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Research on the assignment of elderly care service personnel with time window constraints

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A R T I C L E I N F O

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A B S T R A C T

As the population continues to age, there is a growing need for elderly care services. In China, home care is widely embraced as a preferred method of caring for the elderly, and it has a promising commercial outlook. The strategic allocation of Elderly Care Service Personnel (ECSP) is a crucial component of the operational procedures for home care services. By strategically assigning elderly service personnel, it is possible to enhance the satisfaction and simultaneously minimize expenses. The issue of rationalizing the assignment of ECSP in the face of restricted resources is a genuine challenge that requires a solution, given the many types of elderly service demands and the skill requirements and time limits of certain projects. This study presents a strategy for assigning personnel on an hourly basis, taking into account time frame limits. This method involves several steps. Firstly, it involves assessing the specific service needs of the elderly, including the required door-to-door service time, service level, and gender preferences. Secondly, it calculates the service satisfaction and service operation cost of the Home Care Service Platform (HCSP) separately. Finally, it constructs a multi-objective elderly service personnel assignment method. This method aims to minimize the ECSP 's travel time and wasted time, maximize the satisfaction of the elderly by considering priority levels and ECSP scores, and minimize the operation cost of the HCSP. A model is developed to assign ECSP for elderly individuals, with the goal of minimizing travel time and wasted time, maximizing elderly satisfaction by considering priority and service personnel rating, and minimizing operating costs for the HCSP. Additionally, if there are unserved elderly individuals, an optimized path model is constructed using a cross-modified genetic algorithm to obtain the optimal matching result. Ultimately, an arithmetic example is employed to demonstrate the practicality and efficiency of the strategy put forth in this research. The findings demonstrate that the model presented in this research possesses distinct advantages in comparison to other conventional models.

1. Introduction

The aging of the population is a major societal change in the twenty-first century that will impact several aspects of society, such as the labor market, the service sector, and family structure. According to the 2019 World Population Outlook released by the UN Department of Economic and Social Affairs, there has been a significant global rise in the population of individuals aged 65 and above in recent years [1]. The factors contributing to this significant rise are declining birth rates, extended life expectancies, and migration

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of the labor force. In 2020, the global population of those aged 65 and over surpassed 700 million for the first time, reaching a specific count of 723.484 million [2]. By 2050, the global population of those aged 65 and above is projected to reach 1.5 billion. Based on a poll of China's elderly population, it is estimated that there will be 191 million senior citizens in China by 2020. This number is expected to increase to 300 million by 2030 and further climb to 420 million by 2050 [3]. According to data from the seventh national census collected by the State Council, the percentage of individuals in China who are 60 years old or older is 18.7 %, with 13.5 % of them being beyond the age of 65 [4]. The phenomenon of aging has extended beyond the first cohort of industrialized countries as a result of the swift aging of the populace, and China's population is likewise undergoing a progressive aging process. Consequently, every aspect of society is increasingly focusing on the need to provide care for the elderly, leading to a growing demand for elderly care services [5].

The current classification of elderly care models consists of five main categories: Continuing Care Retirement Community (CCRC) model, family elderly care, transnational elderly care, time bank, and intergenerational learning center. The American Sun City model of Continuing Care Retirement Communities (CCRC) is a typical example that provides a range of services tailored to the specific physical needs of elderly individuals. These services include self-care, assisted care, integrated care within residential facilities, and access to a community equipped with medical staff and facilities, as well as reading rooms with books and audiovisual resources [6]. Family elderly care is a specific model of eldercare that is exemplified in Singapore and Japan. It serves as a means for sons to get the family's property or for children to be legally obligated to support their parents. Families should provide help to the elderly, and the local government will enact specific legislation to allocate funds and caregivers to families that assume the responsibility of caring for the elderly [7]. The concept of transnational elderly refers to the elderly population of the Nordic countries, namely Sweden, Norway, Finland, Denmark, and Iceland. This is a form of long-term care arrangement that caters to elderly people who are unwell or in a frail state, yet are capable of relocating to nursing facilities situated in regions with more scenic surroundings and healthier weather [8]. The time bank schedule, as demonstrated in Switzerland, revolves around the concept of utilizing the wellness and self-care of the elderly to provide care and assistance to individuals who are unable to care for themselves. Several agencies responsible for managing the model will calculate the number of service hours provided by the elderly, which will then be credited to their individual accounts inside the social security system. When aid is needed, the card can be promptly withdrawn and utilized [9]. The intergenerational learning center program is a collaborative initiative between the kindergarten and the nursing home. On a weekly basis, the kindergarten organizes an open day during which children engage in activities alongside the inhabitants of the nursing home [10]. China's population is substantial, and its population density exceeds the global average. However, the implementation of the one-child policy from 1982 to 2016 has led to a reduced number of young individuals in the current generation. This is due to the prevalence of marriages between two only children, which results in the need to provide care for at least four elderly individuals. In China, the primary means of supporting the elderly is through family-based institutions, which adhere to traditional practices. The migration of personnel who provide care for the family's children to economically prosperous regions and cities also contributes to the increase in empty nesters. China's inability to execute the traditional family elderly care model is a result of insufficient support from conventional households. Most elder individuals are hesitant to embrace institutional care, primarily owing to issues such as traditional values, societal disapproval, the present standard of institutional care, and the financial capacity of the elderly. The distinctive historical and cultural backdrop, political framework, fundamental national circumstances, and other factors in China contribute to the distinct nature of the elderly care issue and the diverse approaches to addressing it. Since 2015, the State Council, along with the Ministry of Civil Affairs and other relevant departments, have implemented various planning measures to facilitate the swift growth of the elder service industry. The style of aging among Chinese elder is typically categorized into three types: aging at home, aging in the community, and aging in institutions [11]. Home care involves utilizing professional services to provide social support for elderly individuals living at home, primarily focusing on addressing their daily life challenges. It is characterized by a decentralized workforce and personalized door-to-door assistance. On the one hand, community care centers around providing elderly individuals with day care, life assistance, home services, and emotional solace within the community setting, with the community serving as the primary source of support for the elderly. Community-based elderly care is a system that focuses on providing day care, life care, home services, and spiritual comfort to the elderly. It is centered around the community and utilizes door-to-door service and community day care as its primary forms. This approach combines professional management with the provision of services to elderly individuals in their homes. On the other hand, elderly care institutions are facilities that offer a wide range of services to the elderly, including meals, living arrangements, hygiene and sanitation, health management, and cultural, sports, and recreational activities [12]. Given the significant economic expenses and limited resources associated with community and institutional care, it is evident that home care is the preferred option for the elderly. As a result, a well-established elderly care service system has emerged in major Chinese cities, with home care as the primary approach, supplemented by community care and institutional care [13].

Providing care for elderly individuals in their own homes with the assistance of a local division [14]. The Home Care Service Platform (HCSP) is a comprehensive system that utilizes information databases, intelligent terminals, and the Internet to provide support. It integrates social resources, community elderly service facilities, and a professional service personnel team to offer a wide range of services, including home care for the elderly [15]. The objective of home care services is to enhance the living conditions of elderly individuals in their own residences and provide tailored assistance to meet the unique needs of each elder. Given that older individuals have distinct requirements, the priority and urgency of activities may vary. On the other hand, the overall home-based service industry offers a limited number of services, and any delays or cancellations in service solely impact the elders [16]. The home care market is unique due to the specific needs of older customers, with a focus on ensuring customer satisfaction and maintaining their health without any risks [17]. Currently, there is an imbalance between the supply and demand of endowment resources in China. The existing home endowment platform is unable to fully utilize the service capacity of endowment service personnel, thus failing to meet the demand for home-based elderly care. In order to meet the needs of the elderly, the demand for home-based elderly services should aim to provide a wide range of high-quality services at the lowest possible cost. However, at this stage, the HCSP is incomplete. Hence, the assignment of ECSP is a crucial component of the functioning of home-based elderly care services. There are various types of demands for services catering to the elderly, with certain projects necessitating specific skills and time limitations. Efficient allocation of ECSP in the face of restricted resources for elderly care is a pressing issue that requires resolution. It is important to note that the allocation of ECSP differs from the traditional personnel matching problem. In the allocation of ECSP, one individual may serve multiple elderly people. This requires determining the service sequence and a specific service time plan. Additionally, it should be emphasized that the assignment of ECSP is distinct from traditional development problems. In the assignment process, considerations extend beyond service skills and time constraints to include the welfare of the elderly. Therefore, this study presents a technique for assigning service personnel who have limitations in their skills and availability within specific time frames. This approach involves two steps. Firstly, it entails gathering the precise service requirements of the elderly in advance, including the duration of home visits, the level of service needed, and any gender preferences. Secondly, it involves separately calculating the satisfaction of the elderly with the allocated time, the operational cost of the HCSP, and the priority of the elderly. The model is created in two steps based on this foundation: (1) Initially, a multi-objective matching and path scheduling model is formulated. This model aims to maximize the satisfaction of the elderly while minimizing the operational cost of the HCSP. It achieves this by minimizing the travel time and wasted time of the service personnel, taking into account factors such as priority and the service personnel's score. Additionally, if there are unserved elderly individuals, a survey is conducted after the second step of model construction. (2) Following an inquiry and adjustment of elderly service needs, a multi-objective path optimization model is reconstructed. This model incorporates the price of satisfaction for the elderly and the cost of loss.

2. Related work

Elder adults over 60 who have stopped working in society are said to be in an "elderly support" state, also known as a "resting and recuperating state" (physically and psychologically) [18]. The term "elderly service" refers to the provision of financial support, life care, and spiritual comfort to the elderly by a specific entity. This encompasses various forms of assistance tailored to their specific needs, such as clothing, food, housing, transportation, medicine, education, and recreation [19]. It encompasses policy measures and the provision of facilities and services by the government and society, with the goal of promoting the values of respect and care for the elderly. This includes ensuring the basic needs of the elderly are met, protecting their physical health, and enhancing their spiritual and cultural mental health. The totally intelligent elderly system, commonly referred to as "smart home care," utilizes advanced information technology to deliver intelligent and interconnected home internet of things and services for the elderly. It was proposed by the British Trust Fund in the 20th century for the "Smart Home Care"; at the time, it was known as the "Fully Intelligent Elderly System" [20]、 [21]. Smart care for elders surpasses traditional care models by enhancing the mobility of the elderly, promoting their rights, and substantially reducing the load of social support [22]. The Internet + service data fusion of smart home care has introduced a novel model that aims to establish connections between the elderly, the government, medical professionals, and public health institutions. This model utilizes advanced management and information technology to facilitate close collaboration among all parties involved [23].

Many researchers have developed a smart elderly home care service platform [24–28] for the elderly at home in order to better implement the smart home care service. This platform aims to deliver a more convenient, quick, and smart elderly care service. Wang and Xu [29] propose the integration of big data, cloud computing, artificial intelligence technology, and elderly services to create an "Internet plus" community intelligent home care service platform. They aim to investigate the comprehensive, scientific, objective, and adaptable nature of the intelligent pension model. This is based on Internet technology and the current scenario in China. Xu and Qiu [30] have developed a digital information platform that incorporates emergency assistance, life services, and home-based services for the elderly. This platform utilizes advanced elderly care management innovation and elderly care technology to provide corresponding elderly care services. Cui et al. [31] developed a machine learning-based intelligent home nursing service platform that utilizes a wireless senior network to enhance the dependability of the smart service system for elderly individuals. This study is specifically centered around many aspects of the older population, including their living conditions, stage of illness, physical condition, and psychological health, among other factors. Chen et al. [32] introduced a technology that enables end users to design individualized conversation proxies, allowing for personalized conversation scenarios. Users can effortlessly modify the chat circumstances and distribute changed dialogue sequences to others. Li [33] developed an intelligent service platform for the elderly by combining information integration, information sharing, and cloud computing. This platform aims to meet the integration demands of the elderly, offer rich online features, and efficiently handle user health data.

Due to the increasing prevalence of service matching and personnel assignment difficulties across several areas and the shifting research focus, there is a growing interest among academics in integrating decision theory with the assignment problem. The foundation for additional research was laid by Gale and Shapley's [34] exploratory study on the idea, reality, and other elements of stable assignment in 1962. The scheduling of elderly care personnel has attracted the attention of numerous scholars, as certain western countries possess a well-developed elderly service system as a result of early population aging. These studies are viewed as vehicle routing [35] and multi-agent [36] problems. Concerning the developing of medical services and the routing of vehicles used to transport patients, Coppi et al. [37] proposed an integrated strategy based on column generation technology as a solution. In order to address the issues faced by businesses offering rehabilitation services to the home population, Bard et al. [38] proposed a fresh model and approach. The objective is to ensure that all patients receive treatment within their time frame while minimizing travel for medical staff and treatment and management costs. Bachouch R et al. [39] consider the time frame for delivering patient care, the necessity of utilizing all resources (both human and material) in synchronous care, and the importance of considering the nursing staff's skills in every nursing procedure. This paper proposes a state-dependent routing and scheduling program for the urban family service industry that considers factors such as feasibility, interdependence, time windows, task limits, mandatory working hours, and regulatory compliance for staff serving clients, as discussed by Fikar and Hirsch [40]. For a large family health organization in Austria, Hiermann et al. [41] presented a general framework for a multimodal family health scheduling problem, assigning family caregivers to clients and identifying effective intermodal transport, taking into account staff and customer satisfaction. Rest and Hirsc [42] suggest that caregivers with varying levels of eligibility must visit specific clients at least once a day, adhere to allocation limits and time windows, and limit staff to the longest working hours. Mandatory breaks are required if continuous working hours exceed a certain threshold. Additionally, factors affecting client or caregiver satisfaction should be taken into account. A data-driven approach is suggested for estimating the travel time of nursing staff in the allocation problem. This method builds upon the work of Yalç Nda et al. [43], who recognised that the routes and workload of carers, as well as the length of service, can be affected by the clinical condition of patients and their families. W. Deng et al. [44] introduced an enhanced ant colony optimization method that incorporates a multi-population strategy, a co-evolution mechanism, a pheromone update strategy, and a pheromone diffusion mechanism to achieve a balance between convergence speed and diversity. This approach enhances the efficiency of solving optimization issues on a large scale, enables the efficient retrieval of the optimal value, and tackles the gate assignment problem. The nurse scheduling issue was resolved by S. Captain [45] using a two-stage technique. He used a hybrid Monte-Carlo tree search technique with a hierarchical clustering algorithm to identify and apply a workable and ideal solution. Jangir P et al. [46] introduce a new hybrid meta-heuristic approach to optimize the prevalent Optimal Reactive Power Dispatch problem in modern power systems. The approach utilizes a combination of Particle Swarm Optimization and Multi optimization algorithms, which are then employed to solve an unconstrained benchmark test function. Trivedi I N et al. [47] employed meta-heuristic methodologies to optimize energy management systems dealing with economic load dispatch and combined economic emission dispatch. Jangir P and Jangir N [48] have addressed the problem of designing wind power grid-connected systems while considering economic constraints on emission scheduling. They provide a solution selection method that involves choosing the best solution from a set of Pareto-optimal options. This selection is based on the criteria of coverage and the natural leadership hierarchy of gray wolves. Premkumar M et al. [49] introduced an improved mixed particle swarm optimizer that incorporates a highly effective and dependable development method. This optimizer is designed to address the unit commitment (UC) problem in microgrids that are equipped with an electrical energy storage system. Premkumar M, Jangir P et al. [50] suggest a multi-objective arithmetic optimization algorithm for solving real-world constrained multi-objective optimization problems. This algorithm is built upon a single-objective arithmetic optimization algorithm, incorporating an elitist, non-dominated ordering and congestion distance-based mechanism. Bhesdadiya R H, Trivedi I N, Jangir P et al. [51] applied the Multi-Objective Combined Economic Emission Dispatch problem to the newly proposed Non-Superiority Ranking Genetic Algorithm-III.

