Chapter 2

Literature Review

Disaster management and emergency response have been extensively studied and have received significant focus in operation research from past several years. The research problem presented through the thesis is basically related to the area of Disaster Management and network designing for emergency response for a railway system. Therefore, the literature review is presented in the sequence of the steps taken to identify the research gap and solutions presented in the thesis. The rest of the chapter is organised as - Methodology adopted for literature review in the relevant area is presented in section 2.1 followed by the literature review for reliance and vulnerability of railway network in section 2.2.The literature for efficient emergency response has been reviewed in section 2.3. The literature pertaining to specific areas of network design for emergency response in railroad application has been reviewed in section 2.4. Section 2.5 contains the literature on emergency response network design under stochastic inputs. The literature pertaining to simulation with special focus on railway application has been reviewed in section 2.6 The section 2.7 covers the gap identified in the extant literature. The conclusion of the chapter is presented in Section 2.7.

2.1 Methodology for Literature Review:-

In the preparation phase, evaluation of bibliometric material was carried out. Initially, online resources like 'Web of Science' and 'Google Scholar' databases and other popular sites were explored to collate the relevant literature in related fields by searching important keywords within titles, keywords, and abstracts. The search was restricted to prestigious journal papers and good quality conference papers published between 2010 and 2023. Various software like

Mendeley, Zotero etc. were used to organise the research papers and articles in the order of their relevance and relation with the research idea being undertaken in this study. However, due to the random search mechanisms, many less relevant or irrelevant articles were included in the initial results. Consequently, manual reviews were conducted for the titles and abstracts of each article to cull out the most relevant papers and a compressive directory of such research articles and papers were made as personal repositories .

Additionally, during the literature review process, numerous relevant cited papers, including some highly cited papers appearing with low impact factor journals were identified and included . Employing a snowball sampling approach, a significant number of important articles were further collected.

In total 451 papers consist of study in the field of resilience, disaster management and post disaster activities including relief and rescue operation. These included the specific papers addressing the particular branch of study on relief operation on a railway network. After narrowing down the targeted area for the research work the focus of literature was diverted to the solution methods being employed on solving similar problems. For which, extant literature was separately explored that included the literature on simulation study, multi-objective problem and stochastic modelling. Along with this the literature on multi-criteria decision making techniques is also explored. The papers and journals which were found relevant are mentioned in the subsequent chapters as found suitable.

2.2 Resilience , vulnerability of Railway Network-

Transportation infrastructure is vital for the functioning of society and the economy. Increasing demand for transportation of both human and goods leads to greater congestion in railway networks, making them more interdependent and complex to manage.

This review section of the chapter aims to define 'resilience' specifically within the context of the railway transport system and provides a comprehensive, state of art review of research on the same. As with most social systems, the transportation system faces all types of risks and disruption, and losses are considerable when the system reaches to a state of breakdown. Out of various vital components of a transport system, transportation infrastructure is the most critically affected by such breakdowns, which directly leads to network non-functionality and loss accessibility and continuity of the flow. For a long time, the most important parameters for evaluation of transportation system performance included resilience, vulnerability, robustness, survivability and reliability. Among them, the most appropriate and representative parameters are vulnerability and resilience. These two can cover almost the entire scope of transportation system performance (TSP). Therefore, this section is primarily dedicated to the research progress on the subject of vulnerability and resilience in the field of transportation in recent years.

The vulnerability of transportation systems holds profound implications for our daily lives. However, a universally accepted and comprehensive conceptualization of transportation vulnerability remains elusive. The exploration of transportation vulnerability and reliability gained traction following the 1995 Hanshin Earthquake (Bell et al. 2008). (Berdica 2003) pioneered a definition for transportation network vulnerability, conceptualizing it as a susceptibility factor that could significantly degrade the service standards of road transport

networks when impacted by events. Subsequently, (Yap et al. 2018) have developed a 'methodology to identify the most vulnerable links in the multi-level public transport network'. They have also quantified the societal costs of link vulnerability for the links identified through above methodology. In this study, in contrast to the traditional 'single-level network' approaches, an integrated, total 'multi-level PT network' is considered for identification of vulnerable links and quantification of them.

