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IN PARTENARIATO CON

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Abstract

We set out to estimate the cost-effectiveness of an ambulance-based referral system for emergencies, connecting primary care health centres to a central hospital in a sub-Saharan low-income context. We adopted an observational retrospective study design in the setting of the Beira District (Sofala Region, Mozambique) and classified effective referrals based on the triage emergency codes assigned during transfer. We focused solely on referral running costs required to run the ambulance and complete safe and effective transfer, including staff (nurses and drivers) and communication costs between health centres, ambulance operators and the central hospital. A total of 7849 referrals were included in the analysis, 6295 of which were deemed effective. The total running cost of the intervention (11 months) was $172.071. The cost-per-effective referral was $27,33, which is below the acceptability benchmarks that can be considered "very attractive" ($58,20) and that we defined as 1/10 of the national GDP per capita of Mozambique ($582). Sensitivity analysis corroborates our findings, which confirm and extend previous evidence on the high cost-effectiveness of ambulance-based referral systems for emergencies in sub-Saharan low-income countries.

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1. Introduction and Background

Emergency healthcare services play a fundamental role in improving healthcare outcomes, especially in low-income countries (LICs) (Kobusingye et al., 2005). Access to real-time emergency care is often limited in such regions, posing significant challenges to proper healthcare delivery (Werner et al., 2020; World Health Organization, 2018). In low-resource settings, delays in receiving adequate assistance at healthcare facilities persist as a significant concern for various emergency conditions (Shah et al., 2020). Globally, an estimated 24–28 million lives are lost each year due to conditions necessitating emergency care, comprising 51% of mortality and 42% of the total global disease burden (Hsia et al., 2015). This burden is 4.4 times greater in low and middle-income countries (Chipendo et al., 2021). Delayed requests for assistance by healthcare professionals and inadequate transportation for referrals are among the principal factors hampering timely and effective emergency care (MINISTÉRIO DA SAÚDE Moçambique - Relatório Anual, 2020). Ambulance-based referral systems for emergencies (AbRSEs) emerge as key interventions addressing these challenges, facilitating timely access to emergency care (Mucunguzi et al., 2014.; Ragazzoni et al., 2021).

AbRSEs are particularly beneficial for addressing different types of emergency conditions in LICs, including medical emergencies, surgical emergencies, obstetric complications, and pediatric emergencies stemming from endemic communicable and non-communicable diseases (Shah et al., 2020). They play a crucial role in reducing morbidity and mortality rates by enhancing access to - and quality of - emergency healthcare services, thereby addressing preventable deaths (WHO, OECD & The World Bank, 2018). Skilled management of emergencies, including timely access to specialized care and interventions, is essential to improve outcomes across all emergency types. Many elements of effective emergency care are globally applicable and feasible to implement, often requiring minimal investments (WHO, OECD & The World Bank, 2018). Consequently, numerous non-governmental organizations (NGOs), in collaboration with governmental bodies, are implementing AbRSEs to address a wide range of emergency conditions at various levels (Conti et al., 2022).

However, ensuring the long-term sustainability of AbRSEs necessitates assessing their affordability and cost-effectiveness, especially as initial support often comes from programs whose funding reaches an end across a few years. Consequently, upon cessation of external funding, local and national health bodies must allocate scarce resources appropriately to sustain these services (WHO, 1996). Inadequate allocation may lead to loss of life that would be avoidable instead (Groppi et al., 2015; Somigliana et al., 2011).

Despite evidence supporting the efficacy of AbRSEs, their cost-effectiveness remains underexplored. Moreover, evidence-based advocacy remains crucial to ensure ongoing investments and improvements in their implementation across LICs (Werner et al., 2020; World Health Organization, 2018).

While some economic analyses highlight the cost-effectiveness of comprehensive emergency interventions, studies specifically examining the economic profiles of AbRSEs are limited. Recent studies have started to address this gap, with findings suggesting that AbRSEs can be highly cost-effective in LICs. However, these findings come from AbRSEs mainly dedicated to obstetric and pediatric emergencies (e.g., Accorsi et al., 2017).