3. Problem description

This study specifically addresses the issue of elderly care services personnel facilities on an hourly basis, taking into account the limitations imposed by time windows. This problem falls under the categories of vehicle routing and multiple-traveler problems with time constraints. Conventional path optimization problems often prioritize distance or cost, but the target audience for home-based

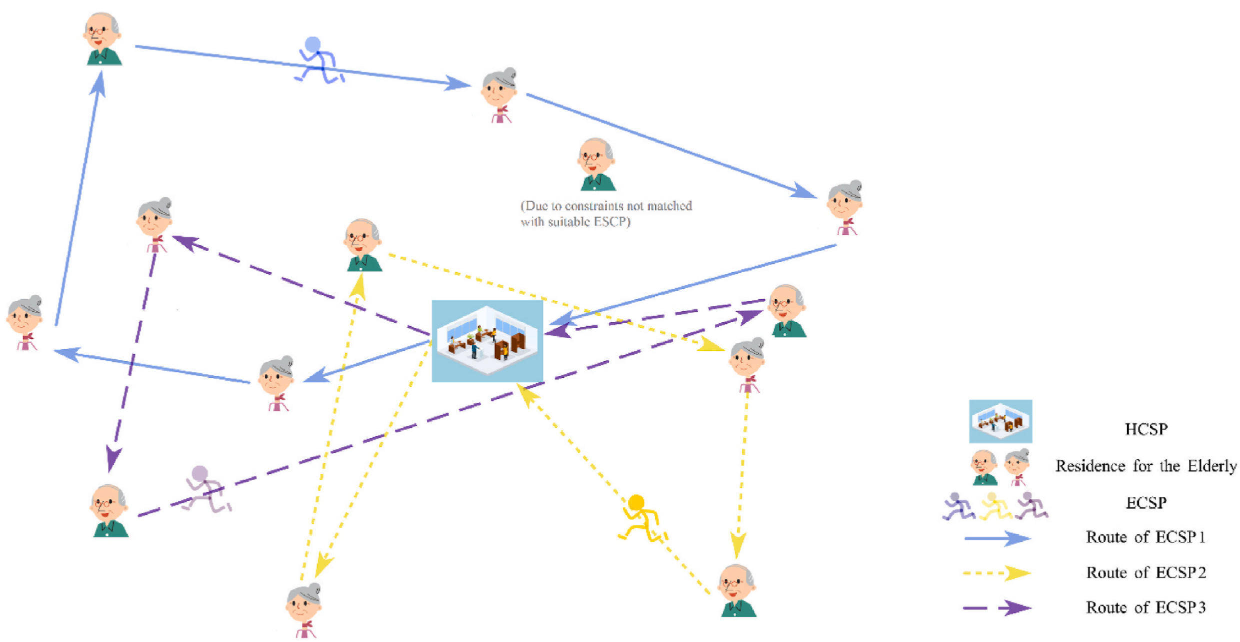

Fig. 1. Illustrates the ECSP's path from the elderly.

elderly care services is the elderly population. The home care service platform is not solely profit-driven, but also emphasizes human and social aspects. This study examines the issue of deploying the elderly and military members in a many-to-many manner. The door-to-door service method can be delineated as follows: To begin with, gather information about the specific service content and time requirements of the elderly within a particular community. The home care service platform has a variety of skilled service personnel available at different levels. These personnel are dispatched from the elderly service center to visit the residences of the elderly and provide door-to-door service systematically. This approach aims to fulfill the service needs of the elderly while minimizing the time and effort expended by service personnel. Additionally, careful consideration is given to prioritizing the service personnel's tasks and minimizing any unnecessary time waste. Optimize the efficiency of service professionals, enhance the happiness of the elderly based on the priority and rating of the service personnel, and limit the operational expenses of the service platform. Fig. 1 displays the schematic diagram of the home service path for military personnel.

The following table lists the set-sum quantities involved in the multi-objective personnel assignment problem for elderly care service personnel.

- $A = \{A_1, A_2, ..., A_i, ..., A_{i'}, ..., A_m\}$ represents a group of m elders, where A_i denotes the i th elder, $i = 1, 2, ..., m$。
- $B = \{B_1, B_2, ..., B_j, ..., B_n\}$ represents a group of n platform-contracted fixed elderly care service personnel, where B_j represents the j th elderly care service personnel.
- $U = U' + U''$ represents the service tasks provided by the home care service platform, where $U = \{U_1, U_2, ..., U_h, ..., U_v\}$, when $U_h \in U'$ means soft time window task; when $U_h \in U''$ means hard time window task.
- $[e_i^h, l_i^h]$ represents the time window in which the i th elderly requires the h th task.
- $[e_i^{h'}, l_i^{h'}]$ represents that the i th elderly require the maximum tolerable time window for the h th task and $U_h \in U'$, when $U_h \in U''$, $e_i^h = e_i^{h'}$、 $l_i^h = l_i^{h'}$.
- $[\inf_{ih}, \sup_{ih}]$ represents the time window in which the i th elderly requires the h th task to reach the minimum level of elderly satisfaction θ_i, where θ_i represents the i th elderly's minimum level of satisfaction.
- $E = \{e_1, e_2, ..., e_j, ..., e_n\}$ represents a set of historical scores of n service personnel on the home care service platform, where e_j represents the historical score of the j th elderly care service personnel on the home care service platform.
- $O^j = (o_1^j, o_2^j, ..., o_h^j, ..., o_v^j)$ represents the actual value vector of the service task level of the j th service personnel, where o_h^j represents the actual value of the j th service personnel for the h th service task level, $o_h^j \in \{0, 1, 2, 3\}$.
- $O^i = (o_1^i, o_2^i, ..., o_h^i, ..., o_v^i)$ represents the actual value vector of the expected service level of the i th elderly, where o_h^i represents the expected value of the i th elderly to the h th service task level, $o_h^i \in \{0, 1, 2, 3\}$.
- $S^j = (s_1^j, s_2^j)$ represents the actual gender value vector of the j th elderly care service personnel. When $s_1^j = 1$, it means that the actual gender of the j th service personnel is "male"; when $s_2^j = 1$, it means that the actual gender of the j th service personnel is "female", $s_1^j + s_2^j = 1$.
- $S_h^i = (s_{h1}^i, s_{h2}^i)$ represents the expected gender value vector of the i th elderly choosing the h th task. When $s_{h1}^i = 1$, it means that the i th elderly chooses the expected gender of the h th task as "male"; when $s_{h2}^i = 1$, it means the i th elderly chooses the expected gender of the h th task as "female".
- $C_{ho} = (c_{1o}, c_{2o}, ..., c_{ho}, ..., c_{vo})$ represents the price-value vector of task h at level o.
- $G = (V, A)$ represents a connected graph, where V represents the distribution point set of all elderly, $V = V_c \cup V_d$, $V_c = \{0, n+1\}$ represents the home care service platform; $V_d = \{1, 2, ..., n\}$ represents the location of the elderly residence; $A = A(i, i')$ represents a distance group of between the elder A_i and the elder $A_{i'}$.
- (x_i, y_i) represents the coordinate position of the i th elderly residence; (x_0, y_0) represents the coordinate position of the home care service platform.
- v_j represents the moving speed of the j th elderly care service personnel.
- t_{ij} represents the expected time when the j th service person starts to serve the i th elder.
- st_{jh} represents the expected duration of the j th elderly care service personnel to complete the h th task.
- represents the time when the j th elderly care service personnel moves from serving the i th elderly to the i' th elderly.
- vt_{ij} represents the time when the j th elderly care service personnel moves from the home care service platform to the i th elderly residence.
- wt_{ij} represents the waiting time of the j th elderly care service personnel at the elderly A_i.
- p_{ijh} represents the time satisfaction of the i th elderly on the h th service task of the j th elderly care service personnel, where $p_{ijh} \in [0, 1]$.
- e_j represents the historical praise rate of elderly care service personnel on the platform, where $e_j \in [0, 1]$.
- pr_i represents the priority of the i th elderly, $pr_i \in [0, 1]$.
- represents that if the j th elderly care service personnel provides the h th service for the i th elderly, $x_{ijh} = 1$; otherwise $x_{ijh} = 0$.

The problem to be studied in this paper is: how to adopt a feasible decision-making method to solve the problem of hourly elderly care service personnel assignment with time window constraints based on relevant decision-making information such as A、 B、 U、 E、 O、 C、 S and so on.

4. Model analysis

This document presents a model analysis and calculation approach for assessing the happiness of the elderly with their time, the travel time of elderly care service personnel, and the cost of the platform. The objective is to identify the problem of assigning hourly senior care service persons with time window limits. Presented here are the fundamental principles and computations for this methodology, along by a comprehensive analysis of the sequential procedures.

4.1. Time and satisfaction description

4.1.1. Time granularity

A standardized system for measuring time-related timescales has been established to simplify time computations. This system employs minutes as the unit of measurement. This standard utilizes a 24-h time system, with minutes as the unit of measurement for the data's time format. The base time is set at the beginning of the day, and the end time is set at the conclusion of the day, both consisting of 24 h. For example, the time 0:00 is equivalent to 0:01, 1:00 is equivalent to 60 min, and 24:00 is equivalent to 1440 min.

4.1.2. Hard time window task satisfaction

When given a hard time window task, elderly care service personnel are required to show up and start working within the window of time that the elderly A_i specifies. The consumer will decline to be served if they arrive outside the designated time window, where $U_h \in U''$. Assume that the elderly A_i has a service task U_h appointment time window $[e_i^h, l_i^h]$, where e_i^h is the time the elderly A_i expects to start the h th service and l_i^h represents the latest time the elderly A_i needs the h th service. The contentment of the elderly is defined in terms of a binary relationship. The elderly will accept the service and rate their satisfaction as 1, provided that it is inside the scheduled time window; otherwise, they will not accept the service and rate their satisfaction as 0. Note that the satisfaction degree of the elderly A_i is p_{ijh}, and the calculation formula [52] for p_{ijh} is shown in Eq. (1).

$$p_{ijh} = \begin{cases} 0, & t_{ij} < e_i^h \text{或} t_{ij} > l_i^h \\ 1, & e_i^h \le t_{ij} \le l_i^h \end{cases}, U_h \in U'' \tag{1}$$

The satisfaction function image of the elderly for the hard time window task is shown in Fig. 2.

4.1.3. Soft time window task satisfaction

The soft time window task means that the elderly care service personnel arrive and provide services within the time period specified by the elderly A_i as much as possible. If they arrive outside the optimal time window, satisfaction will decrease. If the maximum tolerable time window is exceeded, the customer will refuse to accept service, where $U_h \in U'$. For soft time window tasks except appointment time windows $[e_i^h, l_i^h]$, the elderly A_i also has a maximum tolerable time window $[e_i^{h'}, l_i^{h'}]$. $e_i^{h'}$ means the earliest acceptable service start time for the elderly A_i outside the scheduled U_h service task time window, $l_i^{h'}$ means the latest service start time that the elderly A_i can tolerate when the elderly care service personnel is late, but elderly care service personnel starting service outside the appointment time window $[e_i^h, l_i^h]$ has a direct impact on the satisfaction of the elderly A_i. When the starting service time t_{ij} of the elderly A_i is within the range of $[e_i^h, l_i^h]$, the satisfaction of the elderly A_i is 1. When the starting service time t_{ij} of the elderly A_i is within the range of $[e_i^{h'}, e_i^h]$ or $[l_i^h, l_i^{h'}]$, the elderly A_i receives services, but the satisfaction of the elderly A_i linearly increases or decreases with time. When the starting service time t_{ij} of the elderly A_i exceeds the range of $[e_i^{h'}, l_i^{h'}]$, that is, the upper and lower limits of the maximum tolerance time are exceeded, the elderly do not accept the service, and the satisfaction of the elderly A_i is 0.

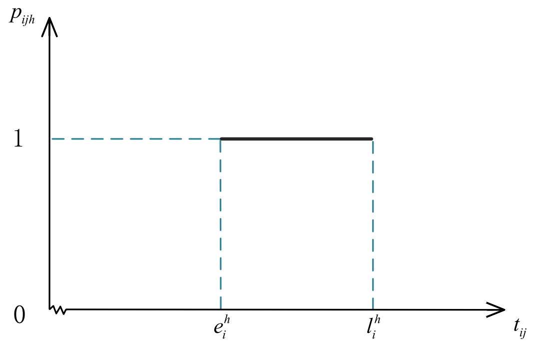

Fig. 2. Satisfaction function of the elderly for hard time window tasks.

The satisfaction degree of the elderly A_i is p_{ijh}, and the calculation formula [52] of p_{ijh} shown in Eq. (2).

$$p_{ijh} = \begin{cases} 0, & t_{ij} < e_i^{h'} \\ \dfrac{t_{ij} - e_i^{h'}}{e_i^h - e_i^{h'}}, & e_i^{h'} \leq t_{ij} < e_i^h \\ 1, & e_i^h \leq t_{ij} \leq l_i^h \\ \dfrac{l_i^{h'} - t_{ij}}{l_i^{h'} - l_i^h}, & l_i^h < t_{ij} \leq l_i^{h'} \\ 0, & t_{ij} > l_i^{h'} \end{cases}, U_h \in U' \tag{2}$$

The satisfaction function image of the elderly for the soft time window task is shown in Fig. 3.

In order to avoid elderly customer loss caused by too low service level, this paper sets the minimum level of customer satisfaction θ_i to ensure the satisfaction $p_{ijh} \geq \theta_i$ of the i th elderly. At this time, the service time window of the soft time window service task of the elderly A_i is $[\inf_{ih}, \sup_{ih}]$, as shown in Fig. 4. The service time window $[\inf_{ih}, \sup_{ih}] = [e_i^h, l_i^h]$ of the hard time window service task for the elderly A_i.

4.1.4. Elderly care service personnel time description

The elderly A_i's service time window is $[\inf_{ih}, \sup_{ih}]$, and the elderly care service personnel B_j's service time is earlier than $\inf_{ih}$ may not be able to serve immediately, so there will be a waiting time for service at this time. Additionally, later than $\sup_{ih}$ may disrupt the elderly's daily routine and habits, and this is when satisfaction is at its lowest or even lowest level. The distance between elderly residents' homes is not particularly concentrated, and each elderly care service personnel's modes of transportation are different because home care service centers depend on different communities and are established in different regions, and the service scope is limited to this area. The distance between and costs about different.

When the elderly care service personnel B_j moves from the i th elderly residence to the i' th elderly residence, the calculation formula of $v_{ii'j}$ is shown in Eq. (3).

$$v_{ii'j} = \frac{\sqrt{(x_i - x_{i'})^2 + (y_i - y_{i'})^2}}{v_j} \tag{3}$$

When the elderly care service personnel B_j moves from the elderly care service platform to the i th elderly residence, the calculation formula of v_{ij} is shown in Eq. (4).

$$v_{ij} = \frac{\sqrt{(x_i - x_0)^2 + (y_i - y_0)^2}}{v_j} \tag{4}$$

When the elderly care service personnel B_j departs from home and arrives at the elderly A_i, the calculation formula of t_{ij} is shown in Eq. (5).

$$t_{ij} = \begin{cases} \inf_{ih}, & \inf_{ih} - v_{ij} - 480 \geq 0 \\ 480 + v_{ij}, & \inf_{ih} - v_{ij} - 480 < 0 \end{cases} \tag{5}$$

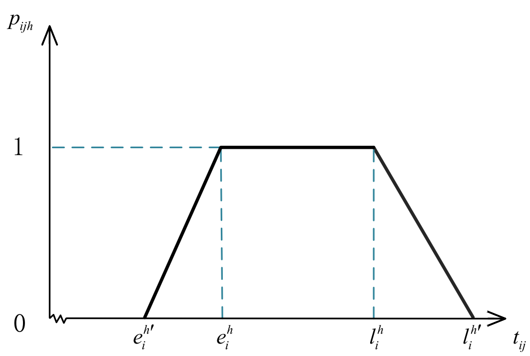

Fig. 3. Satisfaction function of the elderly for soft time window tasks.

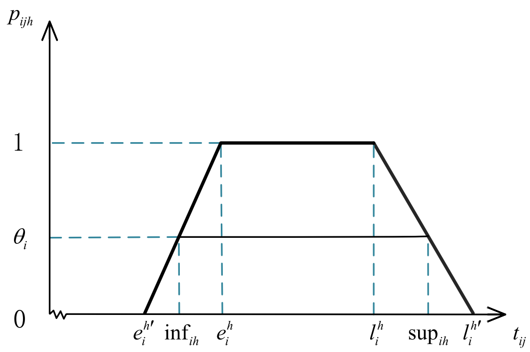

Fig. 4. Service time window at minimum service level factor.

