Team Control Number

10701

Problem Chosen

A

2020
HiMCM
Summary Sheet

Looking for summer jobs is a trend for **high school students** nowadays. The purpose includes getting prepared for college life, gaining experiences for further personal development, and earning money. Due to the wide range and a large amount of summer jobs, there is a need for us to build an objective evaluation model to provide appropriate suggestions on summer jobs for high school students. To make the evaluation system of summer jobs global and fit to students around the world, we carefully develop and test the system. Users will be able to gain a plausible suggestion on what kind of summer job is suitable for them in our model.

To solve this problem, we build a comprehensive evaluation model and apply **Analytical Hierarchical Process** (AHP) and **Technique for Order Performance by Similarity to Ideal Solution**(TOPSIS) to gain the ranking list of the jobs for each typical fictional person. After acquiring the ranking list, we divide the jobs into groups through **cluster analysis** and recommend the jobs with the highest ranking in each group to the students. We also develop the concept and design of an app targeting high school students who would like to find a summer job. We propose its user-friendly features including artistic interfaces and relatively accurate results.

In our program, we first determine the five indexes, which are **salary**, **time**, **knowledge**, **environment**, and **intensity**. In our time index, we consider the recreational time left after excluding the work time, the period when the work time conflicts with the student's schedule, and the student's preference variables for those factors. After calculating the eigenvector of the employee's judgment matrix which can be used as the weighting for the five indexes, we use the information of both the student and the jobs to calculate all the indexes of each job. After acquiring the values, we process and collect the data. Then, we are capable of ranking jobs by TOPSIS analysis. This will result in a ranking list to our targeted customer. In order to ensure the best-fit job to be recommended, cluster analysis is done to avoid recommending highly similar job, enhancing the quality of our recommendation of summer jobs.

Before applying our models, we construct **ten fictional persons** based on different characteristics which can be shown as having different judgment matrices and preference variables. Different judgment matrices and preference variables are applied to reflect those typical fictional persons' choices. An example will be used to give a detailed illustration of our evaluation model. The 10th fictional person is selected and we apply TOPSIS and cluster analysis to form a suitable list of summer jobs for him. The result is highly consistent with our expectation of the person's characteristics.

One of the most creative aspects of our model is that we apply both AHP and TOPSIS to gain the evaluation, and our recommendation is based on cluster analysis. AHP results are used to run TOPSIS analysis for each fictional person. Then we can use the TOPSIS score and **Hierarchical Clustering Dendrogram** to recommend the summer jobs to each person.

We develop our model's function into an app that meets our customers' needs and is able to provide a relatively accurate **ranking list** while ensuring both its usability and clear, artistic design of its interfaces.

Keywords: TOPSIS, AHP, Cluster Analysis, Comprehensive and Detailed Evaluation Model, Highly Sensitive to Student's Situation and Preference

Unlock your **Fabulous** Summer Job Choice

Summer Job
Advising App No. 1

Team#10701

Job Finder

Recommendation
Most
Suitable For you

Contents

1 Introduction

Summer job is a type of job that students do in summer vacation, allowing students to gain experience in their interested field and also earn money. Students are capable of further improving their academic performance, learning about important employment skills, and being immersed in real-world working circumstance ahead of time. What is more, summer jobs enable students to find a meaningful way to relax instead of simply staying at home. To be more detailed, students can refresh their minds and boost their energy through the experience of working for the jobs they are interested in during summer vacation. This is probably because they will gain a sense of personal satisfaction, as they may do something that makes contributions to society[1].

Also, for many young people who struggle with economic burden, they are likely to face the prospect of a difficult transition into work or college. Applying for a job in the current labor market enables them to benefit from being able to perceive why educational attainment is important, besides the income they gain. To fulfill the increasing demand for summer jobs, there are a considerable amount of summer jobs available for students who have an interest in finding a summer job to reach certain goals.

2 Problem Restatement and Analysis

The way people evaluate whether a summer job is suitable for them or not normally depends on lots of factors, including inner factors, such as personal income and fields they are interested in, and external factors, such as the wage and working environment. However, due to the great number of summer jobs existing and the various kinds of factors which people should take into account, people tend to be frustrated when they are choosing what kind of summer job they should participate in. There are indeed some summer job evaluation forms provided by several institutions. However, these forms cannot provide a clear report or evaluation to people, since they only ask people some questions without forming a suggestion about their choices. Thus, there is clearly a need for a comprehensive model to help people evaluate the value of various summer jobs based on their personal interests and the benefit they will gain from this experience.

To solve this problem, we will make a new evaluation system and rank each summer jobs to help students to find the “best” jobs. In our model, based on the preference and personal situation of different students, subjective evaluation methods need to be used.

We are also asked to develop at least ten fictional persons. The purpose of doing this is to ensure our evaluation system to be global and well fit to students around the world. To make these ten persons typical representatives of students around the world, an online survey will be conducted to collect personal information from teenagers. In the end, we need to develop an app to illustrate how we will promote our model to the general public.

3 Our Work

The process of our work first contains introducing the topic and giving a further exploration into the problem. This helps us to better understand the purpose of solving the problem. Next, we need to purpose the assumptions and justification. After dividing the indexes we need to consider, we will use TOPSIS and AHP to evaluate and analyze our data. In order to make our model results reliable and readable, we develop ten fictional persons. After making the sensitivity analysis, we make a thorough consideration of our users’ experiences, both recognizing our app’s advantages and disadvantages. Finally, based on our model results and app’s design, we state our strengths and weaknesses.