The present study assesses the cost-effectiveness of an AbRSE designed to address different emergencies. We assess it by analyzing 7849 referrals throughout an 11-month period in 2022. Our setting is the district of Beira, Mozambique. The AbRSE studied is implemented by the NGO *CUAMM – Doctors with Africa* (from now on, CUAMM) connecting 15 minor Health Centres to the Hospital Central da Beira. Our results suggest a high cost-effectiveness of the intervention.
By generating science-based evidence on the effectiveness and affordability of AbRSEs, stakeholders can advocate for their scaling up and integration into national healthcare systems. This is essential for liberating countries in the Global South from dependency on external aid and fostering self-reliance in addressing their healthcare needs. Therefore, estimating the cost-effectiveness of AbRSEs is not only a scientific endeavour but also a means to empower local governments and ministries to make informed decisions that can positively impact the health and well-being of their populations.

2. Methods

2.1 Study Setting

Mozambique is classified as a LIC with a GDP per capita equal to 582 USD (World Bank, 2022), and as one of the least developed nations globally according to the UNDP Human Development Index (185 out of 191). It has a population of 33’244’414 people, with a life expectancy at birth of 56.1 years (Instituto Nacional De Estatística – Moçambique, 2022; 2024). Its demographic configuration is constituted by a prevalently rural distribution of the population (67.49% as of 2016), a young age structure (45.2% under age 15) and high fertility rates (5.24 births per woman as of 2016) (Yaya et al., 2020). Poverty in the country remains pervasive, with over half the population struggling to meet basic needs, including access to healthcare (Yaya et al., 2020).
Indeed, Mozambique's healthcare indicators do reflect these developmental challenges: despite efforts to improve living standards and continued economic growth following the end of the civil war (1977–1992), as of today, significant challenges persist in the healthcare landscape. Among the main issues afflicting the national healthcare system (NHS) effectiveness, chronic shortage of skilled personnel, poor financial management, and inadequate planning are reported. Accessing essential healthcare for a considerable portion of the population remains very difficult. Not surprisingly, Mozambique scores among the lowest worldwide in terms of coverage rates of basic public health services (22%) and physicians per 1000 inhabitant’s ratio (0.1%) (Vera Cruz & Dlamini, 2021). As of 2022, there are 10.4 health professionals per 1000 inhabitants (Instituto Nacional De Estatística – Moçambique, 2022).
According to the Mozambican Ministry of Health (MISAU), which oversees healthcare governance, the latest investigation on maternal and neonatal mortality - the “III- Relatório Annual de Auditoria de Mortes Maternas e Neonatais – 2018” (MINISTÉRIO DA SAÚDE Moçambique - Relatório Anual, 2020) - shows that Mozambique presents an Institutional Maternal Mortality Ratio (IMMR, deaths occurring within healthcare facilities) of 82 over 100,000 live births in 2018. As of 2020, the WHO estimates an Overall Maternal Mortality Rate (OMMR, TEGEGNE et al., 2023) of 127 over 100,000 live births, quite above the sustainable development goal (target 3.1) objective, i.e., 70 over 100,000 live births (*United Nations - Agenda for Sustainable Development*, 2015). Moreover, the

UNICEF global databases (Unicef, 2014)) indicate 54.8% of institutional deliveries, i.e., deliveries under safe procedures by professional (TEGEGNE et al., 2023), meaning that a bit less than half of deliveries happen in less safe conditions the latest figure shows. Indeed, the WHO (2020) reports that neonatal mortality is at 4 over 1,000 live births whereas infant mortality is at 51 over 1000 live births. Mozambique's epidemiological profile is "pre-transitional", with widely spread communicable diseases (e.g, malaria, HIV/AIDS, tuberculosis, acute respiratory infections and diarrheal diseases) alongside non-communicable ones (e.g., cancers, cardiovascular diseases and injuries) (dos Anjos Luis & Cabral, 2016), ranking globally among the top five countries with the highest tuberculosis prevalence and within the top ten countries with the highest AIDS prevalence (Garrido & UNU-WIDER, 2020)

