



UNIVERSITÀ
DEGLI STUDI
DI PADOVA

University of Padua

School of Medicine

Single-Cycle Master's Degree Course in Medicine and Surgery

Integrated Didactic-Scientific Assistance Department of Surgery

THESIS

***Helicopter or ambulance in interfacility transfers?
Solving the dispatch dilemma.
Experiences from the Padova EMS Base.***

Supervisor: Prof. Andrea Paoli

Graduand: Giovanni Grigolin

Academic Year 2024-2025



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1 Summary

Background

Literature concerning helicopter air ambulance (HAA) use in interfacility transport (IFT) is scarce, and most often revolves around the time dependence of clinical conditions. The vast majority of publications in these terms does not discuss the logistic implications of helicopter use in comparison with standard ground ambulances, nor does it account for geographical variability. Albeit clinical time dependence is essential in dispatch decision-making, assigning the correct team and vehicle to a mission warrants adequate use of the resources available, maximising system efficiency.

Aims

Helicopters are axiomatically seen as the faster response vehicle due to general perception of their superiority in terms of speed as opposed to ground vehicles. Though this may stand true in primary response to emergency calls, IFT has other times to take into account, which may dampen the effects of such speed. Transport times are of difficult estimation and hard data is required to back with confidence resource allocation in favour of either ground or air ambulance dispatch. Other than offering this, the study is aimed at avoiding the overtriaging of missions which may instead benefit from the swift activation times that characterise ground ambulances, and allow the HAA to stand ready for other missions which may require it.

Materials and methods

This retrospective, observational study is based on mission data spanning between January 2021 and July 2024, for all IFT missions completed by Padua's Helicopter Air Ambulance. A pool of emergency ambulance IFT missions has been randomly selected to derive operational times (patient loading-unloading). The data has been harvested from the database available in the operations centre of Complex Operations Unit 118 SUEM (*Servizio Urgenza Emergenza Medica – Medical Emergency Urgency Service*) of Padua University Hospital. Data was elaborated via R software with the support of the University's Biostatistics, Epidemiology and Public Health Unit. Methods used are descriptive and association analysis, as well as linear regression and change-point analysis.

Results

The assessment has highlighted a major advantage in ground ambulance dispatch when the mission is under 44 km via road (29.5% of the sample). The result is mainly attributable to the longer activation and loading-unloading times required to safely operate the helicopter, as well as the good road network available in most of the region of Veneto.

Conclusions

When choosing which vehicle to dispatch in a service where ground and air ambulance are available, other than clinical data and time-dependence, also the potential time advantage of a swift response granted by ground ambulance must be taken into consideration. This holds true especially in a context where no hindrance is foreseeable in geographic terms, meaning the road network is sufficiently developed and the area of interest is prevalently plain.

2 Introduction

Throughout the years, Emergency Medical Services (EMS) have been striving for bringing innovative answers to clinical and logistical dilemmas that make up the everyday reality of their work. Among these, helicopter-based EMS is now increasingly common, thanks to the vehicle's capability to rapidly deliver a highly specialised clinical team to patients in time critical conditions, also in secluded or difficult-to-reach areas. Helicopters are also regarded as the vehicle of choice in case of long-haul interfacility transport (IFT) for most countries where the journey isn't long enough to warrant use of fixed-wing aircraft.

2.1 A brief history of Helicopter Emergency Medical Services (HEMS)

The first accounts of helicopter involvement in rescue operations comes from the United States of America's Army, which deployed helicopters for rescue mission support as far back as during the Korea War (1950-1953) [1]. Nevertheless, these missions were of Search and Rescue nature as there was no crew trained in providing medical care. This changed during the Vietnam War, where the combat grounds made it such that ground ambulances were virtually impossible to deploy. In response to this, a crude concept of what today is regarded in tactical medicine as MedEvac (Medical Evacuation) was born. In this context, an initial treatment was provided to injured soldiers by medics in their unit, and was continued by personnel who manned the aircraft dispatched to evacuate the patient to safety away from battle grounds.

In the meantime, initial experiences in Europe were starting to appear. In Switzerland, in the 1950's the GASS (Guardia Aerea di Soccorso Sanitario) was founded to manage rescue and medical aid in mountainous territory. This entity today takes the name of REGA, one of the most recognised HEMS agencies globally. In the USA, St. Anthony General Hospital in Denver, Colorado was the first to launch its HEMS operation.

In Italy, sporadic experiences in the 50's and 60's mainly regarded isolated Italian Red Cross and Firefighter Corps programmes. Only in the 80's does HEMS in Italy start flourishing, albeit slowly and with uneven nationwide coverage. In 1992, thanks to DPR 27 Marzo 1992 [2], EMS organisation is officially appointed to each region or autonomous province, with the subsequent creation of the common emergency number, 118, and EMS Operations Centres. From here on, HEMS became a mainstay service in Italy, with the pioneering bases located in Palermo (1991), Genova (1994) and Pieve di Cadore (1998).

Up until 2021, Italy counted 55 operational airbases for a total of 74 aircraft available for dispatch, 21 of which are also qualified for night flight. Most recently (Feb-Mar 2024), the Umbria region opened its first airbase in Foligno.



Figure 1: HEMS airbase distribution in Italy as of 2021
[3]

Overall, Italy has good national coverage in terms of HEMS bases, albeit with differences in management between regions and services. For example, the Molise region relies on neighbouring Abruzzo HEMS to cover their territory. Sardinia HEMS has been present only since 2018. This is most probably due to funding differences in the regions, as well as the different interpretations of national legislation [4].

2.2 Dispatch Control Rooms

Dispatch Control Rooms (DCRs) have, under current legislation, the key role of accepting medical emergency calls. Through a strict and detailed protocol, the mission is assigned a priority code associated to a colour (white, green, yellow, red in ascending order) reflecting the patient's supposed critical state. Accordingly, appropriate resources are dispatched. In the region of Veneto, this is legislated via a Unified Dispatch Protocol known as DiRE (Dispatch Regionale Emergenza) [5].

In most general terms, the resources available during standard procedures are the following:

- **BLS (Basic Life Support) Ambulance:** ground ambulances with basic emergency medical technician personnel. These are either volunteers from various local associations with basic training or EMTs hired either by private companies or the Local Health Unit/Hospital. Known in Italian as MSB – Mezzo Soccorso di Base (basic emergency vehicle)
- **ALS-I (Advanced Life Support – Infermierizzata) Ambulance:** ambulance staffed with at least one EMT (driver) and an emergency nurse. ALS is provided in limited forms as per local protocols. Some manoeuvres are exclusively of physician competence.
- **ALS-M (ALS-Medicalizzata) Ambulance:** ambulance staffed with EMT (driver), emergency nurse and EMS physician. Full ALS capabilities are provided in this case.
- **Automedica (Medical Car):** advanced care car without capability of carrying patients. Its role is to join missions where an ambulance without physician is dispatched to a critical patient, or those where further support is required.
- **Helicopter:** carries and advanced clinical team to scene rapidly, with the ability to deliver the team in remote areas or in wilderness with special manoeuvres technically known as Helicopter Hoist Operations.

Helicopter-based missions must be carefully selected due to the resource intensity behind this service. In an optimal context, helicopters are reserved for time-critical patients who find themselves in hard-to-reach areas (islands, mountains) [4].

Within standing legislation for Veneto, the all-clear for critical care transports is given by the on-shift physician in the DCR, who acts as a general manager for that shift and is continuously informed about intensive care bed capacity and emergency room affluences. In this context, the on-shift physician must discern those requests that fall within local protocol before clearing the mission for dispatch.



Figure 2: Padua EMS Dispatch Control Room

In case this is not possible, single hospitals can arrange the transport after previously clearing the request with that institution's Medical Director [6].

2.3 General overview of a helicopter air ambulance service

Helicopter services have now become a mainstay globally, with differences accounting for the clinical and geographical needs the services respond to. Helicopters are a flexible vehicle, which can deploy a variety of teams through an ample series of environments.

2.3.1 Classification of operations

Helicopter services deploy their teams in variable contexts, with the possibility of managing the crew composition to best respond to mission requirements. Mission configurations take specific names, as follows:

- *HEMS (helicopter emergency medical service)*: also termed 'Primary flight'. These flights are directed toward patients for whom an emergency call has been received, and are triaged with priority codes due to their supposed time-critical injury. The clinical team will intervene on the scene of injury.
- *SAR (Search and Rescue)*: subtype of primary flight. It entails the extraction and rescue of patients who may require medical attention from hostile environments. These missions often require the participation of medical and technical rescue services, such as mountain rescue. In Italy, this is represented by CNSAS (Corpo Nazionale Soccorso Alpino e Speleologico).
- *HAA (Helicopter Air Ambulance)*: also known as 'Secondary flight'. Interfacility Transfers fall within this category, and may be further subcategorised based on the patient's time-dependence of disease.

Within primary flights, many helicopters in Italy are qualified for special operations which require equipment and personnel delivery via hoist or hovering operations. These manoeuvres take the name HHO (Helicopter Hoist Operations).

Hoists are mounted on the helicopter's side and allow personnel and payload (gurneys, emergency equipment bags) to be delivered onto an area too restricted for landing.