Amongst the review articles found in the extant literature, some articles mainly focus on the field of resilience. (Bešinović 2020) reviewed research progress on the resilience of rail transit, 'focusing on quantitative methods and indicators'. Leobons et al. (Leobons, Gouvêa Campos, and Mello Bandeira 2019) summarized the 'resilience metrics of urban transportation systems and proposed a framework for the use of these indicators', while Hosseini et al. (Hosseini, Barker, and Ramirez-Marquez 2016) analysed the 'resilience of the whole engineering system' by dividing approaches into qualitative and quantitative assessments. Others consider more aspects, such as 'resilience and vulnerability'. (Mattsson and Jenelius 2015) summarized recent research on the 'resilience and vulnerability of transportation systems by distinguishing different modes of transportation'. In contrast, Reggiani et al.(Reggiani, Nijkamp, and Lanzi 2015) discussed 'the differences and connections between traffic resilience and vulnerability with connectivity as a bridge'. Through a specific case, (Gu et al. 2020) analysed the 'similarities and differences among the reliability, vulnerability and resilience of the transportation network'. In the above research, some analysed one aspect of transportation modes, some described the two concepts separately. Most relevant work on the subject of resilience, vulnerability and reliability is summarised in table no. 2.1

Table No. 2.1

Analysis of Transport System Vulnerability and Resilience in Literature

Reference	Vulnerability	Resilience	Reliability.
Husdal (2004)	√		√
Reggiani et al. (2015)	√	√	
Mattsson and Jenelius (2015)	√	√	
de Oliveira et al. (2016)	√		√
Zhang and Zhang (2019)	√		
Berdica (2002)	√		
Tamvakis and Xenidis (2012)		√	
Reggiani (2013)		√	
Hosseini et al. (2016)		√	
Wan et al. (2018)		√	
Gu et al. (2019)	√	√	√
Leobons et al. (2019)		√	
Zhou et al. (2019b)		√	
Be˘sinovi´c (2020)		√	
Shouzheng Pan (2021)	√	√	
M. Z.Serdar (2022)		√	
Angela Stefania (2024)		√	

2.3 Efficient Emergency Response-

According to (Simpson and Hancock 2009) ‘Designing an effective and efficient emergency response system has been a topic of interest for many researchers and has received enough attention in the area of operations research’. The most studied application areas for emergency response are the ‘location of ambulances’, ‘hospitals’, ‘fire stations’, ‘law enforcement agencies’, and location of facilities to serve the large-scale emergency or disaster. There are many recent reviews available for a closer look at the contributions and trends in the emergency response system designs for disaster management/humanitarian chains. Altay and Green (Altay and Green 2006) reviewed ‘the works in disaster operations management’,

Caunhye et al. (Caunhye, Nie, and Pokharel 2012) reviewed ‘the optimization models’ in the domain, and Başar et al. (Başar, Çatay, and Ünlüyurt 2012) provided an ‘extensive and focused taxonomical review of the literature for emergency service station location problem’. Bélanger et al (Bélanger, Ruiz, and Soriano 2019) presented an ‘overview of the works on location, relocation and dispatching of an emergency medical vehicle’.

In addition to the review papers appearing in the literature, following papers have been found to have contributed in the area of disaster management which is also the central theme of the work undertaken in this thesis. Marianov (Marianov and Marianov 2017) addressed ‘a few successive location models for designing of medical and firefighting systems’, and Khalilpourazari and Arshadi Khamseh (Khalilpourazari and Arshadi Khamseh 2019) have proposed a ‘bi-objective emergency blood supply chain network design during earthquake considering earthquake magnitude’. (Trivedi and Singh, 2018)) provided a general overview of location problems in humanitarian relief chains while Jiang et al. (Jiang and Yuan 2019) focused on emergency logistics in large scale disaster events. Davoodi et al. (Davoodi and Goli 2019) has proposed an ‘Integrated relief model based on covering tour’, Pouraliakbarimamaghani et al.(Pouraliakbarimamaghani, Mohammadi, and Mirzazadeh 2018) have proposed ‘a multi-objective location and allocation model in mass casualty event response’. The general description of the location problem for Humanitarian Supply Chains can also be found in a recent book chapter by kara and Santa (Santa González et al. 2020). There are very specific reviews available such as contribution by (Kovacs and Moshtari 2019) who focused the methodological perspective of research in a humanitarian setting; (Esposito Amideo, Scaparra, and Kotiadis 2019) who addressed the critical issues in locating the shelters and evacuation procedures during disaster operations.