When the elderly care service personnel B_j arrives at the elderly $A_{i'}$ from the elderly A_i, the calculation formula of $t_{i'j}$ is shown in Eq. (6).

$$t_{i'j} = t_{ij} + st_{jh} + vt_{ii'j} + wt_{i'j} \tag{6}$$

Where the waiting time is $wt_{i'j} = \max\{\inf_{i'h} - t_{ij} - st_{jh} - vt_{ii'j}, 0\}$.

4.2. Cost description

4.2.1. Excessive violation costs (C_1、 C_2)

Individuals who offer nursing and care services to the elderly at their homes are referred to as home care personnel. They are only able to provide assistance to the elderly once their level of service and expertise align with the specific requirements of the elderly. Nevertheless, it possesses distinct professional tiers, each characterized by a distinctive set of skills. The acquired skills progress in level from low to high. The running expenses of the elderly care service platform, encompassing both direct expenses and indirect expenses such as time, labor, and price, will increase when the skills of the elderly care service professionals surpass the requirements of the elderly.

In this case, the excessive service time cost means that there is no service skill violation cost when the elderly care service personnel's own service skills are in line with the expectations of the elderly. The additional time cost will have an impact on the platform's ability to provide elderly care services profitably and efficiently. Keep in mind that the time cost of excessive elderly care service personnel infractions is C_1, and the calculation [53] for C_1 is shown in Eq. (7).

$$C_1 = \sum_{i=1}^{m} \sum_{j=1}^{n} \left(o_h^j - o_h^i\right) \cdot st_{jh} \tag{7}$$

If the elderly care service personnel's service level exceeds the service level requested by the elderly, the service skill level may lead to a higher price, a waste of the skill cost, and the need for more manpower to provide additional service. These costs may eventually shift to elderly or to home care service platform. The calculation formula for calculating the cost of excessive breaches of price by pension service personnel is C_2, and the calculation for C_2 is shown in Eq. (8).

$$C_2 = \left(c_h^j - c_h^i\right) \left\lceil \frac{st_{jh}}{60} \right\rceil \tag{8}$$

Among them, c_h^j represents the price of the j th service person for the h th task, and c_h^i represents the price of the h th task requested by the i th elderly.

4.2.2. Labor cost per unit time (C_3)

When all human resource costs are evenly distributed to each unit of time over the course of a given period of time, the amount of labor cost per unit of time remains. Here, time is typically measured in hours or days. The full-time elderly care service personnel on the service platform can fulfil several sorts of service orders, which vary depending on their talents and levels. Consequently, the labor cost per unit hour also varies. Pension service employees' human cost per unit of time is recorded as C_3, and the formula [54] for calculating C_3 is shown in Eq. (9).

$$C_3 = \frac{ami_j}{mwd_j \cdot per_j \cdot 8} \tag{9}$$

Among them, ami_j represents the average monthly income of the j th elderly care service personnel; mwd_j represents the monthly working days of the elderly care service personnel B_j; per_j represents the estimated value of the average working hours of the elderly care service personnel B_j.Here, based on years of service and the unique monthly income of various elderly care service personnel, the average monthly wage of elderly care service personnel is determined. The full-time elderly care service personnel at the home care service platform are paid under a piecework system, which includes a base salary and commission for successfully completing assigned service tasks. Take note that elderly care service personnel's average monthly salary is ami_j. The ami_j and mi_{jr} calculation formulas are shown in Eq. (10) and Eq. (11).

$$ami_j = \frac{\sum_{r=1}^{z_j} mi_{jr}}{z_j} \tag{10}$$

$$mi_{jr} = bs_j + \sum_{h=1}^{v} g_{ho} \times num_{jrh} \tag{11}$$

Where mi_{jr} represents the monthly income of the j th service person in the r th month, $r = 1, 2, ..., z_j$, where z_j represents the number of working months of the j th service person in the home care service platform; bs_j represents the j th service basic salary of the personnel; g_{ho} means the commission of the h task of the o th level; num_{jr} means the number of the j th service personnel to complete the h th service task in the r th month.

4.2.3. The cost of not matching successfully (C_4)

The cost incurred due to the discrepancy between the elderly care service providers and the elderly is a consequence of the elderly requesting services, but no personnel being able to promptly fulfill these services due to time limitations or the specific skills required by the elderly. The operational expenses of the home care service platform increase due to the dissatisfaction of the elderly with a specific service assignment and the inability of the aged care service staff to complete it. Consequently, the wage commission was reduced. Note that the cost caused by failure to match elderly care service personnel is C_4, and the calculation formula for C_4 is shown in Eq. (12).

$$C_4 = \sum_{h=1}^{v} (c_{ho} - g_{ho}) \tag{12}$$

Among them, c_{ho} represents the service price of task h at level o; g_{ho} represents the commission of task h at level o.

4.3. Description of elderly priorities

The elderly should be given priority in service based on their own situation, with the elderly with higher priority being given preference. In this case, the elderly are given priority based on four indicators: age, capacity for self-care, living situation, and physical condition. The weight of elders who reside alone is greater than that of elderly individuals who reside with their spouse, their children, or both, and the weight of elderly individuals in lower physical condition is heavier than that of elderly individuals in better physical condition.

The formula for calculating the age priority agc_i of the elderly is shown in Eq. (13).

$$agc_i = \frac{ag_i - ag_{\min}}{ag_{\max} - ag_{\min}} \tag{13}$$

Among them, agc_i represents the age priority score of the i th elderly and $agc_i \in [0, 1]$; $ag_{\min} = \min\{ag_i | i = 1, 2, ..., m\}$ represents the minimum age among i elderly; $ag_{\max} = \max\{ag_i | i = 1, 2, ..., m\}$ represents the maximum age among i elderly.

The formula for calculating the priority scc_i of self-care ability of the elderly is shown in Eq. (14).

$$scc_i = \frac{sc_i - sc_{\min}}{sc_{\max} - sc_{\min}} \tag{14}$$

Among them, scc_i represents the self-care ability priority score of the i th elderly and $scc_i \in [0, 1]$; $sc_{\min} = \min\{sc_i | i = 1, 2, ..., m\}$ represents the minimum value of self-care ability score among i elderly; $sc_{\max} = \max\{sc_i | i = 1, 2, ..., m\}$ represents the maximum value of self-care ability score among i elderly. Here it is assumed that when the i th elder's self-care ability is not self-care ability, the i th elder's self-care ability score is $sc_i = 3$; when the i th elder's self-care ability is semi-self-care ability, the i th elder's self-care ability score is $sc_i = 2$; and when the self-care ability of the i th elder is self-care ability, the score of the i th elder's self-care ability is $sc_i = 1$.

The formula for calculating the priority lcc_i of elderly citizens' living situations is shown in Eq. (15).

$$lcc_i = \frac{lc_i - lc_{\min}}{lc_{\max} - lc_{\min}} \tag{15}$$

Among them, lcc_i represents the living situation priority score of the i th elderly and $lcc_i \in [0, 1]$; $lc_{\min} = \min\{lc_i | i = 1, 2, ..., m\}$ represents the minimum value of living situation priority score among i elderly; $lc_{\max} = \max\{lc_i | i = 1, 2, ..., m\}$ represents the maximum value of living situation priority score among i elderly. Here it is set that when the living situation of the i th elderly is "living alone and not living in the same city as his children", the score of the i th elder's living situation is $lc_i = 5$;when the living situation of the i th elderly is "living alone and in the same city with their children", the score of the i th elderly's living situation is $lc_i = 4$;When the i th elderly's living situation is "living with his spouse and not in the same city as his children", the score of the i th elderly's living situation is $lc_i = 3$;When the living situation of the i th elderly is “living with the spouse and the same city with the children”, the score of the i th elderly’s residence status is $lc_i = 2$; When the i th elderly’s living situation is “living with children”, the i th elderly’s living situation score is $lc_i = 1$.

The formula for calculating the priority hcc_i of the physical condition of the elderly is shown in Eq. (16).

$$hcc_i = \frac{hc_i - hc_{\min}}{hc_{\max} - hc_{\min}} \tag{16}$$

Among them, hcc_i represents the physical condition priority score of the i th elderly and $hcc_i \in [0,1]$; $hc_{\min} = \min\{hc_i | i = 1, 2, ..., m\}$ represents the minimum value of physical condition score among i elderly; $hc_{\max} = \max\{hc_i | i = 1, 2, ..., m\}$ represents the maximum value of physical condition score among i elderly.

Note that pr_i represents the priority of the i th elderly, and the formula for calculating pr_i is shown in Eq. (17).

$$pr_i = \frac{agc_i + scc_i + lcc_i + hcc_i}{4} \tag{17}$$

5. Model building

The three aims, namely minimizing travel time, minimizing operating expenses, and maximizing service satisfaction, are in conflict with each other. The running costs of a home care service platform are partially influenced by the extent of the services they provide. The trip time is typically considered to be the most concise. As satisfaction levels increase over time, there is a corresponding increase in operating expenditures. Hence, when making judgments, managers should strive to find a middle ground between the two options. It is important to strike a balance between reducing operating expenses and maintaining service quality. While it is not advisable to significantly cut costs at the expense of service quality, it is also unnecessary to pursue high satisfaction without considering the impact on platform running costs and journey time. In order to enhance the satisfaction of the elderly, reduce travel expenses for service professionals, and lower the operational costs of the platform, it is essential to create suitable arrangements and assignments that take into account the distinctive characteristics of the business. To construct a multi-objective model for assigning personnel to elder care services, the objective function in this part aims to minimize travel expenses, maximize service satisfaction, and minimize operational costs. Some service tasks suggested by the elderly cannot be completed promptly by service professionals due to time limitations or the need for specialized skills. This is a common scenario that might happen in real life. The model is solved using a two-step process, resulting in the optimal allocation strategy. The allocation of elderly individuals and staff providing elderly care services is achieved through the development and resolution of a model in Section 5.1. Solicit opinions, and if there are any older individuals who were not successfully paired, proceed to Section 5.2.

5.1. The first step is to optimize the model

Let x_{ijh} be a 0–1 type decision variable, $x_{ijh} = 1$ means that if the j th elderly care service personnel provides the h th service for the i th elderly; otherwise, $x_{ij} = 0$. According to the above description and analysis of the model problem, with the objective functions of minimizing time cost, maximizing service satisfaction considering priority, and minimizing operating cost, a multi-objective elderly care service personnel path optimization model is shown in model (18).

$$\min Z_1 = \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} vt_{i\acute{i}j}\, x_{ijh}\, x_{\acute{i}jh} + \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} wt_{\acute{i}j}\, x_{\acute{i}jh} + \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} C_1 x_{ijh} \tag{18a}$$

$$\max Z_2 = \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} \left(p_{ijh} + e_j\right) pr_i\, x_{ijh} \tag{18b}$$

$$\min Z_3 = \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} C_2 x_{ijh} + \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} C_3\, st_{jho}\, x_{ijh} + \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} C_4 \left(1 - \sum_{j=1}^{n} x_{ijh}\right) \tag{18c}$$

$$s.t. \quad x_{ijh} x_{\acute{i}jh}\left(t_{ij} + st_{jh} + vt_{i\acute{i}j} + wt_{\acute{i}j} - \sup_{\acute{i}h}\right) \le 0 \tag{18d}$$

$$\left(s^i_{hg} - s^j_g\right) x_{ijh} \ge 0\ ,\ g = 1, 2\ ,\ h = 1, 2, ..., v \tag{18e}$$

$$\left(o^j_h - o^i_h\right) x_{ijh} \ge 0\ ,\ h = 1, 2, ..., v \tag{18f}$$

$$\sum_{h=1}^{v}\sum_{j=1}^{n} x_{ijh} \le 1 \tag{18g}$$

$$\sum_{h=1}^{v} st_{jho} + \sum_{h=1}^{v}\sum_{i=1}^{m} vt_{ii'h}\, x_{ijh}\, x_{i'jh} \leq 480 \tag{18h}$$

$$\sum_{j=1}^{n}\sum_{h=1}^{v} x_{0jh} = 2 \tag{18i}$$

$$x_{ijh} = 0 \text{or} 1 \tag{18j}$$

In model (18), formulas (18a), (18b), and (18c) are the objective functions; formula (18a) means that the time cost of elderly care service personnel is minimized; formula (18b) means that considering the favorable rate of elderly care service personnel and the elderly, the level of time satisfaction is the largest; and formula (18c) indicates that the operating cost of the home care service platform is minimized. Constraint condition (18d) means that the time when the j th elderly care service personnel arrives at the residence of the i' th elderly after serving the i th elderly must meet the tolerable latest service time of the i' th elderly; Constraint condition (18e) means that the gender of the j th elderly care service personnel must meet the gender needs of the i th elderly; the constraint condition (18f) indicates that the service level of the j th elderly care service personnel must meet the level required by the i th elderly; the constraint condition (18g) means that each elderly can only match at most one elderly care service personnel for a certain task; the constraint condition (18h) means that the working time of each elderly care service personnel does not exceed 8 h a day; the constraint condition (18i) means that each elderly care service personnel starts from The home care service platform starts at 0, and returns to the starting point after serving every elderly; the constraint condition (18j) indicates that the decision variable is a 0–1 variable.

If the calculations of this model suggest that certain elderly individuals are not being provided with assistance, there are three possible factors contributing to this situation: (1) There is a lack of available elderly care service personnel during the required time period for the elderly. (2) Idle personnel are unable to fulfill the needs of the elderly. (3) Inactive personnel do not fulfill the gender criteria of the elderly. When situation (1) arises, inquire with the old individuals if they would like to modify the designated time frame, namely by delaying the scheduled service time. If the parties consent to modifying the schedule, the cost of the service will be reduced. Please record the computation in Section 2.2.2. If situation (2) occurs, find out if the elderly would prefer a different time window or a lower standard of service. After discounting the service price, if they agree to change the time or reduce the requirement, proceed to Section 2.2.2 for calculation; if not, get in touch with the temporary service personnel. The cost of the service will rise if the task has a flexible time window. When the situation (3) arises, ask the elderly if they want to change the required time window or change the gender requirement. If the service task is a hard time window task, the service price will not increase. If the elderly individuals refuse, contact the temporarily hired service professionals. However, if they agree to adjust the time or gender restrictions, go to Section 2.2.2 for computation after reducing the service charge. The cost of the service will rise if this task has a soft time window. In this solution, the cost of the service won't go up if the task has a tight time window.

5.2. The second step is to optimize the model

The elderly will receive a price discount if their match is unsuccessful and, as a result of the inquiry, the service time or level requirement is postponed or lowered. If the service time is not agreed to be postponed or lowered, the calculation and matching will be done again using the objective function. If necessary, door-to-door service will be offered to the elderly by temporarily hired service personnel.

The time window constraint is altered if the elderly agrees to a delay in service, meaning that the soft time window task is increased

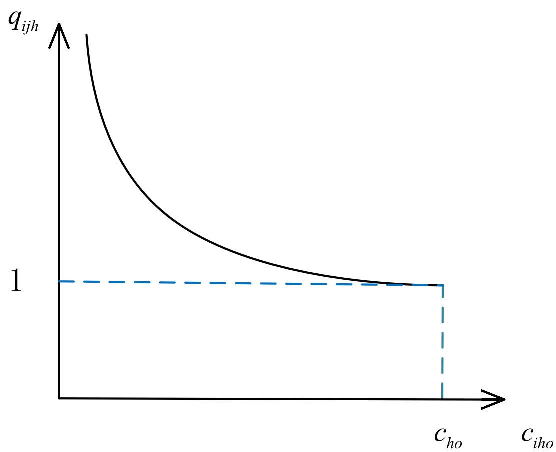

Fig. 5. Price satisfaction function of elderly care service personnel.

and the maximum tolerable time window is changed from $[e_i^{h'}, l_i^{h'}]$ to $[e_i^{h'}, l_{i\,\max}^{h\,'}]$, hard time window tasks changed to $[e_i^{h}, l_{i\,\max}^{h\,'}]$.The formula for calculating the price discount for the elderly with respect to delayed service time is shown in Eq. (19).

$$c_{iho} = \alpha_i \cdot c_{ho} \tag{19}$$

Among them, c_{iho} represents the discounted price after the i th elderly chooses to wait for the o th level h task, and α_i represents the price discount for the i th elderly according to the length of waiting time.

