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Air Traffic Management in Poland in the Context of European Integration, Technological Challenges, and Market Changes

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Abstract:

Purpose: *This article offers a comprehensive assessment of Air Traffic Management (ATM) in Poland within the context of European integration (SES), technological modernization, and environmental and market pressures. It combines an institutional/regulatory overview with an empirical analysis of Poland's RP3 performance (2020–2024) and the scale of unmanned operations, aligning findings with the roles of PANSA (PAŻP), NSA (ULC), EUROCONTROL/Network Manager, and ICAO.*

Design/methodology/approach: *Triangulating a doctrinal review of EU/ICAO frameworks with institutional sources and a structured, indicator-based analysis covering en-route traffic (IFR, SU), ATFM delays (en-route and terminal), environmental efficiency (KEP/KES), terminal service units, safety rates (runway incursions; separation minima infringements). Methods include trend and gap analysis versus the national Performance Plan (PP), with a harmonized 2020–2024 window for ATM KPIs.*

Findings: *Poland's traffic and service units rebounded after 2020 but remained below PP baselines in 2022–2024, indicating structural/network-driven gaps rather than pure demand shortfalls. En-route ATFM delay peaked in 2022 and then stabilized but stayed above target; terminal arrival delay rose in 2024, largely driven by non-ATC factors. Environmental results were asymmetric: while terminal efficiency improved and ground-side pressure (taxi-out) intensified. Safety performance, measured as event rates, was maintained or improved despite higher traffic.*

Practical implications: *Priorities include flexible capacity management (dynamic sector configuration, UDPP) and closer NM coupling; targeted mitigation of airside/apron bottlenecks (A-CDM, ground-planning tools) to convert terminal-area gains into punctuality; continued cross-border FRA maturation alongside ASM/FUA. These actions link policy intent with measurable improvements in delay, predictability, and environmental efficiency.*

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Originality/value: *The study integrates Poland's institutional and technological trajectory with a disciplined, indicator-level reading of RP3 outcomes, connecting network-level constraints to local ground processes and incorporating the emerging drone ecosystem. It delivers decision-oriented evidence suited for regulators, ANSPs, and airport operators seeking SES-consistent performance gains.*

Keywords: *Air Traffic Management (ATM), EUROCONTROL, SES/SESAR, Free Route Airspace (FRA), ADS-B, SWIM, Digital/Remote Towers, Performance Scheme, Safety Management, Environmental Efficiency.*

JEL Codes: *L93, R41, O33, Q55, H83.*

Paper type: *Research article.*

1. Introduction

Air traffic management (ATM) is one of the pillars of the contemporary air transport system, ensuring the safety, smooth flow, and efficiency of operations within airspace. In Poland, the ATM system underwent a significant transformation after 2004, following accession to the European Union and participation in the integration initiatives of the Single European Sky (SES).

The aim of this article is to outline the principal directions of change and the challenges in air traffic management in Poland from regulatory, institutional, and technological perspectives, while taking environmental and economic factors into account.

The analysis covers: the evolution of the national ATM system; the institutional set-up (the Polish Air Navigation Services Agency PANSA, and the Civil Aviation Authority ULC); the process of integration with the European air traffic management network (EUROCONTROL/Network Manager) and the SES regime; the system's safety and resilience; the progress of digitalisation (ADS-B, SWIM, remote/digital towers, virtual centres, AI/Big Data); and environmental and market implications.

2. Literature Review

Following the political and economic transition, the development of air navigation services was gradually aligned with ICAO and EUROCONTROL standards. A key milestone was the establishment of the Polish Air Navigation Services Agency (PANSA) in 2007, which took over the functions of the Polish Air Traffic Agency and consolidated within a single entity the provision of air traffic services (ATS),

aeronautical information services (AIS), and communication, navigation and surveillance (CNS) services (EUROCONTROL, 2025).

