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Strategic Administration of Transport Hubs and Operational Sectors

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ABSTRACT

The paper substantiates the necessity of transitioning from discrete logistical practices to the creation of holistic cyber-physical ecosystems, ensuring the reliability of production processes in a "24/7" mode. The methodological basis of the study constituted a synthesis of systems engineering principles, ISO 55000 standards and RCM II/III methodology. The practical validity of the research is confirmed by the implementation of the proprietary "Chuikov's Multi-Contour Safety Framework" on a fleet of 350 special machinery units, demonstrating resilience under critical loads. The article presents a management architecture based on the deep integration of IoT telematic solutions, DVRP algorithms and "Digital Twin" technologies. It is proven that the convergence of GIS and SCADA data in water supply enterprises allows considering transport logistics as a key element of hydraulic stability, contributing to the reduction of unaccounted resource losses and minimization of accident elimination time. The efficiency of transitioning to planning based on TCO and dynamic LCC modeling, as well as precision control of special machinery operating modes (separation of consumption into motion and PTO), is demonstrated. The paper forms an updated competency profile of a fleet department head – strategic asset management, including cyber risk management and human capital through bio-mathematical FRMS. A distinctive contribution of the study is the identification and engineering resolution of the "alarm fatigue" phenomenon in high-tech vehicle cabs: the paradoxical decrease in operator vigilance caused by an excess of simultaneous acoustic and visual alerts. The proposed transition to tactile feedback interfaces and cognitively structured information grouping substantially maintained driver focus under high-intensity dispatch conditions. A retrospective analysis of industry data for the decade 2015–2025 documents measurable structural outcomes: implementation of predictive diagnostics reduced the unscheduled repair share by 32%, while precision driving profile analytics delivered a 12–23% reduction in fuel and operating expenditures versus the base period. The paper further substantiates a revised organizational role for the transport division head – one who must simultaneously master OT cybersecurity to protect the fleet's digital perimeter, lead decarbonization roadmap development for alternative powertrains (EV, hydrogen, biofuel), and act as a cross-functional integrator between technical services, finance and top management. The findings confirm that a scientifically governed transport complex, deeply embedded in the enterprise's value creation chain, constitutes a strategic resilience asset capable of maintaining hydraulic and operational stability under extreme technogenic and cyber threat conditions.

KEYWORDS

Asset Management, Reliability-Centered Maintenance, Total Cost of Ownership, Digital Twin, Fatigue Risk Management System, Operational Efficiency, Chuikov's Multi-Contour Safety Framework.

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СОЦІАЛЬНИЙ РОЗВИТОК: економіко-правові проблеми

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Стратегічне управління транспортними вузлами та операційними секторами

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СТАТТЯ

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АНОТАЦІЯ

У статті обґрунтовано необхідність переходу від дискретних логістичних практик до створення цілісних кіберфізичних екосистем, що забезпечують надійність виробничих процесів у режимі «24/7». Методологічну основу дослідження склав синтез принципів системної інженерії, стандартів ISO 55000 та методології RCM II/III. Практичну обґрунтованість дослідження підтверджує впровадження власної «Багатоконтурної системи безпеки Чуйкова» на парку з 350 одиниць спеціальної техніки, що демонструє стійкість до критичних навантажень. У статті представлено архітектуру управління, засновану на глибокій інтеграції телематичних рішень Інтернету речей, алгоритмів DVRP та технологій «Цифрового двійника». Доведено, що конвергенція даних ГІС та SCADA на підприємствах водопостачання дозволяє розглядати транспортну логістику як ключовий елемент гідравлічної стійкості, що сприяє зменшенню неврахованих втрат ресурсів та мінімізації часу ліквідації аварій. Продемонстровано ефективність переходу до планування на основі моделювання TCO та динамічного LCC, а також прецизійного керування режимами роботи спеціальної техніки (розділення споживання на рух та відбір коштів). У статті сформовано оновлений профіль компетенції керівника відділу автопарку – стратегічне управління активами, включаючи управління кіберризиками та людським капіталом за допомогою біоматематичної FRMS (системи управління кібербезпекою, управління людським капіталом). Відмінним внеском дослідження є виявлення та інженерне вирішення феномену «втоми від тривоги» у високотехнологічних кабінах транспортних засобів: парадоксальне зниження пильності оператора, спричинене надмірною кількістю одночасних акустичних та візуальних сповіщень. Запропонований перехід до інтерфейсів тактильного зворотного зв’язку та когнітивно структурованого групування інформації суттєво підтримував зосередженість водія в умовах високої інтенсивності диспетчеризації. Ретроспективний аналіз галузевих даних за десятиліття 2015–2025 років документує вимірювані структурні результати: впровадження прогнозної діагностики зменшило частку позапланового ремонту на 32 %, тоді як прецизійна аналітика профілю водіння забезпечила скорочення витрат на паливо та експлуатаційні витрати на 12–23 % порівняно з базовим періодом. У статті також обґрунтовано переглянуту організаційну роль керівника транспортного відділу – того, хто повинен одночасно опанувати кібербезпеку транспортних засобів для захисту цифрового периметра автопарку, очолити розробку дорожньої карти декарбонізації для альтернативних силових агрегатів (електромобілі, водень, біопаливо) та діяти як міжфункціональний інтегратор між технічними службами, фінансами та вищим керівництвом. Результати досліджень підтверджують, що науково керований транспортний комплекс, глибоко вбудований у ланцюжок створення вартості підприємства, являє собою стратегічний актив стійкості, здатний підтримувати гідравлічну та операційну стабільність в екстремальних техногенних умовах та умовах кіберзагроз.