If the elderly agree to postpone the service time, the service price will be reduced, so the elderly's satisfaction q_{ijh} with the discounted price increases. The longer the waiting time for the elderly, the greater the price discount, and satisfaction with the discounted price increases. q_{ijh} represents the satisfaction of the elderly A_i with the discounted price of the h service of the elderly care service personnel B_j. The formula for calculating the satisfaction of the elderly with respect to the discounted price q_{ijh} is shown in Eq. (20).

$$q_{ijh} = \frac{c_{ho}}{c_{iho}} = \frac{1}{\alpha_i} \tag{20}$$

Fig. 5 shows the satisfaction function image of the discounted price of elderly care service personnel.

Let x_{ijh} be a 0–1 type decision variable, $x_{ijh} = 1$ means that if the j th elderly care service personnel provides the h th service for the i th elderly; otherwise, $x_{ij} = 0$. A multi-objective elderly care service personnel path optimization model is created as shown in model (21) accordance with the above description and analysis of the model problems, with the objective functions of minimizing time cost, maximizing time-price satisfaction, and minimizing loss cost as the objective functions.

$$\min Z_1 = \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} vt_{i\acute{i}j}\, x_{ijh}\, x_{\acute{i}jh} + \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} wt_{\acute{i}j}\, x_{\acute{i}jh} + \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} C_1 x_{ijh} \tag{21a}$$

$$\max Z_2 = \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} \left(p_{ijh} + e_j + q_{ijh}\right) pr_i\, x_{ijh} \tag{21b}$$

$$\min Z_3 = \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} (c_{ho} - c_{iho}) x_{ijh} + \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} C_2 x_{ijh} + \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} C_3\, st_{jho}\, x_{ijh} \tag{21c}$$

$$x_{ijh} x_{\acute{i}jh}\left(t_{ij} + st_{jh} + vt_{i\acute{i}j} + wt_{\acute{i}j} - l_{\acute{i}\,\max}^{h\,'}\right) \le 0 \tag{21d}$$

$$\left(s_{hy}^{i} - s_{y}^{j}\right) x_{ijh} \ge 0\ ,\ y = 1, 2\ ,\ h = 1, 2, ..., v; \tag{21e}$$

$$\left(o_h^{j} - o_h^{i}\right) x_{ijh} \ge 0\ ,\ h = 1, 2, ..., v \tag{21f}$$

$$\sum_{h=1}^{v}\sum_{j=1}^{n} x_{ijh} = 1 \tag{21g}$$

$$\sum_{h=1}^{v} st_{jh} + \sum_{h=1}^{v}\sum_{i=1}^{m} vt_{i\acute{i}j}\, x_{ijh}\, x_{\acute{i}jh} \le 480 \tag{21h}$$

$$x_{ijh} = 0 \text{or} 1 \tag{21i}$$

In model (21), equations (21a), (21b) and (21c) are the objective functions, and equation (21a) represents the minimization of the time cost of elderly care service personnel; equation (21b) represents that the time and price satisfaction of considering the priority of the elderly is the maximum; and formula (21c) indicates that the loss cost of the home care service personnel is minimized. Constraint condition (21d) means that the time when the j th elderly care service personnel arrives at the residence of the $\acute{i}$ th elderly after serving the i th elderly must meet the tolerable latest service time of the $\acute{i}$ th elderly; Constraint condition (21e) means that the gender of the j th elderly care service personnel must meet the gender needs of the i th elderly; the constraint condition (21f) indicates that the service level of the j th elderly care service personnel must meet the level required by the i th elderly; the constraint condition (21g) means that each elderly can only match at most one elderly care service personnel for a certain task; the constraint condition (21h) means that the working time of each elderly care service personnel does not exceed 8 h a day; the constraint condition (21i) means that each elderly care service personnel starts from the home care service platform starts at 0, and returns to the starting point after serving every elderly; the constraint condition (21j) indicates that the decision variable is a 0–1 variable.

6. Model solving

The scheduling problem of a home-based care service is a complex multi-objective optimization problem that can be successfully solved by a genetic algorithm [55] due to its built-in parallel mechanism and global optimization feature. The flowchart of the

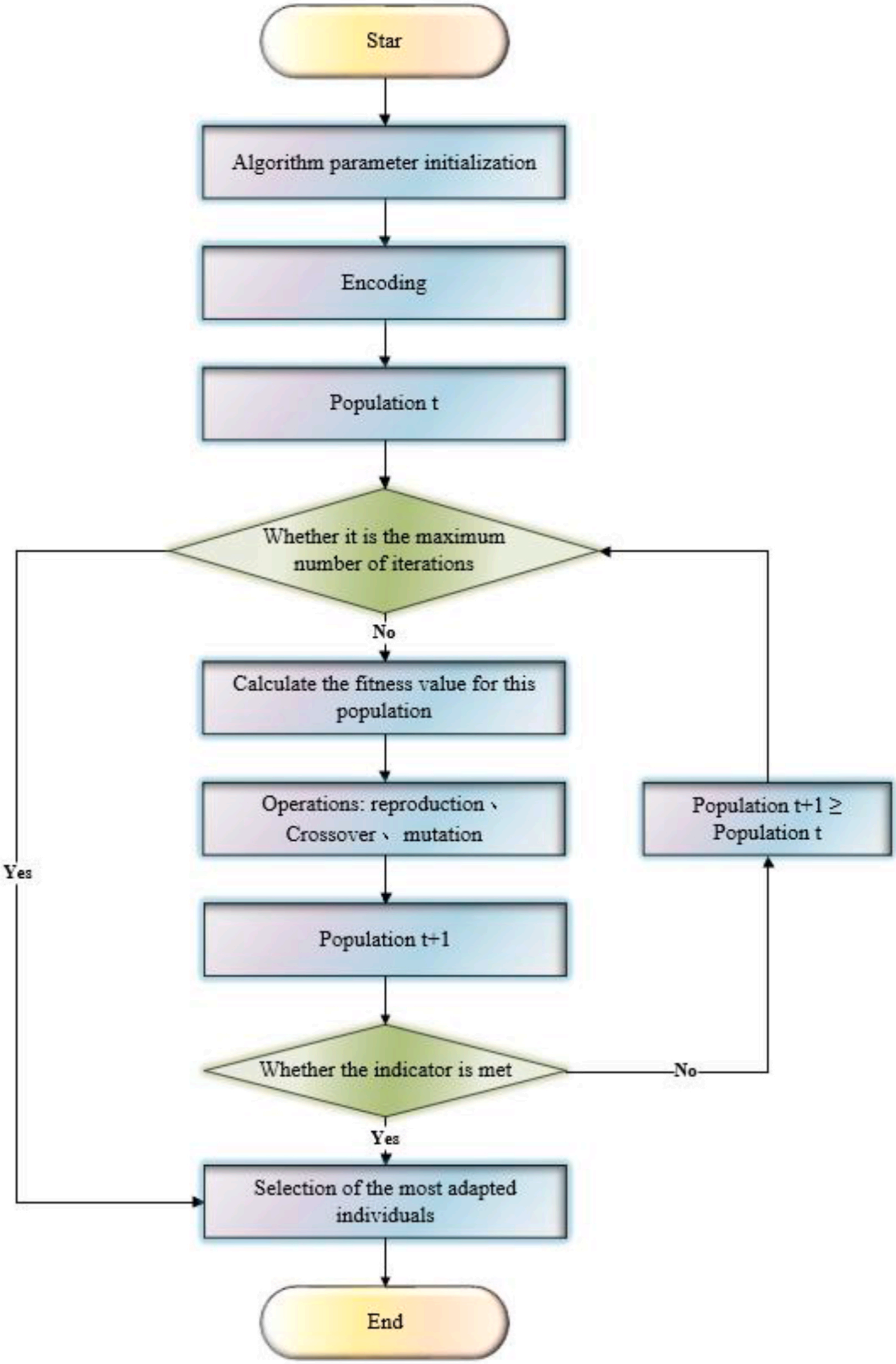

Fig. 6. The flowchart of the algorithm solution.

Table 1
Specific service tasks provided by the pension service center.

Service Type	Service Items	Service Content U_h	Service Description	Price Indication c_{ho} (About an hour at a time	Commission g_{ho} (About an hour at a time)
Spiritual Comfort	Help Chat (Soft time window task)	Chat Companion U_1	Chat companion services such as chatting, reading books and newspapers	c_{11}:10¥/time/hour	g_{11}:5¥/time/hour
		Psychological Counseling U_2	Services for the elderly with mental problems or diseases, according to the actual situation to carry out certain psychological counseling	Grade 1 c_{21}:20¥/time/hour Grade 2 c_{22}:30¥/time/hour Grade 3 c_{23}:50¥/time/hour	Grade 1 g_{21}:12¥/time/hour Grade 2 g_{22}:17¥/time/hour Grade 3 g_{23}:25¥/time/hour
Life Care	Assisted Walking (Soft time window task)	Accompanied Travel U_3	Accompany the elderly to travel, shop, walk, and exercise, and help the elderly to lift heavy objects.	c_{31}:10¥/time/hour	g_{31}:5¥/time/hour
		Run Errands U_4	Charge cards, withdraw money, handle business, buy medicine, etc.	c_{41}:10¥/time	g_{41}:5¥/time
	Help Clean (Soft time window task)	Clean the Room U_5	According to the size of the house, the cost is calculated according to the actual working hours (excluding clearing, cleaning glass, cleaning the range hood, etc.).	c_{51}:20¥/time	g_{51}:10¥/time
		Clothes Washing U_6	Wash clothes, bedding, etc.	c_{61}:20¥/time	g_{61}:9¥/time
		Bed Making U_7	Washing, flipping, changing bedding, etc.	c_{71}:20¥/time	g_{71}:11¥/time
		Cut Nails U_8	Trim fingernails and toenails.	c_{81}:10¥/time	g_{81}:5¥/time
		Shampoo U_9	Home shampoo.	c_{91}:10¥/time	g_{91}:5¥/time
		Haircut U_{10}	Door-to-door haircut	Assistant $c_{10,1}$:25 ¥/time/hour Technician $c_{10,2}$:35 ¥/time/hour Advanced $c_{10,3}$:50 ¥/time/hour	Assistant $g_{10,1}$:14 ¥/time/hour Technician $g_{10,2}$:28 ¥/time/hour Advanced $g_{10,3}$:28 ¥/time/hour
	Auxiliary Bath (Soft time window task)	Auxiliary Bathing U_{11}	The user needs to prepare bathing utensils at home. According to the degree of disability of the elderly, services such as shampooing, body scrubbing, bathing, and other services need to be accompanied by family members.	$c_{11,1}$:30¥/time	$g_{11,1}$:18¥/time
	Meal Aid (Hard time window task)	Community Restaurant Meal Delivery U_{12}	Meals delivered at community restaurants	$c_{12,1}$:5¥/time	$g_{12,1}$:2¥/time
		Order Meal U_{13}	Only provide food ordering, takeaway and delivery, meal expenses are at your own expense.	$c_{13,1}$:2¥/time	$g_{13,1}$:1¥/time
		Purchasing Dishes U_{14}	According to the user's needs, go to the nearest place to buy ingredients and deliver them to the user's home. The weight should not exceed 10 kg, and the cost of ingredients will be borne by yourself.	$c_{14,1}$:10¥/time	$g_{14,1}$:5¥/time
		Home Feeding U_{15}	Nursing services	$c_{15,1}$:10¥/time	$g_{15,1}$:5¥/time
		Home Cooking U_{16}	Users prepare ingredients and provide door-to-door production. (excluding grocery shopping)	$c_{16,1}$:Common home cooking20¥/time $c_{16,2}$: Nutritious meals25 ¥/time	$g_{16,1}$: Common home cooking10¥/time $g_{16,2}$: Nutritious meals12¥/time
Health Management	Medical Assistant (Hard time window task)	Escort for Medical Treatment U_{17}	Accompany the elderly to see a doctor according to their needs	$c_{17,1}$:10¥/time/hour	$g_{17,1}$:5¥/time/hour
		Daily Measurement U_{18}	Measure blood pressure, blood sugar and other daily numerical measurements	$c_{18,1}$:10¥/time	$g_{18,1}$:5¥/time
		Drug Injection and Dressing Change U_{19}	Injecting injections such as insulin that require daily injections, daily dressing changes	$c_{19,1}$:30¥/time	$g_{19,1}$:16¥/time

algorithm solution is shown in Fig. 6. The following are the precise steps of the multi-objective genetic algorithm.

Step 1 Initialize the population: Generate variable seeds randomly, create seed vectors based on the number of populations, and initialize 50 populations. This process is similar to constructing a random table of numbers for sorting services.
Step 2 Coding: Use binary numbers to turn a number into a binary number so that the number corresponding to the seed becomes an alternation of 1 and 0 during cross mutation.
Step 3 Calculation of fitness: By substituting the generated variables into the corresponding objective function, we can calculate the fitness values of all seeds in each generation. The seed with the highest fitness value is then selected as the optimal value for that generation.
Step 4 Selection: The individuals in the seeds are selected with a certain probability, and the ones with a large fitness value have a high probability of being selected. The available selection methods are the roulette wheel selection method and the tournament selection method. In this case, the bidding selection method is chosen for the calculation.
Step 5 Crossover: Crossover is performed on the chosen persons, utilizing various approaches such as single-point crossover, two-point crossover, and scatter crossover. The offspring resulting from this crossover process inherits the valuable variable information from the parent generation, akin to the preservation of advantageous genes in biological evolution. Consequently, the offspring's optimal individuals seek to improve upon the parent generation's optimal individuals. However, since the problem at hand involves personnel ordering, it is necessary to refurbish the offspring after the monotonous crossover to prevent any overlapping of the order. The crossover method employed here differs from that of traditional genetic algorithms, as it incorporates the Partial Matching Crossover method to address any potential issues with sequence number overlap.
Step 6 Mutation: To prevent slipping into the local optimum, the individuals in a specific range in the father are mutated with a certain probability. After a mutation, a poor individual may become an excellent individual after mutation.
Step 7 Update: Reevaluate the fitness value of the individuals who have completed the aforementioned processes, retain the persons with the finest fitness value, and proceed with the subsequent inheritance process.

7. Example analysis

This paper uses Matlab programming tools to analyze an example in order to validate the mathematical model and genetic algorithm of the path optimization problem of elderly care service personnel. The elderly population is generally concentrated throughout the neighborhood. As the China home care service platform operates within a specific geographical area, 25 data points were selected from the dataset to represent the distribution of locations where elderly individuals reside. This is an illustration of how a home care service platform, specifically designed for the number 0, organizes and sends out caregivers to give on-site services to 25 elderly individuals. The platform takes into account the specific needs and preferences of each elder, including their desired service level and the time they require assistance. The initial population for the evolutionary method is $N = 50$, crossover probability is $P_C = 0.86$, mutation probability is $P_m = 0.2$, and iterations are $Gen = 300$.

If there are 25 elderly $\{A_1, A_2, A_3, ..., A_{25}\}$ and 7 optional elderly care service care personnel $\{B_1, B_2, B_3, ..., B_7\}$ in a home care service platform for the elderly, the platform will begin to optimize the route after gathering the elderly's specific information and the elderly care service care personnel's particulars. The potential use of the aforementioned approach is demonstrated by offering home care services to these 25 elderly individuals and optimizing the route of elderly care service personnel. Additionally, it provides a concise overview of the calculating techniques and results obtained from implementing the aforementioned strategy.

The service tasks provided by the Home Care Service Platform are $U = \{U_1, U_2, ..., U_{11}, ..., U_{19}\}$, in which $U' = \{U_1, U_2, ..., U_{11}\}$ indicates that the first 11 service tasks are soft time window service tasks , $U'' = \{U_{12}, U_{13}, ..., U_{19}\}$ indicates that the 12th to 19th service tasks are hard time window service tasks, where tasks U_2 , U_{10} , U_{11} , U_{16} , U_{18} and U_{19} are graded with skill levels for the aged care workers. The specific service tasks, service descriptions, and reference prices [56] provided by the home care service platform are shown in Table 1.

