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Research article

The necessity for an integrated Emergency Operations Center (EOC) among first responders: Lesson learned from two Iranian railway accidents

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ABSTRACT

Introduction: Several train accidents have occurred in Iran in the last twenty years, resulting in considerable loss of human lives. This study aims to investigate and analyze the response process and deficiencies thereof, of three responding organizations to two railway accidents in Iran.
Methods: The study was performed in 2 stages to examine the challenges faced by the first responders in the said accidents. In the first stage, a descriptive statistical analysis was conducted to estimate the injuries and loss of human lives. In the second stage, qualitative description (QD) was performed. Technical reports, official documents, and interviews contributed to the sources of primary data. Study participants were members of first responders who were interviewed.
Results: The lack of key components like coordination, information-sharing, a single unified command between responders from different organizations, a lack of relief and rescue railway train, and poor inter-organizational interactions in the deployment of relief teams, were found to be the most important challenges.
Discussion and conclusion: The analysis of these two accidents showed that the lack of an integrated emergency operations center (EOC) among the organizations involved in the emergency response appears to be the obvious cause of initial confusion and disruption in the response phase which caused a delay which proved fatal. Designing and developing an integrated response plan among responding organizations, preparing an information sharing network, centralized deployment of forces to the site of the accident, strengthening inter-organizational interactions in the form of an incident command system, designing, launching, and using rescue trains on rail routes and use of air emergency facilities in areas with poor accessibility can reduce mortality in future in similar kind of accidents.

1. Introduction

The railway is one of the effective transportation lifelines around the world [1]. The use of trains dates back to the 19th century and

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railways have always played an important role in economic development [2]. The ability to carry large volumes of goods, optimal use of energy, faster transportation, greater safety, and lower cost compared to other transportation methods have led to the growing development of this industry [3]. For centuries, railways have taken over other means of transportation as it ensures a higher level of safety for passengers and goods [4].

Like other transportation routes, railway has always witnessed devastating events, including fatal train accidents [5]. A glance at the most important railway accidents has shown the growing trend of occurrence in developing countries [6]. According to statistics, 74% of railway accidents in the world have occurred in Africa, Asia, and South & Central America from 1970 to 2009 [7,8]. Besides that, in developing countries, research on Technological disasters has rarely focused on infrequently occurring railway accidents as they have lesser mortality than more frequently occurring road accidents [8–11]. Also, disaster Management practices in developing countries are more reactive than proactive [12,13]. All of the above-mentioned issues have led to many challenges in the management of railway accidents.

While the share of passenger transportation by rail is 8% and the share of cargo is 12% of the total transportation of the country [13], figures reveal that the average occurrence of rail accidents is much higher than the global average as compared to the density of rail lines across the country [14–16].

Iran's national railway network comprises of more than 10,000 km of main lines, 3000 km of industrial and commercial lines, 2000 km of two-way routes, and 148 km of power lines (Fig. 1), [17]. The 888 km axis of the Tehran-Mashhad route, of which 501 km is located in Semnan province, is one of the busiest routes in the country. The location of Semnan province in the central desert of Iran along with the long distance between the main stations located in cities leads to poor accessibility for the response team in case of a mishap, leading to many challenges. Some of the worst rail accidents have occurred on this route for instance, the explosion of the Neishabour freight train in 2003, the collision of a freight train with a passenger train in Amravan in 2014, and the collision of passenger trains in the Haftkhan region (between Semnan and Damghan) in 2016 are few examples of these fatal accidents [14,15,18].

Despite the huge advances in technology and infrastructure development, there are still chances of train accidents based on human errors [19–21]. So, Planning and Preparing for Emergency Response to railway Accidents seems necessary [22]. Despite the importance of this issue, it seems that limited research has been done in this area [23,24]. The present study aims to investigate and analyze the emergency response process provided by the responding organizations (first responders) to two railway accidents: Haftkhan &

