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Article

Enhancing Access to Cancer Diagnostics: Drone Delivery of PET Isotopes Amid Weather Challenges and Multimodal Transport Solutions

Karl Arne Johannessen [1,2,*], Paul Royal [3], Anders Mjøs [4], Thor Audun Saga [4] and Mona-Elisabeth Rootwelt-Revheim [1,5]

[1] The Intervention Centre, Oslo University Hospital, Sognsvannsveien 20, 0372 Oslo0188 Oslo, Norway
[2] Faculty of Medicine, Institute of Health and Society, University of Oslo, 0372 Oslo, Norway
[3] Institute of Pharmaceutical Science, King's College, London, UK, Franklin-Wilkins Building, 150 Stamford Street, SE1 9NH
[4] Norwegian Medical Cyclotron Centre, Oslo, Norway; Sognsvannsveien 20, 0372 Oslo
[5] Institute of Clinical Medicine, University of Oslo
* Correspondence: karlarne.johannessen@online.no; Tel.: +47 90895075

Highlights

What are the main findings?
- Long-range drone transport substantially reduces delivery times for PET radioisotopes, improving isotope preservation and enabling significant annual cost savings.
- Weather is a critical operational constraint

What are the implications of the main findings?
- Drone-enabled PET logistics could increase clinical capacity and regional access
- Adoption of drone transport should prompt reconsideration of current practices of PET production and clinical scanning routines

Abstract

Background. Drones may outperform traditional ground transport in medical logistics. While previous studies have focused on short-range deliveries, this study examines long-distance drone transport of 117–376 km for positron emission tomography (PET) radioisotopes delivery. The short half-life of isotopes makes transport time critical. We quantified potential time savings and preservation of fluorine-18 ([^{18}F]FDG) radioactive activity enabled by long-range drone transport. Methods. Drone speeds of 150, 200, and 250 km/h was compared with four existing transports: two ground-only routes (146 km/348 km) and two combined car–airplane routes (532 km/546 km). Hourly weather data from 2023–2024 were used to model flight times and weather-related no-fly conditions. Time savings, radioactive decay, and break-even costs relative to existing transport were analyzed. Results. 150 km/h provided limited benefit on the longest route, while 200–250 km/h preserved 49–64 GBq from an initial 180 GBq. Up to 30% of winter flights were constrained by weather. Break-even drone costs ranged from €3/km to €18/km, increasing to €14–€20/km including preserved isotope. Annual economic gains ranged from €1.0–1.7 million. Conclusion. Long-range drone transport can reduce isotope losses and improve diagnostic capacity. Feasibility depends on drone costs, weather resilience, and clinical logistics adaptation.

Keywords: PET isotope; drone transport

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1. Introduction

Drones are increasingly tested and used in healthcare for emergency response, delivery of blood products, vaccines, medicines, and assistance for elderly populations [1–20]. During the COVID-19

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pandemic, they maintained essential deliveries during lockdowns [21–24]. More advanced proposals include organ transport, though clinical evidence is limited [25,26].

Despite their potential, most drone healthcare projects rely on public or pilot funding and remain economically unproven. Prior studies largely focus on short-range, last-mile deliveries with small payloads, limiting claims of a logistics revolution.

Context is critical. In low-infrastructure regions, drones can provide essential access [7]. Similar needs exist in high-income countries with dispersed populations [11,27–29]. Yet, widespread adoption hinges on sustainable payment models and willingness to pay [30,31].

Technological progress is enabling longer-range drones with greater payloads. However, sustainable business models must demonstrate measurable healthcare value. Within value-based care, higher drone costs must be justified by better outcomes or service quality.

Drones may also inspire broader system change by shifting how logistics and services are organized. But reliability is key. Predictable service is as important as speed, particularly in healthcare. Weather, wind, rain, and temperature extremes can significantly restrict drone operations [32–37]. Achieving dependable services requires resilient drone design and contingency planning.

May drones improve transport of PET radioisotopes?

Positron emission tomography (PET) is a high-cost tool in medical imaging with increasing applications in oncology, cardiology, rheumatology, neuropsychiatry and other diseases [38].

The development of cost-effective digital PET scanners represents a significant advancement in medical diagnostics. Although the accelerating technological advancements reduce the cost of digital PET scanners, large disparities in access to imaging persist in countries of poor income and across isolated geography [39–45].

Radioisotope production is costly, and their short half-lives in relation to transport from cyclotron to imaging centers present logistical constraints. For PET centers without local cyclotrons, service quality hinges on reliable and timely transport. Road congestion or airline delays exacerbate decay. Although some improvements have been achieved through service chain optimization [46], challenges remain.

While clinical PET imaging per se is not strictly time-sensitive, radiotracer decay begins immediately after production. Most scans occur during daytime, requiring morning delivery, which restricts scheduling flexibility and complicates contingency plans for weather-related drone cancellations.

Drones suitable for long-distance PET transport must offer vertical take-off and landing (VTOL) and fixed-wing flight for speed. They must also ensure temperature control (typically 15–25°C) to maintain radiopharmaceutical integrity. Payloads must accommodate heavy shielding (15–30 kg), often needed for [18F] FDG.