The specific information and requirements of the 25 elderly people $\{A_1, A_2, A_3, ..., A_{25}\}$ are shown in the table, that is, the location

Table 2
Location coordinates and priorities of the service center and 25 elderly people.

The elderly A_i	Axis (/10000 km)	Priority pr_i	The elderly A_i	Axis (/10000 km)	Priority pr_i
A_0	(36421138.19,3430109.226)		A_{13}	(36391757.95,3407119.668)	0.86
A_1	(36442062.02,3403658.724)	0.81	A_{14}	(36403647.62,3433416.095)	0.36
A_2	(36441620.71,3443279.669)	0.77	A_{15}	(36410100.45,3455531.38)	0.59
A_3	(36408850.06,3414956.69)	0.22	A_{16}	(36441083.4,3428121.962)	0.78
A_4	(36433150.51,3423500.236)	0.52	A_{17}	(36410455.98,3433095.45)	0.49
A_5	(36405835.32,3427387.229)	0.35	A_{18}	(36412083.96,3440253.865)	0.51
A_6	(36401157.03,3416031.897)	0.18	A_{19}	(36412411.76,3445679.44)	0.38
A_7	(36411337.72,3420097.071)	0.70	A_{20}	(36387070.22,3416043.345)	0.79
A_8	(36389692.77,3410444.538)	0.56	A_{21}	(36444863.8,3411559.407)	0.73
A_9	(36436572.56,3447199.227)	0.45	A_{22}	(36390680.15,3424637.254)	0.38
A_{10}	(36401873.3,3406700.266)	0.31	A_{23}	(36385497.93,3432431.164)	0.52
A_{11}	(36407031.45,3438847.191)	0.64	A_{24}	(36463277.55,3416383.45)	0.69
A_{12}	(36410098.37,3405637.621)	0.46	A_{25}	(36389246.18,3440557.154)	0.55

Table 3
25 elderly tasks and service level requirements.

A_i	U_1	U_2	U_3	U_4	U_5	U_6	U_7	U_8	U_9	U_{10}	U_{11}	U_{12}	U_{13}	U_{14}	U_{15}	U_{16}	U_{17}	U_{18}	U_{19}
A_1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
A_2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
A_3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A_4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0
A_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
A_6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
A_7	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
A_8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
A_9	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A_{10}	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
A_{11}	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A_{12}	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
A_{13}	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A_{14}	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A_{15}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
A_{16}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
A_{17}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
A_{18}	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A_{19}	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A_{20}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
A_{21}	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
A_{22}	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A_{23}	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
A_{24}	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
A_{25}	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4
Gender needs of 25 elderly.

A_i	U_1	U_2	U_3	U_4	U_5	U_6	U_7	U_8	U_9	U_{10}	U_{11}	U_{12}	U_{13}	U_{14}	U_{15}	U_{16}	U_{17}	U_{18}	U_{19}
A_1	–	–	–	(1,1)	–	–	–	–	–	–	–	–	–	–	–	(0,1)	–	–	–
A_2	(1,1)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	(1,1)	–
A_3	–	–	–	–	(1,1)	–	–	–	–	–	–	–	–	–	–	–	–	–	–
A_4	–	–	–	–	–	–	–	–	–	–	–	–	–	(1,1)	–	(0,1)	–	–	–
A_5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	(1,1)
A_6	–	–	–	–	–	–	(1,1)	–	–	–	–	–	–	–	–	–	–	–	–
A_7	–	–	–	–	–	–	–	–	–	–	–	(1,1)	–	–	–	–	–	–	–
A_8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	(1,0)	–	–
A_9	–	–	–	–	–	–	–	–	–	(1,1)	–	–	–	–	–	–	–	–	–
A_{10}	–	–	–	–	–	–	–	–	(1,1)	–	–	–	–	–	–	–	–	–	–
A_{11}	–	(1,1)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
A_{12}	–	–	–	–	–	–	–	–	–	–	–	–	(1,1)	–	–	–	–	–	–
A_{13}	–	(1,1)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
A_{14}	–	–	–	(1,1)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
A_{15}	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	(1,1)
A_{16}	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	(1,0)	–	–	–
A_{17}	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	(1,1)
A_{18}	–	–	(1,0)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
A_{19}	–	–	–	–	(1,1)	–	–	–	–	–	–	–	–	–	–	–	–	–	–
A_{20}	–	–	–	–	–	–	–	–	–	–	–	–	–	–	(1,0)	–	–	–	–
A_{21}	–	–	–	–	–	–	–	–	–	(1,1)	–	–	–	–	–	–	–	–	–
A_{22}	–	–	–	–	–	(1,1)	–	–	–	–	–	–	–	–	–	–	–	–	–
A_{23}	–	–	–	–	–	–	–	(1,1)	–	–	–	–	–	–	–	–	–	–	–
A_{24}	–	–	–	–	–	–	–	–	(1,1)	–	–	–	–	–	–	–	–	–	–
A_{25}	(1,1)	(1,1)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

coordinates of the 25 elderly people and the home care service platform, and the priority of each elderly person are shown in Table 2; the required service tasks, service level requirements, and gender requirements are shown in Table 3 and Table 4; the time window time of each elderly for service tasks, the minimum time satisfaction θ_i set by each elderly, and the minimum time satisfaction set according to each elderly; the time window $[\inf_{ih}, \sup_{ih}]$ calculated by θ_i is shown in Table 5.

Assume that there will be seven elderly care service personnel assigned to the home care service platform. In this calculation example, the needs of the elderly are as closely met as possible with the least amount of money spent. Table 6 provides the demographics of the personnel providing elderly care services, including gender, labor cost per hour, and the historical favorable rating rate. Table 7 displays the service task information for elderly care service personnel.

Calculations are done to create the multi-objective optimization model (18) and produce the result diagram. Fig. 7 depicts the door-to-door service route taken by elderly care service personnel. The elderly care service personnel in the figure begins at the home care service platform and returns to the platform once the service task is finished. Table 7 illustrates the precise door-to-door service pattern of the elderly care service personnel. The findings revealed that the elder 5, 8, and 25 were not attended to by the service personnel. And it was discovered that the elder 5 and 8 required hard time window service tasks, while the elder 25 needed soft time window service tasks see Table 8.

The levels of the elder 5, 8, and 25 service tasks are all fixed levels, and no circumstance can result in a reduction in the level requirements. As a result, the three elderly people are asked whether to postpone the service time; the elder 5 and 25 choose not to do so, while the elder 8 choose to do so. If the elderly 5 requests a difficult window service task, the elder 25 will find another elderly care service personnel to accommodate their needs. If the service task needed by the elder 25 is a soft time window task, it will be changed to match again the following day after seeking advice, and the elderly 25's priority will be raised to 1. The service time window is changed to [780, 1140] after elder 8 agrees to delay it, and a multi-objective optimization model (21) is created for calculation. Fig. 8 depicts the door-to-door service route taken by elderly care service personnel after altering the service window. The specific door-to-door service sequence of the elderly care service personnel is displayed in Table 9 after changing the time window.

8. Discuss

The bulk of traditional scheduling concerns consider two main objectives: total satisfaction and service time cost [57], or complete contentment of the elderly and total operational cost [58]. This study considers three objectives: minimizing travel time and idle time of service personnel, enhancing elder citizen satisfaction by considering service people's interests, and reducing platform operational costs. The conventional scheduling problem solely considers time satisfaction when assessing the objective function of overall

Table 5
Service task time window, minimum satisfaction and minimum satisfaction time.

A_i	Service task	$[e_i^h, l_i^h]$	$[e_i^{h'}, l_i^{h'}]$	θ_i	$[\inf_{ih}, \sup_{ih}]$
A_1	$[e_1^4, l_1^4]$	[540,1020]	[480,1200]	0.2	[492,1164]
	$[e_1^{16}, l_1^{16}]$	[660,780]	[660,780]	1	[660,780]
A_2	$[e_2^1, l_2^1]$	[540,720]	[480,840]	0.2	[492,816]
	$[e_2^{18}, l_2^{18}]$	[480,600]	[480,600]	1	[480,600]
A_3	$[e_3^5, l_3^5]$	[720,1020]	[600,1200]	0.1	[612,1182]
A_4	$[e_4^{14}, l_4^{14}]$	[540,720]	[540,720]	1	[540,720]
	$[e_4^{16}, l_4^{16}]$	[540,810]	[540,810]	1	[540,810]
A_5	$[e_5^{19}, l_5^{19}]$	[480,720]	[480,720]	1	[480,720]
A_6	$[e_6^7, l_6^7]$	[540,720]	[480,840]	0.3	[498,804]
A_7	$[e_7^{12}, l_7^{12}]$	[690,780]	[690,780]	1	[690,780]
A_8	$[e_8^{17}, l_8^{17}]$	[780,1080]	[780,1080]	1	[780,1080]
A_9	$[e_9^{10}, l_9^{10}]$	[840,1020]	[720,1200]	0.1	[732,1188]
A_{10}	$[e_{10}^9, l_{10}^9]$	[540,720]	[480,720]	0.3	[498,720]
A_{11}	$[e_{11}^2, l_{11}^2]$	[540,1020]	[480,1200]	0.2	[492,1164]
A_{12}	$[e_{12}^{13}, l_{12}^{13}]$	[600,720]	[600,720]	1	[600,720]
A_{13}	$[e_{13}^2, l_{13}^2]$	[540,690]	[480,720]	0.2	[492,714]
A_{14}	$[e_{14}^4, l_{14}^4]$	[540,1020]	[480,1200]	0.1	[486,1182]
A_{15}	$[e_{15}^{19}, l_{15}^{19}]$	[480,720]	[480,720]	1	[480,720]
A_{16}	$[e_{16}^{16}, l_{16}^{16}]$	[1050,1140]	[1050,1140]	1	[1050,1140]
A_{17}	$[e_{17}^{19}, l_{17}^{19}]$	[480,720]	[480,720]	1	[480,720]
A_{18}	$[e_{18}^3, l_{18}^3]$	[840,1020]	[780,1080]	0.1	[786,1074]
A_{19}	$[e_{19}^5, l_{19}^5]$	[540,1080]	[480,1200]	0.2	[492,1176]
A_{20}	$[e_{20}^{15}, l_{20}^{15}]$	[720,780]	[720,780]	1	[720,780]
A_{21}	$[e_{21}^{10}, l_{21}^{10}]$	[840,1020]	[720,1200]	0.1	[732,1182]
A_{22}	$[e_{22}^6, l_{22}^6]$	[540,1080]	[480,1200]	0.3	[498,1164]
A_{23}	$[e_{23}^8, l_{23}^8]$	[540,1080]	[480,1200]	0.3	[498,1164]
A_{24}	$[e_{24}^9, l_{24}^9]$	[840,1080]	[780,1140]	0.1	[786,1134]
A_{25}	$[e_{25}^1, l_{25}^1]$	[540,720]	[480,840]	0.2	[492,816]
	$[e_{25}^2, l_{25}^2]$	[840,990]	[840,1020]	0.2	[840,1014]

Table 6
Basic information of elderly care service personnel.

The elderly care service personnel B_j	Sex S^j	Labor cost per unit of time ami_j	Historical favorable rating e_j
B_1	(0,1)	44.46	0.95
B_2	(0,1)	50.00	0.96
B_3	(1,0)	45.83	0.98
B_4	(0,1)	42.86	0.91
B_5	(0,1)	50.96	0.93
B_6	(1,0)	40.18	0.92
B_7	(1,0)	53.70	0.9

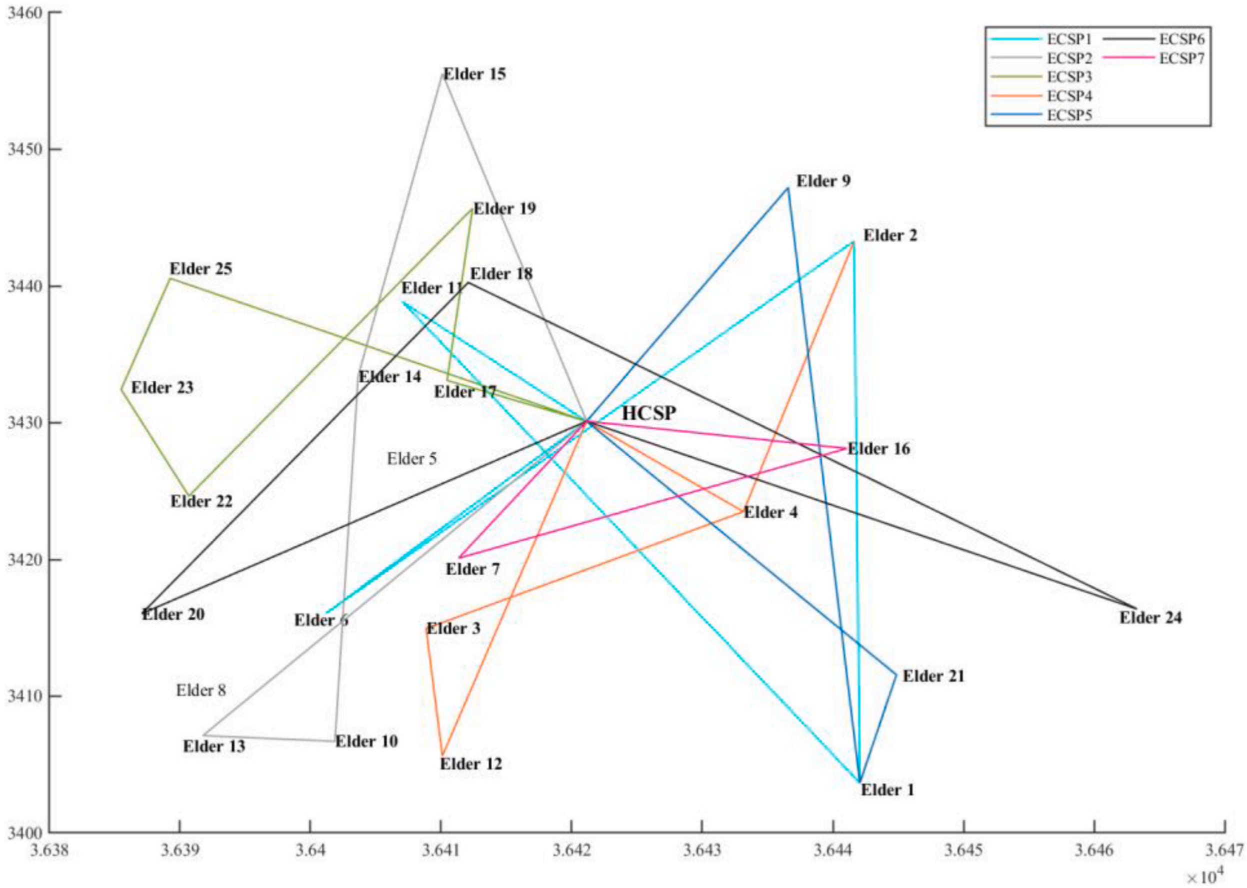

Fig. 7. Route map of elderly care service personnel.

satisfaction. However, this paper additionally incorporates the priority of the elderly and the performance of elderly care service personnel in addressing the specific needs of the elderly. Moreover, it places greater emphasis on human nature. Certain conventional schedulers prioritize either the time cost or the operating cost when evaluating the two factors, neglecting to consider both simultaneously. This study considers the expenditures associated with platform operations and the expenses related to travel for service personnel. The home care service platform ensures both a guaranteed turnaround time and a high level of service from its workers, while also minimizing operating expenses, not solely for the purpose of making a profit. Therefore, we compare the objectives included in the traditional scheduling problem. One approach is to evaluate the combination of overall contentment and labor costs, while the other approach is to evaluate the combination of overall satisfaction and the total costs of operations.

