

PREFACE

In an era characterized by rapid advancements in healthcare and an aging population, the need for efficient and accessible healthcare solutions has never been more apparent. This fact was laid bare during the recent COVID-19 pandemic. On the one hand, where we were able to successfully develop the vaccines in record time, almost seven million people died due to the pandemic. In the case of India, with half a million COVID-19-related deaths, it was clear that a rapid improvement in the healthcare infrastructure was required. In response, the Healthcare Federation of India produced a white paper titled '*Indian Home Healthcare 2.0: Redefining the Modern Care Continuum*'. The document highlighted the benefits of a sufficiently developed home healthcare sector in providing a viable alternative to traditional healthcare services. Hence, in the current work, we aim to design and develop OR techniques to facilitate the logistics operations of home healthcare delivery, an essential part of home healthcare services. Simultaneously, we intend to provide robust solution methodologies that can be used for a wide variety of home healthcare delivery setups.

In this thesis, we consider a single-period home healthcare delivery problem, where a heterogeneous set of caregivers are to be deployed from multiple hubs to fulfill the demands of multiple patients. The thesis focuses on developing methodologies that can be useful for as many home healthcare delivery services as possible without much friction. This translates into the development of generalized home healthcare delivery models alongside efficient and robust solution approaches. Further, the selection of the objective function needs to be done very carefully. With the competitive goals of the different stakeholders and the varying

maturity levels of various home healthcare delivery organizations, any generalized model should be designed to accommodate obscure combinations of objective functions. Finally, the gaps in the existing literature on the home healthcare delivery problem regarding the more refined scheduling, multiple time windows, and contact restriction methods need to be filled. To capture these research themes, three broad sets of objectives are defined.

In the first objective, a mathematical model that can be used to represent a wide variety of home healthcare delivery setups is developed. Patients' demands are modeled in a general fashion, with as many attributes as possible. The mathematical model also incorporates the most commonly appearing constraints from the home healthcare delivery literature. Developed models can be reduced to represent more obscure scenarios by strategically omitting certain constraints or altering parameter values. The resulting monolithic home healthcare delivery model is tested on a benchmark problem set, and a method for adapting the mathematical model to the benchmark problem is provided. The modified model is found to be capable of solving the benchmark problem for 26 out of 30 instances. Two MIP-based metaheuristic, namely single-stage decomposition (SSD) and multi-stage decomposition, alongside the parallelly processed version of the genetic algorithm (p -GA), are developed. Statistical analysis is carried out to establish the appropriate niche for each algorithm. Finally, p -GA was used to find the favorable combination of objective function and 'demand satisfaction policy' for an overburdened healthcare system. In the second objective, we extend the monolithic mixed integer programming model to a multi-objective setup. The multi-objective variant of the model is developed to accommodate the competitive goals of the different stakeholders from a home healthcare delivery setup. Twelve criteria are initially

identified for optimization. These criteria are eventually categorized into five objective functions based on the requirements of three stakeholders (patient, caregivers, and management). Multi-objective metaheuristics like NSGA-III, MOPSO, and MOGWO are used to produce diverse Pareto solutions. NSGA-III with single point crossover operator is found to be the most efficient for solving the multi-objective home healthcare delivery problem. The Pareto set obtained from the same is also tested for the 50% variation in service time and travel time. Approximate Pareto front is found to be robust, with only 11% to 17% maximum degradation in key quality indicators.

Further, as the third objective, the thesis adds novelties to the home healthcare delivery problem. First, an extensive literature review identifies some gaps in the existing literature. Constraints to restrict unnecessary contact between patients and staff have been added to the monolithic mathematical model. 'Contact restriction' constraints use a prescribed maximum number of allowed contacts as a hard limit for each entity. Similarly, models incorporate the 'inconvenient time window' as an example of multiple favorable time windows where a visit can only be scheduled into one of the time slots. The thesis also presents a soft implementation of the 'inconvenient time window' constraints by allowing visits to be scheduled inside it. The extent of violation of the 'inconvenient time window' is subsequently minimized as a part of a novel objective function - The patient's inconvenience due to improper scheduling. Another aspect of the same objective function focuses on improving the quality of schedules when scheduling multiple visits to a single patient by clubbing the scattered visits into the minimum possible number of sessions.