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Costs and resource utilization of a 24/7 physician-staffed prehospital critical care service: a real-world analysis

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Abstract

Background

Specialized prehospital critical care services require continuous operational readiness, but real-world data on the economic requirements of multipurpose physician-staffed ground response systems remain limited. We aimed to characterize service utilization and resource requirements of a continuously available Medical Intervention Car (MIC) service.

Methods

We conducted a retrospective observational cost analysis of all MIC activations in Stuttgart, Germany, between December 2, 2024, and May 31, 2026. Operational data were combined with institutional accounting, procurement, personnel, vehicle, equipment, and consumption data. Costs were annualized to 2026 euros and classified as readiness and service costs (A), non-reimbursed mission-related operating costs (B), or patient-specific resources (C). Deterministic sensitivity analyses examined key personnel and capital-cost assumptions.

Results

During 18 months of continuous operation, 802 missions were recorded, with patient contact in 504 (62.8%). Annual MIC service and operating resource requirements (A + B) were €334,438, while total resource costs including patient-specific resources (A + B+C) were €662,388. These corresponded to €626 and €1,239 per mission and €995 and €1,971 per patient contact, respectively. Personnel and on-call availability accounted for €243,580 annually. Patient-specific resources accounted for €327,950, predominantly ECPR-specific consumables (€317,312). Across sensitivity analyses, annual MIC service and operating resource requirements ranged from €315,701 to €369,556 and total resource costs from €643,651 to €697,506.

Conclusion

Maintaining and operating a continuously available physician-staffed prehospital critical care service required substantial readiness and operational resources, with additional resource use attributable to patient-specific care. Separating these components provides a transparent description of the economic structure of a multipurpose prehospital critical care service.

Introduction

Specialized prehospital critical care systems provide advanced diagnostic and therapeutic interventions for time-critical emergencies beyond the capabilities routinely available within conventional emergency

medical services (EMS). Depending on the healthcare system, these services may be delivered by physician-staffed ground or helicopter-based teams. Previous studies have suggested potential benefits of physician-staffed prehospital care in selected critically ill and injured populations, although effects vary according to patient population and system configuration [1, 2].

Advances in prehospital critical care have also increased the complexity and resource requirements of these systems. One prominent example is extracorporeal cardiopulmonary resuscitation (ECPR) for selected patients with refractory out-of-hospital cardiac arrest. Prehospital ECPR programs have demonstrated the feasibility of establishing extracorporeal support in the field but require highly trained personnel, specialized equipment, consumables, logistics, and continuous operational readiness [3]. Continuous availability requires personnel, vehicles, equipment, and training irrespective of mission volume, while individual care generates additional resource consumption. Economic evaluations of helicopter emergency medical services (HEMS) have demonstrated variation in costs and cost-effectiveness [4, 5], highlighting the importance of readiness and capacity utilization [6]. For multipurpose services, economic performance may depend on patient volume and the utilization of specialized teams beyond individual high-resource interventions such as ECPR [7]. Procedure-based assessments alone may therefore underestimate the resources required for continuous readiness.

Despite increasing implementation of specialized prehospital critical care, real-world economic data on continuously available, multipurpose physician-staffed ground response systems remain limited. Therefore, this study aimed to characterize the utilization and resource requirements of a 24/7 physician-staffed Medical Intervention Car (MIC) service. Specifically, we quantified the resources required to maintain and operate the service, separately described patient-specific resource consumption, calculated resource requirements per mission and patient contact, and examined the influence of key assumptions on annual estimates in sensitivity analyses.

Methods

Study design and setting

This retrospective observational study combined routinely collected operational data with a cost analysis of all MIC activations in Stuttgart, Germany, between December 2, 2024, and May 31, 2026. The study characterized utilization and resources associated with maintaining and operating a continuously available specialized prehospital critical care service; no comparator or cost-effectiveness analysis was included.

The MIC is a physician-staffed, non-transport rapid-response unit integrated into the municipal EMS system serving approximately 635,000 inhabitants. It supplements conventional EMS and provides advanced airway and hemodynamic management, point-of-care ultrasound, blood product administration, trauma interventions, and prehospital ECPR. Pediatric, neonatal, or intensive care specialists may be integrated according to mission requirements.

The MIC operates continuously using a hybrid staffing model. Physicians are available on site weekdays from 08:00 to 16:00; nights, weekends, and public holidays are covered through home-based on-call duty. Activation may occur primarily through the dispatch center, secondarily by EMS personnel on scene, or interregionally.