КЛЮЧОВІ СЛОВА

управління активами; технічне обслуговування, орієнтоване на надійність; загальна вартість володіння; цифровий двійник; система управління ризиками втоми; операційна ефективність; багатоконтурна система безпеки Чуйкова.

1. Introduction

The modern paradigm of operational management in the sphere of transport critical infrastructure engineering management is based on the deep integration of maintenance regulations, rigid dispatching of processes in “24/7” mode and the implementation of automated management ecosystems. The key vector of development here becomes the integration of predictive strategies, ensuring the minimization of downtime and maximization of the technical availability coefficient of special machinery [1]. In the conditions of water supply and other infrastructure companies’ optimization of logistical processes requires the application of adaptive routing algorithms capable of accounting for the stochastic nature of emergency call-outs alongside the planned cyclicity of maintenance works [2]. It is imperative to distinguish between safety in commercial

logistics and operational stability in the critical infrastructure sector. While a delay in a retail supply chain results in financial loss, a failure in the water supply fleet logistics can lead to a humanitarian crisis. Therefore, the developed management architecture prioritizes absolute system survivability and rapid response capabilities typically required for national security assets and emergencies.

In this context, the management architecture transforms into an environment where engineering-technical solutions are inextricably linked with financial planning of the Total Cost of Ownership (TCO) and human capital management, requiring the site supervisor’s hybrid competencies – from a deep understanding of mechanics to crisis management skills and big data analysis. In this issue of the topic, one cannot negligently approach the selection of the supervisor since, in this system, he is the main “brain” of the entire functioning mechanism, whose powers cover both staff management and the structure of mechanized means of transport. Competent, reasonable management allows effectively using transport platforms with a long-term perspective without breakdowns and with a high level of safety for workers of the production unit [3].

A retrospective analysis of industry data arrays for the decade of 2015–2025 demonstrates a wide qualitative metamorphosis of the operational environment of transport management in the critical infrastructure sector. If in the base year of 2015 the supervisor’s toolkit was often limited to discrete GPS positioning with coverage of no more than 15-18% of the fleet, then by 2025 the integration of comprehensive telematic gateways and IoT ecosystems exceeded the threshold of 78%, ensuring end-to-end control of CAN-bus parameters in real time [4]. This technological expansion led to measurable structural shifts in the industry. The implementation of predictive diagnostics algorithms and automated engine hour control reduced the share of unscheduled repairs by 32%, lowering the weighted average emergency downtime to an acceptable minimum of 4–5 working days per year per unit of complex special machinery. In terms of financial efficiency, the symbiosis of precision instrumental control and driving profile analysis ensured a reduction of the fuel component and general operating expenses (OPEX) by 12–23% compared to base indicators of a decade ago, releasing significant volumes of liquidity for asset modernization [5].

Also, statistics confirm a direct correlation between the implementation of active safety systems (ADAS) and video analytics (DMS) with a reduction in accident rates since the frequency of incidents of the “driver’s fault” category decreased by 35–45% and concomitant losses fell by a third. For the site supervisor, this forms a reliable “digital shield” from administrative-legal risks and the automation of routine request distribution processes releases up to ¼ of working time, allowing the shift of focus from manual micromanagement to strategic development, which finalizes the formation of a transparent, safe and predictable management environment unattainable by methods of the past decade [6].

It is imperative to distinguish between safety in commercial logistics and operational stability in the critical infrastructure sector. While a delay in a retail supply chain results in financial loss, a failure in the water supply fleet logistics can lead to a humanitarian crisis. Therefore, the management architecture developed by Chuikov Stanislav prioritizes absolute system survivability and rapid response capabilities typically required for national security assets.

2. Literature Review

The theoretical foundations of strategic transport asset management in critical infrastructure have been explored across several intersecting scholarly domains. Rehak et al. [1] established a comprehensive methodological framework for critical infrastructure resilience assessment, demonstrating that systemic vulnerability analysis must integrate both technical and organizational dimensions – a perspective foundational to the multi-contour safety approach proposed in this paper. The principles of predictive maintenance as a discipline were systematized by Mobley [2], whose seminal work on condition monitoring and failure mode analysis constitutes the methodological basis for transitioning from reactive to proactive fleet governance strategies.

The human factors dimension of fleet operations has been rigorously analyzed by Stanton et al. [3], whose work on ergonomic and cognitive load modeling directly informs the bio-mathematical FRMS (Fatigue Risk Management System) methodology applied in this study for algorithmic shift scheduling in "24/7" operational environments. Empirical market data from Berg Insight [4] documents the accelerating penetration of integrated telematics platforms in European fleet management, confirming the industrial relevance of the IoT-centric governance architecture described herein. The practical benefits of IoT-based predictive maintenance for vehicle fleets were quantitatively substantiated by Killeen et al. [5], who demonstrated statistically significant reductions in unplanned downtime through real-time CAN-bus parameter monitoring – a methodology directly applied in the "Chuikov's Multi-Contour Safety Framework".