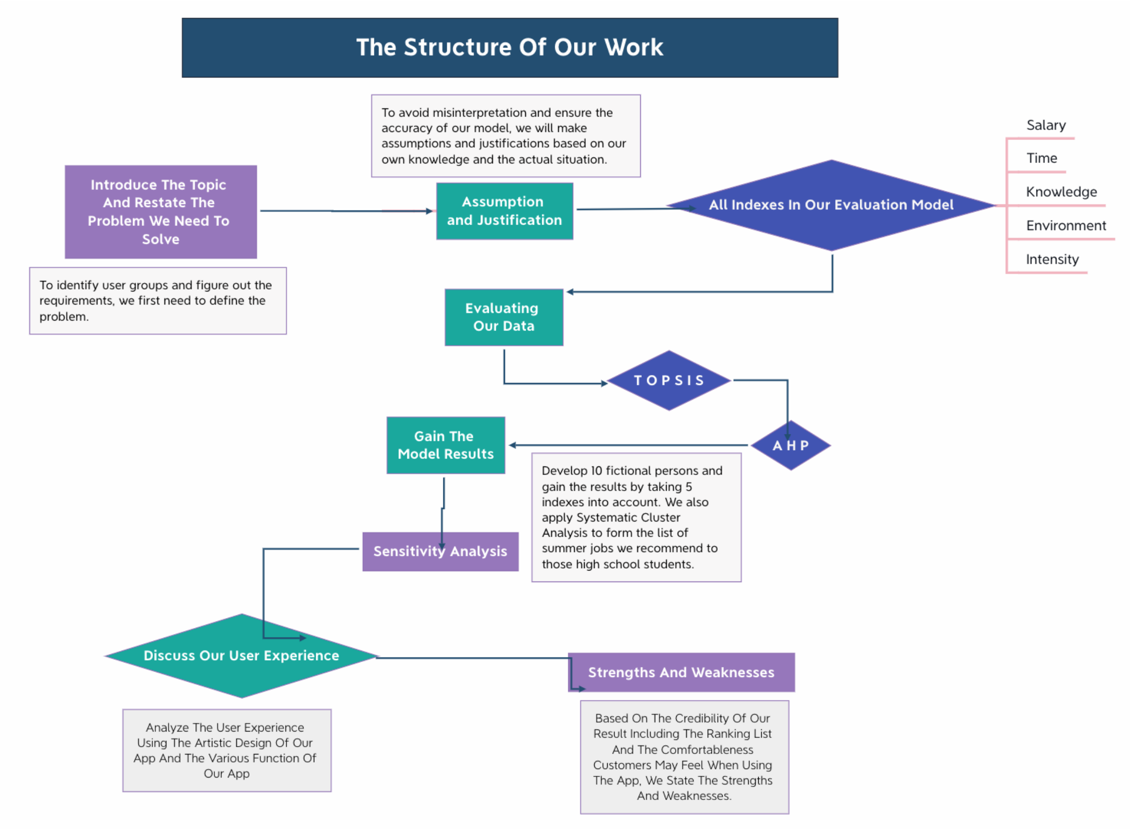


Figure 3.1: Work Structure

4 Assumptions and Justification

- **Assumption 1:** All the jobs we offer are legitimated and suitable for high school students.
- **Explanation 1:** There are situations when illegal jobs are provided on websites. But it's difficult for us to discern those illegal jobs. Also, there are jobs requiring its employees to be above a certain age. However, our model is constructed only for high school students. So the jobs in our list should be legitimated and suitable for high school students.
- **Assumption 2:** The source of data is real and reliable.
- **Explanation 2:** The fact is that data may be fabricated, posing an unfavorable impact on the accuracy of our model. We need to avoid that.
- **Assumption 3:** The job we recommend to the student doesn't require its employees to be experienced. If it does, the student should be able to judge whether he has the experience needed.
- **Explanation 3:** Taking the student's experience into our consideration is not only laborious for us but also reduces the usability of our model, since the student will be required to tell all the experiences he already has. Besides, it's easy for the student to judge whether he has the experience of the jobs we recommend to him. Therefore, our model won't reflect experience requirement.
- **Assumption 4:** Time for commuting is only related to the distance between the home of the employees and the workplace.

- **Explanation 4:** Although the transportation situation of the employees to go to the location of the workplace is important, it's not practical for us to take the factor into account.
- **Assumption 5:** The sum of work time and recreational time is twelve hours. The work time includes both the time spent on commuting and the time spent on work.
- **Explanation 5:** The sum of work time and recreational time varies among different people. When there is a large difference in available time, it's hard for us to recommend a proper job to the students. Therefore, we need a constant available time. After excluding necessary daily routine, we set the available time twelve hours, which is proper for most students.
- **Assumption 6:** Salary is fixed. If the salary is not fixed actually, we will use its expectation value as it is fixed.
- **Explanation 6:** To recommend the students a job, we definitely need to know the salary. If the salary isn't fixed, it's hard for us to make a decision. Therefore, if the salary is probabilistic, we will calculate its expectation value according to the information we have of both the employers and the employees.

5 Variables

Below is the table of all the variables we use.

Variables	Description
S	Salary index
T	Time index
K	Knowledge index
I	Intensity index
E	Environment index
S_{day}	Salary per day
S_{over}	Salary per hour in overtime
$S_{expected}$	Expected salary from overtime
c_t	Average cost per kilometer on transportation
c_m	Average cost per meal
n_m	The number of meals per day
D_{travel}	The distance between workplace and home
s_{travel}	Average commute speed
T_{over}	Duration of overtime
$T_{expected}$	Expected hour of overtime
T_{work}	Regular working hour
T_{travel}	Time spent on transportation
$T_{conflicted}$	The period when job conflicts with schedule
T_{margin}	Potential conflict time
ρ_{over}	Probability of over time
μ	Importance of conflicted activity
γ	Importance of recreational activity
ϵ	Extra expenditure
λ	Measure the experience gained per hour
β	Measure the quality of environment
δ	The amount of the knowledge gain
α	Conformity variable of the academic knowledge
β	The quality of the environment
η	The type of the job in terms of labor requirement
$[K_{ij}]$	The judgment matrix of the factors in knowledge index
$[E_{ij}]$	The judgment matrix of the factors in environment index
$[a_{ij}]$	The judgment matrix of the overall five indexes

Table 5.1: Variables Table

6 Index Extraction and Calculation

After collecting the variables, we construct second layer indexes to measure five aspects of the job to determine its final ranking in our model. The five aspects contain the salary, time, knowledge, environment, and intensity.

6.1 Salary Index

Besides the salary paid by the employers, the actual salary is also an essential indicator of the profitability of a summer job. Thus we define the salary index which can be reflected by the original salary, the fee spent on transportation, and the expense of meals. In addition, we consider the revenue overtime. Thus, we have the equations below.

$$S_{expected} = \rho_{over} * T_{over} * S_{over} \tag{6.1}$$

Here $S_{expected}$ represents the expectation value of the salary gained from overtime.

$$S = S_{day} + S_{expected} - \epsilon \tag{6.2}$$

The variable ϵ represents the extra fee spent because of work. There are mainly two types of extra fee, transportation fee and meal fee. We assume that the transportation fee is positive relative to the D_{travel}, the distance between the workplace and home, and c_t, the average cost per kilometer on transportation. Meal fee is the cost of meals per day, calculated by c_m, the average cost per meal, and n_m, the number of meals per day. The number of meals per day is decided by whether the job offers a meal. If it doesn't, n_m will be three. Additionally, if the job allows employees to work at home, all variables related to transportation will become zero, and D_{travel} will also be equal to zero.

$$\epsilon = c_t * D_{travel} + c_m * n_m \tag{6.3}$$

$$T_{travel} = \frac{D_{travel}}{s_{travel}} \tag{6.4}$$

where s_{travel} is the average commute speed.

