OPTIMAL LOCATION AND ALLOCATION OF ACCIDENT RELIEF FACILITY FOR RESILIENT RAILWAY NETWORK.

Thesis submitted in partial fulfilment for the award of degree

Doctor of Philosophy

by

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Chapter 7

Conclusions and Scope of Future Research

7.1. Introduction :

An efficient disaster management system for rescue, relief and restoration of the system has been found to be a key factor in mitigating the impact of an eventual occurrence leading to loss of human, life and financial loss of the organization. The location of accident relief equipment is the central theme of the research to achieve the objective of quick and efficient relief. To capture the research theme sequentially, we set the problem in three different perspectives. The summary of each chapter is provided in the following section.

7.2. Chapter-Level Summary and Conclusion

Chapter 1: Introduction

This chapter introduces the definition of disaster management as accepted by various international bodies. It further delves into the disaster management act 2005 and overall framework of disaster management in India. Further, the role and responsibility of Indian Railways are discussed in reference to disaster management act, which envisaged the preparedness to meet such eventuality. Accident relief framework and its critical role in overall scheme is discussed next with broader indication towards the research direction. This research problem is identified in this chapter and the motivation to undertake such research is spelled in this chapter. Further, Research Objectives and Scope of the Thesis are also elaborately explained in this chapter. The chapter concluded with the outline of the thesis.

Chapter 2: Literature Review

This chapter reviews the literature related to problems studied in this thesis. In this chapter, we presented a review of contemporary literature for the problem classes from modelling and solution techniques perspectives. This chapter enlists the research gaps identified from the literature, which pave the path for exploration of the topic covered in the research presented through this thesis.

Chapter 3: Vulnerability Analysis and Evaluation of Relative Importance of Links in a Rail Network.

In this chapter, the vulnerability of railway networks is conceptualized in relation to their susceptibility to specific types of accidents, depending on the type of service they support, such as transporting goods, passengers, empty wagons, and other miscellaneous traffic. The importance of individual links in the network is evaluated using Multi Criteria Decision Making techniques, specifically the Analytical Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS).

Overall, the study underscores the critical role of individual network links in determining the vulnerability of transportation systems to accidents and emphasizes the need for comprehensive methodologies to assess and mitigate these vulnerabilities. The importance of the link on the basis of traffic pattern, which influences the possibility of an accident and hence the demand for specific type of equipment becomes a critical parameter in decision locating these equipment over the network. The critical concept presented in this chapter is further enhanced and utilized for designing a resilient railway

network in the next chapter. The Conceptualization of the mathematical model for optimization of location decision includes the link vulnerability.

Chapter 4: Optimal Location of Accident Relief Facilities in a Railway Network- Multi- Objective Approach.

The location of accident relief facilities is one of the most important aspects of emergency preparedness for the railways and it can prove itself vital to restoring operation and saving precious lives at the time of the accident/disaster. In the case of Indian Railways, these decisions are made based on the potential of providing radial coverage to the demand points. However, the presence of different conflicting objectives and several strategic concerns demand a mathematical approach to make the decisions optimal. The present work has proposed a multi-objective integer programming model for this problem. The proposed model is solved using the AUGMECON in an interactive fashion. Set of non-dominated solutions are presented to the decision-maker and with his inputs, the desired areas are further explored. The engagement of the decision-maker at every stage has made the exercise more relevant and shown the potential of the model to cope with various requirements of the decision-maker.

The model is applied to a representative network and the results are testimony for the achievement of the desired objective. Various insights revealed during analysis have opened new possibilities. This model has not only ensured the optimum use of the resources but also thrown us the realization of many other dimensions of the problem. Further analysing the network as a set covering model to assure complete coverage for a

given threshold limit, it is learnt that the available facilities are lesser than the actual requirement of the facilities.

The analysis has thrown open a completely new dimension of the problem for further research and study from different perspectives.

The new problem can now be addressed as an optimization problem with the objective to optimize between the 'new location to be opened' at a completely underdeveloped location by bearing the cost of development of the facility or locating more facilities at the developed and currently suitable place that entails the investment in procured of assets to enhance the coverage of the network.

Chapter 5: A Two-stage Stochastic Programming Model for Optimal Location of Accident Relief Facilities on a Railroad Network

In this work, we proposed a two-stage stochastic programming model for the decision on the purchase of assets, location of newly purchased assets or relocation from an existing place to a better and more desired location, and the allocation of relief equipment as per accident profile i.e., the actual demand of the number of equipment based on historical data has been considered over a railway network. It is distinct and unique from other works in the following ways: *First*, we have considered actual historical data for the calculation of the probability of the requirement of the asset in case of an accident. The quantitative requirement of an asset depends on the type of rolling stock involved in the mishap and the intensity of the accident. *Secondly*, the probability of the occurrence of an accident has been considered by taking the traffic pattern of the section. *Thirdly*, we have proposed an optimization program for evaluating the conflicting parameters of detention

of the train in the section viz-a-viz the cost of restoration when equipment is deployed from a specific location. The cost of purchase, installation and maintenance is considered as a fixed cost decision or a deterministic decision. *Fourth,* various scenarios of accident and demand profiles are considered, and the best solution is achieved by solving the two-stage problem. *Fifth,* the conceptual solution proposed is validated through demonstration on a railway network.

