Faculty of Business

Optimization of Recruitment Process for AI Smart Home Startups in China

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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

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Abstract

The promising prospect and potential growth in the Chinese Artificial Intelligence (AI) industry facilitate the emergence of AI Smart Home startups, which in the meantime, face great challenges in the recruitment process with the rapid growth and changing landscape of the industry in China. It is hence worth studying related recruitment issues to lend impetus to industry prosperity, for which, optimization is introduced to assist in handling the recruitment process.

From a theoretical perspective, human resources management (HRM) research commonly concentrates less on searching for mathematical models for scientific decision-making. In literature on optimization and HRM, only a limited number of papers focus on the recruitment process in AI Smart Home startups. Almost all of them consider a single HRM issue rather than providing a set of solutions to the recruitment process. Therefore, the main objective of this study is to develop a set of optimization models for the recruitment process of the Chinese AI Smart Home startups.

In this study, a set of mathematical models are developed for compensation package designing, recruitment quantum planning, business trips routing, and interview selection. To establish a better HR practice, HR well-being parameters are incorporated into the models, including 'team diversity', 'job enrichment', 'job enlargement', 'work-life balance', and 'flexible working hours'. Illustrative cases are given as computational examples. For the compensation package designing and recruitment quantum planning, optimal solutions of linear and nonlinear models are found, which can be referred to in the recruitment plan. For business trips routing and interview selection, the proposed models provide information about the optimal choices. The computational results suggest that economic efficiency is achieved with

cost savings, both operation and well-being constraints are satisfied, whereby the validity and feasibility of the models are demonstrated. To comprehensively understand the applicability of the proposed models, this thesis also compares different integrations of HR well-being parameters, discussing the advantages and limitations of different situations. Overall, based on the satisfaction of operation and HR well-being constraints, the proposed models can achieve cost-savings, the extent of which depends on the application data. It is suggested that the proposed models are applicable in the recruitment process, while the priority of well-being parameters and expenditures should be judged by startups based on corporate conditions and corporate values. Compared with other commonly used methods in the recruitment process, the superiority of the optimization method is demonstrated as it is more flexible and comprehensive in practice to integrate different factors and assist in making more objective decisions.

The research outcome of this thesis advances the body of knowledge on the application of optimization models, expanding the scope to the recruitment process in AI Smart Home startups. In the HRM aspect, the proposed models support managerial knowledge with mathematical analysis in AI startups. The integration of different knowledge fields suggests interdisciplinary research to solve the targeted problems optimally. Optimization model can serve as an assistant tool to support decision-makings. With the specific attention to the case of the Chinese AI Smart Home industry, this study can assist startups in achieving optimal recruitment.

Chapter 1

Introduction

This section discusses AI Smart Home startups in China with the related recruitment issues in human resources management (HRM). Optimization is introduced with the intention of solving the problems.

1.1 AI Smart Home Startups in China

1.1.1 AI Smart Home

In the 1956 Dartmouth Conference, the concept of 'artificial intelligence' (AI) was first established by J. McCarthy, M. L. Minsky, H. Simon, A. Newell, C. E. Shannon, N. Rochester, and other scholars, and is defined as machines that can simulate human intelligence to understand, learn and think (Pan 2016; McCarthy et al. 1955; Crevier 1993). With the development, AI gets involved with broad research areas including Machine Learning, Intelligent Search, Data Mining, and so on. It has been widely applied in real-life activities, such as Autopilot, Automatic Speech Recognition, Face Recognition, and AI Smart Home (Izario et al. 2017; Smadi et al. 2015; Pannu 2015; Zhang et al. 2014).

In particular, AI Smart Home is a system that can provide a convenient and comfortable living environment, making daily life easier. All digital devices can communicate with each other, and execute orders from the inhabitants automatically. Not only can the devices be remotely controlled by the APP, but also can be voice-controlled by 'talking' to it. Furthermore, some devices can automatically perform functions by machine perception and deeper learning (Hsu et al. 2017; Malche and Maheshwary 2017; Lobaccaro et al. 2016; Alam et al. 2012; De Silva et al. 2012).

Accordingly, AI Smart Home companies are those that provide smart devices and customization services for the whole smart home solutions. Correspondingly, AI Smart Home startups are the young companies in this industry, usually operating using combined business models with different functions, such as the R&D department, manufacturing department and sales department. The range of Smart Home services covers the whole usage areas, including the devices for the smart kitchen, smart washroom, smart bedroom, smart living room, smart home-security as well as smart healthcare. There are many kinds of products that customers can choose based on self-situation to satisfy the daily-life needs, such as smart air-conditioner, smart rice cooker and smart light. Products can be purchased from both online and offline shops (e.g. Haier 2020; Mi 2020; ORVICO 2020 etc.).

As one of the key development fields in AI, AI Smart Home holds a strong position in AI development, including the huge investments, the increased number of companies as well as the bright market prospect in the area (CISTP 2018; CAICT 2018). The power of capital venture is a key factor in the stimulation of the AI Smart Home industry. As the high-tech industry, related technologies in the AI Smart Home system are also paid close attention to a huge amount of investment. It is worth noting that the Chinese top AI investment giants, such as Alibaba, Baidu, Tencent, and Jingdong, all attach great importance to the investment in AI Smart Home. The flourishing financing opportunities have inspired more and more people to set up businesses in the AI Smart Home industry. Taking Beijing as an example, as the top one city of AI development in China, Beijing attracts AI companies to set up businesses, among which, AI Smart Home companies take one of the main proportions (Beijing Municipal Commission 2018). The increasing trend in the number of companies solidifies how significant is the position of AI Smart Home in the development of the AI industry in China. The market prospect of AI Smart Home in China is bright. From the customer and market aspects, AI Smart Home production makes up one of the key components of AI markets. As the products that closely relate to daily life, there is a strong indication that the AI Smart Home products have the potential to develop rapidly in China (Zhao 2020).

AI Smart Home has attracted and will continuously attract investments with a bright prospect. As AI Smart Home is closely related to people's daily lives, it is worth paying attention to this industry. Studying the AI Smart Home companies, noting the currently existing issues, and searching the possible solutions can contribute to better corporate development. With a business boom, there will be more convenient and useful products that companies can provide to customers, whereby the quality of life can be improved.

1.1.2 AI Prospect in China

There are more and more AI startups founded in China in recent years, including AI Smart Home startups. The driving forces for this entrepreneurial boom are the government policies, economic significance as well as bright prospect.

The Chinese government attaches great importance to the AI industry. Since 2015, AI has been incorporated into long-term national development plans and policies. As indicated in Table 1, the AI Smart Home industry is a priority in the vigorous growth of China.

Table 1: Chinese Government AI Policies

Year	Policy	Document link
2015	"Made in China 2025"	《中国制造 2025》
2016	"Three-Year Guidance for Internet Plus Artificial Intelligence Plan"	《"互联网 +" 人工智能三年行动实施方案》
2016	"Thirteenth Five-Year Development Plan for National Strategic Emerging Industries"	《"十三五" 国家战略性新兴产业发展规划》
2017	"A Next Generation Artificial Intelligence Development Plan"	《新一代人工智能发展规划》
2017	"Three-Year Action Plan for Promoting Development of a New Generation Artificial Intelligence Industry (2018 - 2020)"	《促进新一代人工智能产业发展三年行动计划 (2018-2020 年)》
2018	"Action Plan on How China will Promote Artificial Intelligence (AI) Development in Universities"	《高等学校人工智能创新行动计划》

Another government policy, the "Mass Entrepreneurship and Innovation" (The State Council of People's Republic of China 2017; The State Council of People's Republic of China 2015), is also an important engine that encourages the founding of new companies (He et al. 2018). Innovation is the key strategy in Chinese development (Zhao 2019; Zhao 2017). Attaching importance to R&D has been the national plan, which aims to covert to an innovative nation (Zhao 2016). These policies related to AI and entrepreneurship facilitate the establishment of innovative enterprises. AI development has become the national strategy of China, with a huge amount of political and financial resources put into the industry (Robbins 2019; Jia et al. 2018). In such an encouraging environment, AI Smart Home startups are emerging at the right moment.

There is no doubt that AI should be an important part of Chinese economics (Ji and Huang 2019; Tan 2018; Purdy et al. 2017). AI has contributed to Chinese economic growth and it is positively estimated that the contribution will be continuously significant (Bian and Xu 2017). As the Chinese AI industry is booming and playing an increasingly important role in economic development, efforts are deserved to be made to study Chinese AI companies to lend impetus to industry prosperity.

1.2 Recruitment Process

Human resource management (HRM) is defined as a set of strategies and activities that focus on managing the employee-related issues, with the aim to assist the organization to achieve organizational goals successfully. The systematic process of HRM includes recruiting, selecting, training, and developing the required talent for the organization (O'riordan 2017; Byars and Rue 2006). HRM plays an important role in the success of startups. An imperfect HR system would make a negative impact on future development, causing the high possibility of failure due to the poor HRM practices (Salamzadeh and Kesim 2015; Salamzadeh 2015; Salamzadeh 2014).

1.2.1 Recruitment Issues

The Chinese AI companies, including AI Smart Home startups, are facing serious talent wars. These related issues make it difficult for startups to recruit the right person to fill the position, which should be addressed properly for the organization's development. The related issues include AI talent shortage, compensation package, employment preference, and difficulty of selection in recruitment.

There is a serious shortage of AI talent in China. The scarcity of talent in some particular areas affects industry development negatively. Moreover, with the increasing number of companies entering the AI field, the imbalance of supply and demand for AI talent is becoming more serious (Peng 2018; Ma and Hou 2018; Baidu 2018).

In the competitive labor market, there is no doubt that a high salary is one of the strategies to attract talent. The salary of AI engineers in China increases yearly. In addition, some companies would like to provide attractive benefit packages, especially for the top researchers (Takakura et al. 2019; Darboe 2018). As a consequence, startups struggle to offer competitive compensation packages to AI talent. This is a pressing issue with regards to talent recruitment as this competitive situation presents challenges when seeking qualified employees (Xu et al. 2018).

In addition, it is worth noting that not all the talent prefer working for startups even though the salary may be higher (Tencent 2017). This situation exacerbates the recruitment issues that startups face when it comes to the labour market. It makes it difficult to achieve 'team diversity' with different levels of AI talent, especially the experienced professionals (Shen 2018; Big companies snatch AI talent 2017).

Furthermore, the structure of AI talent in different categories has not been perfect enough (Baidu 2018). Based on the current situation of the Chinese AI educational system, for categories of AI talent, the largest supply of AI talent is the first level talent that applies AI tools to products. While the second level talent who combines AI with specific needs to produce AI tools and the third level talent who implements AI theory into algorithm models are relatively in short supply. The top-level scientists who mainly do cutting-edge research on AI theory are highly scarce. The skills and knowledge that the current graduates hold cannot satisfy the corporate requirements well, which leads to the difficulty of selection in the recruitment process. For AI Smart Home startups that focus on both technologies and products, it is desirable to recruit all levels of talent for better corporate development.

In addition to the current recruitment issues in the labor market, for startups that have just been founded, recruitment is the source of getting the right talent for further development. Startups are also unable to employ other strategies to get the right talent (i.e., providing training), unlike mature companies that have held the current workforce. The corporate capacities of startups, such as financial capacity, are not as strong as those in mature companies, which also affects the attractiveness of startups. For startups in the high-tech field, talent with strong backgrounds is one of the key competitive advantages (Alderman and Ray 2017). Moreover, as the AI Smart Home startups usually operate with a combined business model, there are different requirements of talent in different departments to satisfy the operation need. Therefore, for startups, recruitment should be attached great importance as it is the way of getting the right human resources, especially when facing such a serious talent war.

1.2.2 Existing Methods in Recruitment Process

In the recruitment process, the analysis of talent demand is a key factor. The problems of 'how many' and 'what kinds of' talent that the company needs should be answered properly, which will affect the later operation of the startup. Different methods, including both qualitative and quantitative methods, are utilized by HR practitioners and companies during the decision-making process of talent demand (Wu et al. 2017; Wang and Wei 2016). Qualitative methods, such as Delphi Technique and Experience Forecasting, are about analyzing the talent demand based on the views and experience of the trustworthy groups. The quantitative methods consist of using scientific analysis. For example, Statistical Analysis and Trend Forecasting focus on collecting and analyzing historical data to estimate the number of workers that need to be recruited for further development and new projects. To estimate the human resource demand and to decide the number of recruitment with mathematical formulas, Ratio Analysis can be used to directly calculate the result with the known ratio relationship of the productivity and the workload. Regression Analysis analyzes the relationship between the 'target workload' and 'required number of workers' with regression coefficient and regression equation.

The recruitment process involves some subjective factors, such as the personal opinions from the HR manager, which would affect the final decision. For example, in the interview and selection, decisions are institution-specific and even round-specific regarding the background of the candidates, the interviewers' impression of the candidate and so on. In the books and tutorials that systematically introduce recruitment and HRM (e.g. Yuan et al. 2018; Wang and Wei 2016; Wu et al. 2017), it is suggested that HR practitioners should consider both quantitative and qualitative methods to analyse and understand the situation more comprehensively. While, the quantitative methods that can provide objective views, such as mathematical modellings, are briefly introduced. Some objective views toward the targeted problems are deserved to be investigated as the additional supportive analysis tool for better decision-making.

To sum up, HRM is important to corporate development while the Chinese AI Smart Home startups are facing challenging recruitment issues, leading to the difficulty for startups to attract and select suitable talent. Hence, studies on how to address the recruitment problems optimally are required. In order to achieve optimal recruitment, in addition to the existing commonly used methods, this study explores the optimization tool to assist in addressing the current challenges related to these recruitment issues.

1.3 Optimization

Facing such a serious talent war and considering the urgent talent need, it is necessary to create the optimal recruitment solution for startups. Therefore, optimization is introduced to assist in addressing the aforementioned problems. Optimization modeling, which is one of the methods in operations research (OR), devotes to supporting and improving decision-making, focusing on solving the problems through the application of mathematical models and analytical tools. As a field of improving decision-making with advanced modelling, optimization is inherently analytical for complex problems. It includes various methods, such as Linear Programming (LP), Nonlinear Programming (NLP), Multi-objective Linear Programming (MOLP), Stochastic Optimization (SO), and so on (Mortenson et al. 2015; Yadav and Malik 2014).

To address the recruitment issues faced by the Chinese AI Smart Home startups, optimization can be employed based on its nature. Optimization models can describe related parameters with mathematical language, aiming at getting maximum returns based on minimum costs while all constraints can be satisfied (Chen 2005; Blomhøj and Jensen 2003). Employing optimization in HRM is also supported by previous literature. For example, Price et al. (1980) discussed the application of the mathematical model in HRM with literature reviews, concluding that optimization models are suitable when the organization needs to consider complex constraints or conflicting objectives. By reviewing a total of 147 manuscripts about applying mathematical modeling in human resources allocation problems, Bouajaja and Dridi (2017) provided the important mathematical formulations, constraints, and resolution methods that can be used in HRM.

Therefore, optimization modeling can be the method to solve the problem of where and how startups can allocate resources effectively and efficiently. With the understanding of the quantitative relationships of variables, the results of the optimization models can serve as the additional analysis materials for objective views. This study considers the recruitment activities that involve a quantitative nature. Regarding human resources planning, the quantitative problem relates to the costs of the compensation package, the number of employees to be recruited, the arrangement of work hours and the required workload to be completed. For business trips, the costs of visiting targeted talent pools should be measured, such as expenditures, routing selection, and so on. Moreover, in the interview selection section, there should be an optimal strategy towards hiring the candidates with the highest total values to form the team within the budget constraint.

1.4 Problem Statement

1.4.1 Research Problem

Chinese AI Smart Home startups benefit from the booming AI business, while at the same time, there are HRM challenges that startups need to deal with. Due to the increasing number of competitors and the shortage of AI talent, more and more companies, especially mature companies, attract and retain AI talent by providing attractive compensation packages (Takakura et al. 2019; Darboe 2018; Peng 2018; Ma and Hou 2018; Baidu 2018). The competitive salary is one of the key challenges for startups. Employees' preference for mature companies makes it more difficult for startups to recruit talent (Tencent 2017). Additionally, as the existing AI education system is still developing, there is insufficient AI talent to fit the industry requirements, leading to the imperfect AI talent structure (Baidu 2018). As for the startup itself, the corporate capacity is not as strong as the mature companies, including corporate visibility, management experience, budget, and so on. These limited resources aggravate the recruitment plight that startups are facing, in terms of creating undesirable organizational outcomes. Based on the operation in a combined business model, different requirements of talent in different departments should be understood and defined clearly. A study that investigates a set of optimal solutions to the recruitment process of AI Smart Home startups is therefore necessary. The optimal solutions aim at optimizing both quantitative and qualitative perspectives in the recruitment process. From the quantitative perspective, there will be the minimization of costs spent on HRM and the maximization of values obtained from HRM. Regarding the qualitative perspective, with the integration of optimization and HRM, a well-designed recruitment process can assist startups to get desirable human capital, improve working conditions, and establish a better HRM system.

1.4.2 Research Gap

Based on the literature review, there is a gap between optimization, recruitment process, and AI startups. HRM literature that studies the recruitment process with theoretical guidance, pays less attention to the mathematical relationship between variables (e.g. Kaur 2018; Dabic et al. 2011). Optimization, as a mathematical tool, can support scientific decision-making with objective views. As for the literature that investigates optimization and HRM, studies mainly focus on a specific HR issue rather than considering a set of solutions to the recruitment process. As for the targeted field, few works of literature concentrate on AI startups. In books and tutorials that systematically introduce recruitment and HRM (e.g. Yuan et al. 2018; Wang and Wei 2016; Wu et al. 2017), the quantitative methods, such as mathematical modellings, are usually briefly introduced only. Therefore, there is a gap in research on the application of optimization models to the recruitment process in Chinese AI Smart Home startups.

1.4.3 Research Questions

To cover the research gap outlined above, the general research question to be addressed is:

- How can the recruitment process in Chinese AI Smart Home startups be optimized?

The corresponding research questions are:

- How can startups optimally structure the compensation package to be attractive in the labor market and be affordable to startups?

- How can startups optimally plan recruitment quantum to satisfy operational and well-being requirements?
- How can startups design the business trips routing to minimize the costs?
- How can startups select from the candidates to form the optimal team within budget constraint?

1.4.4 Research Objectives

Accordingly, the research objectives are:

- To develop applicable linear and nonlinear optimization models for the recruitment process of Chinese AI Smart Home startups
- To examine the feasibility of the models with data collected from the Chinese AI Smart Home industry
- To demonstrate the superiority of the models with a comparison of the existing methods

1.5 Research Significance

By employing the optimization models for improving the recruitment process in Chinese AI Smart Home startups, this study integrates strengths of different knowledge bases to solve real-life problems. The contributions of this study are enrichments of the knowledge in academic fields of optimization and HRM, with a practical meaning for startups and the industry.

This study can enrich the application of the optimization models on HRM, covering activities in the recruitment process. Based on the nature of activities in Chinese AI Smart Home startups' recruitment process, a set of optimization models are proposed, which can serve as an extension to the practicable applications. The models developed in this study incorporate real-life factors into functions, the satisfaction of all constraints demonstrates the validity of optimization in problem-solving.