8.1. Comparison with the optimization model considering the cost of service time

Considering the optimization model of total satisfaction and service time cost, x_{ijh} is set as a type 0-1 decision variable, $x_{ijh} = 1$ means that if the *j* th elderly care service personnel performs the *h* service for the *i* th elderly; Otherwise $x_{ij} = 0$. According to the above description and analysis of model problems, the multi-objective path optimization model for elderly care service personnel is con-

Table 7
Task level information of elderly care service personnel.

B_j	U_1	U_2	U_3	U_4	U_5	U_6	U_7	U_8	U_9	U_{10}	U_{11}	U_{12}	U_{13}	U_{14}	U_{15}	U_{16}	U_{17}	U_{18}	U_{19}
B_1	1	3	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	0	1
B_2	1	2	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1
B_3	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1
B_4	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	2	1	1	0
B_5	1	0	1	1	1	1	1	1	1	3	1	1	1	1	1	1	1	0	0
B_6	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	0	0
B_7	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0

Table 8
Order of door-to-door service of elderly care service personnel.

The elderly care service personnel B_j	Home service route order
B_1	$A_{11}(U_2) - A_1(U_4) - A_2(U_1) - A_6(U_7)$
B_2	$A_{13}(U_2) - A_{10}(U_9) - A_{14}(U_4) - A_{15}(U_{19})$
B_3	$A_{17}(U_{19}) - A_{19}(U_5) - A_{22}(U_6) - A_{23}(U_8) - A_{25}(U_2)$
B_4	$A_4(U_{14}) - A_2(U_{18}) - A_4(U_{16}) - A_3(U_5) - A_{12}(U_{13})$
B_5	$A_{21}(U_{10}) - A_1(U_{16}) - A_9(U_{10})$
B_6	$A_{20}(U_{15}) - A_{18}(U_3) - A_{24}(U_9)$
B_7	$A_7(U_{12}) - A_{16}(U_{16})$

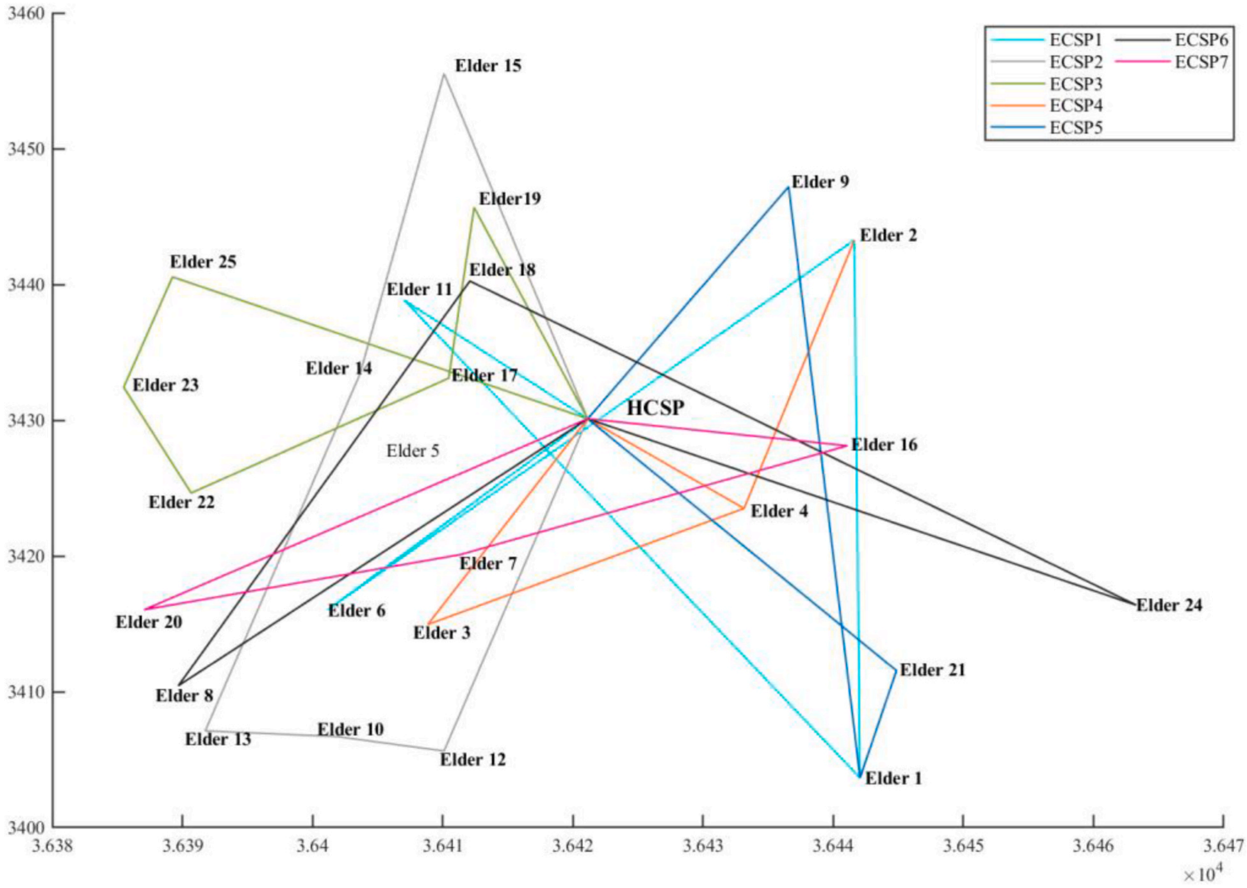

Fig. 8. The path diagram of elderly care service personnel after changing the time window.

Table 9
Change the order of door-to-door service for elderly care service personnel after the time window.

The elderly care service personnel B_j	Home service route order
B_1	$A_{11}(U_2) - A_1(U_4) - A_2(U_1) - A_6(U_7)$
B_2	$A_{12}(U_{13}) - A_{10}(U_9) - A_{13}(U_2) - A_{14}(U_4) - A_{15}(U_{19})$
B_3	$A_{19}(U_5) - A_{17}(U_{19}) - A_{22}(U_6) - A_{23}(U_8) - A_{25}(U_2)$
B_4	$A_4(U_{16}) - A_2(U_{18}) - A_4(U_{14}) - A_3(U_5)$
B_5	$A_{21}(U_{10}) - A_1(U_{16}) - A_9(U_{10})$
B_6	$A_8(U_{17}) - A_{18}(U_3) - A_{24}(U_9)$
B_7	$A_{20}(U_{15}) - A_7(U_{12}) - A_{16}(U_{16})$

structed with maximizing service satisfaction and minimizing service time cost as objective functions.

$$\max Z_1 = \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} p_{ijh}\, x_{ijh} \tag{22a}$$

$$\min Z_2 = \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} vt_{i\acute{i}j}\, x_{ijh}\, x_{\acute{i}jh} + \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} wt_{\acute{i}j}\, x_{\acute{i}jh} + \sum_{h=1}^{v}\sum_{j=1}^{n}\sum_{i=1}^{m} C_1 x_{ijh} \tag{22b}$$

$$s.t.\quad x_{ijh}x_{\acute{i}jh}\left(t_{ij} + st_{jh} + vt_{i\acute{i}j} + wt_{\acute{i}j} - \sup_{\acute{i}h}\right) \le 0 \tag{22c}$$

$$\left(s^{i}_{hg} - s^{j}_{g}\right)x_{ijh} \ge 0\ ,\ g = 1,2\ ,\ h = 1,2,...,v \tag{22d}$$

$$\left(o^{j}_{h} - o^{i}_{h}\right)x_{ijh} \ge 0\ ,\ h = 1,2,...,v \tag{22e}$$

$$\sum_{h=1}^{v}\sum_{j=1}^{n} x_{ijh} \le 1 \tag{22f}$$

$$\sum_{h=1}^{v} st_{jho} + \sum_{h=1}^{v}\sum_{i=1}^{m} vt_{i\acute{i}h}\, x_{ijh}\, x_{\acute{i}jh} \le 480 \tag{22g}$$

$$\sum_{j=1}^{n}\sum_{h=1}^{v} x_{0jh} = 2 \tag{22h}$$

$$x_{ijh} = 0 \text{or} 1 \tag{22i}$$

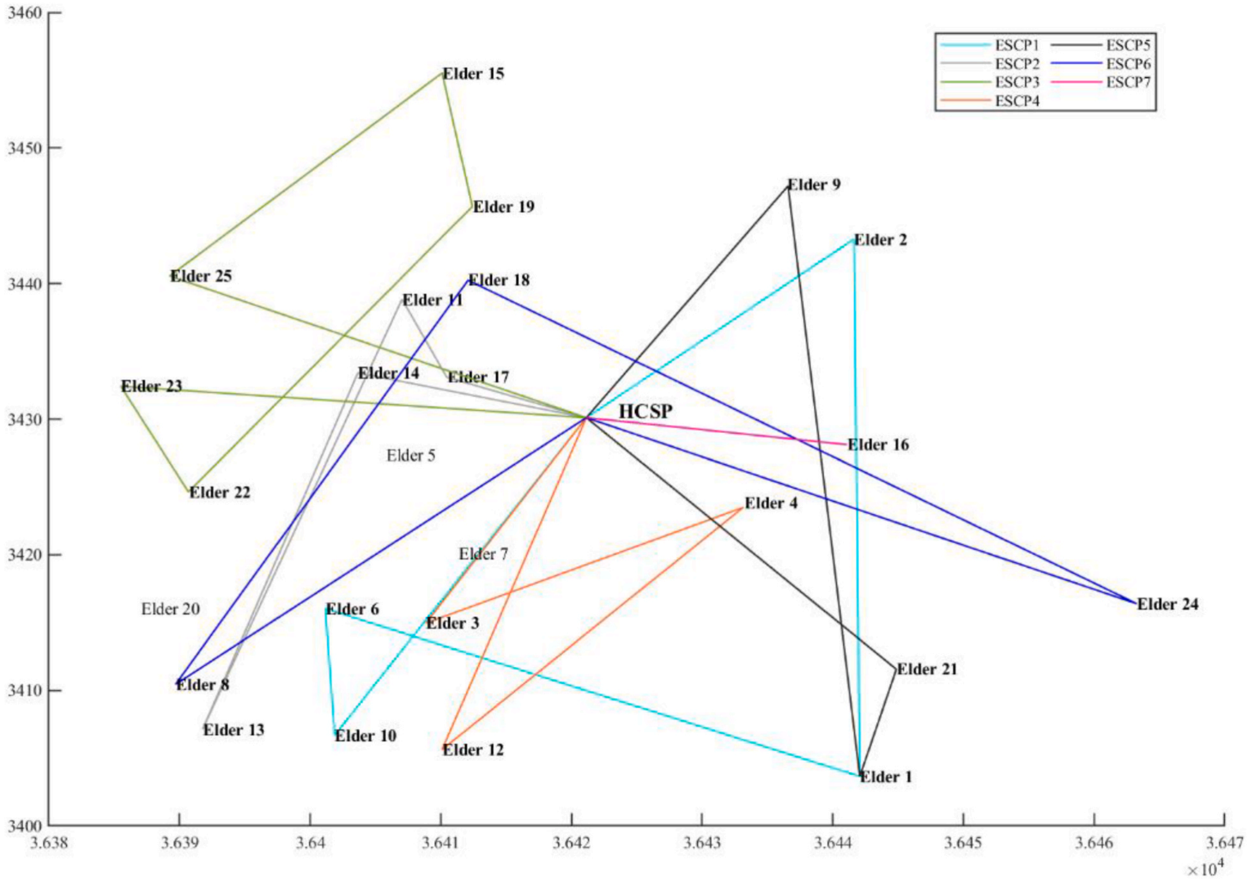

Fig. 9. The resulting path diagram of model (22).

In model (22), equation (22a) and equation (22b) are objective functions, and equation (22a) represents the maximum time satisfaction of the elderly. Formula (22b) indicates that the time cost of elderly care service personnel is minimized, and the time penalty cost in traditional scheduling is not considered here. The Constraint (22c) means that the time when the j th elderly care service personnel arrives at the residence of the i' th elderly after serving the i th elderly must meet the tolerable latest service time of the i' th elderly; the constraint (22d) means that the gender of the j th elderly care service personnel must match the gender needs of the i th elderly; the constraint condition (22e) means that the service level of the j th elderly care service personnel must meet the level required by the i th elderly; the constraint (22f) indicates that a certain task can only be matched by one elderly care service personnel per elderly; the constraint condition (22g) indicates that the working hours of each elderly care service personnel shall not exceed 8 h per day; the constraint condition (22h) means that each elderly care service personnel starts from the home care service platform 0 and returns to the starting point after serving each elderly; the constraint condition (22i) indicates that the decision variable is a 0–1 variable.

The resultant diagram is obtained through calculation. The result of model (22) is shown in Fig. 9, and the specific door-to-door service sequence is shown in Table 10.

According to the model's calculation results (22), the elder 4, 5, 7, 20, 2(27), and 25(29) are not attended to by service personnel. The door-to-door service elder of the service people is contingent solely upon the agreed-upon time and the satisfaction of the elderly. The decision to serve the elderly is made by considering the journey time and waiting time. In contrast to the model (18), the model (22) does not take into consideration the priority of the elderly or the historical score of the service personnel. As can be seen, there is not enough on-site care for the elderly, and a significant number of elderly people have not successfully matched the calculation results of the model (22). Although the total time spent by service providers is minimal, the elderly's overall satisfaction is also minimal. The total cost of model (18) after iteration is 3815.03, and it tends to be stable when the number of iterations is 99. The total cost of model (22) after iteration is 3696.25, and it tends to be stable when the number of iterations is 96. The total cost comparison between model (18) and model (22) after iteration is shown in Fig. 10. In view of the difference between the two models, the total cost of model (18) is greater than that of model (22), but the model (22) does not consider the operating cost, and there are more elderly people who are not served, so the total cost difference between the two models is small. The matching efficiency of model (18) is higher, and the calculated result of model (22) is less plausible than that of model (18).

8.2. Comparison with the optimization model considering operating costs

Considering the optimization model of total satisfaction and operating cost, let x_{ijh} be a decision variable of type 0–1, and $x_{ijh} = 1$ means that if the j th elderly care service personnel provides the h th service for the i th elderly, otherwise $x_{ij} = 0$. According to the above description and analysis of the model problems, with the objective function of maximizing service satisfaction and minimizing operating costs, a multi-objective path optimization model for aged care service personnel is constructed as follows:

$$\max Z_1 = \sum_{h=1}^{v} \sum_{j=1}^{n} \sum_{i=1}^{m} p_{ijh}\, x_{ijh} \tag{23a}$$

$$\min Z_2 = \sum_{h=1}^{v} \sum_{j=1}^{n} \sum_{i=1}^{m} C_2 x_{ijh} + \sum_{h=1}^{v} \sum_{j=1}^{n} \sum_{i=1}^{m} C_3\, st_{jho}\, x_{ijh} + \sum_{h=1}^{v} \sum_{j=1}^{n} \sum_{i=1}^{m} C_4 \left(1 - \sum_{j=1}^{n} x_{ijh}\right) \tag{23b}$$

$$s.t. \quad x_{ijh} x_{i'jh} \left(t_{ij} + st_{jh} + vt_{ii'j} + wt_{i'j} - \sup_{i'h}\right) \le 0 \tag{23c}$$

$$\left(s^i_{hg} - s^j_g\right) x_{ijh} \ge 0 \ , \ g = 1, 2 \ , \ h = 1, 2, \ldots, v \tag{23d}$$

$$\left(o^j_h - o^i_h\right) x_{ijh} \ge 0 \ , \ h = 1, 2, \ldots, v \tag{23e}$$

$$\sum_{h=1}^{v} \sum_{j=1}^{n} x_{ijh} \le 1 \tag{23f}$$

Table 10
The route sequence of that model (22).

