

Systemic Barriers and Health System Fragmentation in Prehospital Emergency Preparedness Trauma Care Along Kenya's Nairobi-Mombasa Highway: A Mixed-Methods Study

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Abstract

This study evaluated the systemic barriers affecting prehospital emergency preparedness for road traffic accidents (RTAs) along Kenya's Nairobi-Mombasa Highway (A109). A convergent parallel mixed-methods design was employed across the seven counties traversed by the highway. 226 respondents completed questionnaire surveys, selected through stratified random, purposive, and convenience sampling, including community first responders, healthcare professionals, ambulance personnel, fire-rescue personnel, police officers, and emergency operations staff. The study obtained qualitative data by interviewing key informants, conducting focus group discussions with service providers, administrators and RTA survivors, inspecting ambulances and undertaking field observations. Quantitative data were analysed descriptively, while qualitative data underwent thematic analysis, with findings integrated during interpretation. Respondents identified several interconnected barriers, including crash concentration at black spots (95.1%), particular vehicle types (97.4%) and nighttime (77.5%). Access to crash scenes was hindered by the absence of emergency lanes (85.9%) and traffic congestion (82.8%). Other challenges included poor coordination among emergency medical services, police and hospitals (81.4%), inadequate real-time communication (92.1%), shortages of emergency-trained personnel (68.6%), limited trauma training among police officers (79.6%), inadequate ambulance equipment (69.0%), insufficient dedicated funding (69.5%) and the absence of standardised guidelines (81.0%). Qualitative findings further revealed fragmented responses to entrapment incidents, staff exhaustion during mass-casualty events, inadequate blood reserves and ambulance downtime. The findings demonstrate that prehospital emergency preparedness is constrained by mutually reinforcing systemic weaknesses. Strengthening preparedness requires unified incident command, interoperable dispatch systems, certified responder training, effective ambulance maintenance, dedicated financing and improved road-safety enforcement, in alignment with Kenya's Emergency Medical Care Policy 2020-2030.

Keywords: Emergency medical services, health system fragmentation, prehospital emergency preparedness, road traffic accidents.

INTRODUCTION

Road traffic accident (RTA) casualties on the Nairobi–Mombasa Highway (A109) depend on a prehospital emergency system that is assembled at each crash from separate actors: bystanders and community responders, traffic police, ambulance crews, fire and rescue teams, dispatch centres and receiving health facilities. When any of these actors is unprepared, or when they fail to act together, survivable injuries can become deaths before definitive care is reached. This study addresses this problem. The World Health Organization (WHO, 2023) reported an estimated 14,926 road traffic fatalities in Kenya in 2021, equivalent to 28.2 deaths per 100,000 people, compared with 4,579 deaths recorded in official national statistics. Police-reported deaths rose from 4,513 in 2023 to 4,748 in 2024, and reported crashes rose by 11.8 per cent (Kenya National Bureau of Statistics [KNBS], 2025). In Nairobi, 40 per cent of injured road users were taken to hospital by bystanders rather than by emergency services, with a median time to hospital arrival of 77 minutes (Mwenda et al., 2023).

Globally, road traffic crashes killed an estimated 1.19 million people in 2021, nine in ten of them in low- and middle-income countries (LMICs) (WHO, 2023). Prehospital emergency care is the first link in the trauma care continuum, and how well it is prepared largely decides whether an injured person reaches definitive care alive. An effective prehospital trauma system depends on prompt activation, a timely response, correct assessment and treatment at the scene, and prompt transport to a health facility (Sasser et al., 2005). These requirements align with the six phases of the Star of Life, namely detection, reporting, response, on-scene care, care during transport, and transfer to definitive care. Performance across these stages is commonly judged against the Platinum Ten Minutes for on-scene stabilisation and the Golden Hour for access to definitive care. The evidence for the Golden Hour is debated (Lerner & Moscati, 2001; Newgard et al., 2010), but where transport times are long and on-scene care is limited, both benchmarks remain useful markers of time-critical performance.

Sub-Saharan Africa has the lowest level of motorisation but the highest road traffic death rate of any region (Lagarde, 2007; WHO, 2023), while formal

emergency medical services (EMS) exist in only about one-third of African countries and cover fewer than 9 per cent of Africans (Mould-Millman et al., 2017). Kenya has made important commitments: the Health Act 2017 guarantees the right to emergency medical treatment (Republic of Kenya, 2017), and the Kenya Emergency Medical Care Policy 2020–2030 identifies non-standardised ambulances, absent emergency care guidelines, poor inter-agency coordination and untrained personnel as structural weaknesses (Ministry of Health, 2020). The Nairobi–Mombasa Highway tests these commitments severely. It runs for about 485 km from Nairobi to the Port of Mombasa through urban, peri-urban and long rural stretches, carries heavy freight and passenger traffic, and lies far from tertiary trauma care for much of its length. Prehospital preparedness is the post-crash response pillar of the Safe System approach, alongside safe road users, safe speeds, safe roads and roadsides, and safe vehicles (WHO, 2021). Its workload is therefore set upstream, by the road traffic culture and road engineering that determine how many crashes occur and how severe they are.

Studies of out-of-hospital emergency care in low- and middle-income countries (LMICs) have documented persistent weaknesses in emergency response systems (Bhattarai et al., 2023; Kironji et al., 2018), while Kenyan surveillance has identified evacuation delays using hospital records (Mwenda et al., 2023). However, existing studies either aggregate evidence across countries or focus on events from the point of hospital arrival, leaving limited evidence on systemic barriers to prehospital emergency preparedness along major transport corridors in Kenya. The closest related study examined hospital surge management along the Nakuru–Eldoret–Malaba (A104) road (Werunga, 2023), rather than prehospital preparedness along the Nairobi–Mombasa Highway. To address this gap, the present study evaluated systemic barriers to prehospital emergency preparedness for road traffic accidents (RTAs) along the Nairobi–Mombasa Highway across seven domains: access and the road environment; road traffic culture, enforcement integrity and the engineering environment; command and coordination; communication and dispatch; human resource capacity; equipment and fleet readiness; and governance, policy and financing.

LITERATURE REVIEW

Theoretical Framework

This study contends that no single theory adequately explains prehospital emergency preparedness for RTAs, which is at once a phased management process, a high-risk operational activity and a network of interdependent organisations. The study therefore triangulated three theories, each selected to answer a distinct part of the research problem and each compensating for a limitation of the others.

Emergency Management Theory, expressed in the Comprehensive Emergency Management framework (National Governors' Association, 1979) and later scholarship (McEntire, 2004; Waugh & Streib, 2006), organises the management of hazardous events around mitigation, preparedness, response and recovery. It provides the organising logic of preparedness: it defines what preparedness comprises, namely the plans, trained people, equipment, protocols and coordination arrangements that must exist before a crash for the response to work. It was used to define the barrier domains as preparedness inputs and to locate each at a Star of Life stage; its mitigation phase also frames road traffic culture and road engineering as upstream conditions, since every crash that mitigation fails to prevent passes to the response phase. The theory is, however, phase-based and linear, framed largely around a lead agency, and silent on how independent actors interact or on the standard of performance a preparedness system should achieve.