It is important to highlight that most of the above engagements in the literature explored so far in the field of disaster management domain is sectors specific, such as marine Razi et al. (Razi and Karatas 2016) , 'offshore oil and gas' Brachner et al. (Brachner, Stien, and Hvattum 2019), and Mohri et al. (Mohri, Akbarzadeh, and Sayed Matin 2020) are 'road accidents' and road transportation disaster management . Similarly, numerous studies have been done in the past for efficient emergency rescue operations, including the deployment of ambulances and the location of medical relief during the calamitous events such as Berche et al. (Berche et al. 2009) have studied 'the behaviour of complex networks under failure or attack'. The analysis presented in this paper focuses on the effects that defunct or removed/disrupted nodes have on the properties of public transport networks. Vulnerability criteria have been driven by simulating different directed attack strategies. (Brown and Dawson 2016) have introduced 'a quantitative resource model that embeds input-output relationships of supply and demand within a spatial network model', which enables the impacts of a spatial hazard, such as a flood, to be evaluated. The analysis corroborates with observations that 'a single flood event can disrupt the movement of resources far beyond the flooded area'. Disruption of critical sectors can lead to a cascading effect of collapse of the entire system, given certain predefined conditions. It further suggests the resource management strategies, such as diversifying supply chains, decentralisation of industrial clusters and development of local warehouses have shown to alleviate the magnitude of the initial impact, and slow the propagation of the disruption. Kelman et al. (Kelman and Gaillard 2016) describe "the importance of vulnerability and resilience research for contemporary investigations involving climate change". They have also suggested ways forward without disciplinary blinkers. Vulnerability and resilience as processes are explored alongside critiques of the post-disaster 'return to

normal' paradigm. In another study, McDaniels et al. 2008 have noticed that the resilience of complex systems is a vital concern for the system managers. The article describes the resilience within infrastructure systems, after an extreme event such as an earthquake. In this research, a conceptual framework for understanding the factors that influence the resilience of infrastructure systems have been developed to address the resilience in terms of two dimensions: robustness (the extent of system function that is maintained as consequence to the disaster) and rapidity (the time required to return to normalcy i.e. full system operations and productivity). The paper also proposes a framework through the use of flow diagrams for understanding the type of critical decisions that can be pursued within infrastructure systems to reinforce above two dimensions of system resilience.(Zhu et al. 2016) , have found that "the hurricanes Irene and Sandy had a significant impact on New York City". The impact of the calamitous event was devastating damage to the New York City transportation systems. It took days, even months to recover. This study explored post hurricane recovery patterns of the roadway and subway systems of New York City on the basis of data for taxi trips and for subway turnstile ridership. The methodology proposed through this study is applicable to evaluate the resilience of transportation systems with respect to natural disasters. The government agencies may find it useful and insightful into emergency management. Yan et al. 2021 offer rescue plans for emergency vehicles on an arterial road caused by accidents. In this study, a rescue path plan for emergency vehicles based on Markov's decision process is proposed. The rescue route proposed by their work claims that the arrival time to the accident site is 67.1%. Similarly, (Duan, Wu, and Xiong 2022) provides a "swarm algorithm for emergency rescue of traffic accidents". In particular, the study proposes a bi-stage

optimization model and algorithm to reduce the emergency response time and control the adverse impact of traffic evacuation on background traffic.

2.4 Emergency Response Network Design for Railroad Applications :

Despite the vital importance of the railway system for any country, it is surprising to note that the relevant studies are rather limited. "The limited engagements are more pronounced in accident analysis and risk assessment", (Accou and Reniers 2019; Liu et al. 2020), and only a handful of work in the location of emergency response facilities is available. In this studies Accou et al. describe the SAfety FRactal ANnalysis (SAFRAN) framework that is developed to guide investigators to explore the composing elements of an SMS in a natural and logical way for accident investigation. Cheng et al. (Cheng and Liang 2014) has proposed "a strategic model for the accident rescue problem for the railway network". They considered probabilistic rescue demand, independent busy fractions of ambulances, and the corresponding risk levels in railway segments. In a similar work, Adlaon et al. (Adlaon, Tejada, and Fajardo-lim 2020) proposed "application of the maximum expected coverage location problem" for siting ambulances to attend to the victims of traffic accidents in Metro Manila. Zhang et al. (Zhang, Jia, and Qin 2018) have presented a measure for selection diversity for Emergency Medical Service. This research is experimented for Metro Stations in Beijing. The work primarily focuses on the availability and vulnerability of ambulance locations for the emergency service in the metro network. Note that these works are limited to metro or urban railway networks and are not amenable to a large geographic area subject to disruptions from accidents and other forms of disasters. The latter calls for different types of special and dedicated relief facilities such as cranes, facility for medical attention and rescue operations and other technical equipment for restoration back to normal state. These critical assets needs to be

