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PREDICTIVE TELEMETRY IN THE MANAGEMENT OF BUSINESS PROCESSES IN THE AUTO TRANSPORT INDUSTRY

ПРОГНОСТИЧНА ТЕЛЕМЕТРІЯ В УПРАВЛІННІ БІЗНЕС-ПРОЦЕСАМИ АВТОТРАНСПОРТНОЇ ІНДУСТРІЇ

The automotive industry is undergoing a significant transformation driven by advances in technology, particularly in IoT, big data analytics, and predictive telemetry. This research explores the development and implementation of predictive telemetry platforms for business process management in the automotive industry. Leveraging IoT devices and big data, these platforms analyze telemetry data from vehicles, enabling informed decision-making and improved management processes. A key focus is on how predictive telemetry enhances the development, safety, and performance optimization of autonomous vehicles, which rely on accurate, timely data for decision-making. By analyzing sensor data, these platforms forecast potential issues, ensuring the safety and reliability of autonomous systems while reducing downtime and enhancing performance. The study also examines the impact of predictive telemetry on customer experience and service personalization. By analyzing data on driving habits, vehicle usage, and performance metrics, companies can create tailored services, such as personalized maintenance schedules based on actual usage. Predictive analytics further informs the development of features and services aligned with customer preferences. In aftermarket processes, telemetry data streamlines operations like inventory management, warranty services, and customer support. For instance, predictive insights help anticipate parts demand, optimize inventory, and reduce costs. Early defect detection allows for proactive recalls or repairs, enhancing customer satisfaction and protecting brand reputation. The research incorporates case studies of companies that have implemented predictive telemetry platforms, highlighting challenges such as data integration, scalability, and cybersecurity. Despite these hurdles, the findings demonstrate substantial benefits, including increased efficiency, cost savings, and customer loyalty. In conclusion, integrating predictive telemetry platforms transforms business process management in the automotive sector. By leveraging IoT and big data, companies can make informed decisions to optimize vehicle performance and elevate customer experiences. This research emphasizes the importance of investing in predictive telemetry technologies to remain competitive in a data-driven industry.

Keywords: predictive telemetry, business process management, automotive industry, Internet of Things, Big Data analytics, autonomous vehicles.

Автомобільна індустрія зазнає значних трансформацій, спричинених розвитком технологій, зокрема Інтернету речей (IoT), аналітики великих даних та предиктивної телеметрії. У цьому дослідженні розглядається розробка та впровадження платформ предиктивної телеметрії для управління бізнес-процесами в автомобільній індустрії. Використовуючи IoT-пристрої та великі дані, ці платформи аналізують телеметричні дані з транспортних засобів, забезпечуючи прийняття обґрунтованих рішень та покращення процесів управління. Основна увага приділяється тому, як предиктивна телеметрія сприяє розвитку, безпеці та оптимізації продуктивності автономних транспортних засобів, які залежать від точних і своєчасних даних для прийняття рішень. Аналізуючи дані з сенсорів, ці платформи прогнозують потенційні проблеми, забезпечуючи безпеку й надійність автономних систем, одночасно скорочуючи простої та покращуючи продуктивність. Дослідження також вивчає вплив предиктивної телеметрії на клієнтський досвід та персоналізацію сервісів. Аналізуючи дані про звички водіння, використання транспортних засобів та показники продуктивності, компанії можуть створювати індивідуалізовані послуги, такі як персоналізовані графіки технічного обслуговування на основі реального використання. Предиктивна аналітика додатково сприяє розробці функцій і послуг, що відповідають уподобанням клієнтів. У процесах післяпродажного обслуговування телеметричні дані оптимізують такі операції, як управління запасами, гарантійне обслуговування та підтримка клієнтів. Наприклад, предиктивна аналітика допомагає прогнозувати попит на певні запчастини, оптимізувати рівні запасів та скорочувати витрати. Раннє виявлення дефектів дозволяє проводити проактивні відкликання чи ремонти, покращуючи задоволеність клієнтів і захищаючи репутацію бренду. Дослідження включає кейсстадії компаній, які успішно впровадили платформи предиктивної телеметрії, висвітлюючи такі виклики, як інтеграція даних, масштабованість та кібербезпека. Незважаючи на ці труднощі, результати демонструють значні переваги, включаючи підвищення ефективності, зменшення витрат і зміцнення лояльності клієнтів. На завершення, інтеграція платформ предиктивної телеметрії трансформує управління бізнес-процесами в автомобільному секторі. Використовуючи IoT і великі дані, компанії можуть приймати обгрунтовані рішення для оптимізації продуктивності транспортних засобів і покращення клієнтського досвіду. Це дослідження підкреслює важливість інвестицій у технології предиктивної телеметрії, щоб залишатися конкурентоспроможними в умовах дедалі більшого впливу даних на галузь.