6.2 Time Index

Students may not be able to go to work every single hour because of their schedule. So we need an index to measure the conflict between students' working period and their original schedules. Besides, we need to leave some hours for their recreational activities. Therefore, we define the time index determined by the degree of conflict and the amount of recreational time, together with two preferences variable for the employees to measure the importance of their former schedules and recreational periods.

$$T_{expected} = \rho_{over} * T_{over} \tag{6.5}$$

$$T = \gamma * (12 - T_{work} - T_{travel} - T_{expected}) - \mu * (T_{conflicted} + \rho_{over} * T_{margin}) \tag{6.6}$$

Here, γ is the preference variable for recreational activities. The larger the variable or the longer the recreational time is, the higher the satisfaction employees will gain. Similarly, μ is the preference variable for the original schedule. Since the existence of fewer conflicts is better, this part is negative. Besides, T_{margin} is the number of hours of potential conflict time following the end of the job, and its maximum is T_{over}.

In addition, the time index relates to the salary index. A higher salary index often means a larger amount of work time, which will reduce the recreational time, leading to a decrease in time index.

6.3 Knowledge Index

Students can acquire skills and experience by attending summer jobs in preparation for their future careers. Knowledge index measures the quantitative data of the knowledge gained by the employees through the process of working in summer. The index is determined by whether the jobs meet the employees' need for knowledge, experience, and social skills. In addition, the time spent on the jobs is also an important variable.

$$\lambda = \sum_{i=1}^{n} w_i \delta_i \tag{6.7}$$

The variable λ measures the knowledge gained from the job, while δ represents the gain of academic knowledge, experience, and social skills. We use qualitative analysis to get δ, according to the judgment table below. Then we calculate the weight through the judgment matrix given by the employees by AHP. In addition, we have a consistent variable α to judge whether the academic knowledge in that job is useful to the employees' future career, and the weighting of the academic knowledge gained will therefore become $\alpha * w_1$. If the knowledge is useful to the student, α will be 1, or it will be 0.

Bad	Fairly Bad	Medium	Good	Excellent
1	2	3	4	5

Table 6.1: Judgment Table

$$K = \lambda * T_{work} \tag{6.8}$$

6.4 Environment Index

Since the environment where the employees work is also an important indicator of the quality of the job. We define the environment index to measure the characteristic.

$$E = \sum_{i=1}^{n} w_i \beta_i \tag{6.9}$$

We take the working condition, interpersonal environment, and geographical location into our consideration. We first use qualitative analysis to determine β. Also, we implement our judgment table. After that, we use AHP to decide the weight with the judgment matrix of the employees.

6.5 Intensity Index

Intensity index measures the intensity of a job. We divide the jobs into mainly four groups by qualitative analysis. The groups include sedentary, neither sedentary nor laborious, laborious, and not sedentary, as a laborious job is rarely sedentary. Then we give each job a grade η according to its group. Therefore, η can be used to decide the type of a job. In our model, a more laborious job will have a lower intensity index.

*The factors included in the intensity index are: job with mobility, field trip, research, fixed point(waiter, waitress), and office job.

$$I = \eta \tag{6.10}$$

6.6 Normalization

After acquiring the values of all the indexes, we process the data through normalization. Because our indexes are all benefit indexes, we can use the formula below to process our data directly:

$$a_{ij}^* = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{n} a_{ij}^2}} \tag{6.11}$$

7 Evaluation Model

7.1 TOPSIS

Technique for Order Preference by Similarity to an Ideal Solution, known as TOPSIS, was first proposed by C.L.Wang and K.Yoon in 1981. TOPSIS is a common intragroup comprehensive evaluation method, which can make full use of the information of the original data, and its results can accurately reflect the gap between the evaluation schemes.

The basic process is based on the normalized original data matrix, and the cosine method is used to find out the optimal and the worst scheme in the finite scheme. Then calculate the distance between each evaluation object and the optimal and the worst scheme respectively, so as to obtain the relative proximity between each evaluation object and the optimal scheme, and take this as the basis for the evaluation.

In addition, the method has no strict limitation on the data distribution and sample content, and the data calculation is simple and easy.

Step 1. We first create an evaluation matrix consisting of m alternatives and n criteria, with the intersection of each alternative and criteria given as x_{ij}. Therefore, we have a matrix $(x_{ij})_{m\times n}$.

Step 2. The matrix $(x_{ij})_{m\times n}$ is then normalized to form the matrix $R = (r_{ij})_{m\times n}$, using the normalisation method:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{kj}^2}}, \quad i = 1, 2, \ldots, m, \quad j = 1, 2, \ldots, n \tag{7.1}$$

Step 3. Calculate the weighted normalized decision matrix:

$$t_{ij} = r_{ij} \cdot w_j, \quad i = 1, 2, \ldots, m, \quad j = 1, 2, \ldots, n \tag{7.2}$$

Where $w_j = \frac{w_j}{\sum_{k=1}^{n} w_k}, j = 1, 2 \cdots, n$, so that $\sum_{i=1}^{n} w_i = 1$, and w_j is the original weight given to the indicator v_j, $j = 1, 2, \ldots, n$.

Step 4. Determine the worst alternative (A_w) and the best alternative (A_b)

$$\begin{aligned} A_w &= \{\langle \max(t_{ij}) \mid j \in J_-\rangle, \langle \min(t_{ij}) \mid j \in J_+\rangle\} = \{t_{wj}\} \\ A_b &= \{\langle min(t_{ij}) \mid j \in J_-\rangle, \langle \max(t_{ij}) \mid j \in J_+\rangle\} = \{t_{bj}\} \end{aligned} \tag{7.3}$$

Where $J_+ = \{j = 1, 2, \ldots, n \mid j\}$ associated with the criteria having a positive impact, and $J_- = \{j = 1, 2, \ldots, n \mid j\}$ associated with the criteria having a negative impact.

Step 5. Calculate the L^2 -distance between the target alternative i and the worst condition A_w

$$d_{iw} = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{wj})^2}, \quad i = 1, 2, \ldots, m \tag{7.4}$$

and the distance between the alternative i and the best condition A_b

$$d_{ib} = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{bj})^2}, \quad i = 1, 2, \ldots, m \tag{7.5}$$

where d_{iw} and d_{ib} are L^2 -norm distances from the target alternative i to the worst and best conditions, respectively.