2.1.1 The Beira District and the AbRSE

Beira is the capital of Sofala Province and the second most populous city in Mozambique, with 719,506 inhabitants as of 2022 (Instituto Nacional De Estatística – Moçambique, 2023). The city covers an area of 633 km2 and is in the Indian Ocean coastal area of Mozambique, making it vulnerable to climate disasters such as cyclones and floods (Macamo, 2021). The Hospital Central da Beira (HCB) is the second largest in Mozambique with 640 beds. It serves as the main hub for emergency referrals in Beira District the Sofala Province. In addition to the central hospital, there are 17 Health Units (HCs) in Beira distributed across the whole area, each dedicated to serving a part of the district and its population (Instituto Nacional De Estatística – Moçambique, 2023). Health services are generally delivered without a direct cost burden for the patient, whereas medicines are provided at a fixed price. Each HC has at least one medical doctor, but larger ones may employ up to four (Lokotola et al., 2022). Alongside doctors, every HC personnel is comprised of a minimum of 15/20 staff, generally composed of nurses, community health workers and technical officers (Lokotola et al., 2022). The HCB is a central hospital at the quaternary level[1], while the 17 HCs mostly deliver primary care services. These basic ambulatory services include general adult and pediatric examination, basic laboratory tests, and drug administration, and may be followed by a short observational stay. However, they cannot provide long-term patient hospitalization, specialized consultation, surgery procedures, or advanced emergency care. Therefore, they refer patients to the HCB for more complex and urgent services (World Bank, 2004). In this context, referrals are managed by the Italian NGO CUAMM through an AbRSE implemented in 2019, as a response to the Cyclone Idai disaster. The AbRSE is constantly strengthened through International Cooperation for Development funding to make it independent and economically sustainable. To this purpose, starting in February 2022, the Italian Agency for Cooperation and Development (AICS) has funded a 36-

[1] The Mozambican NHS is structured into four different levels of care, with each level providing progressively more complex services. Primary care is delivered at the first level and is provided at local health units. These facilities offer basic maternal and child health services. The second level functions at the whole district level, serving as the referral point for the first level. Services offered at the second level might include surgery (e.g, for cesareans). The tertiary level is located at provincial hospitals and functions as a referral level. Finally, the quaternary level is located at central hospitals and represent the main hub for regional referrals (Augusto et al., 2018)

month project led by the Veneto Region, and operationalized by CUAMM with the support of other international and local institutions[2]. The goal of the initiative is to strengthen and manage medical emergencies and urgencies with a focus on obstetric and pediatric emergencies. The interventions aim at improving patient transfers from 15 served peripheral HCs to the city to HCB using an AbRSE. The project provides new ambulances, staff training and effective implementation and management of a coordinated system for referrals. The ambulance fleet is distributed in different HCs according to the patients they treat per day and their location in the area. Each ambulance serves 3 to 4 designated HCs. The number and the location of ambulances vary according to referral flows and resource availability. HC's location spans from a 1,5 km distance to 33 km from the HCB.
See Table 1 for a comprehensive description of ambulance stations, distance from HCB, HCs served by each ambulance and patient flows for every HC. Table 2 reports how ambulance fleet spatial allocation, staff numbers and HCs served by the referral system changed throughout 2022.
Patients cannot directly call for an ambulance and use their means to reach the closest HC. It is the HC staff that can possibly ask for the ambulance through a mobile phone call. After receiving the call, the ambulance staff – a CUAMM-trained nurse and a driver – calls the HCB asking for authorization to transfer the referral. Once at the HC, CUAMM-trained nurses prioritize emergency cases using a triage system (see. Conti et al., 2022 for a detailed explanation of the triage system used in this case). Only yellow, orange, and red emergencies should be transported to the HCB, while green and blue emergencies represent minor conditions that can be treated at the HC.

Table 1. Ambulance location, patient flows per HCs and distance in km to HCB (in parenthesis)

Ambulance Station	HCs served
Chingussura (16km) 1071	• Inhamizua (22km) 812 • Ceramica (33km) 40 • Matadouro (21km) 25 • Chamba (17km) 13
Nhaconjo (14km) 1502	• Manga Loforte (12km) 450 • Nhangau (27km) 242
Munhava (8km) 1043	• Mascarenhas (9km) 505 • Marrocanhe (15km) 165 • Chota (6km) 4
Ponta-Gea (4km) 1101	• Macurungo (3km) 864 • Sao Lucas (1,5km) 2

[2] Ca 'Foscari University of Venice, Green Cross Padova, Beira District Health, Women and Social Action (Serviço Distrital de Saúde, Mulher e Acção Social di Beira (SDSMAS)), Mozambique Emergency Medical Service (Serviço de Emergência Medica em Moçambique (SEMMO)) and Beira Central Hospital. The project is being funded by grants for Government and municipal initiatives for the "Promotion of Territorial Partnerships and Territorial Implementation of the 2030 Agenda," published by Italian Agency for Cooperation and Development (AICS) The project aims to contribute to the reduction of morbidity and mortality rates in the region.

