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Planning of home health care activities with uncertain service time

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Mots-clés : *Vehicle routing problem, multi-objective optimization, uncertainty.*

1 Introduction

Demand for Home Health Care (HHC) has been increasing in recent years as the preference of the elderly for aging in place has grown. Caregivers move to patients' home and provide care services that range from nursing care to specialized medical services. It is based on logistics network and helps to decrease hospital admissions and duration while patients can accept treatment in familiar environments. The short-term daily activities in HHC services are shown in Figure (1). Once patients have their medical treatment prescription and when service time, staff qualifications are defined, decision-makers assign qualified caregivers to patients and schedule for each caregiver given considering the available time of patients. Finally, each caregiver performs the medical service, starting from health care facility, visiting patients in a planned sequence before returning to the origin. These activities in home healthcare are usually formulated as a vehicle routing problem with time windows (VRPTW) which is NP-hard and aim to plan routes with minimum cost.

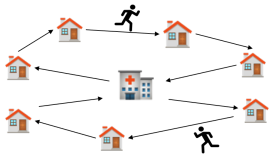

FIG. 1 – Typical daily activities in HHC

In real-life services, common considered features include time windows and precedence of patients, different staff qualifications which makes the model more complex. Besides the operational constraints, the uncertainty is prevalent in such applications. The caregiver may arrive or leave patient's home earlier or later than the previous appointment time as the caregiver is scheduled and routed in a static way. The time that the caregiver spends on the road is relatively fixed unless big traffic accidents happen occasionally. The arrival time and service end time are hard to predetermined mainly because the service time for each patient with unstable health status changes more often. Large delay for patients degrades the service quality and patient satisfaction while large waiting time for caregivers leads to increasing working hours.

The goal of this work is to propose a method and a model enable to manage home healthcare activities with uncertain service time.

2 Related works and contributions

The recent advance in the HHC research has moved to explore the multi-objective optimization method to obtain a Pareto frontier instead of a weighted objective function. Cost, service quality and workload balance are considered in some papers. A memetic algorithm and an artificial bee colony metaheuristic were proposed to get non-dominated solutions to provide effective alternative solutions for managers in HHC companies [1, 2]. Some researchers assumed that uncertain travel time and service time follow normal distributions, then the penalty of exceeding time window can be expressed by the parameter of the distribution. A scenario-based method is more often used to approximate the expected value function of $\mathbb{E}[R(x,\omega)]$ by corresponding sample average function $z(x) = \frac{1}{N}\sum_{i=1}^{N} R(x,\tilde{\omega}^i)$, where $\Omega = \{\tilde{\omega}^1, \tilde{\omega}^2, ..., \tilde{\omega}^N\}$ is a set of realizations (scenarios) of the random vector ω [3]. Min-max objective was applied to generate robust solutions that withstand the uncertainty in worst case [4]. In [5], they propose a stochastic programming with recourse model to tackle the routing problem in HHC. But combining multi-objective and uncertain service time into one model is still scarce in the literature.

In summary, an extension to activities planning problem in HHC is proposed which is multi-objective, with uncertain service time and considering classic operational constraints. To address this problem, a modified Multi-Directional Local Search (MDLS) method has been developed to get Pareto optimal set. The main contributions are outlined as follows :

(1) A new optimization model considering both travelling cost from the perspective of decision makers and patient satisfaction is formulated as a multi-objective problem. Fewer times that service end time is beyond the time window indicate better patient satisfaction.

(2) The uncertain service time is taken into account by the sample average approximation method. Recourse actions are taken when the arrival time exceeds latest time of time window due to uncertainty.

(3) An Adaptive Large Neighborhood Search (ALNS) and a metaheuristc algorithm based MDLS is proposed to get Pareto optimal set. Six kinds of destroy and repair operators are embedded in ALNS.

(4) A hyper parameter tuning method is integrated with proposed model in order to adapt the model to various data sets automatically.

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