Numerous studies have examined the economic and sustainability aspects of drone transport in both healthcare and parcel logistics [17,34,47–58]. Most of them focus on how drones can reduce delivery times by avoiding traffic congestion through lightweight, short-range, last-mile deliveries. Many of these studies were conducted in immature operational settings, i.e., relying on manual piloting and temporary landing infrastructure.

Existing economic assessments of drone solutions frequently overlook key cost elements such as public infrastructure investments, airspace surveillance systems, and broader environmental impacts. Most drone logistic studies in health services focus on short-range and last-mile purposes, and real-world data on heavy, long-range operations are scarce. Extrapolating from short-range parcel models is inappropriate. For example, costs for a 10-mile, 1 kg drone delivery of ~$13 cannot be scaled linearly to 100 miles or 50 kg [57].

This study simulates data for scenarios requiring drones with payload capacities exceeding 50 kg, flight ranges of several hundred kilometers and long-term regular flights. We use break-even analyses to determine the km-based cost thresholds where drone transport of PET isotopes becomes economically viable compared to existing car/airplane logistics.

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We also consider activity preserved through reduced decay as a source of economic value. International regulations, especially IAEA guidelines, governs handling of radioactive substances that impose strict requirements on packaging, labelling, and documentation, adding to logistical complexity [59]. This could not be modelled in this study.

Decay and clinical value depend on isotope half-life. For example, 11C (t½ = 20 min) requires near-instant delivery whereas 18F (t½ = 109 minutes) loses ~50% activity after 109 minutes, making efficient transport of [18F] FDG particularly valuable.

Research questions:

1. How much PET activity of 18FDG can drones preserve vs. current car/air transport, for varying distances and drone speeds?
2. How do varying weather conditions affect drone reliability?
3. Can clinical routines be optimized to increase the value of drone transport?

2. Materials and Methods

The Norwegian Medical Cyclotron Centre (NMCC) [1] delivers PET radioisotopes to several regions in Norway and for all hospitals in Health Region South-East having PET scanners. This constitutes approximately 50 % of the Norwegian hospitals and more than 60% of the Norwegian population, as well as Stavanger University Hospital in Health Region West and Aalesund central hospital in Central Norway Regional Health Authority, located in mid part of Norway.

Models in this study.

We compare drone solutions to four existing models (Figure 1):

- a: Car transport to Central Hospital Kristiansand (KRS) (348 km road, 281 km air)
- b: Car transport to Elverum Hospital (ELV) (146 km road, 117 km air)
- c: Car + plane to Stavanger University Hospital (SVG) (546 km road, 302 km air)
- d: Car + plane to Central Hospital Aalesund (AES) (532 km road, 376 km air)

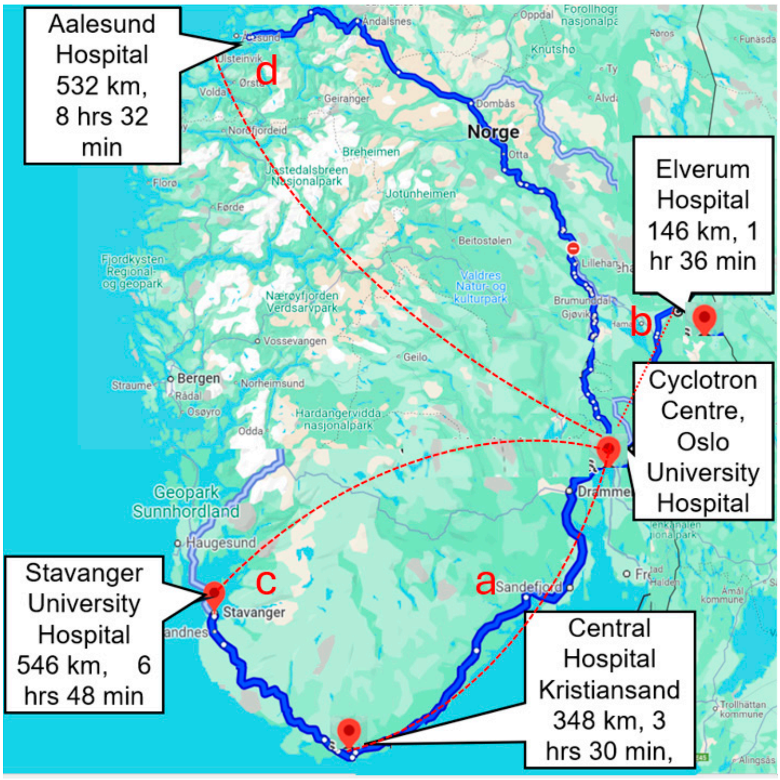

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Figure 1. Transport routes by drone (red lines) and car (blue lines). Transport a and c have a path exposed to intermediate coast/inland weather. Transport is mainly inland climate, whereas d is exposed to more variation of wind with initial leg of inland weather, final route coastal and mountain wind and precipitations. Map: Google.com.

