Oversized Transport of EU States in the Era of Artificial Intelligence

Oversized transport in European countries is an essential component of international logistics, playing a critical role in the transport of industrial equipment, large structures or other goods that exceed the standard dimensions and weight allowed for transport. These operations are regulated by strict laws and involve detailed planning. In the European Union, this type of transport is regulated by a combination of national legislation and European directives, with the aim of ensuring road safety and protecting infrastructure. Although each Member State has its own regulations and procedures, there are common elements thanks to European harmonization. Oversized transport has entered a new era with artificial intelligence, which has led to a significant transformation in the way it is planned, managed and executed. The impact of artificial intelligence on oversized transport is major, from route planning, real-time monitoring and coordination of transport, automation of authorization processes, to transport safety and risk reduction, cost optimization and the use of drones for surveillance and robots for secondary operations. Artificial intelligence is transforming oversized transport into a safer, more efficient and more sustainable field, AI being an essential tool to cope with the complexity of this type of transport, opening up new perspectives for logistics and industry.

Keywords: *Oversized transport, Artificial Intelligence, EU States, digitalization, sustainable development goals.*

Introduction

Road transport constitutes a fundamental pillar of modern economies, facilitating the intricate movement of goods and individuals from origin to destination. Within this expansive domain, oversized transport represents a specialized and inherently complex segment. This category encompasses the movement of indivisible goods or the operation of vehicles that, even unladen, exceed standard constructive masses and/or maximum permissible dimensions. Such operations are characterized by stringent regulatory requirements and significant operational complexities. As a specialized form of road freight transport, oversized transport operations must adhere to general road transport operator regulations, such as those stipulated by EU legislation (e.g., Regulation EC 1071/2009, modified by Regulation (UE) 2020/1055), which mandate criteria like effective and stable establishment, good repute, professional competence, and financial capacity. Furthermore, specific conditions apply to the handling of oversized loads, including specialized driver certifications and, where legally mandated, the use of authorized escort vehicles or specialized operators.

The European Union's oversized transport[1] landscape is currently undergoing rapid evolution. This is primarily driven by an escalating demand for the cross-border movement of large industrial components, specialized machinery, and critical infrastructure elements, essential for various sectors including energy, construction, and manufacturing. Concurrently, Artificial Intelligence (AI) has emerged as a disruptive technological force, demonstrating profound transformative potential across diverse industries. AI promises to revolutionize logistics by optimizing operational processes, significantly enhancing safety protocols, and substantially reducing associated costs.

This academic paper aims to provide an in-depth analysis of the intersection between oversized transport practices in EU Member States and the burgeoning capabilities of AI. The study will meticulously examine the current state of oversized transport, outlining its prevailing regulatory framework and inherent operational challenges. The efficient transport of oversized cargoes is indispensable for urban and industrial development, facilitating the movement of critical components for infrastructure, energy, and manufacturing sectors. However, its integration within increasingly dense and sustainability-focused urban environments presents significant challenges, particularly concerning existing transport infrastructure and environmental objectives[2]. Subsequently, it will delve into the specific applications of AI within this context, exploring both the promising opportunities and the formidable challenges associated with integrating AI-driven solutions into this highly regulated and operationally demanding domain.

Literature Review

The academic discourse on transport and logistics has increasingly focused on the intersection of technological innovation and regulatory frameworks. Traditional research on oversized transport[3] has primarily concentrated on engineering challenges, infrastructure limitations, and the complexities of national permitting procedures[4]. Studies by organizations such as the International Road Transport Union (IRU) have consistently highlighted the administrative burdens and fragmentation of regulations across European borders as significant impediments to efficient oversized transport operations[5]. These challenges often lead to increased costs, delays, and a heightened risk of non-compliance.

[1]Bădescu & Purcar (2017) In *MATEC Web Conf. Volume 121*, “Trends in New Industrial Revolution”, https://doi.org/10.1051/matecconf/201712106001

[2]Petru & Krivda, (2021), 13, 5524. https://doi.org/10.3390/su13105524

[3]Bahram, Haibo & Lutfu (2023) *Logistics*, 7, 98. https://doi.org/10.3390/logistics7040098

[4]European Commission. *Transport policy: Road transport - Weights and dimensions*. Available online: https://transport.ec.europa.eu/transport-themes/road-transport/weights-and-dimensions_en (Accessed for general EU regulatory context).

[5]IRU (International Road Transport Union). *Challenges of Abnormal Loads Transport in Europe*. [Search for reports or articles on IRU website related to special transports and administrative barriers]. Available online: https://www.iru.org/ (Provides insights into cross-border complexities).

The advent of Artificial Intelligence has catalysed a new wave of research across various transport modalities. In general logistics, AI is being explored for its potential in route optimization, demand forecasting, warehouse management, and autonomous vehicle operation[6]. Specifically, in the broader context of intelligent transport systems (ITS), AI algorithms are recognized for their capacity to process vast datasets from sensors, cameras, and telematics devices to manage traffic flow, predict congestion, and enhance urban mobility[7]. The European Commission's Digital Transport and Logistics Forum (DTLF) emphasizes the importance of digitalization and data sharing for improving freight transport efficiency across the EU[8].