Table 2. Relevant event timeline for ambulances and staff variations throughout 2022

Date	Event
Until April 2022	One ambulance and two minibuses adapted to work as ambulance rented.
April 1, 2022	Two ambulances were purchased; two minibuses were decommissioned. Ambulances are operational at Ponta-Gea, Chingussura, and Nhaconjo, covering 12 health centres.
15th March 2022	Six drivers and three nurses were recruited, joining existing teams. A total of 9 drivers and 9 nurses were distributed among operational ambulances.
October 1, 2022	An additional three drivers and three nurses were recruited. A total of 12 drivers and 12 nurses were assigned, with four drivers and four nurses per ambulance. The number of health centres covered increased from 12 to 15.

2.2 Study Design and Data Collection

Our study retrospectively examines ambulance callouts and transfers from the HCs to the HCB from February 1st, 2022, to December 31st, 2022, spanning 11 months. We used various data sources, including databases and logbooks from CUAMM, to gather information on ambulance referrals, vehicles, fuel consumption records, and financial records. Ambulance referral data are the electronic transcription of patient referral charts recorded by CUAMM-trained nurses during emergency transfers. CUAMM staff regularly collects all the paper-made patient referral charts at the HCB so that trained dedicated local data-entry personnel digitize them into an electronic spreadsheet. CUAMM supervises and monitors the accuracy of the process weekly. For our analysis, we extracted the following variables: sex, age, disease category (medical, surgical/trauma, pediatric, obstetric/gynaecological), nurse-assigned triage priority codes (green, yellow, orange, red) and department allocation of the referrals when hospitalised. Data were anonymized upon variable extraction and only complete records were included in the cost-effectiveness analysis. The study was conducted according to the ethical guidelines of the Declaration of Helsinki.

We retrospectively evaluated all cases referred to the HCB by ambulance as effective and non-effective, based on the emergency code assigned by the CUAMM nurses after triaging the patients. We classified green and blue referrals as ineffective, whereas yellow, orange, and red codes as effective. The purpose of this classification is to create indicators to measure the effectiveness of the referral system. It gives us a proxy to determine whether the system is performing its primary functions of assisting and transferring yellow, orange, and red emergencies that cannot be treated at the HCs. However, we understand that in LICs, ambulances have additional social responsibilities. For instance, they transport patients who are not in life-threatening conditions but have no other means of reaching the HCB (Conti et al., 2022). Thus, we also performed a complementary analysis to evaluate the cost-effectiveness of the intervention with a different outcome variable (*number of years saved*) and focusing more specifically on obstetric and neonatal emergencies. This analysis is available in the Annex section of this paper.

3. Cost-effectiveness Analysis

Our analysis aims to determine the cost-effectiveness ratio of the intervention, which in our case is the cost per effective referral. Cost-effectiveness analysis is a comparative method to assess the costs and health outcomes of different interventions. It is generally performed by comparing the costs and health outcomes between different interventions or against the status quo (e.g., intervention vs no intervention). The analysis estimates the cost required to gain a unit of health outcome. By providing a way to assess the costs and benefits of alternative health interventions, cost-effectiveness analysis can be used to prioritize resource allocation and identify projects that can produce the greatest health improvement in locations with limited resources (WHO, 2022).

Cost-effectiveness analysis plays two key roles in the global health landscape. Firstly, it can be used to assess the efficiency of the current and future health systems. It helps in prioritizing processes, resource management insights and planning to achieve the greatest health benefits. Secondly, it can be used to support decision-making by national authorities when evaluating if new interventions should enter a "health benefit package", i.e., to be adopted more broadly within the country. By combining these applications, cost-effectiveness analysis ensures optimal utilisation of financial resources in the health sector, resulting in the greatest possible health gain with the available health budget (Bertram et al., 2016).