Current departures occur at 5:15 a.m. to align with clinic schedules. Delays of ground transport from snow/ice are rare and not modelled. Drone solutions versus current transport routes match existing destination times with flights starting at 6 a.m. Euclidean distances were used to estimate direct drone flight lengths modelling drone speeds of 150, 200, and 250 km/h. Future drones will have to comply with strict rules for temperature regulations of cargo as radiopharmaceuticals have to be stored during transport within a temperature interval that for F18-DG is 15-25 degrees C. Based on a previous study at our hospital [60], we know that take-off from our hospital depends significantly on local wind and wind directions as well as flight direction out of Oslo (Figure 2). We assume that similar conditions exist at the receiving hospitals, and 10 minutes for take-off and landing to all flights were added.

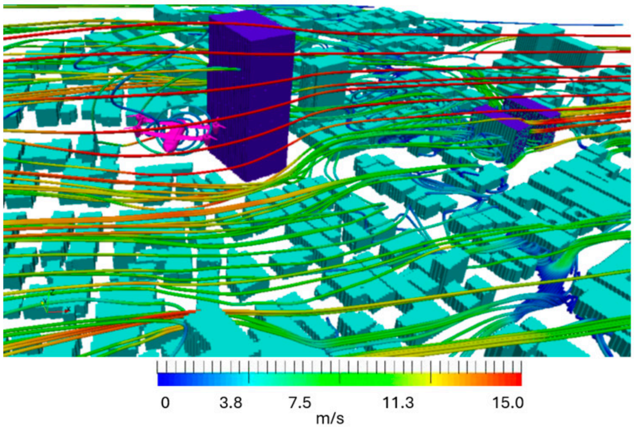

Figure 2. Illustration of wind directions around Oslo university hospital. Analyses from a previous published study in our project [60]. Wind differs with heights, buildings and across terrains.

Weather and drone flight viability

To assess flight times an flyability during varying weather conditions, we used historic weather data from The Norwegian Meteorological Institute [61] for every hour through the complete years 2023 and 2024. Data were measured from ground weather stations located approximately every 50 km of the differing drone routings as a proxy for flight weather conditions. Parameters included wind speed/gusts, direction, temperature, and precipitation. Meteorological data for each flight segment were matched to the corresponding expected hour of drone passage. Wind impact on flight time was calculated using trigonometric projection of wind angle relative to flight path.

Borrowing from the study of Gao et al. [32], no-fly days were defined according as:

- Wind gusts >15 m/s
- Temperature < –20°C
- Precipitation >10 mm/hr.

We used a stepwise approach to assess the number of days in the year and per month where these criteria would make drone flights not realistic due to weather conditions (no-fly days). Some days had tolerance violations of multiple variables, some only one. Resulting times were used to estimate [18F] decay.

The Economics of Drone Transport for PET radioisotopes

Cost-effectiveness was assessed as: Net Gain = (Current Transport Cost – Drone Cost) + Revenue from Preserved Activity. Drone cost thresholds (€ per km) for breakeven were calculated across all

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models and speeds using existing NMCC transport costs as benchmarks. Revenue from preserved radioactivity was estimated based on clinical applicability and dosing.

Analysis of the impact of clinical routines, including scheduling, was included to assess optimization potential.

Revenue Potential from Preserved Isotope Activity

While drone logistics do not lower the production cost of PET radioisotopes, they can reduce radioactive decay by shortening transport times, increasing the usable amount of radioisotope upon arrival. This may generate additional revenue, provided the saved activity can be applied effectively. The economic benefit depends on several factors, including cyclotron batch structure, type of radioisotope used, pricing strategies and ability to reallocate or expand clinical scanning schedules.

A key consideration is the relationship between the cost of drone transport, and the added value from preserved activity as a function of reduced transport time. A practical approach that can guide whether drone deployment is economically justifiable for a specific route, is to compare drone transport costs directly to the monetary value of saved radioactivity.

Assume a radioisotope with half-life $\mathcal{T}_{1/2}$, a drone transport distance of d km, flight velocity v (km/hour) and drone cost c (€/km flight).

Then drone transport time may be calculated as

(1) $T_d = d/v$

and total drone cost

(2) $C_d = c*d$.

The decay constant λ for a radioisotope quantifies the rate at which the isotope decays, i.e. how quickly a radioactive substance will lose its radioactivity and is given by

(3) $\lambda = \ln(2) / \mathcal{T}_{1/2}$.

Ln (2) is the natural logarithm of 2 and applies for all radioisotopes whereas $\mathcal{T}_{1/2}$ is the halftime for the actual isotope (109.7 minutes for the F18 isotope in this study).