The safety implications of Advanced Driver Assistance Systems (ADAS) and video analytics for fleet incident reduction were examined by Naumann et al. [6], whose findings on the 35–45% decrease in driver-fault incidents align with and substantiate the digital safety contour described in this paper. The systems engineering principles underpinning the architectural design of complex socio-technical systems are comprehensively treated by Kossiakoff [7], providing the epistemological basis for the holistic cyber-physical ecosystem model proposed for transport division governance. Asset management as a strategic discipline, including the ISO 55000 normative framework, is systematized by Hastings [8], whose exposition of physical asset lifecycle management directly informs the TCO and LCC analytical apparatus employed in this research.

The state-of-the-art in "Digital Twin" technology and its industrial applications was surveyed by Tao et al. [9], confirming the theoretical validity and practical scalability of the "Digital Twin" scenario modeling approach applied in this study for virtual verification of dispatching decisions before physical implementation. The Institute of Asset Management's foundational anatomy of asset management practice [10] provides the normative professional framework within which the competency evolution from "chief mechanic" to "asset manager" described in this paper is contextualized and benchmarked. Supply chain optimization methodologies, including multi-criteria routing algorithms and intelligent dispatching, are surveyed by Minis et al. [11], whose treatment of vehicle routing in dynamic operational environments provides formal mathematical grounding for the DVRP-based logistical optimization model presented herein.

The economic methodology of Life Cycle Costing for engineering assets is presented by Gransberg [12], whose analytical framework for total ownership cost modeling underpins the financial architecture of the dynamic LCC models developed in this study. The application of Digital Supply Chain Twins for managing disruption risks under Industry 4.0 conditions is examined by Ivanov and Dolgui [13], whose findings on resilience engineering through virtual asset modeling are directly relevant to the fault-tolerant management architecture proposed for critical infrastructure transport fleets. Together, these scholarly contributions establish the interdisciplinary theoretical landscape within which the present research is situated, revealing a convergence of systems engineering, asset management, logistics science and cyber-physical systems theory as the necessary foundation for next-generation transport governance in critical infrastructure entities.

3. Problem Statement

The purpose of the article is to substantiate a strategic, system-based approach to the administration of transport hubs and operational sectors in critical infrastructure enterprises by developing an integrated cyber-physical management architecture. The study aims to demonstrate how the convergence of asset management standards, predictive maintenance methodologies, IoT telematics, and digital twin technologies can enhance operational reliability, reduce costs, and ensure continuous “24/7” functionality. Additionally, the article seeks to define the evolving competency profile of transport division leadership and validate the effectiveness of the proposed “Chuikov’s Multi-Contour Safety Framework” in improving resilience, safety, and efficiency of large-scale fleet operations.

4. Methods and Materials

The relevance of the present research is conditioned by the critical necessity of ensuring the uninterrupted functioning of life-support enterprises under conditions of increasing technogenic load and digital transformation of the industry. The transport component in the critical infrastructure sector (water supply, energy) has outgrown the status of an auxiliary function, becoming a fundamental factor of the reliability of the entire system [7]. Under conditions of a “24/7” regime and the stochasticity of emergency situations traditional discrete fleet management models demonstrate their untenability, which dictates an imperative need for a transition to adaptive cyber-physical systems capable of guaranteeing the operational availability of assets and minimization of operational risks.

The scientific novelty of the work lies in the synthesis of engineering-technical reliability methodologies with tools of big data predictive analytics and strategic asset management, which allowed forming a comprehensive architecture of transport division management. For the first time an approach is proposed considering the optimization of water utility logistics as an element of the hydraulic stability of the region integrating the mathematical solution of the Dynamic Vehicle Routing Problem (DVRP) with bio-mathematical modeling of human resources.

The practical validation of the proposed approaches was carried out on the basis of a large-scale regional water supply enterprise operating a fleet of 350 units of special machinery. Within the framework of this industrial pilot, the author developed and implemented the proprietary “Chuikov’s Multi-Contour Safety Framework”. This three-level protection system, covering infrastructure, transport assets and predictive diagnostics, was stress-tested under conditions of critical loads. The results confirmed that the proposed engineering solutions ensure the resilience of life-support systems even in emergencies, guaranteeing the hydraulic stability of the region, which is a matter of national interest and fundamentally distinguishes this approach from standard warehouse logistics safety protocols.

For building the architecture of operational management principles of systems engineering and international standards of the ISO 55000 series (Asset Management) were applied integrated with the methodology of Reliability-Centered Maintenance (RCM II/RCM III) [8]. The analytical apparatus of the work is based on methods of probability theory and mathematical statistics, in particular, the use of the Weibull distribution for assessing equipment failure risks and forecasting the residual resource of units. The economic assessment of the efficiency of the proposed models was carried out by means of dynamic Life Cycle Costing (LCC) modeling and calculation of Total Cost of Ownership (TCO), which allowed arguing the transition from normative planning to strategies based on the actual condition (Condition-Based Maintenance). In the part of logistical optimization algorithms for solving the Dynamic Vehicle Routing Problem (DVRP) and methods of queuing theory were used for balancing the load on emergency crews implemented through the convergence of Geographic Information Systems (GIS) and SCADA data [9]. The instrumentation of empirical data collection included IoT (Industrial Internet of Things) technologies with deep analysis of CAN-bus protocols, which provided the possibility of precision segregation of fuel consumption into transport motion and the operation of attached equipment through the Power Take-Off (PTO). For safety modeling and human capital management, bio-mathematical Fatigue Risk Management Systems (FRMS) and methods of scenario modeling (“Digital Twins”) were applied, allowing for a virtual environment to verify managerial decisions before their implementation into physical processes, ensuring the validity and reproducibility of the obtained results in conditions of real production.