High-Reliability Theory supplies that missing performance standard. It explains how organisations that operate in hazardous, time-critical environments, such as aircraft carriers and air traffic control, achieve consistently safe performance (La Porte, 1996; Roberts, 1990). Reliable organisations are preoccupied with failure, sensitive to front-line operations, committed to resilience and willing to defer to expertise, and they rely on leadership, standardisation, continuous training and learning from error (Chassin & Loeb, 2013; Weick & Sutcliffe, 2015). The theory defines how reliably preparedness must perform and was used to interpret the findings on unified command, standardised guidelines, training, human and system error, and monitoring. Its limitation is that it focuses

on the internal functioning of single organisations rather than on the relationships between them.

Systems Theory fills the gap left by both. It treats an entity as a set of interacting components whose behaviour cannot be understood by examining the parts in isolation (von Bertalanffy, 1968). An open system exchanges resources and information with its environment (Katz & Kahn, 1978), and a viable system regulates itself through feedback and control (Beer, 1972). The theory explains why the parts succeed or fail together: it treats the corridor's prehospital response as an open system whose performance is constrained by its weakest interacting sub-system, and it allows the transport environment, including road traffic culture, to be analysed as part of the system's environment rather than as background. Taken together, Emergency Management Theory defines what preparedness comprises, High-Reliability Theory defines how well it must perform, and Systems Theory explains why the parts succeed or fail together, which reduces the risk that the findings are interpreted through a single, partial lens.

Conceptual Framework

The conceptual framework (Figure 1) is derived from the three theories. The seven barrier domains are the independent variables. One of them, road traffic culture together with enforcement integrity and the engineering environment, acts upstream by setting the volume and severity of crashes; the other six act within the prehospital chain. All seven act on preparedness at the six Star of Life stages. The dependent variable is the effective prehospital management of RTAs, indicated by timely detection, reporting and dispatch; response within the Platinum Ten Minutes and the Golden Hour; on-scene stabilisation, safe transport and structured handover; and lower preventable mortality and morbidity. The relationship is shaped by intervening variables that the prehospital system does not control directly: devolution of health services to the counties, implementation and funding of the Kenya Emergency Medical Care Policy 2020–2030 (Ministry of Health, 2020), the capacity of receiving facilities, traffic volume and freight demand, and the psychosocial wellbeing of responders.

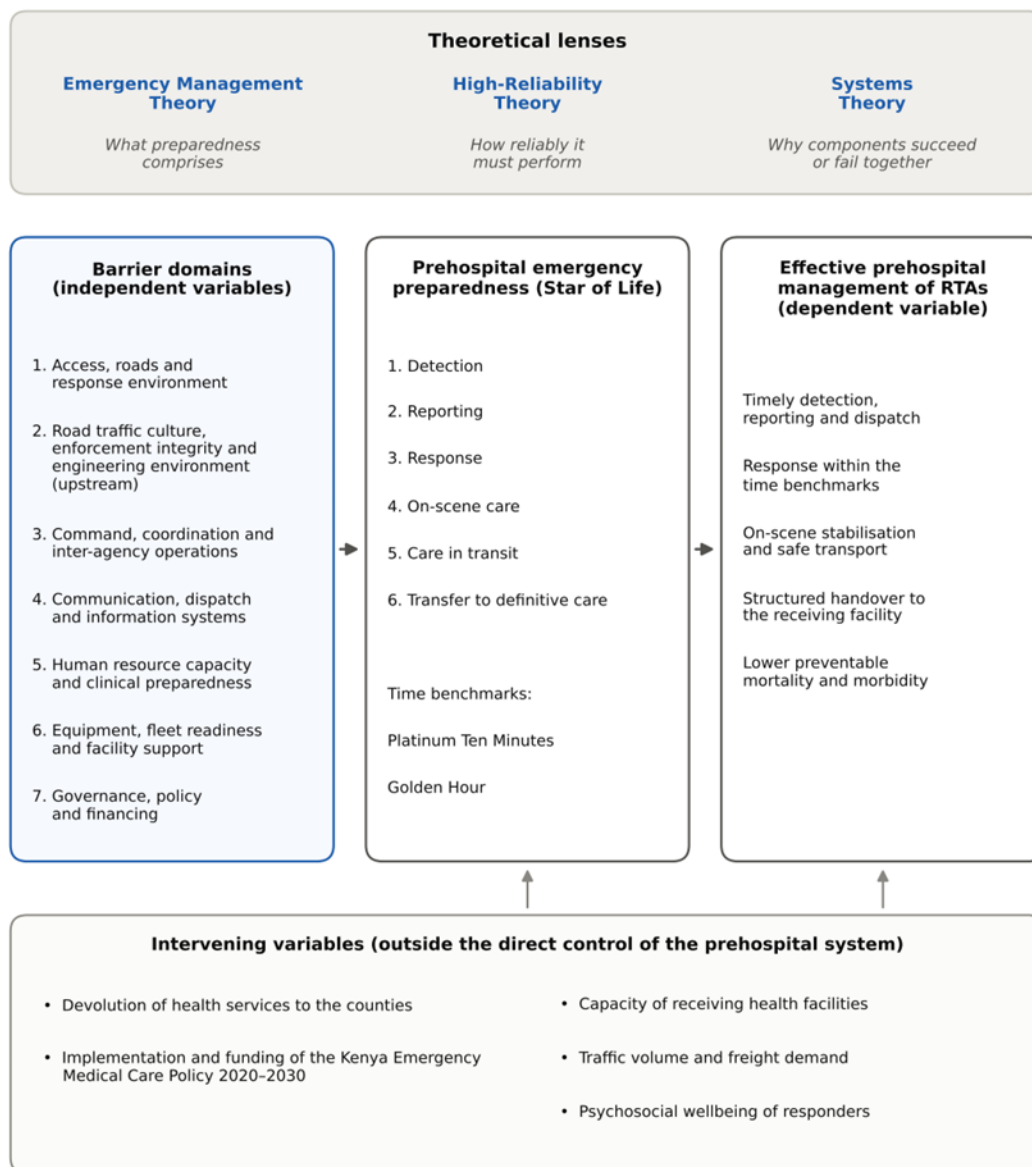


Figure 1: Conceptual Framework Showing the Relationships Among the Study Variables

Empirical Review

The literature is reviewed for each domain, moving from global and LMIC evidence to African and then Kenyan studies, and noting what each body of evidence can and cannot show.