This study concurs with the literature that combines managerial and technical knowledge for better workforce planning (De Bruecker et al. 2015). Based on the mathematical nature, optimization is the complementary analysis tool of the HRM literature that studies theoretical guidance. Some literature focuses on the cause and effect relationships of HRM elements, but this thesis considers the mathematical relationships of elements. In addition to the existing HRM literature that investigates what activities would affect the success of HRM, this thesis pays attention to how to plan activities to obtain optimal results. With optimization technique, this study provides an objective method for staff planning in the recruitment stage, which enriches the literature that investigates practices and effects of staff planning on corporate performance and concurs with the literature that discusses the importance of staff planning to corporate success. This study, with a set of optimization models, provides an analysis method in addition to the literature with empirical research. Based on the literature on the topic of necessary parameters in the recruitment process, this thesis analyzes the quantitative relationships of parameters, which enhances the research on 'how to allocate resources to better realize the plan'.

Numerous HRM studies are mainly concerned about HRM in the larger organizations while the understanding of the important role of human capital in entrepreneurial companies surfaced in recent years (Dabic et al. 2011; Katz et al. 2002). This study can be the supplement of HRM research in startups, aiming at searching for better staff planning from the initial stage of HRM and the initial stage of corporate development. With the introduction of optimization to HRM, the research outcome is the supplement of the managerial knowledge in a mathematical way, providing an approach of optimal decision-making for the recruitment process in new enterprises.

In addition to the normal criteria that is usually considered in recruitment planning, such as salary benchmarks, in this study, from an HRM perspective, for better 'Talent Management' (TM), the HR well-being parameters, are described in a mathematical way to optimize the HR system. This study integrates HRM concepts of well-being and staff planning, which enriches the HRM research related to the topic of achieving a better HR system with employee welfare from the recruitment phase. Parameters of 'team diversity', 'job enlargement', 'job enrichment', 'flexible working hours', and 'work-life balance' are incorporated into a set of optimization models. Thus, another contribution of this study is the incorporation of the mathematical thinking of optimization with the HR well-being parameters. Not only would it support the optimal resource allocation, but it also takes the elements of mental and psychological health of the staff into consideration. It provides a new thought for the combination of different knowledge fields to make optimal decisions. A set of optimal models developed for the recruitment process can assist startups to be successful in the talent war, which reflects the concept of 'Strategic Human Resources Management' (Strategic HRM). From the view of Strategic HRM, an optimal recruitment process can assist the startup in getting human capital and facilitate desired employee behaviors, which will eventually result in a better corporate performance.

In the aspect of contribution to the real-life practices, for the new entrepreneurs of startups, who may not have enough knowledge, experience, and capital, this study could be the reference to establish a well-designed recruitment process for attracting great talent. Optimization models can be utilized to effectively and efficiently allocate resources for HR activities, from planning to implementing. Compared with the commonly used methods, the optimization method is more flexible and comprehensive in practice to integrate different factors. Meanwhile, this study aims at achieving the benefits of well-being parameters as much as possible, helping startups to create better working conditions for employees, which can be an advantage in the talent war. Based on the analysis of the advantages and limitations of the proposed models, this study objectively suggests that the incorporation of the HR well-being parameters is practicable with cost-saving, differences in which depend on a wide variety of factors, including the application data, the corporate values and the priority of HR well-being parameters of the startup. The computational results of the optimization models are also the objective references in the recruitment process, which can assist the better judgement with some other subjective factors. Thus, a set of optimization models presented in this study can be the additional and supplemental analysis tool in decision-making. With suitable talent recruited, the startup can develop and whereby the industry can prosper.

1.6 Thesis Structure

The thesis is organized as follows. Chapter 2 starts with the introduction to the HRM process, in particular the recruitment function, followed by important concepts of Talent Management (TM) and Strategic Human Resources Management (Strategic HRM), from which there is an understanding of the well-being parameters to be incorporated into optimization models. In Chapter 3, the development of optimization and its applications in HRM are reviewed. With the understanding of optimization and HRM, related mathematical models are developed based on the research questions. Chapter 4 is for recruitment plans and Chapter 5 is for recruitment activities. Related HRM well-being parameters are specially incorporated into the models. Computational examples are given to examine the feasibility of the models.

The superiority of the models is demonstrated by comparing the existing methods and the available options. At the same time, the advantages and limitations of the proposed models are objectively analyzed to comprehensively understand the applicability in real-life practices. The conclusion is presented in Chapter 6.

Chapter 2

Recruitment Process

This chapter focuses on reviewing Human Resource Management (HRM) literature. Based on General System Theory (GST), HRM can be regarded as a system that plays an important role in the operation of an organization, in which sub-systems interrelate with each other to achieve goals (Shin 2016; Chaudhry et al 2015; Alsabbah and Ibrahim 2014; Kast and Rosenzweig 1972). Recruitment is one of the sub-systems in HRM, defined as efforts and activities of the organization to identify and attract potential employees, try to increase the chance of the potential employees to accept the job offers (Abraham et al. 2015; Saks and Uggerslev 2010; Mayson and Barrett 2006; Taylor and Collins 2000; Barber 1998). Literature of recruitment process is reviewed to understand the key activities, which will discuss in Section 2.1. In the operation of the HRM system, to realize the desired performance, Talent Management (TM) is one of the essential concepts to be adopted when dealing with employee-related issues. TM is about anticipating and fulfilling the needs of the human capital, contributing to better performance, and creating strategic sustainable measures for the success of the organization (Scullion et al. 2010; Beechler and Woodward 2009; Collings and Mellahi 2009; Cappelli 2008). The literature review of TM provides ideas of well-being parameters that are deserved to be considered for a set of optimal solutions. Section 2.2 deliberates noteworthy parameters based on TM philosophy. As the system is goal-oriented, it works for achieving organizational goals. Therefore, it is essential to link HRM outcomes with organizational strategy (Chaudhry et al 2015; Alsabbah and Ibrahim 2014). Strategic Human Resource Management (Strategic HRM) focuses on aligning HRM with the corporate mission and vision, aiming at adding values to the positive organizational outcomes, such as high employee commitment, cost-effectiveness and better firm performance (Toh and Koon 2017; Koon 2014; Paauwe and Boon 2009; Bowen and Ostroff 2004). In the field of 'Strategic HRM', theories of 'resource-based view', 'human capital' as well as 'behavior perspective' are explored with the linkage of recruitment. Based on the resource-based view of Strategic HRM, human capital is one of the most important resources to provide a competitive advantage that can enhance firm performance. This will be discussed in Section 2.3. Last but not least, commonly-used research methods in HRM research are reviewed with the limitations of these methods in Section 2.4, then it comes to the necessity of optimization.

2.1 Key Recruitment Activities

HRM plays an important role in an organization. HRM closely relates to the success and survival of the organization (Taylor and Collins 2000). The AI Smart Home startups desire great talent but have limited resources to compete in the talent war. Compared with the mature companies that hold richer corporate resources and stronger industry positions, it is difficult for startups to gain a competitive edge over the mature companies in the talent war. Furthermore, talent with vast knowledge and experiences usually receive multiple job offers with competitive compensation packages, which enable the talent to evaluate companies to decide the best-fit employer for themselves (Hoye and Saks 2011; Barber 1998). Therefore, startups should attach great importance to design optimal recruitment strategies to attract talent.

The GST suggests that the sub-system of recruitment works together with other sub-systems and also interacts with the external environment, all activities of which are conscious of achieving organizational goals (Chaudhry et al 2015; Armstrong 2014). The main tasks of recruitment are establishing the recruitment objectives, developing a recruitment plan, carrying out recruitment activities, and evaluating recruitment results (Breaugh 2016; Breaugh 2009). Specific to the main activities of recruitment in China, besides the common recruitment components, China adheres to some specific national regulations and policies (Devonshire-Ellis et al. 2011).

2.1.1 Recruitment Plan

First of all, in the recruitment process, the startup needs to develop a solid recruitment plan based on the understanding of self needs and development objectives. For recruitment planning, designing suitable compensation packages and staffing plans to meet the required workload should be reasonably arranged. It addresses the questions of 'how much to pay for the compensation package' and 'how many employees are needed to complete the workload'. The compensation amount should be competitive in the labor market, meanwhile being affordable to the startup itself. It is of key importance for the startup to be attractive enough to the job seekers in the first phase of the recruitment. It is reasonable to assume that if there is no point of interest that job seekers have towards the startup, there will be no further recruitment phases such as application, interview, and selection (Hoye and Saks 2011; Murphy 1986). Moreover, based on the instrumental-symbolic framework, payment is one of the instrumental image dimensions that affect job seekers' impression of the potential employer in terms of objective, concrete and factual attributes (Hoye and Saks 2011). Therefore, it is imperative that the startup designs an attractive compensation package to attract potential applicants.

2.1.2 Recruitment Activities

Once a well-designed recruitment plan is established, the next course of action is carrying out the recruitment activities to search for and obtain potential job applicants from a targeted talent pool, such as universities. With the development of the Internet, e-recruitment has become more and more popular (Banerjee and Gupta 2019; Branine 2008). However, visiting universities to give presentations and joining graduate recruitment fairs are still considered very useful methods to attract and hire potential talent (Su and Yang 2015; Mathis and Jackson 2011). Meeting the graduates in universities directly is one of the effective channels for startups to reach out to the desired knowledgeable and skilled talent. Based on the literature, the information job seekers get about the company would affect the recruitment process. This is known as 'signaling theory' (Gregory et al. 2013; Cable and Turban 2001). If there are limited data or uncertainties that job seekers have, job seekers would like to evaluate the information based on the signals (Beraugh 2008). There is no doubt that visiting the campus to reach potential employees is one way to disseminate related information about the company as a positive signal to job seekers. Furthermore, employer knowledge that job seekers have is the determining factor of the awareness of job opening and the intention to apply for the vacancies (Cable and Turban 2001). Research has shown that job seekers report a higher attraction to positions if detailed and specific information of the job and organization is provided (Saks and Uggerslev 2010; Roberson et al. 2005; Taylor and Collins 2000). Since startups are new in the industry and job seekers may have insufficient related knowledge, it is a good practice to present specific information during the visits to the campuses, from which job seekers can know more details of startups, including corporate awareness, image and so on (Turban 2001). Engaging in recruitment activities on campus contributes to the 'familiarity' of the startup among job seekers, whereby the attractiveness of the startup can be increased (Breaugh 2013; Saks and Uggerslev 2010; Chapman et al. 2005; Turban and Greening 1997; Gatewood et al. 1993). The startup will begin receiving applications if information about job opening is disseminated to the job seekers. Then the company can begin choosing among the candidates to decide the most suitable talent to fill the vacancies through the interview and selection process (Shih et al 2005). The ideal selection is to find a seamless fit between the candidates and the organization's needs (Abraham et al. 2015). Thus, it is necessary to consistently conduct well-organized recruitment activities for the purpose of reaching a wider talent pool in order to widen the access to a larger number of candidates for a better selection.

With the understanding of the activities involved in the recruitment process, in Chapter 4 and Chapter 5, optimization models are developed for the recruitment plan, including 'compensation package designing' and 'recruitment quantum planning', and for carrying out the recruitment activities, including 'business trips routing' and 'interviews and selection'.

2.2 Recruitment and Talent Management

Recruitment is a vital element in the concept of talent management (TM). The concept of TM provides information on the valuable well-being parameters to be concerned for HRM. One of TM philosophies is the practice approach, which involves several activities, such as identifying, attracting, developing, managing, and retaining talent to the organization (Sparrow and Makram 2015; Sparrow et al. 2014; Cooke et al. 2014). TM is also concerned with managing talented people with the development of a strategic talent pool to fill the identified key positions (Al Ariss et al. 2014; Collings and Mellahi 2009). As one of the unique strategic resources, recruiting and retaining talent to achieve sustained competitive advantage is a continual challenge for organizations (Vaiman et al. 2017; Dries 2013), and TM is a method to source and protect these resources (Sparrow and Makram 2015). For shaping and implementing an effective TM system, recruitment is no doubt a key activity to capture human capital.

Specific to the case of China, there are some TM issues that Chinese companies are facing (Cooke et al. 2014). In the macro aspect, the Chinese education system cannot fully support the skills needed and talent demand in the labor market. From the organizational perspective, TM is not integrated into the long-term development plan due to the 'affordability' as there is a high cost involved in TM. Recruitment issues then arise, making it difficult to find, detect, and hire suitable talent. Specific to the situation in the Chinese startups, there are also some issues related to the unsuitable planning and implementing of recruitment (Mo and Chen 2017; He 2016; Chen 2015). In the early stage of the venture, with inadequate experience and mature policies, startups lack a perfect HR system to address issues related to effective human resource practices. Some startups would like to attach great importance to products and customers while paying less attention to HR. How to get suitable talent is the key strategy for every company as human resources are scarce, especially in high-tech companies. Thus, it is suggested that human resources should be given priority in startups (Robert 2016). Moreover, the visibility of startups in the talent market is not as strong as big companies (Breaugh 2009), which increases the difficulty of the startups' recruitment.

Based on the nature of the AI Smart Home startups, which are the high-tech companies, the recruitment of skilled talent is very important. A TM point of view places emphasis on the key positions in the companies (Al Ariss et al. 2014). In the context of AI Smart Home startups, research positions are regarded as the core positions, which need key employees to fill the vacancies. It is crucial to find high-quality talent with the right knowledge to fill positions (Su and Yang 2015). A knowledgeable workforce definitely establishes a competitive advantage to win a strong industry position (Kundu et al. 2012; Khandekar and Sharma 2006). Besides that, there is the complementarity of R&D resources and skilled talent, which can contribute to the ability of unique innovation, the reinforcement of competitive advantages, and the increase of chance to survive (Yang et al. 2017; Gimmon and Levie 2010). The same to the Chinese AI startups, recruiting the skilled talent who possess advanced know-how in priority technologies is an important activity for Chinese planners to pursue advances in AI technologies (Alderman and Ray 2017).

When recruiting skilled talent, team diversity is a key element that companies need to consider, which is also applicable to the AI industry (Talentseer 2020). With the international talent flow, it is an opportunity to hire staff with different backgrounds, which is a new way to promote R&D

investment in Chinese companies (Wei et al. 2020; Niebuhr 2010). Research shows that a team with educational diversity, has a positive effect on the R&D performance, for both incremental and radical innovation (Martinez et al. 2017; Post et al. 2009). A team with diverse educational backgrounds is better prepared to solve complex problems and generate new ideas. A great amount of information and knowledge are available to a team, generating integrated opinions, mutual learning as well as creative solutions, which are essential in the acceleration of innovation and R&D (Tang and Naumann 2016; Ostergaard et al. 2011; Jackson and Joshi 2004). Furthermore, the diversity of employees' educational backgrounds can positively assist the firm-level openness with regard to the ability to access and use external knowledge for innovation (Bogersa et al. 2018). Diversity of skills and experience are also beneficial elements in R&D, which refer to the diverse working portfolios of researchers and supporting staff. A team with diverse staff backgrounds has the ability to deal with different issues, utilize new knowledge, and enhance the companies' propensity to innovate. Diverse education backgrounds, knowledge bases, and experience positively assist R&D performance (Martinez et al. 2017; Chandrasekaran and Linderman 2015; Lin 2014; Ostergaard et al. 2011).

Apart from benefiting the R&D department, team diversity also plays an important role in other departments, leading to better business performance as a whole, which can be reflected by the aspect of knowledge sharing. Knowledge sharing is concerned with the knowledge, information, idea and experience shared among the team members (Kessel et al. 2012). There will be a richer knowledge pool if team members hold diverse backgrounds. For the teammates, it would be a good chance to learn from each other, broaden horizons, and get inspiration. For the firm level, team diversity can contribute to the wider spectrum of problem awareness, interpretations, and solutions (Bolli et al. 2018), whereby can benefit the firm's performance. Thus, team diversity is deserved to be taken into account in an optimal recruitment plan.

In order to attract skilled talent, it is essential to provide attractive terms of workplace benefits to make the company stand out in the labor market. This is not only beneficial for the recruitment activity, but it also encourages employees to work more effectively and efficiently. The compensation system also heavily influences the productivity and turnover rate, which is closely associated with business performance and development (Hassan 2016; Teseema and Soeters 2006; Frye 2004). The same applies to high-tech companies, it is a good practice to attract qualified employees by providing a package of benefits (Chang and Chen 2002). Specific to Chinese TM practices, as mentioned by Cooke (2008) and Nankervis et al. (2013), workplace benefits play an important role. This is partly due to the Chinese paternalistic culture, which expects employers to provide workplace benefits for employees' welfare. In addition, financial rewards and pecuniary incentives are significant techniques to attract talent, with which employers would like to deploy favorable conditions, offer attractive compensation package, and some other voluntary benefits to the talent (Cooke et al. 2014). In a multi-case study research, Wang and Ma (2015) indicated that the high performance of HRM practices in China emphasizes on the comprehensive consideration of a competitive salary package, which includes basic salary, rewards, and benefits. Therefore, it is a good practice for Chinese AI Smart Home startups to consider the optimal compensation packages which are attractive to talent while remaining reasonable and affordable to startups.

According to Cooke et al. (2014), 'job ration' is also one important TM practice, which is about allocating different kinds of jobs for staff to widen knowledge and experience of the full business operation. This can be considered with 'job enlargement' and 'job enrichment'. 'Job enlargement' is about providing opportunities for employees to get involved with different jobs. It can help to avoid the boring repetitive work and contribute to high commitment towards the company (Saleem et al. 2012; Raza and Nawaz 2011; Dessler 2005). 'Job enrichment' requires the companies to arrange employees to participate in different roles of practicing, administrating, and managing. It is an important element in job design for enhancing employees' feelings of satisfaction and contentment (Kooij et al. 2010; Savall 2010). Hence, it is a good practice for Chinese AI Smart Home startups to integrate different roles and tasks for employees when designing the recruitment plan.

Furthermore, in Chinese TM practices, providing a good working condition should be attached importance by companies (Cooke et al. 2014). 'Work-life balance' is an important element to facilitate a beneficial working condition. It is related to the manageability of the work and non-work matters. Working-hour is an indispensable factor in the measurement of an advantageous working environment (Raziq and Maulabakhsh 2015). The corporate policy with 'flexible working hours' can contribute to both employees and employers. 'Work-life balance' and 'flexible working hours' can enhance job satisfaction, reduce working stress and promote mental wellness (Le et al. 2020; Lu et al. 2015; Shagvaliyeva and Yazdanifard 2014; Jin et al. 2013). When there is a higher satisfaction, there will be higher employee loyalty and a lower turnover rate, leading to higher organizational cohesion. Such benefits can make the company more attractive to job seekers (Timms et al. 2015; Anderson and Kelliher 2009; Cook 2009; Carless and Wintle 2007), which can no doubt assist the recruitment activities. At the same time, with good organizational cohesion, there will be a good corporate image to both internal and external stakeholders, which can contribute to future recruitments.

In China, with the accelerated developments in society and economy, more and more people hold a higher expectation of happiness at working. There is an increasing common realization that the success of a career is not only measured by salary and promotion, but should also be related to the employees' happiness and 'work-life balance'. Scholars have indicated that 'flexible working hours' is suitable in China, with the trend of being the inevitable common working model (Lu and Zeng 2014; Zhang 2013). Furthermore, specific to the Chinese 'One-child' national policy, the current workforce is mainly the 'only-child' in the family, meaning that this kind of employees should spend more time and energy to take care of the family (Wu 2013; Liu et al. 2008). Therefore, startups should attach importance to 'work-life balance' as well as 'flexible working hours' for helping employees to achieve the responsibilities outside work.