In the subsequent decade, modernization programmes stemming from SES/SESAR deployments were implemented: the expansion of secondary surveillance and ADS-B systems, advanced aeronautical data-processing systems, the extension of Free Route Airspace (POLFRA/BALTIC FRA), and the automation of flow management (ATFM). Between 2018 and 2022, Poland introduced POLFRA, and in 2022 it launched the cross-border BALTIC FRA with Lithuania, enabling route planning independent of the ATS route network and shortening flight distances, thereby reducing emissions (POLFRA, 2025).

At the same time, in line with European interoperability requirements, mandatory equipage obligations were introduced for aircraft and ground infrastructure (Mode S/ADS-B) (OJ L 305, 23.11.2011). Historically, three parallel factors have driven the development of ATM in Poland: (a) dynamic growth in demand for air travel after EU accession; (b) the need to comply with EU technical and operational regulations; and (c) pressure to improve the cost-effectiveness and quality of services.

Between 2010 and 2019, traffic in the Central European region grew faster than the European average, necessitating the expansion of ANS infrastructure and the reorganisation of control sectors. The period 2020-2021 brought an unprecedented decline in traffic due to the pandemic, followed by a sharp rebound that caused periodic overloads at some ACC units within the European network (EUROCONTROL, 2025). These experiences reinforced the priority of resilience and flexible capacity management, including dynamic sector configuration and closer cooperation with the Network Manager (NM).

PANSA is the state agency responsible for providing ATM/ANS in Polish airspace, including area, approach, and aerodrome control services, as well as FIS/AFIS and AIS. The Agency also operates CNS systems and manages innovation deployments (including POLFRA, PansaUTM, and remote/digital towers) (EUROCONTROL, 2025). Oversight of service provision is exercised by the President of the Civil Aviation Authority (ULC) acting as the National Supervisory Authority (NSA), operating within the European EASA oversight regime (IR 2017/373) and national implementing regulations (OJ L 62, 8.3.2017).

In planning and reporting, Poland fulfils its obligations under the Performance & Charging Scheme for SES reference periods, pursuant to IR 2019/317 (OJ L 56, 25.2.2019). The governance structure in Poland is based on a separation between service provision (PANSA) and oversight (ULC). As NSA, ULC is responsible for certification, continuous oversight, and enforcement of compliance with IR 2017/373, including assessment of the safety management system and the competencies of ATCO and FISO personnel. As the ANSP, PANSA operates under performance targets set nationally in the National Performance Plan and aligned with

EU-level objectives (RP3/RP4). Supporting roles are played by ministerial institutions responsible for transport policy and defence cooperation in the context of the Flexible Use of Airspace (FUA).

The SES initiative (framework Regulation 549/2004 and associated acts) seeks to increase safety, capacity, and economic efficiency by harmonising rules, ensuring system interoperability, and consolidating network functions. The Standardised European Rules of the Air (SERA 923/2012) unify the rules for conducting flights across the EU (OJ L 96, 31.3.2004; OJ L 281, 13.10.2012).

In terms of performance, Member States are subject to a common system of targets and indicators (cost-efficiency, delay, environment, safety) monitored by EUROCONTROL/PRU and the Performance Review Commission (OJ L 56, 25.2.2019; EUROCONTROL, 2025).

Poland participates in the Baltic FAB with Lithuania; the implementation of BALTIC FRA in 2022 is an example of cross-border integration in the spirit of SES (Baltic FAB, 2025). In parallel, SESAR concepts SWIM, virtual centres, and digital/remote towers are being deployed, enhancing the flexibility of service provision and resilience to disruptions (Sesarju, 2025).

An important dimension of integration is the implementation of Free Route Airspace (FRA), which allows users to plan routes independently of the traditional ATS network between designated entry and exit points, with the option to use intermediate points. In Poland, POLFRA was first promulgated by AIC (2018) and subsequently brought into operation; in February 2022, BALTIC FRA was launched within the Baltic FAB, enabling H24 cross-border route planning with Lithuania (POLFRA, 2025).