Access, Roads and the Response Environment

A systematic review of out-of-hospital emergency care in low- and lower-middle-income countries found transport and personnel among the most frequently reported barriers (Kironji et al., 2018), and a later review found that transport delays reduced the efficiency of prehospital response (Bhattarai et al.,

2023). Both reviews are strong on breadth but count how often barriers are reported rather than how much delay each causes, and neither separates road condition from congestion, distance or the priority given to emergency vehicles. In sub-Saharan Africa, Ouma et al. (2018) used a geocoded inventory of public hospitals to estimate travel times to emergency care; the analysis is rigorous for geographic access, but models travel at assumed speeds and cannot capture congestion or ambulance availability. In Kenya, Mwenda et al. (2023) recorded a median time to hospital arrival of 77 minutes in Nairobi, which measures the outcome of delay but not where in the

chain time is lost. The present study measures congestion, emergency-lane priority and terrain separately.

Road Traffic Culture, Enforcement Integrity and the Engineering Environment

The Safe System approach treats post-crash response as one of five interdependent pillars and accepts that the performance of each depends on the others (WHO, 2021). Weak enforcement of traffic laws has long been identified as a driver of the road traffic burden in developing countries (Nantulya & Reich, 2002), and prevention and trauma care have been argued to belong to one injury-control system (Mock et al., 2004). Yet continental reviews of EMS concentrate on the response system itself (Kironji et al., 2018; Mould-Millman et al., 2017). In Kenya, an ethnographic study of police officers and matatu operators on three busy routes described traffic policing at checkpoints and roadblocks as an institutionalised practice of bribery (Onyango, 2022), and Transparency International Kenya (2018) found that 55 per cent of long-distance drivers had been asked for a bribe by police. On the engineering side, signage was the only infrastructure factor with a significant effect on road safety along Nairobi's Outering Road (Kipchirchir & Moi, 2023), and a review of the roads sub-sector linked substandard works to inadequate supervision and payments certified ahead of work done (Kenya Anti-Corruption Commission [KACC], 2007). These sources come from other routes, an urban road and a dated review, and none connects enforcement integrity or road engineering to prehospital preparedness on the Nairobi–Mombasa corridor.

Command, Coordination and Inter-Agency Operations

Bigley and Roberts (2001) showed that the Incident Command System allows agencies to organise reliably in volatile settings through predefined roles, and Kapucu (2008) argued that collaborative emergency management depends on inter-organisational networks built before incidents occur. Both draw on well-resourced United States agencies, so their assumption of formal command structures may not hold in under-resourced settings. In Iran, stakeholders attributed post-crash failures to unclear roles and the absence of structured scene command (Khorasani-Zavareh et al., 2009), and experts identified the lack of

unified command as a driver of preventable prehospital deaths (Eftekhari et al., 2019); these qualitative studies explain mechanisms but not prevalence. In Africa, Mould-Millman et al. (2017) found existing EMS systems to be mostly government-operated basic services, but their country-level survey cannot describe coordination at crash scenes. In Kenya, national policy acknowledges poor inter-agency coordination (Ministry of Health, 2020), and Werunga (2023) found hospital surge management along the A104 too weak for effective emergency response; neither measured coordination at the prehospital stage.

Communication, Dispatch and Information Systems

Reviews of LMIC prehospital systems describe weak communication between dispatchers, crews and receiving facilities and few shared protocols (Bhattarai et al., 2023; Kironji et al., 2018), and poor communication was a critical bottleneck in post-crash management in Iran (Khorasani-Zavareh et al., 2009). In Malawi, the absence of a formal prehospital system, a universal-access emergency number and an ambulance service left activation to bystanders (Chokocho et al., 2017). In Kenya, Lee et al. (2024) described county EMS in Garissa coordinating through WhatsApp and suggested that it may be a low-cost option for Kenyan EMS. Their report documents a working local solution but is a descriptive site visit rather than an evaluation, and it does not address a high-volume highway on which several agencies and counties must share information.

Human Resource Capacity

High-reliability scholarship holds that reliable teams depend on simulation-based training and that infrequently used skills decay without refresher practice (Arthur et al., 2013; Riley et al., 2010). Training lay first responders has been promoted as a way to extend coverage in LMICs (Callese et al., 2014), and African evaluations report encouraging results in Sierra Leone (Eisner et al., 2020), Uganda (Delaney et al., 2021) and Chad (Hancock et al., 2020), although most were conducted by implementing organisations and relied on self-reported outcomes. In Tanzania, traffic police officers, often first on scene, described lacking training, resources and an organised response system (Lukumay et al., 2019). In Kenya, an educational assessment found no national scope of

practice or certification for EMS providers (Nicholson et al., 2017). This literature rarely separates staffing shortages from training gaps and from human or system error, although each calls for a different remedy.

Equipment, Fleet Readiness and Facility Support

Without functional vehicles and reliable maintenance, EMS in LMICs cannot meet basic response demands (Eisner et al., 2024). A scoping review covering six sub-Saharan African countries and five other LMICs found that 35.3% of first-responder programmes gave basic life support trainees no airway equipment (Pine et al., 2022), which suggests that training often runs ahead of supplies. Organised trauma systems reduce mortality in LMICs (Henry & Reingold, 2012; Reynolds et al., 2017), which makes facility readiness part of the same chain. In Kenya, Werunga (2023) recommended more staff, equipment and infrastructure for hospitals along the A104. How equipment and fleet deficits on a corridor relate to financing and maintenance remains unexamined.

Governance, Policy and Financing

Emergency care in LMICs is poorly documented and unevenly organised (Obermeyer et al., 2015). Professional (Tier-2) EMS systems need sustained public financing and regulation (Sun et al., 2024), while community first responder-driven (Tier-1) systems may be more scalable where resources are scarce (Moussally et al., 2024); both are expert syntheses rather than empirical evaluations. In Africa, most EMS systems were government-operated and charged fees for service (Mould-Millman et al., 2017). Kenya differs in already having a statutory right to emergency treatment and a national policy (Ministry of Health, 2020; Republic of Kenya, 2017), and variation in provider competence has been linked to the absence of a national scope of practice (Nicholson et al., 2017). The Kenyan question is therefore whether policy is financed, standardised and enforced at corridor level.

Research Gap

Four patterns emerge from the studies reviewed. First, Kenyan evidence is hospital-based (Mwenda et al., 2023; Werunga, 2023) or confined to a single component, such as training (Nicholson et al., 2017) or one county's communication practice (Lee et al., 2024). Second, the most detailed analyses of barriers

come from Iran, Tanzania and multi-country reviews (Khorasani-Zavareh et al., 2009; Kironji et al., 2018; Lukumay et al., 2019), whose findings may not transfer directly to Kenya. Third, the closest Kenyan corridor study addressed the hospital end of the trauma chain on a different highway (Werunga, 2023). Fourth, Kenyan studies of traffic enforcement and road infrastructure (Kipchirchir & Moi, 2023; Onyango, 2022) have not been connected to prehospital preparedness. Because the review was narrative rather than systematic, the gap is stated in bounded terms: among the studies reviewed, literature was scarce on assessment of the seven barrier domains across the prehospital chain on the Nairobi–Mombasa corridor or on how they interact. A gap that this study sought to fill.