Hovering operations are required when, albeit spacious, the intervention area is sloped, therefore making a safe landing impossible. In this situation, the helicopter approaches the slope laterally, touching down with only one side. Personnel and equipment are cleared for dismounting the aircraft while the rotor is still moving and the pilot maintains balance. Personnel will then wait for the helicopter to lift off and away from the hovering site before approaching the mission scene.

In Italy, current legislation also allows for emergency services helicopters to be employed in other missions, such as [7]:

- SAR and transport in mass casualty incidents
- Emergency transport of blood products, antidotes and rare drugs
- Emergency transport of personnel and equipment involved in organ transplant networks
- Training and simulation flights



Figure 3: Padova HEMS personnel training in a hoist operation. Photo Courtesy: mr. S. Zampieri



Figure 4: hovering operation.

2.3.2 Aviation-related limitations to helicopter use

General limitations include:

- Technical maintenance stops
- Fuel limitations
- Transport space limits (excess payload weight, class III obesity etc.)
- Weather conditions not in line with standing regulations (fig. 5)
- Elapsing of local ephemeris time for services not qualified for IFR (instrumental flight rules) [8]

In recent years, a new avenue has become available to amplify HEMS operational availability: satellite navigation. Systems such as PBN (Performance Based Navigation) base themselves on evolved forms of GPS grids, allowing to overcome the limit of instrumental and ground radio-guided flight. This would essentially entail the creation of networks of flight corridors for emergency helicopters between one helipad and another, through which HEMS can fly safely also in poor visibility conditions or at night [9].

Altitudine ⁽¹⁾	Classe di spazio aereo	Visibilità in volo ⁽⁴⁾	Distanza dalle nubi ⁽⁴⁾
A o al di sopra di 3 050 m (10 000 ft) AMSL	A ⁽²⁾ B C D E F G	8 km	1 500 m in orizzontale; 300 m (1 000 ft) in verticale
Al di sotto di 3 050 m (10 000 ft) AMSL e al di sopra di 900 m (3 000 ft) AMSL, o al di sopra di 300 m (1 000 ft) AGL, a seconda di quale delle due è più alta	A ⁽²⁾ B C D E F G	5 km	1 500 m in orizzontale; 300 m (1 000 ft) in verticale
A e al di sotto di 900 m (3 000 ft) AMSL o 300 m (1 000 ft) AGL, a seconda di quale delle due è più alta	A ⁽²⁾ B C D E	5 km	1 500 m in orizzontale; 300 m (1 000 ft) in verticale
	F G	5 km ⁽³⁾	Fuori dalle nubi ed in contatto visivo con il suolo e/o con l'acqua

Figure 5: Italian National Civil Aviation Authority: flight regulations, edition n.4 (13/05/2021) - minimal meteorological thresholds for HEMS flight.

2.3.3 Flight Crew members

In Italy, a standard flight crew is made up of:

- *Pilot, single or dual configuration*: single pilot configuration is sufficient for HEMS flight, but dual configuration is mandatory in case the helicopter is qualified for night flight. Pilots are responsible for managing the flight, as well as clearing the aircraft for departure after receiving dispatch in compliance with aforementioned limitations.
- *TCM (Technical Crew Member)*: necessary crew member when the helicopter is equipped with hoist. The TCM is responsible for all HHO on board the aircraft.
- *Medical Doctor*: specialist in anaesthesia and intensive care or emergency medicine, with adequate training in HHO and SAR operations based on the helicopter service's configuration.
- *Critical Care Nurse*: nurse with previous experience in EMS, emergency department or intensive care, and adequate training in HHO/SAR.
- *SAR Technician*: present only in helicopters qualified for SAR operations. Generally, part of CNSAS (Corpo Nazionale Soccorso Alpino e Speleologico) in Italy.

The crew can be modified based on varying mission needs, and implemented with canine units for avalanche rescue, or rescue swimmers in case of water rescue [8]. All crew members must be trained and briefed frequently in all rescue operations, ordinary and special. Medical staff on board often are also trained in basic mountaineering or water rescue skills, depending on the region of deployment.

Outside of Italy, the Critical Care Nurse can be substituted by critical care paramedics, such as in the United Kingdom, Switzerland or Germany. In the USA, the most common medical team is a critical care nurse and paramedic, without a medical doctor. Some services, especially in the UK, have a double paramedic team. The latter is being abandoned in favour of an interdisciplinary model, as a growing body of evidence suggests better patient outcomes in physician/paramedic cooperation [10].

2.4 HEMS in the Veneto Region

In Veneto, the EMS system denominated SUEM 118 (Servizio Urgenza Emergenza Medica) manages 7 DCRs and 5 helicopters:

- **Belluno:** 2 helicopters (2 Airbus H145-T2, the first based in Pieve di Cadore year-round, the second in seasonal service at Belluno airport), cover the Venetian Dolomites between Belluno and Treviso
- **Padova:** 1 helicopter (Leonardo AW169) covering the central-eastern area of the region (Padova, Rovigo, Venezia, Verona, Vicenza)
- **Rovigo:** 0 helicopters, fully covered by Padova or, rarely, Verona
- **Treviso:** 1 helicopter (Leonardo AW169 with night flight capabilities) covering the whole Treviso province, the northernmost part of Padova, shares competence in part of the Dolomites
- **Verona:** 1 helicopter (Airbus H145-T2) covers western Veneto (Verona, Vicenza, Padova, Rovigo)
- **Vicenza:** 0 helicopters, shared competence between Verona and Padova

Except for Treviso HEMS, all other aircraft in Veneto are on limited schedules. Padova HEMS is an ephemeris-based service, meaning from dawn to ephemeris-related dusk (30 minutes after sunset). Verona and Pieve di Cadore are instead on fixed 12-hour shifts throughout the year thanks to the use of Night Vision Goggle technology that allows the aircraft to fly also in winter months when light hours are less than 12 in a day.

The first HEMS base to open in Veneto was Verona in 1987, followed by Pieve di Cadore (1988), then Treviso (1991) and Padova (2000). The 4 helicopters have specific configurations to best serve their coverage territory. The HEMS airbases cover the whole region and are located strategically based on a series of criteria to enhance care and rapid response [7]:

- Extension and morphology of covered territory
- Demographic density and tourism influx
- Hospital network (number of hub/spoke hospitals, diagnostic-therapeutic capabilities, expertise)
- Road networks
- Ground vehicles available per DCR
- Capability of granting, in full working order, a maximum 20-minute response time to the farther areas of the covered territory in a HEMS mission

2.4.1 Regional legislation on HEMS

Current legislation on Interfacility Transport in Veneto stratifies the service into 3 levels of care, depending on how clinically and time-critical the patient is [6]. This translates seamlessly into the priority given, in the following manner:

- **Emergency** transport: to be dispatched and managed as soon as possible, and in any case within 30 minutes of receiving the request. These cases regard patients for whom a delay in transport over 30 minutes may lead to clinical worsening or determine a delay in delivering the patient to appropriate intensity of care. HAA activation must be evaluated as a first line and, if not feasible or indicated, a ground ambulance from the IFT rota will be dispatched. If unavailable, it is possible to dispatch an ambulance from the EMS rota with prior authorisation from DCR.
- **Urgent** transport: to be handled within some hours, depending on the balance between requests from the sending and receiving hospital, as well as DCR's status. EMS vehicles are generally not authorised for these transports, with specific cases in which this may be superseded.
- **Programmed** transport: to be managed within hours/days. These cases are directly legislated upon by the sending hospital's policy, depending on the rota of physicians and nurses available to travel via ambulance with the patient. General rules include avoiding transport during nights, weekends and national/local festivities.

2.4.2 Focus on Padova HEMS

Padova HEMS airbase is located in the city's 'Gino Allegri' airport, and is dispatched by the DCR in the University Hospital. Its operational territory covers the whole province of Padova, with the exception of the two northernmost towns that fall under Treviso HEMS. Furthermore, Padova HEMS covers the whole province of Rovigo, the southern half of Venice and the eastern half of Vicenza.

This territory offers a number of different features relevant for HEMS dispatch and operational management, such as:

- *Venetian Lagoon and Po River Delta*: islands and marshlands with patchy ambulance or outpatient clinic coverage
- *Euganean and Berici Hills*: two large hill ranges with a relatively dense population, and a relevant number of touristic and sports activities (trail running, rock climbing, downhill biking...)
- *High traffic intensity road networks*: two major motorways cross the province of Padova, the A4 and A13
- *Seasonal increase in population due to tourism*: the coastal area is a seaside tourism location with very high peaks of population density in summer; the central area of Abano, Montegrotto, Battaglia and Galzignano Terme are a thermal centre with large tourist influx throughout the year.

Padova HEMS is the only helicopter in Veneto that does not carry a SAR Technician on a daily basis, as mountain territory is not within its competence. Local Mountain Rescue teams are activated in case hill rescue is necessary, but this service can be managed by ground vehicles. SAR Technicians in the past have implemented the flight crew on summer weekends due to the higher relative incidence of hill rescue in that time of the year. As of June 2025, Padova HEMS has been working on implementing a SAR Technician in continuous service, in an effort to bring the base's capability up to its maximum.

Considering the high number of Hub hospitals in Padova HEMS' territory, the helicopter is often involved in critical care IFT. Local Hub hospitals such as Vicenza, Mestre and Rovigo hospitals often request to centralise critical patients from their Spoke centres to the highest levels of care represented by Padova and Verona University hospitals.



