

Road accidents on Indian National highways, ambulance reachability and transportation of injured to trauma facility: Survey-based introspection of golden hour

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ABSTRACT

Background: The transportation system plays a crucial role in the context of socioeconomic development, whereas the highway infrastructure acts as a base for the transportation system. In recent years, a rich impetus has been given to the development of road infrastructure by Indian governance. There is a need to introspect how well the prevailing highway infrastructure is equipped with emergency rescue management during road accidents. Lack of ambulance service and trauma facilities along the highways results in a steady loss of lives and injuries and increases people's exposure to risks. **Objective:** This study aims to determine the response time of ambulance reachability to the accident spot on Indian national highways associated with heavy commercial transportation. Also, determining the time to transport the injured to the nearest trauma facility is another factor included as an objective in this investigation. **Methods:** The study adopted survey-based research, whereby the variables in the questionnaire were designed to record and assess the time for an ambulance to reach the accident spot and, from there, to transport the injured to the trauma management facility on Indian highways. Two hundred twenty-five participants who were either victims/relatives of victims or those involved in the rescue of the injured have participated in the survey. The dates of the accident events were 2017 and 2022. **Results:** The survey resulted in the identification of two categories of highway accidents. The first category of accidents happened on the highways near city limits/dense settlements, and the second category occurred on the core highways. The percentage of accidents caused on the highways either adjacent to or passing through the city limits/dense settlements was reported to be higher than the accidents on the core highways. Ninety percent of the participants reported successful contact with the ambulance call/service centre, but only ~75% success rate exists for ambulances to reach the accident scene. On the core highways, the time taken for the ambulance to arrive at the accident scene is 25–35 minutes. The results from the survey ascertained that the patients were prioritised for treatment in the nearest hospitals (irrespective of having a trauma facility) at a distance of ~12–20 km, for which the time taken is ~15–25 minutes. Importantly, from the interviews, it is understood that in many cases, these hospitals have further referred to specialty hospitals located in nearby cities or trauma centres with greater facilities. Occasions exist where the injured were taken directly to hospitals 30–40 km from the accident spot, for which the time was more than 40 minutes. **Conclusions:** The results provide evidence that in either of the accident cases on the highways that are adjacent to/passing through the city limits or on the core highways, the total time for emergency care accessibility is nearly 60 minutes or greater; this implies that in the majority of cases, there is very meagre time left to provide emergency medical care to the needy and injured on the Indian highways to abide by the concept of golden hour. Plausible reforms backed by technology for enabling highways into 'emergency rescuable highways' are highly needed to guarantee a safer and more sustainable transportation system in India.

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Introduction

Transportation is one of the top priorities for developing and developed countries for sustained economic development.^[1] Recognising the importance of the transport system, the United Nations Sustainable Development Goals (UN SDGs) adopted indicator 9.1.2 – ‘Passenger and freight volumes, by mode of transport’ under target 9.1 – ‘Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all’.^[2] SDG 9 aims to ‘Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation’. The concept of SDGs has recognised the importance of avoiding road accidents by adopting necessary indicators as a part of their strategy. Road traffic injuries are currently estimated to be the eighth leading cause of death across all age groups globally. Recognising the fatal effects of road traffic accidents, SDG 3, which aims to ‘Ensure healthy lives and promote well-being for all the ages’ encompasses a dedicated target of 3.6 to ‘By 2030, halve the number of global deaths and injuries from road traffic accidents’.^[3]

For a country like India, where the transport sector accounts for a 6.4% share of the gross domestic product (GDP), not only does this sector act as a backbone of its development but also an indicator of its progress.^[4] By 2022, India’s total length of national highways was estimated to be 1,44,634 km, and the nation’s transportation system is credited as the second largest in the world after the United States.^[5,6] The synthesis of the statistics from the available data sources reports the total number of road accidents in India for the year 2021 as 4,12,432, claiming 1,53,972 lives and causing injuries to 3,84,448 persons.^[7] Besides the injuries and human loss, the dent in the form of socio-economic costs of road accidents on the nation’s GDP is around 3.14 percent^[8,9]; thus, nearly 50 percent of the accrued economic advantage of India’s road network gets eroded due to the lack of emergency rescue management on the highways.