Our analysis develops along the lines of previous studies (Accorsi et al., 2017; Breman & Britan 2011) and considers the perspective of the governmental health provider who would be responsible for financing the AbRSE once external aid funds are no longer available. The purpose of our research is to provide a means to assist LICs health authorities in making evidence-based, rational, and effective choices. Hence, we evaluated the cost-effectiveness of the system in everyday clinical operations, excluding its setup and initiation, presupposing that all expenses would need backing from the designated governmental health provider to sustain the AbRSE's operation once external international aid is terminated.

We excluded the additional costs required for starting the service, such as supervision, training, health education advertisement and advocacy. Our focus was on the running costs of the AbRSE, and we considered only the costs falling within the referral service, excluding those of the primary care delivered by the HCs and those falling onto the HCB for further care. As such, pre- and post-referral costs were not included in this analysis. We included only the costs of pick-up, transfers, assistance during transfer, and delivery to HCB of the patients referred. Thus, considered costs are ambulance operational costs associated with transportation, such as ambulance amortization, maintenance, fuel, personnel costs for ambulance staff like nurses and drivers solely employed for the referral service, and medical equipment costs. We also considered costs for communication among ambulance staff, HCs, and the HCB, which encompasses expenses related to cellular devices, computers, and communication credit.

We estimated benefits considering the number of emergencies correctly referred (yellow, orange, red) assuming that without immediate transfer, those cases would have resulted in patient death or disability. This measure serves as a robust proxy for the number of lives saved, an indicator used in previous cost-effectiveness research (e.g., Pinto et al., 2016).

To determine whether an intervention is cost-effective the ratio resulting from the comparison of costs and benefits is then compared with an acceptability threshold. Only cost-effectiveness ratios falling below the threshold are considered favourable and attractive. There is an everlasting academic debate regarding the choice of the most adequate acceptability threshold (e.g, Leech et al., 2018; Bertram et al., 2016). However, most research uses the WHO's (2001) Commission on Macroeconomics and Health's GDP-based thresholds based on 1 to 3 times the national GDP per capita values. As such, similar to Accorsi et al. (2017), we set the acceptability threshold for the cost-per-referral below the GDP per person per year in the country, which is 582 US dollars (World Bank, 2022). Additionally, we included two more levels. It was attractive if the cost was below half of Mozambique's GDP per person per year, i.e., 291 US dollars, and very attractive if it was below one-tenth of it, i.e., 58.20 US dollars (see Table 3 for a detailed explanation of the threshold chosen).

Table 3. Acceptability threshold for the Cost-Effectiveness Analysis

Ratio Level	Acceptable	Attractive	Very Attractive
$/effective referral	< $582	< $291	< $58.20
	GDP per capita in Mozambique (World Bank, 2022)	*50% GDP per capita*	*10% GDP per capita*

4. Results

A total of 7849 ambulance referrals from the 15 served HCs to the HCB were recorded during the 11-month study period. Nhaconjo was the centre with the highest flow of referrals (n = 1502). The ambulance average scene time from HC staff call to arrival at the hospital was 46 minutes. Table 4 reports the referral breakdown per type of emergency. Obstetric emergencies (n = 3151, 40%) were the most numerous, whereas surgical the less frequent (n = 720, 9%).

Out of the total referrals, 20% were classified as ineffective (n =1554) as CUAMM-trained nurses assigned green and blue codes to the transfer. We excluded ineffective referrals from our analysis and focused on the 6295 effective referrals completed. See Table 5 for a complete breakdown of effective referrals into emergency codes.

Table 4. Referrals breakdown per emergency type

Type of Emergency	N	%
Obstetrical	3151	40
Neonatal/pediatric	1903	24
Medical	2075	27
Surgical	720	9
Total Emergencies	7849	

Table 5. Referrals classification into ineffective (green and blue code) vs effective (red, orange, yellow codes).

Referrals Evaluation	N	%
Ineffective referrals (green or blue codes)	1554	20
Effective Referrals	**6295**	**80**
Red	802	13
Orange	2387	38
Yellow	3106	49

The extrapolated cost of the AbRSE for the 11 months, based on the cost of one full year (2022) is displayed in Table 6. We considered a 4-year ambulance utilization (Accorsi et al., 2017) for cost imputation and used 7 years (Tsegaye et al., 2016) for sensitivity analysis. In the 11 months, the total running costs of the AbRSE were $172.070,82. Ambulance rental was the most expensive cost ($62.059,64), followed by CUAMM proprietary ambulance amortization quotas for the 11 months ($39.998,42).