Ключові слова: прогностична телеметрія, управління бізнес-процесами, автомобільна індустрія, Інтернет речей, аналітика великих даних, автономні транспортні засоби.

Statement of the problem. The automotive industry is undergoing a rapid transformation driven by technological advancements, particularly in predictive telemetry, IoT, and big data analytics. These innovations promise smarter, safer, and more efficient vehicles while revolutionizing business process management (BPM) by enabling real-time insights and predictive decision-making. However, the integration of these technologies into the automotive sector faces significant challenges.

Predictive telemetry offers immense potential to enhance operational efficiency, improve vehicle safety, and optimize performance. Despite this, the lack of standardized frameworks for implementing predictive telemetry platforms hinders widespread adoption. Key issues include the seamless integration of IoT devices with existing systems, the scalability of platforms to handle vast amounts of telemetry data and ensuring robust cybersecurity to protect sensitive data from unauthorized access.

Moreover, as the industry shifts toward electrification and autonomous vehicles, predictive telemetry platforms must support increasingly complex systems, including battery management for electric vehicles (EVs) and sensor-driven decision-making for autonomous vehicles (AVs). These advancements require high accuracy, reliability, and predictive capabilities, particularly for safety-critical applications, which are often underdeveloped in current solutions.

Additionally, while predictive analytics can improve customer experience and service personalization, many automotive companies struggle to leverage telemetry data effectively due to limited expertise in big data analytics and machine learning. Challenges also extend to aftermarket business processes, where predictive insights could optimize inventory management, streamline warranty services, and enhance customer support, yet these opportunities remain underutilized.

This research aims to address these challenges by exploring the development and implementation of interactive predictive telemetry platforms tailored to automotive BPM. By identifying gaps in current technologies and providing practical solutions, the study seeks to unlock the full potential of predictive telemetry in transforming the automotive industry's business processes, ensuring efficiency, safety, and customer satisfaction in an increasingly competitive and data-driven landscape.

Analysis of recent research and publications. Business Process Management (BPM) represents a systematic approach to analyzing, designing, implementing, monitoring, and optimizing organizational processes to improve performance and achieve business objectives (Dumas M., La Rosa M., Mendling J., & Reijers H.A. [1]). In the automotive sector, BPM is crucial due to its complexity, high competition, and the increasing need for efficiency and innovation. By adopting BPM, automotive companies can respond swiftly to market dynamics, comply with regulatory requirements, and meet evolving customer expectations (Mendling J., Pentland B.T., & Recker J. [2]). The integration of Industry 4.0 technologies, such as the Internet of Things (IoT), big data analytics, and artificial intelligence (AI), into BPM has transformed manufacturing, predictive maintenance, and supply chain management. This integration facilitates smarter operations, reduced downtime, and enhanced visibility in supply chains (Sony M. & Naik S. [3]). Li X., Ding Q., & Sun J. demonstrated that predictive maintenance using deep learning models effectively reduces engine failures by analyzing sensor data [4]. Similarly, Xu W., Zhou H., Cheng N., Lyu F., Shi W., & Shen X. emphasized that IoT-enabled vehicular communication systems improve traffic safety and efficiency by enabling real-time data exchange [5]. Big data analytics has become integral to enhancing vehicle safety and user experiences. For instance, Jahani H., Jain R., & Ivanov D. discussed how data analytics allows personalized services, such as tailored maintenance schedules and insurance premiums, based on driving patterns [6]. Moreover, Ozkan-Ozen Y.D. highlighted the cost-saving benefits of IoT in inventory management by predicting spare parts demand and optimizing stock levels [7]. Despite these benefits, implementing IoT and big data analytics in automotive BPM poses challenges, particularly in data security and scalability. El-Rewini Z., Sadatsharan K., & Selvaraj D.F. stressed the need for robust cybersecurity measures, including encryption and intrusion detection systems, to mitigate vulnerabilities in connected vehicle networks [8].