In short, the recruitment process is important for startups in HRM and TM, while there are some difficulties that startups need to address. A study of the recruitment of qualified talent in Chinese AI startups is needed to support business success. With the aim of being outstanding in the job market, based on TM, it is deserved to consider the attractive compensation package, good working conditions with 'team diversity', 'job enlargement', 'job enrichment', 'work-life balance', and 'flexible working hours' in a set of optimal solutions.

2.3 Recruitment and Strategic Human Resource Management

With the understanding of the elements in HR recruitment, it is essential to link HRM outcomes with organizational strategy, which is known as Strategic HRM. Centered on the organizational mission and vision, HRM commits to assist the development of the startup. As recruitment is the start phase of HRM, it is necessary to link recruitment with organizational strategy at this initial point with the aim of achieving final goals and desired outcomes. There should be a clear cognition that the planning and implementing of recruitment activities should be conducive to the startups' growth. Thus, in the sense of achieving Strategic HRM, a set of optimal recruitment solutions are deserved to be considered.

Based on the resource-based view of Strategic HRM, human capital is one of the most important resources to provide a competitive advantage that can enhance firm performance (Crook et al. 2011; Becker and Huselid 2006). Human capital can enhance the ability of the firm to generate values, such as economic value, by achieving strategic goals (Coff and Kryscynski 2011). From another perspective, Strategic HRM focuses on employee behavior, which can be regarded as the mediator between strategy and performance (Wright and McMahan 1992; Chuler 1990). Based on the organizational strategies, there are some desirable behaviors for achieving the organizational objectives, which should be elicited by suitable HRM practices. The appropriate behaviors, which create high productivity and desired working outcomes, can lead to a high-performance work system for better corporate performance (Alfes et al. 2013; Kehoe and Wright 2013).

Specific to the HR recruitment function, it is the way of acquiring human capital and is the cornerstone of Strategic HRM (Gully et al. 2013). The aim of strategic recruitment is to connect the goals and characteristics of the firm to its recruitment activities (Phillips and Gully 2015). From a competitive advantage standpoint, it is necessary to attract, hire and retain the employees with the right skills, knowledge and abilities to fulfill the needs for corporate operation and achievement, thereby enabling the organization to lessen the likelihood of failure (Chakraborty and Biswas 2019; Goedhuys and Sleuwaegen 2016). In the worst case, without suitable and sufficient talent, the company will fail regardless of any strategies that have been established (Gully et al. 2014). Only when the company can get suitable talent will tasks be accomplished, thus transforming the ideas into real outcomes and achieving the organizational objectives (Gully et al. 2013). For this reason, an optimal recruitment process, from planning to implementing, is required. A set of optimization solutions should consider the 'human capital' that the company needs in the planning stage, so in the implementation stage, the company is able to reach the correct target talent pool to choose suitable talent. Optimal recruitment contributes to better HRM, which can assist in eliciting the desired employee behaviors. The whole optimal outcome of recruitment will align with the organizational strategy to achieve goals and get positive values for the organization.

2.4 HRM Research Methods

Among the preceding research, some research papers focus on exploring, explaining, and concluding the important impacts of HRM on startups (Kaur 2018; Surywanshi 2013; Guadamillas et al. 2008; Manev et al. 2005). It is common that researchers provide theoretical solutions to HR issues, such as Cogliser and Brigham (2004), Ensley et al. (2003) and Ucbasaran et al. (2003), focusing on the improvement on behavioral management with the theoretical frameworks as guidance. Based on the research done by Dabic et al. (2011), which analyzed 62 papers that deal with HRM and entrepreneurial firms, a lot of literature in this field is exploratory, explanatory and descriptive nature with empirical analysis. The research that studies the causes and the consequences of HRM activities does not consider mathematical relationships so much (De Bruecker et al. 2015). Mathematical relationships can help the decision-makers to identify the quantitative logic between variables, which can act as the complementary analysis of the qualitative aspects to understand the problem comprehensively. Thus, as a mathematical tool, optimization can be applied to the HRM field to support scientific analysis, which is discussed in the following sections.

2.5 Summary

This chapter reviews related HRM literature, understanding the main activities in the recruitment process, including 'compensation package designing', 'recruitment quantum planning', 'business trip routing', and 'interview and selection'. The worthy HR well-being parameters are derived from the concept of TM. Recruiting employees from different backgrounds to form a diversity team can contribute to better performance in innovation and problem-solving. Task assignments with 'job enlargement', 'job enrichment', 'flexible working hours' as well as 'work-life balance' are important elements when considering a better working condition. Practicing well-designed recruitment has a positive effect on working performance, which reflects 'Strategic HRM' for getting human capital and achieving desired employee behaviors. Regarding the research methods in HRM literature, besides the methods researching theoretical framework, this study applies optimization for the scientific analysis to support decision-making, which is discussed in the following chapters and sections.

Chapter 3

Optimization

In this chapter, the development of optimization and its applications are briefly discussed. Then specifically, the application of optimization to HRM is zoomed in for details, which leads to the comprehension of a set of optimal solutions for HR recruitment.

3.1 Development of Optimization

Back to 1939, the Russian mathematician L.V. Kantarovich applied mathematical models to assist in solving the business problem (Kantarovich 1939). Later, more and more scholars do research on addressing the business matters optimally and optimization has been widely applied to address real-life problems, such as container terminal operation (e.g. Yan et al. 2020; Do et al. 2016; Tran and Haasis 2015; Zeng et al. 2015; Angeloudis and Bell 2010; Steenken et al. 2004; Cao and Uebe 1995), supply chain management (e.g. Tseng et al. 2019; Ba et al. 2015; Verma et al. 2013; Huang et al. 2011; Wang et al. 2011; Chen et al. 2010), transportation management (e.g. Corlu et al. 2020; Calabrò et al. 2020; Masson et al 2017; Jain and Arya 2013; Garaix et al. 2010), sustainable energy (e.g. Rastetter and Kwiatkowski

2020; Siddaiah and Saini 2016; Sinha and Chandel 2015; Fadaee and Radzi 2012; Avril et al 2010; Kusiak and Song 2010; Zhou et al. 2010; Yang et al. 2008), mine industry (e.g. Guo et al. 2010; McKenzie et al. 2008; Ta et al 2005; Naoum and Haidar 2000), and also human resources management (details on Section 3.2).

3.2 Optimization and Human Resource Management

As the quantitative analysis tool, optimization pays attention to discover the mathematical relationships among the concerned HR elements, providing the objective view. Optimization can contribute to a rational and logical recruitment process, with which, related resources will not be wasted due to unreasonable practices. Moreover, for cost-effectiveness, startups can apply the optimization model to recruit the optimal team and get the maximum returns with minimum or affordable costs. At the same time, the objective results can assist HR managers in decision-making with some other subjective views, to make a more comprehensive judgement. From the perspective of TM, based on the understanding of HR well-being, optimization models can provide a clear picture of resources allocation to satisfy the constraints of welfare. Furthermore, incorporating HR well-being in optimal recruitment can lead to the accumulation of better human capital and facilitate appropriate employee behaviors, and eventually achieve Strategic HRM with higher productivity and better performance. Thus, optimization can support scientific decision-making, acting as the bridge to link the HR parameters and the achievement of organization goals.

As optimization can contribute to better HRM, it is necessary to review the literature on optimization and HRM in order to better understand the application of optimization to HRM and the incorporation of HR parameters to optimization models for the recruitment process. Table 2 to Table 5 categorize the related publications of optimization and HRM with different topics. Some researchers have applied the models to a specific industry while others discuss the general application without the targeted field.

Table 2: Research Topic on Optimization with Human Resources Planning and Allocation

Human resources planning and allocation			
Author(s)	Year	Research objectives/contents	Targeted field of application
Charne et al.	1978	Multi-level system of goal programming models for manpower planning with equal employment opportunity (EEO)	US Navy
Gaballa and Pearce	1979	Manpower requirement plan to effectively meet corporate needs	Telephone sales offices
Martel and Price	1981	Stochastic programming formulations for human resources planning	Canada military
Corominas et al.	2010	Manpower planning with the consideration of production, staff size and cash management	General application
Murakami et al.	2011	Pareto multistage decision based genetic algorithm for human resources allocation	Hotel
Kang et al.	2011	Human resource allocation in project management	Software project
Azimi	2013	Linear programming for human resources allocation with the integration of various decision variables	Beverage companies
Silva et al.	2013	Human resources allocation with the consideration of the complexity of information system projects	Software companies

Zhang	2017	Human resources allocation with the consideration of competency condition	Process industry
Sheikhalishahi et al	2017	Minimization of maintenance costs with the consideration of human factors	Electrical power plant
Aviso et al.	2018	Human resources allocation on business continuity with the consideration of crisis conditions	Hospital; Outsourcing firms
Dai and Liu	2019	Workforce planning with the consideration of incoming demand across time in a day	O2O delivery systems
Arash et al.	2020	An optimization method based on the Bat algorithm to differentiate and predict manpower requirement in emergency department	Hospital

As shown in Table 2, based on the specific situation of the targeted fields, research focuses on finding the optimal solutions that can maximize the expected rewards while the constraints can be satisfied. Different constraints include the staff size, production demands, services demands, cash management and so on. The application areas cover a wide range of business matters in hospitals, software companies, power plants and so on. In this study, the application focuses on satisfying the needed human resources in the Chinese AI Smart Home startups which are the new companies and usually operate several departments.

Table 3: Research Topic on Optimization with Staffing and Scheduling

Author(s)	Year	Research objectives/contents	Targeted field of application
Ernst et al.	2004	Literature review of models and algorithms for solving staffing problems	General application
Liu and Wang	2012	Optimization of schedule problem and improvement of efficiency with the consideration of multi-skilled crews	Linear bridge case

Rocha et al.	2013	Staff scheduling with the consideration of sequence constraints and workload balance	Glass industry; Continuous care unit
Shahnazari-Shahrezaei et al.	2013	Multi-objective manpower scheduling model with the considerations of employers' objectives and employees' preferences	General application
Guyon et al.	2014	Employee timetable and job-shop-scheduling	General application
Parisio and Jones	2015	Employee scheduling with the consideration of uncertain demand	Retail outlets
Bonutti et al.	2017	Shift and break design for the workers who have different skills with the consideration of a common set of shifts that must be selected for all skills	General application
Shuib and kamarudin	2019	Shift schedule problem with the consideration of day-off preference of workers	Malaysian power station
Qin et al.	2020	Mixed-integer linear programming with the consideration of multi-skill staffing for aircraft hangar maintenance planning and staff assignment problems	Aircraft hangar maintenance

Some literature pays attention to staffing with the consideration of specific manufacturing or servicing requirements in different industries as categorized in Table 3. Different requirements, such as workload, working period and short break, are described as the constraints in optimization models. In this study, a way of staffing with the combination of time-period options is presented, the expected result of which is a staffing timetable that can satisfy the required production meanwhile it is flexible for employees.

Referring to Table 4, other HRM matters such as teammate arrangement and task assignment, are also taken into consideration with optimization models. These publications focus on optimally engaging and involving the employees in operation based on the different characteristics that the employees have. The expected outcomes are to maximize efficiency and minimize the stress levels of employees. In this study, with the consideration of staff welfare, HR well-being parameters are incorporated into different circumstances of task arrangements.

Table 4: Research Topic on Optimization with Employee Management

Author(s)	Year	Research objectives/contents	Targeted field of application
Ma	2012	Tasks assignment to proper athletes; Courses arrangement for PE teachers	Sport management
Zhang et al.	2013	Tasks assignment with ‘four-in-one’ strategy	General application
Guler et al.	2015	Task assignment for teaching assistant	Education system
Lukovac et al.	2017	Human resource portfolio regarding improving and promoting the potential of employees	General application
Bányai et al.	2018	Mathematical analysis of HR deployment and promotion processes	Manufacturing companies
Azadeh	2018	Optimization of resilient HRM system	Coal mine industry
Starkey et al.	2018	Optimal selection of engineers to be upskilled and to warp team	General application

As for the topics that directly relate to recruitment, some literature studies the hiring and selection strategy for the organizations as listed in Table 5. This study also adopts ideas of the minimization of the costs and the maximization of the benefits in the recruitment process.

Table 5: Research Topic on Optimization with Recruitment Directly Related Topics

Author(s)	Year	Research objectives/contents	Targeted field of application
Feichtinger	1984	Hiring and firing policies with optimization on firms' profits and workers' income	General application
Bohlouli et al	2017	Mathematical approach for finding best fitting candidates for specific job positions with competence analytics	General application
Fu	2018	Probing policy for searching the best suitable candidate	General application
Lin et al.	2018	Recruitment and training plans with the consideration of workload, locations, and districts	Care service distributing
Berk et al.	2019	Hiring decision with maximum profit and flexibility	Contract-based professional services firms
Lee and Ahn	2020	Optimization model with the consideration with skill preferences, working area constraint and Myers-Briggs Type Indicator (MBTI) for a better new hires	General application

To sum up the literature on optimization and HRM, it is clear that optimization is applicable in HRM, including resource allocation, staffing, employee management and so on. The application areas of previous literature cover a wide range of business matters and this study enriches the application field to the startups in the AI industry. Different specific HRM issues are studied by scholars, however, most research targets a single problem and this study proposes an integrated set of optimal solutions for the recruitment process. In recruitment planning, based on the understanding of corporate needs, models can be developed for compensation package and recruitment quantum with the consideration of operation requirements, such as task arrangement. Meanwhile, as employee welfare is one of the key concerns of this study, related HR well-being parameters are incorporated in the research problems, which enrich the literature related to achieving a better HRM system with concepts of staff planning and employee welfare.

Based on the activities in the recruitment process, the consideration of salary and workforce is mainly for recruitment planning. Another key recruitment activity that needs to be considered is visiting the targeted talent pools to disseminate job information and attract potential employees. As stated in HRM literature, some startups desire skilled talent but possess the lower visibility in the job market (Breaugh 2009). Thus, in a set of models for the recruitment process, a model for startups to join job fairs and visit as many universities as possible with minimum costs is included. The decision of routes to visit different cities and universities can refer to the well-known optimization problem—travelling salesman problem (TSP). TSP is about finding the optimal route with minimum costs and/or shortest path when travelling n cities with resource constraints (Mike and Daniel 2019; Lawler 1986; Robinson 1949). The research in this field is not only limited to travelling by people, but it has also extended to a wide range of applications related to multiple travelling to targeted destinations, such as transport and delivery system. Table 6 displays the literature review of optimization and route selection.

Table 6: Research Topic on Optimization and Route Selection

Author(s)	Year	Research objectives/contents	Targeted field of application
Mavrovouniotis and Yang	2013	Ant colony optimization algorithms adapted to dynamic TSP with traffic factors	General application
Baudel et al	2016	City-wide freight delivery rounds optimization system under real-life constraints	City traffic information
Goerigk and Westphal	2016	Minimization of total distances driven by different teams with the application of traveling tournament problem	Sports leagues scheduling
Todosijević et al.	2017	Research on optimal Hamiltonian tour for ships to transport products to a set of ports with draft limit constraints	Maritime transportation
Pešić et al.	2017	Optimal route selection with the consideration of travelling time and road safety	Transport system
Defryn and Sörensen	2018	Optimization of logistics cooperation with multiple companies, considering the interests of partners and objectives	Logistics system
Baniasadi et al	2020	Study of the clustered generalized TSP with the applications of relevant problems in logistics, robotic warehousing and drone delivery	Logistics problems

Applying TSP specific for business trips of AI Smart Home startups can assist companies in routing planning to reach all the targeted talent pools and promote positions directly to the potential employees. As the TSP model can provide information about the routing with the minimum travelling costs, it is clear for the HR manager to allocate related resources and arrange a remaining budget for the business trips.

Following the steps of recruitment, another recruitment activity, interview, will be conducted when the startup receives job applications after the dissemination of position information. Interview is about the 'selection' and 'decision' among the potential employees, aiming at hiring the best candidates (Kumari 2012; Gusdorf 2008). Knapsack problem (KP) is fitted properly to address the select-related issues, such as portfolio, project, recruitment and so on (Table 7). Knapsack problem considers the capacity of the knapsack, searching the highest total value of items that the knapsack can pack (Pisinger 2005; Martello et al. 1999; Chvátal 1980; Balas and Zemel 1980). Applied into the selection situation, knapsack problem can be converted to select the optimal collection of items, options or candidates with certain constraints, such as the budget.

Table 7: Research Topic on Knapsack Problem and Selection

Author(s)	Year	Research objectives/contents	Targeted field of application
Cao and Wang	2007	Optimization of outsourcing process and vendor selection with knapsack problem	Vendor selection
Öncan	2007	Applications of knapsack problem to real-life problems, such as timetabling, scheduling and so on	Generalized Assignment Problem (GAP)
Babaiof et al	2007	Algorithms for a knapsack version of the secretary problem with the consideration of its applications, such as hiring workers and scheduling jobs	Knapsack Secretary Problem
Sadi-Nezhad et al	2010	Fuzzy knapsack problem for optimum portfolio selection with the lowest cost and maximum profit from available investment situations	Project selection

Song et al	2014	Optimization problem of selecting the most appropriate participants in data collection with nonlinear knapsack problem	Participants selection
Nip et al.	2017	Hiring and salary determination with knapsack under linear constraints (KLC) problem	Candidates selection
Kwac	2017	Application of the knapsack problem to efficiently select customers for demand response (DR)	Demand response (DR) programs

Knapsack problem is employable in hiring workers (e.g. Nip 2017 and Babaiof et al. 2007). In this study, based on the real situation of the AI Smart Home startups, a model for the selection of talent is proposed in a set of optimal recruitment solutions. AI talent at different levels will be given different scores (values) and be paid with different estimated salaries. KP model can be used for hiring teammates with the total highest value while satisfying the budget constraint.

3.3 Mathematical Modelling and Application

With the understanding of optimization and HRM, mathematical modelling is utilized to describe the recruitment issues to optimization models. Related mathematical models are developed based on the research questions, including the models for 'compensation package designing', 'recruitment quantum planning', 'business trips routing' as well as 'interview and selection'. An integrated model of 'compensation package designing' and 'recruitment quantum planning' is also developed for better optimization of the whole recruitment plan. Related HR well-being parameters are specially incorporated into the models.

The general formula is

$$
\begin{aligned}
&min \quad or \quad max \quad Z = \sum_{i=1}^{n} c_i x_i && (3.1a)\\
&s.t. \quad a_1x_1 + a_2x_2 + ... + a_ix_i \geq b, i \in \{1, ..., n\} && (3.1b)\\
&\qquad a_1x_1 + a_2x_2 + ... + a_ix_i = b, i \in \{1, ..., n\} && (3.1c)\\
&\qquad a_1x_1 + a_2x_2 + ... + a_ix_i \leq b, i \in \{1, ..., n\} && (3.1d)
\end{aligned}
$$

Where x_i are variables, c_i, a_i, b are the coefficients, $\sum_{i=1}^{n} c_i x_i$ is the expected result to obtain for maximum return or minimum cost (Zhu et al. 2013; Huang and Han 2006; Sierksma 2001).

For a set of models developed for each research question, computational examples are given to examine the feasibility. With regards to the demonstration of the superiority of the models, for 'compensation package designing' and 'recruitment quantum planning', there are the comparisons of the computation results with the existing situations (hereinafter known as 'non-optimal situation'), as well as the comparisons between optimization method and other commonly used methods. For 'business trips routing' and 'interview selection', the proposed models provide information about the optimal choices. At the same time, to comprehensively understand the incorporation and achievement of the HR well-being parameters in the proposed models, based on different computational examples for different departments, different application situations are compared, with which the advantages and limitations of the proposed models are analyzed.