Figure 6: official territory coverage for the four helicopters in Veneto. Padova HEMS is highlighted in red. Source: Padova University Hospital internal documentation.

Padova's helicopter is configured in compliance with national regulations on HEMS [7]. Necessary features include the ability to embark a horizontal gurney, or alternatively a neonatal critical care incubator, without compromising the flight crew's capability to occupy the aircraft. The helicopter must be fitted with racks and upholstery to safely carry all the equipment a critical care team needs to carry. This must be certified for safety by the national civil aviation authority. The helicopter is also fitted with SAR and HHO equipment. Other than the medical and rescue equipment, aeronautical requirements such as weight balancing, fuel mileage and safe equipment locking are satisfied.

The helicopter in service for Padova HEMS is an AgustaWestland 169 produced by Leonardo, callsign Leone 2. It is a light-intermediate class bi-turbine helicopter with a maximum take-off weight of 4800kg. Its top speed is 305.5 km/h, with a full tank capacity of 800km. The current configuration allows to carry up to 7 crew and 1 patient on a gurney. Occasionally, a substitutive helicopter is necessary for ordinary maintenance. In this event an identical model is provided to maintain the service active.



Figure 7: Leone 2. Photo courtesy: mr. A. Meneghetti

2.5 Operational costs

In terms of exercise costs, the Regional Health Service pays the service in full and attributes the cost to the local health unit the patient resides in, based on standing regional fees. In Veneto, HEMS missions are calculated to cost EUR 90-120 per minute, considering differences in crew configuration and mission territory.

A recent study highlighted the cost intensity of HEMS services, reporting that in Western Europe the cost per hour of use is around EUR 2488 when adjusted to average income for the area considered [11].

2.6 HEMS dispatch guidelines

Other than local protocols, each HEMS agency in Italy aligns HAA dispatch rationale to national consensus review that are periodically published by competent scientific societies.

2.6.1 SIAARTI Guidelines for critical patient management in HEMS [9]

IFT is generally requested for:

- Clinical competence limitations (advanced procedures, neurosurgery, cardiovascular surgery)
- Advanced diagnostics that are not available in the sending hospital
- Intensive Care bed management
- Back transport: patients are transported to a hospital closer to their residence

2.6.2 HEMS Association recommendations on HAA [12]

Helicopter-based IFT is reasonable when patients are considered critical, unstable (SIAARTI-modified Ehrenwerth Class III or over), or anyways clinically time-dependent (even in class I-II), towards a centre capable of managing said patient. It must be considered urgent when time is a critical factor in the definitive management of the case at hand.

In considering transport times, activation of HAA must be justified by a significant reduction in transport time. The patient is under care of the HEMS Crew throughout the whole transport.

All cases where a transport is not time critical are deemed non-urgent. The only reasonable requests for helicopter activation in this context are intensive care-to-intensive care transfers to free beds for high specialty care, or 'in-utero' transport involving a pregnant patient. Other minor criteria that can justify HAA activation are:

- Ground transport times deemed unreasonable
- Need to execute an atraumatic transport due to unstable/incomplete lesions
- Unavailability of ground vehicles within reasonable time windows

Contraindications to helicopter transport include:

- Aeronautical unfeasibility
- Incompatible patient or travelling equipment size when compared to aircraft
- Psychiatric patient with frank psychomotor agitation
- Highly infectious patients in cases the flight crew can't be adequately isolated
- Patients affected by chemical contamination
- Pregnant patient with imminent childbirth
- Patients for whom clinical stability might be jeopardized in transport, or unstable upon departure

The stakeholders in HAA activation include:

- DCR dispatcher who receives the request
- On-shift DCR Physician
- Physician on duty who is responsible for managing the patient and their transport request
- Physician on duty in the receiving hospital service
- HEMS Crew physician

2.7 Technical spotlight: phases of interfacility transport

All IFT missions start with a request call to DCR, where the dispatcher (critical care nurse) receives data on time-dependence and clinical state of the patient. The DCR nurse will discuss the case with the on-shift physician, who gives the all-clear to proceed with dispatch.

The following timepoint is known as 'Alert', the moment in which the DCR contacts the vehicle for mission assignment. In case of HAA alert, the pilot will clear the aircraft for safe take-off and prime the helicopter for departure. In some cases, such as in Padova itself, the airbase is not necessarily on top of a hospital. For this reason, the mission may require a flight towards the sending hospital. In other cases, as is for patients departing the two hospitals in Padova, a ground ambulance can be dispatched to transport the patient to the airbase, extending mission times noticeably.

Ground ambulances often depart from the sending hospital, but this might not always be the case. If ambulances are dispatched from a local ambulance station, similar schematics apply to the aforementioned case. The ambulance therefore will have an additional travel time amounting to the time needed for reaching the sending hospital.

Once the patient is safely on board, the team departs directed towards the receiving hospital. Once the patient has been handed over to the receiving service, the vehicle is flagged by the DCR as 'free and operational', meaning it can be dispatched to another mission regardless of whether the team is back at base or not.

Another fundamental discriminating point between ground and air ambulance times is represented by the patient embarking/disembarking procedures. In both cases, albeit critical, patients must be stable enough to be transported before even the request is sent. Nevertheless, patients who are embarked on aircraft require specific attention as, unlike a ground ambulance where a patient who worsens may be treated enroute, handling a patient in flight is more complex. To make an example, defibrillation procedures during helicopter flight require that the patient has been previously placed on an electric isolation mattress above the helicopter gurney, which will increase the embarking times.

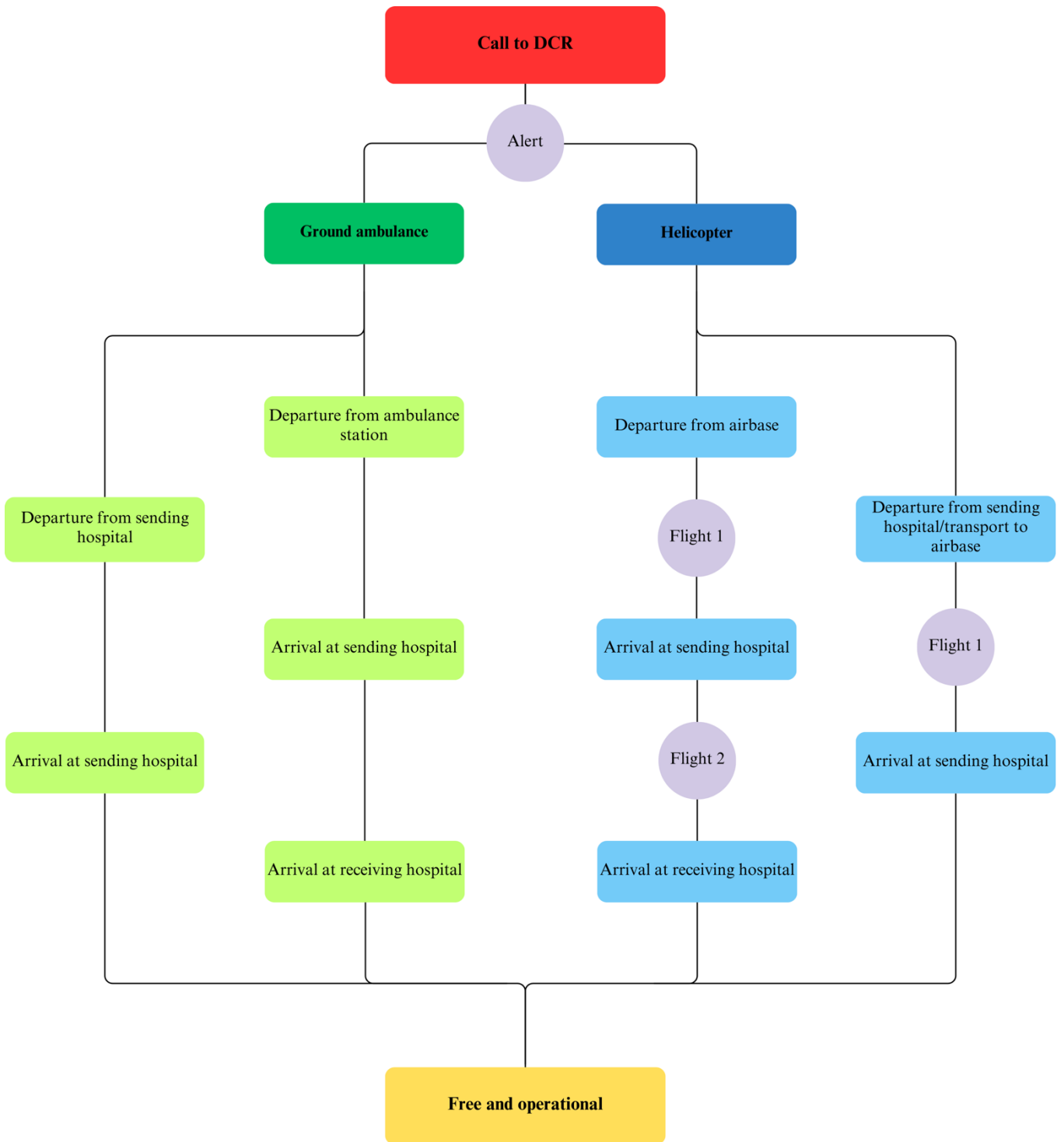


Table I: flowchart of transport times

3 The Study

3.1 Rationale

Since its initial days, HEMS has become a central service in emergency medical services and has broadened both its global availability and deployment scenarios. Helicopter-based services represent the real turning point in managing areas that were once considered remote, either due to their geographic location or scarce road networks. Veneto mainly has 3 critical areas of application in this sense:

- *Dolomites*: mountainous territory has always represented a complex area to manage both in EMS and IFT, both for the inhabitants and for those who work or train in mountainous territory. The Venetian Dolomites represent a hotspot for mountaineering-related activities and tourism in general, as well as being moderately populated.
- *Venetian Lagoon*: this area presents a number of cities and towns on islands, which are either connected by a single road to the mainland or only by ferry services. Albeit developed, boat-based ambulances are characterised relatively slow response times in time-dependent missions.
- *Agricultural areas*: the primary sector is importantly developed in Veneto, with substantial amounts of land devoted to agriculture. For example, the province of Rovigo has extensive patches of land with little road network traversing them, which hinders the effectiveness of ground ambulance services. Furthermore, the local hospitals serving this type of areas generally are categorised as ‘Spoke’ structures, allowing for a primary and generic response, but heavily reliant on IFT for complex cases.