Step 6. Calculate the scoring according to the distance to the best and worst conditions:

$$s_{iw} = \frac{d_{tw}}{(d_{iw} + d_{ib})}, 0 \leq s_{iw} \leq 1, i = 1, 2, \dots, m \tag{7.6}$$

$s_{iw} = 1$ if and only if the alternative solution has the best condition; and $s_{iw} = 0$ if and only if the alternative solution has the worst condition.

Step 7. Rank the alternatives according to $s_{iw}(i = 1, 2, \dots, m)$.

7.2 Analytic Hierarchy Process

Analytic Hierarchy Process, known as AHP, is a model that aids people in making decisions by applying pairwise comparisons. Linear algebra is the basic principle of this mathematical thinking process. Fundamentally, priorities for alternatives and the criteria used for judging the alternatives are developed in the AHP. When we are intended to use the AHP, it is necessary for us to construct a hierarchic or a network structure to represent that problem and use pairwise comparisons to establish relations within the structure. With AHP, the indexes we take into consideration will be ranged in hierarchic structure.

The figure given below shows the fundamental four steps we will take in AHP.

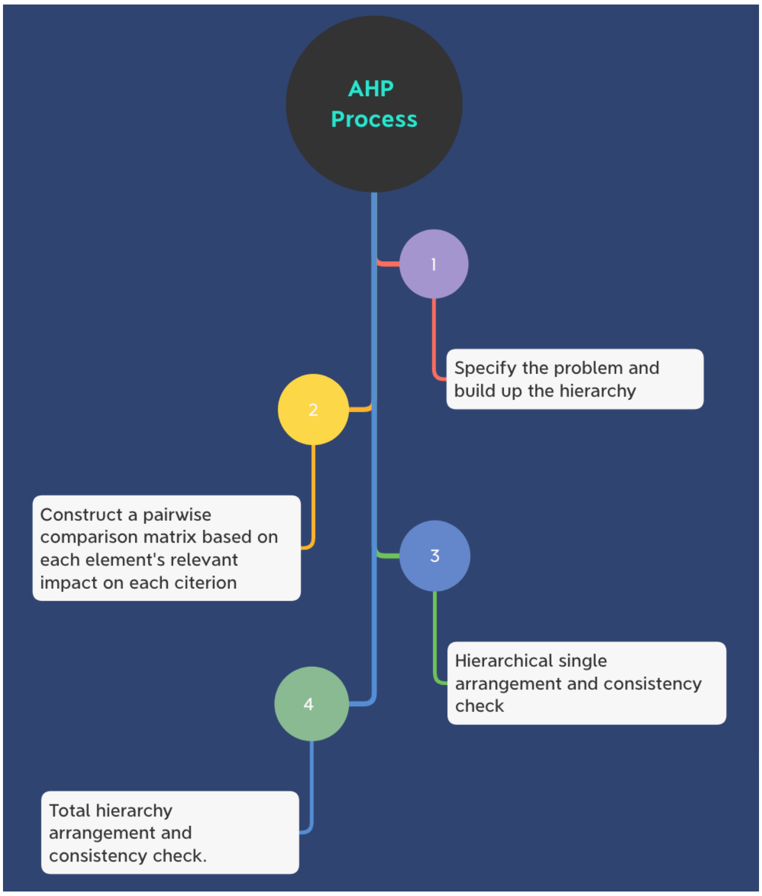


Figure 7.1: Four Main Steps of AHP

The process is divided into two steps. Our first step is to construct a hierarchical model. The mutual relations, the decision objectives, factors and decision objects are divided into the highest level, the middle level, and the lowest level separately.

Next we are going to construct a judgment matrix.

$$[a_{ij}] = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \tag{7.7}$$

The data analysis procedure involves the following steps. First, the pairwise comparison matrix which is called matrix A is extracted from the data collected from the questionnaire. The principal right eigenvector of the matrix A is computed as $'w'$.

If the formula 7.8 is not confirmed for all k,j, and i, the eigenvector method will be applied.

$$a_{ik} \cdot a_{kj} = a_{ij} \tag{7.8}$$

If the matrix is incompatible and incomplete consistency exists, the pair comparisons matrix cannot be used normalizing column to get W_i.

For a positive and reversed matrix, the eigenvector technique can be applied based on the following two formulas:

$$e^T = (1, 1, \ldots, 1) \tag{7.9}$$

$$W = \lim_{k \to \infty} \frac{A^k \cdot e}{e^T \cdot A^k \cdot e} \tag{7.10}$$

When facing an incompatible matrix, the calculation should be repeated several times in order to make a decision for the purpose of reaching a convergence among the set of answers which is involved in a successive repetition of this process.

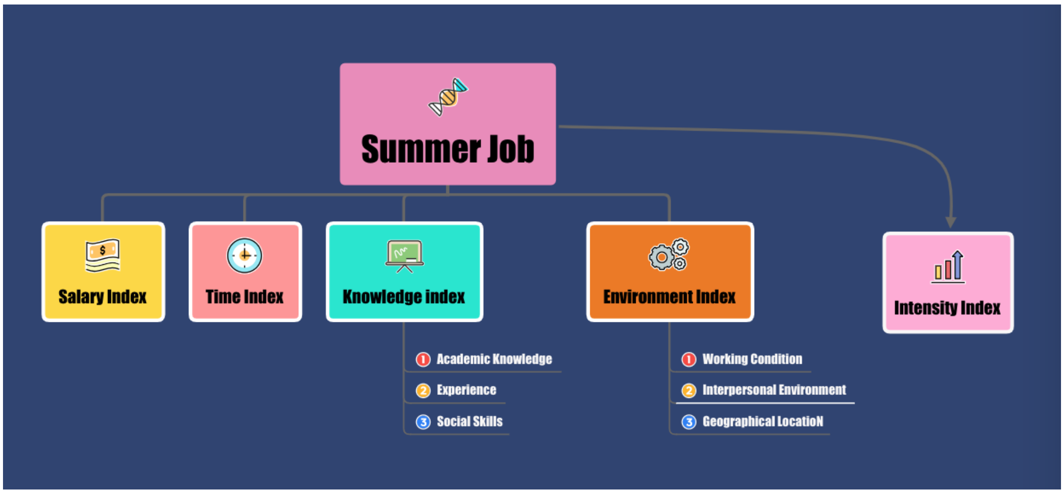


Figure 7.2: Hierarchical Structure

Our second step is to use the score of importance table proposed by Saaty and Formula 6.1 to make a pair comparison. We need to judge the consistency of the judgment matrix. The judgment matrix has the following properties:

$$a_{ij} = \frac{1}{a_{ji}} \tag{7.11}$$

$$Aw = \lambda_{\max} w, \lambda_{\max} \geqslant n \tag{7.12}$$

$$\lambda_{\max} = \frac{\sum a_j w_j - n}{w_1} \tag{7.13}$$

Then, these three formulas given above are used to transform the raw data into meaningful values.