At the network level, Poland co-shapes NM initiatives to reduce en-route delays and improve flow management (ATFM), using tools such as the User Driven Prioritisation Process (UDPP), the e- helpdesk, and B2B interfaces. In the interoperability context, the roll-out of SWIM and digital AIM data services continues, including integration with eEAD.

Interoperability requirements for Mode S and ADS-B (IR 1207/2011 and subsequent amendments) have modernised surveillance and improved the quality of trajectory data, translating into better forecasting and separation (OJ L 228, 15.9.2023; EASA, 2020).

In Poland, the PansaUTM unmanned traffic management ecosystem is being developed a platform for coordinating UAS operations and the cornerstone of U-space deployment in line with Regulation 2021/664 (mandatory services: network identification, geo-awareness, flight authorisation, and traffic information) (Al.-Alawi *et al.,* 2025).

In terms of service digitalisation, PANSA is implementing remote/digital tower projects for example, for Warsaw–Modlin Airport, with an operations centre in Warsaw which increase TWR service availability and optimise costs (PPL, 2024; SAAB, 2025).

The virtual-centre concept, in turn, envisages decoupling data services (e.g., flight, radar, and meteorological data) from the controller's physical working position, enabling resource sharing between units and continuity of operations under contingency conditions (Sesarju, 2025).

Artificial intelligence and advanced analytics play an increasingly important role: sector load prediction models, 4D trajectory optimisation, and decision support for ATCOs (examples include EUROCONTROL's FlyAI and SESAR projects), accompanied by a parallel emphasis on data reliability and compliance with safety requirements (SESAR, 2022; Oliveira *et al.,* 2025; EUROCONTROL, 2025).

In surveillance, Poland is expanding Mode S and ADS-B coverage which together with the growing use of multilateration data and sensor fusion allows optimisation of separations and supports operations where conventional radars are limited. Remote tower (rTWR) deployments form part of a wider European trend towards the digitalisation of TWR/APP; their advantage lies in providing services from a single centre to multiple regional airports, increasing resilience and resource flexibility.

In the AI domain, work is advancing on conflict prediction, real-time sector allocation, and support for flow-management strategies (e.g., tactical ATFM regulations that account for weather and airspace constraints). These solutions require rigorous safety assessment (ALARP) and model compliance (XAI) to be operationally acceptable (SESAR, 2025).

Safety remains a priority within the ATM system. In the EU, the requirements for safety management systems and oversight are defined by IR 2017/373, complemented by EASA AMC/GM materials and national documents such as the National Civil Aviation Safety Programme (KPBwLC) (OJ L 62, 8.3.2017; ULC, 2025).

In Poland, the NSA (ULC) exercises oversight of PANSA and other ATM/ANS entities, including certification, audits, and corrective actions. From a crisis-management perspective, the importance of infrastructure resilience (cybersecurity, network redundancy, service recovery capabilities) is increasing, in line with the SESAR direction (virtual centres, digitalisation) (Sesarju, 2025).

Operationally, episodes of sharp traffic growth and adverse weather remain a particular test for the system; EUROCONTROL reports point to capacity pressure and higher en-route delays in 2024, which requires action in terms of resources and sector organisation (EUROCONTROL, 2025). Crisis management in ATM covers

technical scenarios (CNS/ATM system failures, power outages), operational scenarios (sudden capacity constraints due to weather or staffing), and security scenarios (cyber incidents, unmanned aircraft in CTRs). Good practices include link redundancy, provision of backup operational locations, simulation exercises, and mechanisms for rapid coordination with the NM and neighbouring ANSPs.

The KPBwLC requires cyclical hazard identification and risk management, consistent with a data-driven approach based on occurrence data and safety performance indicators (SPIs).