However, the application of AI specifically to oversized transport, a niche yet critical segment, remains an area requiring more dedicated academic attention. While general AI applications in smart transport[9] (e.g., smart parking, traffic optimization in urban settings) have been extensively studied[10], the unique complexities of oversized loads – such as specific infrastructure constraints (bridge capacities, tunnel clearances), stringent safety requirements, and highly individualized permitting processes – present distinct challenges and opportunities for AI integration. Existing literature often overlooks the intricate relationship between oversized cargo transport and the principles of sustainable urban infrastructure, failing to comprehensively analyse how the unique demands of oversized loads—including their dimensions, weight, and specific routing requirements—conflict with or can be harmonized with urban[11] sustainability goals, such as reduced emissions, optimized traffic flow, and minimized infrastructure wear[12].

Existing literature on AI in governance and public service highlights the potential for automation in administrative processes, such as permit issuance and compliance checks[13]. However, these studies also caution about the ethical, legal, and social implications of AI, including issues of liability, data privacy,

[6]KPMG. *Driving change: How AI is transforming the transport industry*. Available online: https://kpmg.com/xx/en/home/insights/2023/10/driving-change-how-ai-is-transforming-the-transport-industry.html (Accessed for AI applications in route optimization and logistics).

[7]European Parliament Think Tank (EPRS). *Artificial intelligence and transport: New challenges for EU law*. Available online: https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2020)642838 (Analyses legal and ethical challenges of AI in transport).
Also, see https://digital-strategy.ec.europa.eu/ro/policies/digitalisation-mobility

[8]European Commission's Digital Transport and Logistics Forum (DTLF). Search for reports and best practice guides on the digitalization of freight transport in the EU. Available online: https://transport.ec.europa.eu/transport-themes/digitalisation-transport-and-logistics_en (Relevant for EU-level digital initiatives in transport).

[9]Petru & Krivda (2020)

[10]ENISA (European Union Agency for Cybersecurity). *Cybersecurity in the Transport Sector*. Available online: https://www.enisa.europa.eu/publications/cybersecurity-in-the-transport-sector (Provides insights into cybersecurity risks in connected transport infrastructures).

[11]Szczucka-Lasota (2017) Series Transport, vol 97: 157-165. DOI: https://doi.org/10.20858/sjsutst.2017.97.14

[12]Petru & Krivda (2021) 13, 5524

[13]Deloitte. *AI in Government: The Future of Public Service*. Available online: https://www2.deloitte.com/us/en/insights/focus/cognitive-technologies/ai-in-government-future-public-service.html (Accessed for AI in automating administrative processes and digital permits).

algorithmic bias, and job displacement[14]. The European Parliament Think Tank (EPRS) and ENISA (European Union Agency for Cybersecurity) have underscored the urgent need for robust regulatory frameworks and cybersecurity measures to govern AI applications in safety-critical sectors like transport[15].

This paper aims to bridge the gap in the literature by specifically analysing how AI's capabilities can be adapted to the unique demands of oversized transport within the fragmented regulatory landscape of the EU, while critically assessing the associated opportunities and challenges.

Methodology

This paper employs a qualitative, analytical, and systemic review methodology to examine the integration of Artificial Intelligence into oversized transport within EU Member States. The research approach is structured as follows:

Literature review and synthesis

- An extensive review of academic literature was conducted using scientific databases
- Reports and policy documents from key international organizations (e.g., European Commission, OECD, IRU, World Economic Forum, UNECE, ENISA) were analysed to understand the current regulatory landscape, technological trends, and policy recommendations.
- The synthesis of this literature aimed to identify prevailing challenges in oversized transport, existing AI applications in broader transport sectors, and the specific opportunities and risks of applying AI to oversized logistics.

Conceptual framework development

- Based on the literature review, a conceptual framework was developed to map the potential applications of AI across the lifecycle of an oversized transport operation (planning, permitting, execution, monitoring, maintenance).
- This framework also integrates the socio-technical dimensions, considering the interplay between technological advancements, human factors, regulatory environments, and societal impacts.

Challenges and opportunities assessment

[14] Journal of Transport Geography / Transportation Research Part C: Emerging Technologies. (Academic journals for research on AI applications in logistics, heavy transport, and traffic management). Example: ScienceDirect or SpringerLink (Search for relevant articles).

[15] ENISA. *Cybersecurity in the Transport Sector*. Deloitte. *AI in Government: The Future of Public Service*.

- A critical assessment of the identified opportunities (e.g., safety, efficiency, cost reduction, sustainability) and challenges (e.g., regulatory lag, infrastructure investment, cybersecurity, data governance, ethical concerns) was performed. This involved analysing the interdependencies between these factors and their potential implications for EU Member States.
- The assessment draws upon existing academic critiques and policy debates surrounding AI implementation in complex public and private sectors.