The elderly care service personnel B_j	Home service route order
B_1	$A_2(U_1) - A_1(U_4) - A_6(U_7) - A_{10}(U_9)$
B_2	$A_{17}(U_{19}) - A_{11}(U_2) - A_{13}(U_2) - A_{14}(U_4)$
B_3	$A_{25}(U_1) - A_{15}(U_{19}) - A_{19}(U_5) - A_{22}(U_6) - A_{23}(U_8)$
B_4	$A_{12}(U_{13}) - A_4(U_{16}) - A_3(U_5)$
B_5	$A_{21}(U_{10}) - A_1(U_{16}) - A_9(U_{10})$
B_6	$A_8(U_{17}) - A_{18}(U_3) - A_{24}(U_9)$
B_7	$A_{16}(U_{16})$

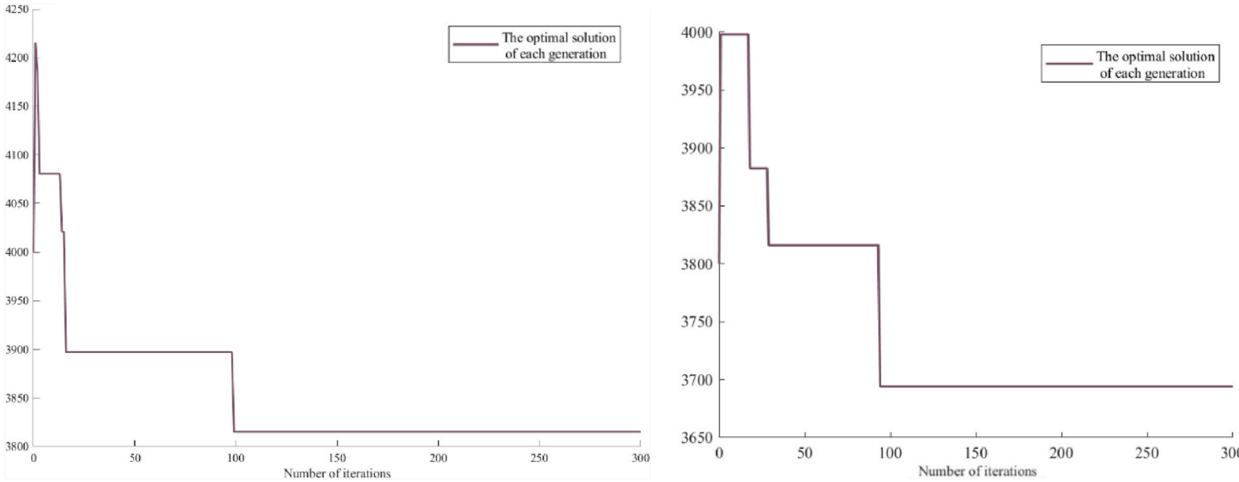

Fig. 10. Comparison of the total cost of model (18) and model (22) after iteration.

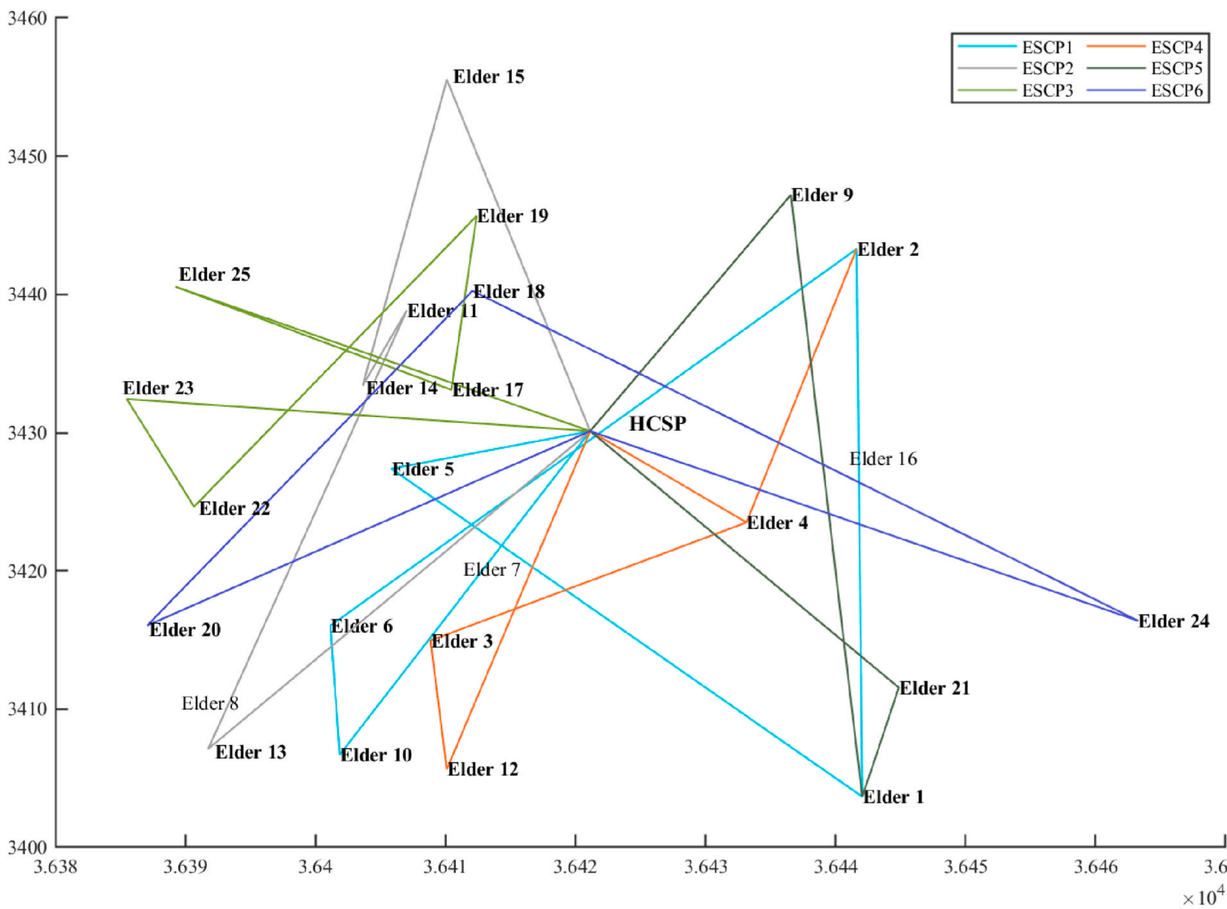

Fig. 11. The resulting road map of the model (23).

$$\sum_{h=1}^{v} st_{jho} + \sum_{h=1}^{v} \sum_{i=1}^{m} vt_{i\acute{i}h}\, x_{ijh}\, x_{\acute{i}jh} \leq 480 \tag{23g}$$

$$\sum_{j=1}^{n} \sum_{h=1}^{v} x_{0jh} = 2 \tag{23h}$$

$$x_{ijh} = 0 \text{or} 1 \tag{23i}$$

In model (23), equations (23a) and (23b) are objective functions, and equation (23a) represents the maximization of time satisfaction for the elderly; formula (23b) means that the operating cost of the home care service platform is maximized. The Constraint (23c) means that the time when the j th elderly care service personnel arrives at the residence of the $\acute{i}$ th elderly after serving the i th elderly must meet the tolerable latest service time of the $\acute{i}$ th elderly; the constraint (23d) means that the gender of the j th elderly care service personnel must match the gender needs of the i th older person; the constraint condition (23e) means that the service level of the j th elderly care service personnel must meet the level required by the i th elderly; the constraint (23f) indicates that a certain task can only be matched by one elderly care service personnel per elderly; the constraint condition (23g) indicates that the working hours of each elderly care service personnel shall not exceed 8 h per day; the constraint condition (23h) means that each elderly care service personnel starts from the home care service platform 0 and returns to the starting point after serving each elderly; the constraint condition (23i) indicates that the decision variable is a 0–1 variable.

The resultant diagram is obtained through calculation. The result of model (23) is shown in Fig. 11, and the specific door-to-door service sequence is shown in Table 11.

According to the model's calculation result (23), the elder 7, 8, and 16 and 25 are not served by the elderly care service personnel. The service order of the service personnel is only based on the agreed time and the time satisfaction of the elderly, and only takes into account the operating cost when deciding whether to send a service personnel to serve the elderly, in contrast to the model (18), which does take into account the priority of the elderly and the scores of the service personnel. As can be seen from this, more elderly people than model (18) did not successfully match the calculation results of model (23), some service personnel's walking route is lengthy, and some elderly people are not served because the service provider decided to send one fewer service personnel in order to reduce operating costs. In the comparison diagram of the total costs of models (18) and (23) after iteration, the total cost of model (18) is 3815.03 and tends to stabilize at 99 iterations; the total cost of model (22) is 3802.67 and tends to stabilize at 120 iterations. The total cost comparison between model (18) and model (23) after iteration is shown in Fig. 12. Given the differences between the two models, model (18) has a slightly higher total cost than model (23), but because model (23), which does not account for the cost of service time and which leaves more elderly people unattended, has a close total cost difference, model (18) is more reasonable in terms of service sequence and matching effectiveness.

8.3. Discussion on the dynamic factors

This paper focuses on a specific context involving the assignment of elderly care service personnel. The assignment is based on established rules and relies on accurate advance information about the demand for senior care services. The demand information is obtained in advance through predetermined means, and the assignment of personnel is based on this established demand. In the case of the elder care service personnel assignment problem, the smart home care service platform assigns elderly care service personnel to elderly individuals based on their specific time and service level needs, as well as their known geographic locations. The platform determines the service tasks by combining information from offline surveys of home care service platforms, home care companies, and the needs of the elderly in the target area. Based on the collected and consolidated demand information, the platform establishes specific tasks that can be provided. Using pre-collected and integrated demand information, the platform establishes unique service offerings and establishes the following ordering principles for elderly care services: Scheduling elderly care services in advance. The platform streamlines the allocation of elderly care service personnel by utilizing precise data on the demand for elderly service jobs and the specific characteristics of the elderly individuals to be assisted. To account for potential delays, a specific amount of extra time is allocated for each service task, as the service time can differ among the elderly individuals being served.

It is crucial to recognize that the smart home care service platform may encompass diverse dynamic aspects that can impact the design and execution of the assignment program for elderly care personnel. Therefore, it is necessary to conduct a detailed analysis of these dynamic factors, including.

Table 11
The route sequence of that model (23).

The elderly care service personnel B_j	Home service route order
B_1	$A_5(U_{19}) - A_1(U_4) - A_2(U_1) - A_6(U_7) - A_{10}(U_9)$
B_2	$A_{13}(U_2) - A_{11}(U_2) - A_{14}(U_4) - A_{15}(U_{19})$
B_3	$A_{25}(U_2) - A_{17}(U_{19}) - A_{19}(U_5) - A_{22}(U_6) - A_{23}(U_8)$
B_4	$A_4(U_{14}) - A_2(U_{18}) - A_4(U_{16}) - A_3(U_5) - A_{12}(U_{13})$
B_5	$A_{21}(U_{10}) - A_1(U_{16}) - A_9(U_{10})$
B_6	$A_{20}(U_{15}) - A_{18}(U_3) - A_{24}(U_9)$

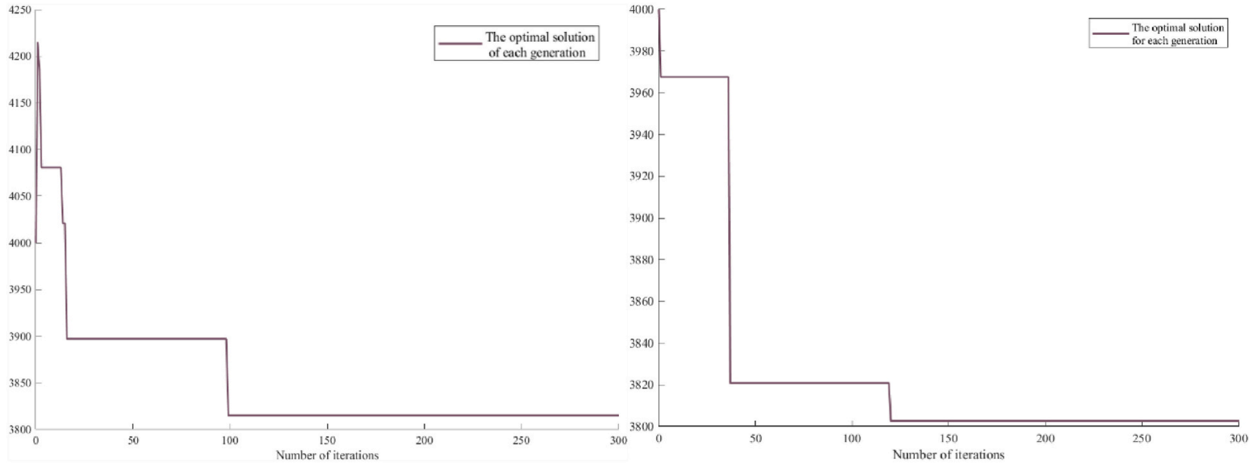

Fig. 12. Comparison of total cost between model (18) and model (23) after iteration.

(1) Fluctuations in user demand for services. There can be changes in the demand for services due to changes in the situation of the elderly or the external environment. These changes can include changes in the specific services needed and changes in the demand for each service item. For example, an elderly person may need to replace the need for "chatting and accompanying" with the need for "psychological counseling" due to changes in mental health. Similarly, an elderly person may temporarily increase the need for "accompanying medical treatment" due to physical or family circumstances. For instance, an older individual may need to shift their need for social interaction and companionship to a need for psychological counseling as a result of changes in their mental health condition. Alternatively, an elderly person may temporarily require more support and assistance with seeking medical treatment and companionship due to their physical and familial circumstances. To effectively respond to these dynamic changes, the platform must promptly identify the patterns of service demand and make appropriate adjustments to the number of service professionals and their professional qualifications. In addition, it is imperative to regularly administer satisfaction surveys and service quality evaluations in order to get insight into the genuine sentiments of the elderly towards the service and to identify any evolving needs. This will enable prompt adjustments to be made to the service's content and the allocation of associated resources.
(2) Fluctuations in user order information. There are multiple guidelines for requesting elderly care personnel, including the flexibility to order or modify services at any given moment, the ability to pre-order or modify services on the same day, the option to order or modify services only one day in advance, the availability of ordering extra services for specific needs, and the choice to discontinue care for an elderly individual. These different ordering rules may also come with different prices, times, and specific requirements for the content of the services. Various ordering regulations may also encompass distinct pricing, scheduling, and service specifications. Varying protocols for arranging elderly care services directly influence the allocation of elderly care service personnel, necessitating the optimization of personnel assignment for varied situations. The relationship between the strictness of booking rules for senior care services and the accuracy of order information obtained in advance is straightforward. The stricter the rules, the higher the accuracy of the obtained information. Additionally, strict rules make it easier to achieve the optimal assignment of senior care service personnel. On the other hand, flexible ordering rules for senior care services increase the likelihood of random orders. This means that the order information is constantly changing, requiring the consideration of dynamic adjustments to the senior care service staffing plan based on the specific ordering rules.
(3) Fluctuations in external variables. Several extrinsic and intrinsic elements can influence the execution of the program for assigning personnel to services for the elderly. The elements that are outside the users' control encompass severe weather, traffic congestion, emergencies, the temporary unavailability of elderly service individuals, and other weather and traffic-related concerns. Consequently, the elderly service company may need to make dynamic adjustments to the established assignment program. For instance, factors such as inclement weather or road congestion may cause delays in the scheduling of elderly care services. Additionally, the temporary unavailability of an elderly care service personnel due to personal circumstances may prevent them from delivering the service. If there are any dynamic factors that impact the implementation of the senior care staff assignment program, the program can be adjusted in a dynamic manner based on specific ordering rules. The objective is to maximize the satisfaction of the elderly while also meeting the demand for senior care orders to the greatest extent possible.

It is important to emphasize that the smart home care platform for the elderly should analyze the specific characteristics and number of elderly individuals with specific needs in its region. This analysis should be conducted in response to potential changes in users' service demands. Additionally, the platform should conduct surveys to assess the demand for elderly services systematically. This will help optimize the establishment of elderly service projects and the allocation of resources for elderly care. Initially, the platform will primarily address the fundamental service requirements of the elderly, such as daily care and medical assistance.