Study population and data sources

A MIC mission was defined as any formal activation by the dispatch center, irrespective of subsequent patient contact. No missions were excluded. Patient contact was defined as arrival of the MIC team at the patient with direct clinical assessment; missions cancelled before arrival were classified as missions without patient contact.

Operational data were obtained from electronic mission documentation and dispatch records and included mission volume, patient contact, activation pathway, interregional deployment, selected clinical mission categories, potential ECPR missions, ECPR procedures, response and driving times, and travel distance. Potential ECPR missions were identified retrospectively from the available mission and dispatch data and were defined as MIC activations for cardiac arrest in which, based on the information available at dispatch, prehospital extracorporeal support could potentially have been required. This classification reflected the potential need for ECPR at the time of activation and did not imply fulfillment of definitive ECPR eligibility criteria.

Economic data were obtained from institutional accounting and procurement records, personnel information, invoices, and vehicle and equipment records. Actual consumption data were used where available. Cost components were reviewed for duplication, and resources already included within broader categories were not entered separately. Costs that could not be reliably identified or attributed to MIC service provision were excluded from the base-case analysis.

Economic cost classification

Costs were classified into three categories. Category A (readiness and service costs) comprised resources required to maintain continuous MIC capability irrespective of mission activity, including physician staffing and on-call availability, vehicle and medical-equipment capital costs, communication and information technology, training, and staff equipment. Category B (non-reimbursed mission-related operating costs) comprised fuel, vehicle servicing and repairs, and tires. Categories A + B represented the MIC service and operating resource requirement.

Category C comprised patient-specific resources consumed during individual care that were economically attributable to the patient-specific treatment episode rather than to MIC service readiness, including ECPR-specific and other medical consumables. Depending on the receiving institution and resource type, these costs could be allocated to subsequent treatment or compensated through material replacement.

Personnel costs

Physician personnel costs were estimated using a tariff-based model rather than project-specific remuneration. The staffing pool comprised six senior physicians and five board-certified specialists, with weighted average remuneration based on representative mid-level salary steps of the applicable TV-Ärzte/VKA remuneration groups.

Eight weekday hours were assigned to regular working time; the remaining 16 hours on weekdays and 24 hours on weekends and public holidays were valued according to tariff-based on-call compensation. Mission-related work during on-call periods was additionally incorporated using the observed mean mission duration of 56.6 minutes and 554 on-call missions. Night, weekend, and public-holiday supplements were incorporated using a weighted average tariff-based allowance reflecting the temporal distribution of on-call coverage. Personnel expenditure was converted to employer costs using the institutional factor of 1.30; observed project-specific personnel expenditure was examined in sensitivity analysis.

Specialist support from neonatology, pediatrics, and internal/intensive care medicine was provided within existing staffing structures and generated no incremental MIC-specific remuneration. Accordingly, no incremental personnel expenditure was assigned in the base case; associated opportunity costs were not quantified.

Valuation and annualization

All costs were expressed in 2026 euros. Costs observed during the 18-month period were converted to annual equivalents by multiplying by 12/18 where appropriate. Capital expenditures were annualized over predefined useful lives using a 3% annual discount rate. For acquisition cost C, discount rate r, and useful life n, annual equivalent cost (AEC) was calculated as:

$$AEC = C \times r / [1 - (1 + r)^{-n}].$$

Equipment-specific useful-life assumptions are provided in Supplementary Table S1. Recurring costs were annualized without discounting. No additional inflation adjustment was applied because costs were standardized to 2026 prices. Capital assets used across clinical indications were treated as shared readiness resources and were not allocated to individual mission types.

Outcomes and cost analysis

Primary outcomes were annual MIC service and operating resource requirements (A + B), total annual resource costs (A + B+C), and corresponding costs per mission and patient contact. Secondary outcomes included category contributions, costs per day and hour of continuous availability, patient-contact ratio, and monthly mission volume.

Unit costs were calculated using annualized activity denominators. ECPR-specific consumables were reported separately but were not interpreted as total ECPR costs because shared readiness resources

were not allocated to individual indications. Detailed decomposition is provided in Supplementary Table S3.

Sensitivity analyses

Deterministic one-way sensitivity analyses examined uncertainty in personnel and capital-cost assumptions. The base case used an employer cost factor of 1.30, tariff-based physician remuneration, a 3% discount rate, predefined equipment-specific useful lives, and a CARDIOHELP acquisition cost of €75,000. Scenarios varied the employer cost factor to 1.20 and 1.40, substituted observed project-specific personnel expenditure, varied useful lives by ± 2 years, applied a 0% discount rate, and varied the CARDIOHELP acquisition cost between €60,000 and €90,000. Only the specified parameter was varied in each scenario. A + B and A + B+C were recalculated; full results are provided in Supplementary Table S2.

