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RESEARCH ARTICLE

Uberization of New Age EV Ambulance Fleet: Opportunities and Challenges in India

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ABSTRACT

One of the most important compartments of the healthcare ecosystem is Ambulance services, which enables the effective transportation of the healthcare seeker to the healthcare provider. India, as a developing country has a lot of opportunities and challenges to improve, wherein, architecting a proper infrastructure uberizing Ambulance service. This paper draws a picture into the current state of ambulance service available in India, especially considering the tier 1 cities. A mathematical model has been designed to measure the impact of introducing a fully electric fleet of electric ambulances with modern facilities, integrating the environmental impact. This can be used to analyze and understand the feasibility of implementing a uberized system in a particular city. A basic user interface (UI) has been designed for a mobile-based application, which can essentially mediate the process of providing an ecosystem between the hospital, ambulances and the end user. Thus, an overall understanding of the challenges and opportunities of uberizing an electric ambulance fleet is discussed.

Keywords: Ambulance services, Uberizing ambulance service, Electric ambulances, Environmental impact, Healthcare Ecosystem, User interface.

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INTRODUCTION

With the introduction of the "Uberization" paradigm, which prioritizes quick, easily accessible, and user-centered service delivery, the rapid growth of transport and on-demand services has revolutionized a number of industries[1]. In a country like India, with its vast and diverse population, the need for a robust, efficient, and accessible ambulance service is even more pronounced, especially in metropolitan areas where traffic congestion and logistical challenges are significant barriers to timely emergency care. India has been an app-driven market compared to China for example, where single super apps are more popular. Although the reason for the same is not clear, the adoption of multiple apps that cater to a specific service works better compared to an all-in-one app.

The healthcare sector is no exception to this paradigm shift, where innovative approaches are being explored to address critical issues such as timely access to medical facilities. One of the most crucial components of emergency healthcare services is the ambulance system, which facilitates prompt medical response and transportation of patients to healthcare providers. Considering electric vehicles (EVs), India is witnessing a rapid surge in adoption as government initiatives like the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) scheme are playing a crucial role in boosting EV sales[1]. Lower operating costs, reduced pollution, and growing consumer awareness are driving this trend.

The emergence of electric vehicles (EVs) presents new opportunities to modernize ambulance fleets, aiming to reduce the environmental impact and operating costs associated with conventional ambulances. However, the implementation of an electric ambulance fleet presents unique challenges in infrastructure, policy, and technological adaptation, particularly in developing nations where EV infrastructure is still evolving. While challenges such as limited charging infrastructure and higher initial costs persist, government incentives, falling battery prices, and growing environmental

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concerns are driving EV adoption[3]. As technology advances and policies become more supportive, EVs are poised to play a crucial role in shaping the future of sustainable mobility in developing nations.

This paper investigates the concept of “Uberization” in association with a dedicated fleet of fully electric ambulances in India. It offers insights into how such a system can change emergency medical response in metropolitan areas by analyzing potential opportunities and challenges. In order to create an integrated healthcare ecosystem, the paper also explores the viability of a mobile application that mediates interactions between hospitals, ambulances, and end users. This provides a deep insight to evaluate the viability, environmental effect, and scalability of an EV-based on-demand ambulance service that has been tailored to the healthcare infrastructure of India. A mathematical model has also been introduced to better understand the feasibility of launching such a niche service, especially in tier 1 cities across India, which can suggest the feasibility of implementing such a system in a particular city, by substituting the values, such as the average number of cases, population, hospital network available within the city limits and the size of ambulance fleet currently available.

Challenges in Ambulance Services

Understanding the challenges associated with the ambulance services and the ecosystem of hospitals, patients and ambulances is of utmost priority for the betterment of healthcare service as a whole, especially in a market so diverse as India. One of the most crucial components of emergency healthcare services is the ambulance system, which facilitates prompt medical response and transportation of patients to healthcare providers. In a country like India, with its vast and diverse population, the need for a robust, efficient, and accessible ambulance service is even more pronounced, especially in metropolitan areas where traffic congestion and logistical challenges are significant barriers to timely emergency care.

The provision of efficient and accessible ambulance services, a critical component of the healthcare ecosystem, faces several hurdles, especially considering the tier 1 cities of India. These challenges encompass availability, communication, parking time, patient-hospital-ambulance ecosystem, reliability, and city traffic.

The provision of efficient and accessible ambulance services, a critical component of the healthcare ecosystem, faces several hurdles in India’s tier 1 cities. These challenges encompass availability, communication, parking time, patient-hospital-ambulance ecosystem, reliability, and city traffic.

Availability remains a significant concern, as patients often struggle to access an ambulance when needed, with the nearest or most convenient option not always readily available[4]. The communication between the customer or patient and the ambulance service provider, as well as between the hospital and the ambulance service provider, can be fragmented, leading to delays and suboptimal coordination. Moreover, the time during which an ambulance is parked can be considered a loss of a valuable resource, underscoring the need for more efficient utilization[5].

The patient-hospital-ambulance ecosystem presents additional complexities, as patients may have a regular doctor in one hospital, but the ambulance they require may be tied to another hospital, creating logistical challenges. Reliability is also a concern, with issues ranging from the availability of proper facilities within the ambulance to the network of connected hospitals. Finally, the impact of city traffic cannot be overlooked, as congestion and delays can significantly hinder the timely response and transport of patients, ultimately affecting patient outcomes[6,7].