positioned strategically so that adequate coverage within the specified time could be achieved. The study by Diab et al. (Diab and Shalaby 2020) aims at “understanding the impact of outdoor track segments (or open-air sectors) of the metro system and weather conditions on the number of service interruptions and the magnitude of resulting delays at the stop level”. The paper offers policy makers and planners with useful “policy-relevant information” related to the impact of outdoor tracks and weather conditions on the metro system interruptions. This information could be used to support higher capital investment decisions, when planning rail transit systems to achieve the system resilience.

There are some applications focused on transportation of hazardous materials. For example, (Verma 2009) assessed the “cost and expected consequence approach to planning and managing railroad transportation of hazardous materials”, while (Verma, Verter, and Gendreau 2011) studied “the tactical planning model for railroad transportation of dangerous goods”. In a recent work, Vaezi et al. (Vaezi, Dalal, and Verma 2021), proposed “a two-stage stochastic programming model to determine the location of response facilities and equipment packages to be stockpiled to respond to rail hazmat incidents”.

It is pertinent to note that the above do not cater to the railways' requirement for locating and transporting the relief equipment to meet the eventuality effectively, whereas the limited engagements focused on metro rail system or urban railway networks. These works are not applicable to a large geographic span subjected to disruptions or complete breakdown of the flow, from accidents and other forms of disasters. This is because railway accidents are unique, and calls for different, special and unique types of relief facilities designed to cater railway related emergencies. The nature of the disaster on a railway network varies in frequency, and so does the degree of implications it has for the overall surrounding environment. The severity

of it also varies with relative effect on humans or material affected. As already mentioned in the previous section, (Bešinović 2020) has undertaken extensive literature survey on resilience of a railway network and identifies the rising trends in the application of data driven approach in the post disaster management in railways. This study sets the stage for future direction of research in the area of disaster management in railways. There has been ample research conducted in the field of analysis of the cause of an accident on a rail network. In particular, along with the unique and complex nature of operational requirements, the peculiarity of the accident and the accessibility of location during an accident in railways are the primary factors in rescue operations. Usually, the location is not accessible by any means other than the railway network itself (Reggiani et al. 2015). So, the requirement for disaster management or accident attention also require special treatment. It has been observed from past railway-related accidents data that the requirement of such rescue operations is quite different from road-related rescue operations e.g. an accident may happen at a remote location where no other option is available and the rescue solely depends on the response facility through the rail network.

To the best of our knowledge, (Bababeik, Khademi, and Chen 2018) is "the first work that has attempted to study the location of emergency response facilities in the railway network". This work is the first systematic attempt for decision location keeping operational parameters and other strategic constraints influencing the location of the emergency response facility on a railway network. Mishra et al. (Mishra, Mishra, and Abhyuday 2022) is another paper which attempts to address the problem of locating emergency response facilities. However, this paper does not consider the actual parameters influencing the location decision for an emergency

response facility. This paper is based on the concept of 'betweenness and centrality' which considers only clusters of the nodes on the network and their distance.

Bababeik et al. have proposed "a bi-objective mixed-integer deterministic model to determine optimal location and allocation of relief trains in a vulnerable railway network to increase its resilience". In this study, the 'demand' of the relief trains was assumed to be on every point (nodes and links) of the network. An augmented $\varepsilon-$constraint (AUGMECON) method is applied to solve the bi-objective optimization program, with the objective to maximize coverage and minimize response times. But this study is conducted for Iran Railways where operational conditions are completely different from that of the conditions in Indian Railways. In this study the accident relief train has been considered as a single consist. Every component of which needs to move together as one unit whereas the relief facility in Indian Railways is considered as the three separate entities known as 'Accident Relief Train', 'Accident Relief Medical Van' (ARMV) and Crane. They can move in combination of the units or a single unit depending on the actual requirement of rescue and relief at the site. The location of these facilities is primarily dominated by the demand of the equipment for rescue operation, which depends upon the type and intensity of the accident.