The pressure to decarbonise aviation in the EU (including the Fit for 55 package, the EU ETS, and ReFuelEU Aviation) is shaping the development of ATM: shortening routes (FRA), improving trajectory planning (TAAM, CTOT/UDPP), limiting contrail formation, and integrating environmental data into decision-making (EASA, 2025; IATA, 2025).

The latest EASA/EUROCONTROL reports confirm that cross-border FRA deployments translate into fuel savings and CO_2 reductions. From the perspective of ATM/ANS economics, SES mechanisms (IR 2019/317) have linked cost-efficiency targets to the charging policy and ACE benchmarking, which stimulates innovation and process consolidation but also requires adequate funding of human resources amid controller shortages (OJ L 56, 25.2.2019; EUROCONTROL, 2025).

The implementation of FRA and the Flexible Use of Airspace (FUA) results in shorter trajectories and lower emissions. At the EU policy level, regulatory incentives also matter: the gradual tightening of EU ETS rules for aviation and the SAF blending mandates under ReFuelEU implying that ANSPs and the Network Manager will increasingly incorporate environmental indicators into operational decisions and slot planning.

In the public debate, contrail management is gaining prominence; according to recent analyses, contrail formation can be reduced by adjusting the trajectories of a small fraction of flights, at an acceptable unit cost (Financial Times, 2025).

3. Research Methodology

The study provides an evidence-based assessment of Air Traffic Management (ATM) in Poland by triangulating an institutional/regulatory review with a structured, indicator-level analysis.

The empirical component focuses on Poland's RP3 window (2020-2024) with a harmonised time frame across all ATM KPIs. The unit of analysis is Poland as a whole (national ATM/ANS), without sub-national disaggregation unless explicitly defined in the source (e.g., Terminal Charging Zone 1- EPWA vs. Zone 2 - regional airports).

All quantitative inputs are drawn exclusively from the Monitoring Report Poland 2024 (correction: Aug 2025) for ATM performance (plans vs. actuals, capacity/delay, environmental KPIs, safety rates) No external datasets were used.

To ensure consistency and comparability, a single observation window was adopted for all ATM indicators (2020–2024). Where the source provides both planned (Performance Plan, PP) and actual values, the PP series serves as the ex ante baseline and the actuals as ex post outcomes.

Variables and measurement. The analysis covers: en-route IFR movements (thousand), en-route service units (SU, thousand); terminal IFR departures and terminal service units (TSU-L) for Zone 1 (EPWA) and Zone 2 (regional airports), en-route ATFM delay per flight (min/flight), terminal arrival ATFM delay per flight (min/flight), with stated PP targets for each year, KEP (additional taxi-out time), KES (terminal efficiency metric), recorded as provided and separation minima infringements (events, controlled flight hours, rate per million hours). Source tables were validated against internal totals and labelling in the report.

4. Research Results and Discussion

The analysis begins with en-route IFR movements and service units (SU) for Poland over 2020–2024, benchmarked against the Performance Plan (PP) and expressed in thousands. A clear post-2020 rebound is observed in both IFR and SU actuals; however, values remain below PP at the end of the window. In 2024 the gap reached -17.6% for IFR (758 vs. 920) and -25.5% for SU (3824 vs. 5130).

The largest annual increase in IFR occurred in 2021→2022 (+32.6%; +154k), while the deepest PP shortfalls were IFR in 2023 (-166k; -19.2%) and SU in 2024 (-1,306k; -25.5%); the steepest percentage SU gap was in 2023 (-25.7%). In the terminal domain, EPWA (Zone 1) shows IFR departures slightly below PP, but TSU-L above PP from 2023, indicating rising workload per departure; regional airports (Zone 2) outperform PP for both IFR and TSU-L from 2021 onward.

Turning to capacity outcomes, en-route ATFM delay per flight peaks in 2022 (1.09 min/flight) and then improves to 0.23 in 2024, yet remains above the 0.12 target. Terminal arrival delay stays modest through 2022, rises to 0.36 in 2023, and jumps to 0.80 in 2024 (target: 0.38), pointing to ground-side constraints and the need for tighter airport ANSP coupling.