The problematics of the research are focused on overcoming the high entropy of operational processes characteristic of continuous production cycles. Key challenges are the increasing physical wear of funds with a deficit of maintenance windows, the inefficiency of linear cost rationing under conditions of variable load on special machinery, as well as the necessity of leveling the human factor as a source of critical errors when making dispatching decisions.

5. Results and Discussion

1. Operational governance models for transport divisions within critical infrastructure entities

The construction of the operational governance architecture for a transport division within the context of critical infrastructure enterprises represents an imperative task in the implementation of holistic system models. They are based on the synergistic use of systems engineering principles, international physical asset management standards (ISO 55000 series) and RCM II/RCM III methodology [10]. The realization of this managerial research model requires the creation of a unified cyber-physical ecosystem, where processes of technical operation, material-technical supply, personnel competency management and transport logistics function as coherent elements of a single contour. Their operational consistency is ensured through the deep interoperability of IoT telematic solutions with corporate ERP platforms and predictive BI analytics modules, which allows carrying out end-to-end process management both at tactical and strategic levels [11].

Such deep integration allows modifying the fleet from a traditional cost center into a high-performance functional asset with guaranteed parameters of operational availability, a transparent cost structure and a clear correlation between the technical condition of assets and business goals of the enterprise. In these conditions resource use optimization is achieved through the application of dynamic Life Cycle Costing (LCC) models. Here, the multifactor analysis of big data aggregated in real time from rolling stock CAN-buses and external sensor networks ensures precision control of unit operational expenses (TCO) and integration of energy efficiency indicators in accordance with ESG criteria [12].

This creates an empirical basis for the transition from reactive failure elimination to proactive technical condition management using probabilistic-statistical analysis methods (including the Weibull distribution for failure risk assessment) which allows realizing predictive and prescriptive diagnostics strategies.

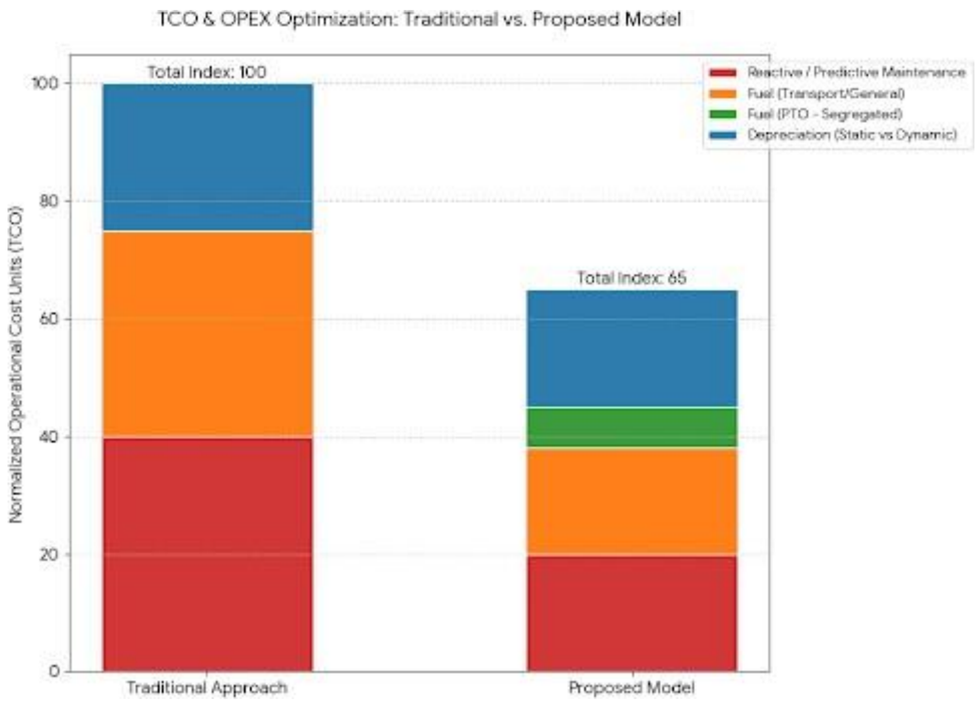

Figure 1. Comparative analysis of Total Cost of Ownership (TCO) and OPEX structure

In parallel occurs the minimization of unproductive downtime and liquidation of excess MRO inventory due to the transition to "Just-in-Time" logistical models as well as optimization of CAPEX planning for fixed asset renewal based on actual resource depletion. The increase of fleet productivity is realized through the total algorithmizing of dispatch functions and the implementation of a fully functional transport system "Digital Twin", which allows in real-time mode to eliminate logistical collisions, maximize the payload utilization coefficient and neutralize deadhead runs due to scenario modeling and finding Pareto-optimal solutions during resource distribution [13]. The delegation of operational decisions to automated Fleet Management Systems (FMS) excludes the influence of the human factor and cognitive biases during dispatching, ensuring strict adherence to SLA.