Additionally, it will assess the regional service resources to determine the availability of personnel and facilities. As the platform gains traction and expands its services, it will conduct more comprehensive surveys to ascertain the elderly's demand for various types of additional services. Smart home care platforms should assess their service-providing capability and partnership with external firms to adapt to potential changes in user order information. They should then establish suitable ordering rules for their operations. In general, when the platform lacks sufficient service capacity and resources, and there is no effective collaboration with external service departments in the new region, the ability to respond to temporary changes in service tasks or additional service orders is relatively limited. In this case, it is advisable to establish rules for booking elderly care services in advance to ensure optimal assignment of elderly care service personnel. Conversely, if the platform has sufficient service capacity and resources, and there is successful cooperation with external service departments in the service coverage area, it can fully or partially handle transitory changes in service tasks or additional service orders. In such situations, it is more appropriate to establish rules that support ordering at any time. When the platform has enough service capacity and resources, and has established effective collaboration with external service departments in the service coverage area, it is fully or partially capable of responding to temporary changes in service tasks or additional service orders. In such cases, it is more appropriate to establish rules that facilitate ordering and changing of elderly care services at any time, or allow for ordering or changing of elderly care services in advance on the same day. This will help improve user satisfaction. To address potential fluctuations in external factors beyond the control of the user, the smart home care platform should systematically examine the unique attributes of its geographical location and the movement patterns of personnel within the organization. This analysis will enable the platform to optimize the distribution of standby elderly care resources and develop effective emergency response strategies. When the service coverage area is affected by weather, traffic, and other external factors, and there is a significant amount of personnel movement within the organization, it is crucial to have an adequate number of standby elderly care service resources and establish emergency response departments. This will enable better management of various non-user factors that may cause dynamic changes. In cases where the service coverage area is minimally affected by weather, traffic, and other external factors, or when there is a significant amount of personnel movement within the organization, it is advisable to provide multiple standby elderly service resources and develop comprehensive emergency response plans. This will help minimize the impact of dynamic changes in non-client-side factors on the assignment of pension service personnel. Enterprises should conduct a thorough and unbiased analysis of all potential dynamic factors, taking into account the specific region and their own circumstances. This will enable them to develop rational rules and methods to ensure the optimal functioning of the smart home care service platform.

9. Conclusion

As people's living standards improve and the population ages, China's elderly care industry has entered a new era. The home-based elderly service model is a necessary response to the country's situation, and improving the elderly's access and happiness is closely tied to enhancing the supply and quality of elderly services. This study presents a strategy for deploying elderly service personnel on an hourly basis, taking into account limits related to service skills and time windows. The method is based on gathering information about the service demand of the elderly, the expected time it takes to provide door-to-door service, the desired level of service, and any gender preferences. It then calculates the satisfaction of the service and the cost of operating the senior care service platform. Using this information, an optimization model is created with the objectives of minimizing travel costs, maximizing satisfaction, and minimizing operation costs. The model takes into account constraints such as the door-to-door time, gender preferences, service demand, and working time. By solving this optimization model, an assignment plan for elderly service personnel is obtained. Ultimately, a method comparison is performed on the cases, revealing that the service order achieved through the implementation of the technique provided in this research is both rational and highly efficient in terms of matching. The method proposed in this paper for deploying elderly service personnel on an hourly basis, with time window constraints, has a broad range of practical applications. In the actual operation of the elderly service platform, it is important to adapt to local conditions and consider individual variations and temporal dynamics. The method allows for flexible utilization, taking into account the trade-offs between travel costs, satisfaction, and operating costs. It emphasizes a service approach that prioritizes the needs of the elderly, improving communication and understanding their specific requirements. Timely data on the time window is also collected. Furthermore, it gives priority to services that cater specifically to the elderly population, strengthens relationships with older individuals, understands their unique needs, and carries out prompt and effective analysis of data within a certain time period to ensure optimal and efficient allocation of elderly personnel.

The research in this paper is restricted to specific limitations. It focuses solely on a particular set of scenarios that are based on predetermined rules for deploying elderly service personnel. However, in the actual operation of a smart home care platform, there are various dynamic factors that may affect the assignment of service personnel. These dynamic factors can give rise to different problem scenarios. This work solely examines the potential dynamic elements and does not provide a focused methodological investigation. In the next stage of the study, we will perform a more thorough examination of the implementation of services for elderly individuals, considering many changing factors.

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Data availability statement

Data included in article/supp. material/referenced in article.

CRediT authorship contribution statement

Chao Yu: Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Tianxiang Gao:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] D. Gu, K. Andreev, M.E. Dupre, Major trends in population growth around the world, China CDC weekly 3 (28) (2021) 604.
[2] M. Zhou, G. Zhao, Y. Zeng, et al., Aging and cardiovascular disease: current status and challenges, Rev. Cardiovasc. Med. 23 (4) (2022) 135.
[3] E.F. Fang, M. Scheibye-Knudsen, H.J. Jahn, et al., A research agenda for aging in China in the 21st century, Ageing Res. Rev. 24 (2015) 197–205.
[4] Kimberly A. Kline, Dawn ME. Bowdish, Infection in an aging population, Curr. Opin. Microbiol. 72 (29) (2016) 63–67.
[5] Q. Shao, J. Yuan, J. Lin, et al., A SBM-DEA based performance evaluation and optimization for social organizations participating in community and home-based elderly care services, PloS one16 (3) (2021) 1–25.
[6] S. Chaulagain, J. Li, A. Pizam, What matters, and what matters most? Exploring resident satisfaction in continuing care retirement communities, Int. J. Contemp. Hospit. Manag. 34 (7) (2022) 2472–2495.
[7] W.Y. Chung, W.J.J. Yeung, S. Drobnič, Family policies and care regimes in Asia, Int. J. Soc. Welfare 30 (4) (2021) 371–384.
[8] M. Zechner, Care of older persons in transnational settings, J. Aging Stud. 22 (1) (2008) 32–44.
[9] W. Cai, Z. Liu, Y. Ma, et al., "Time Bank" Diversified Mutual Assistance Urban Pension New Form, 2022 6th International Seminar on Education, Management and Social Sciences (ISEMSS 2022), Atlantis Press, 2022, pp. 2621–2632.
[10] J. McAlister, E.L. Briner, S. Maggi, Intergenerational programs in early childhood education: an innovative approach that highlights inclusion and engagement with older adults, J. Intergener. Relat. 17 (4) (2019) 505–522.
[11] Zhongsheng Liu, Huanxing Liu, Analysis of the option factors of the residents pension mode taking Beijing as an example, in: China's Road and Aging Population, Springer Nature Singapore, Singapore, 2023, pp. 319–341.
[12] Y. Zhang, Application of blockchain technology in community-based home elderly care services under population aging. Proceedings of the 11th International Conference on Software and Information Engineering, 2022, pp. 86–91.
[13] Y. Zhang, M. Zhang, H. Hu, et al., Spatio-temporal characteristics of the supply and demand coupling coordination of elderly care service resources in China, Int. J. Environ. Res. Publ. Health 19 (16) (2022) 10397.
[14] M. Lin, K.S. Chin, L. Ma, et al., A comprehensive multi-objective mixed integer nonlinear programming model for an integrated elderly care service districting problem, Ann. Oper. Res. 291 (2020) 499–529.
[15] J. He, Construction of a diversified integrated platform based on home care services, Open J. Soc. Sci. 7 (6) (2019) 161–167.
[16] C.J. Su, C.Y. Chiang, IAServ: an intelligent home care web services platform in a cloud for aging-in-place, Int. J. Environ. Res. Publ. Health 10 (11) (2013) 6106–6130.
[17] R. Li, Y. Li, X. Gao, Study on the current situation of urban empty nest elderly of community home care and innovation strategy, in human aspects of IT for the aged population. Acceptance, in: Communication and Participation: 4th International Conference, ITAP 2018, Held as Part of HCI International 2018, 2018, pp. 108–117. Las Vegas, NV, USA.
[18] J. Zhu, K. Shi, C. Yang, et al., Ethical issues of smart home-based elderly care: a scoping review, J. Nurs. Manag. 30 (8) (2022) 3686–3699.
[19] J. Hu, Y. Zhang, L. Wang, et al., An evaluation index system of basic elderly care services based on the perspective of accessibility, Int. J. Environ. Res. Publ. Health 19 (7) (2022) 4256.
[20] Q. Zhang, M. Li, Y. Wu, Smart home for elderly care: development and challenges in China, BMC Geriatr. 20 (1) (2020) 1–8.
[21] D. Pal, S. Funilkul, N. Charoenkitkarn, et al., Internet-of-things and smart homes for elderly healthcare: an end user perspective, IEEE Access 10 (2018) 10483–10496.
[22] D.K. Jain, R. Jain, X. Lan, et al., Driver distraction detection using capsule network, Neural Comput. Appl. 33 (2021) 6183–6196.
[23] R. Zhuo, X. Sun, Design of Personalized Service System for Home-Based Elderly Care Based on Data Fusion, Big Data Analytics for Cyber-Physical System in Smart City: BDCPS 2019, 28-29 December 2019, Shenyang, China, Springer, Singapore, 2020, pp. 412–419.
[24] L.M. Camarinha-Matos, O. Castolo, J. Rosas, A multi-agent based platform for virtual communities in elderly care, in: EFTA 2003, 2003 IEEE Conference on Emerging Technologies and Factory Automation, Proceedings (Cat. No. 03TH8696), IEEE, 2003, pp. 421–428.
[25] C.J. Su, C.Y. Chiang, IAServ: an intelligent home care web services platform in a cloud for aging-in-place, Int. J. Environ. Res. Publ. Health 10 (11) (2013) 6106–6130.
[26] J. Qi, P. Yang, G. Min, et al., Advanced internet of things for personalised healthcare systems: a survey, Pervasive Mob. Comput. 41 (2017) 132–149.
[27] R. Menghi, A. Papetti, M. Germani, Product Service Platform to improve care systems for elderly living at home, Health Policy and Technology 8 (4) (2019) 393–401.
[28] J. Xiong, M. Zuo, Understanding factors influencing the adoption of a mobile platform of medical and senior care in China, Technol. Forecast. Soc. Change 179 (2022) 121621.
[29] B. Wang, L. Xu, Construction of the "internet plus" community smart elderly care service platform, Journal of Healthcare Engineering (2021) 4310648.
[30] Y. Xu, M. Qiu, Research on the design of internet plus home care service platform for intelligent elderly, in: Application of Big Data, Blockchain, and Internet of Things for Education Informatization: First EAI International Conference, BigIoT-EDU 2021, Virtual Event, August 1–3, 2021, Proceedings, Part II 1, Springer International Publishing, 2021, pp. 607–612.
[31] Y. Cui, L. Zhang, Y. Hou, et al., Design of intelligent home pension service platform based on machine learning and wireless sensor network, J. Intell. Fuzzy Syst. 40 (2) (2021) 2529–2540.
[32] S. Chen, M. Nakamura, S. Saiki, Developing a platform of personalized conversation scenarios for in-home care assistance, in: 2021 IEEE International Conference on Industry 4.0, Artificial Intelligence, and Communications Technology (IAICT), IEEE, 2021, pp. 148–153.
[33] J. Li, Smart home care Service platform based on cloud computing, in: Innovative Computing: IC 2020, Springer, Singapore, 2020, pp. 1461–1468.
[34] D. Gale, L.S. Shapley, College admissions and the stability of marriage, Am. Math. Mon. 69 (1) (1962) 9–15.

[35] T. Schouwenaars, B. De Moor, E. Feron, et al., Mixed integer programming for multi-vehicle path planning, in: 2001 European Control Conference (ECC), IEEE, 2001, pp. 2603–2608.
[36] H. Allaoua, S. Borne, L. Létocart, et al., A matheuristic approach for solving a home health care problem, Electron. Notes Discrete Math. 41 (2013) 471–478.
[37] A. Coppi, P. Detti, J. Raffaelli, A planning and routing model for patient transportation in health care, Electron. Notes Discrete Math. 41 (2013) 125–132.
[38] J.F. Bard, Y. Shao, A.I. Jarrah, A sequential GRASP for the therapist routing and scheduling problem, J. Sched. 17 (2) (2014) 109–133.
[39] R.B. Bachouch, A. Guinet, S. Hajri-Gabouj, A decision-making tool for home health care nurses' planning[C]//Supply Chain Forum: an International Journal, Taylor & Francis 12 (1) (2011) 14–20.
[40] C. Fikar, P. Hirsch, A matheuristic for routing real-world home service transport systems facilitating walking, J. Clean. Prod. 105 (2015) 300–310.
[41] G. Hiermann, M. Prandtstetter, A. Rendl, et al., Metaheuristics for solving a multimodal home-healthcare scheduling problem, Cent. Eur. J. Oper. Res. 23 (2015) 89–113.
[42] K.D. Rest, P. Hirsch, Daily scheduling of home health care services using time-dependent public transport, Flex. Serv. Manuf. J. 28 (2016) 495–525.
[43] S. Yalçındağ, A. Matta, E. Şahin, et al., The patient assignment problem in home health care: using a data-driven method to estimate the travel times of care givers, Flex. Serv. Manuf. J. 28 (2016) 304–335.
[44] W. Deng, J. Xu, H. Zhao, An improved ant colony optimization algorithm based on hybrid strategies for scheduling problem, IEEE Access 7 (2019) 20281–20292.
[45] S.L. Goh, S.N. Sze, N.R. Sabar, et al., A 2-Stage approach for the nurse rostering problem, IEEE Access 10 (2022) 69591–69604.
[46] P. Jangir, S.A. Parmar, I.N. Trivedi, et al., A novel hybrid particle swarm optimizer with multi verse optimizer for global numerical optimization and optimal reactive power dispatch problem, Engineering Science and Technology, an International Journal 20 (2017) 570–586.
[47] I.N. Trivedi, P. Jangir, M. Bhoye, et al., An economic load dispatch and multiple environmental dispatch problem solution with microgrids using interior search algorithm, Neural Comput. Appl. 30 (2018) 2173–2189.
[48] P. Jangir, N. Jangir, A new non-dominated sorting grey wolf optimizer (NS-GWO) algorithm: development and application to solve engineering designs and economic constrained emission dispatch problem with integration of wind power, Eng. Appl. Artif. Intell. 72 (2018) 449–467.
[49] M. Premkumar, R. Sowmya, C. Ramakrishnan, et al., An efficient and reliable scheduling algorithm for unit commitment scheme in microgrid systems using enhanced mixed integer particle swarm optimizer considering uncertainties, Energy Rep. 9 (2023) 1029–1053.
[50] M. Premkumar, P. Jangir, B.S. Kumar, et al., A new arithmetic optimization algorithm for solving real-world multiobjective CEC-2021 constrained optimization problems: diversity analysis and validations, IEEE Access 9 (2021) 84263–84295.
[51] R.H. Bhesdadiya, I.N. Trivedi, P. Jangir, et al., An NSGA-III algorithm for solving multi-objective economic/environmental dispatch problem, Cogent Engineering 3 (2016) 1269383.
[52] B. Feng, F. Lai, Multi-attribute group decision making with aspirations: a case study, Omega 44 (2014) 136–147.
[53] J. Decerle, O. Grunder, A.H. El Hassani, et al., A hybrid memetic-ant colony optimization algorithm for the home health care problem with time window, synchronization and working time balancing, Swarm Evol. Comput. 46 (2019) 171–183.
[54] H. Chen, Y. Qiu, K. Wang, et al., Calculation strategy and empirical study on labor cost for delivering community-based integrated pension service and medical service, Chinese General Practice 22 (16) (2019) 1915.
[55] S. Mirjalili, S. Mirjalili, Genetic Algorithm, Evolutionary Algorithms and Neural Networks: Theory and Applications, 2019, pp. 43–55.
[56] P.M. Alt, Community resources for older adults: programs and services in an era of change, Contemp. Gerontol. 11 (4) (2005) 170.
[57] A.M. Fathollahi-Fard, A. Ahmadi, F. Goodarzian, et al., A bi-objective home healthcare routing and scheduling problem considering patients' satisfaction in a fuzzy environment, Appl. Soft Comput. 93 (2020) 106385.
[58] H. Chen, L. Gao, Z. Zhang, Multi-objective optimal scheduling of a microgrid with uncertainties of renewable power generation considering user satisfaction, Int. J. Electr. Power Energy Syst. 131 (2021) 107142.