As mentioned in Chapter 1, there is a serious talent war in the Chinese AI industry, including AI Smart Home, leading to recruitment issues. As new companies in the industry, it is difficult to access accurate data of the competitors in the industry, especially the salary data and reports. This is because there is usually a confidentiality agreement signed by the employers and employees (Xiaozhi 2019), which reduces the chance of information disclosure. Most companies keep salary data private to retain competitive power. Furthermore, operating in the complex business environment, it is difficult to find a case of a specific company that can present the whole situation of the industry to be referred to, as different conditions exist in different companies and different locations. However, referring to the industry situation is one way that can help startups to formulate the proper HR policies to attract talent (Yuan et al. 2018; Wu et al. 2017; Wang and Wei 2016). Therefore, standing in the position of startups, referring to the existing situation of the industry, and analysing from the credible data, in this study, different cases are derived based on the common industry situations. From the computational examples, startups can find out the overall industry situation and understand the 'optimization models'. In the real-life context, different startups and HR managers would have views on the related value of different criteria, which are subjective and possibly institution-specific. Without claiming generally, and for illustrative purpose only, based on the real common situation in the industry, related data are reasonably generated to be experimental cases.

As one of the most important AI cities in China, Beijing is taken as an example for illustrative purpose. For HR practitioners and startups, it is practicable to focus on the located city or province to analyze and understand the business environment. Regarding the applications of the models, startups should analyze their current situation and apply their own data for specific optimization.

From the employees' point of view, as discussed in Chapter 2, there is an increased awareness of HR well-being and 'work-life balance' among employees. The assumption is made that, the salary amount is not the only measurement that employees used for judging the position and the company, the better HR well-being parameters and working environment would also be taken into account.

3.4 Summary

Based on the literature review, it is clear that optimization is applicable in HRM. As employee welfare is the key concern of this study, in a set of solutions to the recruitment process, not only should resources constraints of the startup be satisfied, HR well-being parameters are also considered. Regarding the 'business trip routing' and 'interview selection', TSP and KP will be referred to respectively for searching for optimal solutions. The feasibility and superiority of the models are demonstrated with the computational examples as well as comparisons of the existing situations. The advantages and limitations of the incorporation of HR well-being parameters are also analyzed.

Chapter 4

Optimization of Recruitment Plan

4.1 Compensation Package Designing

4.1.1 Mathematical Modelling

In the recruitment process, the designing of the compensation package is one of the key elements to be considered. In a compensation package, basic salary, benefits and award should be included. Furthermore, apart from the monetary reward, other non-monetary items should also be taken into account. In this study, the non-monetary items are included together with awards into the general item named ‘annual subsidy’ for remuneration calculation. And for the insurance rate, it should refer to the Chinese national policies of ‘Five social insurance and one housing fund’ (The State Council of People’s Republic of China 2018). Moreover, in a reasonable compensation package, the ratio of the living allowance and the basic salary should be balanced based on the corporate conditions to increase employee satisfaction (Zhou 2018). It is practicable to use index points as a measurement (Yuan et al. 2018; Peng 2004). Based on the qualification and experience of talent, different levels of employees are awarded different points for the calculations of the compensation amounts. A range of index points is set for each level, with which there is a guidance of the overall salary situation. The actually paid amount is negotiable with some other subjective factors, such as the interview performance.

To be attractive in the labor market, it is necessary to use the industry average amounts as benchmarks, and design the corporate policies based on own situation, as the salary expenditure should be affordable to the startup. The revenue that the company earns can contribute to the designing of the budget for compensation packages, while as for the startup that may not earn profits at the initial stage of founding (Smith 2019), budget designing depends on the investment capitals. Even though the startup may not get profits during the initial stage, recruiting suitable talent with the offer of reasonable compensation package is still necessary for its development. Not only does the recruitment of the right team play an important role in the execution of the first stage of the company, but it will also affect the investment. Especially for the high-tech startups, those that do not have great human resources, or cannot prove the ability to hire the right talent, usually face difficulty in funding (Gage and Chapman 2011). For the startup at the initial stage, compensation expenditures may rely on the venture capital. With the development of the startup, revenue may increase year by year, correspondingly, compensation expenditure will be rearranged at the later stage. For the model in this study, the focus is on the initial stage of the founding of the startup, aiming at designing the reasonable compensation package based on the industry benchmarks in order to attract talent. Therefore, the relation of the revenue and the decision of compensation amount would not be considered as the constraint in the model.

When designing a compensation package, decision variables are
x_i: index point value of different item

Based on the case of Chinese AI Smart Home startups
x_1: index point value of annual basic salary
x_2: index point value of allowance
x_3: index point value of annual subsidy

Insurance rate — "Five social insurance and one housing fund" policy in China
f_1: endowment insurance ($f_1 = 19\%x_1$)
f_2: medical insurance ($f_2 = 0.8\%x_1$)
f_3: unemployment insurance ($f_3 = 0.5\%x_1$)
f_4: work-related injury insurance ($f_4 = 0.8\%x_1$)
f_5: childbirth insurance ($f_5 = 10\%x_1$)
f_6: housing accumulation funds ($f_6 = a\%x_1, 5 \leq a \leq 12$)

Related notations are
q_j: points based on qualifications levels, $j \in \{1, ..., n\}$
e_k: points based on experiences levels, $k \in \{1, ..., m\}$

Industry standards
s_1: salary amount standards
s_2: subsidy standards

Real conditions of the startup
$[(1 - c\%)s_1, (1 + c\%)s_1]$: bounds of salary amounts
$[(1 - r\%)s_2, (1 + r\%)s_2]$: bounds of subsidy
$[t_1\%, t_2\%]$: bounds of ratio of living allowance to basic salary

The optimization model for the planned compensation package is

$$
\begin{aligned}
min\ Z = (q_j + e_k) \cdot (x_1 + x_2 + x_3 + f_1 + f_2 + f_3 + f_4 + f_5 + f_6) \\
s.t. \quad f_1 &= \frac{19}{100}x_1 \\
f_2 &= \frac{0.8}{100}x_1 \\
f_3 &= \frac{0.5}{100}x_1 \\
f_4 &= \frac{0.8}{100}x_1
\end{aligned}
$$

$$
\begin{aligned}
&f_5 = \frac{10}{100}x_1 \\
&f_6 = \frac{a}{100}x_1 \\
&f_6 \geq \frac{5}{100}x_1 \\
&f_6 \leq \frac{12}{1000}x_1 \\
&(1-\frac{c}{100})s_1 \leq (q_j+e_k)\cdot(x_1+x_2+f_1+f_2+f_3+f_4+f_5+f_6) \leq (1+\frac{c}{100})s_1 \\
&\frac{t_1}{100} \leq \frac{(q_j+e_k)\cdot x_2}{(q_j+e_k)\cdot(x_1+f_1+f_2+f_3+f_4+f_5+f_6)} \leq \frac{t_2}{100} \\
&(1-\frac{r}{100})s_2 \leq (q_j+e_k)\cdot x_3 \leq (1+\frac{r}{100})s_2 \\
&\forall x_i \geq 0, i \in \{1,2,3\}
\end{aligned}
$$

Simplify to

$$
min\ Z = (q_j+e_k)\cdot[(1.311+\frac{a}{100})x_1+x_2+x_3] \tag{4.1a}
$$

$$
s.t. \quad (1-\frac{c}{100})s_1 \leq (q_j+e_k)\cdot[(1.311+\frac{a}{100})x_1+x_2] \leq (1+\frac{c}{100})s_1 \tag{4.1b}
$$

$$
\frac{t_1}{100} \leq \frac{x_2}{(1.311+\frac{a}{100})x_1} \leq \frac{t_2}{100} \tag{4.1c}
$$

$$
(1-\frac{r}{100})s_2 \leq (q_j+e_k)\cdot x_3 \leq (1+\frac{r}{100})s_2 \tag{4.1d}
$$

$$
\forall x_i \geq 0, i \in \{1,2,3\} \tag{4.1e}
$$

This model (4.1) is to provide the guided amount of the compensation package. Constraints (4.1b) - (4.1d) guarantee that the compensation amount is competitive in the labor market and fits the range of the salary amount based on the corporate policy. Constraint (4.1b) considers the amount and constraint (4.1c) considers the ratio of basic salary and allowance. Constraint (4.1d) is for the annual subsidy.

4.1.2 Application

Non-optimal Solution

As for the practice in the startup, the compensation package should be designed based on its own situation to fit the development of the corporate and department. As the R&D department is the key importance of the AI Smart Home startups, it is worth taking the designing of the compensation package for researchers in R&D department as the computational example to test the viability of the optimization model. Referring to the common industry situation (e.g. Career International 2019; Xiaozhi 2019; Tencent 2019 etc.), the computational example of the salary amount of the top researcher, who is the AI chief scientist with 15+ years' experience and a PhD degree, is given as RMB 6000k per year (excluding stocks).

Optimal Solution

In order to design a better compensation package, as modelled above (4.1), different items need to be considered and balanced with industry benchmarks and corporate policies. As for the a% of the 'housing accumulation funds', according to the government policy of the Beijing government (Beijing Housing Fund 2019), the upper bound of the amount of 'housing accumulation funds' paid by the employer is RMB $27783 * 12\% = 3334$ per month, meaning that for those salary amounts are less than RMB 27783 per month, there is an a% set for the fund, while for those salary amounts that are more than RMB 27783 per month, the calculated amount is RMB 3334. Therefore, as for the design of the compensation package for researchers, whose salary amount is over RMB 27783 per month, the item of 'housing accumulation funds' is the certain amount of RMB $12 * 3334 = 40008$ per year.

Different startups and HR managers would subjectively design related criteria and policies for different considered items. Based on the optimization model, assuming that the bound of the compensation package is set as 10% upper or lower than the industry salary benchmark. Regarding the ratio of living allowance to basic salary, the example is given 10% – 15%. For the computation of subsidy amount, referring to the industry situations, the amount of annual award for the staff is about 3-6 months' basic salary (e.g. Toutiao 2018; Xiaozhi 2019 etc.), so in the computational example, $(1 \pm \frac{r}{100})s_2$ converts to 25%−50% of the annual basic salary. One example of index points of researchers can be stated as in Table 8. For the top researcher who is a PhD holder with 15 years' experience, the index point is $q_j + e_k = 4 + 15 = 19$.

Table 8: Index Points of Researchers

Criteria	Points
PhD	4
Master	3
Bachelor	2
College diploma	1
Experience	years of working experience

Related computation is

$$\begin{aligned}
& min\ Z = 19 \cdot (1.311 \cdot x_1 + x_2 + x_3) + 40008 && \text{(4.2a)}\\
& s.t. \quad 19 \cdot (1.311 \cdot x_1 + x_2) + 40008 \leq 1.1 \cdot 6000000 && \text{(4.2b)}\\
& \qquad 19 \cdot (1.311 \cdot x_1 + x_2) + 40008 \geq 0.9 \cdot 6000000 && \text{(4.2c)}\\
& \qquad \frac{x_2}{1.311 \cdot x_1 + 40008} \leq \frac{15}{100} && \text{(4.2d)}\\
& \qquad \frac{x_2}{1.311 \cdot x_1 + 40008} \geq \frac{10}{100} && \text{(4.2e)}\\
& \qquad 19 \cdot x_3 \leq 0.5 \cdot (19 \cdot 1.311 \cdot x_1 + 40008) && \text{(4.2f)}\\
& \qquad 19 \cdot x_3 \geq 0.25 \cdot (19 \cdot 1.311 \cdot x_1 + 40008) && \text{(4.2g)}\\
& \qquad \forall x_i \geq 0, i \in \{1, 2, 3\} && \text{(4.2h)}
\end{aligned}$$

There are different kinds of methods that can be used in computation. Software such as Matlab, LINDO, Python, C++ and so on, are well-developed and user-friendly, from which HR managers can choose their preferred one. This study provides Matlab Optimization APP and coding in appendices as examples for HR managers' reference.

Applying data of this computational example, the optimal solution of the compensation package is (rounded number)

$x_1 = 183135$, $x_2 = 42015$, $x_3 = 60549$, $f_1 = 34796$, $f_2 = 1465$, $f_3 = 916$, $f_4 = 1465$, $f_5 = 18314$, and f_6 is the certain amout of RMB 40008.

The guided annual amount of compensation package for the top researcher is

$Z^c = 19 \cdot (1.311 \cdot 183135 + 42015 + 60549) + 40008 = 6550434$ RMB

Compared with the industry benchmarks, the amount of compensation package is competitive in the labor market and complies with the startups' policies (4.2b)-(4.2g). Adopting the idea of model (4.1), in real-life practices, HR managers will set different criteria, such as the values of $q_j + e_k$ points for different categories of staff. It is not suitable to apply the criteria of top researchers to fresh graduates. HR managers get different reference standards for different levels as the salary amounts and consideration of values for different levels should be different. It is not a continuous description of the compensation package amount. The proposed model mainly aims at providing the guided amount of the compensation package to a certain category of staff. As in the computational example, the points set for top researchers is 19, and the corresponding amount is 6550434. This amount of 6550434 serves as the guided amount for those who are categorized as top researchers. The computational result acts as the reference when setting the range of index point value for top researchers, such as $\pm 10\%$ of the computational result.

Based on the setted pay scale and the guided amount, the final decision of compensation package amount will be made based on both objective and subjective factors, including backgrounds, rankings of the university and the previous employer, interview performance and so on.

4.1.3 Discussion

As there is a serious talent war in the Chinese AI Smart Home industry, the highly competitive salary amount creates a lot of burden on startups (Section 1.2.1). It is important for startups to design an attractive compensation package to gain a competitive edge in the labor market (Section 2.2). Model (4.1) provides the detailed guidance of several indexes, including the necessary salary item and well-being items, which can assist the startup to design a more attractive compensation package and show the potential employees that the startup attaches importance to employee welfare. When negotiating with the desired talent, the startup can provide the guided amount with related compensation items to potential employees, showing the transparency of the corporate policies, which can contribute to the positive impression that the potential employees hold towards the startup. For the potential employees, based on the introduction of the gradient of the salary components, the clear information helps employees to judge the suitability of the compensation amount and the startup with the comparison of the industry situation and/or previous career experience.

For the application of this model in startups, it can be utilized in the initial phase of designing the compensation package. It can also extend to further recruitment and evaluation to adjust the salary amount based on the experience of real operation. When determining the points of criteria items, adjusting the ratio of living allowance and basic salary, calculating the exact compensation package amount, related values of points will depend on the startups' conditions and the real performance of recruited employees.

This model of compensation package considers the application on the companies in general, some other scholars have a specific focus on the different business departments, such as the sales department (e.g. Kräkel and Schöttner 2016; Lal and Srinivasan 1993; Dearden and Lilien 1990). The proposed model can be applied to different departments based on the real corporate situation. Regarding the timing of compensation package designing, the proposed model can be utilized in the recruitment phase of the startup, attached to later phases with the consideration of the timing of the salary increases (e.g. Cokyasar et al. 2019) and the turnover rate (e.g. Parker and Rhine 1991), to make a full flow of the compensation package designing at different stages with the development of the startup.

4.2 Recruitment Quantum Planning

The number of employees to be recruited depends on the real situations of different departments. For the Chinese AI Smart Home startups that usually operate in the combined business models, there should be respective recruitment plans to match the needs of the respective departments. Regarding employees' welfare, different suitable HR well-being parameters, including 'team diversity', 'job enlargement', 'job enrichment', 'flexible working hours' as well as 'work-life balance', are incorporated into optimization models based on the conditions and circumstances of different departments.

4.2.1 R&D Department

4.2.1.1 Mathematical Modelling

In the high-tech companies, the R&D department is the important department tasked with propelling innovation and creation. In the highly competitive industry, unique technology owned by the company is the key resource for holding a strong industry position, no matter the technologies or products. For the R&D team, with the consideration of the benefits discussed in Chapter 2, team diversity is phased into the model. The consideration of 'team diversity' is to hire teammates with different qualification and experience levels, such as AI Professionals, PhD and so on. The top researcher can lead the team with the cutting-edge research background, the knowledge of which may not be held by other levels of employees. For the employees from the lower levels, it is the great opportunity to learn from top researchers. At the same time, employees who have experiences in workshops can provide ideas about the realization of research to application, manufacturing as well as production. For the company, the multi-background team can contribute to the stronger R&D capability and better competitive advantages (Conte and Vivarelli 2014; Kim et al. 2011). Moreover, benefits regarding 'job enlargement' and 'job enrichment' are also incorporated into the model in task arrangements. Subtasks in projects for different roles, such as research and administration, are assigned to team members. The integration of employees in a combined team can also simplify the employee structure, helping the startup to manage the human resources regarding the arrangement of multiple sub-teams. Based on the estimated abilities of the team members from different levels, which can be converted as 'estimated contribution' to the research projects, there should be a sufficient number of team members to satisfy related requirements. Regarding the compensation amount for the team, it should be affordable for the startup.

Decision variable:

x_i: number of employees from level i to be recruited

Related notations:

i: level of employees, $i \in \{1, ..., n\}$
j: subtask, $j \in \{1, ..., m\}$
d_i^j: working days of employees from level i for subtask j
s_i^j: daily salary of per employee from level i to complete subtask j
r_i^j: daily contribution of per employee from level i to complete subtask j
w^j: monthly workload of subtask j

$$min\ Z = \sum_{i=1}^{n} \sum_{j=1}^{m} d_i^j s_i^j x_i \tag{4.3a}$$

$$s.t. \quad \sum_{i=1}^{n} r_i^j d_i^j x_i \geq w^j, j \in \{1, ..., m\} \tag{4.3b}$$

$$\forall x_i \in \mathbf{Z}^+ \tag{4.3c}$$

The objective function (4.3a) is to minimize the salary expenditure. (4.3a) comprises different salary items based on the tasks assigned to the employee. (4.3b) and (4.3c) present the ideas of 'team diversity', 'job enlargement' and 'job enrichment'. There may be several projects that the startup is conducting, each of which consists of different subtasks for different roles. A team with employees from different levels will complete subtasks in different projects. As for the workload, if each subtask in the respective project can be satisfied, the whole project can be 100% completed, whereby all the projects that the startup is conducting can be completed. Regarding the timeframe of the project, if the respective workload allocated for the respective time period can be satisfied, the whole project can be completed on time. 'Flexible working hours' is considered by the total workload assignment. A specific day for a specific task is not restricted by the policy, which can be decided by staff based on the individual's situation.

4.2.1.2 Application

In R&D department, the most important task is research, associated with some necessary administration tasks. A gradient of employee levels and salary standards are practicable in the AI industry, which can be referred to by startups (Ai Tech Yun 2019; Xiaozhi 2019; Tencent 2019). Based on the decision criteria that the company sets, such as the experience and qualification, different levels and values are awarded to employees, which are directly related to the estimated contributions of employees. In the R&D department, the main focus is on research, thus the consideration of 'contribution' can be the ability and effort that the employee can dedicate to the success and achievement of the innovation of the research targets. In this study, as an illustrative example, the value of the 'estimated contribution' of the employee is judged by the consideration of the knowledge that the employee possesses towards AI research, especially the top technology that the employee grasps, which can be inferred from related education and experience. At the same time, the corresponding industry salary benchmarks can be the inferential source to determine the estimated contribution. Referring to the common industry situation (e.g. Career International 2019; Xiaozhi 2019; Tencent 2019 etc.), related data of the computational example of the R&D department are generated as in Table 9. As a new company, startup has no current workforce to be compared and has no experience to accurately judge the productivity of the potential employees. Referring to the industry common situation of the segmentations of salary levels, qualification levels as well as position levels, the startup can understand the overall situation in the initial corporate stage. Later, with the development of the company, the criteria of the indication of productivity will be made based on its own real-time situation, the accumulated experience as well as the changing business environment.