In recent years, vehicle manufacturers have substantially improved the design standards and implemented safety sensors to withstand crashes or minimise the effects of crashes.^[10] Similarly, the government authorities are accentuating safety standards and accident-proof road networks.^[11] However, the annual rate of accidents and mortality seems to be increasing annually.^[7] The golden hour concept, introduced by R. Adams Cowley,^[12,13] is based on research that if a severely injured person is not rendered emergency treatment within the 60-minute post-trauma period, the opportunity for further life will be unlikely or difficult. To date, the concept of the golden hour has remained relevant in many countries.^[14] Thus, the mortality rate due to road accidents can be reduced by enabling the severely injured to be admitted to an in-patient facility with trauma management and definitive care within 60 minutes of succumbing to the injuries. Notably, the period of golden hour includes the time taken for the ambulance service to reach the accident scene and, from there, transporting

the patient(s) to the facility of trauma management; of course, the transport system – the ambulance service – is assumed to have all the pre-hospital emergency medical services enabled.^[15-19]

This study aims to determine the response time of ambulance reachability to the accident spot on Indian national highways as well as transporting the patient to the nearest trauma facility; for this, a pan-India survey has been conducted by interacting with the victims or their family members. The results from this survey were analysed and synthesised to understand the prevailing situation of ambulance reachability on Indian National Highways; thereby, the results should be helpful for policymakers while developing the transport infrastructure and recognising the importance of emergency and rescue management on the highways.

Materials and Methods

The study adopted a survey-based research design. The survey inclusion criteria intend to record only those accidents on the highways (national or state) associated with heavy commercial transportation like trucks/lorries. The participants were screened based on the accident’s severity, which is preferred to be severe to critical and in need of getting treatment in the trauma facility. Accidents occurred within the urban area, and those of passenger vehicles were excluded as a part of the survey because this research ambition is to assess the time of ambulance reachability to the accident spot that happened only on highways and, further, the time taken for transporting the patient to the nearest hospital with a trauma facility. Table 1 shows the variables that are associated with the survey questionnaire.

The survey mode constituted an initial consultation with the district-level transport/truck/fleet/lorry associations located in various states. These include cities like Ahmedabad/Vadodara/Surat, Amritsar/Bathinda, Bengaluru/Mangalore, Kochi/Kannur, Chennai/Coimbatore, Bhopal/Indore, Jaipur, Kolkata/Siliguri/Cooch Behar, Nagpur/Nashik/Pune, Guntur/Vijayawada/Vishakhapatnam, and Hyderabad/Warangal. The transport associations helped the interviewers provide information and access to the truck drivers (or their relatives) who encountered severe to critical accidents during recent years, that is, 2017–2022, on highways. The survey has also considered respondents who have actively participated in the accident rescue operation; for this, the inclusion criteria included only those involved right from the accident scene until the critically injured patient was transported and admitted to the trauma center. Mostly, the interviews happened in the victims’ dwelling units or transport office premises. These interviews initially consisted of brief counselling sessions that explained the motive of the survey and their expected scientific outcomes. All the columns in the questionnaire are mandatory.

Results

A total of 225 participants are involved in this survey. Out of these, 161 respondents are the direct victims of road

Table 1: Variables associated with the survey questionnaire to assess the time taken for an ambulance to reach the accident spot and from there to transport the injured to the trauma management facility on Indian highways