METHODOLOGY

The study adopted a pragmatic research philosophy and a descriptive, cross-sectional, convergent parallel mixed-methods design (Creswell & Plano Clark, 2018; Kaushik & Walsh, 2019; Morgan, 2007). The study collected quantitative and qualitative data simultaneously from June to December 2025, analysed them independently, and then integrated them during interpretation. The quantitative strand assessed the extent to which stakeholders experienced different barriers, while the qualitative strand explored how these barriers operated and interacted within the prehospital emergency response system.

The study was conducted along Kenya's Nairobi–Mombasa Highway (A109), an approximately 485-km transport corridor traversing Nairobi, Machakos, Makueni, Taita-Taveta, Kwale, Kilifi and Mombasa counties. The corridor was selected because of its heavy passenger and freight traffic, recognised accident black spots and extended sections located far from tertiary trauma care facilities. Data collection sites included selected health facilities, emergency response centres, ambulance stations, traffic posts and accident black spots along the corridor.

The target population comprised stakeholders involved in the prehospital management of road traffic accidents (RTAs), including healthcare professionals, ambulance personnel, facility administrators, emergency response agency officials, traffic police officers, RTA survivors and bystanders. The accessible

population consisted of 723 individuals across 14 strata. A minimum sample of 213 respondents was targeted using the sampling allocation guidelines of Mugenda and Mugenda (2003). Healthcare professionals and traffic police officers were selected through stratified random sampling using available staff registers. Purposive sampling was applied to

identify administrators and officials with expertise in emergency planning, coordination and policy, whereas convenience sampling was used to recruit road traffic accident (RTA) survivors and bystanders because no sampling frame existed for these groups. The sampling frame, allocation guidelines, target sample and selection techniques are presented in Table 1.

Table 1: Sampling Frame, Sample Allocation and Selection Technique by Stratum

Stratum	Accessible population	Allocation guideline	Target sample	Selection technique
Doctors	100	10–30%	30	Stratified random
Nurses	300	10–30%	50	Stratified random
Paramedics	70	10–30%	20	Stratified random
Emergency medical technicians	50	10–30%	15	Stratified random
Traffic police officers	15	10–50%	8	Stratified random
Health facility administrators	15	30–50%	10	Purposive
Kenya Red Cross Society officials	20	10–50%	10	Purposive
St John Ambulance officials	20	10–50%	10	Purposive
National Transport and Safety Authority officials	10	10–50%	5	Purposive
Kenya Council of Emergency Medical Technicians officials	5	Census	5	Purposive
Safe Way Right Way Kenya officials	5	Census	5	Purposive
Kenya National Highways Authority emergency highway patrol	5	Census	5	Purposive
RTA survivors	30	10–50%	15	Convenience
Bystanders	78	10–50%	25	Convenience
Total	723		213	

Source: Author (2025).

The survey yielded 226 completed questionnaires, representing 31.3 per cent of the accessible population, and all completed questionnaires were included in the analysis. The sample was designed to capture perspectives across stakeholder groups rather than achieve statistical generalisability. Purposive sampling was used to identify key informants and focus group participants based on their RTA response experience and positions in the emergency response chain. Qualitative adequacy was assessed by ensuring coverage of the different stages of the Star of Life and

the perspectives of both emergency care providers and recipients.

Data collection instruments comprised structured questionnaires, semi-structured key informant interview guides, focus group discussion guides and an ambulance inspection checklist. The questionnaire covered participant demographics and five-point Likert-scale items relating to the study's barrier domains. Key informant interviews explored emergency response roles, communication, coordination, protocols, triage, training and resource

constraints. Focus group discussions were conducted separately with frontline providers and RTA survivors. Ambulance inspections assessed vehicle condition, emergency medical equipment, communication and documentation, personnel readiness and essential supplies. Field observations were undertaken at emergency departments, ambulance stations, traffic posts and accident black spots. Documentary evidence on emergency care, road safety, traffic statistics and governance was also reviewed to contextualise the primary findings.

Content validity was assessed by emergency care and disaster management specialists at Masinde Muliro University of Science and Technology. The instruments were piloted in May 2025 at two health facilities and accident response centres along the Nairobi–Nakuru Highway. Internal consistency was evaluated using Cronbach’s alpha, adopting 0.70 as the acceptance criterion. Items that did not meet this standard were reviewed and revised.

Quantitative data were coded, cleaned and analysed using SPSS. Likert-scale responses were summarised using frequencies and percentages, while an agreement index was calculated by combining the strongly agree and agree categories. No inferential statistical tests were conducted. Qualitative interviews and discussions were audio-recorded with participants’ consent, transcribed verbatim and, where necessary, translated into English. The data were analysed thematically following Braun and Clarke’s (2006) six-phase approach. Coding combined deductive categories based on the study’s barrier domains and the Star of Life stages with inductive codes emerging from the data. Quantitative findings were integrated with qualitative, observational and documentary evidence during interpretation to

identify convergences, explanations and differences across the evidence sources.

Ethical clearance was secured from Masinde Muliro University of Science and Technology (Ref. MMU/COR: 509099, 24 June 2025), while research authorisation was granted by the National Commission for Science, Technology and Innovation (Licence No. NACOSTI/P/25/4176021; Ref. No. 824191, 30 June 2025). Further approvals were obtained from the relevant education, health and county authorities. Informed written consent was obtained after participants were briefed on the study’s purpose, procedures, risks and benefits. Participation was voluntary, withdrawal was allowed at any time, and data were anonymised and securely maintained.

RESULTS AND DISCUSSION

The results are presented across the seven barrier domains, with quantitative findings presented first, followed by qualitative and observational evidence. Each domain is then discussed in relation to previous studies and relevant theoretical perspectives. The final section integrates the findings across all domains to provide an overall understanding of the systemic barriers to prehospital emergency preparedness for road traffic accidents along the Nairobi–Mombasa Highway.

Access, Road Infrastructure and Response Environment

Road infrastructure and the physical response environment emerged as major barriers (Figure 2). The lack of designated emergency lanes drew the highest agreement (85.9%; 54.0% strongly agreed), followed by terrain and road infrastructure limitations (83.6%) and traffic congestion (82.8%; 54.9% strongly agreed); a minority of 12.3–13.7 per cent disagreed, almost all strongly.