Environmental efficiency indicators show persistently elevated HFE - with KEP worse in 2024 than 2020 and KES remaining above its 2020 baseline - consistent with network and airspace restrictions. Finally, safety rates remain stable or improve despite traffic recovery: the runway-incursion rate falls from its 2022 local maximum to 12.27 per million movements (2024), while SMI declines markedly from 205.45 to 68.09 per million hours (2020→2024).

Table 1. *En-route traffic and workload in Poland (PP vs. actual), for the years 2020–2024.*

Year	IFR movements (thousand) – PP	IFR movements (thousand) – actual	Diff. (thousand)	Diff. (%)	En-route SU (thousand) – PP	En-route SU (thousand) – actual	Diff. SU (thousand)	Diff. SU (%)
2020	377	377	0	0	2146	2146	0	0
2021	461	473	12	3	2549	2586	37	1,5
2022	752	627	-125	-17	3991	3129	-862	-21,6
2023	863	697	-166	-19	4763	3537	-1226	-25,7
2024	920	758	-162	-18	5130	3824	-1306	-25,5

Source: *Own elaboration based on statistical data from Monitoring Report Poland 2024. Third Reference Period (2020-2024), correction: Aug 2025, Poland, 2025.*

The analysis begins with en-route IFR movements and service units (SU). A post-2020 rebound is evident in both series, yet the PP–actual gap persists through 2024. IFR movements increased from 377k (2020) to 758k (2024), while SU rose from 2,146k to 3824k. Relative to PP the largest shortfall in IFR occurred in 2023 (-166k; -19.2%), and in SU in 2024 (-1,306k; -25.5%), with the steepest percentage SU gap in 2023 (-25.7%).

Growth decelerated over time (IFR: +25.5% → +32.6% → +11.2% → +8.8% YoY; SU: +20.5% → +21.0% → +13.0% → +8.1% YoY), indicating a transition from rapid recovery to maturation. Taken together, the results point to structural/network drivers not merely demand as the main source of under-performance vs. PP, consistent with the need for flexible capacity management and close NM coupling highlighted in the paper.

Table 2. *Terminal Zone 1 (EPWA): IFR departures and TSU-L (PP vs. actual) for the years 2020–2024.*

Year	IFR dep. (thousand) – PP	IFR dep. (thousand) – actual	TSU-L (thousand) – PP	TSU-L (thousand) – actual
2020	40	40	44	44
2021	52	47	55	53
2022	81	72	87	83
2023	87	83	97	99
2024	92	91	103	112

Source: *Own elaboration based on statistical data from Monitoring Report Poland 2024. Third Reference Period (2020-2024), correction: Aug 2025, Poland, 2025.*

At EPWA, IFR departures remained slightly below PP for most of the window (e.g., 91k vs. 92k in 2024), but TSU-L exceeded PP from 2023 onward (2024: 112k vs. 103k; +8.7%), signalling rising workload per departure (fleet/procedural mix, push-

back/sequence complexity). This pattern aligns with the paper's emphasis on airport–ANSP digital integration (A-CDM) and procedural enhancements (e.g., RECAT-EU and planned 5→3 NM TMA radar separation), intended to transform terminal-area efficiency into punctuality gains despite ground-side pressures.

Table 3. *Terminal Zone 2 (regional airports): IFR departures and TSU-L (PP vs. actual) for the years 2020–2024.*

Year	IFR dep. (thousand) – PP	IFR dep. (thousand) – actual	TSU-L (thousand) – PP	TSU-L (thousand) – actual
2020	57	57	62	62
2021	70	71	76	79
2022	112	119	124	141
2023	118	134	131	162
2024	127	148	142	180

Source: *Own elaboration based on statistical data from Monitoring Report Poland 2024. Third Reference Period (2020-2024), correction: Aug. 2025, Poland, 2025.*

In Zone 2, both IFR departures and TSU-L outperformed PP from 2021 onward, with widening positive gaps (2024 IFR: 148k vs. 127k; +16.5%; TSU-L: 180k vs. 142k; +26.8%).