In this context, DCRs have been developing throughout the years to give the most precise response in terms of dispatch to both emergencies and critical care transport requests. A relevant part of the DCR’s work is managing helicopter activation requests in a way that optimises response times and complies with the level of care required for the patient. Committing the HEMS team to a mission is a resource intensive practice, and the decision-making process is guided by local protocols and vehicle availability. In areas where road networks are well developed, the key challenge is discerning whether a helicopter is the right choice as, despite its undisputed superiority in terms of travel speed, both its activation and patient embarking procedures require longer with respect to a ground ambulance. This relates to competitiveness between services in terms of cost-effectiveness and overall mission risk, considered that clinical expertise is on the same level [13, 14, 15]. In the USA, a study has shown that HEMS is a risk-prone occupation as it highlighted 200 deaths in the line of work in the 1980-2008 time frame, amounting to a 100 deaths every 100.000 operators [16].

Another study in a similar time frame (1983-2014) showed that, within this period, HEMS-related incidents have decreased by 71% albeit remaining stable in their lethality (36-50%). The current estimate for deadly incidents in HEMS is 0.04-0.23 every 10.000 missions [17].

3.2 Aims

In the context of HEMS, available literature mainly focuses on HEMS service rather than HAA, with important focus on the advantages of responding to a variety of emergencies (such as STEMI, traumatic CNS injury or stroke [9]) that have been proven to be time-dependent and, consequently, have clinical advantage in being attended to an advanced team with the most rapid response capabilities available. HAA is less covered in literature, partly because geographical territory, hospital networks, local protocol and ground EMS capabilities are particularly variable between services. The production of multicentric randomised trials [18] is directly hampered by the aforementioned points, and is further made more challenging by the common occurrence of incomplete data in the context of it being registered in an emergency setting.

The Padova ground EMS territory (extending through the whole province with some shared competence at its borders) and HEMS territory have very developed road networks, from local roads to highways and motorways between major cities. This allows for relatively agile control of ground ambulances, with some exceptions for the island cities of Chioggia and Venice and part of the Euganean Hills. Even rarer are the occasions in which requests for IFT from mountainous territory that fall under Padova's jurisdiction. This setting makes it challenging to adequately assign an IFT mission to the right vehicle. Most studies assessed relate to missions within the competence territory or its outskirts, rarely moving outside of Veneto. Some commonly observed travel pathways include various centralisation requests towards Padova University Hospital, or Chioggia-Mestre for PCI capabilities.

A number of unique cases fall under the 'delayed primary' definition: this is a patient who is admitted to a PPI (Punto di Primo Intervento – First Aid Outpost), meaning a small, remote area emergency room with limited capabilities, who requires centralisation. Due to the geographical localisation of these outposts and their obvious limitations in diagnostics and therapy, the call is triaged and dispatched as a primary emergency. Another key point in this type of handling is of aeronautical nature: regulations for flight vary between flights declared as primary emergency or secondary transport. The most crucial of all is the possibility of landing the aircraft on a field or road in primary missions, whereas secondary ones require a helipad that is registered and compliant with national civil aviation authority, and this may not be available in all outposts.

The main endpoint of assessing these variables is avoiding the under- or overtriaging of a mission, where the two extremes are either dispatching an ineffective vehicle to a highly critical patient or keeping the helicopter occupied on an IFT mission while it could be kept free for emergencies, causing large patches of territory to be uncovered from HEMS service for hours.

The study aims at demonstrating that there is a limit under which ground ambulance activation is more advantageous than HAA dispatch, by assessing a pool of mission times and distances. In this direction, measurement of a series of objective parameters has been obtained for all IFT missions completed by Leone 2 and compare it to a pool of 90 ground ambulance IFT missions. This allowed to highlight factors other than pure travel speed, for which helicopters are clearly superior, which are less obvious but fundamentally relevant in the total mission times for both vehicles. These include:

- Team activation times
- Patient embarking/loading times
- Patient disembarking/unloading times

Mere travel times between hospitals are not the most realistic parameter to consider in dispatching HAA or ground ambulances. Once also the aforementioned variables are taken into account, helicopters may not always be the most appropriate vehicle to activate in some missions.

3.3 Materials and methods

The data pool is represented by all HAA interfacility transports completed by Padova EMS' helicopter in a time frame ranging from January 2021 to July 2024. The sole exclusion criterion for missions was insufficient or totally absent data, with a total of 13 out of 260 missions excluded from analysis (247 effective missions assessed). No other distinctions such as pathology, sex or age group were made. Clinical and prognostic data was not assessed in light of the very high variability and relatively scarce informative value in the direction of the present study.

The collected data was represented by:

- All mission times from first alert to mission concluded
- Departure and destination hospitals
- Emergency triage code of the mission (Emergent or Programmed)

Helicopter flight times have been derived from real life mission data, saved into the Padova DCR's dispatch software.

For ground ambulance time estimation, two methods were applied, one for estimating technical times (alert time, patient loading/unloading), and another for the travel times. Technical times have been derived from a pool of 88 real ground ambulance transports, which allowed to give a realistic estimate of average alert time for the ambulance crew, as well as the average time needed to safely load and unload patients from the vehicle. To best compare travel times between ground and air ambulance, an estimate was made using as templates helicopter journeys and inserting departure and destination hospitals on Google Maps, adjusting the latter's settings to reflect a road trip done at night on a weekday. The shortest travel times estimated by the software have been taken into account. This allowed to minimise as much as possible the variable of road traffic, in order to account for the fact that an ambulance would be travelling on lights and sirens.

HAA Mission Logs include the following timepoints, which have been taken into consideration: alert, first take-off (from airbase), first landing (sending hospital), second take-off, second landing (destination hospital), mission concluded (free for dispatch) and back at base. Within these, a series of partial times have been assessed:

- *Alert Time*: time elapsed from DCR dispatch (alert) to first take-off
- *Patient Embarking Time*
- *Patient Disembarking Time*: includes both actual disembarking and handover at destination hospital
- *Net Flight Time*: from sending to destination hospital, or from airbase to destination hospital in case the Sending Hospital was one of Padova's hospitals

On this basis, three variables have been selected for final comparisons between ground ambulance and helicopter air ambulance IFT:

- *Pure Travel Time*: time elapsed between the take-off from sending hospital to landing at destination hospital
- *Delivery Time*: time elapsed between alert and patient arrival at destination hospital, not taking into account final delivery/disembarking operations
- *Total Mission Time*: time elapsed between alert and mission concluded, when the helicopter is ready to accept another mission

Assessment of pure travel time would yield an obvious advantage of flight against road travel, therefore the study has been implemented with two metrics that correct this by accounting for technical times. Delivery Time will therefore show the difference in alerting a ground ambulance versus the helicopter, as well as the difference in time taken with patient loading. Total Mission Time is an overall metric considering also unloading, handover and, when needed, rapid vehicle restocking/cleaning before freeing up for other missions.

3.4 Statistical analysis

Data elaboration was executed under the supervision of the Biostatistics, Epidemiology and Public Health Department of the University of Padova.

Continuous variables have been reported using median and interquartile range (I-III quartile), whereas categorical variables have been reported in absolute numbers and percentage (relative frequency).

The outcome measure in study has been defined as the difference between helicopter time and ambulance time, calculated in the following formula:

$$\text{Delta: Helicopter } T - \text{Ambulance } T$$

Linear regression was the method of choice for the study of associations between Delivery/Mission Time, vehicle used and distance.

Change-Point Analysis [19] was applied to assess the kilometeric cutoff at which a significant change in the aforementioned Delta occurred. This method allows to detect the point or points when a statistically significant change occurs in a given quantity. To further reinforce the result, sensitivity analysis has been run. Change-Point Analysis has been applied to both air distance for helicopter, and road distance for ground ambulance data.