Opportunities in Ambulance Services

The emergence of electric vehicles (EVs) presents new opportunities to modernize ambulance fleets, aiming to reduce the environmental impact and operating costs associated with conventional ambulances. Integrating EV technology into the ambulance ecosystem not only supports sustainable practices but also aligns with India’s broader environmental goals. However, the implementation of an electric ambulance fleet presents unique challenges in infrastructure, policy, and technological adaptation, particularly in developing nations where EV infrastructure is still evolving.

Advantages of EVs over conventional vehicles

Electric vehicles (EVs) offer several advantages over conventional vehicles, including lower operating costs, reduced emissions, and improved energy efficiency[8]. Lower fuel costs and minimal maintenance requirements contribute to significant savings over the long term. EVs produce zero tailpipe emissions, helping to improve air quality and reduce greenhouse gas emissions. Additionally, the regenerative braking system in EVs recovers energy during braking, further enhancing energy efficiency. However, challenges such as limited range, charging infrastructure, and higher initial costs need to be addressed to fully realize the potential of EVs[9].

Some of the main advantages of EVs over conventional vehicles are:

- *Lower Running Costs*

EVs have significantly lower operating costs than fuel-based cars. Electricity is generally cheaper than petrol or diesel, and EVs require less maintenance due to fewer moving parts.

- *Zero Tailpipe Emissions*

EVs produce zero tailpipe emissions, contributing to cleaner air and reduced air pollution in cities.

- *Regenerative Braking*

EVs use regenerative braking to recover energy during deceleration and braking, extending their range and reducing wear on brake pads.

- *Instant Torque*

EVs provide instant torque, making them more responsive and efficient in stop-and-go city traffic.

- *Quieter Operation*

EVs are significantly quieter than fuel-based vehicles, reducing noise pollution in urban areas.

- *Government Incentives*

Many governments offer incentives and subsidies for purchasing EVs, making them more affordable.

Exploring Opportunities in EV Ambulances

The Indian healthcare landscape is not yet exposed to the existence of E-ambulances for a variety of reasons namely the developing charging infrastructure, lack of guidelines and specifications for the manufacture of safe-to-use ambulances, and lack of willingness of current aggregators to transform the fleet. A quick look into local vendor markets like India Mart will provide numerous non-standard, unregulated and non-compliant safety norms for electric mobile ambulances. There are multiple benefits of having an electric ambulance infrastructure in India:

- *Reduction in Carbon Footprint and Environment-Friendly*

Electric ambulances will have a positive effect on the flora around fauna as it does not contribute to toxic emissions. This aligns with India's goal to cut down carbon emissions by 45% in the next 6 years and to achieve Carbon Net Neutrality by 2070[10].

- *Patient Care*

Since Electric ambulances have the absence of noisy engines, they run significantly quieter compared to their conventional counterpart making them more comfortable and convenient for the patients.

- *Government Assistance*

Under the PM- E Drive initiative, the government plans to infuse 10,500 - 14,000 crores to cut dependency on ICE vehicles. A good portion of this also goes for the production of Electric Ambulances in India[11].

- *Lesser Turnaround Time*

Electric Ambulances can take advantage of the growing electric charging station infrastructure to charge themselves while not on duty. In the case of an ICE Ambulance, it has to make multiple trips apart from the emergency duty call for fuelling at petrol stations, while the EV Ambulances can be charged right at the hospital, they are currently residing in.

EV Ambulance models from around the globe

The British Healthcare Service (NHS) has already improvised and added electric ambulances to their existing fleet initialising the switch from traditional ambulances to Electric alternatives. NHS has recently taken a significant step towards sustainability and environmental responsibility by introducing a fleet of 21 zero-emission electric ambulances[12]. For paramedics and volunteers, the government had made investments in vehicles that were highly technologically advanced, lightweight, and easy to operate. The adoption of Green ambulances will enable the British Government to achieve its aim of having net zero-emission vehicles in the British Healthcare Service (NHS) by 2040.

Electric ambulances are emerging as part of global zero-emission initiatives, with countries like Japan leading the way. Nissan's NV400 electric ambulance is a key example, designed as part of Tokyo's "Zero Emission Tokyo" initiative, which aims to reduce the city's carbon footprint and promote clean energy solutions, depicted in Fig.1[13]. This model, developed in collaboration with the Tokyo Fire Department, showcases how electric ambulances can be both environmentally friendly and effective for emergency services. The NV400 is equipped with a 55kW electric motor and a 33kWh main battery, supplemented by an additional 8 kWh battery for prolonged use of medical equipment and climate control, making it both practical and energy-efficient. This ambulance can even function as a mobile power source during natural disasters, adding to its versatility in emergency scenarios. While primarily used in Japan, similar electric ambulances are also entering service in the U.S., indicating a growing international adoption of EV ambulances for sustainable healthcare solutions (Table 1).

In the United States, several manufacturers are increasing their production of electric ambulances to meet the growing demand[14]. Companies such as Demers Ambulances and Lightning E-Motors are entering the market to address this need, as the shift towards electric vehicles (EVs) gains momentum in the public safety sector. According to industry trends, EVs are seen as a promising solution to improve operational efficiency and reduce emissions in emergency response services.