*Table 9: Data of R&D Department (*20 working days per month)*

Level	Experience	Average compensation amount	Estimated contribution (index point)
Researchers			
1	AI Chief Scientist (15+ years)	6000k pa (500k per month, 25k per working day)	15 points per working day
2	AI Expert (5-7 years)	2500k pa (209k per month, 10.4k per working day)	6.25 points per working day
3	Senior AI Researcher (PhD graduate)	500k pa (42k per month, 2.1k per working day)	1.25 points per working day
4	Software Engineer (3+ year)	400k pa (33k per month, 1.7k per working day)	1 point per working day
Manager			
1		700k pa (59k per month, 2.9k per working day)	1 point per working day

Non-optimal Solution The non-optimal situation is that subteams are formed by a single type of researchers to take charge of different projects and a single type of work is assigned to employees (research or administration). A case is given that there are two projects that the startup is conducting, carrying different weights in the practice, Project A with 60% and Project B with 40% (Table 10).

Table 10: Non-optimal Arrangement of R&D Department

Project A team	Project B team
5 level 2 researchers 1 manager(administration)	3 level 2 researchers 1 manager(administration)

Total salary expenditure is

$Z^{R'} = (5 + 3) \cdot 209k + (1 + 1) \cdot 59k = 1790k$

Index of task contribution (*20 working days per month)

Research:

Project A: $5 \cdot 6.25 \cdot 20 = 625$points

Project B: $3 \cdot 6.25 \cdot 20 = 375$points

Administration:

Project A+B: $(1 + 1) \cdot 1 \cdot 20 = 40$points

Optimal Solution For startups, it is a good practice to recruit researchers from multiple levels to form a team. The contributions of employees from different levels are different, especially in the AI field, where the strong high-tech background is of key importance. There is no doubt that higher level employees with rich experience can contribute more to the R&D research, and certainly should be paid based on the higher salary standards. Even though the compensation amounts of the top researchers are much higher than the other levels of researchers, it would be better to recruit the top researchers to form the team together with other levels of researchers in order to facilitate innovation and creation. To optimize the case in the non-optimal solution, the salary expenditure should not be over the current amount, at the same time, all tasks should be completed. To improve the situation, taking 'job enlargement' and 'job enrichment' into consideration, human resources in R&D department should be reallocated. In some mature companies, 'job enrichment' and 'job enlargement' are incorporated into job design (Gao 2019). In this study, with the consideration of these concepts, works are assigned to all levels of employees to achieve a better working situation, whereby all employees can be benefited. The new optimal situation is arranged as in Table 11.

Table 11: Optimal Arrangement of R&D Department

Task arrangement (*20 working days per month)				
	level 1	level 2	level 3	level 4
Research time	90%	85%	80%	75%
Project A	11 days	11 days	10 days	9 days
Project B	7 days	6 days	6 days	6 days
Administration time	10%	15%	20%	25%
Project A+B	2 days	3 days	4 days	5 days

As different kinds of tasks are assigned to employees, the new salary amount should consider different salary standards of the tasks. Based on the task arrangement in Table 11, the new salary amounts can be composed as Table 12.

Table 12: New Salary Amounts of R&D Department

Level	New salary amount (per month)
1	$(25k \cdot 18 + 2.9k \cdot 2) = 455.8k$
2	$(10.4k \cdot 17 + 2.9k \cdot 3) = 185.5k$
3	$(2.1k \cdot 16 + 2.9k \cdot 4) = 45.2k$
4	$(1.7k \cdot 15 + 2.9k \cdot 5) = 40k$

The optimization model is

$$min\ Z = 455.8k \cdot x_1 + 185.5k \cdot x_2 + 45.2k \cdot x_3 + 40k \cdot x_4 \tag{4.4a}$$

$$s.t. \quad 15 \cdot 11 \cdot x_1 + 6.25 \cdot 11 \cdot x_2 + 1.25 \cdot 10 \cdot x_3 + 1 \cdot 9 \cdot x_4 \geq 625 \tag{4.4b}$$

$$15 \cdot 7 \cdot x_1 + 6.25 \cdot 6 \cdot x_2 + 1.25 \cdot 6 \cdot x_3 + 1 \cdot 6 \cdot x_4 \geq 375 \tag{4.4c}$$

$$2 \cdot x_1 + 3 \cdot x_2 + 4 \cdot x_3 + 5 \cdot x_4 \geq 40 \tag{4.4d}$$

$$\forall x_i \geq 1 \tag{4.4e}$$

Related results are rounded as $x_1 = 2$, $x_2 = 3$, $x_3 = 6$ and $x_4 = 1$.

The total compensation amount is:

$Z^R = 455.8k \cdot 2 + 185.5k \cdot 3 + 45.2k \cdot 6 + 40k \cdot 1 = 1779.3k$

With different data of different companies, there may be situations that no optimal integer results can be obtained with the satisfaction of all constraints and get the cheaper cost than the non-optimal solution. In the real-life practices, the number of recruitment should be integer. Therefore, in this study, if the integer results cannot be searched, for a near-optimal solution, the constraint $\forall x_i \in \mathbf{Z}^+$ is replaced as $\forall x_i \geq 1$. Correspondingly, there are reasonable rounded numbers for final decisions. As for the acceptable error, HR practitioners arrange the resources based on real situations. Fraction results of the optimization models have meaning to the HR managers regarding providing the information of the possible minimum costs. Considering some subjective factors in the recruitment process and referring to the possible minimum costs, the HR manager will then determine related resource allocation to get the near-optimal solution as close to the optimal solution as possible.

Based on the results $Z^{R'}$ and Z^R, the superiority of the optimization model can be demonstrated. Tasks can be completed with less expenditure, while at the same time, 'job enlargement' and 'job enrichment' can be achieved (4.4b, 4.4c, 4.4d). Moreover, 'team diversity' with 4 different levels of researchers composes a better talent structure.

4.2.1.3 Discussion

Similar to the existing literature, this study adopts the common constraints considered by scholars, such as costs and skills. For the constraints of 'skills' that the company requires, some researchers consider the type of skills generally while others consider exact skills in different situations (e.g. Berk et al. 2019; De Bruecker et al. 2015; Srour 2005; Haas et al. 2000). In this study, with the specific attention to the R&D department in AI Smart Home startups, 'skill' refers to the knowledge and experience backgrounds of AI technology, which correlates with the segments of the researchers' levels.

In addition, with the specific attention to R&D department, in order to advance R&D innovation and create a better working condition, the model (4.3) incorporates HR well-being parameters of 'team diversity', 'job enlargement' and 'job enrichment' (Section 2.2). The satisfaction of related constraints can no doubt assist in the recruitment. Recruitment results have positive effects on human capital development and employee performance, which can achieve 'Strategic HRM' that great values are added to corporate development (Section 2.3).

To comprehensively analyse the practicability of the proposed model (4.3), different situations are compared. One is that only focusing on expenditure without considering HR well-being parameters, there may be the cheaper situation to hire a certain amount of only one category of staff in the lower level. For instant, as in the computational example, hiring 50 level 4 staff and 2 managers to complete the workload. However, this is not easy to be achieved in real-life practices as the limitation of capability of the office as well as the difficulty in recruiting the required number of people. At the same time, benefits of 'team diversity', such as the facilitation of innovation cannot be obtained. HR well-being parameters are the main concerns of this study, aiming at obtaining as many related benefits as possible to achieve a better HR system. Based on the comparison with the 'non-optimal solution' in the computational example, the proposed 'optimal solution' achieves cost-saving and obtains benefits of HR well-being parameters. Therefore, in real-life practices, based on the corporate well-being policy and subjective criteria, HR managers can refer to and compare different cases (the proposed optimal situation, the existing non-optimal situation as well as the cheaper situation without well-being parameters) to make the final decision of the recruiting plan.

4.2.2 Manufacturing Department

4.2.2.1 Mathematical Modelling

The manufacturing department takes charge of the productions, which are the sources of revenues of the startup. It is necessary to arrange reasonable human resources to guarantee that both quantity and quality requirements in the manufacturing department can be satisfied. Furthermore, with a focus on employees' benefits, in order to avoid poor working conditions as in the sweatshops (ifeng 2018; China Daily 2018), in addition to the operation requirements, welfare parameters should also be taken into consideration.

In the manufacturing department, product installation and product quality control ensure that products can meet both quantity and quality requirements. Based on the real conditions of the company, there can be the recruitment of different levels of workers and/or testers, such as the senior workers (testers) and junior workers (testers), with the consideration of different levels of the salary, accuracy, and proficiency. Based on the policy of 'job enlargement', employees have the opportunity to involve in the manufacturing process of different products. Considering the 'work-life balance' parameters, the workload assigned to employees should be reasonable based on the abilities of employees at different levels. In the manufacturing department, besides the cost of salary, it is necessary to consider the costs of defective products, as mistakes in the manufacturing process are unavoidable. Moreover, due to the capacity of the workshop, such as the number of lathes, the number of employees to be recruited is restricted based on the real situation of the startup.

Decision variable:

x_i: number of employees from level i to be recruited

Related notations:

i: level of employees, $i \in \{1, ..., n\}$
j: subtask (e.g. install or test), $j \in \{1, ..., m\}$
r_i^j: number of products that subtask j has been done by employees from level i per month
s_i^j: monthly salary of employees from level i to complete subtask j
w^j: monthly workload of subtask j
c^j: cost per mistake in subtask j
h_i^j: accuracy rate of employees from level i to completed subtask j
$k\%$: percentage of the amount of mistakes in the total production
L: limited number of employees in workshop restricted by the workshop's capacity

$$min\ Z = \sum_{i=1}^{n}\sum_{j=1}^{m}[s_i^j x_i + c^j r_i^j (1 - h_i^j) x_i] \tag{4.5a}$$

$$s.t. \quad \sum_{i=1}^{n} r_i^j x_i \geq w^j, j \in \{1, ..., m\} \tag{4.5b}$$

$$\frac{\sum_{i=1}^{n}\sum_{j=1}^{m}(1 - h_i^j) r_i^j x_i}{\sum_{i=1}^{n}\sum_{j=1}^{m} r_i^j x_i} \leq k\% \tag{4.5c}$$

$$\sum_{i=1}^{n} x_i \leq L \tag{4.5d}$$

$$\forall x_i \in \mathbf{Z}^+ \tag{4.5e}$$

The objective function (4.5a) is the minimization of total costs, including the salary expenditure and the costs of mistakes. Constraint (4.5b) considers the workload of different subtasks, which is concerned with the requirement of the number of manufactured (or tested) products. Control of mistakes is represented by constraint (4.5c) and the limitation of the workshop's capacity is represented by (4.5d). (4.5e) reflects 'team diversity' with employees from every level. Same as the R&D department, 'flexible working hours' is reflected by assigning total workload during a certain period of time, which allows as much flexibility as possible as long as the total workload can be completed on time.

4.2.2.2 Application

For resource allocation in the manufacturing department, startups can refer to the situation of the outsourcing manufacturers. In this section, the computational example of salary amounts refers to the salary search websites (e.g. Jobui 2019; Kanzhun 2019; Zhipeng 2019 etc.). For productivity, data are generated based on the reference of the working situation in the outsourcing manufacturers (e.g. China Labor Watch 2018). Related data of the manufacturing department are shown in Table 13.

Table 13: Data of Manufacturing Department

	Level 1	Level 2	Level 3
Estimated accuracy rate	98%	96%	94%
Estimated productivity (number of products)	2500	2000	1500
	Salary amount (per month)		
Installation	8000	5600	5000
Test	6400	5600	5200

Non-optimal Solution A case is given that two types of tasks, installation and test, are assigned to employees. The capacity of the workshop (such as the number of lathe machines) is limited to ten employees.

In the non-optimal situation, repeated works are assigned to employees. Assuming that the tasks are assigned to respective types of five level 2 employees. It is inevitable that some mistakes will occur during the manufacturing process, whereby it is necessary to consider the costs of mistakes. Taken the AI voice-control chip as an example for the calculation of the cost of mistakes, referring to the market price, it is about RMB 50 (e.g. Chipintelli 2019; JD 2019 etc.), thus assuming that each mistake will cause the loss of RMB 50.

The total expenditure of non-optimal situation is

$Z^{M'} = 5600 \cdot 5 + 5200 \cdot 5 + 2000 \cdot (5 + 5) \cdot (1 - 96\%) \cdot 50 = 96000$

Tasks amounts are

Installation: $5 \cdot 2000 = 10000$ products

Test: $5 \cdot 2000 = 10000$ products

Optimal Solution Based on the model (4.5), different tasks are designed for the employees. As all manufactured products should be tested for quality assurance, assuming that each task, installation and test, takes 50% of the workload respectively. Referring to the salary standard in Table 13, the new combined salary amounts are arranged as in Table 14.

Table 14: New Salary Amounts of Manufacturing Department

Level	New salary amount (per month)
1	$8000 \cdot 50\% + 6400 \cdot 50\% = 7200$
2	$5600 \cdot 50\% + 5600 \cdot 50\% = 5600$
3	$5200 \cdot 50\% + 5000 \cdot 50\% = 5100$

As for the mistake, it is set as $\leq 10\%$ of the total production. Due to the capacity of the factory workshop, the total number of employees should not be over ten. And the tasks to be completed cannot be less than the non-optimal situation.

In this situation, the optimal model is

$$\begin{aligned} min \quad Z &= 7200 \cdot x_1 + 5600 \cdot x_2 + 5100 \cdot x_3 \\ &+ 50 \cdot [2500x_1 \cdot (1-98\%) + 2000x_2 \cdot (1-96\%) + 1500x_3 \cdot (1-94\%)] \\ &= 9700x_1 + 9600x_2 + 9600x_3 \end{aligned} \tag{4.6a}$$

$$s.t. \quad 50\% \cdot (2500 \cdot x_1 + 2000 \cdot x_2 + 1500 \cdot x_3) \geq 10000 \tag{4.6b}$$

$$\frac{2500x_1 \cdot (1-98\%) + 2000x_2 \cdot (1-96\%) + 1500x_3 \cdot (1-94\%)}{2500 \cdot x_1 + 2000 \cdot x_2 + 1500 \cdot x_3} \leq 10\% \tag{4.6c}$$

$$x_1 + x_2 + x_3 \leq 10 \tag{4.6d}$$

$$\forall x_i \in \mathbf{Z}^+ \tag{4.6e}$$

Optimal solution is $x_1 = 5$, $x_2 = 3$, and $x_3 = 1$.

The total cost is:

$Z^M = 9700 \cdot 5 + 9600 \cdot 3 + 9600 \cdot 1 = 86900$

Based on the results $Z^{M'}$ and Z^M, cost-saving is demonstrated. At the same time, ‘team diversity’ and ‘job enlargement’ can be achieved (4.6b, 4.6e). The amount of mistake is controlled by (4.6c) and the workshop capacity is controlled by (4.6d).

4.2.2.3 Discussion

For model (4.5), compared with the ‘non-optimal solution’ in the computational example, the achievement of ‘team diversity’ and ‘job enlargement’ in the manufacturing department benefits employees with a richer knowledge pool while avoiding the problem of performing a single kind of task boringly (Section 2.2). These benefits can increase the attractiveness to job seekers, thus assisting startups to have more advantages when competing with mature companies (Section 1.2.1).

The proposed model can serve in the initial stage of work arrangement to decide the recruitment quantum for startups that are newly founded. With the startup’s development, it can also be utilized when there is a labor shortage in further practice. The proposed model (4.5) can provide a clear picture of the quantum of workers needed, and can also work together with the existing literature that studies the task arrangement based on the current workforce (e.g. Ammar et al. 2012; Shewchuk 2008; Nakade and Ohno 1999), for a better human resource allocation with workload assignment in the manufacturing department from the planning phase to the implementing stage.

To understand the incorporation of HR well-being parameters in the optimization model, the proposed model is compared with the less-cost case. With ‘job enlargement’, different types of tasks (manufacturing and test) are assigned to a single teammate structure of 8 level 1 workers, the cost of which is 77600 with 2% mistake. It is adoptable to consider the well-being parameter of job enlargement in task arrangement together with cost-saving. While, compared with the proposed 'optimal solution', the benefits of team diversity would not be achieved in this situation. Another factor in corporate long-term human resource management, the reserve talent plan, is deserved to be considered. Model (4.5) plans to recruit different levels of workers in the manufacturing department, the expected result of which is that senior workers who are proficient in the tasks of the production process can act as the teachers/trainers for the junior workers. Some operating skills in the processing workshop with accumulated experience is the great resource for the junior workers. Training junior workers as the reverse talent contributes to the corporate development, especially for startups that desire employees who understand and experience the growth and continuity of the company to be the potential leaders (Kirillov et al. 2017; Song 2017; Lin 2016). Therefore, for HR managers in real-life practices, as the data are various in every organization, there is a trade-off between the consideration of well-being parameters and the expenditure to make a suitable application of optimization.

4.2.3 Sales Department

4.2.3.1 Mathematical Modelling

The sales department plays an important role in broadening the market prospects. Many startups are looking to own a solid sales team to achieve corporate goals (McDougall 2002). The recruitment quantum of the sales department should ensure that there is the sufficient number of employees to serve the estimated number of customers during a period. With the trend of international trade, the sales department focuses on both national and international markets. Thus, 'team diversity' is about different language skills and cross-culture experience that employees hold. 'Team diversity' of people from different backgrounds also adopts the idea of rich knowledge pool for learning from each other. Communication with employees who hold different language skills is also a good way for employees to broaden the horizon and know more about different cultures and oversea situations, which can further benefit employees in career development to better serve customers from different backgrounds. Regarding 'job enlargement', those employees, who can serve the customers in different languages are assigned to multiple service tasks. Furthermore, as the working period in the sales department is longer than the normal 8 am - 5 pm period, especially in companies that trade with foreign countries with time differences, it would be better to arrange 'flexible working hours' for employees. 'Flexible working hours' can be achieved by providing different staffing options to be chosen by employees based on their own situations. The actual working time period would be decided by the company.

Decision variable:

x_i^{jk}: number of employees with i skill(s) in working periods $j+k$ to be recruited

Related notations:

i: numbers of kinds of skills that employee holds, $i \in \{1, ..., n\}$
n: numbers of kinds of skills that employer requires, $n \in \mathbf{Z}^+$
j, k: choices of working time period, $j \in \{1, ..., t\}, k \in \{1, ..., t\}, j \neq k$
t: optional working time periods, $t \in \mathbf{Z}^+$
h: skills (e.g. $h = 1$ is Chinese, ...), $h \in \mathbf{Z}^+$
s_i^{jk}: monthly salary of employees with i skill(s) in working time periods $j + k$
w_h^j: required number of employees with skill h in working time period j
l: limited number of employees per staffing option, $l \in \mathbf{Z}^+$

$$min\ Z = \sum_{i=1}^{n} \sum_{j=1}^{t} \sum_{k=1}^{t} s_i^{jk} x_i^{jk} \tag{4.7a}$$

$$s.t. \quad \sum_{i=h}^{n} (\sum_{k=1}^{j-1} x_i^{kj} + \sum_{k=j+1}^{t} x_i^{jk}) \geq w_h^j, h \in \{1, ..., n\}, j \in \{1, ..., t\} \tag{4.7b}$$

$$\sum_{i=1}^{n} (\sum_{k=1}^{j-1} x_i^{kj} \sum_{k=j+1}^{t} x_i^{jk}) \leq l, j \in \{1, ..., t\} \tag{4.7c}$$

$$\forall x_i^{jk} \in \mathbf{Z}^+, i \in \{1, ..., n\}, j \in \{1, ..., t\}, k \in \{1, ..., t\}, j \neq k \tag{4.7d}$$

The objective function (4.7a) is to minimize the salary expenditure. Constraint (4.7b) satisfies the required workload and constraint (4.7c) limits the number of workers per staffing option. Constraint (4.7d) guarantees that there are employees with different backgrounds to form the team.