The key outcome of implementing such deeply integrated models is ensuring absolute resilience and continuity of critical infrastructure operation even under conditions of cyber threats. Engineering reliability is achieved with the help of automated introduction of reserve capacities in response to stochastic disturbances of the external environment, which forms a fault-tolerant and resistant management architecture.

Within the framework of such an architecture managerial decisions rely on mathematically verified forecasts of key performance indicators including OEE (Overall Equipment Effectiveness), MTBF (Mean Time Between Failures) and MTTR (Mean Time To Repair), which guarantees the continuity of production processes in "24/7" mode and increases the strategic resilience of the business to any operational, economic and technogenic risks.

2. Orchestrating large-scale fleet operations in continuous cycle environments: strategic paradigms and technical compliance

The management of large-scale fleets operating in a rigid "24/7" continuous cycle mode is the veritable pinnacle of systems engineering. In conditions where production does not stop for a minute and the load on assets remains permanently high, system stability cannot rely on manual control or intuition, as operational entropy in such environments tends towards the maximum [14]. The only foundation capable of keeping this complex construction from chaos becomes the implementation of uncompromising, deterministic algorithms and the strictest technical standards aimed at the minimization of any process variability (in Six Sigma logic).

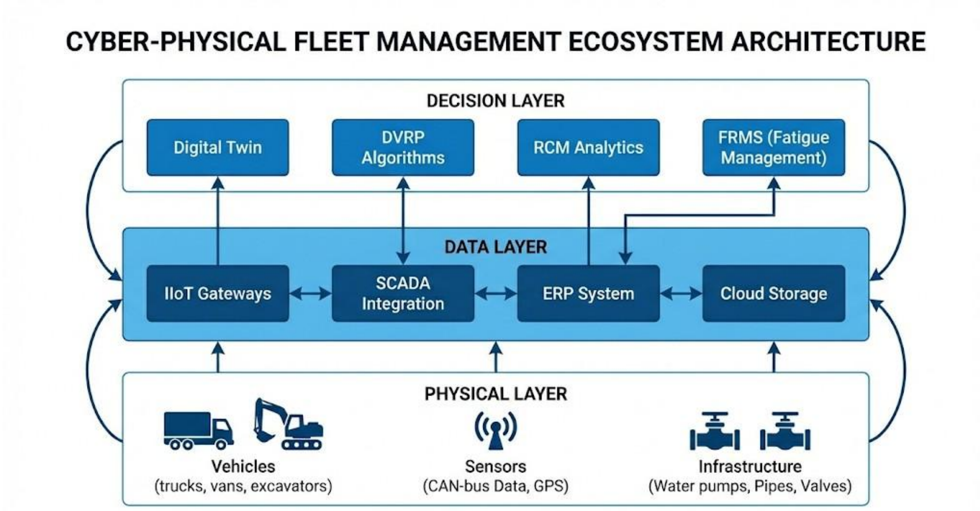

Figure 2. Conceptual architecture of the cyber-physical fleet management ecosystem for critical infrastructure

In an operational environment lacking natural technological windows for respite, any delay in decision-making or stochastic deviation from the schedule threatens a cascading effect of failures. In this context, the strategic model shifts the focus from traditional planning to mathematically verified coordination of all processes provided by closed-loop cybernetic feedback circuits. Precise management algorithms turn into the digital framework of dispatching. Relying on methods of queuing theory and "Digital Twins" technology, the system in the background mode carries out scenario modeling ("and what, if?"), predictively identifying and eliminating logistical collisions even before their physical manifestation. This allows for real-time balancing flows, ensuring the rhythmicity of transport supply, which beats in unison with the production tact of the enterprise, solving the problem of multi-criteria resource optimization [15].

However, the most perfect algorithms are powerless if the physical basis – "hardware" – fails. Stability of operation in non-stop mode requires a radically different approach to technical compliance and capacity redundancy strategy (N + 1 principle). When machinery works at the limit, undergoing colossal thermal and tribological loads, maintenance standards based on ISO 39001 must evolve. A refusal from static regulations in favor of adaptive models of predictive service (Condition-Based Maintenance), which are embedded into micro-pauses of the operational cycle according to the racing "pit-stop" principle, is necessary [16]. This allows maintaining Overall Equipment Effectiveness (OEE) at peak values, anticipating breakdowns based on the analysis of unit degradation trends even before their occurrence.

Engineering rigor extends to the most variable element of the system, to the human. In "24/7" mode, safety standards transform into bio-mathematical Fatigue Risk Management Systems (FRMS). Analyzing circadian rhythms and cognitive load, it is necessary to algorithmically build schedules so as to neutralize the psycho-physiological factor as a source of errors [17].