This review underscores the transformative potential of BPM enhanced by IoT and big data technologies. While challenges remain, the benefits in efficiency, cost reduction, and customer satisfaction make these technologies essential for competitiveness in the automotive industry.

Formulation of the research task. The primary objective of this research is to explore the integration and application of predictive telemetry in automotive BPM. By leveraging the capabilities of IoT, big data analytics, and advanced telemetry platforms, the study aims to achieve the following goals:

– analyze the role of predictive telemetry in BPM;
– evaluate customer-centric applications;
– identify challenges and solutions;
– demonstrate benefits through case studies;
– provide strategic recommendations.

This research aims to provide actionable insights for automotive manufacturers, technology providers, and industry stakeholders, enabling them to leverage predictive telemetry for sustainable growth and competitive advantage in a data-driven era.

Summary of the main research material. BPM has emerged as a critical tool for automotive companies to enhance efficiency, improve quality, foster innovation, and maintain a competitive edge. BPM involves the systematic approach to designing, executing, monitoring, and optimizing business processes to achieve organizational goals. The Table 1 summarizes the key aspects that highlight the significance of BPM in the automotive industry.

Automotive companies employ Business Process Model and Notation (BPMN) to visualize workflows and Robotic Process Automation (RPA) to streamline repetitive tasks, enhancing efficiency and reliability [19]. Lean and Six Sigma methodologies reduce waste and improve quality, critical in a competitive market [20]. IoT devices enable real-time data collection for predictive maintenance and optimized production schedules, while big data analytics drive insights for decision-making [21]. Agile practices support rapid innovation, vital for the development of electric and autonomous vehicles [22].

IoT integration has transformed vehicles into connected devices. Sensors (e.g., LiDAR, cameras, radar) collect data on performance and safety parameters, powering Advanced Driver Assistance Systems (ADAS) for adaptive cruise control, lane-keeping, and collision avoidance [23]. Vehicle-to-Everything (V2X) communication facilitates real-time data exchange, enhancing intelligent transportation systems [24]. Edge computing processes vehicle data locally, reducing latency and improving real-time analytics.

Big data analytics processes vast telemetry datasets for predictive maintenance, traffic management, and personalized services. Machine learning models identify patterns, predict failures, and optimize processes, supporting strategic planning [25–27]. Techniques include data preprocessing, distributed computing, and real-time analytics, enabling actionable insights across performance, safety, and customer experience [28].

Predictive telemetry platforms integrate sensors, connectivity modules, data storage, and analytics engines to monitor and optimize operations. Examples include:

– Tesla's over-the-air updates for diagnostics [29].
– Bosch's predictive solutions for component wear [30].
– Continental's fleet management platform [31].
– Sigma Software's maintenance forecasting for brake pads [32].

Autonomous vehicles (AVs) heavily rely on telemetry for navigation and decision-making. Predictive telemetry improves sensor fusion, predictive maintenance, and redundancy systems while addressing cybersecurity and ethical challenges [26]. Enhanced mapping and V2X communication enable cooperative driving [28].