Variable	Remarks/options for the interviewer to record the participant's statements
Participant type	One option from below. <ul style="list-style-type: none"> • Victim • Relative of a victim • Bystander/witness • Person actively participated in the rescue operation.
The nearest place/landmark details where the accident happened	To ascertain the location details of the accident (used to screen the survey data)
Year of accident	2017–2022
Time of accident	Early morning/noon/afternoon/evening/night
Type of highway	National highway or state highway
Nearest city/dense settlement area from the accident spot	Name of the city/dense settlement area
Distance of the nearest city/dense settlement from the accident spot	Approximate distance (in km)
Time taken for crowd gathering immediately after the accident/collision	Approximate time (in minutes)
Who called the ambulance?	To ascertain the person who called the ambulance (one option from below). <ul style="list-style-type: none"> • The victim himself (if he is in a position to call the ambulance) • One in the crowd/Good Samaritan • Police • Others
Response status of the ambulance call/service centre	One option from below. <ul style="list-style-type: none"> • Responded and agreed to send the ambulance • No response/call not connected/call dropped • Responded but ambulance service was not available
Status of ambulance reachability to accident spot	<ul style="list-style-type: none"> • Ambulance reached • Ambulance not reached • Not applicable if ambulance call/service centre has not responded
Time taken for the ambulance to reach the accident spot	Approximate time (in minutes)
Time taken to place the victim into the ambulance/vehicle extrication process	Approximate time (in minutes)
If the ambulance has not reached the accident spot, who has taken the patient to the hospital	One option from below. <ul style="list-style-type: none"> • Police • Highway patrolling team • one in the crowd
Source of reference who suggested to which hospital the patient is to get the treatment	One option from below. <ul style="list-style-type: none"> • Ambulance staff • Police • Highway patrolling team • One in the crowd • Victim himself is aware of the nearest treatment facility
Distance between the accident spot and the hospital where the treatment was facilitated for the patient	Approximate distance (in km)
Time taken to reach the trauma centre	Approximate time (in minutes)
Type of trauma facility where the patient was admitted	One option from the below. <ul style="list-style-type: none"> • Government • Private
Status of treatment received from the first attended hospital/trauma centre	One option from the below. <ul style="list-style-type: none"> • Full treatment provided • Referred to another hospital

accidents associated with heavy commercial transportation; mostly, all these victims are drivers. Thirty-two respondents are the victim's relatives, who have narrated the incidents to the interviewers on behalf of the victims. Seventeen respondents who have described the events are bystanders/witnesses – these respondents are typically working in dhabas (hotels situated on the sides of highways), puncture works, and petrol bunks. Lastly, 15 respondents have actively participated in the accident rescue operation. All these

participants have narrated their accounts of incidents from the time of the accident until the point where either the victim reached the trauma centre for treatment or was referred to another hospital with greater facilities. Even though the survey has collected the narrations of accidents between 2017 and 2022, the reported accidents were almost nil or minimal during the lockdown periods imposed due to COVID-19 restrictions. Figure 1 shows the infographic of data that was collected through this survey.