Policy-oriented recommendations formulation

Drawing from the analytical findings and best practices identified in the literature, a set of actionable policy recommendations was formulated. These recommendations are designed to guide EU Member States and relevant stakeholders in strategically leveraging AI to overcome current challenges and foster a more robust, safe, and sustainable oversized transport ecosystem.

This methodology ensures a comprehensive and structured approach to understanding the complex dynamics of AI integration in oversized transport, providing a robust foundation for the discussions and conclusions presented.

Oversized transport in the EU: current framework and challenges

Oversized transport operations within the European Union are governed by a multi-layered regulatory architecture. This framework comprises overarching EU Directives and Regulations, which establish harmonized principles for general vehicle weights and dimensions, complemented by specific national legislation enacted by each Member State. The primary objectives of this intricate regulatory system are to ensure paramount road safety, safeguard critical infrastructure, and minimize disruptions to general traffic flow.

EU regulatory framework

General Directives: The European Union sets forth broad principles concerning vehicle weights and dimensions. However, it strategically grants Member States a degree of flexibility in regulating exceptional transports. This approach allows for the incorporation of national adaptations that account for unique infrastructure characteristics, diverse geographical conditions, and specific local requirements. This ensures that while a common baseline exists, the practicalities of diverse national contexts are accommodated[16].

National legislation: Each EU Member State maintains its distinct and detailed procedures governing the authorization of oversized transports. These national regulations encompass specific requirements for designated routes, the

[16]European Commission. *Transport policy: Road transport - Weights and dimensions*.

mandatory use of escort vehicles, and various traffic restrictions (e.g., limitations on specific hours, days, or under certain weather conditions). This national discretion frequently results in a fragmented and time-consuming process for obtaining cross-border permits, often necessitating approvals from multiple national, regional, and local authorities, thereby creating significant administrative complexities[17].

Within this national legislative landscape, it is crucial to acknowledge the strategic direction set by individual Member States. For instance, Romania's National Strategy for Intelligent Transport Systems (2022-2030), approved by Government Decision No. 877/2022 on the approval of the National Strategy on Intelligent Transport Systems for the period 2022-2030[18], outlines a clear commitment to digitalizing transport infrastructure and services. While not exclusively focused on oversized transport, this strategy's objectives – such as enhancing road safety, improving traffic flow efficiency, and promoting data exchange and interoperability – directly influence the environment in which oversized transport operates and pave the way for AI integration.

Key challenges in EU oversized transport

Complex route planning: The planning of oversized transport routes demands a meticulous, often manual, analysis of numerous infrastructure constraints. These include, but are not limited to, bridge capacities, tunnel clearances, the geometry of sharp turns, the presence of overhead obstacles (such as power lines or low-hanging structures), and the load-bearing resistance of road surfaces. This complexity is particularly pronounced for international routes that traverse diverse infrastructural landscapes[19].

Fragmented permit acquisition: The process of obtaining Special Transport Authorizations (STAs) across the EU is widely recognized as bureaucratic, protracted, and costly. Significant variations in regulatory requirements, application procedures, and processing times among Member States impose substantial administrative burdens and lead to considerable delays for cross-border operations, hindering the efficiency of the single market[20].

Safety concerns: The inherent physical characteristics of oversized vehicles – their immense size and reduced manoeuvrability – intrinsically elevate the risks of accidents. This necessitates the implementation of exceptionally stringent safety measures, specialized training for drivers, and, in many cases, mandatory professional escorts to manage traffic and mitigate potential hazards.

Infrastructure impact: The passage of oversized transports contributes disproportionately to the accelerated wear and tear of road networks and bridge

[17]IRU (International Road Transport Union). *Challenges of Abnormal Loads Transport in Europe*.

[18]National Strategy on Intelligent Transport Systems for the period 2022-2030. Approved by Government Decision no. 877/2022, published in the Official Gazette of Romania, Part I, no. 894 of September 8, 2022 [Strategia Națională privind sistemele de transport inteligente pentru perioada 2022-2030. Aprobată prin Hotărârea Guvernului nr. 877/2022, publicată în Monitorul Oficial al României, Partea I, nr. 894 din 8 septembrie 2022.]

[19]European Commission. *Transport policy: Road transport - Weights and dimensions*.

[20]IRU (International Road Transport Union). *Challenges of Abnormal Loads Transport in Europe*.

structures. This necessitates continuous and rigorous monitoring of infrastructure integrity, proactive maintenance schedules, and, in certain instances, temporary structural reinforcements to accommodate exceptionally heavy loads. The integration of oversized cargo transport within increasingly dense and sustainability-focused urban environments presents significant challenges, particularly concerning existing transport infrastructure and environmental objectives, including infrastructure limitations (e.g., bridge capacities, narrow streets) and environmental impacts[21].