Telemetry also supports personalized services:

– adaptive driving assistance based on driver profiles;
– predictive maintenance alerts for proactive service;
– customized infotainment systems.

These advances improve customer satisfaction, loyalty, and overall user experience. Privacy concerns must be addressed through robust security measures and transparent policies [26].

The automotive industry is characterized by intricate and multifaceted business processes that span product development, manufacturing, supply chain management, sales, and after-sales services. Managing these complex processes presents numerous challenges that can impact efficiency, profitability, and competitiveness. Key challenges include globalization and supply chain complexity, rapid technological advancements, stringent regulatory requirements, evolving customer expectations, digital transformation hurdles, and workforce skill gaps (Table 2).

Managing complex automotive business processes requires addressing challenges like globalization, technological innovation, regulatory pressures, and evolving consumer behaviors. Companies must develop agile,

Table 1

Key aspects of BPM in the automotive sector

Key aspect	Description
Enhancing operational efficiency	Streamlines manufacturing processes, reduces waste, and optimizes resource utilization, resulting in reduced production cycle times and operational costs.
Facilitating digital transformation	Aligns advanced technologies such as IoT, AI, and big data analytics with business objectives, ensuring measurable improvements.
Improving quality and compliance	Establishes standardized processes for adhering to international quality standards and reduces defects.
Enhancing customer experience	Optimizes customer-centric processes, improves service delivery, and enhances customer satisfaction and loyalty.
Supporting innovation and agility	Enables rapid process reconfiguration to adapt to trends like electric vehicles and fosters collaboration.
Optimizing supply chain management	Improves visibility and coordination in global supply chains, managing risks and enhancing resilience.
Reducing costs and increasing profitability	Minimizes waste and operational expenses, leading to better financial performance.
Enabling data-driven decision making	Integrates data analytics into processes, supporting real-time, informed decision-making.
Enhancing collaboration and communication	Promotes teamwork and reduces organizational silos by defining clear processes and responsibilities.
Achieving sustainability goals	Identifies areas for reducing emissions and conserving energy, promoting eco-efficient practices.

Source: compiled based on [9–18]

Table 2

Challenges in managing business processes in the automotive industry

Challenge	Description
Globalization and supply chain complexity	Globalization has led automotive manufacturers to establish extensive supply chains across multiple countries. Managing this network increases complexity, highlighted during the COVID-19 pandemic, which caused supply chain disruptions. Addressing risks like geopolitical tensions and natural disasters requires resilient strategies.
Rapid technological advancements	The rise of EVs, autonomous technologies, and connected systems demands significant investment and changes in manufacturing. Balancing innovation with efficiency often requires transforming business models.
Regulatory compliance and environmental standards	Meeting international safety, emissions, and environmental standards requires continuous adaptation. Stricter sustainability requirements demand changes in product design and supply chains, with non-compliance risking penalties and reputational damage.
Evolving customer expectations	Customers demand personalized, high-quality, and technology-equipped vehicles. Manufacturers must adapt to shared mobility services and new ownership models while managing costs. Integrating customer feedback into product and service processes is crucial.
Digital transformation and data management	Integrating digital technologies with legacy systems introduces challenges. Managing data generated by connected vehicles requires advanced analytics and strong IT infrastructure. Cybersecurity threats add to the risks.
Supply chain disruptions and risk management	Events like pandemics and natural disasters disrupt supply chains, exacerbated by the just-in-time inventory model. Resilient supply chains require comprehensive risk assessment and contingency planning.
Workforce skills gap and organizational change	Adopting advanced manufacturing and digital tools demands new workforce skills, such as expertise in AI and robotics. Recruiting talent and fostering an innovative organizational culture is challenging.
Integration of complex IT systems	Automotive companies face challenges integrating legacy systems with new platforms. Seamless communication is essential for real-time data sharing, but system integration issues can hinder efficiency and decision-making.
Managing product complexity and lifecycle	Advanced electronics and connectivity increase vehicle complexity. Managing lifecycle processes, from design to disposal, requires sophisticated coordination among departments and careful tracking of numerous components and configurations.
Sustainability and circular economy integration	Adopting sustainability and circular economy principles involves practices like recycling and responsible sourcing, adding complexity to supply chain processes. Balancing environmental and economic goals requires precise management.

