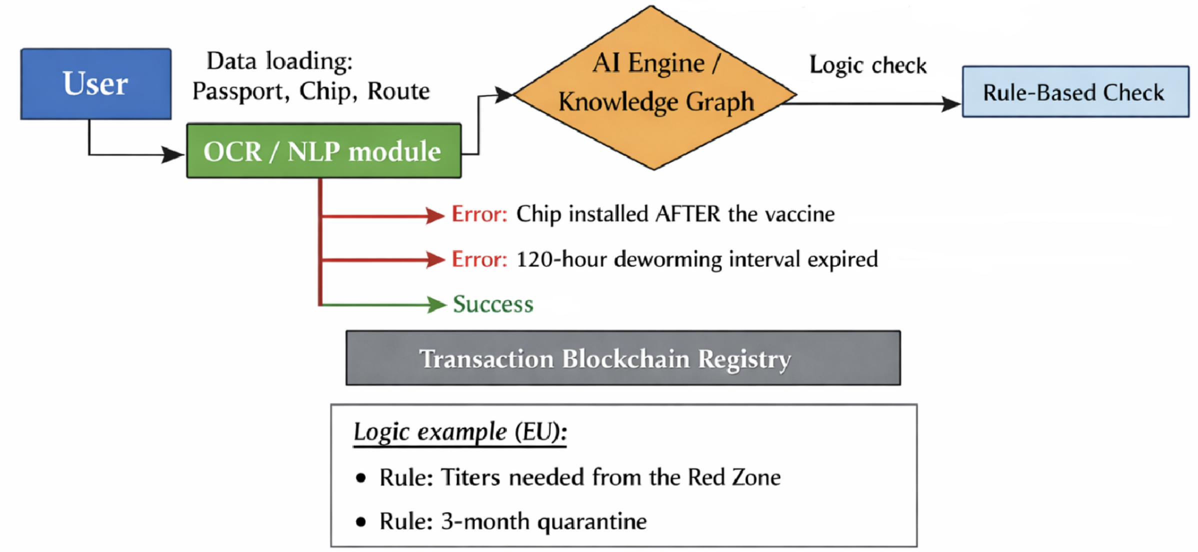

Fig. 3. Conceptual diagram of the AI validator based on the Knowledge Graph

Source: compiled by the author based on [2, 8, 9, 15]

The application of a graph-based schema ensures the implementation of a proactive compliance mode in which control is reduced not to an ex post recording of non-compliance, but to the computable construction of a permissible action scenario taking into account temporal and procedural constraints. Within this loop, the system forms a prescriptive model by linking the planned date of movement with the regulatory windows of mandatory procedures. Thus, for a departure on the 15th, parasite treatment must be performed strictly on the 13th within the interval 10:00–18:00 in order to comply with the required 24–120 hour window characteristic of rules applied, in particular, by the United Kingdom or Finland. Such functionality translates requirements from static textual norms into dynamically calculated temporal constraints, reducing the probability of accidental errors arising from manual counting of deadlines and interpretation of floating intervals.

At the same time, the digital transformation of compliance circuits is associated with a set of systemic risks and ethically significant consequences. The most sensitive area is data protection and countering fraud, since digitization increases the scalability of both good-faith and bad-faith practices. In a number of jurisdictions with elevated corruption risks, the circulation of grey certificates persists, including forged titer results, manipulation of identifiers, and cases of duplicated microchips, which undermines trust in documentary confirmation and increases biosecurity threats. Consequently, embedding mechanisms for preventing falsification and ensuring data integrity should be regarded as a mandatory component of the architecture rather than a secondary option. The analysis of technological solutions reflected in Table 2, aimed at minimizing these risks, serves as a basis for comparing approaches according to the criteria of provable data provenance, resistance to substitution, and the possibility of interagency validation in cross-border scenarios.

Table 2

Comparative analysis of identification and verification technologies in zoological logistics

Technology	Advantages	Disadvantages/Risks	Implementation status
RFID (ISO 11784/85)	Global standard, low cost, passive operation (does not require power).	The chip can be cloned or reprogrammed. Absence of a single global owner database.	De facto standard (mandatory in the EU, USA, UAE).
Biometrics (Nose print)	Uniqueness (analogous to a fingerprint), impossibility of forgery or loss.	Requires high-quality cameras and complex software. Low accuracy in puppies.	Experimental projects (USA, China, Korea).