2.5 Emergency Response Network Design Under Stochastic Inputs :

It is also a noticeable fact that due to the inherent uncertainty in the problem setting, two-stage stochastic programming is a method of choice of many researchers working in the domain of location problem for humanitarian logistics/emergency response systems. (Grass and Fischer, 2016)) has aptly summarized the state-of-the-art literature of the last decade in their review paper. It is important to note that most of the aforesaid literature pertains to the disaster management domain in general such as (Noyan 2012) and Rath et al. (2016) or in

specific sectors, such as marine (Razi and Karatas 2016b), “offshore oil and gas” (Brachner, Stien, and Hvattum 2019b), and (Mohri, Akbarzadeh, and Sayed Matin 2020b) on road accidents. Several recent studies adopted the two-stage stochastic modelling technique to solve the temporary/permanent disaster relief facilities (Boonmee, Legsakul, and Arimura 2023; Oksuz and Satoglu 2020). In a recent review, (Yáñez-Sandivari, Cortés, and Rey 2021) explained the significance and need of stochastic modelling for Humanitarian logistics operation models.

2.6 Simulation with Special Focus on Railway Application:

Simulation is a powerful tool used to model and analyse complex systems. It also has the potential to provide insight under different dynamic conditions and identify critical issues in implementing a theoretical concept by exploring various scenarios without being a costly and time-consuming real-world experiment (Jahangirian et al. 2010). In the area of simulation techniques, (Jain and McLean 2003) have proposed “a framework for integrating modelling, simulation, and visualization tools for emergency response”, which is the basis for the methodology development. "This paper introduces a conceptual framework that divides the simulation and gaming solution space for incident management into standardized components. A review of recent literature is conducted to identify related models and/or simulators available for each defined component. The proposed components and the literature review provide an initial foundation for developing a comprehensive model of the incident response domain." Overall, disaster operations management focuses on the use of simulation methodology, which can be classified into Spatial Decision Support System (SDSS) and Discrete Event Simulation (DES) models (De Silva and Eglese 2000)). In this research, simulation modelling and spatial technologies are coupled to design a system that would

combine powerful capabilities of both to aid disaster preparedness. SDSS mainly focuses on the integration of GIS applications with forecasting early warning of the event. In the Discrete Event Simulation (DES), the system is modelled as a series of 'events' that occur over time. It assumes that there is no change in the system between the events. Numerous works have been done in DES including,(Homer and Downs 2008) which have researched a flexible geographic information system-based network flow model for routing. In their study, scenario visualization is made possible by identifying the locations of the localized distribution centres and including multiple policies. Similarly, the "Disaster Digital Twin" platform consisting of a fusion of real-time hazard simulation to support disaster response teams in the anticipated disaster viz tsunami is proposed in a study proposed by (Koshimura and Mas 2023.). "This study explores the use of social sensing to identify dynamic exposed populations, as well as the application of multi-agent simulations to optimize the allocation of disaster response efforts and strategies". In another study (Ünlüyurt and Tunçer 2016) have "evaluated Emergency Medical Service by simulating a locational model". The authors have conducted simulation analysis to evaluate the performance of optimal location of ambulances by using optimization tools and the 'real coverage' of population was estimated in this study. Similarly, (Basaglia et al. 2022) have "studied the sudden arrival of a high number of injured people to a hospital following a major disaster". "Their research examines various emergency plans, conducts interviews with healthcare professionals, and reviews extensive literature to develop two Discrete-Event Simulation models for a hospital digital twin, depicting operations under routine and post-earthquake conditions."

Similarly(Ceferino et al. 2020) "have demonstrated how plans that leverage hospital-system coordination can address this demand-capacity mismatch, reducing waiting times of critically

injured patients by a factor larger than two". In this study also, the authors have proposed a methodology to simulate the effective plans for patient transfer and allocation of the ambulances and mobile operating rooms.