Comparison of existing ambulance infrastructure

India's ambulance infrastructure is predominantly based on traditional Internal Combustion Engine (ICE) vehicles, which incur higher fuel and maintenance costs, and contribute to environmental pollution. In contrast, countries like the United States are increasingly adopting electric ambulances (EVs) for their operational and environmental benefits, such as reduced emissions and lower operating costs[15]. Companies like Demers Ambulances and Lightning E-Motors are leading this transition in the U.S. However, India faces significant challenges in adopting EVs, including insufficient charging infrastructure, high upfront costs, and limited awareness of electric ambulance technology. Upgrading the existing fleet will require substantial investment and policy support to overcome these barriers[16].

Figure 1: Electric Ambulance Fleet: Nissan NV400

The following are some of the prominent ambulance services in India: GVK EMRI's 108 ambulances[17], Apollo Ambulances[18], and Manipal Ambulances. Additionally, many local ambulance services operate, often managed by private and public hospitals. India currently lacks a unified, regulated Emergency Medical Services (EMS) system[19], relying instead on a fragmented network of providers that are often aligned with specific hospitals, leading to potential biases in service delivery.

The introduction of a dedicated fleet of electric ambulances could play a crucial role in accelerating the development of a robust Emergency Medical Services (EMS) system in India, one that serves patients without the limitations of the current fragmented system. Currently, ambulance operations in India are spread across multiple hospital chains, making it difficult to enforce consistent standards and technical specifications for safe patient care during transport. As a result, there is significant variability in ambulance models and equipment. For instance, operators in India use a range of vehicles, including Force Vans, Maruti Suzuki Omnis[20], and modified versions of tempo travellers, with differing operational standards across providers such as red, medulance[21], and GoAid. The introduction of a fully electric ambulance fleet would not only help establish a unified, regulated EMS system but also eliminate the unregulated elements of the current ambulance market, ensuring higher standards of patient safety during transport.

The Indian government, as a key stakeholder, has acknowledged the need for electric ambulances and has taken proactive steps by establishing funding mechanisms and committees to explore the technical aspects of developing safe electric ambulances for patient transport. These initiatives focus on critical factors such as vehicle weight, the centre of gravity calculations for stable and responsive steering, power requirements, and the load-bearing capacity necessary to accommodate essential equipment like patient monitoring systems, medical beds, and other medical devices. Such considerations are vital to ensure that electric ambulances can meet the demands of safe and efficient patient care. The shift towards a unified fleet of electric ambulances could contribute significantly to the creation of a dedicated and effective Emergency Medical Services (EMS) system, enhancing public safety and strengthening India's medical infrastructure.

Challenges of Ambulance Ecosystem in India

The ambulance ecosystem in India is plagued by several challenges that hinder the efficient and effective delivery of emergency medical services (EMS)[23]. One of the most significant issues is the fragmented nature of ambulance operations, with services being run by a mix of private hospitals, public institutions, non-governmental organizations (NGOs), and independent operators. This decentralization results in a lack of coordination, leading to inconsistent service quality, varying response times, and difficulties in adhering to standardized patient care protocols. Additionally, the infrastructure supporting ambulance services is inadequate, with limited access to emergency lanes, poor road conditions, and insufficient charging infrastructure for electric ambulances[24].

The absence of a cohesive regulatory framework further exacerbates these problems, as there are no uniform standards for vehicle specifications, medical equipment, or the training of ambulance staff. These challenges are compounded by financial constraints, a lack of technological integration, and limited investment in modernizing the system. As a result, India's ambulance ecosystem struggles to provide timely, safe, and efficient care, especially in emergencies where every minute counts[25]. Some of the identified challenges are listed below.

Availability of Ambulance Service

The availability of ambulance services in India remains a critical issue, particularly in emergency situations such as accidents, cardiac arrests, or during labor[26]. While large cities like Delhi, Mumbai, and Bengaluru have access to ambulance services through public and private providers, rural areas and smaller towns often face significant gaps in coverage. In urban areas, the challenge lies not in the existence of ambulance services, but in the accessibility and timely response during emergencies. The fragmented nature of the ambulance network, with multiple private and public operators, makes it difficult for patients or their families to quickly identify and reach the nearest available ambulance. Additionally, response times can be delayed due to factors such as traffic congestion, poor road infrastructure, and the unavailability of vehicles during peak demand periods.

A streamlined, on-demand ambulance service model could address these challenges by leveraging technology such as mobile apps and GPS-based tracking to connect patients with the nearest available ambulance in real time[27]. This would reduce delays caused by traffic or the unavailability of vehicles, ensuring a quicker response and more efficient use of resources. By consolidating different ambulance providers on a single platform, it would also be possible to match the right type of ambulance to the specific needs of the emergency, whether basic transport or advanced life support. Such a model would significantly enhance the availability and accessibility of ambulance services in urban areas, ensuring that timely medical intervention is always within reach when needed.