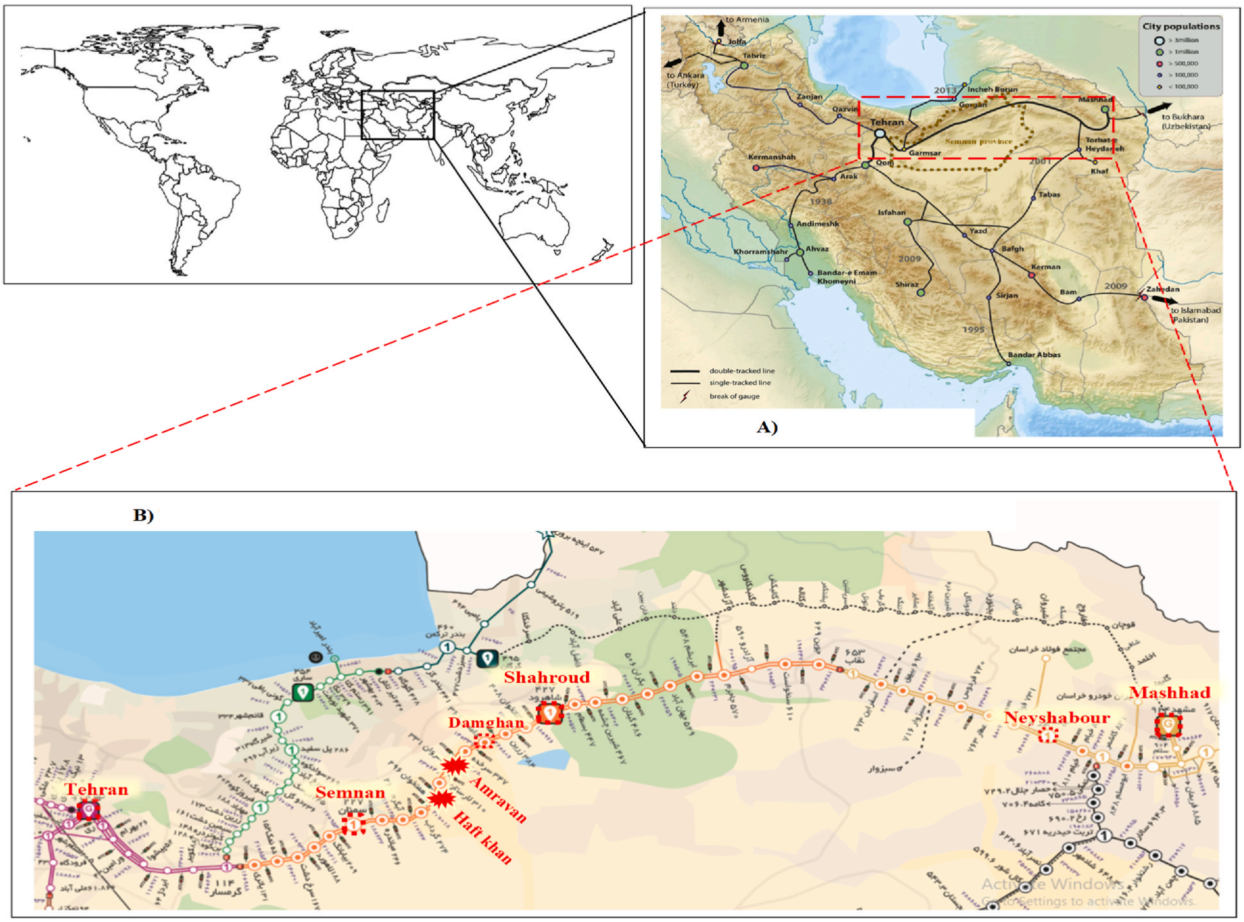

Fig. 1. (A) Iran's railway map. (B) The Tehran-Mashhad railway route and the locations of the Haftkhan and Amravan accidents.

Amravan, which resulted in incredibly traumatic experiences and huge loss of lives and severe injuries.

2. Method

This study was done with two-stage mixed method research. Quantitative research was followed by qualitative research to investigate the challenges of the response process.

In the quantitative part, a descriptive statistical analysis was performed to estimate the injuries and loss of human lives of these two accidents. The information of the injured people including demographic information such as sex, type of injury, etc., was extracted and analyzed.