Table 7.1 presents the importance of scale ranging from one to nine and the corresponding level of importance. The scaling method for judging matrix elements is as follows:

Numerical Scale	The Level of Importance
1	Equal Importance
2	Equal to Moderate Importance
3	Moderate Importance
4	Moderate to Strong Importance
5	Strong Importance
6	Strong to Very Strong Importance
7	Very Strong Importance
8	Very Strong to Extreme Importance
9	Extreme Importance

Table 7.1: Scores for the Importance of Variable

The consistency index is defined as:

$$CI = \frac{\lambda - n}{n - 1} \tag{7.14}$$

Our next step is to calculate the consistency ratio (CR) in order to confirm the results from the AHP. The formula is shown below:

$$CR = \frac{CI}{RI} \tag{7.15}$$

To measure the of CI, the random consistency index RI is introduced:

$$RI = \frac{CI_1 + C_2 + \ldots + CI_n}{n} \tag{7.16}$$

The value of RI is influenced by the dimension of the matrix, as shown in Table 7.2.

n	1	2	3	4	5	6	7	8	9	10	11
RI-Value	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

Table 7.2: The RI Value

8 Systematic Cluster Analysis

Systematic Cluster Analysis refers to algorithms that divide similar objects into groups called clusters. The endpoint of cluster analysis is a set of clusters, where each cluster differs from each other cluster, and the objects within each cluster are broadly similar to each other.

The principle of Systematic Cluster Analysis:

Based on a sample of multiple observation index and specific similarity between samples, we can find out some measures or indicators of statistics. With these statistics as a basis for the partition type or group, some samples with high similarity (index) are classified, and then these clusters are merged step by step to a larger category until all the samples polymerization is completed. This method is the most common and basic one, which is called Systematic Cluster Analysis.

Steps of Systematic Clustering Analysis:

Systematic Clustering Analysis is to gradually combine individuals into some subsets until the whole population is in a set. Variables or samples with numerical characteristics can be classified by this method. Set $\Omega = \{w_1, w_2, \cdots, w_7\}$

Step 1. Calculate the distance between n pairs of sample points $\{d_{ij}\}$, and remember to matrix $D = (d_{ij})_{n\times n}$. This process is done by the following formula:

$$|AB| = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + \cdots + (w_1 - w_2)^2} \tag{8.1}$$

Step 2. Construct n classes, each class contains only one sample point, and the platform height of each class is zero.

Step 3. The two closest classes are merged as new classes, and the distance value between the two classes is used as the platform height in the cluster diagram.

Step 4. Calculate the distance between the new class and the current class. If the number of classes is already equal to 1, go to step 5; otherwise, go back to step 3.

Step 5. Draw a cluster diagram.

Step 6. Determine the number and class of classes.

9 The Model Results

In this part, we will explain how our model works for a typical student to whom knowledge is the most important, and we will show how our model fits the preference and the special needs of the student.

First, we get the characteristics and information of employees from the survey we give to them and from the setting in their profiles. After we have the information we need for our model, we construct a special judgment matrix for each employee. Below is a typical judgment matrix of a student whose judgment ranking is **knowledge > salary > time > experience**, which means that this student wants a job which can give out more knowledge (knowledge inclined). The scales we set in the matrices obey the following rules:

1) All the scales are used to compare the degree of importance between two things. For example, if a student thinks salary is better than the environment he works in, the scale will be: $a_{SE} > 1$.

2) All the scales considering our indexes can be divided into 9 degrees.

3) We all use positive integer scales. And when two indexes are compared, the latter might be better than the former, a fraction occurs. In case the reciprocal of the fraction can also be an integer, the format of the fractional scale should be:

$$a_{ij} = \frac{1}{n}, n \in N^* \tag{9.1}$$

Thus, the final judgment matrix of this student will be:

$$[a_{ij}] = \begin{bmatrix} 1 & 2 & \frac{1}{2} & 4 & 4 \\ \frac{1}{2} & 1 & \frac{1}{4} & 3 & 3 \\ 2 & 4 & 1 & 5 & 5 \\ \frac{1}{4} & \frac{1}{3} & \frac{1}{5} & 1 & 1 \\ \frac{1}{4} & \frac{1}{3} & \frac{1}{5} & 1 & 1 \end{bmatrix} \tag{9.2}$$

Then we calculate the eigenvector of the matrix, which is [0.262, 0.158, 0.446, 0.067, 0.067], indicating a larger weighting for knowledge index than for salary and time index.

After that, we calculate each job's time index and salary index by the information of both the job and the employee. The employee should give his available time schedule, his home location, and the time he wants to spend on the job. We measure the preference variables for recreational time using the time he can spend. We will then ask him the priority of the factors inside the knowledge index, including academic knowledge, experience, and social skills, to construct a new judgment matrix for his knowledge index:

$$[K_{ij}] = \begin{bmatrix} 1 & 3 & 3 \\ 1/3 & 1 & 1 \\ 1/3 & 1 & 1 \end{bmatrix} \tag{9.3}$$