An initial assessment of the whole data pool was then divided into results with and without outliers, in an effort to study the impact of extreme values in both delta and distance. Upon further reasoning, only analysis with outliers has been taken into consideration as all the values assessed come from ascertained, real-life data that necessarily has to comprise also extreme values in order to reflect the true operational reality of HAA/HEMS dispatch.

Missing values have been managed with the Random Forest (MissForest) Data Imputation technique [20]. This allows to give a precise estimate of a given missing value based on the rest of the complete dataset. The estimate will therefore be realistic, and further stabilise the data.

Analysis was run on R software, with ChangePoint [21] and MissForest packages.

3.5 Study limitations

HEMS has been gaining recent attention in terms of research, but still remains a relatively underexplored milieu of EMS. More in general, building multicentre or prospective studies for EMS proves to this day challenging due to the marked heterogeneity between one service and another in terms of available personnel and vehicles, geography and operational protocols. Furthermore, the very nature of EMS as a field makes for often partial or imprecise charting, giving the present datasets less precision. At times, the registered mission times are unrealistic either due to operator error or even operational loopholes, such as when a helicopter in HAA setting is rerouted to a HEMS mission after having taken off for the first mission, which it would reprise after concluding the primary intervention.

Clinical outcomes have not been explored in this study due to the difficulty in accessing patient files outside of Padova University Hospital. Similarly, ground estimates have been extrapolated with use of navigational software due to the fact that very often ground ambulances are dispatched from a sending hospital that is outside of Padova EMS' domain.

The present study stands valid for the context of Padova EMS, but might not be generalised to other operational territories due to stark geographic or service difference. A mountainous area, or an island, or even an EMS service lacking a helicopter that relies on mutual aid from neighbouring areas may not benefit from the assessment at hand if parameters are not adapted to that specific context.

4 Results

4.1 Descriptive analysis

Partial Helicopter Times (n= 247)	Median in Minutes (IQR)
Alert T	12 (8, 17)
Missing Data	17
Patient Embarking T	32 (24, 42)
Missing Data	50
Flight T	14 (9, 23)
Missing Data	31
Patient Disembarking T	31 (23, 42)
Missing Data	54
Delivery T	73 (59-87)
Missing Data	16
Total Mission T	103 (90, 128)
Missing Data	10

Table II: partial helicopter time medians with related interquartile ranges

Partial Ambulance Times (n=247)	Median in Minutes (IQR)
Alert T	8
Patient Loading T	8
Road Travel T	45 (40, 60)
Patient Unloading T	16
Delivery T	58 (53, 73)
Total Mission T	74 (69, 89)

Table III: partial ground ambulance time medians with related interquartile ranges

In table III, the values lacking IQR are those estimated by assessment of the 88 real ground ambulance IFT missions.

Characteristic	Helicopter n=247 [1]	Ambulance n=247 [1]	p-value [2]
Delivery T	73 (60, 87)	58 (53, 73)	<0.001
Unknown	16	0	
Mission T	103 (89, 126)	74 (69, 89)	<0.001
Unknown	10	16	
Pure Travel T	14 (9, 23)	45 (40, 60)	<0.001
Unknown	31	0	

[1] Median (IQR);

[2] Wilcoxon Sum Test

Table IV: significance analysis of helicopter and ambulance partial times in minutes

4.2 Partial time association analysis

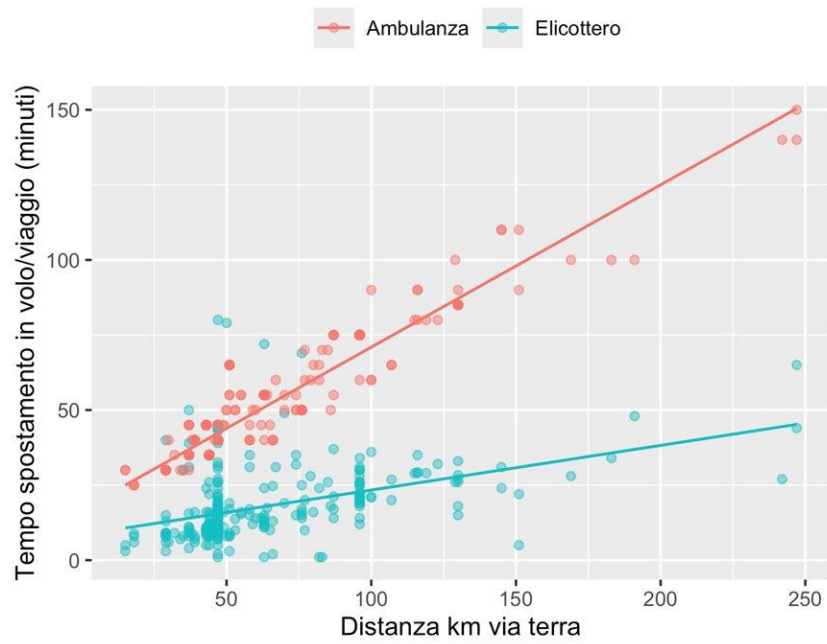


Figure 8: Pure Travel Time (*tempo spostamento in volo/viaggio*) associative analysis

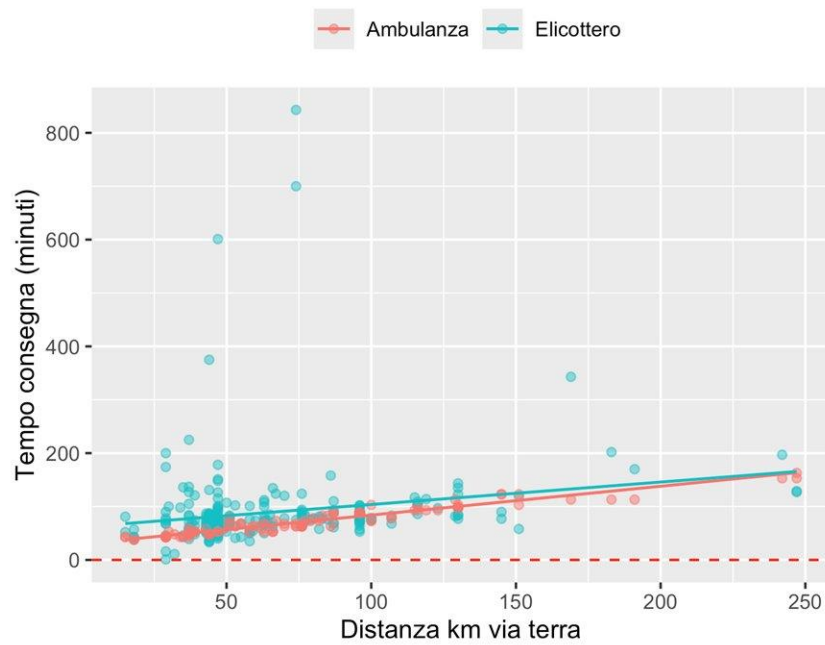


Figure 9: Delivery Time (*tempo consegna*) associative analysis

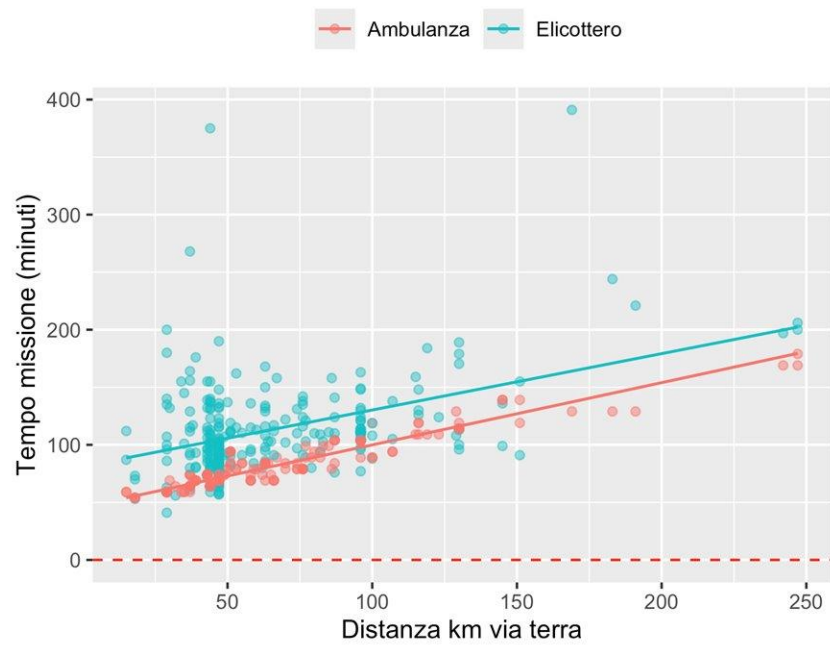


Figure 10: Total Mission Time (tempo missione) associative analysis

4.3 Outcome variable analysis: delta of partial times

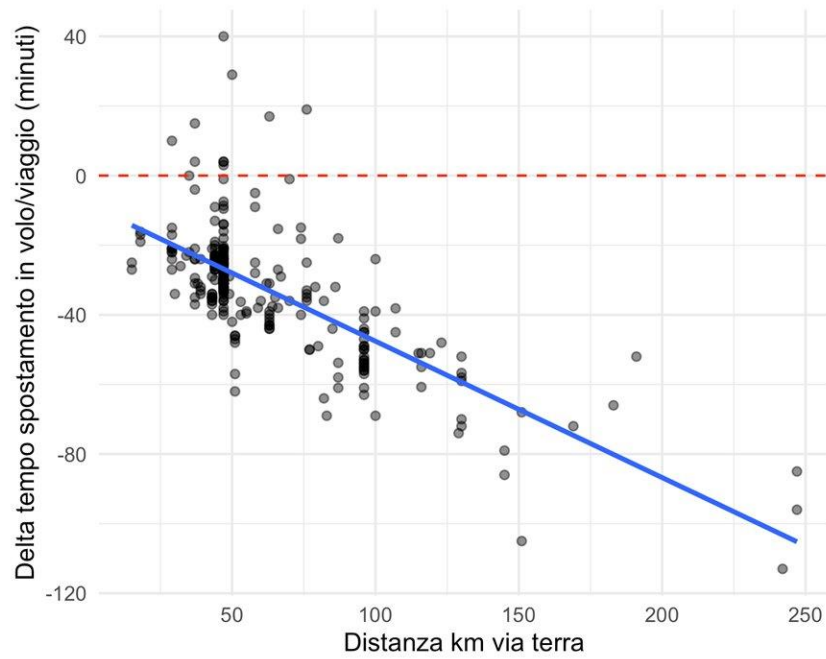


Figure 11: Pure Travel Time Delta in relation to road distance (distanza km via terra)