Assume that we compare two differing transport times, $T_{d1} = t$ and a longer $T_{d2} = t + \delta t$. If R_o is the radioactivity at start of transport, for T_{d1} the remaining radioactivity R_1 for $\mathcal{T}_1$ is

(4) $R_1(t) = Ro * e^{-\lambda t}$

For the longer transport time $T_{d2} = (t + \delta t)$,

(5) $R_2(t + \delta t) = Ro * e^{-\lambda(t+\delta t)} = Ro\, e^{-\lambda(t)} * e^{-\lambda(\delta t)}$

Then, the relative increase in the remaining radioactivity of transport 1 compared to the longer transport 2 will be

(5) $R_1 / R_2 = \dfrac{Ro * e^{-\lambda t}}{Ro * e^{-\lambda(t)} * e^{-\lambda(\delta t)}} = e^{\lambda(\delta t)}$

We can then construct a stepwise incremental cost efficient ratio (ICER) [62]) as the ratio comparing increased cost per km drone flight to additional radioactive benefit (R1/R2) (Figure 3).

Drone Transport Times

All drone flights began at 6 a.m., aligning with current arrival schedules. We assumed drones would combine VTOL and fixed-wing capacities. Simulations tested speeds of 150, 200, and 250 km/h., speeds currently achievable for many commercially drones in EASA category C3 specific or above.

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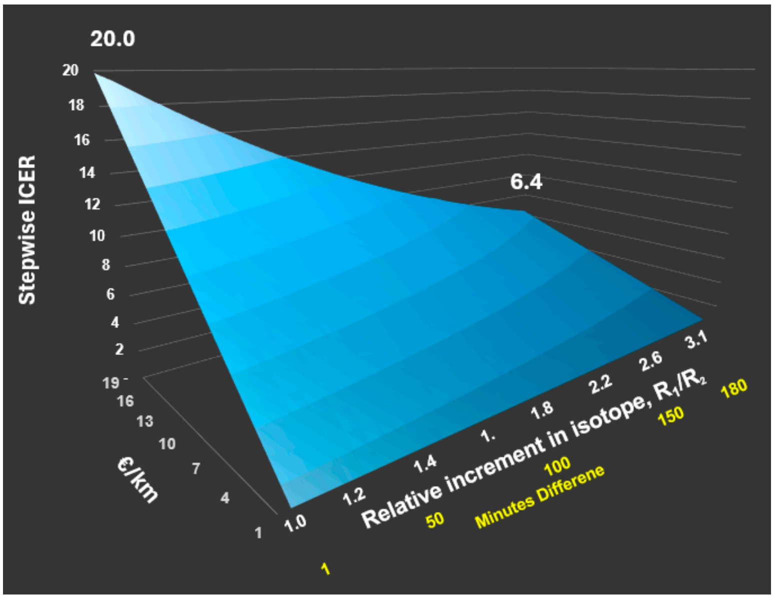

Figure 3. The Z-axis = ICER cost/gained radioactivity across a 20-fold increase in €/km drone flight (Y-axis). X-axis: The relative increase in saved isotope as function of 1 - 180 minutes reduction in transport time.

Patient Throughput and Isotope Utilization

We used a simplified model assuming 250 MBq per patient and 30-minute injection intervals, common in current practice. Two approaches were analyzed:

1. Extend scanning schedules using increased arrival activity.
2. Maintain current arrival activity but reduce starting activity, reallocating the surplus to other imaging centers.

3. Results

Current Transport Characteristics

Table 1 summarizes the total costs of the current transport models, including car drivers, vehicle, energy, and, for SVG and AES, flight costs.

Table 1. Descriptive data of existing isotope transport.

	KRS	ELV	SVG	AES
Isotope Activity at Start of Transport	40	26	26	26
Current Transport Costs	820	435	5 222	5 222
Departure Time from Cyclotron Centre	05:15	05:15	05:15	05:15
Arrival Time Imaging Centre	09:30	07:00	07:30	07;30
Total Transport Time	04:15	01:45	02:15	02:15
Typical Isotope Activity at Arrival	7.9	9.1	9.1	9.1

Simulated Time Gains

Time savings depended on drone speed and route distance. As an example, at 150 km/h, flights to KRS and ELV saved 1.4 and 0.5 half-lives of 18F, respectively. At 250 km/h, savings increased to 1.8 and 0.7 half-lives, though with diminishing returns (Figure 4).

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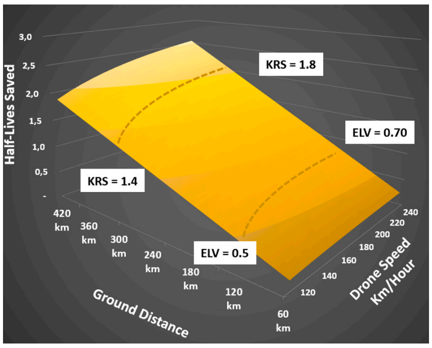

Figure 4. Illustration of relative half-life savings for differing ground distance and the converging effect of increased drone speed. Assuming no weather impacts.

Weather-Adjusted Drone Flight Times and No-fly days

Most mean drone speeds including the wind impacts outperformed existing solutions, except for the AES route at 150 km/h.

Figure 5 illustrates the simulation speeds and weather data for the KRS model, having the largest time potential, and the AES route, where gains only were obtained by mean velocities above 200 km/hour. Some of the large deviations in transport times seen in Figure 5 occurred on days where large wind caused no-fly days and were not used when calculating maximum flight times in the differing routes. As Figure 5 depicts, both KRS and AES routings had significant challenges with no-fly days in winter season, mostly caused by wind gusts.