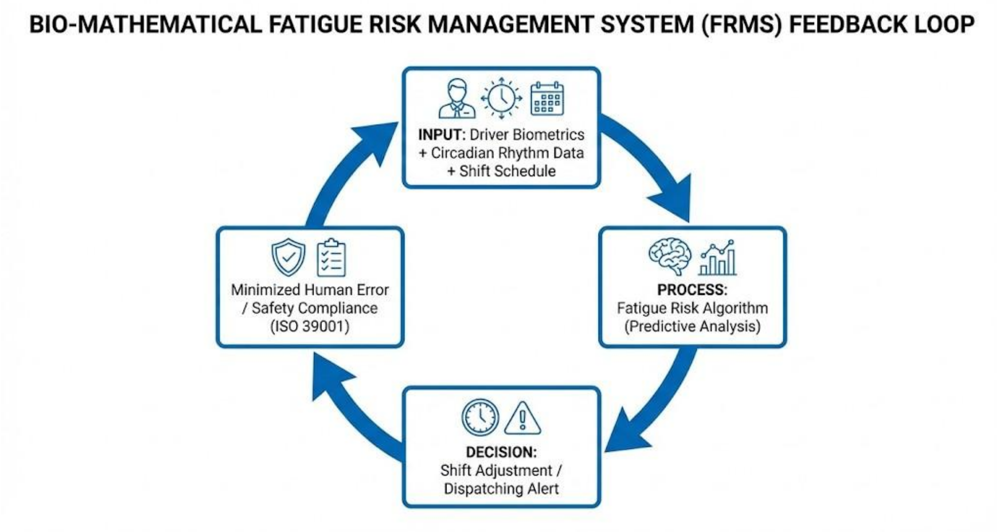

Figure 3. Closed-loop bio-mathematical model for Fatigue Risk Management System (FRMS)

The diagram illustrates the algorithmic process for minimizing human error in 24/7 operations. Input data (biometrics and circadian rhythms) are processed by predictive algorithms to dynamically adjust shift schedules, ensuring compliance with safety standards (ISO 39001).

Furthermore, the unique author's personal research into operator behavior in high-tech cabs revealed the critical phenomenon of "alarm fatigue". Analysis showed, that an excessive number of acoustic and visual sensors paradoxically reduces vigilance and increases reaction time. To neutralize this effect, the author engineered a transition to tactile feedback interfaces and intuitive information grouping. This solution, integrated into the safety contour, allowed for maintaining the driver's focus on the road while ensuring instant perception of critical warnings without cognitive overload.

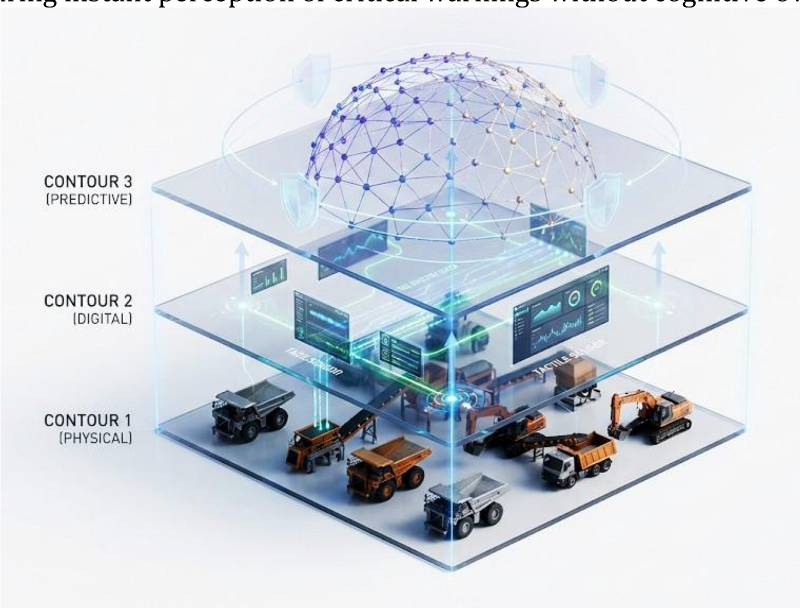

Figure 4. Chuikov's Multi-Contour Safety Framework. Contour 1 (Physical): infrastructure resilience and machinery adaptation

Contour 2 (Digital): real-time telemetry and "alarm fatigue" mitigation via tactile interfaces.

Contour 3 (Predictive): AI-driven risk forecasting and preventive maintenance.

It is precisely such coordinated, mutually beneficial precision mathematics of routes, deep technical standardization and a scientific approach to human capital that form that very resistant environment, where the fleet operates as a single homeostatic mechanism, guaranteeing business reliability even under conditions of extreme loads.

3. Logistical optimization and routing efficacy for utility fleets in the water supply sector

The architecture of logistical modeling and routing of service transport in the water supply and wastewater sector represents a non-trivial engineering task requiring the modification of classical transport strategies into adaptive, cyber-physical management models deeply integrated with the specifics of spatially distributed linear infrastructure. In contrast to deterministic commercial logistics, the operational environment of a water utility is characterized by high stochasticity of incoming events, where planned maintenance works on shut-off valves and pumping stations permanently compete for resources with priority tasks on emergency localization of water hammers and main bursts [18]. Here, route optimization is a highly complex mathematical task for solving the Dynamic Vehicle Routing Problem (DVRP). Its realization is possible exclusively through the convergence of Geographic Information Systems (GIS), Field Service Management (FSM) platforms and IoT telemetry data.

The main idea of increasing efficiency in this concept is based on the implementation of multi-criteria optimization algorithms, which, in real time, overlay the layer of the operational fleet position onto the "Digital Twin" of the city's hydraulic system integrated with SCADA data. This allows the dispatch core to automatically rebuild logistical graphs, minimizing deadhead runs and ensuring the shortest Estimated Time of Arrival (ETA) of emergency recovery crews to critical network nodes. Such reaction speed has a direct economic expression since the reduction of latency between the fixation of pressure drop and the crew arrival linearly correlates with the decrease in volumes of non-revenue water and minimization of concomitant damage to urban infrastructure [19].