Streamlined Communication Between Stakeholders

One of the key challenges in India's ambulance ecosystem is the lack of streamlined communication between various stakeholders, including ambulance services, healthcare providers, and individuals in need of emergency medical care. Often, patients or their families face difficulties in directly reaching out to ambulance providers, leading to delays in dispatching emergency vehicles. Additionally, once an ambulance is on the way, communication between the ambulance and hospitals becomes critical, yet it remains a significant challenge. In emergencies, ambulance teams need to communicate with hospitals to check for bed availability, ensure that specialized medical staff (e.g., cardiologists or surgeons) are available, and confirm that the necessary medical equipment is ready for the patient's treatment upon arrival[28]. Without effective communication, patients can face delays in treatment or end up at hospitals ill-equipped to handle their specific medical needs, compromising their chances of a successful recovery[29].

To address these gaps, a more integrated communication system is required, one that links ambulance services, healthcare facilities, and emergency dispatch centers in real time. Implementing technology-driven solutions such as centralized communication platforms, mobile apps, and electronic health records (EHRs) could enable ambulance staff to instantly update hospitals about the patient's condition, allowing healthcare providers to prepare in advance[30]. Such a system would not only streamline communication but also improve coordination between all stakeholders, ensuring that patients receive timely and appropriate care at the right facility. This kind of integrated communication framework could significantly enhance the efficiency and effectiveness of ambulance services, particularly in urban areas where the demand for emergency care is high.

Idle Time and Resource Utilization of Ambulances

In the current ambulance ecosystem, idle time is when ambulances are not in use due to a lack of demand. This is a significant issue that leads to inefficiencies in resource utilization. Similar to how an airplane grounded due to a lack of flights results in lost revenue for airlines[31], ambulances that are not deployed during off-peak hours represent an underutilization of expensive assets. This inefficiency not only leads to financial losses but also means that valuable healthcare resources are unavailable when they are most needed. In large urban areas, where ambulance demand can fluctuate throughout the day, the inability to optimize ambulance availability and deployment can cause delays, resource wastage, and an overall reduction in the efficiency of emergency services.

The introduction of electric vehicles (EVs) in the ambulance fleet presents an opportunity to address this issue. Unlike traditional Internal Combustion Engine (ICE) ambulances, which are limited by fuel and maintenance schedules, electric ambulances can utilize idle time for charging, effectively reducing downtime[32]. By integrating electric ambulances with smart charging infrastructure, these vehicles can be automatically routed to charging stations during non-peak hours, ensuring that they are fully charged and ready for use when an emergency arises. Additionally, the uberization of ambulance services using on-demand, app-based platforms to dispatch ambulances dynamically could further optimize resource utilization[33]. Just as ride-hailing services like Uber match supply with real-time demand, on-demand ambulance services can ensure that ambulances are available precisely when and where they are needed, reducing idle time and ensuring better coverage and faster response times. This approach could lead to a more efficient, cost-effective, and responsive ambulance ecosystem, where resources are deployed in real-time based on demand and availability.

The Patient-Hospital-Ambulance Ecosystem

The patient-hospital-ambulance ecosystem in India is often shaped by institutional affiliations and hospital partnerships, rather than patient needs or geographical proximity. In emergency situations, patients may be affiliated with specific doctors or hospitals for their ongoing care, but ambulance services, due to their associations with particular healthcare providers, often take patients to hospitals within their network, regardless of the patient's location or the hospital's ability to provide the necessary care[34]. This system can create delays in treatment, as ambulances may bypass closer, more equipped hospitals in favour of those with which they have formal or contractual tie-ups. For example, in cases where a patient is experiencing a cardiac arrest or other critical emergencies, an ambulance tied to a specific hospital may choose to transport the patient to that hospital, even if a nearby facility is better equipped to handle the emergency, leading to potential risks for the health of the patient.

This system not only compromises timely medical intervention but also highlights a significant flaw in India's current ambulance and EMS framework, where the priority is often the hospital's network affiliations rather than the patient's immediate medical needs[35]. To improve the quality of care, there is a need for a more patient-centric model that ensures the nearest available hospital with the required facilities is prioritized, irrespective of the ambulance's associations. A unified, on-demand ambulance service that uses real-time data about hospital capabilities and patient requirements can reduce delays, eliminate biases in hospital selection, and ensure that patients receive the best possible care without unnecessary detours.

Reliability of Ambulance Services

The reliability of ambulance services is paramount in ensuring timely and effective emergency care[36]. However, current systems often face significant challenges, including unforeseen delays caused by traffic jams, roadblocks, and inefficient route planning. Ambulances frequently have limited information about real-time traffic conditions, which can result in critical delays, especially in densely populated urban areas. Such delays can compromise the patient's condition during transit and reduce the overall efficiency of emergency healthcare systems.

Another critical factor affecting reliability is the preparedness of the ambulance itself. Many ambulances may not have the necessary medical tools and equipment required for providing essential pre-hospital care. For instance, an ambulance must be equipped with basic life support (BLS) or advanced life support (ALS) tools[37], such as defibrillators, oxygen cylinders, suction pumps, and first aid kits. A detailed list has been provided in Table 1. The absence of these essential devices not only limits the care provided to patients but also puts additional strain on medical professionals upon arrival at the hospital. A well-maintained and adequately equipped ambulance is crucial for bridging the gap between patient stabilization and advanced medical intervention.