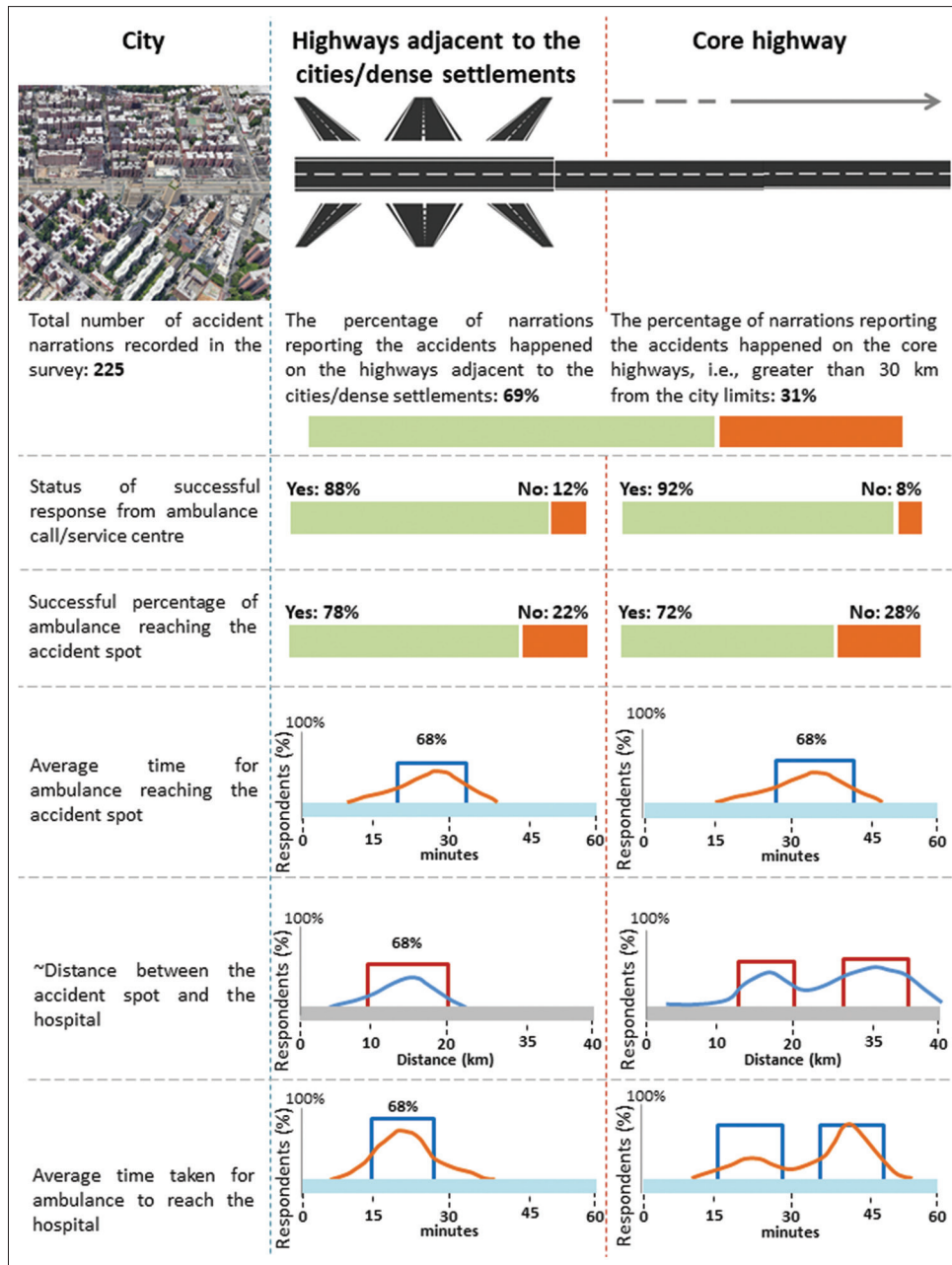


Figure 1: Infographic showing the results of a survey conducted to assess the time taken for various events during the accidents of high-impact collisions on Indian national highways. The events include getting a positive response from the ambulance call/service centre, the ambulance reaching the accident spot, and transporting the injured to the trauma facility

At the outset, the synthesis of narrations given by the participants in the survey has resulted in two categories of accidents that happened based on the proximity of city limits, where the first category of narrations reported 69% of accidents that happened on the highways adjacent (up to a distance of 25–30 km) or passing through the city limits/dense settlements. The second category of narrations is from the remaining 31% of accidents that happened on the core highways. Ninety-two percent of participants reported that the crowd gathered within the first five minutes at the accident scene, while the remaining participants reported that it took more than ten minutes for crowd aggregation in those accidents that occurred on the ghat

roads/hilly terrains, highways across forest/forest fringes and especially during night times. Ninety-five percent of participants reported that ‘one in the crowd’ had called the ambulance service, whereas the remaining participants reported that it was the police personnel or highway patrolling service who had called the ambulance after their arrival at the accident scene; primarily, the well-recognised emergency services ‘dial-102/108/112’ service was given preference subsequent to dialling the private ambulance service.

In both cases of accidents, that is, on the highways adjacent to/passing through the city limits/dense settlements or on the

core highways, the ambulance call/service centre's response was successful for ~90% of participants. In contrast, the remaining participants reported that the 'call could not connect', 'call dropped', or 'line busy'. Only ~78% of narrations reported the successful reaching of an ambulance to the accident scene; however, on the core highways, the success rate of the ambulance reaching the accident spot is lowered to ~72%.

Results from the participants' responses have yielded a normal distribution in some cases and a bimodal distribution in others [refer to Figure 1]. In the normal distribution, the majority of the data are clustered around the middle of the graph and tapers off towards the left and right ends contains a smaller portion of the data; thus, a specific percentage of the data is assigned to each standard deviation and in our analysis, we have considered 68% of the data falling within the 1 standard deviation of the mean. Standard deviation refers to how far the data are spread from the mean value. The bimodal distribution shows two peaks indicating two different groups; at certain times, the two modes in the bimodal distribution show unequal, where the larger mode is known as the major mode and the other as the minor mode.

For the accidents that happened on the highways adjacent to/passing through the city limits or dense settlements, from the narrations in the survey, it is understood that the average time of ambulances reaching the accident scene for the majority of the participants is 20–30 minutes. In contrast, for the accidents on the core highways, the average time is more than this and happens to be 25–35 minutes. Respondents narrated that the vehicle extrication procedure took more than five minutes in many cases, and this process consumed more time in heavy collision instances. In the event of an ambulance never reaching the accident scene, it was the police personnel or national highway patrolling or someone in the crowd who had taken on the responsibility of transporting the injured to the hospital. Certain times, towards the transportation of the injured to the hospital, instances like taking help from one of the vehicles gathered at the accident scene were also reported in the survey.