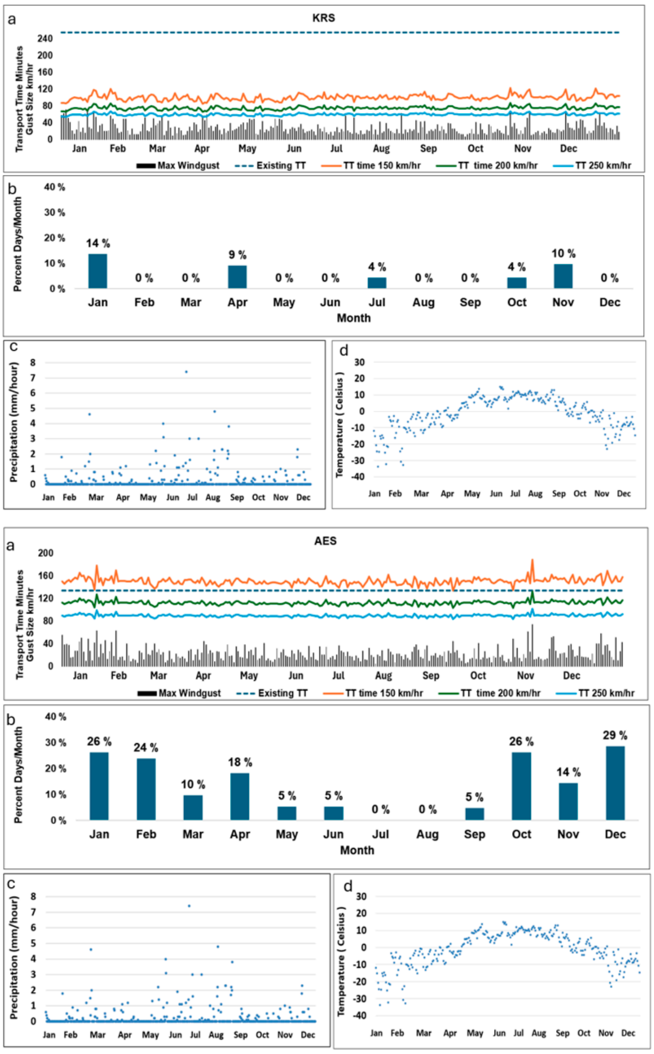

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Figure 5. Simulated transport times as function of wind, wind gust, precipitation and temperature in KRS and AES route. a: Transport time. b: Percent no-fly days per month. c: Precipitation. d: temperature.

An overview comparing seasonal no-fly days in the years 2023 and 2024 for all routings are illustrated in Figure 6. Although the patterns may seem somewhat similar, large annual differences exist.

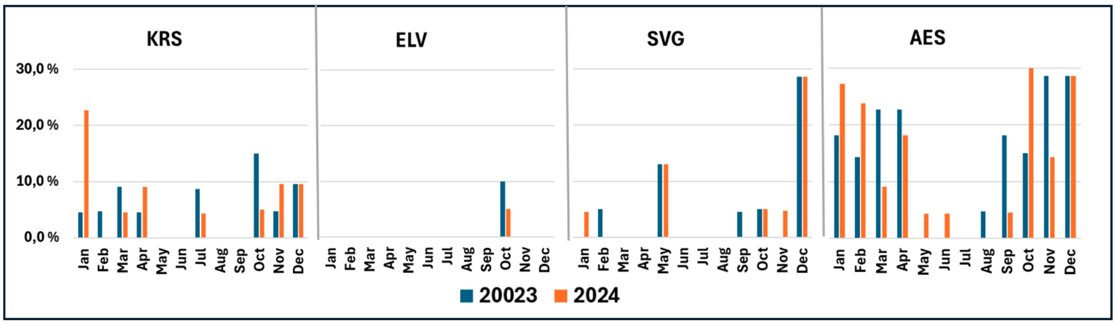

Figure 6. Percent of no-fly days in the four routings in 2023 and 2024.

Based on the simulation times we could estimate the time and half-life savings for all routes, Table 2. The best case for transport time improvements was the long-distance KRS ground transport; the long-haul air transport of AES shows the lowest advantage.

Table 2. Maximum (Max), mean and minimum (Min) simulated time savings for drone speeds of 150, 200 and 250 km/hour at the four routings.