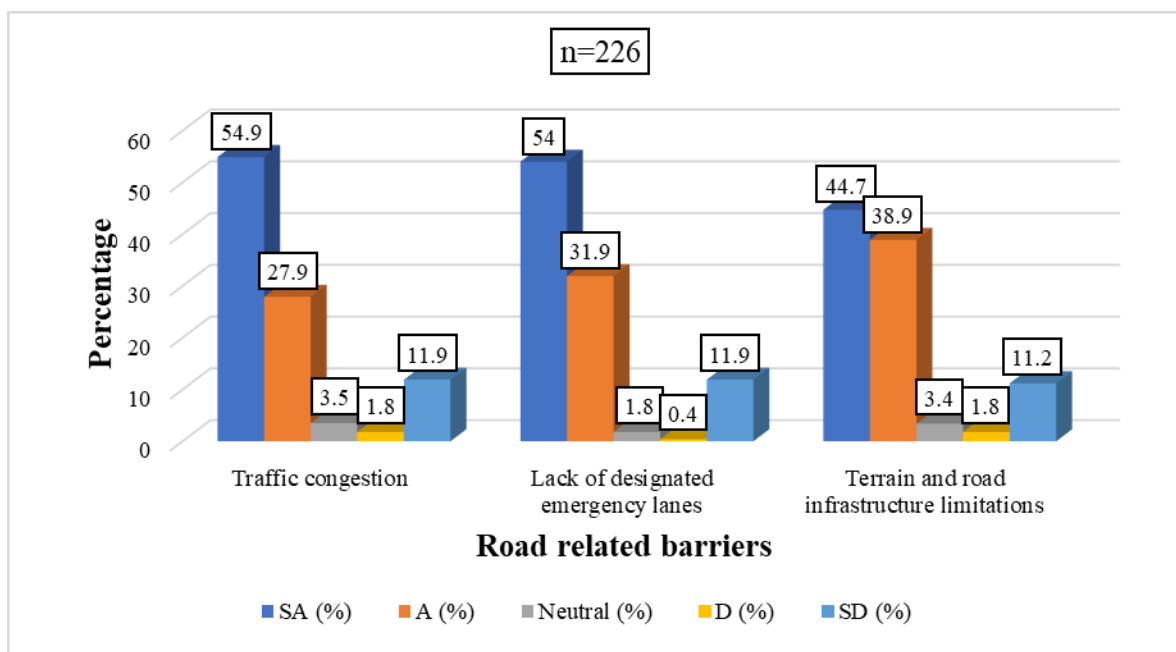


Figure 2: Road-Related Barriers Affecting Emergency Response Along the Nairobi–Mombasa

The three items capture different components of access: congestion concerns travel time, emergency lanes concern the priority given to emergency vehicles within traffic, and terrain and infrastructure concern road condition and scene geometry, which affect extrication, ambulance positioning and on-scene care. Distance and ambulance distribution were not measured by survey items and come from the qualitative evidence. An emergency nurse explained:

We had two vehicles, but currently we only have one. Suppose an accident occurs around 10 kilometres from here – this single ambulance has to pick up one patient, come back, then pick the other, and this takes time ... the vehicle must be refuelled before it can move ... and the patient may arrive dead (Emergency Nurse, Makindu Level IV Hospital, 30 July 2025).

At black spots, field observation found no emergency contact signage, pre-positioned first-aid equipment or designated staging areas. The findings agree with reviews that place transport among the most frequently reported barriers in LMICs (Bhattarai et al., 2023; Kironji et al., 2018) and with evidence of uneven geographic access to emergency care in sub-Saharan Africa (Ouma et al., 2018). They differ in emphasis: access models estimate travel time from distance and assumed speeds, whereas on this corridor agreement

was slightly higher for the lack of emergency-vehicle priority than for congestion itself. A plausible reason is the corridor's traffic mix, in which heavy freight and passenger vehicles share the carriageway, so that an ambulance's delay depends as much on whether it can pass slower traffic as on distance. The 77-minute median reported in Nairobi (Mwenda et al., 2023) comes from a city with short distances; on rural stretches served by a single ambulance, distance and fleet size compound congestion. In Emergency Management terms, emergency lanes, staging areas and pre-positioned equipment are preparedness investments whose absence shifts the burden to the response phase; in Systems terms, the road environment is an input that shortens the time available for every later Star of Life stage.

Road Traffic Culture, Enforcement Integrity and the Engineering Environment

Road traffic culture was assessed through indicators of the crash burden it generates (Table 2). Agreement was near-universal that certain vehicle types, such as motorcycles, public service vehicles and heavy trucks, are more frequently involved in crashes (97.4%) and that crashes are frequent at identified black spots (95.1%). Most respondents also agreed that crashes produce severe or multiple casualties (90.2%), that pedestrians and other vulnerable road users are often

among the casualties (89.8%) and that crashes occur mainly at night (77.5%), although 14.1 per cent disagreed with the last statement. Field observation found black spots without emergency signage, and the interview evidence reflects the enforcement

culture from the response side: an ambulance EMT reported that crews had been stopped by government check-units while responding under siren, and a mass-casualty crash that kept Makindu staff working until morning occurred at 9 PM.

Table 2: Crash-Burden Indicators of Road Traffic Culture and the Engineering Environment

Statement	n	SA (%)	A (%)	Neutral (%)	D (%)	SD (%)	Total (%)
There are frequent road traffic accidents in identified black spot areas along the Nairobi–Mombasa Road.	226	63.7	31.4	3.1	1.4	0.4	100.0
Road traffic accidents predominantly occur during night-time hours along this road corridor.	226	31.0	46.5	8.4	10.1	4.0	100.0
Most road traffic accidents in this area result in severe or multiple casualties.	226	42.9	47.3	4.0	5.4	0.4	100.0
Certain vehicle types (e.g., motorcycles, PSVs, heavy trucks) are more frequently involved in road traffic accidents along this highway.	226	44.7	52.7	1.8	0.4	0.4	100.0
Pedestrians and vulnerable road users are often among the casualties in accidents occurring along the Nairobi–Mombasa Road.	226	45.1	44.7	6.2	4.0	0.0	100.0

Source: Field Data (2025).

The indicators describe a crash burden that is structured rather than random: concentrated at particular places, at night, among particular vehicle types and among pedestrians. Under the Safe System approach, such a load is generated upstream, by road-user behaviour, speed, enforcement and road design (WHO, 2021). Its spatial and temporal concentration implicates engineering as much as individual conduct, which is consistent with evidence that signage affects road safety in Nairobi (Kipchirchir & Moi, 2023) and that substandard road works have been linked to weak supervision (KACC, 2007). Where traffic offences can be settled at the roadside (Onyango, 2022; Transparency International Kenya, 2018), the expected cost of violation falls, deterrence weakens, and the resulting casualties are passed downstream to responders and hospitals. This differs from the prehospital literature, which treats crash volume as given (Bhattarai et al., 2023; Kironji et al., 2018). In Emergency Management terms, these are failures of mitigation; in Systems terms, the transport system,

with its enforcement regime and infrastructure, is part of the environment of the prehospital system, so gains in response can be offset by an unchecked upstream flow of casualties. Because road traffic culture was assessed through indicators and documents, these findings establish the pattern of the crash burden and its plausible causes, not their relative contribution.

Command, Coordination and Inter-Agency Operations

Results. Fragmented command and weak inter-agency coordination were major barriers (Table 3). More than four in five respondents (81.4%) agreed that response is hindered by poor coordination among EMS providers, police and hospitals; 71.3 per cent agreed that there is no unified command structure at crash scenes, and 73.4 per cent that referral and communication protocols between EMS providers and facilities are inadequate. Views on institutional support for multi-agency command centres were divided (44.2% agreed; 33.6% neutral).