High operational costs: These specialized transports incur substantially higher operational costs compared to standard freight movements. These costs stem from the intricate planning requirements, significant permit fees, expenses associated with escort services, elevated fuel consumption due to vehicle size and speed limitations, and extended transit times resulting from regulatory complexities and operational constraints.

Limited real-time information: A pervasive challenge is the lack of comprehensive, real-time data concerning infrastructure conditions, unforeseen temporary road closures, or unexpected obstacles across multiple national jurisdictions. This information deficit impedes dynamic route adjustments and proactive risk management[22].

Oversized transport in Greece, Romania, Germany and Poland – comparative study

Oversized transport is carried out differently depending on the legislative, infrastructural and administrative particularities of each Member State of the European Union. In the following, we analyze the situation in three representative countries: Greece, Romania and Germany, highlighting the common challenges and innovative solutions adopted in the context of the digital transition and the use of artificial intelligence (AI).

I. **Greece** – Difficult topography and slow digitalization

Greece, characterized by a predominantly mountainous topography and a road network composed largely of narrow national roads, faces major difficulties with regard to oversized transport. The road infrastructure is not always adapted to such transport, and the island networks further complicate logistics.

The challenges for this activity are multiple: lack of corridors dedicated to special transport; insufficiently digitalized port infrastructure for handling large loads; lack of digital interoperability between regional agencies. Recent developments in this area are important for the development of this sector. The most significant are: the Hellenic Road Authority has launched a digital portal for the authorization of special transport, but the system is not yet integrated at

[21] Petru & Krivda, 2021, 13, 5524. https://doi.org/10.3390/su13105524
[22] Ramūnas & Artūras (2012) No 1: 51–56, DOI 10.2478/v10244-012-0005-9

national level; pilot projects in collaboration with the Technical University of Athens use artificial intelligence to simulate oversized routes in mountainous areas.

Oversize transport in Greece – status, challenges and prospects

Background Greece, due to its geographical position in South-East Europe and its predominantly mountainous terrain, faces specific challenges in the field of oversize transport. The country has a major port on the Mediterranean Sea (Piraeus), which is a major hub for maritime freight transport, and road and rail connectivity to the interior of the continent is vital for European and Balkan trade.

Infrastructure and transport conditions:

- Mountain roads and islands: The difficult terrain imposes strict restrictions on oversized transport, especially on roads in mountainous areas (e.g. the Pindus Mountains or the Peloponnese area), where sharp curves and steep slopes limit the size and weight of vehicles.
- Lack of extensive motorways: The motorway network is still under development, which means that a large part of special transport uses national or regional roads, with traffic and infrastructure limitations.
- Combined maritime transport: Greece partially compensates for road limitations through the intensive use of combined maritime and river transport (roll-on/roll-off and oversized containers), especially in the transport of heavy industrial equipment and components for the energy industry.

Regulations and permits:

- Permits for oversized transport are issued by the Ministry of Infrastructure and Transport in cooperation with local authorities and the traffic police.
- The process is generally bureaucratic and lengthy, with approval times that can exceed 7 days.
- In 2023, Greece launched a digital pilot project for electronic issuance of permits, which includes a digital simulation component of routes to verify compatibility with road infrastructure and bridges.

The major challenges of this activity are:

- Insufficiently adapted infrastructure: The lack of dedicated corridors for special transport and old infrastructure hinder fast and safe transport.
- Natural limitations: Island and mountainous areas impose severe restrictions, often requiring complex logistical solutions (e.g. ferry transfers).

- Limited institutional cooperation: Fragmentation of competences between local and central authorities slows down the approval and planning process.

Perspectives and innovations

Greece is trying to integrate artificial intelligence and digital solutions to optimize the route and shorten the approval time.

The use of Digital Twins is being explored to simulate the impact of oversized transport on infrastructure, preventing damage and increasing safety. This technology is closely linked to European initiatives to digitize transport corridors (TEN-T), where Greece is investing heavily to become a logistics gateway between Asia and Central Europe.

Highway and expressway network development projects also include investments in special infrastructure for oversized transport, especially near ports and industrial centers.

II. Romania

Romania occupies a key geostrategic position within the European and Eurasian transport corridors, being located at the crossroads of trade routes linking Central and Western Europe with the Balkans, Ukraine, the Black Sea and Central Asia.

Oversized transport is vital for development of the energy sector (wind, hydro, nuclear power plants), large infrastructure projects (bridges, refineries, factories), defense and heavy equipment industries. However, Romania faces multiple systemic deficiencies that hinder efficiency and competitiveness in this area.

Road infrastructure and its limitations

The major problems in Romania are:

- Lack of continuous motorways: Although there are motorway sections (A1, A2, A3), they are fragmented and poorly connected to each other, which forces oversized transport to use national roads, which are often inadequate.
- Old bridges with restrictions: Many bridges in the national network have tonnage and height limitations, which impose long and expensive detours.
- Passing through urban areas: The lack of detour options forces oversized transport to transit large localities, exposing themselves to risks and delays.
- Lack of specialized corridors: There are currently no logistics corridors specifically dedicated to oversized transport, except for ad-hoc routes established by CNAIR for specific projects (e.g. transport to Cernavodă or refineries).