Source: author own elaboration

resilient processes, integrate advanced technologies, upskill their workforce, and adopt sustainability practices to remain competitive in the rapidly evolving industry.

Traditional BPM approaches without real-time data limit efficiency and competitiveness. Integrating real-time data into BPM enables timely decision-making, proactive management, enhanced customer engagement, and scalability. Real-time analytics within BPM frameworks improve performance and adaptability in complex environments.

Interactive predictive telemetry platforms are transforming BPM in the automotive industry by providing real-time insights and predictive analytics. These platforms collect and analyze data from IoT devices, sensors, and connected systems, enabling proactive management, reduced downtime, and optimized resource utilization.

Key benefits of predictive telemetry in BPM include:

1. Real-time monitoring: continuous monitoring detects inefficiencies and anomalies, ensuring optimal performance.

2. Predictive analytics: machine learning forecasts potential issues, enabling timely interventions and reducing costly downtimes [21].

3. Enhanced decision-making: interactive dashboards help stakeholders analyze data intuitively, facilitating informed decisions.

Telemetry data from production lines and machinery improves real-time monitoring of equipment health, production rates, and quality metrics, dynamically optimizing efficiency and reducing waste. It also enhances supply chain visibility by tracking the condition and movement of materials, reducing disruptions.

Connected vehicles generate vast data on performance and usage patterns, which can be analyzed to improve vehicle design, personalize services, and boost customer satisfaction.

Interactive predictive telemetry platforms are essential in modern industries for monitoring and optimizing operations. These platforms consist of multiple technical components that work together to collect, process, and present data effectively. Table 3 outlines the primary technical components and their respective functions across three key layers of such platforms.

Table 4 presents comparing KPIs before and after implementation predictive telemetry platform. Outcomes:

1. Reduction in downtime: Equipment failures decreased by 40% due to predictive maintenance scheduling.

2. Increase in production efficiency: overall efficiency improved by 15% through real-time adjustments.

3. Cost savings: maintenance and operational costs reduced by $2 million annually.

Table 3

Technical components of interactive predictive telemetry platforms

Layer	Component	Description
Data collection layer	Sensors and IoT devices	Collect data on parameters such as temperature, vibration, speed, and pressure.
	Connectivity solutions	Employ wireless technologies (e.g., 5G, Wi-Fi 6) for reliable data transmission.
Data processing and analytics layer	Data storage	Utilize cloud-based or edge computing solutions for secure, large-scale data storage.
	Analytics engines	Use machine learning algorithms to identify patterns and make predictions.
	Data integration tools	Ensure data compatibility and coherence from diverse sources.
User interface layer	Interactive dashboards	Provide visual data representation using graphs, charts, and KPIs.
	Customization options	Allow users to tailor the interface to focus on relevant metrics.
	Alert systems	Deliver real-time notifications for anomalies or critical events.

Source: author own elaboration

Table 4

Comparing KPIs before and after implementation predictive telemetry platform

KPI	Before implementation	After implementation
Equipment downtime (hours)	200	120
Production efficiency (%)	80	92
Maintenance costs ($)	5 million	3 million
Defect rate (%)	5	2

Source: author own elaboration

Advancements in AI will enhance predictive capabilities, allowing for more accurate forecasting and automated decision-making. Processing data closer to the source reduces latency, improving real-time analytics essential for critical operations [13]. Beyond manufacturing, these platforms can optimize logistics, sales processes, and customer service operations within BPM. By leveraging real-time data and predictive analytics, automotive companies can enhance decision-making processes, optimize operations, and deliver superior products and services. Table 5 summarizes the impact of predictive telemetry across development, safety, performance, and customer experiences domains.