Chapter 6 :Optimizing Strategic Placement of Railroad Accident Relief Equipment: A Simulation-Based Decision Tool.

The vital realm of accident relief simulation is explored in this chapter, shedding light on the complex dynamics and intricate decision-making processes involved in responding effectively to unexpected incidents across a vast network. Through the application of Monte Carlo simulation, and transportation problem-solving, it addresses the challenges and opportunities of location of accident relief equipment and effective utilization of resources over a railway network. The interplay of various factors in real life situations has been captured through simulation modelling. The strategy of movement of one facility with another emerges as a single primary factor influencing the location decision of the equipment on the network. The study further revealed intriguing variations in asset utilization across different locations.

7.3. Contributions of the Thesis :

The thesis has addressed an important problem of locating and allocating the relief equipment over a railway network, which is motivated from the prevalent practice in the Indian railways and has taken cue for disaster management act. Mathematical models and

efficient solution techniques have been developed in this research. The key contributions of the thesis in the domain of preparedness for disaster situations over a railway network. We developed two mathematical models for strategic decision of location of the accident relief equipment in different data settings. The third model is the simulation of allocation of the equipment from their location to an accident site. In this manner a system is proposed to not only evaluate the solution found through different methods but also independent decision can be deduced by repeatedly simulating the scenarios on accident as per historical data. Following are broad contributions of the thesis.

- Although the present study is stemmed from instances and data for Indian Railway, the proposed models are generic and allow flexibility for application in the similar situation in other networks.
- The first two mathematical models are useful in demonstrating the diversity of the problem dimension and quantum of the problem. The third approach i.e. simulation is generic in nature providing the possibility of immediate utilization in any situation.
- This research further points out the lack of data-modelling and data-based decision support systems and sets the direction for collective efforts for data integrity and data validity by the software-based system.
- The thesis demonstrated extensive computational experiments to evaluate the performance of the proposed solution approaches.
- The thesis presented the interactive method for decision making where the consultative approach for practical purposes remains valid and gives larger acceptability to the computer-based decision.

- The engagement of the decision-maker at every stage has made the exercise more relevant and shown the potential of the model to cope with various requirements of the decision-maker. This mechanism and the model have the potential to prove itself as a handy tool and an intelligent assistant to the authorities' making decisions. The model guarantees the best possible solution for all possible combinations of the location of the assets.
- The thesis also provides a tool for justification of the demand for extra requirements of the assets and identifies their location also, which may be used as a handy tool for pursuing various authorities for consenting and vetting the proposals.

7.4. Scope of future research :

The thesis delivers mathematical models and solution techniques for the location and allocation of accident relief facilities, which is one of the most important aspects of emergency preparedness for the railways. It can prove itself vital to restoring operation and saving precious lives at the time of the accident/disaster. The network considered in this work is a part of a bigger network of Indian railways. Future research on a holistic consideration of the entire network of Indian railways is a way ahead for advancing the concepts proposed through this research. This avenue also calls for specialized solution approaches such as evolutionary algorithms to efficiently solve the problem due to the resulting size of the network.

In addition to this, uncertainty related to the railway accidents and actual deployment of the relief facilities needs to be explored further. The probability of an accident on the links of the rail network can be considered from the past data and the model can be revisited

using better tools for predictive analysis of the possible location of the accident and the quantum of demand it may seek in real life scenarios.

The proposed model can then be revisited, and the problem can be reformulated with different angles all together. There is continuous upgradation in type and design of the rolling stock being currently used as accident relief equipment. The emphasis being on the high speed and latest tools for relief and rescue, which may relax certain constraints currently imposed on the model. It calls for further research from this angle every time a latest technology is adopted which has potential of influencing the current set up.

This work can also be extended as a part of a broader disaster management plan that includes several players in addition to the railroad operators. Such a perspective can open avenues for emergency preparedness for other essential items, determining optimal placement of emergency health facilities in addition to the relief types of equipment, use of information and communication technology and internet of things in improving the response to the accident sites.

Alternate approaches to model uncertainty are robust optimization and/or simulation. In particular, simulation provides a practical way to consider the uncertainty associated with the location and magnitude of an accident. A simulation-based optimization framework can also be used for obtaining alternate solutions. Another research dimension would be consideration of risk in addition to uncertainty of accidents.

As we move forward, these findings can serve as a foundation for further research and practical applications in the field of accident relief and emergency response. This can be integrated with predictive analysis by use of machine learning and AI tools to forecast the

possible occurrence in future and a preparedness strategy for disaster management can be planned with a holistic approach. The mathematic model for such a huge network is bound to become massive as the number of variables increase and solution becomes increasingly complex dictating requirement of high compute power and other hardware. Therefore, use of latest methods for solution procedure by adopting large scale optimisation techniques like column generation and decomposition methods may be explored in future research for speedy conversance of optimality.

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