Interpretations from the survey data confirm that if the transportation of the injured is done through the ambulance service, the ambulance staff has decided on the hospital to which the patient is to be admitted; otherwise, 'one in the crowd' or the police personnel or the highway patrolling team has suggested a nearby hospital irrespective of thinking about the availability of trauma management facilities in it.

Victims who got injured in accidents on the highways adjacent to the city limits/dense settlements were mostly taken to hospitals that are either in the city or within the city limits; as per the results from the survey carried out in this research, for the majority of the participants (i.e., 68%), the distance to the hospital from the accident scene is in the range of 10–20 km and for this generally, the time taken is 15–25 minutes.

Whereas for accidents on the core highways, the general trend of distance from the accident spot to the referred hospital and the duration of patient transportation are bimodal. Synthesised results from the survey in this study ascertained that the patients were prioritised for treatment in the nearest hospitals at a distance of ~12–20 km, for which the time taken is ~15–25 minutes. Importantly, from the interviews, it is understood that in many cases (22 respondents), these hospitals have further referred to specialty hospitals located in nearby cities or trauma centres with greater facilities. Occasions exist that the injured were taken directly to hospitals that are 30–40 km from the accident spot, for which the time taken was more than 40 minutes.

Discussion

Adequate reasons were reported for the causes of accidents on the highways.^[20-23] Similarly, the timings of high probability for accidents on the highways were well reported by previous researchers.^[24-26] Generally, the probability of accidents on the highways is higher in the early morning. Bigdeli *et al.*^[27] and Harmsen *et al.*^[28] have reviewed the pre-hospital care timing among the victims of road traffic injuries. Figure 2 illustrates the general episodes of events that consume time from the moment of the accident until the injured person is taken to the trauma facility.

The timeline for rescuing the injured in the accident can be conceptualised into four sequential episodes. The initial episode starts after the accident on the highway, where the 'accident spot' becomes the 'accident scene' and includes recognising the impact of the vehicle collision as well as the degree of injury caused to the victims by the nearby crowd or commuters travelling on the same road. From the survey, as carried out in this study, it is understood that within (or approximately) five minutes (T_1) of the accident, the gathering of the crowd takes place on the highways with regular traffic. For the accidents on the highways running across the remote ghats, forests/forest fringes and fewer traffic highways, T_1 may take significant time, that is, greater than five minutes. Recognising the state of consciousness and situation of the injured by the crowd who have gathered at the accident scene is an important element in rescuing the injured; however, the presence of a 'Good Samaritan' in the crowd is of utmost importance because he is the one who can prompt or initiate calling the ambulance call/service center. The so-called 'Good Samaritan' takes on the role of describing the accident location, the pressing need for an ambulance and other related information as needed by the officials of the ambulance call/service centre. The time (T_2) taken for this humanitarian act completely depends on the successful connection of the call to the ambulance service centre and their reciprocation. Any unsuccessful attempts to the well-recognised emergency services like 'dial-102/108/112/etc'. should be immediately followed by calling a private ambulance service or nearby police stations or highway authorities. In our study, that is, for Indian highways, mostly both the T_1 and T_2 were nearly ten minutes. However, narrations from the survey suggest that most of the crowd gathered at the accident scene are