		Saved Transport Time			Saved PET Half life		
Route		**150 km/hr.**	**200 km/hr.**	**250 km/hr.**	**150 km/hr.**	**200 km/hr.**	**250 km/hr.**
KRS	Max	165.2	184.1	196.4	1.52	1.69	1.80
	Mean	143.5	171.2	187.9	1.32	1.57	1.72
	Min	106.6	152.0	176.1	0.98	1.39	1.62
ELV	Max	66.8	75.0	80.3	0.61	0.69	0.74
	Mean	57.8	69.7	76.8	0.40	0.57	0.66
	Min	43.6	62.3	72.3	0.53	0.64	0.70
SVG	Max	41.8	60.8	73.4	0.38	0.56	0.67
	Mean	14.7	44.7	62.7	- 0.22	0.22	0.46
	Min	- 24.5	24.3	50.2	0.14	0.41	0.58
AES	Max	12.4	38.6	55.5	0.11	0.35	0.51
	Mean	- 16.7	21.5	44.3	- 0.62	- 0.04	0.26
	Min	- 67.4	- 4.7	28.3	- 0.15	0.20	0.41

Route Paths and Transport Viability

The long-haul routes SVG and AES had the greatest variability of geographic terrain and climate for their transports. Using AES as a case, Figure 7 illustrates adaptive routing with 19 km longer path, mitigating no-fly challenges.

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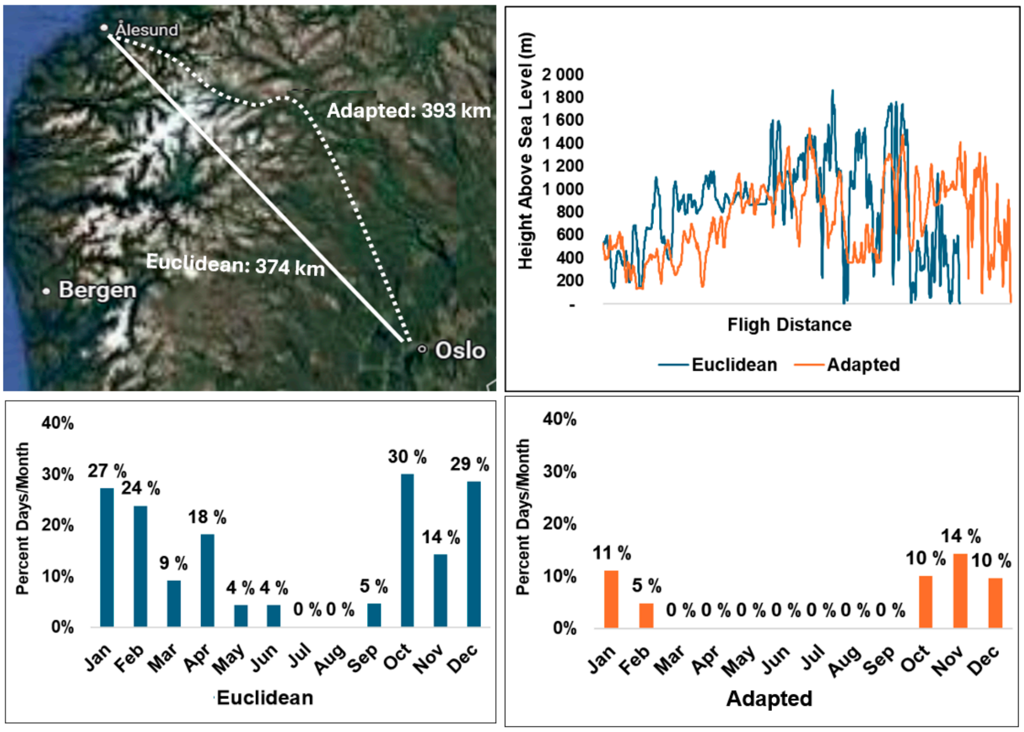

Figure 7. Illustration of how alternative routes for AES may represent differing occurrence of no-fly days.

PET Activity Savings

Compared to current solutions, shorter transport times allow for reduced start activity or increased output. Table 3 shows estimated isotope savings (GBq) by route and drone speed. Figure 8 illustrates two approaches for utilizing saved activity, one with extended scanning schedules and one using parallel sessions.

Table 3. Estimated PET isotope savings (GBq) with shorter drone transport times, assuming current activity (number of scans) at arrival.

Transport	Current GBq at start	Needed GBq at start with 150 km/hr.	Needed GBq at start with 200 km/hr.	Needed GBq at start with 250 km/hr.	Saved GBq with 150 km/hr.	Saved GBq with 200 km/hr.	Saved GBq with 250 km/hr.
KRS	40	16,1	13,5	12,1	23,9	26,5	27,9
ELV	26	17,6	16,3	15,6	8,4	9,7	10,4
SVG	26	23,6	19,5	17,4	2,4	6,5	8,6
AES	26	28,9	22,6	19,6	- 2,9	3,4	6,4
All	118	86	72	65	32	46	53
Percent saved isotope capacity					27,0 %	39,1 %	45,2 %

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Consume 23.8 MBq

a

Patient no.	Injection time (minutes from first)	Consume of arrival dose to obtain patient dose 250 MBq	Accumulated isotop consumed
1	0	250	250
2	30	303	553
3	60	366	919
4	90	443	1362
5	120	536	1898
6	150	649	2547
7	180	785	3332
8	210	950	4283
9	240	1150	5433
10	270	1392	6825
11	300	1684	8509
12	330	2039	10548
13	360	2467	13015
14	390	2986	16000
15	420	3613	19613
16	450	4372	23986