In the qualitative part, the study adopts an empirical qualitative and descriptive approach employing strategies such as thematic and narrative analysis. The response process of responding organizations in the field of technological disasters was extracted with respect to these two accidents. This qualitative descriptive approach is very useful when researchers want to know regarding who, what, and where about the events [25]. The goal of Qualitative Descriptive studies is a comprehensive summary of specific events experienced by individuals or groups of individuals [26].

Technical reports, official documents, and interviews comprised sources of primary data. All the available documents and reports from diverse sources (news, websites, scientific associations, as well as the accident reports registered in the Emergency Medical Service Center of Semnan University of Medical Sciences, the Ministry of Health, and the Red Crescent society) were extracted, reviewed, and thoroughly analyzed.

In-Depth interviews (both offline and online) were conducted between January and February of 2022 regarding the response processes to the above-mentioned railway accidents. Initially, a purposeful sampling technique was used to identify 8 first responders from different organizations who were involved in the operational management of the accidents.

The information obtained from the participants included roles, responsibilities, and personal experiences of how they responded to the two accidents.

To enhance the validity of the research, empirical data were triangulated with other information sources such as formal reports, policy/technical documents, academic journals, and gray literature.

According to Ethical considerations, this study was approved by Shahid Beheshti University of Medical Sciences, Tehran, Iran under the code of IR. SBMU.PHNS.REC.1400.080. To conform to the ethics, oral informed consent was obtained from all interviewees. They were also explained about the research aims, interview method, and confidentiality of personal information, and were given the choice to either participate or abstain from the study and assured that the collected data would be used only for research purposes.

3. The Haftkhan & Amravan accidents

3.1. The Haftkhan accident

3.1.1. Description of the accident

On the morning of 25th November 2016, the Tabriz-Mashhad passenger train No. 480 with 13 wagons and 432 passengers on the Gerdab-Haftkhan axis stopped due to a technical defect. At 7:21 a.m., the Semnan- Mashhad passenger train No. 3242 with five

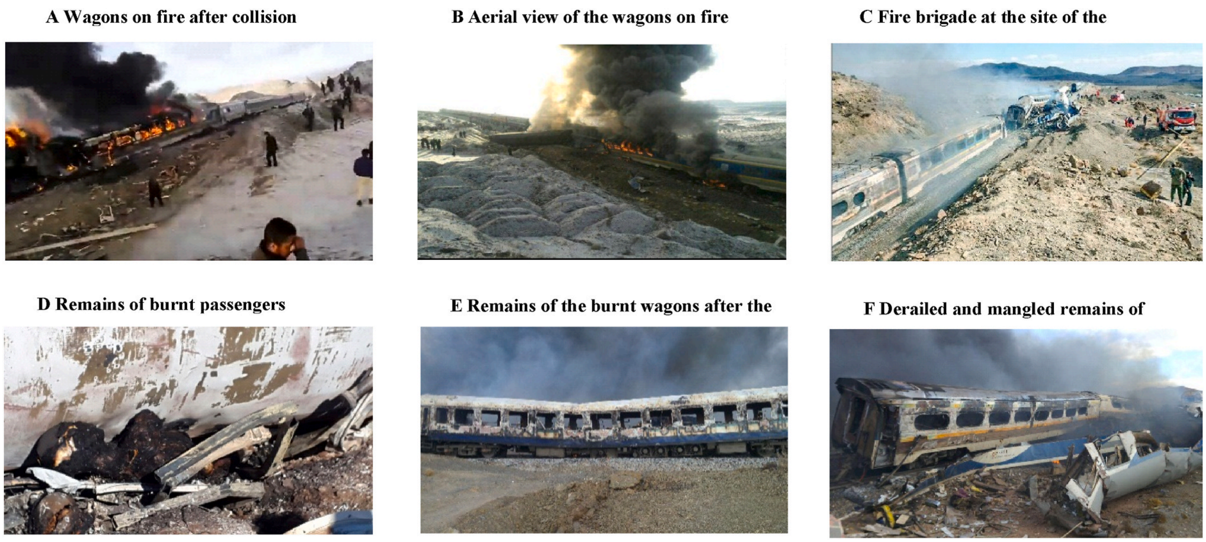

Fig. 2. Accident scene in the Haftkhan block in 2016. Wagons on fire after collision (A), Aerial view of the wagons on fire (B), Fire brigade at the site of the accident (C), Remains of burnt passengers (D), Remains of the burnt wagons after the accident (E) and Derailed and mangled remains of wagons (F) (reprinted from Ref. [27] with permission from Semnan Emergency Medical Service center).

wagons, traveling at a speed of 132 km per hour from Semnan to Mashhad with 110 passengers, collided with the Tabriz-Mashhad train (Fig. 2).