The findings indicate a faster-than-planned regional rebound and higher workload intensity, consistent with partial traffic redistribution outside EPWA and the need for balanced TMA resourcing and network solutions (FRA, cross-FIR coordination) referenced in the article.

Table 4. *En-route ATFM delay per flight (target vs. actual) for the years 2020–2024.*

Year	Target (PP) en-route ATFM delay (min/flight)	Actual en-route ATFM delay (min/flight)
2020	0,3	0
2021	0,07	0,07
2022	0,12	1,09
2023	0,12	0,20
2024	0,12	0,23

Source: *Own elaboration based on statistical data from Monitoring Report Poland 2024. Third Reference Period (2020-2024), correction: Aug. 2025, Poland, 2025.*

After historically low levels in 2020-2021 (0.00–0.07 min/flight), en-route delay peaked in 2022 (1.09), then fell to 0.23 in 2024 still above the 0.12 target. The sharpest annual swing was 2021→2022 (+1.02), followed by the largest improvement 2022→2023 (−0.89).

The persistence above target despite moderating traffic delay co-movement supports the paper's call for tactical ATFM measures (UDPP), dynamic sector configuration, and robust NM interfaces to manage exogenous constraints.

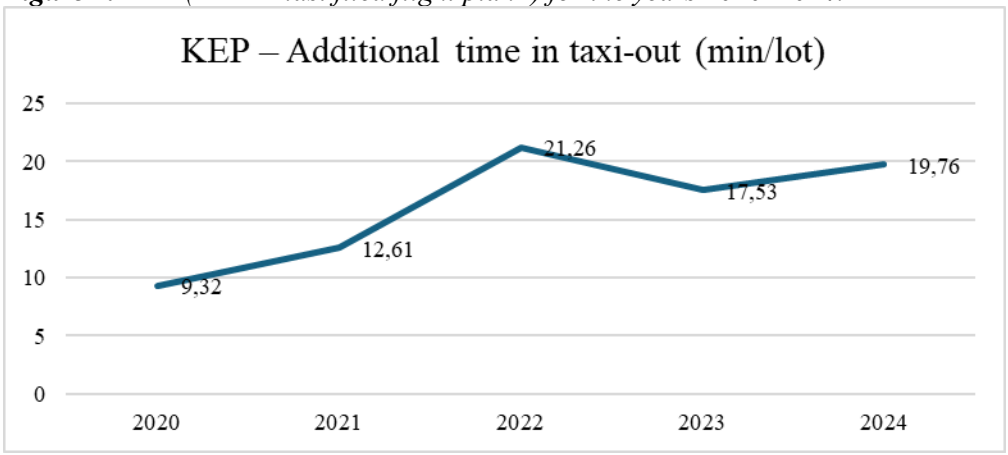
Table 5. *Terminal arrival ATFM delay per flight (target vs. actual), 2020–2024.*

Year	Target (PP) – terminal arrival ATFM delay (min/flight)	Actual – terminal arrival ATFM delay (min/flight)
2020	0,95	0,04
2021	0,04	0
2022	0,42	0,02
2023	0,39	0,36
2024	0,38	0,80

Source: *Own elaboration based on statistical data from Monitoring Report Poland 2024. Third Reference Period (2020-2024), correction: Aug. 2025, Poland, 2025.*

Terminal arrival delay remained subdued through 2022, rose to 0.36 in 2023, and increased to 0.80 in 2024 (target: 0.38). The largest annual increase (2023→2024: +0.44) coincided with a predominance of non-ATC causes, underscoring the importance of airside/apron bottleneck relief (A-CDM re-validation, dedicated ground-planning tools) and tighter airport ANSP coupling to convert terminal-area efficiency into schedule adherence.