Consume 13.6MBq

b

Patient no.	Injection time (minutes from first)	Consume of arrival dose to obtain patient dose 250 MBq	Accumulated isotop consumed
1	0	250	250
2	30	303	553
3	60	366	919
4	90	443	1362
5	120	536	1898
6	150	649	2547
7	180	785	3332
8	210	950	4283
9	240	1150	5433
10	270	1392	6825

Patient no.	Injection time (minutes from first)	Consume of arrival dose to obtain patient dose 250 MBq	Accumulated isotop consumed
1	0	250	250
2	30	303	553
3	60	366	919
4	90	443	1362
5	120	536	1898
6	150	649	2547
7	180	785	3332
8	210	950	4283
9	240	1150	5433
10	270	1392	6825

Figure 8. Two differing hypothetical approaches for the application of saved isotope at the KRS. a. 16 patients Scanned in Single line. b. 20 patients scanned in two parallel lines, each scanning 10 patients.

Economic Advantages

Transport Costs

Break-even drone transport costs varied by route. The KRS and ELV must remain below €3/km, whereas SVG/AES could tolerate up to €17-18/km due to current reliance on high-cost air transport Figure 9.

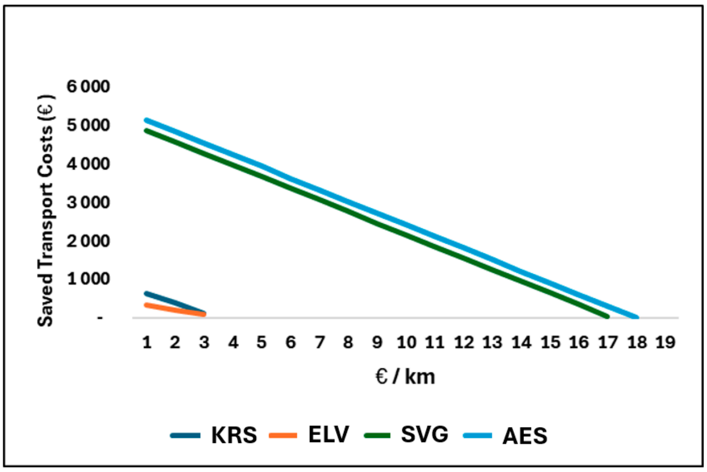

Figure 9. Saved transport costs as a function of Euro/km drone flight compared to existing transport costs.

Potential Increased Revenue from Saved Isotope

Table 3 shows how drones reduced the amount of PET activity needed for each transport, which could free up doses for other uses, such as redistribution or sale to other imaging centers. While isotope prices vary widely between suppliers and isotopes, making exact calculations difficult, we have estimated a potential income increase in Table 4. This estimate is based on an average dose price of €525 (with a range from €350 to €700) and assumes that the increase in available isotope activity translates into a proportional increase in income.

Table 4. Estimated increase in income for amplified capacity of the delivery compared to existing solution.

Route	Drone Speed 150 Km/hr.	Drone Speed 200 Km/hr.	Drone Speed 250 Km/hr.
KRS	2 490	2 760	2 901
ELV	1 352	1 556	1 671

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SVG	378	1 035	1 373
ALE	-458	537	1 027
All	3 762	5 888	6 971
Year	940 559	1 471 964	1 742 863

Break-Even Analysis

Combining both transport and PET savings, we modelled breakeven scenarios across drone costs from €1-20/km. Figure 10 shows route-specific cost thresholds where drones outperform existing models.

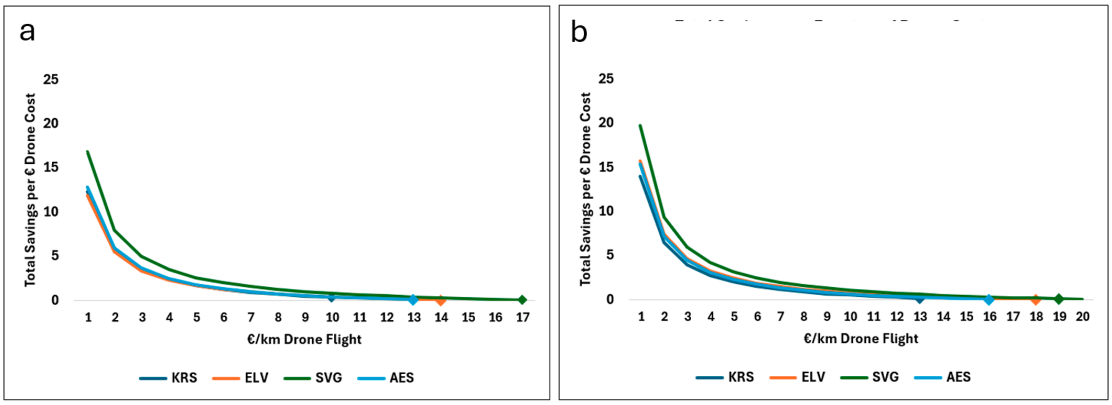

Figure 10. Potential savings of total costs as function of drone flight costs and speeds in the differing transports. Panel a 150 km/hour, panel b 250 km/hour.

4. Discussion

Principle findings.