4.2.3.2 Application

As the working time periods in the sales department cover day shift and night shift, if the night shift is regarded as overtime working, based on the regulation of the Beijing government (Beijing Government 2019), the salary of the night shift should be 1.5 times of day shift. A case is given that there are three language services that the startup requires. Referring to the common industry salary situation (e.g. Jobui 2019; Kanzhun 2019; Zhipeng 2019 etc.), related data of the sales department are shown in Table 15.

Table 15: Data of Sales Department

	Chinese	Chinese and English	Chinese, English and Japanese
Day shift	6600	7200	7800
Night shift	9900	10800	11700

Non-optimal Solution Assuming that there is the certain number of employees in different service lines that the startup needs as in Table 16.

Table 16: Non-optimal Arrangement of Sales Department

	Chinese	English	Japanese
Day shift	5	4	3
Night shift	4	3	2

Each employee is assigned to a single type of language service with one shift, either day shift or night shift. In this situation, the total salary expenditure is

$Z^{S'} = 5 \cdot 6600 + 4 \cdot 9900 + 4 \cdot 7200 + 3 \cdot 10800 + 3 \cdot 7800 + 2 \cdot 11700 = 180600$

Optimal Solution In the optimal situation, based on the model (4.7), for the total number of employees per period, the number is limited to 12 due to the startup's capacity. For 'flexible working hours', one of the examples is 8 am –24 am period, with 4 shifts of 4-hour each. Based on their own situations, employees can choose any of two shifts to satisfy the requirement of 8 working hours per day.

Example of time period:

1: 8 am –12 pm (Day shift)

2: 12 pm –16 pm (Day shift)

3: 16 pm –20 pm (Night shift)

4: 20 pm –24 am (Night shift)

There will be $C_k^n = \binom{n}{k} = \frac{n!}{k!(n-k)!} = \frac{4!}{2!2!} = 6$ options. This study aims to provide all of the options to be chosen by employees. Related decision variables are shown in Table 17. Based on the new arrangement in the sales department, Table 18 lists the new salary amounts.

Table 17: Optimal Arrangement of Sales Department

	Chinese	Chinese, English	Chinese, English and Japanese
Option A: 1+2	x_1^{12} (x_1)*	x_2^{12} (x_7)*	x_3^{12} (x_{13})*
Option B: 1+3	x_1^{13} (x_2)*	x_2^{13} (x_8)*	x_3^{13} (x_{14})*
Option C: 1+4	x_1^{14} (x_3)*	x_2^{14} (x_9)*	x_3^{14} (x_{15})*
Option D: 2+3	x_1^{23} (x_4)*	x_2^{23} (x_{10})*	x_3^{23} (x_{16})*
Option E: 2+4	x_1^{24} (x_5)*	x_2^{24} (x_{11})*	x_3^{24} (x_{17})*
Option F: 3+4	x_1^{34} (x_6)*	x_2^{34} (x_{12})*	x_3^{34} (x_{18})*

*For HR managers who are not familiar with superscripts and subscripts, variables can be renumbered in computation.

Table 18: New Salary Amounts of Sales Department

	Chinese	Chinese, English	Chinese, English and Japanese
day shift + day shift	6600	7200	7800
day shift + night shift	8250	9000	9750
night shift + night shift	9900	10800	11700

In this situation, the optimization model is

$$\begin{aligned}
min\ Z = {} & 6600 \cdot x_1^{12} + 8250 \cdot (x_1^{13} + x_1^{14} + x_1^{23} + x_1^{24}) + 9900 \cdot x_1^{34} \\
& + 7200 \cdot x_2^{12} + 9000 \cdot (x_2^{13} + x_2^{14} + x_2^{23} + x_2^{24}) + 10800 \cdot x_2^{34} \\
& + 7800 \cdot x_3^{12} + 9750 \cdot (x_3^{13} + x_3^{14} + x_3^{23} + x_3^{24}) + 11700 \cdot x_3^{34} && \text{(4.8a)} \\
s.t. \quad & x_1^{12} + x_1^{13} + x_1^{14} + x_2^{12} + x_2^{13} + x_2^{14} + x_3^{12} + x_3^{13} + x_3^{14} \geq 5 && \text{(4.8b)} \\
& x_1^{12} + x_1^{23} + x_1^{24} + x_2^{12} + x_2^{23} + x_2^{24} + x_3^{12} + x_3^{23} + x_3^{24} \geq 5 && \text{(4.8c)}
\end{aligned}$$

$$x_1^{13} + x_1^{23} + x_1^{34} + x_2^{13} + x_2^{23} + x_2^{34} + x_3^{13} + x_3^{23} + x_3^{34} \geq 4 \tag{4.8d}$$
$$x_1^{14} + x_1^{24} + x_1^{34} + x_2^{14} + x_2^{24} + x_2^{34} + x_3^{14} + x_3^{24} + x_3^{34} \geq 4 \tag{4.8e}$$
$$x_2^{12} + x_2^{13} + x_2^{14} + x_3^{12} + x_3^{13} + x_3^{14} \geq 4 \tag{4.8f}$$
$$x_2^{12} + x_2^{23} + x_2^{24} + x_3^{12} + x_3^{23} + x_3^{24} \geq 4 \tag{4.8g}$$
$$x_2^{13} + x_2^{23} + x_2^{34} + x_3^{13} + x_3^{23} + x_3^{34} \geq 3 \tag{4.8h}$$
$$x_2^{14} + x_2^{24} + x_2^{34} + x_3^{14} + x_3^{24} + x_3^{34} \geq 3 \tag{4.8i}$$
$$x_3^{12} + x_3^{13} + x_3^{14} \geq 3 \tag{4.8j}$$
$$x_3^{12} + x_3^{23} + x_3^{24} \geq 3 \tag{4.8k}$$
$$x_3^{13} + x_3^{23} + x_3^{34} \geq 2 \tag{4.8l}$$
$$x_3^{14} + x_3^{24} + x_3^{34} \geq 2 \tag{4.8m}$$
$$x_1^{12} + x_1^{13} + x_1^{14} + x_2^{12} + x_2^{13} + x_2^{14} + x_3^{12} + x_3^{13} + x_3^{14} \leq 12 \tag{4.8n}$$
$$x_1^{12} + x_1^{23} + x_1^{24} + x_2^{12} + x_2^{23} + x_2^{24} + x_3^{12} + x_3^{23} + x_3^{24} \leq 12 \tag{4.8o}$$
$$x_1^{13} + x_1^{23} + x_1^{34} + x_2^{13} + x_2^{23} + x_2^{34} + x_3^{13} + x_3^{23} + x_3^{34} \leq 12 \tag{4.8p}$$
$$x_1^{14} + x_1^{24} + x_1^{34} + x_2^{14} + x_2^{24} + x_2^{34} + x_3^{14} + x_3^{24} + x_3^{34} \leq 12 \tag{4.8q}$$
$$\forall x_i^{jk} \geq 1, i \in \{1,2,3\}, j \in \{1,2,3,4\}, k \in \{1,2,3,4\}, j \neq k \tag{4.8r}$$

Optimal Solution is x_1^{12} (x_1) = 1, x_1^{13} (x_2) = 1, x_1^{14} (x_3) = 1, x_1^{23} (x_4) = 1, x_1^{24} (x_5) = 1, x_1^{34} (x_6) = 1, x_2^{12} (x_7) = 1, x_2^{13} (x_8) = 1, x_2^{14} (x_9) = 1, $x_2^{23}(x_{10})$ = 1, x_2^{24} (x_{11}) = 1, x_2^{34} (x_{12}) = 1, x_3^{12} (x_{13}) = 1, x_3^{13} (x_{14}) = 1, x_3^{14} (x_{15}) = 1,x_3^{23} (x_{16}) = 1, x_3^{24} (x_{17}) = 1, and x_3^{34} (x_{18}) = 1.

The total compensation amount is

$$\begin{aligned} Z^S &= 6600 + 8250 \cdot 4 + 9900 \\ &\quad + 7200 + 9000 \cdot 4 + 10800 \\ &\quad + 7800 + 9750 \cdot 4 + 11700 \\ &= 162000 \end{aligned}$$

Based on the computational results $Z^{S'}$ and Z^S, cost-saving is demonstrated. Different tasks can be completed by the 'diversity team' with the achievement of 'job enlargement' and 'flexible working hours' (4.8b - 4.8m, 4.8r). The capacity of the workplace is controlled by (4.8n) - (4.8q) as the upper bound of 12 workers per shift.

4.2.3.3 Discussion

Apart from 'team diversity' and 'job enlargement' parameters, due to the longer working time period and the non-stop service nature in the sales department, 'flexible working hours' is also taken into consideration with different combinations of different staffing options. There is no doubt that better working condition that the startup can provide is an attractive point for job seekers in the serious talent war (Section 1.2.1).

Similar to the literature that discusses staffing problems (e.g. Qin et al. 2020; Bhulai et al. 2008; Atlason et al. 2004), the model developed in this study also considers the requirement of services skills, the completion of estimated workloads, the minimization of related costs and the maximum number of workers scheduled during a period. Regarding the rostering, researchers consider the consecutive working days, day-offs, extended weekends and so on (e.g. Prot et al. 2015; Van den Bergh et al. 2013; Fukunaga et al. 2002). The model developed in this study presents a way of choosing different options by combination, which is another way that provides flexibility in staffing.

To analyse achievements of cost-saving and well-being benefits as the 'optimal solution' proposed, other situations are compared. In addition to the consideration of the minimization of cost and 'job enlargement', for the consideration of 'flexible working hours', instead of providing all the combinations of staffing options, there are other cheaper situations if only providing partial options, such as period 1+2 combination and period 3+4 combination. Comparing the proposed model (4.7) and the situation of partial achievement of 'flexible working hours', providing all the combinations can attract different potential employees who prefer different options, which is one way of widening the talent pool and increasing the chance of choosing the best-fit candidates (Maxwell et al. 2007). Based on the real situation of the targeted talent market, HR managers should make a judgement of the difficulty of getting multi-skilled candidates suitable for two staffing options and the difficulty of choosing multiple levels of employees with the provision of all six staffing options. The benefit of team diversity in the sales department regarding the knowledge learning and sharing among employees is another factor in determining the application of HR well-being parameters, which is also related to the personnel training, career development as well as the reserve talent plan. Therefore, depending on the real situation of the startup, the proposed model (4.7) is workable as all benefits can be achieved with the comparison with the 'non-optimal solution', or there can be the choice of adopting a part of well-being parameters with the first priority of expenditure.

4.2.4 Integrated Model

4.2.4.1 Mathematical Modelling

The linear models outlined in the above sections are to help startups design the recruitment plan by considering different aspects. In the real-life context, in some scenarios, it would be better to consider different unknown variables together. For startups that are new in the industry and may possess insufficient knowledge, it is deserving to consider the integration of the problems of 'compensation package' and 'recruitment quantum' in one model in order to achieve the optimization of the recruitment plan as a whole. This suggests the need for a nonlinear model that considers two types of variables in the model, the number of the employees to be recruited and the amount of the compensation package to pay. It overcomes the limitations of the linear planning model that only considers either the compensation amount or recruitment quantum, as the compensation amount may lead to the insufficient number of employees to be recruited due to the budget constraint, while the decision of recruitment quantum will limit the level of the compensation amount, which may cause negative effects on the attractiveness of the startup in comparison of industry benchmarks. The determination of the right number of employees has a close relationship with the satisfaction of workload requirement. The advantage of this model is the consideration of different variables from different perspectives in the objective function, aiming at achieving the optimization of the recruitment planning as the whole, allowing relations between different areas to be coordinated optimally. Within the corporate budget constraint, a sufficient number of employees with suitable backgrounds can be recruited based on the attractive compensation amount, which can improve the fulfillment of the requirements of demand and development.

Decision variables:

x_i: number of employees from level i to be recruited
y_i^j: daily salary of employees from level i to complete subtask j

Related notations:

i: level of employees, $i \in \{1, ..., n\}$
j: subtask, $j \in \{1, ..., m\}$
d_i^j: working days of per employee from level i for subtask j
r_i^j: contribution of per employee from level i to subtask j per working day
s_i: industry monthly salary benchmarks of employees from level i
w^j: monthly workload of subtask j
$k\%$: corporate policy of percentage of salary amount referring to industry benchmark
L: limited number of employees from each level

$$\min Z = \sum_{i=1}^{n}\sum_{j=1}^{m} d_i^j y_i^j x_i \tag{4.9a}$$

$$s.t. \quad \sum_{i=1}^{n} r_i^j d_i^j x_i \geq w^j, j \in \{1, ..., m\} \tag{4.9b}$$

$$(1-k\%)s_i \leq \sum_{j=1}^{m} d_i^j y_i^j \leq (1+k\%)s_i, i \in \{1, ..., n\} \tag{4.9c}$$

$$\forall x_i \leq L \tag{4.9d}$$

$$\forall x_i \in \mathbf{Z}^+ \tag{4.9e}$$

$$\forall y_i^j \geq 0 \tag{4.9f}$$

The objective function (4.9a) is to optimize the total expenditure with consideration of planned compensation package and number of recruitment. The targeted workload should be achieved by the team with employees from different levels, which is represented by constraints (4.9b, 4.9e). As for designing the compensation package, it comprises different amounts for different kinds of tasks, at the same time, the compensation amount should fit the range set by the startup based on the industry benchmark, as shown in constraints (4.9c, 4.9f). Constraint (4.9d) considers the capacity of the workshop.

4.2.4.2 Application

As the central department in AI Smart Home startups, R&D department is again taken as the computational example, and the case with related data are derived from Section 4.2.1.

Non-optimal Solution As the same case in the section above (Section 4.2), in the non-optimal situation, the total salary expenditure is RMB 1790k, with 625 index points of the task to be completed for research in Project A, 375 index points of the task to be completed for research in Project B, and 40 index points of the task to be completed for administration (management) in Project A and Project B.

Optimal Solution Based on the integrated model (4.9), tasks are redesigned with the consideration of HR well-being parameters and the industry benchmarks, with which, $i \in \{1, ..., 4\}$ for the segment of employees' levels for research task $j = 1$ and $i = 5$ for all levels of employees involved in admin task $j = 2$. As the salary standard of admin task is for all levels of employees, for easier understanding, y_i^2 is converted as y_5^2 in the computation below.

$$\begin{aligned}
min\ Z = &(18 \cdot y_1^1 + 2 \cdot y_5^2) \cdot x_1 + (17 \cdot y_2^1 + 3 \cdot y_5^2) \cdot x_2 \\
&+ (16 \cdot y_3^1 + 4 \cdot y_5^2) \cdot x_3 + (15 \cdot y_4^1 + 5 \cdot y_5^2) \cdot x_4 && (4.10a) \\
s.t.\quad & 15 \cdot 11 \cdot x_1 + 6.25 \cdot 11 \cdot x_2 + 1.25 \cdot 10 \cdot x_3 + 9 \cdot x_4 \geq 625 && (4.10b) \\
& 15 \cdot 7 \cdot x_1 + 6.25 \cdot 6 \cdot x_2 + 1.25 \cdot 6 \cdot x_3 + 6 \cdot x_4 \geq 375 && (4.10c) \\
& 2 \cdot x_1 + 3 \cdot x_2 + 4 \cdot x_3 + 5 \cdot x_4 \geq 40 && (4.10d) \\
& 18 \cdot y_1^1 + 2 \cdot y_5^2 \geq (1 - 10\%) \cdot 500k && (4.10e) \\
& 18 \cdot y_1^1 + 2 \cdot y_5^2 \leq (1 + 10\%) \cdot 500k && (4.10f) \\
& 17 \cdot y_2^1 + 3 \cdot y_5^2 \geq (1 - 10\%) \cdot 209k && (4.10g) \\
& 17 \cdot y_2^1 + 3 \cdot y_5^2 \leq (1 + 10\%) \cdot 209k && (4.10h) \\
& 16 \cdot y_3^1 + 4 \cdot y_5^2 \geq (1 - 10\%) \cdot 42k && (4.10i) \\
& 16 \cdot y_3^1 + 4 \cdot y_5^2 \leq (1 + 10\%) \cdot 42k && (4.10j) \\
& 15 \cdot y_4^1 + 5 \cdot y_5^2 \geq (1 - 10\%) \cdot 33k && (4.10k) \\
& 15 \cdot y_4^1 + 5 \cdot y_5^2 \leq (1 + 10\%) \cdot 33k && (4.10l)
\end{aligned}$$

$$y_5^2 \geq (1 - 10\%) \cdot 2.9k \tag{4.10m}$$

$$y_5^2 \leq (1 + 10\%) \cdot 2.9k \tag{4.10n}$$

$$\forall x_i \leq 10, i \in \{1, ..., 5\} \tag{4.10o}$$

$$\forall x_i \geq 1, i \in \{1, ..., 5\} \tag{4.10p}$$

$$\forall y_i^j \geq 0, i \in \{1, ..., 5\}, j \in \{1, 2\} \tag{4.10q}$$

Up to the preference of HR managers, for those who are not familiar with superscripts and subscripts, related variables can be renumbered in the computation. Related rounded results are $x_1(x_1) = 2$, $x_2(x_2) = 3$, $x_3(x_3) = 6$,$x_4(x_4) = 1$, $y_1^1(x_5) = 24.7$, $y_2^1(x_6) = 10.6$, $y_3^1(x_7) = 1.7$, $y_4^1(x_8) = 1$, and $y_5^2(x_9) = 2.8$.

Correspondingly, the total salary expenditure is

$$\begin{aligned} Z &= 2 \cdot (18 \cdot 24.7 + 2 \cdot 2.8) + 3 \cdot (17 \cdot 10.6 + 3 \cdot 2.8) \\ &+ 6 \cdot (16 \cdot 1.7 + 4 \cdot 2.8) + 1 \cdot (15 \cdot 1 + 5 \cdot 2.8) \\ &= 1725.6k \end{aligned}$$

In this computational example, setting of $\forall x_i \in \mathbf{Z}^+$, the integer results are $x_1 = 2$, $x_2 = 3$, $x_3 = 5$, $x_4 = 3$ with the total cost of $1742.4k$.

The result suggests that the model (4.9) is feasible to solve the integrated problem of the number of employees to be recruited, and the amount of compensation package for a minimum cost with the satisfaction of constraints. Based on the corporate data and some subjective factors in real-life practices, the solutions of rounded number or integer number can be compared, and the HR manager will decide the final resources allocation to get the suitable arrangement to fit the corporate development.

4.2.4.3 Discussion

In general, algorithms can find the optimal solution to the linear models. For the nonlinear functions such as this integrated model (4.9), global optimal solution or local optimal solution would be searched based on the constraints. In the case of this computational example, concerned with the constraints in the model, within the feasible region, the optimal solution is searched, which can be utilized as the solution to be referred to in recruitment planning.