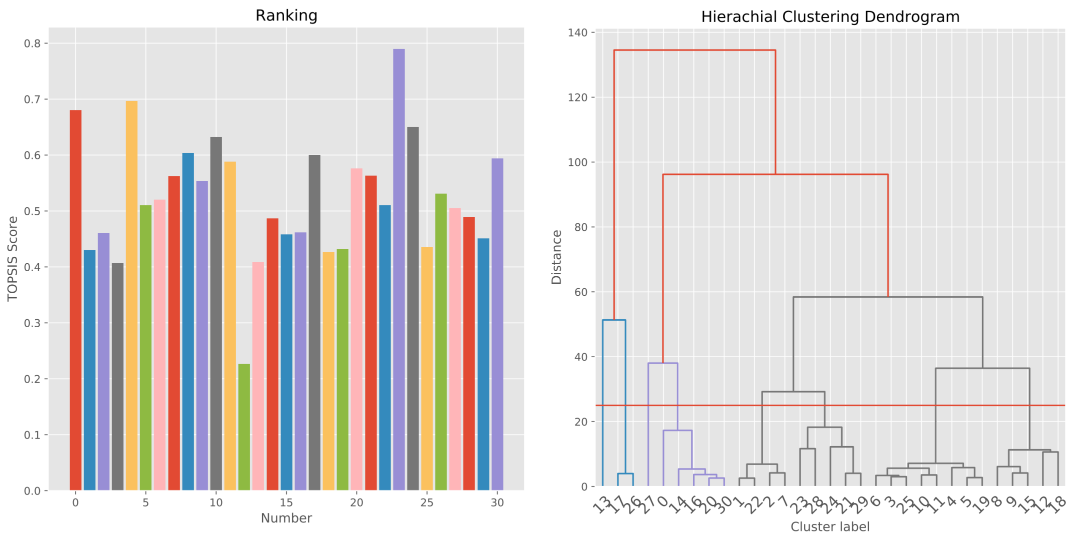
The eigenvector of this matrix is $[0.6, 0.2, 0.2]$. Since eigenvector can be used as the weighting, the result means that the student prioritizes the gain of academic knowledge and places the same value on the gain of experience and social skills. Additionally, if the employee thinks the job we recommend to him fit his need for knowledge, the conformity variable will be 1, otherwise it will be 0. Here we assume that the student wants knowledge about science.

Since the student doesn't care about the environment index compared with other indexes, we simply give the same weighting to the factors under the environment index:

$$[E_{ij}] = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \tag{9.4}$$

which indicates a weighting of [0.333,0.333,0.333]. After transforming the characteristics of the student into the preference variables, judgment matrices, and conformity variable, we can calculate all the five indexes of each job and rank all the jobs through TOPSIS. After we get the ranking, we will do cluster analysis and give the student the best job in each group in terms of the score in TOPSIS ranking.

After calculation, we have the top 3 ranking: cybersecurity teaching, entry level behavior techs, and chemistry lab assistant. Cybersecurity teaching has the highest salary per hour in our jobs data and a high knowledge gain of 4. Both entry level behavior techs and chemistry lab assistant have the highest knowledge gain of 5, which is consistent with our expectation.



(a) Score (b) Cluster

Figure 9.1: The Job Scoring and Clustering for 10^{th} Fictional Person

For the 10^{th} fictional person, he is knowledge inclined. The bar chart results from processing the data gained by TOPSIS. From the graph, we can see that the TOPSIS Score is high for the number 23, 4, 0, etc. This is because this fictional person is knowledge inclined, leading to a result that jobs that have higher knowledge index will have a higher TOPSIS score.

Graph (b) was done with Hierarchical Cluster Analysis. Jobs are divided into 8 groups when the height was 25. For the diversity of the results, the results will be selected first from the eight different groupings of Graph (b).

According to the figures above, we will finally recommend the employee the jobs with the serial number of 0, 4, 7, 8, 13, 17, 23, 27 at first, leaving other jobs below those typical jobs. The jobs we recommend here include the top 3 jobs mentioned above. We also want to find why the job with a serial number of 12 is so low. After checking its information, we find out that it is a job that requires working for 24 hours and has the lowest salary per hour, also with a medium gain of knowledge. Since the student's weighting for salary is also high, it's reasonable that the medium knowledge index can't compensate for the low salary and time index.

The index result shows the five indexes of the jobs we recommend to the student. It can be seen that all the knowledge indexes of the jobs are high, and the lowest one has a very high time index to compensate its weakness. Besides, the diversity of our recommendation is high.

After using our algorithm for the knowledge-inclined student as an example, we create other nine fictional persons, with each representing a unique characteristic. Here are ten fictional persons that we have created:

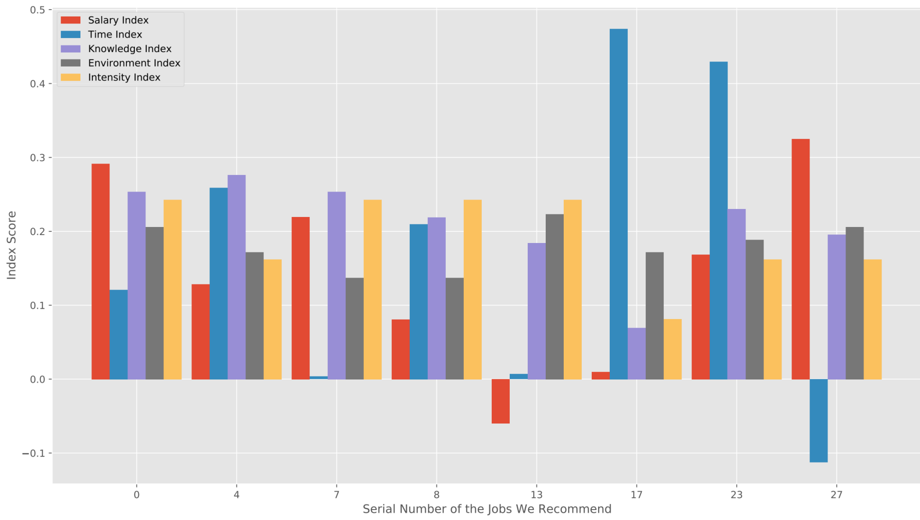


Figure 9.2: Index Result

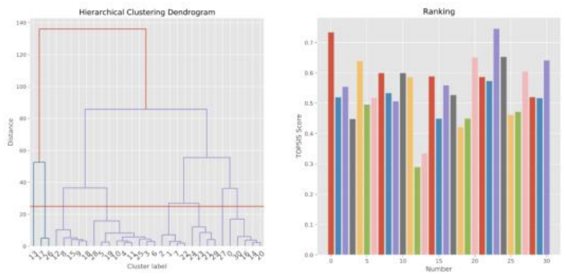
Fictional Persons	According Inclinations
1^{st} person	More money (Salary inclined)
2^{nd} person	Little conflicted time (time inclined)
3^{rd} person	Better geographical location for transportation (environment inclined)
4^{th} person	More recreational time (time inclined)
5^{th} person	Better working condition (environment inclined)
6^{th} person	More meaningful experience (knowledge inclined)
7^{th} person	Better social skills (knowledge inclined)
8^{th} person	Great friendships with workmates(environment inclined)
9^{th} person	Less intensity (intensity inclined)
10^{th} person	Wants to learn more knowledge (knowledge inclined)

Table 9.1: Ten Fictional Persons and Their Inclinations

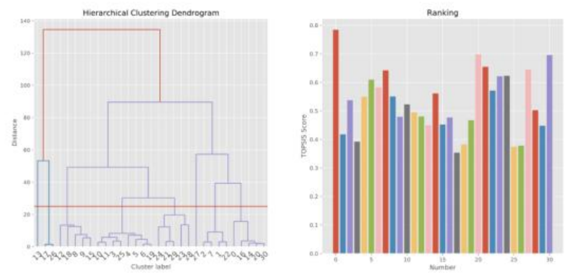
Next, we set our scales according to these ten persons' distinct characteristics or inclinations. We use our judgment matrices (see in 8.1, 8.2, and 8.3) to calculate the weighting of indexes.