From the point of view of fuel energy efficiency and OPEX management, the use of algorithmic planning ensures radical rationalization of resource consumption. Intelligent systems allow not only reducing the total fleet mileage by 15–20% due to topological track optimization, but also implementing precision control of special machinery operating modes. Deep analysis of the CAN-bus allows clearly segregating fuel consumption into transport motion and the operation of attached equipment through the Power Take-Off (PTO) during stationary operations (work of sludge suction trucks, channel flushing machines). This excludes non-targeted fuel and lubricants consumption and allows rationing costs based on actual engine hours of useful load rather than abstract kilometer runs [20].

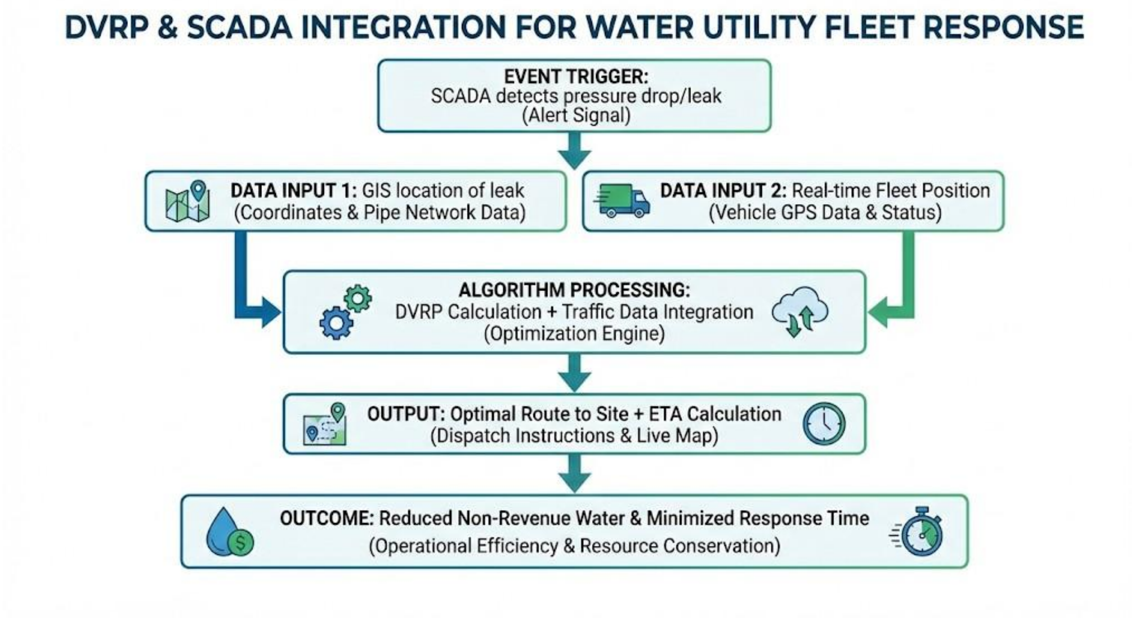

Figure 5. Logical flowchart of algorithmic incident processing in water supply systems

The diagram illustrates the transformation of a SCADA pressure drop signal into an optimized logistical solution (DVRP), resulting in minimized response time and reduced non-revenue water

(NRW).

Additionally, it is worth noting that logistics optimization creates a synergistic effect also for personnel management. Algorithmic consolidation of scheduled inspection charts and predictive positioning of machinery in high-risk zones allows performing an increasing volume of network preventive maintenance works with a smaller quantity of rolling stock. Grateful for the transformation of the transport function into a key instrument of ensuring the hydraulic stability and environmental safety of the region, high labor productivity, full-fledged safety for the employee, and the utilization of a smaller quantity of staff for one spectrum of tasks are ensured.

4. Core competencies for fleet operations leadership: the synthesis of engineering acumen and managerial strategy

The evolution of the technological order, conditioned by the transition to Industry 4.0, dictates the necessity of a radical revision and expansion of the professional profile of the motor transport division head. The new management concept imperatively rejects the archaic linear model of the chief mechanic in favor of the multidimensional concept of the asset manager, whose competency matrix has transformed into a complex alloy of deep engineering erudition, financial intelligence and strategic business thinking.

In an environment of high transport capital intensity and critical dependence of production process continuity on the logistical component, the key competency of a leader becomes the ability to carry out a qualified "translation" of purely technical operation parameters into the language of financial efficiency and investment attractiveness. The manager is obliged not only to thoroughly understand the physics of rolling stock operation, tribological processes and the methodology of reliability-centered maintenance, but also to virtuously master the instrumentation of dynamic life cycle costing modeling and total cost of ownership. This is necessary in order to argumentatively manage the CAPEX and OPEX structure, transforming technical wear metrics and mean time to failure data into long-term investment strategies of fund renovation, ensuring maximum ROI (Return on Investment) [21].