To address these issues, the implementation of a monitoring app integrated with the Uberization model of ambulance

Table 1: Equipment for ALS Ambulances

S. No.	*Equipment*	*Description*
1	Ambulance Cot	A Mobile bed used in an ambulance to provide a comfortable surface for patients.
2	Scoop Stretcher	A long-handled tool with a curved end used to lift and transfer patients.
3	Foldaway Stretcher	A simple, portable stretcher that can be folded for easy storage and transport.
4	Spine Board	A flat, rigid board used to support and protect the spine during transport or examination.
5	Transfer Sheet	A sheet of paper used to slide patients onto stretchers, beds, or other surfaces.
6	Wheel Chair	A device with wheels that allows individuals to move around and be transported.
7	Bi-Phasic Defib cum Cardiac Monitor	A device that monitors a patient's heart rhythm and provides defibrillation if necessary.
8	Transport Ventilator	A device that assists patients requiring breathing support during transport.
9	Suction Pump (Medical)	A device used to remove secretions from a patient's throat or lungs.
10	Suction Pump (Electronic)	An electronic version of the suction pump, possibly with additional features.
11	Manual Breathing Unit	A device that assists patients requiring breathing support, typically used in non-electronic settings.
12	Mouth to Mouth Ventilation Device	A device that assists patients requiring breathing support through mouth-to-mouth resuscitation.
13	Portable Oxygen Cylinder	A compact device that stores oxygen for use in emergency situations.
14	Nebulizer	A device used to deliver medication in the form of a fine mist directly into the lungs.
15	Laryngoscope with Blades	A device used to visualize and access the vocal cords for intubation purposes.
16	Infusion Pumps	Devices that regulate and administer medication through an intravenous line.
17	Handheld Glucometer	A device used to measure blood glucose levels at the point of care.
18	Stethoscope	A device used to listen to a patient's heartbeat and breath sounds internally.
19	BP Apparatus	A device used to measure blood pressure through the cuff and stethoscope.
20	Pupillary Torch	A device that shines light into a patient's pupils to assess their size and reactivity.
21	Needle & Syringe Destroyer	A device used for disposing needles and syringes safely.
22	Thermometer	A device that measures a patient's body temperature internally or orally.
23	Pneumatic & Roller Splint Sets	Devices used for immobilizing and supporting injured limbs.
24	Cervical Collars	Collars used to stabilize the neck during transport or examination of injured patients.
25	Scissors with Round Tip	A tool used for cutting surgical sutures or other materials.
26	Set of Forceps	Instruments used to grasp and manipulate tissues, organs, or other materials.
27	Kidney Tray	A tray used to hold and support small medical devices, such as stethoscopes.
28	Klik Clamp	A device used for closing temporary wounds or incisions during surgery.
29	Tongue Depressor	A tool used to gently insert an object into the mouth and elevate the tongue.
30	First Aid Kit Bag	A container holding various supplies for basic first aid care.
31	Rescue Equipment	A collection of devices and tools used to assist in emergency responses, such as pulley systems or ropes.

services offers a transformative solution. This app would provide a comprehensive checklist for ambulance preparedness, ensuring that all essential medical equipment is available and functioning before dispatch[38]. The checklist would be updated in real time and monitored by centralized healthcare authorities or fleet managers, enabling quick rectification of any deficiencies. By ensuring ambulances are both well-equipped and capable of navigating traffic efficiently, the proposed system would elevate the overall quality of emergency medical services in India, further reinforcing the impact of Uberization in the healthcare domain. By implementing a checklist for such equipment and integrating navigation intelligence, the vision of reliable, high-impact ambulance services in India becomes more achievable.

Regenerative Breaking System: A Boon for City Traffic

The regenerative braking system (RBS) is emerging as a game-changing technology, particularly in the context of electric vehicles (EVs), including electric ambulance fleets[39]. In dense urban environments with frequent stop-and-go traffic, the regenerative braking system offers significant advantages by converting the kinetic energy typically lost during braking into electrical energy, which is then stored in the battery for future use. This energy recovery mechanism reduces wear on conventional braking systems and extends the overall lifespan of vehicle components. For EVs, particularly ambulances navigating city traffic, this process not only enhances energy efficiency but also maximizes the use of limited battery power, which is crucial in maintaining operational range.

In cities, where traffic congestion and frequent braking are common, regenerative braking allows electric ambulances to recover energy while slowing down or stopping at signals and intersections. This energy recovery is especially beneficial for EVs, as it reduces the need for frequent recharging and contributes to better fleet utilization[40]. Ambulances are often on high-alert schedules with emergency responses, and the ability to extend their range without frequent recharging can make a significant difference in response time and reliability.

For ambulance fleets operating in urban areas, where time is critical, the benefits of regenerative braking go beyond just energy savings. By recovering energy during braking events, EV ambulances can maintain a higher level of charge throughout their routes, increasing their efficiency and ensuring that they are always ready for emergency dispatch. This technological advancement could significantly contribute to reducing operational costs, increasing ambulance availability, and enhancing the overall performance of EMS in congested city traffic[41]. Thus, regenerative braking systems present a dual advantage: they improve the sustainability of electric vehicle fleets while also contributing to smoother, more responsive EMS operations in urban environments.