3.1.2. Geographical description of the region

The Haftkhan region is located in Semnan province between Damghan city and the capital city of Semnan. The site of the accident was located at 65 and 71 km from Semnan and Damghan respectively via rail route. To be more precise, the collision happened between two crossing stations namely Gerdab and haftkhan, poorly accessible by road due to dirt roads and seasonal conditions.

3.1.3. Accident damages and losses

In this accident, three out of 13 wagons of the Tabriz-Mashhad train along with the locomotive of the Semnan-Mashhad train got derailed, burnt, and destroyed. The total number of passengers traveling in both trains was 542, out of which 48 lost their lives at the site of the accident, and 103 were injured, recording the highest number of casualties in Iran's railway accidents in recent years. This also lead to the blockage of both routes.

3.2. The Amravan accident

3.2.1. Description of the accident

At 10:11 p.m., 5th June 2014, a passenger train No. 3342 consisting of 12 wagons with 447 passengers on board traveling at a speed of approximately 107 km/h collided with a stationary freight train number 305 with two locomotives and 35 empty wagons at Amravan station.

3.2.2. The Region's geographical characteristics

The Amravan station is located at about 90 km from Semnan city and 30 km from Damghan city. Amravan is a crossing station that controls the movement of trains.

3.2.3. Accident damages and losses

The accident led to one dead and 37 injured. None of the wagons derailed. The first cabin of the passenger train was severely hit but since it was empty, the number of injured were less. (Fig. 3).

4. Results

This section analyses the management of two railway accidents with focus on the response. We assess the disaster response in terms of how the accidents were managed. Quantitative research was followed by qualitative research to investigate the challenges of the response process.

4.1. Quantitative descriptive statistical analysis

A total of 48 dead and 103 injured were the casualties reported by the authorities at the Haftkhan railway accident. Out of these, there were records available with respect to 27 injured who were transferred by the Emergency Medical Service (EMS) team. There was no information with respect to the type of injuries and other details of the injured victims who were transferred by the other first responders and only their numbers were mentioned. As regards the Amravan accident, one person was killed and 37 others were injured in the said accident.

According to Table 1, despite the proximity of the Haftkhan Railway Accident site to Semnan city, 89% of the injured were transferred to Damghan hospital from local road and rail route due to poor connectivity on account of dirt road, inadequately equipped

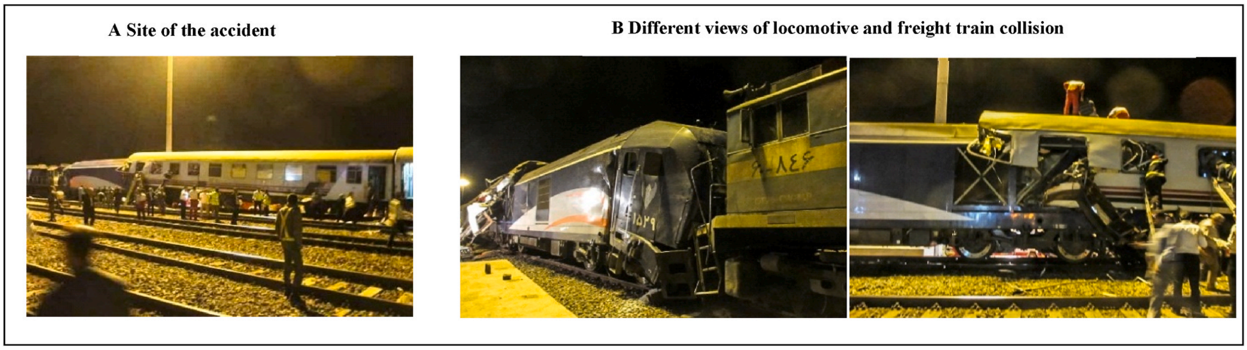

Fig. 3. Accident scene in the Amravan railway station in 2014. Site of the accident (A) and Different views of locomotive and freight train collision (B) [28].