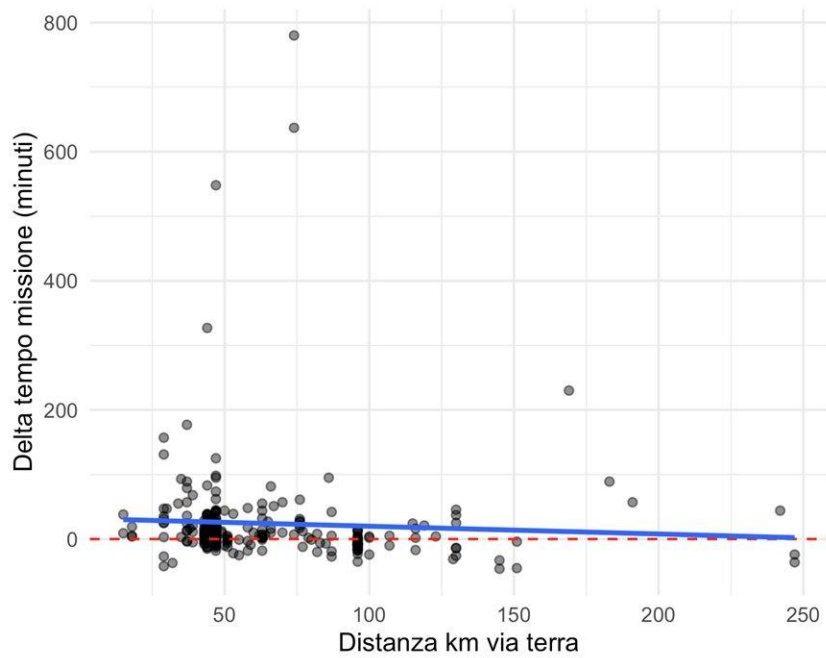


Figure 12: Delivery Time Delta in relation to road distance

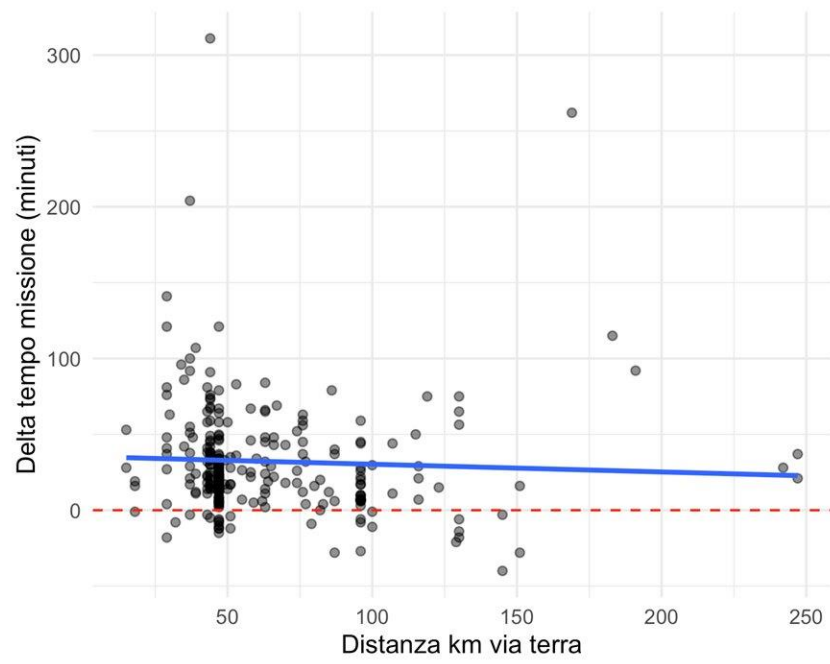


Figure 13: Total Mission Time Delta in relation to road distance

4.4 Linear regression models of partial times

<i>Characteristic</i>	Beta	95% CI¹	p-value
<i>Kilometres</i>	0.48	0.34, 0.62	<0.001
<i>Ambulance</i>	—	—	
<i>Helicopter</i>	24	14, 34	<0.001

¹CI = Confidence Interval

Table V: linear regression analysis of delivery times in relation to ground distance and vehicle type

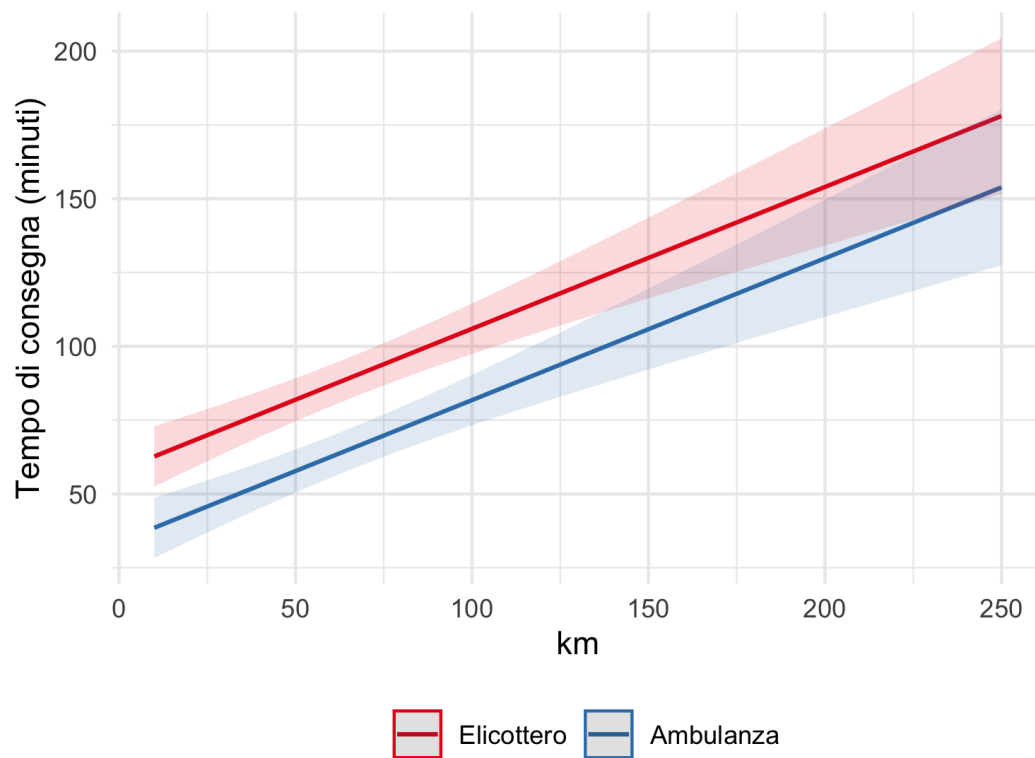


Figure 14: linear regression model of delivery times in relation to ground distance and vehicle type

<i>Characteristic</i>	Beta	95% CI¹	p-value
<i>Kilometres</i>	0.52	0.45, 0.58	<0.001
<i>Ambulance</i>	—	—	
<i>Helicopter</i>	32	27, 37	<0.001

¹CI = Confidence Interval

Table VI: linear regression analysis of total mission times in relation to ground distance and vehicle type