Statistical analysis and missing data

Analyses were descriptive. Continuous variables are presented as means with standard deviations or medians with interquartile ranges, as appropriate, and categorical variables as numbers and percentages. Cost data are reported as annualized costs, proportions, and costs per predefined service unit. No hypothesis tests, mission-level cost regression models, or probabilistic sensitivity analyses were performed because the analysis focused on observed system-level resource utilization and substantial shared costs could not reliably be allocated to individual missions. Analyses were performed using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA).

Operational analyses used available data without imputation; denominators were reported where observations were incomplete. Unavailable cost components were neither assigned a value of zero nor estimated unless an explicit valuation assumption was defined.

Results

During the 18-month study period, the MIC was continuously available for 546 days (13,104 h) and was activated 802 times, corresponding to 44.6 missions per month. Patient contact occurred in 504 missions (62.8%). Primary dispatches accounted for 594 missions (74.1%), secondary requests for 160 (20.0%), and interregional missions for 48 (6.0%).

Potential ECPR missions accounted for 334 activations (41.6%), with ECPR performed in 67 cases (8.4% of all missions; 20.1% of potential ECPR missions). Neonatal, pediatric, and trauma missions accounted for 68 (8.5%), 36 (4.5%), and 62 (7.7%) activations, respectively. Mean response time was 16.8 ± 7.5 min, driving time 14.5 ± 7.3 min, and travel distance 12.1 ± 10.3 km. Detailed operational characteristics are presented in Table 1.

Table 1
Operational characteristics of the MIC service during the 18-month study period.

Characteristic	Value
Observation period and utilization	
Observation period	18 months
Observation days	546
Total availability, h	13,104
Total missions	802
Average missions per month	44.6
Patient contacts	504 (62.8%)
Missions without patient contact	298 (37.2%)
Dispatch characteristics	
Primary dispatches	594 (74.1%)
Secondary requests	160 (20.0%)
Interregional missions	48 (6.0%)
Selected mission characteristics	
Potential ECPR missions	334 (41.6%)
ECPR procedures performed	67 (8.4%)
ECPR performed among potential ECPR missions	67/334 (20.1%)
Neonatal missions	68 (8.5%)
Pediatric missions	36 (4.5%)
Trauma missions	62 (7.7%)
Operational intervals and distance	
Response time (min), mean ± SD	16.8 ± 7.5
Driving time (min), mean ± SD	14.5 ± 7.3
Travel distance (km), mean ± SD	12.1 ± 10.3

Data are presented as n (%) unless otherwise indicated. Percentages refer to all MIC activations (n = 802), except for ECPR procedures among potential ECPR missions. Selected mission characteristics represent predefined clinically relevant mission categories and are not intended to constitute a mutually

exclusive or exhaustive classification of all MIC activations. ECPR, extracorporeal cardiopulmonary resuscitation; SD, standard deviation.

Annual cost structure

Total annual resource costs (A + B+C) were €662,388, of which €334,438 (50.5%) represented the MIC service and operating resource requirement (A + B) and €327,950 (49.5%) patient-specific resources (C).

Readiness and service costs (A) amounted to €325,178 annually, including €243,580 for physician personnel and on-call availability. Non-reimbursed mission-related operating costs (B) were €9,260. Patient-specific resources (C) were €327,950, predominantly ECPR-specific consumables (€317,312). Detailed cost components are presented in Table 2 and Supplementary Table S1.

Table 2
Annualized costs of the MIC service according to economic cost category.

Cost category	**Annual cost (€)**	**Proportion of total resource costs (%)**
A. Readiness and service costs	325,178	49.1
Personnel and on-call availability	243,580	36.8
Vehicle and vehicle infrastructure	34,160	5.2
Medical equipment and technical readiness	36,045	5.4
Communication and IT infrastructure	1,596	0.2
Training and staff equipment	9,797	1.5
B. Non-reimbursed mission-related operating costs	9,260	1.4
Fuel	5,267	0.8
Service and repairs	3,126	0.5
Tires	867	0.1
A + B. MIC service and operating resource requirement	334,438	50.5
C. Patient-specific resources	327,950	49.5
ECPR-specific consumables	317,312	47.9
Other patient-specific medical consumables	10,638	1.6
Total resource costs (A + B+C)	662,388	100.0

Readiness and service costs (category A) represent resources required to maintain continuous MIC operational capability independent of individual missions. Non-reimbursed mission-related operating

costs (category B) comprise mission-dependent expenditures remaining attributable to the MIC service. Categories A and B together represent the MIC service and operating resource requirement. Category C comprises medical resources consumed during individual patient care that are economically attributable to the patient-specific treatment episode rather than to MIC service readiness. Depending on the receiving institution and resource type, these costs may be allocated to subsequent treatment or compensated through material replacement. Total resource costs represent the sum of categories A, B, and C. Personnel costs were estimated using a tariff-based staffing model according to TV-Ärzte/VKA and an institutional employer cost factor of 1.30. Values may not sum exactly because of rounding.