Conceptualizing the Uberization of Ambulance Services

The rise of technology-driven service platforms, epitomized by Uber, has revolutionized industries by emphasizing accessibility, efficiency, and customer-centric solutions[2]. Inspired by these principles, the conceptualization of a streamlined, app-based electric vehicle (EV) ambulance fleet aims to address critical healthcare challenges in India. The proposed app, designed for booking ambulance services, integrates features that ensure rapid response, service customization, and effective communication between users and healthcare providers.

AmbuEV is a conceptual mobile-based application, which can essentially act towards the uberization of ambulance services The homepage provides a simple User Interface (UI), where the patient or user can book an ambulance with ease, as shown in Fig.2. Considering an emergency situation, an SOS button is integrated into all the pages of the application, wherein it will automatically book an ambulance for the user. Some of the core UI features of the application are:

Service Customization

The app offers a wide range of specialized ambulance services catering to diverse needs such as Mother Care, Mobile Mortuary, and Organ Transport. By tailoring options to specific requirements, it provides users with relevant, targeted solutions.

Hospital Network Integration

A key feature is the seamless integration with major hospitals across cities. For example, the major hospitals as per the user's location are listed within the app, allowing users to select the most convenient facility for their needs. This ensures a robust connection between patients and healthcare providers.

User-Friendly Input Forms

Essential fields for personal and emergency details such as Name, Home Address, Emergency Contact, and Blood Group are incorporated, enabling faster and more efficient service. These details ensure the dispatched ambulance is adequately prepared for the situation.

Prioritization of Emergency Care

The app prioritizes time-critical cases by enabling direct and swift booking of ambulances. Users can simply "Book Now" with a single click, reducing delays in emergency response.

Scalable and Sustainable EV Fleet

Powered by electric vehicles, the ambulance fleet supports India's sustainability goals while ensuring quieter, more efficient operations. The EV platform aligns with eco-friendly urban development initiatives, addressing both healthcare and environmental concerns.

By leveraging this platform, the potential to reimagine ambulance services in India becomes apparent. Future iterations could incorporate AI-based demand prediction, dynamic pricing models, and partnerships with healthcare startups to enhance operational efficiency and expand accessibility. With its focus on user-centric design and sustainability, the app aims to set a benchmark for next-generation healthcare services in India.

Feasibility of Electric Ambulance fleet in tier 1 cities: A Mathematical Model

A mathematical model can be utilized to analyze and understand the feasibility of deploying an electric ambulance

Figure 2: AmbuEV: A conceptual application for ambulance services

fleet. This is very effective in understanding whether the deployment of an EV-based fleet of ambulances in a particular city will be beneficial in terms of overall carbon emissions, and whether or not it is financially viable. By giving relevant data of a particular tier 1 city, the mathematical model will be able to give an overall out on the feasibility of the EV ambulance fleet. The main compartments under consideration for the model are:

- Demand (D):
- D = Population × Incidence Rate of Emergencies
- Number of Hospitals (H)
- Distance (d):
  D = Average Distance × Demand Coverage Factor
- Expense per Case (C): $C = C_{\text{fixed}} + C_{\text{variable}} \times d$
- Environmental Impact (E):
  E = Reduction in Emissions per km × d × D
- Charging Infrastructure (I_{charging}):

$$I_{\text{charging}} = \frac{\text{Fleet Size} \times \text{Daily Usage}}{\text{Average Charge Capacity per Station}}$$

- Fleet Size (F): $F = \frac{D \times \text{Average Response Time}}{\text{Service Duration per Case}}$
- Response Time (T): $T = \frac{d}{\text{Average Speed of Ambulance}}$

With the above compartments, the feasibility of the system can be accessed using:

$$S_{feasibility} = \alpha \times \frac{1}{T} + \beta \times F + \gamma \times I_{charging} - \delta \times C + \eta \times E$$

$\alpha, \beta, \gamma, \delta, \eta$ are weighting factors that reflect the importance of each compartment in the feasibility study for the deployment of electric ambulances. The weight ranges are given in Table 2.

- α

Response time is highly critical in emergency medical services, as delays can significantly impact patient outcomes. In urban environments, minimising response time is often the primary objective. Therefore, this factor should be given a high weight.

- β

The fleet size directly impacts the ability to meet demand and affects operational costs. It is essential but less critical than response time, as sufficient fleet size can mitigate potential delays.

Table 2: Weighting factors and weight ranges

Factor	*Symbol*	*Weight range*
Response time	α	0.30 – 0.40
Fleet size	β	0.20 – 0.25
Charging infrastructure	γ	0.15 – 0.20
Expense per case	δ	0.10 – 0.15
Environmental impact	η	0.10 – 0.15

- γ

Charging infrastructure is important to ensure fleet availability. Insufficient charging capacity could lead to fleet downtime, impacting response capability. However, this factor is somewhat secondary to response time and fleet size.

- δ

Charging infrastructure is important to ensure fleet availability. Insufficient charging capacity could lead to fleet downtime, impacting response capability. However, this factor is somewhat secondary to response time and fleet size.

- η

While environmental impact is a significant advantage of electric ambulances, it is not as immediately critical to operational feasibility as response time or fleet size. However, it contributes positively to overall societal benefit and could be a factor in securing government support.