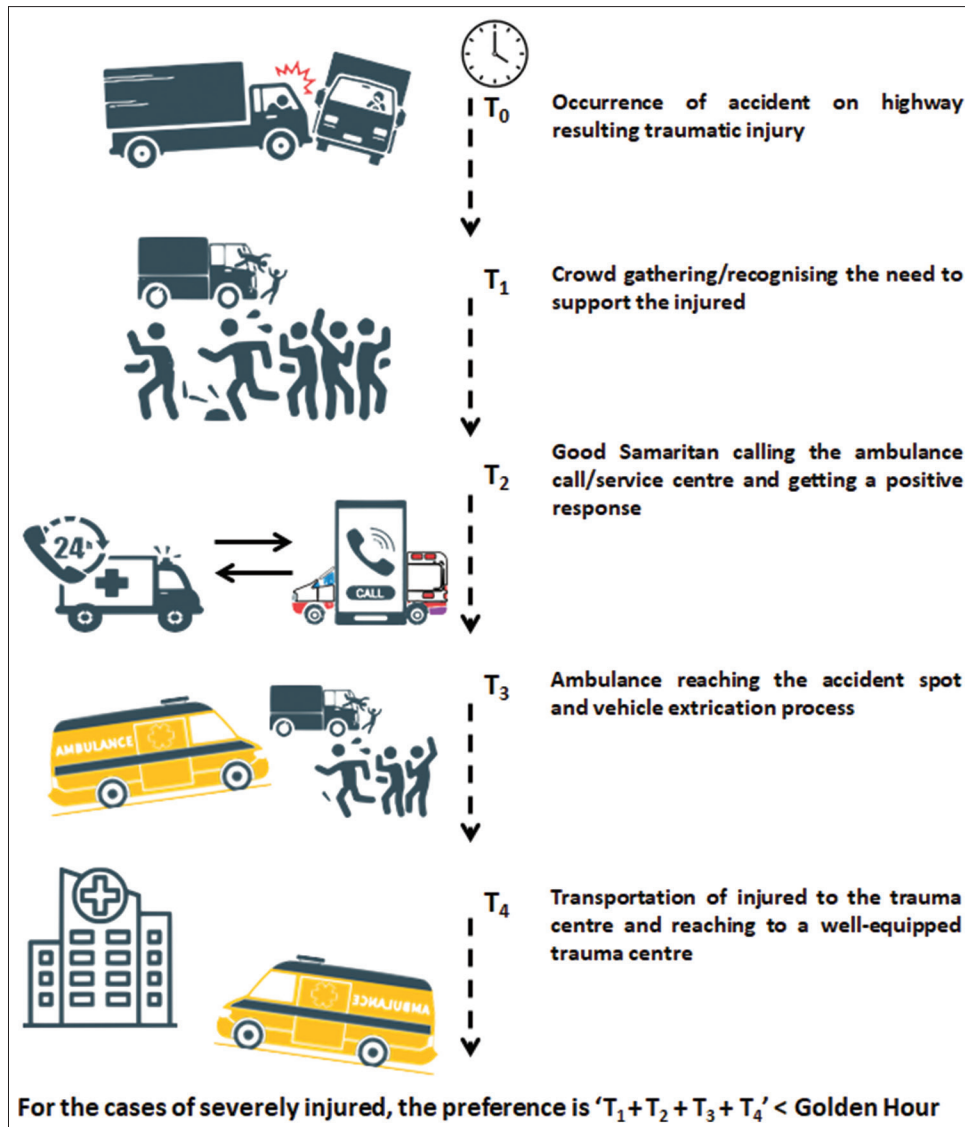


Figure 2: Illustration of timelines for various episodes of events right from the moment of accident until the injured is taken to the trauma facility

mere spectators and the percentage of 'Good Samaritans' who initiate a dialogue with the ambulance call/service centre is less.

Highways adjoining the cities, which generally stretch across suburban or peri-urban areas, do contain conjunction roads, factories/industries, and loading/unloading units will significantly transform the traffic characterization compared to the core highways. Also, there needs to be a drastic change in the driving temperament of the driver while the vehicle is approaching the conjunction roads, or else the probability of an accident increases. It was revealed from the recent road accident report that approximately 45% more accidents are reported on the highways adjoining the cities/dense settlements compared to the core highways^[11]; even though random sampling was considered in our survey, the results from this study have confirmed the same. The success rate of calls getting connected to the ambulance call/service centre and receiving a positive response from our survey stands at ~90%. However, the rate of ambulances reaching the

accident spots on the highways adjoining the city limits is only 78%; the reason for ambulances not reaching the accident scene is due to no service availability. In our survey, the success rate of ambulances reaching the accident scene has reduced to 72% on the core highways, prompting the police/highway authorities to 'one in the crowd' take on the responsibility of transporting the injured to the nearby hospital.