Finally, we put the weighting into the TOPSIS system to rank the jobs. The ranking will still be displayed through bar charts and the cluster analysis to help the students to recognize diverse jobs that are also suitable for them. All the calculations and algorithms follow our example shown in **9 The Model Results**.

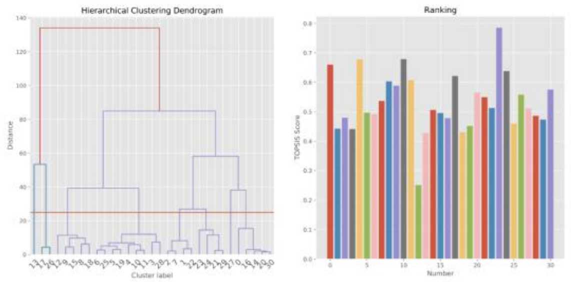
Here are our ten fictional persons' rankings and their suitable jobs:



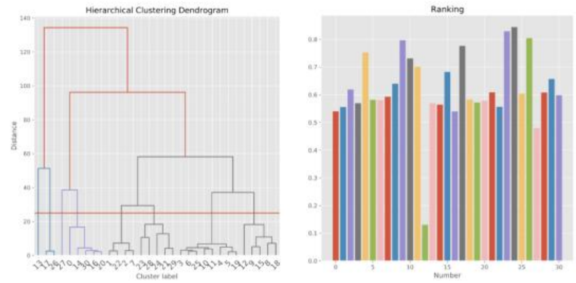
Person 1



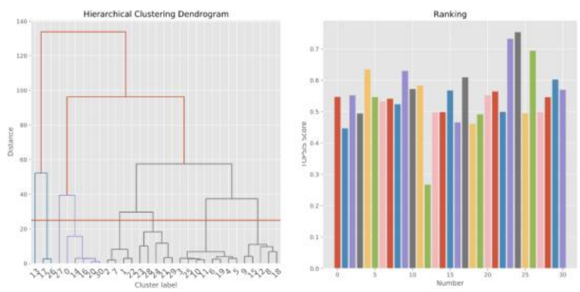
Person 2



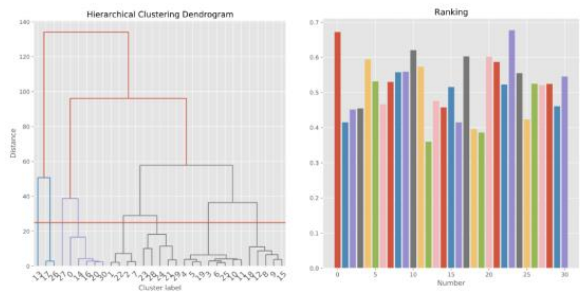
Person 3



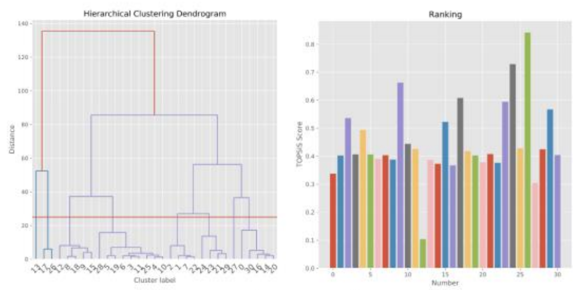
Person 4



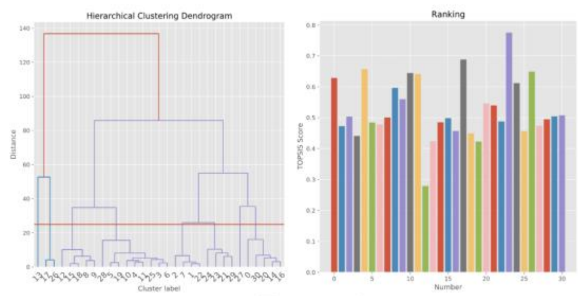
Person 5



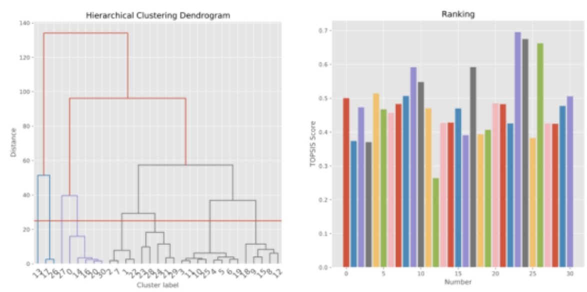
Person 6



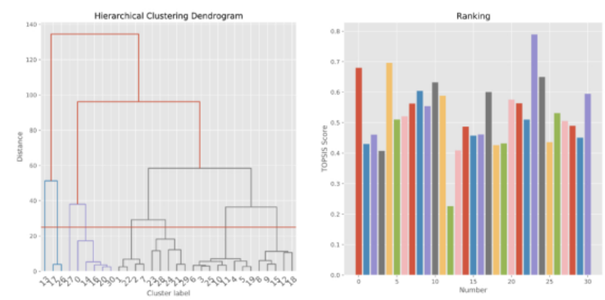
Person 7



Person 8



Person 9



Person 10

From these 10 bar charts, we can conclude that job 23 in the bar chart is often the job with the highest score, which means that this job is often the best job for other people. The other jobs, such as jobs 24, 0, 4, also have very high scores. Jobs 23, 24, 0, 4 matches cybersecurity teaching assistant (1), cybersecurity teaching assistant (2), chemistry lab assistant, and entry level behavior techs accordingly.