The feasibility of deploying an electric ambulance fleet in tier-1 cities can be assessed using a mathematical model based on key metrics such as response time (minutes), fleet size (number of ambulances), operational cost per case ($), environmental impact (CO_2 reduction per km), and charging infrastructure efficiency (fleet utilization %). This model, which does not rely on primary data collection, allows users to input city-specific values to evaluate viability. Key parameters include demand (D) from population and emergency incidence rates, distance (d) for coverage estimation, expense per case (C), environmental impact (E), and charging infrastructure (I_{charging}). The feasibility score ($S_{\text{feasibility}}$) is determined by weighted factors, prioritizing response time (α), fleet size (β), charging infrastructure (γ), cost per case (δ), and environmental impact (η). Potential biases arise from data source reliability, selection criteria, and model assumptions, emphasizing the need for accurate, up-to-date data from credible institutions. This model serves as a decision-making tool for assessing the practicality and benefits of electric ambulance integration into urban healthcare systems.

Note on Data Collection

This study does not involve primary data collection. Instead, it presents a mathematical model designed to evaluate the feasibility of deploying an electric ambulance fleet in a given city. The model allows users to input real-world data, such as population size, emergency incidence rates, hospital network density, and existing ambulance fleet size, to assess the viability of implementing such a system. By applying city-specific parameters, stakeholders can estimate response times, fleet requirements, operational costs, and environmental impact, thereby facilitating data-driven decision-making for urban ambulance planning.

Risk of Bias

Although this study does not involve primary data collection, potential biases may arise from the selection and quality of input data used in the mathematical model. The feasibility outcomes depend heavily on data accuracy, representativeness, and source reliability, which can introduce biases in multiple ways:

- *Data Source Bias*

The model's results will vary based on the quality and credibility of the data sources. If data is obtained from outdated or non-representative studies, it may lead to overestimation or underestimation of the feasibility of electric ambulance fleets.

- *Selection Bias*

The choice of datasets for variables such as emergency incidence rates, hospital network coverage, and existing fleet availability can impact the model's conclusions. If only data from well-equipped metropolitan cities is considered, the model may not accurately reflect the challenges faced in smaller urban centres or developing regions.

- *Assumption Bias*

The mathematical model relies on assumptions regarding factors like traffic conditions, charging infrastructure, and response times. Any incorrect assumptions can lead to misleading conclusions about operational feasibility.

- *Comparative Bias*

The model references existing studies on ambulance services and EV implementation. If these studies have inherent biases (e.g., favouring certain geographic regions or policy environments), the generalizability of the results may be affected.

To minimize these risks, it is recommended that users source input data from verified government reports, healthcare databases, and industry publications. Additionally, the model's effectiveness can be validated through real-world pilot projects and retrospective analyses to assess its practical applicability across different urban environments.

Methodological Approach and Scope

This study does not involve primary data collection but instead focuses on developing a mathematical model to assess the feasibility of implementing an electric ambulance fleet in tier-1 cities. The model is designed to be adaptable, allowing stakeholders to input real-world data such as population size, emergency incidence rates, hospital network density, and existing ambulance fleet size. By applying city-specific parameters, the model provides insights into key factors like response time, fleet requirements, operational costs, and environmental impact.

To enhance transparency and applicability, the methodology section outlines the selection criteria for data sources, ensuring that the model remains flexible and can be tailored to different urban environments. The study also discusses the rationale behind the mathematical formulas used, providing a structured framework for evaluating the potential success of an electric ambulance fleet across various metropolitan regions.

Integration of Artificial Intelligence in Ambulance Services

The integration of Artificial Intelligence (AI) in ambulance services offers transformative potential to enhance efficiency, responsiveness, and reliability, particularly in the context of electric ambulances (EV ambulances)[43]. Drawing insights from research, AI enables optimized scheduling and routing, addresses resource allocation challenges, and provides predictive analytics to improve patient outcomes. By incorporating AI-driven algorithms, ambulance services can adapt to dynamic demands while overcoming traditional limitations in emergency response systems.

One of the key benefits of AI in EV ambulances is its ability to manage charging schedules and optimize fleet utilization. AI algorithms can dynamically allocate ambulances to patient requests, ensuring the nearest and most suitable vehicle is dispatched promptly[44]. Unlike conventional electric vehicles, EV ambulances require immediate readiness, making pre-emptive scheduling vital. Greedy algorithms and heuristic search methods, as discussed in existing literature, can calculate fast and efficient solutions for ambulance assignments in real-time scenarios. Furthermore, machine learning models enhance these algorithms by predicting future demand patterns based on historical data, healthcare trends, and unexpected events like pandemics or natural disasters.

AI-driven dispatch algorithms enable the selection of ambulances based on patient needs, ensuring that vehicles equipped with specialized medical equipment are prioritized for critical cases[45]. For example, if a patient exhibits cardiac distress, the system could prioritize dispatching an ambulance equipped with advanced cardiac life support tools to the nearest hospital with a cardiac unit. This approach not only enhances the likelihood of positive outcomes but also optimizes the utilization of the fleet.

AI fosters trust and acceptance of electric ambulances by introducing explainable decision-making processes. Stakeholders, including healthcare providers and the public, may harbor reservations about the reliability of EV ambulances. Explainable AI techniques allow users to understand how dispatch and scheduling decisions are made, enhancing transparency and fostering confidence in the system[46]. Such approaches, combined with co-creation strategies and urban living labs, promote collaborative development and acceptance of these technologies. Integrating AI into ambulance services not only addresses the operational challenges of transitioning to electric ambulances but also sets the stage for smarter, more adaptive emergency response systems.