- Regulations and bureaucracy: Transport authorization is done through CNAIR, through the SEAST platform (Electronic System for Issuing Special Transport Authorizations). Although the platform is functional, in many cases the process is: slow (5–10 days for approval), fragmented (requires approvals from local authorities, traffic police, county road administrators), non-automated (lack of automatic route or infrastructure evaluation).

The identified problems in this activity are: lack of interoperability between SEAST and infrastructure, traffic or technical approval databases, lack of a real-time tracking system for requests and transports.

Examples and Case Studies

A. Transports for the Cernavodă nuclear power plant: some of the most complex oversized transports in Romania were organized to bring nuclear components; routes were planned manually, with extensive escort and temporary infrastructure repairs.

B. Wind farms in Dobrogea: transport of turbine blades (length > 60 m) was hampered by narrow roads and unstable bridges; in many cases alternative solutions were used, such as river transport combined with road transport.

C. Constanța Port expansion project: oversized transports through the port were delayed due to the lack of an efficient road connection between the terminals and the national network.

Artificial Intelligence in oversized transport – potential and initiatives

Although Romania is at an early stage in terms of the use of AI in logistics, specific initiatives have emerged in collaboration with the private sector:

- Romanian logistics start-ups (e.g. CargoPlanning, Trans.EU Romania) are testing algorithms for route optimization and clearance calculation based on satellite maps and GPS data.
- Pilot project in the Pitești industrial area: simulation with a “digital twin” of an oversized transport for the Dacia plant, in collaboration with the Politehnica University of Bucharest (2023).
- International collaborations: some Romanian companies involved in pan-European projects (through Horizon Europe) are testing AI modules for transport time predictability and infrastructure risk analysis.

Recommendations for Romania

1. Complete digitalization of the SEAST platform and its integration with: traffic police systems, CNAIR geospatial databases, county road networks.
2. Creation of permanent oversized logistics corridors, with adapted infrastructure and digital signage, at least on the following axes: Constanța – Bucharest – Pitești – Arad; Giurgiu – Bucharest – Ploiești – Brașov – Târgu Mureș.
3. Partnerships between technical universities and authorities for the development of AI tools applied to oversized transport planning.
4. Financing through PNRR or Cohesion Funds for the modernization of critical infrastructure (bridges, access ramps, roundabouts dedicated to special transport).

III. Germany – European leader in digitalization and regulation

Germany is considered one of the models of good practice in the field of oversized transport. Thanks to a modern infrastructure and a solid digital framework, Germany efficiently manages highly complex transports.

Solutions and best practices are done by VEMAGS platform (Verfahren für die Erteilung von Ausnahmegenehmigungen gemäß StVO) – national digital system for online authorizations, integrated with local authorities and police. Also, they have adapted infrastructure – federal roads and motorways designed to allow the transport of up to 150 tons without route deviation. Germany is using AI for predictive modeling – projects in partnership with the Fraunhofer Institute to optimize routes and reduce fuel consumption. Also, use integration with rail and ship logistics systems, with AI-assisted planning.

IV. Poland – An expanding regional logistics hub

Poland has become a strategic hub for European logistics in recent years, located at the crossroads of transport corridors connecting Eastern Europe with Germany, the Baltic countries and Scandinavia. This geographical position favors the development of oversized transport[23], especially for industrial components[24], energy equipment and construction materials for large infrastructure projects.

Challenges for this field:

- Regional bureaucracy: Special transport permits are still issued by local or regional road authorities, leading to variations in time and procedures.
- Data aggregation: Lack of an integrated national data system on road infrastructure adapted to oversized transport.
- Tensions in international transit: Poland handles a high volume of transport from Belarus and Lithuania, leading to congestion at customs points and busy routes.

[23]Macioszek (2019) 109-117, DOI:10.20858/sjsutst.2019.102.9
[24]Sławomir (2022) 136-152. DOI: 10.14254/jsdtl.2023.8-2.10.

Poland's initiatives and innovations in this field:

- e-Koncesje project: A digital system for issuing special permits for oversized transport, currently in the testing phase (2024). The platform uses artificial intelligence elements to automatically check the eligibility of routes based on vehicle dimensions.
- Collaboration with the Warsaw University of Technology: Polish researchers are working on risk simulation models for oversized transport, using digital twins and satellite data.
- Infrastructure investments: Construction and modernization of “oversized logistics corridors” between Gdańsk, Warsaw, Katowice and the German border, connected to intermodal terminals.
- Public-private collaboration: Companies such as PKP Cargo and Orlen Logistics are integrating AI for multimodal transport planning – combining road, rail and river – especially for energy transport.

Also, having a strategic positioning, Poland is investing significantly in its transformation into an AI-ready logistics hub, aiming to become a leader in Central Europe for special transport. However, digital fragmentation and differences between regional administrations continue to be an obstacle to the uniform implementation of AI-based solutions.