Table 6. Running costs 11 months (February-December 2022) with 4 and 7-year proprietary ambulance amortization.

Item	4-Year Amortization (Accorsi et al., 2017)	7-Year Amortization (Tsegaye et al., 2016)
N. 12 Nurses (3 for each of the 4 ambulances)	$28.838,55	$28.838,55
N. 12 Drivers (3 for each of the 4 ambulances)	$22.037,10	$22.037,10

Item	4-Year Amortization (Accorsi et al., 2017)	7-Year Amortization (Tsegaye et al., 2016)
Fuel, maintenance, insurance, taxes, etc. for ambulances	$2.158,59	$2.158,59
Ambulance Rental	$62.059,64	$62.059,64
Ambulance Amortization (11 months)	$39.998,42	$22.856,24
Amortization of computers complete with printers, operating system, and various accessories (4-year usage)	$894,61	$894,61
Telephone credit for emergency reference system from health centres to central hospital	$156,11	$156,11
Amortization quota for cell phones for ambulance service management (4-year usage)	$5.214,06	$5.214,06
Medical supplies, disposable materials, drugs	$10.713,74	$10.713,74
Total Running Costs (11 Months) 2022	**$172.070,82**	**$154.928,64**

Note: All amounts are in US dollars. CUAMM's balance sheet is reported in Euro. To convert values into USD for this analysis, we used Banca D'Italia exchange rate on the 31st December 2022 - 1 Euro = 1,0666 USD

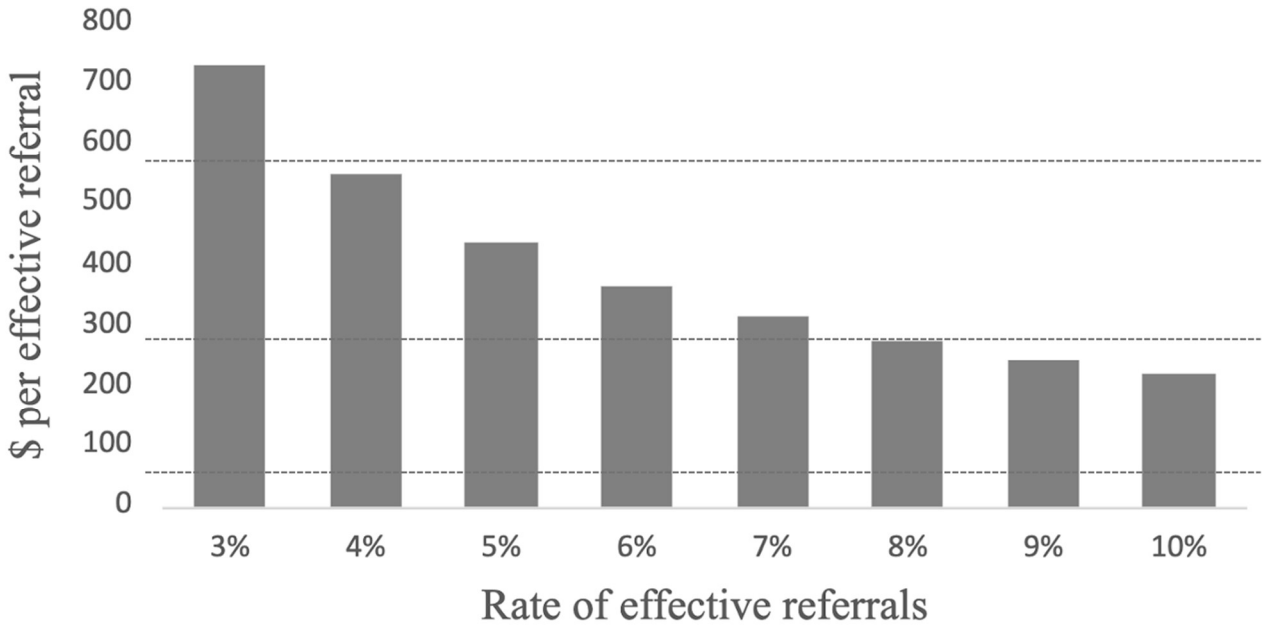
Considering only effective referrals (n = 6295), the cost per effective referral was $27,33, which is well below $58.20, and thus fulfils the *Very Attractive* criterion for our acceptability threshold (see Table 7).