The adoption of interactive predictive telemetry platforms profoundly impacts the automotive industry, enabling accelerated innovation, enhanced safety, optimized vehicle performance, and personalized customer experiences. These platforms improve operational efficiency, strengthen brand reputation, and boost customer loyalty, making them essential for competitiveness in a dynamic market.

Strategic importance:

1. Competitive advantage: offers advanced features, superior performance, and personalized services.
2. Operational efficiency: real-time monitoring and predictive analytics streamline processes, cut costs, and enhance resource utilization.
3. Innovation and adaptability: access to data supports continuous improvement and rapid market adaptation.
4. Industry 4.0 alignment: promotes digital transformation and smart manufacturing.
5. Customer satisfaction: enhances safety and personalization, improving loyalty and long-term success.

Steps for adoption:

1. Set objectives: define goals for efficiency, safety, or customer service improvements.
2. Invest in scalable infrastructure: leverage cloud and edge computing for data management and scalability.
3. Prioritize security and privacy: implement robust cybersecurity measures, ensure regulatory compliance, and develop clear privacy policies.
4. Ensure data quality: establish governance frameworks and use standardized formats for seamless integration.
5. Foster readiness: engage stakeholders, provide training, and manage organizational changes effectively.
6. Collaborate with partners: work with experienced vendors and stay updated on emerging technologies.
7. Monitor performance: define KPIs, track outcomes, and optimize processes.

By following these steps, automotive companies can minimize risks and fully realize the benefits of predictive telemetry platforms.

Conclusions. The findings underscore the transformative potential of predictive telemetry in optimizing business processes within the automotive sector. Key benefits include enhanced decision-making, optimized development cycles, improved performance and safety, and elevated customer experiences. Real-time data and predictive insights drive operational efficiency, reduce downtime, and enable personalized services that boost customer satisfaction and loyalty. However, challenges such as data integration, scalability, cybersecurity, and regulatory compliance must be addressed. Best practices include robust data governance, scalable infrastructure, and employee training to facilitate effective adoption.

In conclusion, predictive telemetry platforms offer significant opportunities for innovation, efficiency, and competitiveness. Strategic implementation and continued collaboration among stakeholders are vital to overcoming challenges and unlocking the full potential of these technologies.

Table 5

The impact of predictive telemetry across development, safety, performance and customer experiences domains

Category	Subcategory	Description
Impact on vehicle development	Accelerated development cycles	Predictive telemetry accelerates development cycles by providing real-time performance data, enabling rapid prototyping and iterative improvements. Reduces time-to-market by up to 20%.
	Enhanced design optimization	Telemetry data informs better material selection, component design, and system integration, resulting in more efficient and reliable vehicles.
Impact on safety	Proactive safety measures	Early detection of safety issues through telemetry enables manufacturers to prevent accidents by predicting failures. Reduces safety-critical failures by 30%.
	Enhanced autonomous driving safety	Telemetry feeds ADAS systems with real-time data, improving decision-making algorithms for obstacle detection and avoidance by 25%.
Impact on performance	Optimization of vehicle efficiency	Continuous monitoring and adjustment of engine performance and fuel consumption lead to a 15% increase in fuel efficiency.
	Reduction of downtime through predictive maintenance	Forecasting part failures with telemetry reduces unexpected breakdowns, cutting vehicle downtime by 40%.
Impact on customer experience	Personalized services and improved satisfaction	Telemetry enables customized maintenance schedules and feature recommendations, increasing customer satisfaction by 20% and brand loyalty by 15%.
	Enhanced reliability and trust	Predictive telemetry enhances vehicle reliability, increasing customer trust and influencing repurchase decisions.
	Streamlined after-sales support	Real-time telemetry data improves diagnostics and reduces repair times by 30%, enhancing after-sales service experiences.

Source: compiled based on [21–28]

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