Cost and utilization metrics

Based on annualized activity, MIC service and operating resource requirements (A + B) were €626 per mission and €995 per patient contact, compared with total resource costs (A + B+C) of €1,239 and €1,971, respectively. Continuous availability corresponded to €916 per day and €38.18 per hour for A + B and €1,815 per day and €75.62 per hour for A + B+C (Table 3).

Table 3
Annualized cost metrics of the MIC service.

Cost metric	**MIC service and operating resource requirement (A + B)**	**Total resource costs (A + B+C)**
Annual cost (€)	334,438	662,388
Cost per mission (€)	626	1,239
Cost per patient contact (€)	995	1,971
Cost per day of 24/7 availability (€)	916	1,815
Cost per hour of 24/7 availability (€)	38.18	75.62

Mission- and patient-contact-based unit costs were calculated using annualized activity denominators derived from the 18-month observation period (534.7 missions and 336.0 patient contacts per year). MIC service and operating resource requirements comprise readiness and service costs and non-reimbursed mission-related operating costs (categories A + B). Total resource costs additionally include patient-specific resources (category C). Daily and hourly costs represent annual costs distributed across 365 days and 8,760 hours of continuous 24/7 service availability.

Cost decomposition and sensitivity analyses

Patient-specific resources accounted for 49.5% of total annual resource costs. Within this category, ECPR-specific consumables accounted for €317,312 annually, corresponding to 47.9% of total resource costs and 96.8% of category C. The detailed decomposition is provided in Supplementary Table S3.

Across all sensitivity scenarios, annual MIC service and operating resource requirements ranged from €315,701 to €369,556, compared with €334,438 in the base case, while total resource costs ranged from €643,651 to €697,506, compared with €662,388. Reducing assumed capital-asset useful lives by two years produced the highest estimates. Varying the CARDIOHELP acquisition cost between €60,000 and €90,000 had only a minor effect on total resource costs (€660,252–€664,525). Full scenario-specific results, including alternative personnel-cost assumptions, are presented in Supplementary Table S2.

Discussion

Principal findings

This real-world analysis demonstrates that annual MIC service and operating resource requirements amounted to €334,438, compared with €662,388 including patient-specific resources. Personnel and on-call availability dominated readiness costs, whereas patient-specific resource consumption was largely attributable to ECPR consumables. Distinguishing these categories provides a more comprehensive picture of resource use than departmental expenditure alone, particularly where patient-specific resources are allocated to subsequent treatment or replaced by receiving institutions.

Readiness, utilization, and service-level costs

Continuous readiness generates costs irrespective of dispatch volume, as also described for physician-staffed HEMS [6]. During 18 months, the MIC completed 802 activations, with patient contact in 62.8%. Missions without patient contact should not necessarily be considered inefficient, as dispatch decisions are made before the need for specialized interventions can be fully established. Scenario-based HEMS modelling similarly highlights capacity utilization as an important economic determinant [8].

Annual MIC service and operating resource requirements corresponded to €626 per mission and €995 per patient contact. These average costs do not represent the marginal cost of an additional dispatch but may inform planning of comparable services.

Patient-specific resources and the multipurpose model

Patient-specific resources (€327,950 annually) were dominated by ECPR consumables. These expenditures represent resource consumption rather than MIC readiness costs or the total costs of ECPR. Most ECPR-specific materials are allocated to subsequent treatment episodes or replaced by receiving hospitals, making their separate classification essential for distinguishing service costs from patient-specific resource use.

This distinction is particularly relevant when considering prehospital ECPR. Economic modelling has shown that the cost-effectiveness of prehospital ECPR depends substantially on patient volume and utilization of specialized team capacity [9]. Subsequent analysis based on the PRECARE study similarly demonstrated that assumptions regarding dedicated versus multipurpose team utilization substantially influence the economic profile of prehospital ECPR [7].