Table 7. Cost Effectiveness Ratio per total referrals (including ineffective) and per effective referrals.

Cost Effectiveness Ratio	4-year amortization	7-year amortization	Acceptability Threshold
Cost per referral (Tot. Cost/Tot. referrals)	$21,92	$19,74	< $58.20 Very Attractive
Cost per effective referral (Tot. Cost/Tot. *effective* referrals)	$27,33	$24,61	< $58.20 Very Attractive

We then carried out a sensitivity analysis to assess the consistency of our results. We used different amortization rates for the proprietary ambulances and included in the analysis also ineffective referrals (blue and green codes). The intervention remains very attractive in both cases.
As mentioned in Section 4, the rate of effective referrals recorded, used for our analysis was equal to 80% (n = 6295). We conducted a simulation to determine the cost-effectiveness of the intervention if the rate of effective referral was lower at current costs. We compared this with the acceptability threshold, as shown in Figure 1. Our results indicate that the intervention remains attractive up to a rate of effective referrals of 8.5% and acceptable up to a rate of 4.25%. Similarly, effective referrals equal, the intervention remains Very Attractive up to an 11-month cost of the AbRSE of $366301, Attractive up to a cost of $1831861 and still Acceptable for $3675000.
This confirms the robustness of our analysis and suggests that even if the triage code criterion used to classify referrals is subject to selection error by CUAMM nurses, the intervention remains cost-effective with ample margins.

Figure 1. Sensitivity Analysis



Note: Sensitivity analyses according to the proportion of effective referrals. The dotted lines represent our acceptability thresholds to define the intervention as acceptable ($582, upper line), attractive ($291, middle line), and very attractive ($58,20, lower line). The costs refer to 11 months of AbRSE usage.

5. Discussion and Conclusion

Our results showed that the implementation of an AbRSE connecting peripheral minor HCs delivering primary care to a central hub hospital for further emergency care is highly cost-effective in LICs. Our findings are in line with previous research (Werner et al., 2020), confirming that relatively low investments can save lives and drive a high increase in the quality of life of beneficiaries (WHO, 2022). Our main analysis focused on the cost-per-effective referral, excluding transfers of green and blue codes that should have been assisted at the primary care level. The cost-per-effective referral was $27,33, falling below our Very Attractive threshold of 1/10 of national GDP per capita. This result is robust, corroborated by sensitivity analysis taking into consideration different amortization rates and rates of effective referrals. It remains consistent even when comparing it to more restrictive thresholds such as the WHO (1996), which sets Very Attractive interventions < $30. These results are ulteriorly confirmed if we adjust WHO's thresholds for inflation using the Consumer Price Index method - from 1996 to 2022, the compounded inflation rate in Mozambique was approximately 610%, pushing the cut-off values of Attractive and Very Attractive tiers much higher than our GDP-based ones.

Although the specificity of our context and analysis makes comparison with similar projects difficult, our results are in line with most studies and complement previous research. For example, Accorsi et al., (2017), found that implementing an AbRSE for Emergency Obstetric and Neonatal Care (EmONC) services in a rural setting in Ethiopia was highly cost-effective, with a cost per year saved of $ 24.7. Similarly, Tayler-Smith et al., (2013) demonstrated the effectiveness of emergency obstetric care through a referral network, emphasizing the importance of timely interventions in reducing neonatal mortality. Finally, Adene, T. (2016) highlighted the positive impact of dedicated ambulance service in facilitating referrals and improving resource utilization in Ethiopia.

Our research provides novel evidence on the economic profile of AbRSE as it isolates the referral process cost and benefits. However, the AbRSE studied is an intervention part of a more complex multistakeholder strategy committed to improving access to healthcare. Moreover, as Accorsi et al., (2017) point out, the effectiveness of a referral also depends on factors such as "the timeliness of the decision for referral, pre-referral care, en-route stabilizing care, time taken to arrange referral vehicle, time taken to reach higher facility and promptness with which the case was attended at the higher facility", which were not taken into account for this study.