Compared with a set of models developed with one variable, which can be the direct way to search for the optimal solutions, this integrated model (4.9) is practicable for the recruitment cases where related data are insufficient, such as in the initial stage when the startup is founded, or if there are new projects that the startup wants to conduct. The advantage of this model is the consideration of different variables from different perspectives in the objective function, aiming at achieving the optimization of the recruitment planning as the whole, better assisting the startup in the circumstances with uncertainties.

4.3 Discussion of Optimization Models in Recruitment Plan

4.3.1 Application of Optimization Models in Recruitment Plan

Based on the results of respective models, the validity and feasibility of the proposed models are demonstrated, indicating that the proposed models are applicable in the recruitment process. The models can be used by startups that key criteria for recruitment are startups' salary expenditures and employees' welfare. Economic efficiency can be achieved by cost savings. Furthermore, results are presented for the satisfactions of both operation and welfare constraints. It is safe to assume that a set of models developed above can assist startups to make it clear of arranging the human resources in different departments based on respective needs. With considerations of optimization, operations requirements as well as well-being parameters, a better HR system can be established. It is also worth noting that a good working condition based on the HR well-being parameters can allow a win-win situation for both employers and employees. Compared with the non-optimal solution, to employees, a good working condition benefits employees a lot, such as a richer knowledge pool based on 'team diversity'. Having conducive working experience with 'job enlargement' and 'job enrichment' can better motivate employees to participate in the development of the startup. At the same time, the achievement of 'flexible working hours' can assist the startup in helping employees with regards to the responsibilities outside work, especially for those 'Only-child' in the family (Section 2.2). The achievement of the well-being constraints assists in creating better 'Talent Management' regarding the anticipation and fulfillment of the needs of the human capital, the contribution to better performance, and the creation of strategic sustainable success of the organizations (Section 2.2). There is no doubt that such welfare can be an attractive point to the potential employees, which is helpful in retaining employees in the company, whereby to some extent, can help the startup to be advantaged in the talent war (Section 1.2.1). With suitable and adequate employees, the desirable behaviors for corporate performance can be elicited, which will add values to the positive organizational outcomes, achieving 'Strategic HRM' (Section 2.3).

A set of proposed models in Chapter 4 considers 'team diversity', 'job enlargement', 'job enrichment', 'work-life balance', and 'flexible working hours' in different circumstances, aiming at obtaining as many benefits of well-being parameters as possible and achieving the minimization of expenditures. Several computational examples provide different cases for comprehensively analysing the incorporation of HR well-being parameters and cost-saving. As the variety of different data sets in real-life practices, in some situations, there are trade-offs between the application of full/partial HR well-being parameters and the expenditures. The proposed models in this study provide a clear picture of expenditures, resources arrangement as well as employee welfare. It is a good practice for HR managers to analyse the situation with the proposed method and the commonly-used methods. The proposed optimization models can serve as the analysis tool with objective views. Regarding the balance of HR well-being parameters and the expenditure, it will then be judged based on the real corporate situations and corporate values, which is case-by-case different.

4.3.2 Superiority of Optimization Models in Recruitment Plan

Based on the computational results of all models developed for the recruitment plan, the superiority of optimization models is prominent as different requirements are satisfied, no matter in cost or well-being dimensions. The superiority of optimization models can also be demonstrated by the comparison with the existing methods that are commonly used by companies and HR practitioners in recruitment planning (Section 1.2.1). Delphi Technique and Experience Forecasting involve some subjective opinions from the experts, which may lead to inaccurate judgements and bias. The quantitative methods are more objective with scientific analysis. Statistical Analysis and

Trend Forecasting, which requires historical data, are not suitable for startups' recruitment, especially at the early stage of founding as there is no mature database for startups to refer to. For Ratio Analysis and Regression Analysis, the disadvantage is that the main concern is the focus on obtaining the results of 'how many employees need to be recruited' while other factors, such as HR well-being parameters, are not emphasized.

Another mathematical analysis method, as presented in this study, optimization method, can be utilized as the complementary method in startups' recruitment process to make a more comprehensive analysis. Optimization models developed in this study consider multiple decision factors together, including budget, costs, workload and so on, achieving the balance of the factors and getting the optimal solutions. Compared with other methods, optimization is suitable at the initial stage of the startup when there is no mature database. With the satisfaction of all constraints, the dimensions of decision making are wider than those methods that only concern with workload and productivity. Furthermore, the integration of the HR well-being parameters gives prominence to the optimization method, as it can not only help the startup satisfy the operational requirement, but also can create the additional value in decision-making process regarding workforce welfare. With respect to the number of variables, optimization method is more flexible in application with linear model for one variable and nonlinear model for more variables. Therefore, it is a good practice for startups to introduce the optimization method in the recruitment planning process for an integrated consideration. The optimization result can be a reference point for HR practitioners to understand HR well-being parameters and expenditures, acting as the supplemental analysis tool in decision-making processes.

4.4 Summary

In this chapter, respective models for the recruitment plan are developed, including 'compensation package designing' as well as 'recruitment quantum planning'. Considering the real situation of the Chinese AI Smart Home startups, which usually operate in the combined business model, respective models are designed to suit the needs of different departments with essential workload requirements and worthy-considered HR well-being parameters. The computational results of models and the comparisons of different application situations suggest the feasibility of the proposed models. At the same time, the superiority of the models is demonstrated with the comparison made to existing commonly-used methods.

Chapter 5

Optimization of Recruitment Activities

5.1 Business Trips Routing

5.1.1 Mathematical Modelling

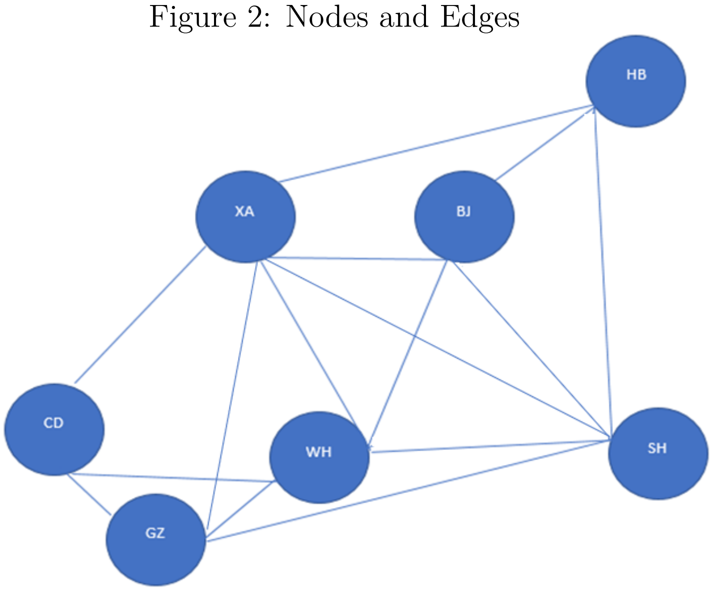
With the approval of the recruitment plan, in order to advertise the job vacancies to the targeted talent, visiting the universities to reach the talent pool directly is one of the choices (Talentseer 2020; Su and Yang 2015; Mathis and Jackson 2011). As AI Smart Home startups require talent with special AI background, it is essential to travel to cities that have universities with AI-related courses to recruit prospective employees. To optimize the business trips routing, travelling salesman problem (TSP) is referred to for modelling. The targeted cities can be simplified into nodes (Figure 1, Figure 2). Each node represents a targeted city, and the edge is the route to be chosen.

The HR team will visit all the targeted cities, each of which once, and then go back to the home city, which is the Hamilton cycle. The objective is to minimize the cost of the business trip. From an HRM perspective, it is a good practice that the startup HR team visits the universities during the graduation season, which is usually from June to July in China, in order to reach talent pools as many and as large as possible. The startup can consider joining the university job fairs during the specific time period and/or give a presentation to the graduates to share and disseminate related information. For those targeted cities (universities) that job fairs have been fixed during the suitable business trip period, the HR team will join the job fairs. For the other cities (universities) which do not hold job fairs, or the date of job fair does not fit the schedule, there will be the choice of giving a presentation to the targeted talent. Startups can negotiate with the university to give a presentation, date and time of which can be arranged to fit the schedule of the business trip. Related information can usually be found on the university website. Considering both choices can assist the HR manager in arranging necessary tasks for completing the business trip within the allocated time period, to ensure that the information about vacancies can be disseminated to the graduates on time. Meanwhile, the business trip itinerary can be arranged without interruptions. For the HR team members who are on a business trip, less travelling times allow more time to stay in the home city. This can also reflect the HR well-being of 'work-life balance', which can better assist the employees, especially those 'only child' to achieve responsibilities outside work. Moreover, regarding constraints in the optimization model, combining both methods to visit the cities (universities) can simplify the time constraints. In the optimization of routing problem, 'time window' is the constraint for limiting the timing of 'arrival', 'serve' as well as 'leave', which is widely concerned in 'Vehicle Routing Problem with Time Window' (VRPTW) (e.g. Toth and Vigo 2002). Each targeted city i is associated with a time interval $[a_i, b_i]$, called a time window. If the HR manager only concerns about joining the job fairs during the specific fixed date, there should be the consideration of the 'hard time window'.

‘Hard time window’ ensures that time constraints should be satisfied strictly, meaning that the HR team should visit the targeted city only within the specific time window. However, it may be difficult to complete the visits to all targeted cities in a single business trip routing as the dates for job fairs in different cities (universities) may not be in the same interval. Even though there can be the consideration of ‘soft time window’ with the ‘penalty’ to allow the flexibility in time constraints, the penalty is not easily converted to ‘money’. Furthermore, if the schedule cannot be arranged continuously, some ‘waiting’ time should be spent in the targeted city until the date of the job fair, which will lead to the inefficiency of HR performance, especially for the startup that the HR resource is not strong enough. This will not just incur extra costs spent during the waiting time, but it also affects task arrangements, as the HR team members can be assigned other tasks if they are in the offices rather than staying in the hotels while waiting for the job fairs. Therefore, in this study, by adopting different choices to visit the targeted cities (universities), the model is developed for reaching talent pools without ‘time window’, which simplifies the decision-making process for HR managers. It is more cumbersome to consider the arriving time, serving time and leaving time in the business trip planning. It would be better to choose an easier way to plan resource allocation, which is effective and efficient in saving time and improving working performance. Moreover, it is an easier practice for HR managers in the computation regarding data collection and result calculation.

Figure 1: Map of Targeted Cities

Figure 2: Nodes and Edges



The decision of departure from city i to city j is represented by x_{ij}, where

$$x_{ij}= \begin{cases} 1, & \text{this decision is chosen} \\ 0, & \text{this decision is not chosen} \end{cases}$$

i: targeted city to be visited

j: next city to be visited after city i

Related notations:

c_{ij}: cost of business trip from city i to city j

S: set of cities

Model for business trips routing is

$$min\ Z = \sum_{i,j=1}^{n} c_{ij} \cdot x_{ij} \tag{5.1a}$$

$$s.t. \quad \sum_{j=1}^{n} x_{ij} = 1, i = \{1, 2, ..., n\} \tag{5.1b}$$

$$\sum_{i=1}^{n} x_{ij} = 1, j = \{1, 2, ..., n\} \tag{5.1c}$$

$$\sum_{i \in S, j \in S}^{n} x_{ij} \leq |S| - 1, \forall S \subset \{1, 2, ..., n\}, 2 \leq |S| \leq n - 2 \tag{5.1d}$$

$$x_{ij} \in \{0, 1\} \tag{5.1e}$$

The objective function (5.1a) is to minimize the travelling costs to visit universities. Constraints (5.1b) (5.1c) and (5.1d) is to guarantee that each targeted city will be visited and only be visited once, the traveling route of which is the Hamilton cycle. As for constraint (5.1e), it represents whether the route from city i to city j is either be chosen or not. Based on the certain fixed budget B for the business trip, as $min \sum\limits_{i,j=1}^{n} c_{ij} \cdot x_{ij}$ is found, there are maximum remaining budget $\sum\limits_{i=1}^{n} d_i \cdot s_i$ (the planned staying time (d_i days) in city i and the cost s_i of staying in city i), which can be calculated based on $\sum\limits_{i=1}^{n} d_i \cdot s_i = B - \sum\limits_{i,j=1}^{n} c_{ij} \cdot x_{ij}$. More budget for $\sum\limits_{i=1}^{n} d_i \cdot s_i$ reflects employee welfare with benefiting team members better hotels, meals and so on.

5.1.2 Application

Targeted cities to be visited are sites where universities with AI education are located, such as Beijing (BJ), Harbin (HRB), Xi'an (XA), Shanghai (SH), Chengdu (CD) and Guangzhou (GZ). Related costs for the business trip include the costs of traveling as well as the costs of staying in the targeted cities. In this thesis, the computational example is given for searching for the minimum costs of traveling. Regarding the cost of staying in the targeted cities, such as hotels, transport, food and so on, based on the optimal solution of the traveling cost and the total business trip budget, the HR manager will then adjust the costs of staying in the targeted cities on a case by case basis. Generated by referring to fees in travelling websites (e.g. Ctrip 2020; Qunar 2020 etc.), related data are shown in Table 19.

Table 19: Travelling Costs

	BJ	HRB	XA	SH	CD	GZ
BJ	0	700	600	500	700	600
HRB	700	0	650	500	750	650
XA	600	650	0	500	450	500
SH	500	500	500	0	550	500
CD	700	750	450	550	0	450
GZ	600	650	500	500	450	0

The minimum cost of the computational example is RMB 3150 with the routing of '1-4-2-3-5-6-1'. By decoding, the HR team departures from Beijing where the startup is located, then visits Shanghai, Harbin, Xi'an, Chengdu, Guangzhou sequentially, and then return to the home city, Beijing. Compared with one of the other decisions, such as Beijing - Harbin - Chengdu - Shanghai - Xi'an - Guangzhou - Beijing with the cost of RMB 3600, there can be 12.5% saving, which is equivalent to RMB 450. On the other hand, if the

HR team only considers joining the job fairs in the separated periods rather than visiting all the targeted cities in one business trip, there is a higher cost of RMB 6200, which is RMB 3050 more expensive than the optimal solution. Therefore, the optimal solution indicates cost-saving directly.

5.1.3 Discussion

Utilizing the advantages of different knowledge fields improves the efficiency and effectiveness in the implementation of recruitment activities. From a management perspective, the consideration of different alternatives (job fairs and presentations) allows the visiting to be completed on one business trip. Based on the computation, the optimization method shows a clear picture of the routing arrangement. All parties can benefit from the optimal business trip arrangement. For the HR manager, it is the easier and businesslike approach for a busy working schedule. Given the fixed budget and the certain travelling fees from city to city, if the expenditures of the total travelling cost can be minimized with TSP routing decision, even though there may be a tiny difference, for HR manager when planning the business trip, there can be more budget for a better meal or a better hotel, which are some kinds of welfare to the employees who are on trips. At the same time, an efficiently planned business trip reflects the concern of 'work-life balance' with the increased possibility of spending time with family as the reduction of times for business trips. Eventually, the startup can benefit from optimal recruitment regarding overall working performance.

The employment of TSP model in business trip routing enriches the application scenarios for real-life problems. Same as other applications of TSP, such as traffic and transport system (e.g. *Pešić* et al. 2017; Goerigk and Westphal 2016), the proposed model (5.1) also incorporates the real-life factors into constraints. Based on the situation of AI Smart Home startups, the proposed model considers factors of corporate operations, university graduation as well as labor market condition comprehensively, which can help startups reach talent pools during the graduation season directly and timely, to be more advantageous in the serious talent war.

5.2 Interview and Selection

5.2.1 Mathematical Modelling

With the dissemination of related job information to the targeted talent, there will be some applications received by the startup. Therefore, the next step of recruitment is to choose suitable candidates to form the team. Knapsack problem (KP) is referred to. There will be n candidates to be interviewed, with which scores are given to candidates. With evaluations and assessments of candidates, decisions are made to hire teammates to form an optimal team with the highest total scores, while the budget constraints of salary expenditures can be satisfied. With the consideration of 'team diversity', candidates from different levels are recruited. The levels of the candidates are dependent on the real conditions of the concerned department. For example, for the talent requirements in R&D department, there can be different levels of researchers with different qualifications and experiences. As for the sales department, there is the requirement of language skills, such as Chinese, English and other foreign languages. In the respective interview section for a certain level, based on the recruitment plan, there will be a required number of m candidates to be selected, which ensures the satisfaction of the operation requirement.

Decision variable:
x_i: decision on candidate i

$$x_i = \begin{cases} 1, & \text{candidate } i \text{ is selected} \\ 0, & \text{candidate } i \text{ is not selected} \end{cases}$$

Related notations:
i: candidate i, $i \in \{1, 2, ..., n\}$
v_i: interview score of candidate i
s_i: salary of candidate i
m: required number of candidates
B: total budget of salary

$$max\ Z = \sum_{i=1}^{n} v_i x_i \tag{5.2a}$$

$$s.t. \quad \sum_{i=1}^{n} s_i x_i \leq B \tag{5.2b}$$

$$\sum_{i=1}^{n} x_i \geq m \tag{5.2c}$$

$$\forall x_i \in \{0, 1\} \tag{5.2d}$$

The objective function (5.2a) is to maximize the scores that all the selected candidates will hold. Constraint (5.2b) is about the budget constraint. Constraints (5.2c) guarantees that the required number of teammates are selected from all levels to form the team, which reflects the HR well-being of 'team diversity' in the whole department.

5.2.2 Application

Data of the evaluation of a group of candidates during the interview are institution-specific, or even round-specific. It is difficult to collect a representative data set of a specific interview that can reflect the overall industry situation. In each round of interviews, every candidate is awarded a specific score. As a new company, it is difficult for the startup to make an accurate judgement of the suitability of the interviewed candidates towards the corporate situation due to the lack of experience and recruited workforces to be compared. Candidate score is a kind of references in the recruitment process to make decisions of candidates. In addition to the basic score of the qualification background, the final score of the candidate includes the score of the performance during the interview process, which involves subjective factors from interviewers. There may be the situation that the interview score of the candidate who holds less experience/qualification but performs better is higher than or the same as the candidate with higher qualification. While the starting salary level is correlated with qualification and experiences.

In this study, the R&D department, which plays an important role in AI Smart Home startups, is again used as the experimental example. Referring back to Section 4.2.4, an example is given for the interview of level 3 researchers, whose recruitment quantum is six with the guided salary level of RMB 38400 per month. The total budget for this level is RMB 230400.

For the interview section, HR managers should consider the ratio relationship of related parameters, including the number of hires, number of offers, number of interviewees, number of interview offers as well as number of applications (Ge et al. 2011; Mathis and Jackson 2010). The pyramid (Figure 3) shows the ratio relationships among related parameters, the values of which are determined by the company based on its own situation. For illustration purpose, in this study, as the targeted recruitment quantum is 6, assuming that the ratio is 50% between the number of hires and the number of interviewees, so the selection is 6 out of 12 candidates. If the company considers the difference between the number of hires and the number of offers, there can be the selection of more than 6 candidates to send offers, which is judged by the HR manager in real practice. The computational example is given in Table 20.

