# Preface

For the development of decentralized economic activities across the vast span of the geography the role of the transportation system becomes more vital in the safe transportation of passengers and goods . Railways is a critical player in the transportation matrix, leading any country's societal, and economic growth. The criticality, complexity and vastness of the railway network make it highly susceptible to accidents or disruptions and necessitate a robust emergency preparedness framework to sustain the continuous operation of the system. The disaster management plan -2009, in reference to Indian Railways, puts emphasis on preparedness to tackle any situation causing disruption to the railway network or affecting its infrastructure. It also enlarges the definition of disaster and alters the ambit of accidents on a railway network. Historically, the Indian railways have suffered a significant number of accidents annually, highlighting the need for strategically placing accident Relief facilities including Accident Trains (ART), Accident Relief Medical Vans (ARMV), and heavy-capacity cranes. These relief facilities are crucial for mitigating the impact of accidents, enabling rapid response, and ensuring the safety and recovery of both infrastructure and passengers, accordingly.

In this thesis, the optimization of the location of accident relief facilities within the Indian railway network is studied. The work encapsulates a multi-faceted approach to addressing one of the most critical aspects of railway operations. The primary objective of the research is to minimize response time to accidents and ensure efficient deployment of resources. For this purpose, optimization models including a multi-objective optimization model, a two-stage stochastic programming model have been developed , complemented by a simulation-based validation tool. In particular, the first model discusses a mixed-integer programming (MIP) model. This model integrates various conflicting objectives and strategic concerns, providing a comprehensive decision-making tool for railway authorities. The multi-objective model deals with conflictive objectives encompassing practical requirements of railways. The solution approach used for solving this model is the Augmented ε-constraint method (AUGMECON), which facilitates the generation of a set of non-dominated solutions. These solutions are then iteratively refined based on input from a decision-maker (DM) within the railway administration. This interactive process ensures that the model remains aligned with practical requirements and constraints, enhancing its applicability in real-world scenarios.

Building on the insights from the Multi-objective model, the second part of the study presents a two-stage stochastic programming model. This model addresses the decision-making process for the purchase, location, and allocation of relief assets based on historical accident data. By considering the probability of accidents and the specific demand for equipment, the model offers a unique and practical approach to optimizing resource allocation. The model's distinctiveness lies in its incorporation of historical data to calculate asset requirements, factoring in the type of rolling stock involved and the accident's severity.

The two-stage stochastic programming model is particularly effective in dealing with the inherent uncertainties of disaster management. Accidents are unpredictable by nature, and their locations and magnitudes can vary widely. By incorporating stochastic elements into the model, the research accounts for these uncertainties, providing more robust and resilient solutions. The first stage of the model involves strategic decisions

such as the purchase and initial placement of relief equipment, while the second stage addresses the operational decisions made in response to specific accidents.

As these solutions address different dimensions of the same problem, efficacy of the solution obtained remains in the realm of debate and discussion for want of validation tools. Therefore, further extension of the objective has been done to validate the decision in a real life situation. A simulation framework has been proposed as the third objective of this thesis for simulating the real life scenarios. Historical data of accidents over the representative network is considered for simulating the demand for equipment at any random location on the network. Then, a transportation model is solved as a demand and supply problem. The simulation is run iteratively creating various scenarios of the accident, hence the demand of the equipment.

Overall, this research provides a comprehensive framework for optimizing the location and allocation of accident relief facilities within the Indian railway network. By combining a Multi-objective optimization approach with a two-stage stochastic programming model, the study addresses the multifaceted nature of emergency preparedness and response. The iterative simulation and interactive decision-making process ensures that the models remain practical and relevant, aligning with the strategic and operational needs of railway authorities.

A representative network from the North Central zone of Indian railways serves as the case study for this model.

**Key-words:** Accident relief Equipment; Disaster management; Multi-objective optimization; Railways; simulation; Two stage stochastic modelling;.