An ambulance EMT illustrated how agencies arrive in sequence:

Sometimes you find someone trapped, and we do not have the resources to free them, so we have to call the fire brigade to help us" (Ambulance EMT, Makindu Level IV Hospital, 29 July 2025); each team arrives at its own time,

and coordination becomes a challenge. Not all accounts described fragmentation: "When we have a massive accident ... we inform other centres in Kilungu, Sultan to activate their ambulances ... We actually collaborate well together with EMT teams (Emergency Nurse, Makindu Level IV Hospital, 30 July 2025)

Table 3: Command, Coordination and Inter-Agency Operations Barriers

Statement	n	SA (%)	A (%)	Neutral (%)	D (%)	SD (%)	Total (%)
Emergency response is hindered by poor coordination among EMS providers, police and hospitals.	226	39.8	41.6	3.6	2.2	12.8	100.0
There is no unified command structure at crash scenes, which leads to role confusion during emergency response.	226	38.1	33.2	7.5	6.2	15.0	100.0
There are inadequate referral and communication protocols between EMS providers and health facilities.	226	31.4	42.0	9.3	4.4	12.9	100.0
There is growing institutional support to establish multi-agency command centres for rapid EMS coordination.	226	19.4	24.8	33.6	11.1	11.1	100.0

Source: Field Data (2025).

The findings agree with continental evidence of fragmented EMS development (Mould-Millman et al., 2017) and with Iranian studies that trace post-crash failures to unclear roles and absent scene command (Eftekhar et al., 2019; Khorasani-Zavareh et al., 2009), and they extend Werunga's (2023) hospital findings on the A104 to the prehospital stage. The qualitative evidence adds two qualifications: fragmentation is partly a matter of capability, because crews call the fire brigade when they lack extrication equipment, and cooperation exists but is informal and local, which is consistent with the large neutral share on command centres. A plausible contextual reason is the division of responsibility between devolved county health services and national police and highway agencies, with no corridor-wide arrangement linking them. The Incident Command System allows reliable organising in such conditions by fixing roles in advance (Bigley & Roberts, 2001); in High-Reliability terms the corridor lacks the structure that would allow it to defer to expertise under pressure, and in Systems terms the weakness lies at the interfaces between agencies rather than within any one of them.

Communication, Dispatch and Information Systems

The majority of respondents (92.1%) agreed that inadequate real-time communication systems delay dispatch and response, and only 4.4 per cent disagreed (Table 4). The remaining items concerned potential solutions and drew near-unanimous agreement: integrating trauma surveillance with EMS operations (98.2%), mobile and digital alert platforms (97.3%) and Geographic Information Systems (GIS) for ambulance routing (96.4%). Elsewhere in the survey, 70.3 per cent indicated that toll-free emergency numbers were not reliably available or effectively used.

An ambulance EMT described a call chain built on personal contacts:

Often we receive the call before the traffic police, and then we call the traffic base at Salama, since they have our number; at the same time we call the dispatch centre in Wote to request an ambulance ... Past Malili, I have to go to Machakos because of the distance, and before going I have to call them

(Ambulance EMT, Makindu Level IV Hospital, 29 July 2025).

The same informant described an institutional barrier: "The government check-unit causes a lot of problems.

Our operator has been stopped by the check-unit while responding to a call ... They do not understand emergency response.

Table 4: Communication, Dispatch and Information Systems Barriers

Statement	n	SA (%)	A (%)	Neutral (%)	D (%)	SD (%)	Total (%)
Inadequate real-time communication systems delay dispatch and response at accident scenes.	226	46.5	45.6	3.5	1.8	2.6	100.0
Integration of trauma surveillance systems with EMS operations can enhance real-time decision-making.	226	50.0	48.2	1.8	0.0	0.0	100.0
Mobile and digital platforms (e.g., EMS alert apps) can enhance crash detection and reporting times.	226	43.8	53.5	1.8	0.9	0.0	100.0
Integrating Geographic Information Systems (GIS) in EMS routing can optimise ambulance response time.	226	52.2	44.2	3.6	0.0	0.0	100.0

Source: Field Data (2025).

The findings mirror reviews describing weak communication between dispatch, crews and facilities in LMICs (Bhattarai et al., 2023; Kironji et al., 2018). Unlike settings in which activation depends wholly on bystanders (Chokocho et al., 2017), receiving hospitals on this corridor are notified, but through personal phones rather than a dispatch system. This resembles the WhatsApp-based coordination described in Garissa (Lee et al., 2024), which works locally; on a multi-county highway, however, such arrangements depend on who knows whom, leave no record and break down across jurisdictions. The check-unit account shows that communication failures are institutional as well as technical, because enforcement officers who do not recognise EMS protocols can halt an ambulance responding under siren. Support for surveillance integration, digital alerts and GIS routing indicates readiness for technology, but technology without shared protocols across health, police and transport agencies would reproduce the same gaps. In Systems

terms, communication is the feedback channel through which components adjust to one another; where it runs through personal networks, the system cannot regulate itself at corridor scale.

Human Resource Capacity and Clinical Preparedness

Table 5 distinguishes three problems. On staffing, 68.6 per cent agreed that there is a severe shortage of emergency-trained personnel (24.8% disagreed). On training, perceptions of EMTs were divided (52.7% agreed that they are insufficiently trained for time-sensitive trauma care; 31.4% disagreed), whereas 79.6 per cent agreed that police officers and traffic enforcers are inadequately trained in basic trauma response. On error, 93.3 per cent agreed that human and system errors adversely affect outcomes. Support was near-universal for standardised EMT training (96.0%) and for refresher courses and simulation (97.3%).

Table 5: EMS Clinical Capacity and Human Factors Barriers

Statement	n	SA (%)	A (%)	Neutral (%)	D (%)	SD (%)	Total (%)
There is a severe shortage of emergency-trained personnel in prehospital care units.	226	39.8	28.8	6.6	6.2	18.6	100.0
Emergency Medical Technicians (EMTs) are not sufficiently trained to handle time-sensitive trauma cases.	226	23.9	28.8	15.9	8.6	22.8	100.0
Frequent human and system errors negatively affect outcomes of prehospital emergency care.	225	38.2	55.1	4.9	0.0	1.8	100.0
Police officers and traffic enforcers are inadequately trained in basic trauma response and patient handling.	226	37.6	42.0	6.2	4.4	9.8	100.0
Standardising EMT training can reduce variation in emergency care quality.	226	49.1	46.9	2.7	0.0	1.3	100.0
Structured refresher courses and simulations for EMS personnel can improve time-sensitive decision-making.	226	47.3	50.0	2.3	0.0	0.4	100.0

Source: Field Data (2025).