Comparative conclusions country degree of digitalization and infrastructure for oversize transport (2025)

Country	**Digitalization Level**	**Adapted Infrastructure**	**Authorization Time**	**AI & Digital Twins Use**
Greece	**Low / Developing**	**Medium** – Limited in mountainous areas and islands.	**High** (≥ 7 days)	**Pilot:** Route simulation and sensor-based monitoring for old bridges.
Romania	**Developing**	**Deficit** in key areas; new corridors (A1, A7) are being adapted.	**High** (≥ 10 days)	**Pilot:** GPS-based planning and flyover technologies for critical bridges.
Germany	**Advanced**	**Expanded & Modernized** with detailed tonnage databases.	**Low** (1–2 days)	**Active:** Real-time route optimization and Digital Twins for structures.
Poland	**Rapidly Progressing**	**Accelerated Expansion** of highway networks and logistics hubs.	**Medium** (3–6 days)	**Active:** AI-driven planning and integrated e-

Country	Digitalization Level	Adapted Infrastructure	Authorization Time	AI & Digital Twins Use
				authorization systems.

This comparison highlights a significant technological and administrative gap between EU member states in the heavy-lift and oversize transport sector:

- Digital Leaders (Germany, Poland): These countries have successfully integrated digital tools into their logistics chains. Germany utilizes Digital Twins to simulate structural stress on bridges under extreme loads, allowing for rapid approvals. Poland has drastically reduced bureaucracy through e-authorization systems (like the SENT system), significantly shortening wait times.
- Transitioning States (Greece, Romania): While these nations are receiving substantial EU funding for infrastructure, they remain in the early stages of digital integration.
    - In Greece, the focus is on 3D route simulations to navigate difficult coastal and mountainous terrain.
    - In Romania, there is a shift toward digital data planning for national strategic projects, but administrative bottlenecks remain a challenge.

The future of oversize transport relies as much on digital mapping as it does on physical infrastructure. Without a unified digital database of bridge capacities and road dimensions, countries like Greece and Romania will continue to face higher logistics costs due to administrative delays.

The role of Artificial Intelligence in transforming oversized transport in the EU

Artificial Intelligence presents a suite of innovative solutions capable of addressing many of the entrenched challenges within the oversized transport sector. By leveraging AI, significant advancements in optimization, predictability, and safety can be achieved.

AI for route optimization and logistics planning

The role of AI in this field is high:

Intelligent routing algorithms: AI-powered algorithms possess the capacity to analyse vast and complex datasets. These datasets include detailed Geographic Information Systems (GIS) data, real-time traffic conditions, dynamic weather forecasts, and granular infrastructure constraints (e.g., temporary bridge weight limits, structural integrity data). This analytical capability enables the identification of optimal routes that are not only the safest and most efficient but also fully compliant with all relevant regulations, thereby minimizing detours and optimizing fuel consumption[25]. These strategic approaches, including intelligent routing, are crucial technological solutions to mitigate conflicts between oversized transport demands and urban sustainability goals, such as optimized traffic flow[26].

Advanced simulations: AI-driven simulation models can accurately predict the multifaceted impact of oversized transport convoys on overall traffic flow and critical infrastructure. This predictive capability empowers operators and regulatory authorities to anticipate potential bottlenecks, structural stresses, or congestion points, facilitating proactive adjustments and mitigation strategies before the actual journey commences.

AI for streamlining authorization processes

Regarding this authorization process, AI can be used for:

- Automated compliance checks: AI systems can significantly enhance the efficiency of permit acquisition by automating the verification of permit applications against intricate national and EU regulations. These systems can rapidly cross-reference vehicle specifications, proposed routes, and legal requirements, thereby reducing manual review times, minimizing human error, and accelerating the approval process[27].
- Cross-border permit facilitation: A harmonized, EU-level AI system holds the potential to fundamentally streamline the acquisition of permits for multi-country routes. By enabling automated data sharing and validation between national authorities, such a system could drastically reduce administrative burdens, cut down on delays, and lower costs associated with international oversized transports.
- Predictive permitting: Leveraging historical data, AI can analyse past permit processing times to generate accurate predictions for future applications. This predictive capability assists operators in more precise planning and scheduling of their oversized transport operations.

AI for enhanced safety and monitoring

The advantages of AI in this sector are given by:

- Real-time obstacle detection: AI-powered computer vision systems, integrated with vehicle-mounted cameras and LiDAR sensors, can continuously monitor the oversized vehicle's dimensions in real-time relative to its immediate surroundings. This includes detecting potential

[25]KPMG. *Driving change: How AI is transforming the transport industry*. Available online: https://kpmg.com/xx/en/home/insights/2023/10/driving-change-how-ai-is-transforming-the-transport-industry.html (Accessed for AI applications in route optimization and logistics).
[26]Petru & Krivda, 2021, 13, 5524. https://doi.org/10.3390/su13105524
[27]European Parliament Think Tank (EPRS). *Artificial intelligence and transport: New challenges for EU law*. Available online: https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2020)642838 (Analyses legal and ethical challenges of AI in transport).

collisions with overhead cables, bridge structures, roadside obstacles, or other vehicles, providing immediate alerts to the driver or autonomously guiding the vehicle.