EMS ambulances, lack of rescue and relief trains including through transferring with non-damaged wagons of Tabriz-Masshad train which had met with the accident. Similarly, in the Amravan accident, about 6% of the injured were transferred to Semnan city.

The impact on the human body during such accidents generally leads to significant consequences and injuries that could be fatal. These injuries and fatalities are caused on account of precious time being lost in extricating victims trapped under mangled metal parts resulting from such accidents. In such instances, immediate emergency medical services are warranted to save lives. Table 2 illustrates the types of injuries recorded in the Emergency Medical Service Center of Semnan University of Medical Science (SUMS). Of the 62 cases with traumatic injuries caused by the two accidents, almost 6% of them were amputations and most injuries were blunt trauma.

4.2. Qualitative descriptive analysis

4.2.1. Response to the Haftkhan accident

The research team was informed that there are 3 separate EOCs (Emergency Operation Centers) in 3 organizations namely the Red Crescent Society (RCS), the Semnan University of Medical Science, and the fire department for responding to the accident. The EOC of the RCS after being informed about the accident, informed the EOC of EMS of Semnan University of Medical Sciences. Even though there is no record of such a reference being made to the third EOC at the fire department. The research team was informed that while 7 RCS teams were deployed initially at the site of accidents but no fire tenders were deployed. Hence, the RCS, despite arriving earlier than the others at the site of the accident were ineffective due to their inability to extinguish the fire (Table 3).

At SUMS, the main activities in response phases have been defined in the national Emergency Operation Plan (EOP) [29] who after verifying the news by the EOC of the RCS activated alert level of Red. It means that, the threat has happened or its occurrence is definite. So, activating the incident command system (operations) and executing response operation measures excepted. The guidelines' table for setting alert levels in the national EOP is available in supplementary file.

The University's Incident Command System (ICS) was activated and personnel were summoned. The incident commander who in this case was the President, Vice-Chancellor, and Head of the Emergency Medical Services Center of SUMS led the operation. The ICS chart of SUMS at this accident is available in supplementary file. Due to the scale and uncertainty of the accident, all personnel of the ICS team were on standby. All the interviewees stated that despite the existence of the Public Information Section in the ICS, the golden time to inform the public and next of kin of the victims was lost. Thus, the incident command system did not play an effective role in the accident and only existed on paper.

This was followed by the summoning of local EMS team who were dispatched to the site of the accident. The first EMS team arrived 95 min later. According to formal reports, some of local EMS teams were sent to the site of the accident from direction 1. Fig. 4a shows the direction of these local EMS teams. As shown in Fig. 4b, there were 17 EMS teams stationed all around Semnan and Damghan at the time of the accident. 4 of the interviewees confirmed that, due to the lack of accessibility of the accident site from the nearest road (direction 1 as shown in Fig. 4a), the EMS ambulances had to change their route and accessed the site from the alternative road (direction 2 as shown in Fig. 4a). In this situation, the nearest EMS station to the accident site was the Seyedabad Damghan team, which arrived at the scene at 9:10 a.m. as the first EMS team (Fig. 4b). Interviewees reported that RCSs EOC didn't inform EMS team on existing blocked access road to the accident site. So they miss golden time of relief.

The first EMS team was the part of Incident Command Post and performed an initial rapid assessment (shown in Table 3) and informed the EOC which subsequently alerted level E1 for the accident. There is an Accident grading according to the National Health Response Framework and level E1 means that, The accident extends over a medical university's coverage area (10 < killed people < 100, 100 < injured people < 1000, 1000 < affected people < 10,000). Accident grading according to the National Health Response Framework is shown in Table 1 in supplementary file. Based on the E1 level, the required operational units, in this case, including ambulance buses, two helicopters, and several ambulances were sent to the scene. According to the guideline and the existence of fire at that accident, the site should have been divided into three zones: hot, warm and cold. So, the location of the EMS teams was in the warm zone. The search and rescue operation were carried out by the Red Crescent relief forces and the firefighting operation was carried out by the fire brigade in the hot area. Police were also present to provide security in the cold zone. Interviewee confirmed that the first fire brigade arrived 95 min later and retrieved several dead bodies and injured passengers trapped in the burning train wagons.