An emergency nurse described a surge:

The accident occurred at 3AM, and there were so many injured people; we worked using tents and stayed until 9 AM handling the victims" (Emergency Nurse, Makindu Level IV Hospital, 30 July 2025). A clinical officer added: "Most of the staff are not trained on emergency response, and even those present may lack adequate knowledge on how to proceed with particular cases (Clinical Officer, Makindu Level IV Hospital, 30 July 2025)

The staffing shortage is consistent with continental evidence that African EMS systems rely on small numbers of basic-level staff (Mould-Millman et al., 2017), and the surge account shows how shortage becomes a reliability problem when the same staff work through the night. The divided view of EMT training is best explained by the absence of a national scope of practice and certification (Nicholson et al., 2017): where standards vary, competence varies with the team. The sample may also contribute, because most respondents were community responders who observe EMTs at scenes rather than assess them. The police training gap agrees with Tanzanian evidence (Lukumay et al., 2019). In High-Reliability terms, near-universal attribution of adverse outcomes to error

points to error as a property of the system, produced by fatigue, inconsistent training and absent protocols, which explains the support for standardised training and simulation that counter skill decay (Arthur et al., 2013; Riley et al., 2010). Evidence from lay responder programmes (Delaney et al., 2021; Eisner et al., 2020) suggests that the community responders who dominate early response could be trained and certified.

Equipment, Fleet Readiness and Facility Support

Results. Respondents agreed that most ambulances lack critical life-saving equipment (69.0%), that facilities along the road are not adequately equipped to support advanced prehospital trauma care (75.3%) and that emergency response units are underfunded, leading to poor maintenance (73.0%; 20.8% neutral) (Figure 3). An emergency nurse recalled:

There is a time we received 2 patients with crashed lower limbs, and we do not have any blood reserves. We had to send the ambulance to Wote to pick blood, but unfortunately both died ... The surgery room is too small ... others are managed in the corridor (Emergency Nurse, Makindu Level IV Hospital, 30 July 2025)

An EMT explained that splints and collars leave with patients and are not replaced: "at the moment we do not have a single neck collar" (Ambulance EMT, Makindu Level IV Hospital, 29 July 2025).

Field visits found grounded and abandoned ambulances on facility premises, and checklist inspections showed marked variation between well-equipped vehicles and others with incomplete inventories or mechanical faults.

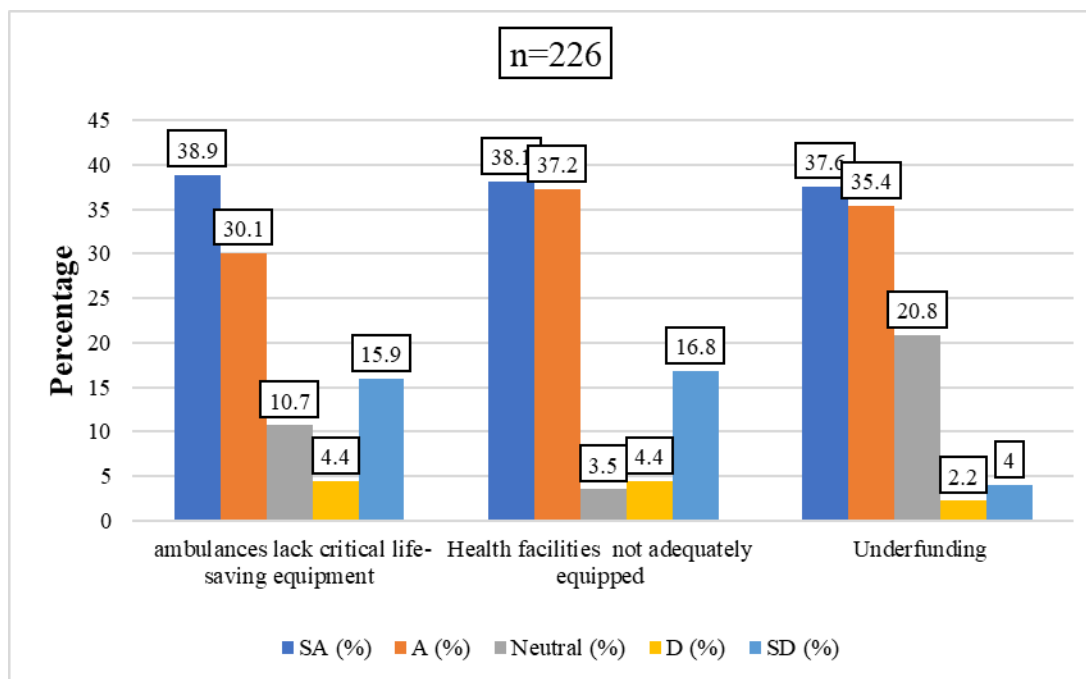


Figure 3: Equipment, Fleet Readiness and Facility Support Barriers

The findings agree with evidence that vehicles and equipment remain basic bottlenecks for EMS in LMICs (Eisner et al., 2024) and that many first-responder programmes in sub-Saharan Africa lack airway equipment (Pine et al., 2022). They add that scarcity is partly a supply-chain problem, since readiness falls with every transfer, and that facility readiness is part of prehospital preparedness: as on the A104 (Werunga, 2023), facilities lacked surge capacity, and the absence of blood meant that casualties who were transported still died. Organised trauma systems reduce mortality in LMICs (Henry & Reingold, 2012; Reynolds et al., 2017), but only when every link functions. The grounded ambulances illustrate a broken maintenance feedback loop in Systems terms: vehicles are procured but not repaired or replaced, so the functional fleet shrinks while the nominal fleet does not. In Emergency Management terms, preparedness should be measured by functional assets rather than assets on paper.

Governance, Policy and Financing

Results. Most respondents (69.5%) agreed that there is no dedicated funding mechanism for EMS in the region; only 3.6 per cent disagreed, but 26.9 per cent were neutral (Table 6). Agreement that prehospital systems lack standardised operational guidelines was 81.0 per cent. Respondents endorsed stronger government enforcement of EMS policy (92.4%) and regular monitoring and evaluation of Tier-1 EMS (97.3%). An ambulance EMT linked financing to training and fleet readiness:

Training such as ACLS [advanced cardiovascular life support] and BLS [basic life support] refresher courses requires money, around 24,000 Kenya shillings. Without funding, staff cannot be retrained, and systems cannot improve. Even ambulances remain grounded for years due to minor issues (Ambulance EMT, Makindu Level IV Hospital, 29 July 2025)

Table 6: Financing, Policy and Standardisation Barriers

Statement	n	SA (%)	A (%)	Neutral (%)	D (%)	SD (%)	Total (%)
There is no dedicated funding mechanism to ensure the sustainability of EMS operations in this region.	226	28.8	40.7	26.9	1.8	1.8	100.0
Prehospital emergency systems suffer from a lack of standardised operational guidelines.	226	38.5	42.5	13.2	0.9	4.9	100.0
Government support in enforcing EMS policy frameworks is crucial for structured service delivery.	226	38.9	53.5	5.8	1.4	0.4	100.0
Regular monitoring and evaluation of Tier-1 EMS systems can enhance accountability and improve response outcomes.	226	45.1	52.2	2.7	0.0	0.0	100.0

Source: Field Data (2025).