Blockchain (Pet Passport)	Immutability of vaccination history. Elimination of vaccines entered retroactively.	Complexity of integration with state registries (TRACES, Mercury). GDPR issue.	Pilot projects, startups.
AI document analysis (OCR+NLP)	Detection of photomontage in certificates. Cross-checking of vaccine batch numbers with manufacturer databases.	Possibility of false positives (False Positives). Dependence on scan quality.	Actively implemented in FinTech, beginning in PetTech.

Source: compiled by the author based on [10-14; 17]

Thus, it has been demonstrated that the market for international animal transport services is entering a phase of accelerated growth and, by 2034, according to aggregated estimates, may exceed 5 billion US dollars, while demand remains weakly price-sensitive due to the prioritization of safety and risk minimization; however, this growth encounters a bottleneck of an analog, paper-oriented veterinary control infrastructure, where route complication (multimodality, transit jurisdictions, geopolitical constraints) increases the number of points of normative coordination and sharply raises the probability of formal errors; empirical evidence (TRACES/USDA) indicates that a significant share of non-compliance at the border (about 45%) is associated precisely with documentation defects and the human factor, therefore the most economically and operationally justified approach appears to be shifting the compliance burden to the pre-transit stage through an automated AI pre-check; at the same time, the requirements matrix demonstrates high heterogeneity of regulatory regimes (the same veterinary events lead to different admission trajectories in the EU/USA/UAE/China), which makes static schemes (SQL) insufficient and substantiates a knowledge-graph-based architecture capable of dynamically deriving a permissible route of actions and procedural time windows; finally, digitization requires embedded data integrity protection and anti-fraud measures (accounting for risks of grey certificates, substitution of chips/titers), where a combination of AI-based document analysis, strengthened identification methods, and (given integration readiness) immutable registries can reduce operational failures without degrading the quality of biosecurity and compliance.

Conclusion. The formation of a global AI platform for the international transportation of animals should be regarded not as a futurological project, but as an applied necessity driven by the scale of a multibillion-dollar market and contemporary ethical standards of animal treatment. The development logic of the sector indicates the exhaustion of the potential of fragmented procedures and paper-oriented control mechanisms: with the growth of transport volumes and the increasing complexity of routes, the preservation of the current model leads to the accumulation of transaction losses, an increase in regulatory uncertainty, and the intensification of biosecurity threats.

The results of the study make it possible to substantiate a number of conclusions. The economic rationality of digital unification is manifested in a reduction of the duration of document preparation and reconciliation by approximately 40% through standardized pre-control, automated verification, and the elimination of repeated documentation cycles. An additional effect is associated with a reduction in the costs of error correction, which in existing practice form a noticeable share of the total relocation cost, especially when delays occur, repeated visits to veterinary specialists are required, and emergency re-issuance logistics become necessary.

In the plane of technological sovereignty, the limitations of using fragmented specialized circuits (including TRACES and VEHCS) as a standalone solution for the private segment have been identified. Despite the institutional usefulness of such systems, they are oriented toward departmental tasks and do not provide non-governmental participants with an integrated user loop. Consequently, an overlay interface in the form of an API layer (API Layer) is required, aggregating data and transforming it into operationally applicable forms—structured checklists, contextual notifications, and event-based prompts—aligned with a specific route and the status of jurisdictions.

The priority of biosecurity sets requirements for provable data provenance and resistance to falsification. Embedding mechanisms of end-to-end traceability and distributed recording of critically significant events, including the use of blockchain components, creates conditions for the early detection of anomalies and the rapid containment of risks of zoonosis spread, including rabies and African swine fever (ASF). In such a configuration, control circuits become more transparent for legitimate movements due to the acceleration of verification of reliable data and simultaneously more closed to illegal traffic, since the cost and complexity of falsifying the evidentiary base increases.

Overall, the implementation of the proposed model sets a trajectory for the transition of the sector from a state of regulatory fragmentation to a managed digital ecosystem in which animal welfare is ensured not by intuitive interpretations and manual checks, but by algorithmically reproducible compliance procedures based on formalized rules, traceable data, and predictive verification.

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