Table 1
The number of casualties and injuries in the Amravan and Haftkhan Railway accidents.

Variables		Haftkhan Accident		Amravan accident	
		N	%	N	%
Affected people	All passengers	542	100	447	100
	No damage	391	72	409	91.5
	Casualties	48	9	1	0.2
	Injured	103	19	37	8.3
Transported injured	Via the ambulances of other organizations	57	55.3	0	0
	Via the ambulances of EMS	27	26.2	35	95
	Outpatient injured	19	18.5	2	5
Recipient hospitals	Velayat, Damghan	75	89.3	33	94.3
	Kowsar, Semnan	9	10.7	2	5.7
Gender of transported injured	Male	59	70	20	57
	Female	25	30	15	43

Table 2
The types of injury in the two railway accidents of Haftkhan and Amravan.

Accident	Number of injured transported to the hospital by EMS	Types of injury/injuries	N	%
The Haftkhan accident	27	Blunt Trauma	21	77.7
		Fractures and Lacerations	5	18.5
		Amputation	1	3.7
The Amravan accident	35	Blunt Trauma	30	85.7
		Fractures and Lacerations	4	11.4
		Amputation	1	2.9

Table 3
The rapid assessment form by the pre-hospital emergency team in the Haftkhan train accident (29).

Assessment team authority's name: EMS1	Location: Haftkhan region, Damghan, Amirieh county	Longitude: E:54.18564842814054 Latitude: N: 35.84810544181334
Date: Nov 25, 2016 **Time of departure:** 7:35 a.m.	**Time of arrival:** 9:10 a.m.	**Type of accident:** the collision of two passenger trains
Possible extent of damage and wreckage: Four halls of two passenger trains		
The situation of the pre-hospital emergency units and hospitals of the region:		
The estimated number of affected people: 600	**The estimated number of injured:** 140	**The estimated number of casualties:** 70
The number of ambulances present at the scene: 8 (including Red Crescent ambulances)	**The type and number of required ambulances:** At least one bus ambulance and 30 ambulances	**Possible need for air rescue:** Yes
The number of required advanced rescue bases: Unknown.	**Possible need for a portable hospital:** No.	**Other requirements:** Railway rescue, aircraft fire extinguishing system
The recommended location for the incident command post: The site of the incident, the Amravan railway station	**Recommended locations for staging area:** Unknown.	Access routes: ✓ The access route of Amravan station from Damghan ✓ The access route of Amravan station from Semnan-Amirieh Road
Special considerations and explanations: Due to the impassibility of the accident area and the blockade of the nearest access route, the time of the arrival of the first EMS team on the scene was 1 h and 35 min after the accident.		