Figure 1. *KEP (HFE -"last filed flight plan") for the years 2020–2024.*

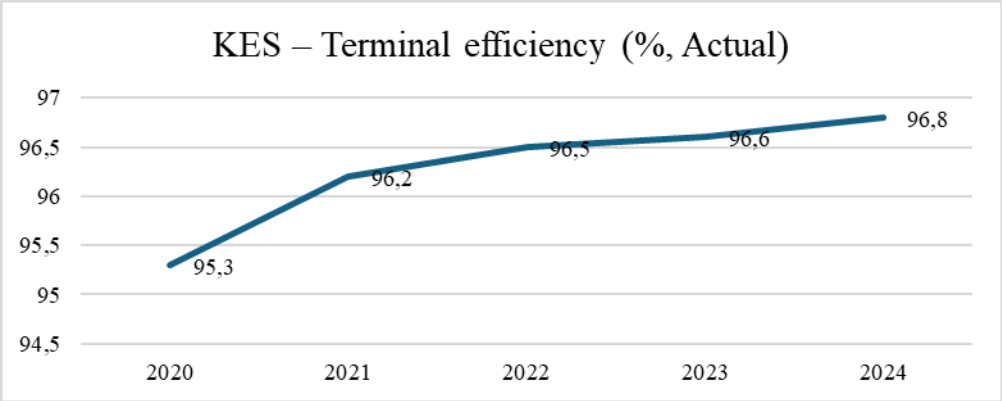


Source: *Own elaboration based on statistical data from Monitoring Report Poland 2024. Third Reference Period (2020-2024), correction: Aug 2025, Poland, 2025.*

The KEP series deteriorated over RP3, reflecting longer planned trajectories amid airspace restrictions and network constraints.

While FRA expansion continued (including 2024 extensions), its benefits were partly muted by exogenous factors, reinforcing the article's recommendation to strengthen ASM/FMP processes and cross-border coordination as enabling conditions for HFE gains.

Figure 2. *KES (HFE - "shortest constrained route") for the years 2020–2024.*



Source: *Own elaboration based on statistical data from Monitoring Report Poland 2024. Third Reference Period (2020-2024), correction: Aug 2025, Poland, 2025.*

Analogous to KEP, KES remained higher in 2024 than in 2020, indicating persistent network limitations. Expected improvements are linked to structural initiatives (e.g., staged vertical re-design in FIR Warszawa) and continued FRA development - consistent with the paper's modernization pathway, albeit contingent on broader geopolitical conditions.

Table 6. *Runway incursions - events, traffic, and rate per million movements for the years 2020–2024.*

Year	Runway incursions – events	Traffic (takeoffs + landings)	Frequency (per million movements)
2020	7	495562	14,12
2021	7	640748	10,92
2022	16	858653	18,63
2023	11	958801	11,47
2024	13	1059714	12,27

Source: *Own elaboration based on statistical data from Monitoring Report Poland 2024. Third Reference Period (2020-2024), correction: Aug. 2025, Poland, 2025.*

Runway-incursion rates fluctuated year-to-year (peak: 18.63 in 2022; low: 10.92 in 2021) without a sustained deterioration as traffic recovered (2024 rate: 12.27). Stability at rate level, despite rising movements, is consistent with effective SMS practices (Runway Safety Teams, occurrence investigation, SPAS reviews) described in the article.

SMI rates decreased markedly from 205.45 (2020) to 68.09 (2024), with intermediate variability (peak 154.15 in 2022). The downward trend alongside increasing controlled-flight hours supports the view that data-driven safety oversight and continuous improvement in procedures/tools are containing conflict risk in a more complex traffic environment fully in line with the paper's safety narrative.