Figure 3: Interview Pyramid

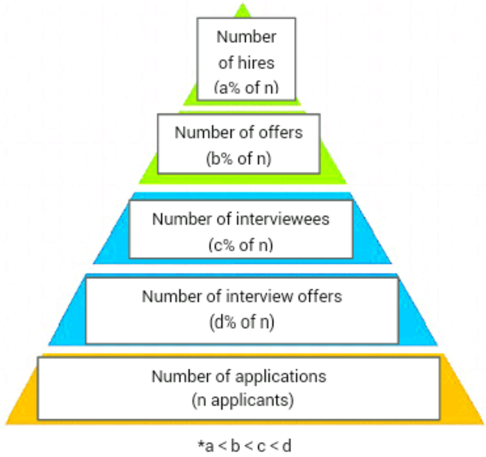


Table 20: Interview Records

Candidate	Scores	Salary
Candidate 1	98	40000
Candidate 2	95	39000
Candidate 3	92	38800
Candidate 4	96	38800
Candidate 5	96	38500
Candidate 6	94	38300
Candidate 7	95	38300
Candidate 8	96	38000
Candidate 9	88	37800
Candidate 10	91	37500
Candidate 11	85	37500
Candidate 12	90	37300

In this computational example, based on the model (5.2), candidates 2, 4, 5, 7, 8 and 10 are selected to be the teammates of level 3. The total salary expenditure is RMB 230100 with the total scores of 569. Comparing one of the solutions with the total scores of 569, the selection of candidates 1, 4, 5, 7, 8 and 9, there will be the salary expenditure of RMB 231400, which is over the budget constraint and is RMB 1300 higher than the optimal solution. For the selection of the top 6 candidates with the highest scores, the total salary expenditure is 232600, which is not a suitable decision as it is also over the budget. Therefore, the optimal solution is deserved to be adopted by the HR manager in 'Interview and Selection' process.

5.2.3 Discussion

The computational result demonstrates that the objective of getting the maximum total scores of candidates is achieved, at the same time, the total salary expenditure can be controlled within the budget constraint. In each interview of different levels, there is a targeted number of candidates to be selected, thus for the whole department, the idea of 'team diversity' can be achieved. Considering the HR well-being parameter in the interview and selection assists in achieving a better HR system from the initial stage of recruitment.

As there are subjective factors involved in the selection process, the relationships of background, starting salary and final score are not directly proportional. If only considering the score of the candidate, the total score of one high and one low is equal to the amount of two medium scores, while the salary amounts of which should also be considered. The computational result of the proposed model (5.2) can serve as the analysis tool from an objective view, providing the information that if the company choose these candidates, there can be the total highest scores that the team can hold with a minimum cost. Therefore, considering the budget constraint, model (5.2) is practicable in selecting candidates.

The application of KP in the interview and selection process helps the HR manager to form the optimal team, which enhances the practicability of KP in solving the real-life problem, and enriches the application fields besides optimal investment, container loading problem and so on (e.g. Assi and Haraty 2018; Morita et al. 1989). Same as the previous literature, the model (5.2) also considers the essential factors based on the targeted problem. Especially, combined with the knowledge from the management side, based on the pyramid of the ratio relationships among different decision factors, the relationship of the number of hires, offers and interviewees can be inversely inferred, which can assist the HR manager in dealing with the data when employing KP model.

Compared with other applications of KP, introducing KP in recruitment practice is significant in the meaning of acting as an objective analysis tool in decision making. Some applications, such as the container loading problem, are about decisions with the exact constraints and the certain value of items, all data of which are fixed. There are few subjective opinions from the manager. While for the interview and selection, apart from the experience and qualification of the candidates, other subjective factors may also affect the final decision. For better decision-making, model (5.2) can assist HR managers to consider in different dimensions. Not only can the optimal result provide a clear picture of the highest total scores of the team within the number and budget constraints, but it can also be a reference of which candidates to be selected. Referring to the optimal result and judging with some other necessary subjective factors, the HR manager can understand the overall situation better, especially when there is a difficult choice to be made among the candidates with similar qualifications.

5.3 Discussion of Optimization Models in Recruitment Activities

5.3.1 Application of Optimization Models in Recruitment Activities

Based on the computational results of respective models for recruitment activities, the validity of the proposed models is demonstrated. Among options, the optimal result indicates the economic efficiency as there is the minimization of costs, and achieves the benefit obtainability as there is the maximization of values. At the same time, the incorporation of the HR well-being parameters, such as 'team diversity' and 'work-life balance', enhances the practical meaning of the proposed models, which can contribute to the better implementation of the recruitment activities. For the Chinese AI Smart Home startups that are facing challenges in recruitment, the achievement of the HR well-being parameters can no doubt assist startups to succeed in the serious talent war, at the same time, implement a better HR system for further development.

5.3.2 Superiority of Optimization Models in Recruitment Activities

Besides the superiority that the optimization models can satisfy the concerned constraints and get the optimal results, the proposed models for recruitment activities enhance the prominence by integrating the knowledge of both sides of management and mathematics. Not only can it assist the simplification of the modelling process, but it can also support management performance. For example, considering multiple choices in the business trip routing arrangement simplifies the modelling process regarding the consideration of 'time window', meanwhile, shares a win-win situation among the company, HR manager as well as teammates on trip. Therefore, it is a good practice to consider the problem from both sides of management and mathematics, to develop a simple and effective model with an integrated action plan by widely choosing and combing alternatives. Furthermore, the computational results of the optimization models can serve as the additional reference in decision-making. In interview selection, the combination of management and optimization provides an objective reference to HR managers. Such a scientific method is supportive in making a more comprehensive decision and getting a better outcome.

5.4 Summary

In this chapter, models for recruitment activities are proposed, including 'business trips routing' as well as 'interview and selection', optimal solutions of which are found. The integration of knowledge from both management and mathematics fields benefits all parties, no matter in the aspects of economic efficiency, HR well-being, or real-life practicability. The computational result provides a clear picture of the optimal choice among alternatives, which can act as a supportively objective analysis tool for better decision-making.

Chapter 6

Conclusion

With the notice of the recruitment issues faced by the Chinese AI Smart Home startups, a set of optimization models are developed for the recruitment process, covering activities from the planning stage to the implementing stage. The integration of the HR well-being parameters enhances the significance of the presented models regarding real-life practicableness, especially for startups to be more attractive and advantaged in the serious talent war. A set of models can assist startups in practising optimal recruitment to attract desired talent, satisfying operation requirements to achieve economic efficiency, at the same time, considering employee welfare to establish a better HR system. Therefore, it is safe to assume that a set of models proposed in this study are noteworthy to assist in addressing the recruitment issues that the Chinese AI Smart Home startups are facing.

For the recruitment planning, linear models are developed for 'compensation package designing' and 'recruitment quantum planning'. Based on the real operations of the Chinese AI Smart Home startups that usually operate different departments, models for the R&D, manufacturing and sales departments are proposed respectively. Besides, for optimizing the recruitment plan as a whole, a non-linear model is also developed with the integration of both ‘compensation package designing’ and ‘recruitment quantum planning’. HR well-being parameters, including ‘team diversity’, ‘job enlargement’, ‘job enrichment’,‘flexible working hours’, as well as ‘work-life balance’, are incorporated into models based on conditions of different departments. In ‘compensation package designing’, the optimal result of the compensation package amount is competitive in the labor market when compared to the industry benchmarks, meanwhile, it is affordable for the startup as it is aligned with the corporate policy. Regarding the models for ‘recruitment quantum planning’, there is a clear picture of the number of employees to be recruited with the satisfaction of both operation and well-being requirements. The optimal result of the integrated model is also found to be referred to in the recruitment planning process. Following the recruitment process, for the HR team to visit universities to disseminate job information and reach targeted talent pools directly, a model for the ‘business trip routing’ is proposed. With the combination of different management methods (job fair and presentation), it is achievable to visit all targeted talent pools in one single business trip, which allows cost-saving for startups, provides a businesslike approach for HR managers and reflects the idea of ‘work-life balance’ for employees. ‘Interview and selection’ is then optimized to recruit the team members with the maximum values within the budget constraint. Several computational examples in this study suggest that applying optimization models in the recruitment process is practicable and achievable, as all the objective functions and constraints are satisfied. It is mentionable that this study attaches importance to obtain benefits of HR well-being parameters and to achieve economic efficiency. While in real-life practices, as the application data and corporate value are institution-specific, there are trade-offs between the choices of HR well-being parameters and the priority of expenditure.

6.1 Research Implications

The integration of HRM and Optimization has implications for research and real-life practices. With the focus on the recruitment process, the optimization models proposed in this study are expected to lend a valuable understanding of the application of optimization, demonstrating the significance of employing optimization models to solve real-life problems. As the feasibility of the models has been verified, the incorporation of the HR well-being parameters makes the class of presented models a powerful instrument in recruitment practices.

This study integrates the knowledge of HRM and Optimization with the aim of solving real-life problems, suggesting the interdisciplinary research for exploring better solutions. The management knowledge provides the guidance of 'what kinds of parameters are needed to be considered in order to achieve goals?', which is then adapted into optimization for a better operation in respect of 'how related practices can be optimized in order to achieve goals?'. It is valuable to encompass different knowledge fields in the research to analyze the problem and search for possible solutions in a more comprehensive way. Regarding the research in HRM aspect, the introduction of mathematical tool to managerial discipline acts as the supplement analysis in business research. Not only did this research investigate the necessary measures in HRM, such as the operation and welfare requirements, but also verify the mathematical relationships of the managerial variables. It provides guidance for resource allocation from the planning stage to the implementing stage. This is expected to be the implication of HRM research on the subject of a better flow, from understanding essential elements and then arranging resources to achieve the managerial goal. Furthermore, in addition to the empirical research to explore relationships between variables, considering the mathematical relationships as the supplemental analysis tools can support the scientific decision-making.

For research on optimization, integrating managerial knowledge makes the models more significant with practical meanings, which is the addition of the rational sense to the numeral intention. The presented models incorporate HR well-being parameters based on different situations, such integration allows the achievement of both operation and welfare requirements, which not only solves the targeted problem of recruitment, but further contributes to a better HR system. The additional benefit of improving HR performance enhances the value of the optimization research. Moreover, in the aspect of mathematical modelling, adapting ideas from the management side can contribute to easier practices as it may simplify the modelling process. For example, when referring to the TSP for 'business trip routing' model, the consideration of combining different alternatives can simplify the modelling process regarding the concern of 'time window'. Extending such an idea to other areas of business is also workable. For instance, even though nowadays, online shopping is popular, the marketing team still would like to join the product shows held by the industry associations to advertise the corporate brand and promote products to customers in different cities directly. There is also the 'time window' that needs to be considered with the date of the product show. Concerning from the marketing practices, during a specific period when the startup promotes the new Smart Home product to grab business opportunities, in addition to the product show, one of the alternatives is to rent a showcase in the main shopping mall where a great number of potential customers would likely visit, with which, customers can also have the excellent experience with the new product as visiting the product show. Combining different marketing strategies can help in the related modelling process. It would be better if the model is simpler and easier, but effective, to be developed, understood, applied and computed, especially when the models are introduced to the business managers who may not be the experts in optimization. Therefore, it is deserved to do interdisciplinary research with the involvement of different knowledge fields.

The specific focus on the serious talent war in the Chinese AI industry makes the research outcome of this study a customized reference to the Smart Home startups with respect to optimal recruitment. A set of models are developed based on the steps of the recruitment process, at the same time, considering the operations situation of Smart Home startups that usually operate several departments. A class of models can assist in the recruitment process, from which HR managers can choose the suitable one for solving the concerned problem in different circumstances. Facing such a serious talent war, the incorporation of the HR well-being parameters enhances the practical meaning of the research outcome, as it can contribute to the increase of the attraction of startups in the labor market. The models proposed in this study can also be employed by other companies in the recruitment process, as long as the situation can be formulated into the same functions, and the key concerns in the recruitment are employee welfare and corporate expenditure. It is a good practice to consider HR well-being parameters from the initial stage of HRM and utilize optimization models to improve the decision making, both of which eventually support the establishment of a better HR system for a better corporate development.

Introducing optimization method in the recruitment process provides another approach that can assist the comprehensive analysis in decision-making. Recruitment process involves some subjective factors, which may affect opinions and judgments. It would be better to analyze the problem with some objective views. In addition to the commonly used methods, the proposed optimization models can serve as the supportive approach with objective factors. For example, regarding ‘team diversity’, this study considers employees with different education and experience backgrounds, which is also the source of the inference of the employees’ level. While, ‘team diversity’ can also be defined as the equilibrated team that includes different nationalities, cultural backgrounds and so on. To be more comprehensive consideration in the decision-making, based on the optimization results of the proposed models, such as the compensation package amount for such type of potential employees with related qualifications, and the optimal analysis in interview section, HR managers will then choose the best candidate with the consideration of the other subjective factors.

Besides providing solutions to recruitment issues, this study also introduces the optimization tool to decision-makers. With the knowledge of optimization, mathematical relationships of variables can be well understood, which will help managers to better allocate resources. The proposed model has a simple structure and is computationally amiable. It can be solved in reasonable times with optimization software, which is understandable and practicable to decision-makers who may not be the experts in optimization. Multiple tools can enrich decision-makers’ knowledge, from which decision-makers can take the well-understood method in real-life practices. Furthermore, the idea of integrating different knowledge to search the better solution has the implication of improving the problem-solving skill. Viewing and considering problems from different dimensions can assist in getting a more comprehensive understanding, and then exploring a superior solution.

6.2 Future Work

Apart from the optimization method introduced in this thesis, other methods that can serve as objective tools to assist better decision-making can be investigated in future research. The introduction and adoption of applying optimization models and other analysis tools to balance objective factors with subjective matters in business operations can be further researched. It can be a thorough investigation and understanding of the utilization of both qualitative and quantitative methods regarding "why is it?", "how to improve?" and "what to do?". HR well-being is one of the main concerns of this study, which is expected to create excellent working conditions to attract talent, retain employees as well as encourage desired performance. In addition to the HR well-being parameters considered in this study, for a more comprehensive understanding of employee welfare, some other elements related to employees' mental health can also be incorporated into the optimization model. As for the constraints in this study, with the specific focus on startups, who are just founded at the initial stage, the satisfaction of operation requirements is concerned for a certain amount of demands. To extend the consideration for the further development of startups, with business growth, stochastic optimization can be further investigated to fit the dynamic situation. For the decision variables of the recruitment plan, future studies may optimize the task arrangement of 'working days' in addition to the 'compensation package designing' and 'recruitment quantum planning' together. Regarding the algorithm, this study adopts algorithms from the existing research in computation. New impactful contribution in the algorithmic scheme can be further investigated to solve the targeted problems.

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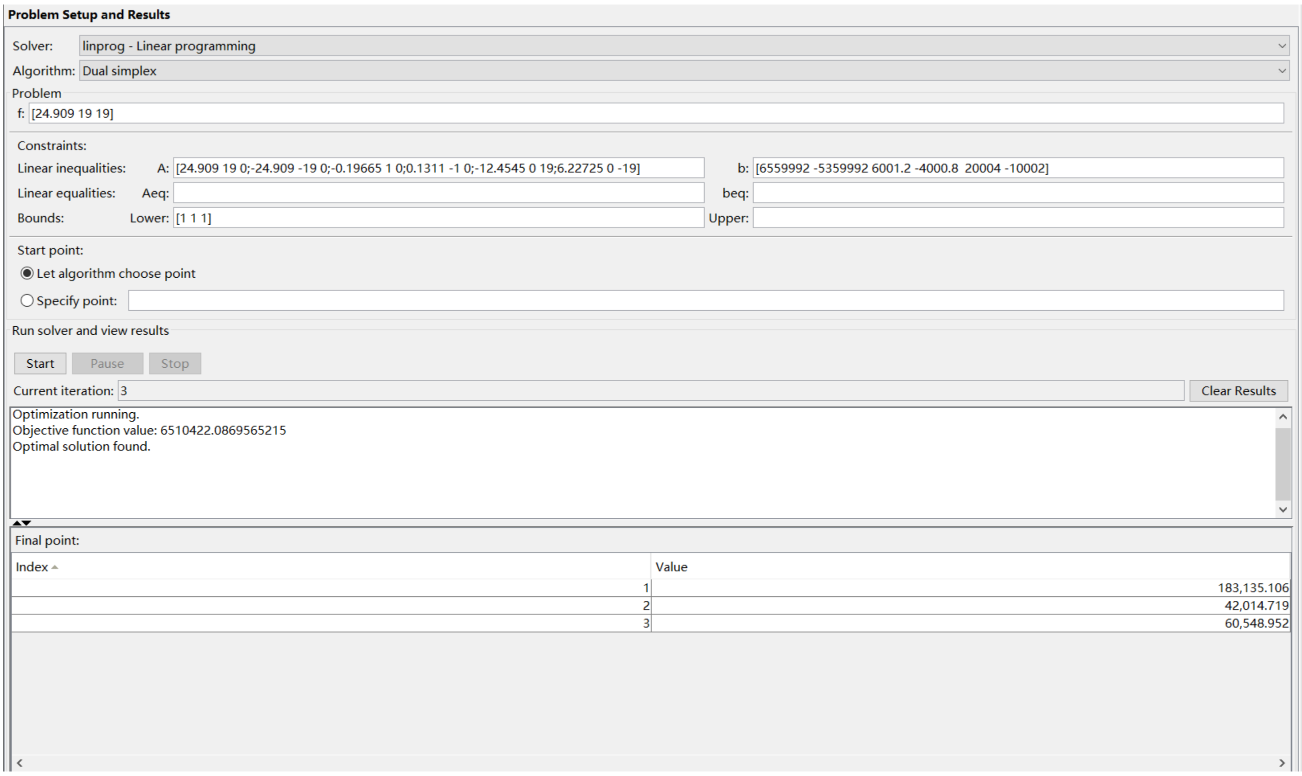
Appendices

Appendix 1

Computation with Matlab Optimization APP



Appendix 2

Computation with Matlab Coding

```
clear;clc;close all;
cost = [0 700 600 500 700 600
700 0 650 500 750 650
600 650 0 500 450 500
500 500 500 0 550 500
700 750 450 550 0 450
600 650 500 500 450 0];
n = size(cost,1);
x = binvar(n,n,'full');
u = sdpvar(1,n);
z = sum(sum(cost.*x));
C = [];
for j = 1:n
    s = sum(x(:,j))-x(j,j);
    C = [C, s == 1];
end
for i = 1:n
    s = sum(x(i,:)) - x(i,i);
    C = [C, s == 1];
end
for i = 2:n
    for j = 2:n
        if i~=j
            C = [C,u(i)-u(j) + n*x(i,j)<=n-1];
        end
    end
end
ops = sdpsettings('verbose',0);
result   = optimize(C,z);
if result.problem== 0
    value(x)
    value(z)
else
    disp('mistakes');
end

ans =
       NaN         0         0    1.0000         0         0
         0       NaN    1.0000         0         0         0
         0         0       NaN         0    1.0000         0
```

```
         0    1.0000         0       NaN         0         0
         0         0         0         0       NaN    1.0000
    1.0000         0         0         0         0       NaN


ans =
    3150

a=[ NaN 0 0 1.0000 0 0
    0 NaN 1.0000 0 0 0
    0 0 NaN 0 1.0000 0
    0 1.0000 0 NaN 0 0
    0 0 0 0 NaN 1.0000
    1.0000 0 0 0 0 NaN];
    k = 1;
    path = [k];
    for i=1:size(a,1)
         for j=1:size(a,2)
            if(a(k,j) == 1)
                k = j;
                path = [path, k];
                break;
            end
         end
    end
    path

path =
     1     4     2     3     5     6     1
```