This pattern differs from much of the African literature. Mould-Millman et al. (2017) describe many countries without any EMS system, whereas Kenya has a statutory right to emergency treatment and a national policy that names the weaknesses found here (Ministry of Health, 2020; Republic of Kenya, 2017). The gap on the corridor is therefore one of implementation: financing that is not ring-fenced, standards that are not enforced and performance that is not monitored. This agrees with Nicholson et al. (2017) on the absence of a national scope of practice and with Sun et al. (2024) on the need for dedicated financing. The neutral quarter on funding suggests that EMS financing is opaque to front-line actors. The interview account shows how a financing gap travels through the system: refresher courses lapse and minor faults ground ambulances, reducing trained staff and functional vehicles. In Beer's (1972) Viable System Model, governance is the control function that allocates resources and corrects deviations; when it is weak, failures elsewhere go uncorrected. In High-Reliability terms, the support for monitoring reflects recognition that a system cannot learn from failures it does not measure.

Synthesis: How the Barrier Domains Interact

The seven domains describe one mechanism rather than seven separate problems, and each link in it is supported by both strands of evidence. First, road traffic culture and the engineering environment set

the load: crashes concentrate at black spots, at night, among particular vehicle types and among pedestrians (77.5–97.4% agreement), and documentary evidence of compromised enforcement and poorly supervised road works suggests why. Second, delays accumulate along the Star of Life. Detection and reporting depend on personal phones rather than a functioning emergency number (92.1% and 70.3%; the call-chain account); response is slowed by congestion, the lack of emergency lanes, single-vehicle fleets and enforcement stops (82.8% and 85.9%; the Makindu and check-unit accounts); on-scene care is limited by the sequential arrival of agencies and untrained first responders (81.4% and 79.6%; the entrapment account); and transfer is compromised by facilities without blood or surge space (75.3%; the blood account). Third, governance and financing act as the upstream condition within the system: the lack of dedicated funding and standards (69.5% and 81.0%) is linked in the interviews to lapsed training, grounded ambulances and unreplaced supplies, which reappear as human resource and equipment deficits. Fourth, there is no corrective loop: without corridor-wide command, shared dispatch or monitoring, failure at one interface is neither detected nor corrected elsewhere.

This mechanism maps onto the conceptual framework. Emergency Management Theory identifies the failures of mitigation that raise the crash load and

the missing preparedness inputs, such as emergency lanes, staging areas, maintained fleets, trained responders and protocols. High-Reliability Theory identifies the missing reliability mechanisms: unified command, standardisation, simulation training and monitoring. Systems Theory explains why improving one component alone is unlikely to change outcomes: performance is bounded by the weakest interacting component, so additional ambulances achieve little if they cannot pass traffic, lack equipment, or deliver patients to facilities without blood, and gains in response can be absorbed by a growing upstream flow of crashes. Where the strands diverge, as with the divided views on EMT training and the informal cooperation that coexists with poorly rated coordination, they point to the same conclusion: the corridor has capable parts but no structure that makes their performance consistent.

CONCLUSION AND RECOMMENDATIONS

Conclusion: This study established that prehospital emergency preparedness along the Nairobi–Mombasa Highway is constrained in all seven domains examined and that the constraints are linked. Road traffic culture and the engineering environment generate a high and concentrated crash load; delays then accumulate from detection to transfer; financing and governance gaps feed the workforce and equipment deficits; and the absence of unified command, shared dispatch and monitoring means that failures are not corrected. The study contributes in three ways. Empirically, it provides evidence across the whole prehospital chain on Kenya's principal transport corridor and treats road traffic culture as a barrier to preparedness rather than as background. Methodologically, it separates related barriers that are often merged, such as congestion and emergency-lane priority, or staffing, training and error, and integrates survey, interview, observational and documentary evidence. Theoretically, it assigns distinct roles to Emergency Management, High-Reliability and Systems theories, showing respectively which preparedness inputs are missing, which reliability mechanisms are absent and why single-component investments are unlikely to succeed. For stakeholders, the main implication is that investment should follow the chain rather than the component. The contribution of road traffic culture to the crash load, response intervals and patient outcomes, and the effect of interventions such as unified command

and certified responder training, have yet to be measured directly.

Recommendations: The findings point to six priorities. First, the Ministry of Health and the corridor county governments should establish a corridor-level unified incident command protocol defining the roles of ambulance services, police, fire and rescue, KeNHA and receiving facilities, tested through regular multi-agency drills. Second, county and national authorities should develop interoperable dispatch, with a functioning toll-free number, shared radio or digital channels and routine pre-notification of receiving facilities, and enforcement agencies should be briefed on EMS operating protocols. Third, training bodies, working with KCEMT, should standardise and certify EMT training, fund refresher and simulation cycles, and extend basic life support and trauma training to traffic police and community first responders. Fourth, EMS financing should move from procurement to asset lifecycle management, with ring-fenced budgets for maintenance, fuel, consumables and replacement, minimum equipment standards checked by routine inspection, and support for corridor facilities to hold blood and maintain surge space. Fifth, the Kenya Emergency Medical Care Policy 2020–2030 should be implemented through corridor-specific standards and monitoring of response intervals, equipment readiness and patient outcomes. Sixth, prehospital preparedness should be coupled with the preventive pillars of the Safe System: NTSA, KeNHA, the National Police Service and the ministry responsible for transport should restore the integrity of traffic enforcement through transparent, technology-based enforcement and cashless fines, confirm through independent road-safety audits that lighting, markings, signage and crossings are delivered and maintained, and prioritise the corridor's black spots for emergency lanes, staging areas and retrofitting.

Limitations and Future Research: Several limitations should be noted. Because of the purposive and convenience sampling and the predominance of community first responders (65.4%), the aggregate percentages describe stakeholder perceptions weighted towards community responders and cannot be generalised statistically. The findings rely on self-reported perceptions rather than recorded response intervals or outcomes, since no corridor-wide trauma

registry exists, and self-reports are open to social-desirability bias, which could lead institutional respondents to understate weaknesses, and to recall bias, because severe or recent crashes are remembered more readily; triangulation with interviews, inspections and observation reduced but did not remove these risks. Victims and bystanders recruited by convenience may differ from those who declined or could not be reached, and the direction of any non-response bias cannot be determined. Integration was limited by design: the qualitative participants were a small purposive subset of the survey sample, quotations come mainly from Makueni

County, and individual responses could not be linked across strands. Road traffic culture was assessed through indicators, observation and documents rather than measured directly, and the documentary evidence on enforcement comes from other Kenyan routes. Finally, the study was cross-sectional and descriptive and was limited to facilities within 10 km of the highway. Future studies should link crash-causation, enforcement, response-time and survival data through a shared trauma registry, compare stakeholder groups and corridor segments using inferential methods, and evaluate

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