Table 7. *Separation minima infringements - events, controlled-flight hours, and rate per million hours for the years 2020–2024.*

Year	Separation minimum violations – events	Controlled flight hours	Frequency (per million hours)
2020	59	287121	205,45
2021	56	432170	129,58
2022	103	668200	154,15
2023	74	764243	96,83
2024	57	837330	68,09

Source: *Own elaboration based on statistical data from Monitoring Report Poland 2024. Third Reference Period (2020-2024), correction: Aug. 2025, Poland, 2025.*

5. Conclusions, Proposals, Recommendations

The quantitative analysis for the RP3 period (2020-2024) shows that Poland's ATM system simultaneously rebuilt traffic volumes and improved selected quality parameters, yet continued to operate under conditions of persistent network variability and environmental constraints. The number of en-route IFR operations and service units (SU) rose steadily after 2020 but remained below the reference values of the national Performance Plan (PP).

In 2024, 758 thousand IFR movements were recorded versus 920 thousand in the PP, and 3824 thousand SU versus 5130 thousand in the PP, confirming a sustained demand-and-structure gap and increasing traffic complexity. This is consistent with observations of changing overflight patterns and the need for flexible capacity organisation (dynamic sector configuration, close cooperation with the Network Manager).

In terms of capacity, there was a pronounced "spike" in en-route delays in 2022 (1.09 min/flight), followed by stabilisation at 0.23 min/flight in 2024 still above the 0.12 target. The weak to moderate relationship between traffic volume and delays suggests that outcomes are driven by tactical factors (sector organisation, resource availability) and airspace constraints.

At the same time, terminal arrival delays reached 0.80 min/flight in 2024 against a target of 0.38, with non-ATC causes predominating, indicating the need for stronger coupling of airport processes, resource planning, and predictive tools with ANSP actions.

Environmental indicators confirm an asymmetry between outcomes in TMA and en-route navigation conditions. In the TMA, a gradual improvement in efficiency (higher KES) was observed, alongside increasing ground-side pressure (higher KEP longer taxi-out), which reinforces the case for prioritising airside/apron

"bottlenecks" through A-CDM solutions, dedicated planning tools, and deeper airport–ANSP data integration.

From a safety perspective, despite the traffic rebound, rate-based indicators remained at acceptable levels or trended downward. The runway-incursion rate fell from its local 2022 peak, and the rate of separation minima infringements declined markedly between 2020 and 2024 supporting the conclusion that the national Safety Management System (SMS), under IR 2017/373, is effective, including the roles of cyclical reviews, risk analysis, and NSA/ULC oversight.

Further improvement requires system-level measures rather than purely "capacity" fixes: flexible sectorisation, enhanced tactical ATFM tools (including UDPP), consistent cooperation with the NM, and better alignment of TMA capacity with airport flow cycles. Second, on the environmental side, maintaining the FRA trajectory and network solutions should be combined with a realistic appraisal of exogenous constraints; in the short term, the greater potential lies in improving ground processes (KEP) and optimising terminal operations, where tangible effects are observed. Third, sustaining the positive safety trend calls for continuation of data-driven approaches (SMS, SPAS), expansion of analytics, and selective deployment of AI tools under a human-in-the-loop paradigm and ALARP requirements.

Over the next five to seven years, the following are recommended:

- closing the gap vis-à-vis the PP by better matching resources to diurnal/seasonal variability and maintaining the ability to reconfigure sectors;
- accelerating FRA integration (including cross-border) alongside ASM/FUA measures;
- reducing ground "bottlenecks" through full A-CDM re-validation, deployment of dedicated planning tools (e.g., a GND-planner), and broader use of operational data;
- maintaining high SMS standards while introducing AI/Big Data decision-support for ATCOs in a controlled, auditable manner.

Delivering these actions within a stable regulatory and financial regime - is a prerequisite for sustained improvements in punctuality, efficiency, and environmental performance, and, consequently, for the competitiveness of Poland's ATM/ANS segment within the European network.

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