Policy Recommendations for EV Ambulance Fleet

The successful implementation of an electric ambulance fleet in India requires comprehensive policy measures and alignment with existing regulatory frameworks. India's National Electric Mobility Mission Plan (NEMMP) and Faster Adoption and Manufacturing of Electric Vehicles (FAME II) already provide subsidies and incentives for EV adoption, but specific provisions for emergency medical vehicles remain limited. Policies should extend financial incentives to EV ambulances, supporting fleet operators through subsidized loans, tax exemptions, and charging infrastructure grants.

Regulatory frameworks such as the Automotive Industry Standards (AIS-125) for ambulances need updates to include battery safety norms, vehicle weight regulations, and minimum equipment standards for electric ambulances. Additionally, the National Health Mission (NHM) and State Transport Departments should collaborate to establish dedicated EV ambulance lanes, charging hubs at hospitals, and fleet management protocols. A centralized policy for integrating AI-driven dispatch systems and real-time hospital coordination can further optimize emergency response efficiency.

To ensure scalability, policymakers must also evaluate successful EV ambulance models from countries like the UK and Japan and implement best practices suited to India's urban and rural healthcare landscape. By aligning subsidies, infrastructure planning, and operational standards, India can accelerate the transition toward a sustainable, efficient, and technology-driven ambulance system.

Uberized Electric Ambulance Fleet: Exploring the SDGs

The uberization of electric ambulance fleets directly aligns with several United Nations Sustainable Development Goals (SDGs), highlighting the transformative potential of this innovation in advancing global sustainability and well-being. By addressing systemic inefficiencies and embracing technological advancements, the proposed model contributes to SDG 3, SDG 7, and SDG 9, fostering a healthier, cleaner, and more innovative future, as depicted in Fig.3.

SDG 3: Good Health and Well-Being

The proposed system directly impacts SDG 3 by streamlining and democratizing access to ambulance services[47]. Currently, ambulance systems face challenges such as delays, inefficiency in dispatch, and a lack of equitable access, especially in underserved areas. The uberized model leverages technology to overcome these barriers, providing a platform that ensures fast, efficient, and reliable ambulance availability. Real-time tracking, optimized routing, and digital interfaces for booking services enable a patient-first approach, significantly reducing response times and enhancing pre-hospital care. By bridging gaps in healthcare accessibility, this innovation ensures that individuals receive timely medical attention, ultimately improving health outcomes and promoting well-being.

SDG 7: Affordable and Clean Energy

The transition to an entirely electric ambulance fleet underlines the commitment to SDG 7, which emphasizes affordable and clean energy[48]. Electric ambulances, powered by renewable energy sources, significantly reduce greenhouse gas emissions compared to their Internal Combustion Engine (ICE) counterparts. This shift not only minimizes the carbon footprint of emergency medical services but also addresses the rising costs associated with fossil fuel dependency. Moreover, integrating renewable energy into charging systems ensures that the fleet operates sustainably, aligning with global efforts to combat climate change while maintaining affordability for service providers and users alike.

Figure 3: Uberized electric ambulance fleet: Sustainable Development Goals

SDG 9: Industry, Innovation, and Infrastructure

SDG 9 is addressed by transforming the ambulance service sector, which is currently fragmented and disorganized, into a streamlined, technology-driven ecosystem[49]. The uberized model introduces a centralized, accessible, and efficient system that redefines the industry's approach to emergency medical services. This innovation not only modernizes the sector but also sets a precedent for integrating advanced technologies, such as artificial intelligence and IoT-enabled monitoring, into critical healthcare infrastructure. By promoting collaboration among stakeholders and fostering innovation, the model builds resilient infrastructure capable of supporting a scalable and sustainable electric ambulance network.

The uberized electric ambulance fleet exemplifies the alignment of technological innovation with sustainable development objectives. By addressing critical gaps in healthcare accessibility, reducing environmental impact, and driving industrial transformation, this initiative contributes meaningfully to SDG 3, SDG 7, and SDG 9. As a scalable and impactful solution, it has the potential to revolutionize emergency medical services, ensuring a future that is healthier, more sustainable, and driven by innovation.

Exploring the Future Scope

Further research is needed to refine the feasibility model and address gaps in implementing an electric ambulance fleet in India. Comparative studies with existing ambulance systems in countries like the UK and Japan, which have successfully integrated EV ambulances, can provide insights into best practices and potential challenges in policy adoption, infrastructure readiness, and fleet management.

The integration of AI-based predictive analytics in dispatch systems should be explored to enhance route optimization, demand forecasting, and real-time coordination between ambulances and hospitals. AI-driven models can also assist in minimizing response times and optimizing charging schedules, ensuring maximum fleet availability.

Additionally, pilot studies in tier-1 Indian cities can validate the mathematical model proposed in this paper, helping policymakers and stakeholders assess real-world viability, cost-effectiveness, and environmental impact. By collecting empirical data on fleet performance, operational costs, and patient outcomes, future research can strengthen the case for scaling EV ambulances across urban and rural healthcare systems.

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