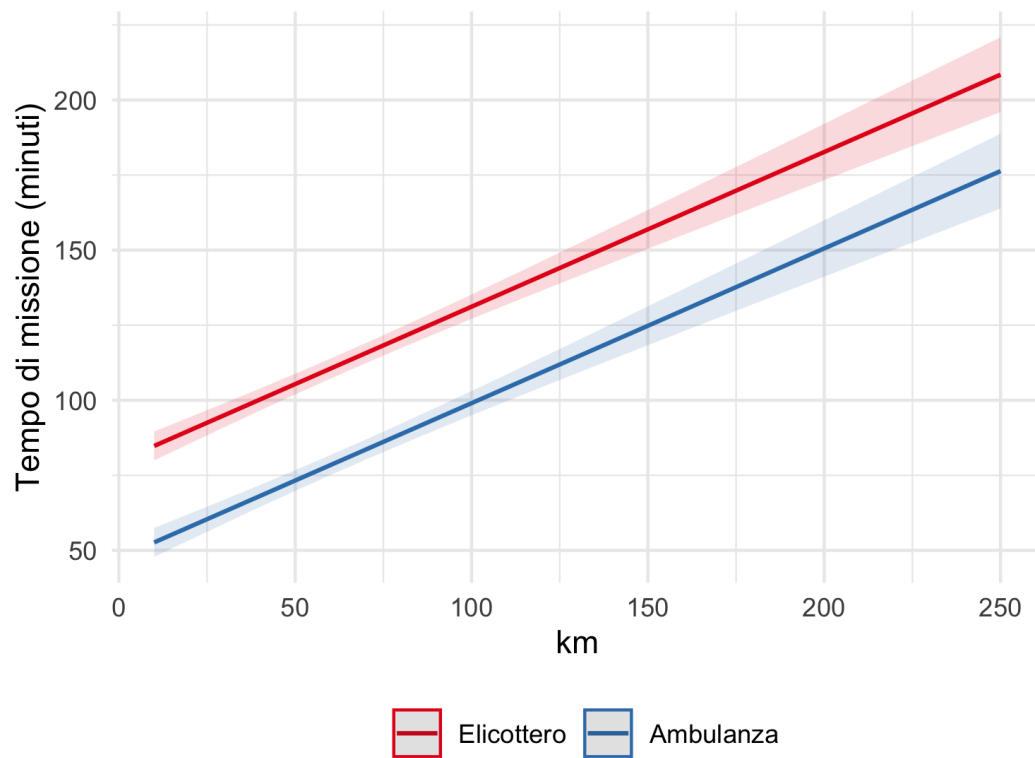


Figure 15: linear regression model of total mission times in relation to ground distance and vehicle type

4.5 Change-point analysis of Delta Time outcome variable

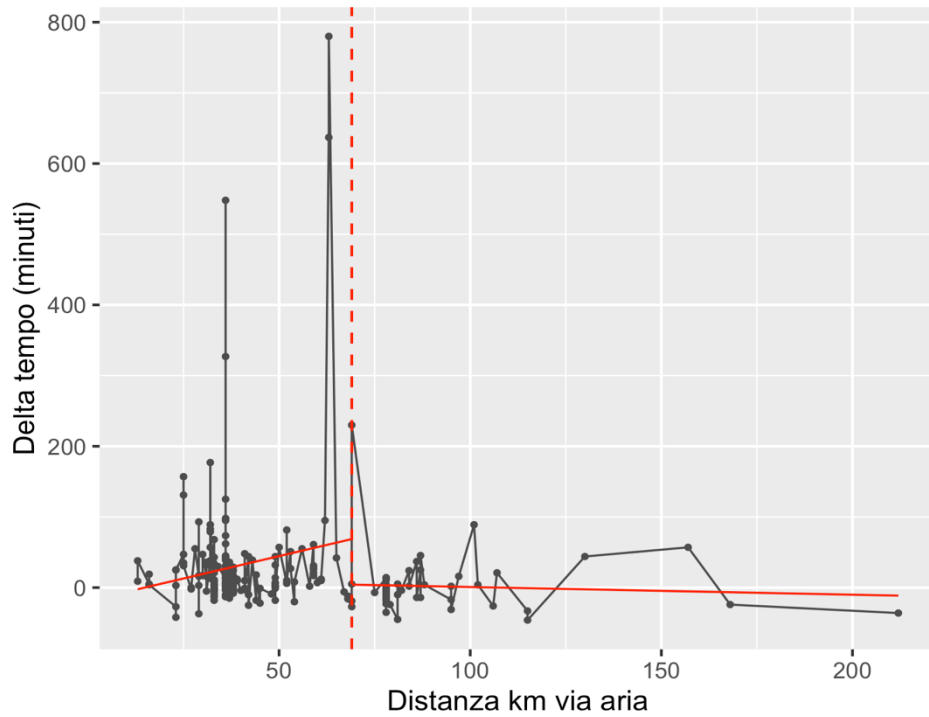


Figure 16: change-point and trend in delivery times highlighted by considering air distance

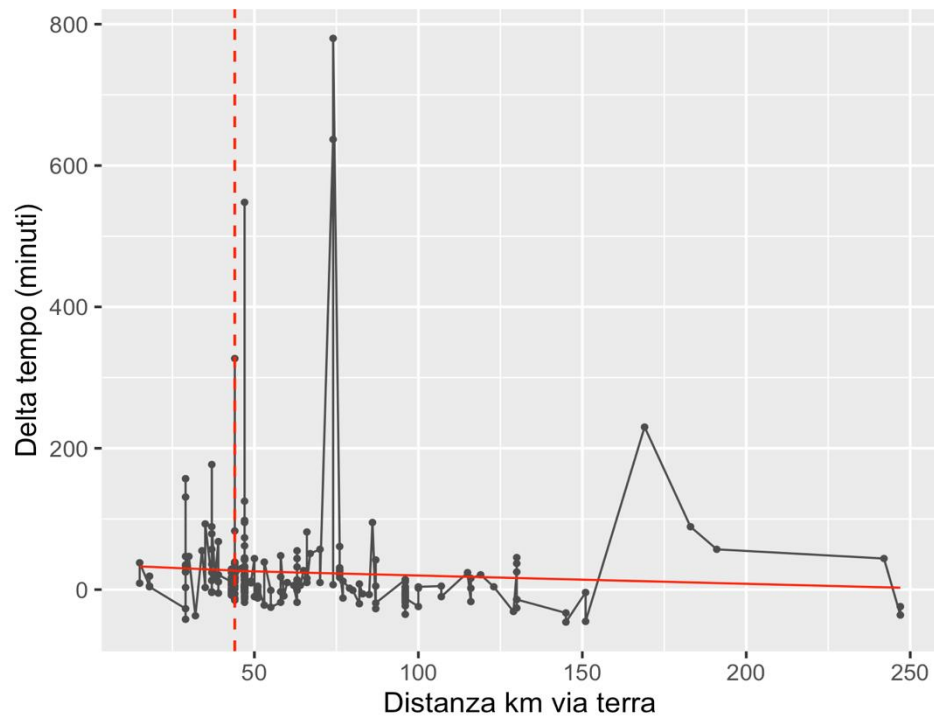


Figure 17: change-point and trend in delivery times highlighted by considering ground distance

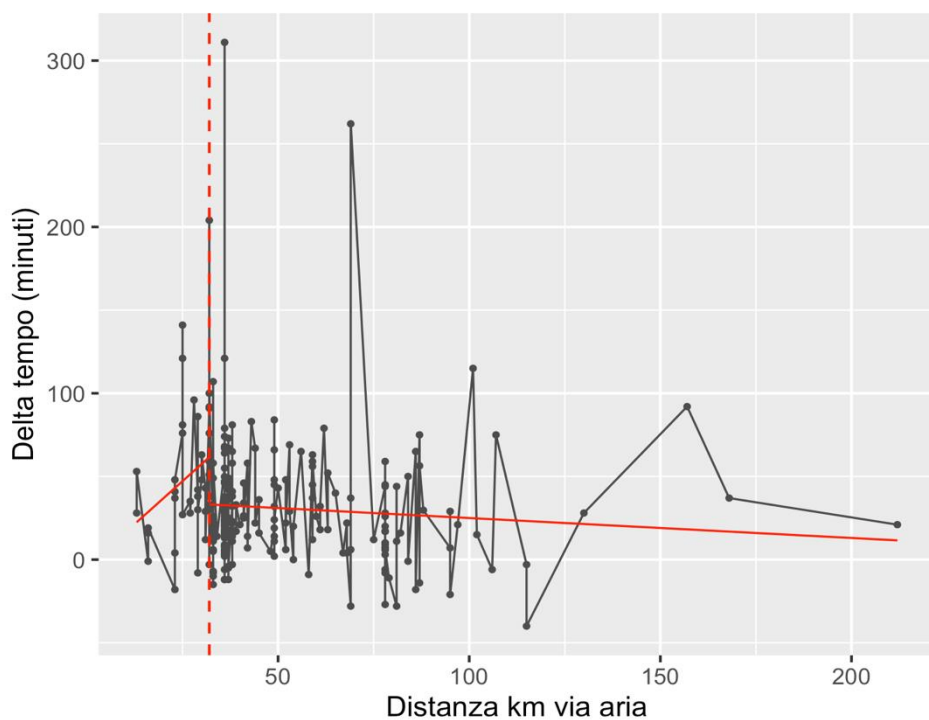


Figure 18: change-point and trend in total mission times highlighted by considering air distance