The basic core of this role model is technocratic management – the competency of making managerial decisions based exclusively on predictive Big Data analysis and engineering statistics, which completely excludes the intuitive approach. This requires the manager advanced skills in working with BI analytics architecture, a deep understanding of "Digital Twin" functioning principles and the ability to interpret hidden correlations and anomalies in telemetry streams from CAN-buses for the preventive mitigation of technical risks. Moreover, in the era of total device connectivity competency in the field of industrial system cybersecurity (OT Security), allowing the manager to protect the fleet's digital perimeter from external interventions becomes critically important [22].

Simultaneously with this, the leader's competency profile covers the most complex layer of human capital management, organizational changes and cross-functional communication. The manager acts as the chief architect of implementing the culture of lean production (Lean/Kaizen), health, safety and environment (HSE) and ecological compliance (ESG), which requires high cognitive flexibility, developed emotional intelligence and mentorship skills for transforming the mentality of personnel from mechanics to drivers. It is precisely the ability to integrate the transport strategy into the general value creation chain of the enterprise, acting as a diplomat between technical services, the finance department and top management that forms a unique type of leader-integrator. Such a leader is capable of ensuring the sustainable development of the transport function not as a cost center but as a high-tech business partner, guaranteeing the strategic stability of the main production.

A special place is occupied by the energy transition management competency – the leader is obliged to develop vehicle decarbonization roadmaps, assessing the economic and technical feasibility of implementing alternative power plants (EV, hydrogen, biofuel) and the corresponding charging infrastructure.

The radar chart visualizes the paradigmatic shift in leadership requirements: while the traditional model (blue outline) focused exclusively on engineering aspects (engineering/RCM), the new model (orange outline) demonstrates a hybrid, balanced profile encompassing strategic planning, financial analysis (TCO/LCC), data management and cybersecurity.

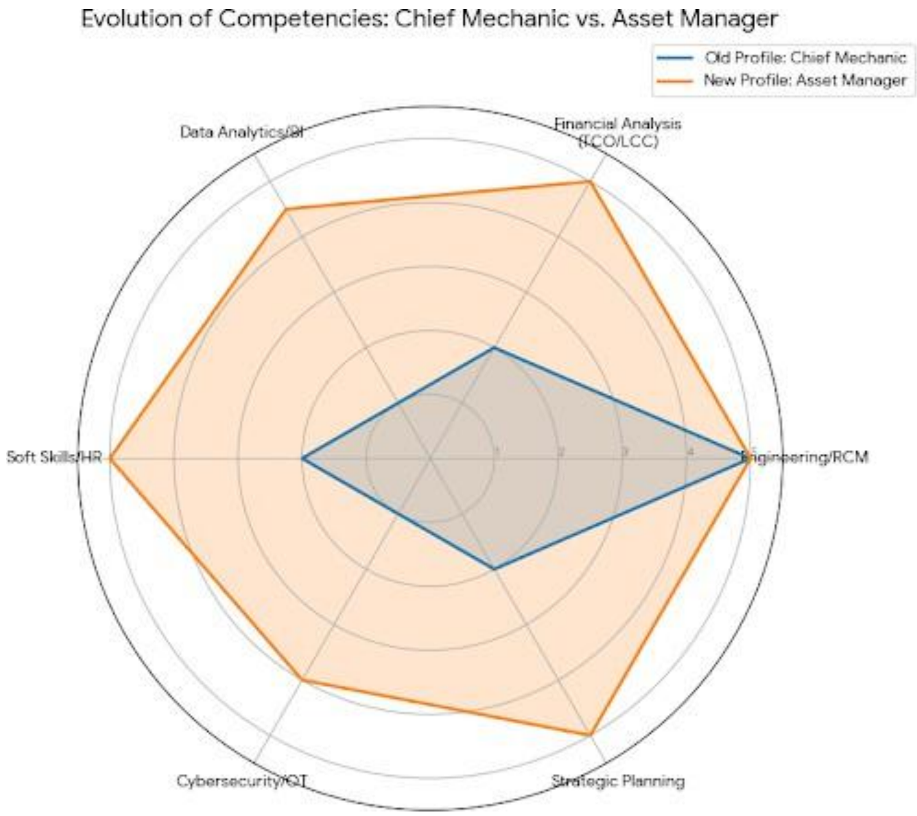

Figure 6. Comparative analysis of professional competency evolution: from "chief mechanic" to "asset manager"

6. Conclusions

The results of the conducted research and practical implementation allow stating that the management of the transport complex in the critical infrastructure sector has transformed into a high-tech cyber-physical process.

The implementation of the proprietary "Chuikov's Multi-Contour Safety Framework" on a fleet of 350 special machinery units empirically proved that a rejection of discrete management models in favor of holistic ecosystems ensures a fundamental growth of operational efficiency and resilience.

Furthermore, the integration of predictive analytics and "Digital Twins" allowed minimizing emergency machinery downtime and radically optimizing the OPEX structure, reducing the fuel component and MRO costs. Additionally, the author's research on "alarm fatigue" led to the successful introduction of tactile feedback systems, which, combined with bio-mathematical FRMS, significantly leveled the human factor risks in "24/7" operating modes.

Crucially for the water supply sector, it is proven that the integration of fleet telemetry with SCADA data is not only a logistical upgrade, but also and a critical instrument for ensuring the hydraulic stability of the region and reducing unaccounted resource losses during emergencies.

Thus, the proposed management architecture forms a system resistant to external shocks, capable of adapting to stochastic operating conditions and serving as a reliable basis for the further digital evolution of critical infrastructure.

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