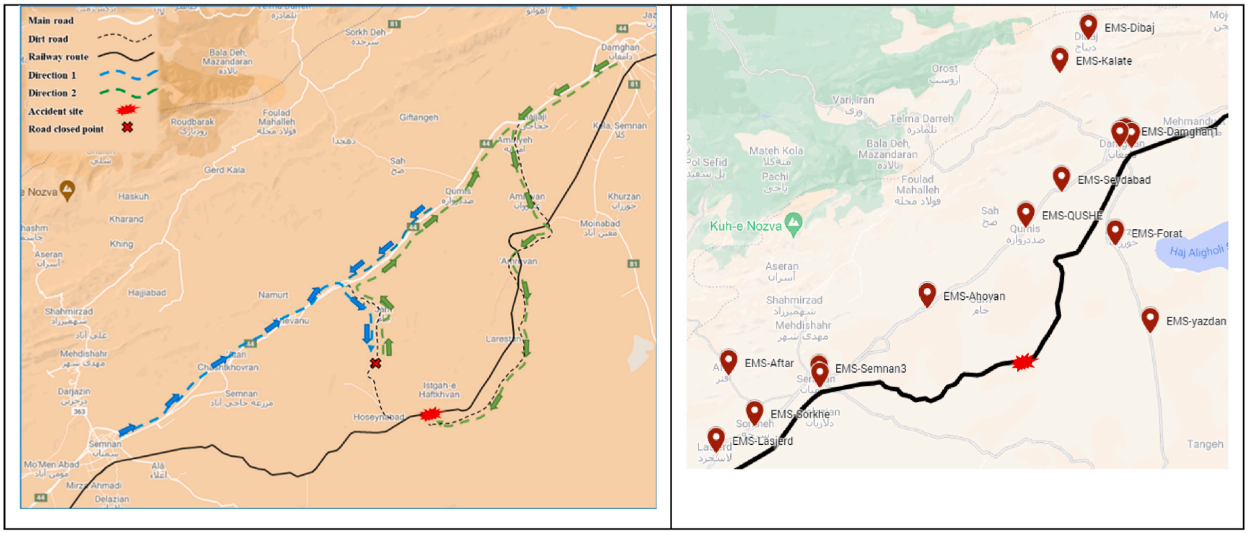

Fig. 4. (a) The access route to the accident site, (b) EMS stations in the Damghan-Semnan area (17 posts).

According to the interviewees, the process of dispatching the right teams from right road according to the conditions of the accident were not done effective.

Besides that, interviewee informed there was weak coordination among first responders (EMS team, RCS team, and firefighters) at the site of the accident which lead to the delay in rescuing the injured hence increasing the mortality rate of injured.

4.2.2. Response to the amravan accident

Reports indicate that this accident was reported to the EOC of SUMS at 22:24 who sent an ambulance bus and 12 EMS ambulances to the site of the accident. Following this, 9 rescue teams from the RCS were sent to the site of the accident. An on-site safe place was designed by Red Crescent paramedics as first responders to deliver the injured to the EMS team. Out of 37 injured in this accident, 35 people were transported to the hospital by ambulances and the other two were outpatients injured. Three ambulances from Semnan were present as support ambulances until the end of the mission. This accident held out an example of a relatively better response as borne out by fewer casualties.

2 of the interviewees who were present at that site, stated due to some circumstances like the proper access route and site of the accident being the passenger station, no additional hazard like fire and fewer injuries and mortality, this accident was easier to manage. The EMS teams arrived on time and the triage and transportation of the injured were done quickly.

Onn the other hand, Because of the lack of systematic recording and documentation of this accident, there is no detailed information about response processes. Interviewees share the same opinion that better record keeping of the accident and its response by emergency responders could have offered insights to policy planners for implementation of learnings from this accident to future accident scenarios. This opportunity was missed on account of non-record keeping.

5. Discussion

The analysis of this research showed that the lack of an integrated EOC among the responding organizations appears to be the major cause of the lack of coordinated response. One of the main objectives of the EOC is to coordinate [30]. The EOC is the nodal point for coordination of the entire emergency response process [31] and an integrated EOC coordinates the multi-agency response to an accident into an effective and efficient response [32,33]. Three studies mentioned the word “regional-level EOC” or “county-level EOC” which is made up of representatives from a range of organizations including fire, police, hospital, utility, RCS and etc. [30,34,35] and in our study, it can be considered as an integrated EOC in disasters for a coordinated response.

Our findings showed that these following challenges led to lack of coordination amongst first responders (EMS team, RCS team, and firefighters) specially in Haftkhan accident.

First of all, in Haftkhan accident, the response was delayed by 95 min due to issues like the blockage of the main accessible road and lack of effective information sharing between the first responder teams. Khademi et al. (2018) showed that good accessibility to the site of an accident is an important factor in determining an effective response [17] but Haftkhan being away from the main city with poor accessibility led to mismanagement. In addition to this, the lack of information sharing about blocked accessible road to the accident site between the EOCs of RCS, EMS and fire fighter was another reason for delay. Studies have shown that one of the most important functions of an EOC is collecting required information and distributing the collected information [32,36,37] but it seems this was not done in this case.

Also, in another study conducted by Jahangiri et al. (2018), about the Neishabur train accident, the need for immediate medical intervention and time was considered as an important parameter in reducing human and financial losses [18] which was not true for this said case.