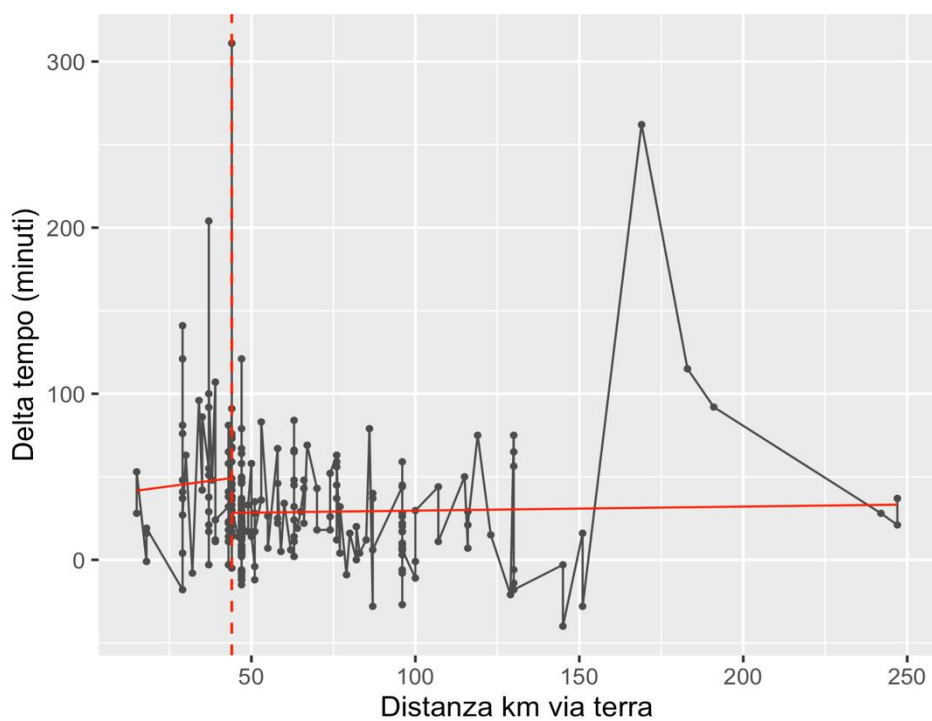


Figure 19: change-point and trend in total mission times highlighted by considering ground distance

5 Discussion

5.1 Technical times

In the descriptive analysis of all partial time medians, all partial helicopter times resulted higher with respect to ambulance times (*tables II, III*).

	Helicopter	Ambulance
Alert T	12 min	8 min
Loading/Embarking T	32 min	8 min
Unloading/Disembarking T	31 min	16 min

Table VII: technical times for helicopter and ambulance IFT

Helicopter times are noticeably extended with respect to ambulance times due to a variety of reasons, the most common include:

- For alert times, there is a necessary waiting time between receiving the mission and taking off where the pilot confirms the flight path, primes the aircraft and completes pre-flight checks
- For embarking and disembarking times, it is often necessary to move the patient between helipad and hospital with a short ground ambulance transfer
- Helicopter embarking requires a series of extra steps to secure patients to the flight-certified gurney, as well as all the equipment travelling with them (monitor, infusion pumps etc.)

5.2 Pure travel time (flight/road)

A foreseeable advantage of helicopter flight times against road travel has been confirmed by descriptive analysis, with a median of 14 minutes of flight against 45 minutes of road travel for ground ambulances. Significance analysis highlighted a p-value < 0.001 (*table IV*).

When assessing *figure 7*, associative analysis further supports the helicopter's undisputed advantage in terms of speed, even more so as the distance increases. *Figure 10* shows a consistent negative Delta = Flight T – Travel T, thus in favour of the helicopter, especially as the travel distance increases.

5.3 Delivery Times

Taking delivery time (alert to arrival at destination hospital) into consideration as the most reliable parameter for the present study, a complete inversion of the result is observed. Despite not taking into account unloading/disembarking times, an advantage in favour of ground ambulances is already appreciated. Ground ambulance median delivery time is represented by a value of 58 minutes, as opposed to 72 minutes for the helicopter (*table IV*). The advantage is higher the shorter the travel distance is, as represented by the value cluster in *figure 8*.

Assessment of $\Delta = \text{Helicopter Delivery T} - \text{Ambulance Delivery T}$ highlights a positive value in most cases, therefore in favour of the ground ambulance, especially on shorter distances (*figure 11*). Extremely positive Δ values are often attributable to missions that lasted for a number of hours, mainly due to the issue of the helicopter being alerted for an IFT mission and, after alert, being rerouted in flight to a HEMS mission. This is a rare occurrence, which nevertheless may occur commonly in programmed IFT flights due to their non-urgent nature.

Cases where Delivery T Δ appeared extremely negative have been singularly studied and most often refer to specific situations, such as:

- Transports involving mountainous regions (Feltre, Belluno, Asiago hospitals).
- Transports from coastal areas: centralisation of patients from Venice hospital would require water ambulance travel to Piazzale Roma, where a ground ambulance would later receive the patient to proceed inland. Helicopter flight represents the optimal choice in critical patients.
- Transports through the Venetian Lagoon: emergent transfers between Chioggia and Mestre hospital (spoke to local hub) are a common occurrence, especially during summer months when tourism affluence is at its highest. Flight offers the possibility of travelling over the Venetian Lagoon instead of travelling coastally via road.

These missions are representative of adequate HAA dispatch, where a helicopter has clear advantage in transporting a critical patient towards their destination. Furthermore, in the singularly assessed cases, technical times were often reduced with respect to the observed median. This can be interpreted as a measure of the experience of dispatch, flight and ground teams in managing a safe, secure and rapid patient embarking/disembarking due to the frequency with which HAA services are required.

Long-haul flights have been singularly assessed and are generally represented by interregional, programmed back transports. These are in most cases stable, albeit critical, patients who require transfer closer to their place of residence. Though the important travel distance makes the helicopter an obvious choice, these are marginal missions that are not representative of a helicopter air ambulance's performance in emergency transfers.

The linear regression model and contextual analysis (*table V, figure 13*) allowed to observe a Delivery Time 24 minutes (Confidence Interval 14-34 min) longer for the helicopter compared to ground ambulance, considering the same journey for both. In these conditions, also an increase of 0.48 minutes per each kilometre (CI=0.34, 0.62) was observed for helicopter transfer as opposed to ground ambulance on the same travel length. This parameter is known as Beta, a coefficient representing an estimated change of a dependent variable (time in minutes) per each unit change in a predictor variable (kilometre). More in general, the model allows to predict a Delivery T based on road travel distance, and the choice of either helicopter or ground ambulance.

Change-point analysis allows to search for a point where there is a shift in a trend under study. In the present case, taking delivery time Delta as a parameter, the change-point was identified as (*figures 15-16*):

- 69 kilometres via air distance
- 44 kilometres via road distance

This change-point represents a significant shift in Delta T, which can be interpreted as the point when an inversion occurs in the trend between time and distance.

5.4 Total Mission Times

Descriptive analysis of total mission time for HAA resulted in a median of 103 minutes (CI= 89, 126), and 74 minutes for ground ambulance (CI= 69, 89). This takes into assessment time elapsed from alert time to when the helicopter or ambulance is newly ready to accept missions.

Albeit less informative in terms of pure transport performance with respect to delivery time, total mission time is still taken into assessment as it reinforces the result obtained in previous analyses. Furthermore, it can serve as a global assessment of travel performance in association to team efficiency in managing rapid response, safe loading and unloading of patients, and precise handovers at destination.

Figure 9 shows a larger distance between the blue 'Helicopter' line and the red 'Ambulance' line, attributable to how incisive technical times are in extending helicopter mission time.

Assessment of Delta = Helicopter Total Mission Time – Ambulance Total Mission Time most often resulted in positive values (*figure 12*), with an advantage for the ground ambulance especially on short distances.

The linear regression model resulted in an additional 32 minutes (CI = 27, 37) per equal distance mission for the helicopter in comparison to ground ambulance. Contextually, the Beta resulting from total mission time regression analysis is 0.52 min/km (CI = 0.45, 0.58) for the helicopter (*table VI, figure 14*).

Change-point analysis for total mission time identified the following points for Delta T shift (*figures 17-18*):

- 32 kilometres via air distance
- 44 kilometres via ground distance

When referred to ground distance, the change point can be interpreted as the threshold over which helicopter travel would result advantageous.

6 Conclusions

The final results referred to the 247 IFT missions managed by Padova HEMS base between January 2021 and July 2024 allowed to highlight how the undisputed speed of helicopter air ambulances may be misleading in dispatch decision-making, leading to an overestimation of the real rapidity the helicopter may offer in concluding an IFT mission. This holds especially true for short-distance transports.

Change-point analysis of both delivery and total mission times allowed to observe a shift in Delta T at 44 kilometres (ground distance). Out of the 247 assessed missions, 73 (29.5%) were under 44 kilometres in ground distance. The *primum movens* for the study, represented by the hypothesis that helicopter air ambulance IFT could be subject to overtriage in the context of Padova EMS, was therefore proven. Within the 44-kilometre change-point, helicopter-based IFT

Pure travel time is a parameter too labile and too little informative for it to be considered alone in HAA dispatch decision-making. A holistic comprehension of technical times, vehicle performance and territorial geography are necessary to optimise mission dispatch related to vehicle choice. This is further informed by evaluation of the patient's clinical condition, local EMS and hospital networks, logistical organisation, aeronautical clearance and meteorological conditions. Optimal helicopter dispatch is fundamental in avoiding the event where the aircraft is occupied in an IFT mission that could be managed otherwise, while an emergency occurs that may be eligible for HEMS activation.

Adequate dispatch is a cornerstone of modern-day EMS, most notably in when evaluating the activation of a resource-intensive and rare service such as HEMS, which covers large stretches of territory and represents the pinnacle of advanced emergency medical services.

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