This study illustrates that drone transport can significantly reduce delivery times for PET radioisotopes across long distances, enhancing isotope preservation and enabling substantial annual cost savings. The work demonstrates the potential impact and provides a framework for evaluating early feasibility in sandbox exercises. Future test flights may provide real life data to demonstrate a reduction in delivery times.

However, the magnitude of these benefits depends on several factors: transport distance, drone speed, isotope half-lives, clinical workflow integration, available drone park and infrastructure, and not the least, meteorological conditions. Weather emerged as a key barrier to consistent drone operations, suggesting up to 30% of flights could be disrupted during some winter months, particularly on routes exposed to coastal or mountainous conditions. This aligns with prior research indicating that wind gusts, precipitation, and temperature extremes limit drone reliability [32,37,60,63–67].

Operational adaptations may possibly mitigate these challenges. Fallback to ground transport based on high-resolution weather forecasts, seasonal route suspension, flexible scheduling or reconfiguring route path (Figure 7).

Drone Design and Technical Considerations

Drone feasibility for PET logistics requires designs capable of carrying ≥50 kg to accommodate shielded, temperature-controlled containers (15–25 °C). Long-range missions necessitate hybrid VTOL-fixed wing systems that balance vertical mobility with cruising efficiency.

Battery-powered drones lack range and remain unsuitable for long-distance flights in cold climates due to limited energy density and cold-weather degradation. Despite recharging infrastructure has been proposed [57,68–70], recharging or battery swapping would consume valuable time and remains impractical for PET transport over remote areas with no infrastructure.

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Although fuel-powered systems involve higher operating costs and emissions, they offer superior range and will be necessary for the distances and payloads studied until battery energy densities improve [57,68–70].

Organizational and Economic Implications

Drones have the potential to catalyze broader changes in PET logistics. Faster delivery may enable increased capacity by extended scanning hours or parallel scanner usage, as illustrated in Figure 8, maximizing clinical throughput. Alternatively, shorter transport durations could support isotope reallocation to underserved sites, enhancing regional imaging access.

There is a historical analogy to be drawn from the evolution of theragnostics, once limited to iodine treatments for thyroid cancer, now a cornerstone of precision oncology [71]. Similarly, integrating drone logistics may reconfigure how PET services are designed and delivered.

Adopting drones may prompt reconsideration of current practices, such as current single-batch isotope productions. Drones allow for staggered deliveries, reducing waste and increasing responsiveness to clinical demand. Furthermore, combining drone logistics with next-generation whole-body PET scanners, requiring lower doses, could defer the need for costly cyclotron expansion.

However, unidirectional flights present inefficiencies. Economically viable implementation may depend on backhaul use, transporting other medical goods or diagnostics. Integrating PET deliveries with other services, via mixed on-demand and scheduled flights, will require redesigning ground logistics, drone ports, and digital infrastructure [57,68–70].

The cost-effectiveness of drones is highly context specific. Extensive literature exists on optimizing drone routing strategies [72–77]. But while last-mile drone deliveries have shown potential cost savings [57,78–81], this evidence does not extend to long-haul healthcare logistics. Our simulations highlight that drone solutions are more economically viable on routes currently reliant on expensive air transport (e.g., AES), but less so for routes with low-cost road delivery (e.g., KRS).

Cost optimization remains essential and must balance speed, regulatory compliance, and operational expense to meet stakeholder expectations. The evolving U-space regulatory framework in Europe will be critical to ensure safe and cost-efficient integration [82].

Overall, drone logistics for PET require further empirical validation, full cost modelling (including infrastructure and staffing), and robust regulatory alignment.

Limitations

Several limitations warrant consideration. Currently there is no real-world operator data available to compare drone transport and existing PET isotopes transportation. Future studies should aim to validate these estimates with real-world drone service pricing, including airspace usage, drone-port costs, and operational overhead.

Weather data were based on ground-level measurements; future integration with aviation-grade weather forecasting systems will be essential for future operational planning.

Infrastructure effects, such as turbulence near urban landing sites, were not modelled.

Regulatory uncertainties remain, in particular related costs and implementation timelines.

Future Directions

Future research should explore hybrid logistics models that dynamically switch between drone and ground transport based on weather forecasts or clinical urgency. Multi-sectoral partnerships may also enable shared drone services, increasing utilization and cost-efficiency beyond PET transport.

A comprehensive modelling of drone logistics costs, including infrastructure, airspace access, and staffing, is critical. Standardizing these inputs would improve comparability across studies and strengthen the evidence base for drone integration in healthcare logistics.

Conclusion

Drone-based transport of PET radioisotopes offers considerable potential to improve delivery efficiency, reduce expensive decay-related losses, and expand access to imaging in remote areas. However, successful implementation depends on more than technical feasibility, it requires weather-adapted operations, regulatory readiness, workflow integration, and sustainable business models.

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Rather than simply replacing current transport methods, drones could enable a broader transformation in medical logistics. With system-wide planning and stakeholder coordination, drone logistics may become a cornerstone of a more flexible, decentralized, and responsive healthcare infrastructure.

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