The MIC differs from a dedicated ECPR response unit because ECPR is one capability within a multipurpose critical care platform that also supports severe trauma, neonatal and pediatric emergencies, and other critically ill patients. Personnel, vehicles, training structures, and technical infrastructure can therefore be shared across indications. This concept is consistent with previous economic analyses indicating that broader utilization of specialized prehospital capacity may improve system-level economic performance [6–9]. However, the present study did not compare alternative service configurations and cannot establish whether the MIC model is cost-effective relative to conventional EMS or dedicated specialized teams.

Likewise, the substantial resource consumption associated with ECPR should not be interpreted as evidence for or against its cost-effectiveness. Such an assessment requires survival, neurological outcome, quality-adjusted life-years, and downstream healthcare costs. Previous analyses of prehospital ECPR have incorporated such outcomes into cost-effectiveness modelling [7, 9]. Similarly, economic evaluation of prehospital plasma transfusion has demonstrated the importance of incorporating downstream outcomes when evaluating resource-intensive prehospital interventions [10]. The present study deliberately addresses service-level resource requirements rather than cost-effectiveness.

Implications for service planning

Sensitivity analyses demonstrated that annual estimates were influenced by capital-asset useful lives and personnel assumptions, whereas varying the CARDIOHELP acquisition cost had only a minor effect. These factors should be considered when transferring cost estimates to other systems.

Service planning should distinguish readiness costs from patient-specific resource consumption, including resources reimbursed or replaced by receiving institutions. Multipurpose utilization of specialized personnel and infrastructure may be economically relevant when high-cost interventions are infrequent [6–9]. Comparisons between services should account for staffing, reimbursement, and cost allocation.

Strengths and limitations

This study included all 802 MIC activations over 18 months of continuous operation, including missions without patient contact. Operational data were combined with detailed resource and consumption records. Capital expenditures were annualized, physician costs were modelled using tariff-based remuneration, and key assumptions were examined through deterministic sensitivity analyses.

Several limitations should be considered. First, this was a single-center analysis within a German physician-based EMS system, limiting direct transferability of absolute costs. Second, no comparator service or patient outcomes were included; incremental costs, cost-effectiveness, and clinical benefit relative to conventional EMS therefore cannot be determined. Third, shared readiness resources could not reliably be allocated to individual missions or clinical indications, and mission-specific costs were intentionally not estimated. Fourth, some valuation assumptions were required, particularly for capital-

asset useful lives and personnel costs, although the influence of selected assumptions was examined in deterministic sensitivity analyses.

In addition, institutional overhead and shared administrative or infrastructure costs that could not be reliably attributed to the MIC were not included; the estimates therefore represent identifiable MIC-related resource requirements rather than comprehensive institutional costs.

Finally, specialist support from neonatology, pediatrics, and internal/intensive care medicine was provided within existing institutional staffing structures and was therefore assigned no incremental MIC-specific personnel expenditure. This does not imply absence of opportunity costs, which were not quantified and may be relevant in systems requiring dedicated additional staffing. Similarly, the allocation or replacement of patient-specific resources reflects the local financing structure and may differ between institutions. The separation of service-level requirements from patient-specific resource consumption was intended to make these differences transparent rather than imply universal reimbursement arrangements.

Conclusion

Maintaining and operating a continuously available physician-staffed prehospital critical care service required substantial readiness and operational resources, while additional resource use was attributable to patient-specific care. Separating these components provides a transparent description of the economic structure of a multipurpose prehospital critical care service. These real-world data may inform the planning and economic evaluation of similar systems, while comparative studies incorporating clinical outcomes are needed to assess cost-effectiveness.

Abbreviations

EMS
emergency medical services
MIC
Medical Intervention Car
ECPR
extracorporeal cardiopulmonary resuscitation
HEMS
helicopter emergency medical services
AEC
annual equivalent cost
SD
standard deviation

Declarations

Ethics approval and consent to participate

Operational data were processed in pseudonymized form. The study used retrospectively collected routine operational, administrative, and economic data without patient-identifiable information. According to local regulations, formal ethics approval and individual informed consent were not required.

Consent for publication

Not applicable.

Availability of data and materials

The datasets analysed during the current study are available from the corresponding author upon reasonable request, subject to applicable data protection regulations and institutional approval.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

MB: Conceptualization, Methodology, Data curation, Formal analysis, Visualization, Writing - original draft, Project administration. MaMe, DR, AW, MM, NR and CW: Investigation, Data curation, Writing - review and editing.

All authors reviewed and approved the final manuscript and agreed to be accountable for the work.

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Declaration of AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT (OpenAI) to support language editing and manuscript condensation. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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Supplementary Files

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