The two factors of time and coordination in the process of dispatching first responder teams according to the conditions of the accident are considered critical factors for the effective response [38]. In this study, our findings showed that the problems caused by the dispatching were related to the lack of coordination between the responding organizations. Therefore, lack of coordination between first responders, unified and centralized information sharing could improve with an integrated EOC.

The other function of an EOC is to provide credible and factual information to the public and media organizations [37]. Also, it is the nodal point of accident information sharing to the mass media and the public [32]. Our findings show that despite the fact that there were 3 organizations with 3 ICSs charts, 3 EOCs, and 3 public information officers, the golden time to inform the public and next of kin of the victims was lost.

Synchronization between EOCs is very important for managing response [37] while this was not true in Haftkhan. As mentioned in the results, there was lack of information with respect to the type of injuries and other details of the victims who were transferred by other first responders like RCS teams. Only the numbers were mentioned.

Challenges associated with coordination during crisis response are well documented via lessons learned from disasters in the real world [39,40]. Lack of coordination between first responders, non-unified, decentralized information management, and poor organizational interactions in the deployment of relief teams appear to be deficiencies identified from our research. Establishing an integrated emergency operations center would accelerate and improve these functions.

Railways is one of the most sustainable forms of transportation [41]. Evans in 2003 and Rautji in 2004 in two different studies showed that train accidents, although relatively infrequent than road accidents, are more likely to result in death or serious injuries in the victims [42,43]. According to Evans in 2011, human error was the most common cause of rail accidents [44]. Eftekhari et al. in their study found that accidents that happened in Haftkhan and Amravan regions were found to have been caused on account of human error but the study did not examine the response phase [14]. The focus of our research was finding the deficiencies in the response phase and suggesting improvements for the management of similar kind of accidents in future.

6. Conclusion

Accidents and in specific rail accidents are inevitable in today’s world of fast-moving transportation. However, it is the effective response to such accidents that could mitigate the adverse impacts of such accidents. In Iran, there are several organizations such as

EMC, police, firefighting, and RCS who are responsible for the management and mitigation of such accidents. An analytical study of the Haftkhan and Amravan railway accidents showed that the lack of an integrated EOC lead to uncoordinated response resulting in mismanagement. A comprehensive response to such events through inter and intra-organizational coordination, implementing unified standards for response and robust information management, will not only save time, cost, human resources but also mitigate the adverse consequences of such events in future.

Based on the lessons learnt from these accidents, the following policy formulations are advised for a better response to such events in the future.

- ❖ Integration of EOCs between different agencies for information sharing, coordination and management of similar kind of accidents in future.
- ❖ Better record keeping of the accident and its response by emergency responders could have offered insights to policy planners for implementation of learnings from this accident to future accident scenarios.
- ❖ Developing and practicing an integrated and unified ICS (Incident Command System) for providing high-quality coordinated responses at all levels for the management of national, regional, and local disasters.
- ❖ Continuous and periodic assessment of access roads to railways, especially during the winter season and in regions with potential/propensity for flooding.
- ❖ Prompt and accurate broadcasting of the incident news in the official media while maintaining the principles of risk communication.
- ❖ Prompt announcement of a specific point of contact/phone number with multiple lines at the response center, through which passengers' families can keep track of the status of their kin.
- ❖ Equipping trains with satellite phones for emergency conditions considering the blind spots of mobile phones and wireless systems on some routes with poor network connectivity.
- ❖ Equipping all passenger trains with an emergency hammer and instructions on its use along with periodic checks to ascertain its availability.
- ❖ Installing fire extinguishers and providing instructions on how to use them.
- ❖ Well documented and clearly defined work distribution defining explicit work charter of each response team stakeholder in the EOC and ICP (Incident Command Post).
- ❖ Installing a camera in the train's corridor to post facto investigate more accurately the various phases of accidents and draw lessons to avoid possible railway accidents in the future.

Authors' contribution

KJ, FSH Conceived and designed the project; FSH, PQ, AF Performed this research, KJ, FSH, DCH Analyzed and interpreted the data; FSH, PQ, AF Contributed analysis tools and data; All authors listed have significantly contributed to the development and the writing of this article.

Data availability statement

The authors do not have permission to share data.

Declaration of competing interest

The authors declare that they have no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e15599.

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