From the review of these past studies, it is pretty evident that simulation techniques have proven beneficial for performance analysis of various strategies of disaster management. In railway specific application of simulation, (Goodman, Siu, and Ho 1998) traces the use of Simulators and different approaches and scales of simulation techniques being used in Railways. (Ho et al. 2002) discuss "the difficulties and requirements of effective simulation models for this specialized industrial application and the development of a general-purpose multi-train simulator". In this work, the author attempts to study integrated applications of various systems, from train movements to signalling and other allied systems. It includes the study of the performance of multiple machines installed on rolling stock through simulation of the functions of this equipment. In another application of simulation techniques in railways, the behaviour of passengers is studied in order to design the safe space required for handling the projected passenger traffic at a railway installation forecasted with rapid economic growth and an increase in the speed of trains. The study is presented by (Cao et al. 2020) Similarly, the delay in train operation due to nodes and station congestion is studied by (Kianinejadoshah and Ricci 2021). In their work comparative application of analytical and simulation methods have been done for combined railway node-lines capacity assessment.

Simulation techniques have been proven to be a validation tool for abstract concepts in various critical applications, including simulation of various complex dimensions affecting operation and visualization and planning of various critical activities during an emergency. However, there is a need for research on the application of simulation to railway accident rescue

operations, which involve complex operations and the location of rescue relief equipment. Accordingly, in this work, we have proposed to simulate the random events of accidents over a railway network and generate the demand for the resources at the time of the accident by utilizing historical data. Through this work, we have attempted to address the gap in modelling of location of accident relief trains over a railway network. The mathematical concept of optimization through simulation has been applied to a practical problem to provide a ready-made tool to a decision maker for the validation of a decision based on mathematical fundamentals.

2.7. Gaps Identified in the Literature:

A in depth review of the literature on disaster relief and rescue operation provides the following direction for the present research.

i. Most of the studies traceable in the literature consider the relief and rescue operation post disaster in the areas pertaining to natural calamity like earthquake, flood and hurricane etc. In general the deployment of ambulance, distribution of relief material like food and medicine has been the primary focus of the post disaster literature. The literature on pre-emptive efforts to mitigate the impact of disaster is abysmally small and it is almost missing in the area specific to railway owing to nonuniform administrative structure and the repercussions of an event being different in different geographical set up.

ii. In the railway specific relief and rescue literature the primary focus is once again on the relief activity managed through the resources from outside the railways network. Central point of literature is noticed to be the metro railways or sub-urban railways with limited reach and smaller network coverage. It ignores the geographical stretch and the vastness

of the railway network, which is mostly remote from the urban facilities being considered for the rescue operations.

iii. The limited engagement of the academic research on the facility location for increasing the resilience of the railway network is either found to be catering to the specific need of a particular country's railways or the operational parameters are not considered while deciding the location of the relief equipment. The limited engagement of the academics was more pronounced for the diverse requirement of the mixed traffic pattern of the rail operation, where goods and passenger trains are being operated on the same track.

iv. The unpredictable component of the accident in terms of intensity and frequency of the accident along with the location of the accident is also a challenge in the locational decision modelling for relief facilities, which is primarily missing in the extant literature.

v. The above mentioned points indicate two glaring gaps demanding serious research for the disaster management in railways. *First,* to propose strong mathematical formulation for the problem and business rules of the organisation and offer results obtained by various methods for adoption and application in the field. *Second,* to develop a tool to evaluate the effectiveness of different solution in different scenarios to capture the essence of the real world problem and the impact of the solutions on the ground .

2.8. **Conclusion:**

In this chapter, the literature falling in the domain of resilience, vulnerability and reliability of a transport network is reviewed with post disaster management of the relief and rescue operations as a central theme. In order to mitigate the impact of an inevitable accident due to technical fault or human error or due other natural or man-made possibility is explored. It is noticed that quick response to a situation arising out of an unusual event

is the only and sustainable solution to handle any unfortunate calamity. However, despite the criticality of the nature of the accident and dire consequences for operator and user both the current practice of locating the relief equipment lacks mathematical basis and the employed are inadequate for the decision of such critical nature. The existing literature is primarily replete with scholarly works undertaken to address the preparedness for disaster situations. However, major attention has been toward the medical emergency and deployment of ambulances and provision of relief storage and transportation after natural calamity. Despite railways being a critical component of societal and economic growth having potential to impact almost human aspects in the case of disruption by any means, have been largely missing in scholarly engagement. The proposed study aims to address those gaps, and recommend the optimal location of relief equipment and their deployment.

Hence, in the subsequent chapter we study the problem of locating the accident relief equipment on a railway network with the aim to provide immediate relief during accidents and other disasters hitting the railway's operation and its infrastructure.

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