- Predictive risk assessment: AI can analyse comprehensive telematics data, driver behaviour patterns, and dynamic road conditions to identify high-risk road segments or anticipate potential hazards, providing proactive warnings.
- Advanced driver-assistance systems (ADAS): AI can significantly enhance existing ADAS features, such as adaptive cruise control, lane-keeping assist, and emergency braking. These systems can be specifically tailored to the unique dynamics and operational requirements of oversized vehicles, providing critical support to drivers.
- Drone surveillance: AI-equipped drones offer real-time aerial monitoring capabilities of the convoy and its surrounding environment. This technology can provide invaluable assistance to escort vehicles and traffic police, particularly during complex manoeuvres, in areas with limited visibility, or across challenging terrains[28].

AI for predictive maintenance and operational efficiency

AI can be used successfully for:

- Vehicle health monitoring: AI algorithms can analyse continuous data streams from sensors embedded within oversized vehicles (e.g., engine performance, tire pressure, braking system integrity). This enables the prediction of potential mechanical failures before they occur, facilitating proactive maintenance, minimizing costly breakdowns, and significantly reducing vehicle downtime.
- Infrastructure integrity monitoring: AI can process data from sensors strategically installed on critical infrastructure components (e.g., bridges, viaducts, road surfaces). This allows for the early detection of stress, fatigue, or damage caused by heavy loads, enabling timely repairs, extending the lifespan of infrastructure, and preventing catastrophic failures. This aligns with the need for dynamic infrastructure assessment to minimize infrastructure wear[29].
- Fuel optimization: AI can dynamically adjust vehicle operating parameters and suggest optimal driving behaviours based on real-time factors such as load weight, specific route characteristics, and prevailing traffic conditions. This leads to substantial improvements in fuel efficiency and reduced operational costs.

[28]ENISA (European Union Agency for Cybersecurity). *Cybersecurity in the Transport Sector*. Available online: https://www.enisa.europa.eu/publications/cybersecurity-in-the-transport-sector (Provides insights into cybersecurity risks in connected transport infrastructures).

[29]Petru & Krivda, (2021), 13, 5524. https://doi.org/10.3390/su13105524

Discussion of findings and general arguments

The analysis reveals a compelling case for the strategic integration of AI into the EU's oversized transport sector. The findings underscore that AI is not merely an incremental improvement but a transformative technology capable of fundamentally reshaping operational paradigms and addressing long-standing systemic inefficiencies.

However, this AI must be used under human oversight.

Enhanced safety and risk mitigation

The most significant argument for AI integration lies in its potential to drastically improve safety. By moving beyond reactive measures, AI's predictive capabilities for route hazards, infrastructure stress, and driver fatigue can prevent accidents before they occur. The ability to conduct real-time obstacle detection and provide advanced driver assistance, as highlighted up, offers a new layer of protection that manual processes cannot match. This aligns with the broader goals of intelligent transport systems to create safer road environments[30].

Economic efficiencies and competitiveness

The current fragmented permit acquisition process and complex route planning are major cost drivers. AI's capacity to automate compliance checks, facilitate cross-border permitting, and optimize routes directly translates into substantial cost reductions and improved operational efficiency. These efficiencies can enhance the competitiveness of EU transport operators, allowing them to offer more reliable and cost-effective services, thereby strengthening the single market. This also supports the economic dimension of sustainable development by fostering innovation and growth[31].

Advancing environmental sustainability

Oversized transports, due to their size and weight, have a considerable environmental footprint. AI-driven fuel optimization and intelligent routing can significantly reduce fuel consumption and associated emissions. By minimizing detours and optimizing speed profiles, AI contributes directly to the EU's Green Deal objectives and various Sustainable Development Goals, particularly SDG 13 (Climate Action) and SDG 11 (Sustainable Cities and Communities)[32]. This directly supports urban sustainability goals, such as reduced emissions[33].

[30]European Parliament Think Tank (EPRS). *Artificial intelligence and transport: New challenges for EU law*. Available online: https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2020)642838 (Analyses legal and ethical challenges of AI in transport).

[31]World Economic Forum. *The Future of Mobility*. Available online: https://www.weforum.org/reports/the-future-of-mobility/ (Includes sections on innovation, emerging technologies, and sustainability in transport).

[32]Idem

[33]Petru & Krivda, (2021), 13, 5524. https://doi.org/10.3390/su13105524

Addressing regulatory and governance gaps

While AI offers solutions, it also exposes critical gaps in the existing regulatory framework. The fundamental challenge of liability for AI-driven decisions, data governance, and ethical considerations is amplified in the context of cross-border oversized transport. The "regulatory lag" – the slower pace of legislative adaptation compared to technological evolution – demands urgent attention. A key argument is that without a harmonized and agile legal framework, the full potential of AI cannot be realized, and its deployment might even be hindered or lead to unintended consequences[34].