With 225 participants as respondents in this survey, it is observed that if the ambulance dispatch is successful and reaches the accident spot, T_3 – the time taken is in the range of 20–30 minutes (or, say, an average of 25 minutes) for the cases of accidents on highways adjacent to/passing through the city limits. However, in the cases of accidents on the core highways, the range of T_3 is higher and happens to be 25–35 minutes (or, say, an average of 30 minutes). Our results are similar to the observations conducted by earlier researchers.^[29-31]

Successful vehicle extrication leads to the episode of an ambulance transporting the injured to the nearest trauma care facility, and the time taken to T_4 plays a vital role in the context of the 'golden hour'. From the synthesis of the survey data of this study, T_4 , in the case of accidents on highways adjacent to/passing through the city limits and dense settlements is in the range of ~15–25 minutes (or, say, an average of 20 minutes).

But, in the cases of accidents on the core highways, the range for T_4 is bimodal; from the narrations of the participants falling in the range of minor mode [refer Figure 1], probably to save the injured, and due to the quick decision to admit the victim to the possible nearest hospital with whatever medical infrastructure is available, the time taken is between ~15–25 minutes (or, say, an average of 20 minutes). However, a larger percentage of participants (major mode) in the survey who met with severe accidents on the core highways reported T_4 to be greater than 40 minutes. Table 2 shows the summarised timelines for various episodes, starting from the accidents on highways to the transportation of the injured to the trauma centre; the time taken is considered from the 68% of the data falling within the 1 standard deviation of the mean.

From Table 2, it is evident that in either of the accident cases on the highways that are adjacent to/passing through the city limits or on the core highways, the total time for emergency care accessibility is nearly 60 minutes and greater; this implies that in the majority of cases, there is very meagre time left to provide emergency medical care to the needy and injured on the Indian highways. It is not out of scope to specify that the majority of road accidents on the highways result in severe injuries that include fatal head/brain injuries, blood loss, bone fractures and need definitive emergency trauma care as quickly as possible.^[32]

Currently, there is a rich impetus given towards Indian road infrastructure development, which plays a vital role in the economic and social development of the country.^[33] By and large, the investments made by India for highway infrastructure development are highly appreciated.^[34] However, the need of the hour is to introspect how far these highways are integrated

with emergency rescue systems. A plausible solution for enabling highways into 'emergency rescuable highways' needs an assessment or survey for documenting the available trauma care facilities along the national highways; this assessment enables the identification of the stretches lacking trauma care facilities. Similarly, improving ambulance availability with technology-enabled 'ease of access' on the highways will ensure them with an integrated emergency rescue system.

Conclusions

The present study attempts to understand the intricate details associated with the timings of various episodes during accidents on the Indian national highways; for this, a survey was conducted with the 225 real-time accident victims. The article has presented the results after analysing the records from this survey. The results indicate that in most of the accidents on Indian highways, there is very little time left to provide emergency medical care to the needy and injured. Thus, reforms to strengthen the availability of both the ambulance service and trauma centres along the highways are the need of the hour; these reforms should envisage the concept of emergency rescue integrated highways, bearing that the requirement is not complementary but essential towards sustainable transport systems. The ambulance, which plays a pivotal role in transporting the victims to the trauma facility, needs sophisticated life-saving medical equipment; our study does not deal with the inbuilt infrastructure of the ambulance, which is a limitation of this study.

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Table 2: Typical timings for various episodes after a severe accident on highways to transport the injured to the trauma centre: Synthesised from a survey with 225 participants

Episode of timeline	Time taken in the case of accidents on the highways adjacent to the city limits/dense settlements	Time taken in the case of accidents on the core highways
T_1 – the time between the occurrence of an accident on the highways and the crowd gathering and recognising the need to support the injured	5 min	Five minutes or greater on remote ghat roads or highways along forests/forest fringes and fewer traffic highways
T_2 – the time taken for a Good Samaritan to call the ambulance call/service centre and get a response	5 min	5 min with a reduced success rate
T_3 – the time taken for an ambulance to reach the accident spot and the vehicle extrication process	25 min	>30 min
T_4 – the time taken to transport the injured to the trauma centre	20 min	Bimodal: within 20 min if the nearest trauma centres exists or >40 min
Total time ($T_1 + T_2 + T_3 + T_4$)	55 min	Either ~60 min or greater

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Ethical statement

The ethical approval for the current study was obtained from the Institutional Ethics Committee of All India Institute of Medical Science (AIIMS), Jodhpur (Ref# AIIMS/IEC/2020-21/2092).

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Conflicts of interest

There are no conflicts of interest.

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