Our study objective was solely to determine the cost-per-effective referral, on average, across types of emergencies. We did not therefore include any consideration regarding central hospital buffer or workload increase, although a relevant factor that decision-makers have to take into account. Our study extends throughout a larger period in comparison to previous studies which generally consider shorter time-frames and smaller samples. This allowed us to overcome some of our study's limitations which can however serve as prompts for future research. For example, road conditions and weather seasonality were ruled out by the 11-month time frame chosen for the study, whereas previous studies were impacted by rain seasons impacting road viability. Our criterion for the selection of effective cases was based on CUAMM-trained nurses assigned triage codes. Although the large number of

referrals might rule out a lack of accuracy and misspecification of codes, our classification criterion remains sub-optimal as it was not performed by health professionals with specific skills across types of emergencies. Moreover, the judgment on effectiveness remains theoretical and there is no way to assess the counterfactual, i.e., whether referral assessed by other means would have caused patient deaths or irremediable damages such as disability.

More broadly, especially in the case of emergency services, the benefits or losses in health cannot be measured (only) in economic terms, as dealing with human life pertains also to the ethical domain. Finally, this was a retrospective study and although weekly monitoring and supervision by experts were performed, erroneous recording and data entry may have been still possible.

Despite the very high cost-effective economic profile of the AbRSEs recorded, it can still be enhanced in several ways. For example, HCs could refer patients only when needed, delivering primary care through the best of their means. This requires implementing a change in the organizational culture of the HCs, which needs to recognize the actual utility of AbRSEs. It also requires specific personnel training, improved drug availability, and strengthened supervision at peripheral units, as noticed by Conti et al. (2022). Thus, the room for improvement is still very relevant.

Research on the cost-effectiveness of emergency services, particularly in LICs settings, is an area that has not been explored enough. This issue falls within the so-called 10/90 gap, where only 10% of medical research is dedicated to conditions affecting 90% of the world's population. The objective of this study was thus to contribute also to this issue by evaluating whether the model tested in Beira can be replicated at the provincial and national levels.

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ANNEX

One of the main objectives of the intervention is the reduction of maternal and neonatal mortality, we run a complementary analysis focusing on obstetric and neonatal emergencies. Using the same dataset, we focused on the subgroup of mothers referred from the HCs and hospitalized in the delivery room of the HCB to estimate the total number of years saved (YLS) of mothers and newborns, using local life expectancy data, similar to previous studies (e.g., Accorsi et al., 2017). As this is a retrospective study, we only had limited control over data collection. As such, we could not include prevention of disabilities in the model as we lacked information in this respect. We included a 6% (WHO, 1996) discount rate for the life years gained and used only the proportion of costs referring to obstetric referrals, multiplying their total number for the average cost per referral.
The total YLS for mothers admitted to the delivery room was calculated by summing the difference between the life expectancy of Mozambique and the age of each mother admitted to the delivery room. Maternal deaths were excluded from the count. To calculate the YLS for the newborns, the number of live births was multiplied by the life expectancy of Mozambique. Eighty-three neonatal deaths were reported and thus excluded from the count.
In our case, the discounted total YLS are 150504 whereas the proportion of the cost for an effective maternal and obstetric emergency which led to hospitalization in the delivery room and to delivery was $48.546,11.
The $/year of life saved for this specific type of emergency is $0,32, indicating an extremely convenient and cost-effective intervention.

Annex 1. Calculation of discounted YLS obstetric and maternal emergencies.

CEA YLS Effective obstetric and maternal emergencies	**Units**	**YLS Delivering Mothers** Σ Life Expectancy Mozambique – Age of delivering mothers
Obstetric emergencies transported from health centers to the HCB and admitted to the delivery room	1776	60388
Maternal Death	3	-105
Total YLS Obstetric emergencies	(1776-3)1773	60283

	Units	**YLS Alive Births** Life Expectancy Mozambique * n. Alive Births

Total births	1775	
Neonatal deaths	83	
Total YLS Alive Births	(1775-83) 1692	99828

TotaleYLS (Mothers + Alive Births)		(60283+99828) **160111**
6% Discount		9606,66
Discounted Total YLS		**150504,34**

Annex 2. Cost per year of life saved obstetric and maternal emergencies.

	Tot. cost-effective obstetric referral (cost per referral * effective obstetric emergencies)	**$/year per saved life**	**Acceptability Threshold**
C/E 4 years amortization	$48.546,11	$0,32	< $58.20 Very Attractive
C/E 7 years amortization	$43.709,81	$0,29	< $58.20 Very Attractive