The imperative of interoperability and data quality

The effectiveness of AI systems hinges on high-quality, standardized, and interoperable data from diverse sources. The current lack of seamless data exchange across national systems within the EU poses a significant barrier. This underscores the need for substantial investment in digital infrastructure and the development of common data standards to enable the full benefits of AI, as emphasized by Digital Transport and Logistics Forum[35].

Socio-economic considerations

The integration of AI will undoubtedly impact the workforce, particularly drivers and administrative personnel. Addressing concerns about job displacement through proactive reskilling and upskilling initiatives is crucial for social acceptance and a just transition. Furthermore, ensuring public trust in AI systems, especially in safety-critical operations, requires transparency and robust ethical guidelines.

In essence, the findings suggest that AI holds immense promise for revolutionizing oversized transport in the EU by addressing its core challenges of safety, efficiency, and environmental impact. However, realizing this potential is contingent upon a concerted effort to overcome significant regulatory, infrastructural, and socio-economic hurdles through strategic investment, harmonized policy-making, and collaborative governance. The necessity of integrated urban planning[36] and policy frameworks that balance economic development needs with environmental protection and infrastructure

[34]ENISA (European Union Agency for Cybersecurity). *Cybersecurity in the Transport Sector*. Available online: https://www.enisa.europa.eu/publications/cybersecurity-in-the-transport-sector (Provides insights into cybersecurity risks in connected transport infrastructures).

[35]European Commission's Digital Transport and Logistics Forum (DTLF). Search for reports and best practice guides on the digitalization of freight transport in the EU. Available online: https://transport.ec.europa.eu/transport-themes/digitalisation-transport-and-logistics_en (Relevant for EU-level digital initiatives in transport).

[36]Szczucka-Lasota (2017): 157-165. DOI: https://doi.org/10.20858/sjsutst.2017.97.14

resilience is paramount, advocating for smart, adaptive solutions to ensure the sustainable accommodation of oversized transport within future cities[37].

And, as I previously argued, this AI system must be constantly supervised and verified by the human factor.

Recommendations for EU Member States

- **Develop a Harmonized EU AI-in-Transport Framework:** It is imperative to establish clear, flexible, and future-proof regulations at the EU level. This framework must comprehensively address critical AI-specific issues such as liability in autonomous operations, robust data governance protocols, stringent cybersecurity standards, and seamless interoperability requirements specifically tailored for oversized transport.
- **Invest in Digital Infrastructure:** Prioritize and allocate substantial funding for the accelerated deployment of advanced 5G networks, the widespread implementation of smart sensor technologies, and the creation of integrated data platforms along key European transport corridors. These infrastructures must be specifically designed and optimized to support the unique and demanding needs of oversized logistics.
- **Foster Public-Private Partnerships (PPPs):** Actively encourage and facilitate robust collaboration between public authorities, private transport companies, cutting-edge technology developers, and leading academic institutions. This collaborative approach should aim to co-create innovative AI solutions, share the associated risks, and equitably distribute the benefits across the entire ecosystem.
- **Standardization and Interoperability:** Drive the development and adoption of common technical standards for AI and Internet of Things (IoT) systems within the transport sector. This is crucial to ensure seamless data exchange, operational continuity, and efficient cross-border movements of oversized loads across diverse national systems.
- **Capacity Building and Training:** Implement comprehensive and continuous training programs targeting transport operators, specialized drivers, administrative staff, and regulatory bodies. These programs should aim to equip all personnel with the necessary digital literacy, AI operational skills, and a deep understanding of the new technological paradigms.
- **Pilot Projects and Research:** Provide dedicated funding and robust support for pilot projects that rigorously test and validate AI solutions for oversized transport in real-world conditions across various EU Member States. This approach will facilitate iterative learning, enable rapid adaptation of best practices, and build a strong evidence base for wider deployment.
- **Promote Data Sharing and Governance:** Establish secure, transparent, and standardized mechanisms for sharing relevant data (e.g., real-time infrastructure data, traffic conditions, weather patterns) between public and

[37]Petru & Krivda, (2021), 13, 5524. https://doi.org/10.3390/su13105524

private entities. Crucially, these mechanisms must be underpinned by stringent data privacy and security protocols to build trust and ensure responsible data utilization.

By proactively addressing these recommendations, EU Member States can collectively harness the transformative power of AI to make oversized transport not only safer and more efficient but also significantly more sustainable, solidifying Europe's leadership in intelligent mobility.

Conclusions

The integration of Artificial Intelligence into oversized transport within the European Union represents a profoundly promising frontier for significantly enhancing safety, efficiency, and sustainability. While the challenges associated with this integration are considerable, particularly those pertaining to regulatory adaptation, digital infrastructure development, and cybersecurity, the demonstrable potential benefits unequivocally warrant sustained investment and collaborative efforts from all stakeholders.

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