Below is the job recommendation chart for our 10 fictional persons:

Fictional Persons	**Top 3 Best Jobs that Fits them**
1^{st} person	Cybersecurity Teaching Assistant (1) Chemistry lab assistant Player Behavior Sr Analyst
2^{nd} person	Chemistry lab assistant Player Behavior Sr Analyst Paralegal/Legal Assistant
3^{rd} person	Cybersecurity Teaching Assistant (1) WAITER/WAITRESS (PART-TIME) Entry Level Behavior Techs & RBTs - Work 1:1 with Children
4^{th} person	Cybersecurity Teaching Assistant (2) Cybersecurity Teaching Assistant (1) Sanitation Worker
5^{th} person	Cybersecurity Teaching Assistant (2) Cybersecurity Teaching Assistant (1) Sanitation Worker
6^{th} person	Chemistry lab assistant Cybersecurity Teaching Assistant (1) WAITER/WAITRESS (PART-TIME)
7^{th} person	Sanitation Worker Cybersecurity Teaching Assistant (2) WAITER/WAITRESS (PART-TIME)
8^{th} person	Cybersecurity Teaching Assistant (1) Kitchen Design and Sales Entry Level Behavior Techs & RBTs - Work 1:1 with Children
9^{th} person	Cybersecurity Teaching Assistant (1) Cybersecurity Teaching Assistant (2) Sanitation Worker
10^{th} person	Cybersecurity Teaching Assistant (1) Entry Level Behavior Techs & RBTs - Work 1:1 with Children Chemistry lab assistant

Table 9.2: The Job Recommendation for 10 Fictional Persons

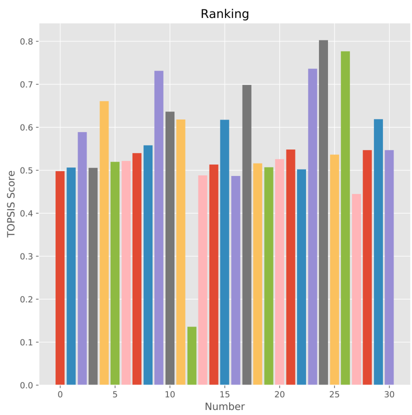
The main reason why such jobs as the cybersecurity teaching assistant, chemistry lab assistant, entry level behavior techs are usually the best jobs for different people of different characteristics is that their indexes are very perfect. For example, both jobs of the cybersecurity teaching assistant have 0% of the probability of overtime. Besides, these jobs have high salary per hour and relatively low work time, in addition to high gain of knowledge. Of course, some of these jobs require specific experiences or knowledge to be done(eg. jobs in cybersecurity and chemistry field), but it's normal and necessary for these jobs to set some standards and thresholds.

10 Sensitivity Analysis

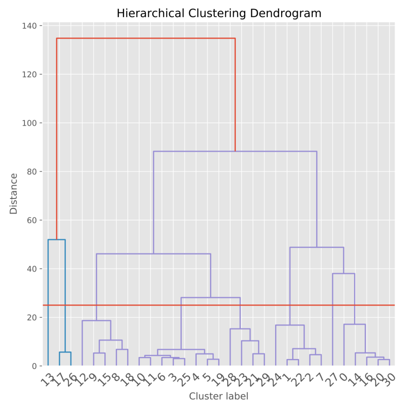
Here we will use the example above to test the sensitivity of our model. We change the student's characteristics into those of a student who wants to have more recreational time and whose judgment ranking is **time > salary > knowledge > experience**. Therefore, he will have larger preference variables and his judgment matrix should be like this:

$$[a_{ij}] = \begin{bmatrix} 1 & \frac{1}{3} & 2 & 3 & 2 \\ 3 & 1 & 4 & 5 & 4 \\ \frac{1}{2} & \frac{1}{4} & 1 & 2 & 1 \\ \frac{1}{3} & \frac{1}{5} & \frac{1}{2} & 1 & \frac{1}{2} \\ \frac{1}{2} & \frac{1}{4} & 1 & 2 & 1 \end{bmatrix} \tag{10.1}$$

Here, the eigenvector is $[0.209, 0.480, 0.120, 0.071, 0.120]$, showing a higher weighting for time index than others. Then, we use the same setting as the example above except this judgment matrix to decide the jobs we will recommend for this student. Here is the result:



(a) Score



(b) Cluster

Figure 10.1: Results of sensitivity test

The top 3 jobs are cybersecurity teaching, sanitation worker, and waiter at compass group. All these jobs have work hours no more than 4 hours, which fits our employee's characteristics. We will finally recommend the job with serial numbers of 4, 8, 13, 23, 24, 26, 27, 30, which is significantly different from the jobs we recommend to the student who is knowledge inclined.

The index result shows the five indexes of the jobs we recommend to the student. It can be seen that most time indexes of the jobs are high. and those with a low time index have a high salary index except the job with the serial number of 13. The reason why it is recommended is to ensure the diversity of our recommendation.

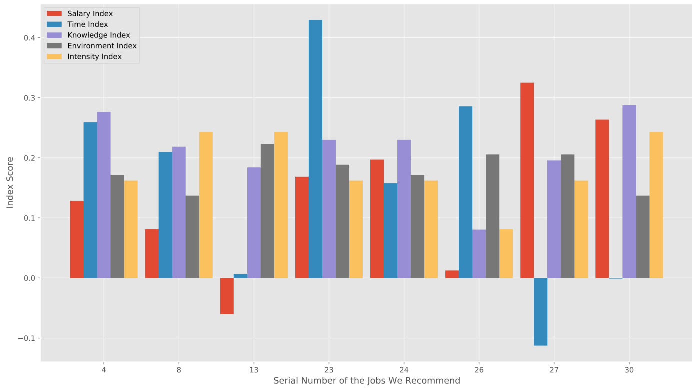
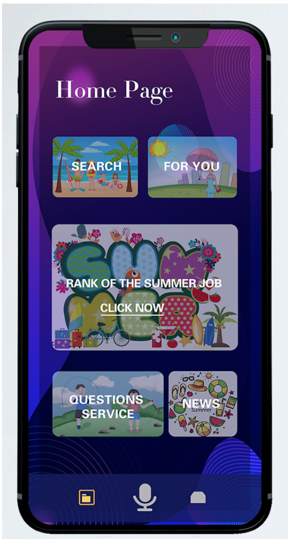
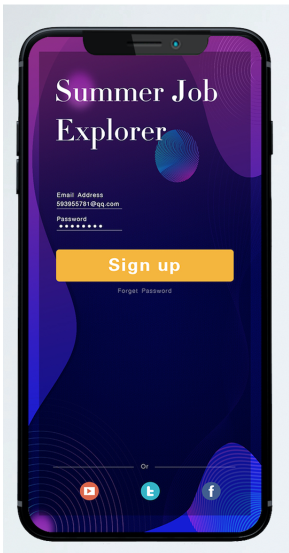


Figure 10.2: Index Result

11 User Experience



(a) Home Page



(b) Log-in Page

Figure 11.1: APP page 1 and 2

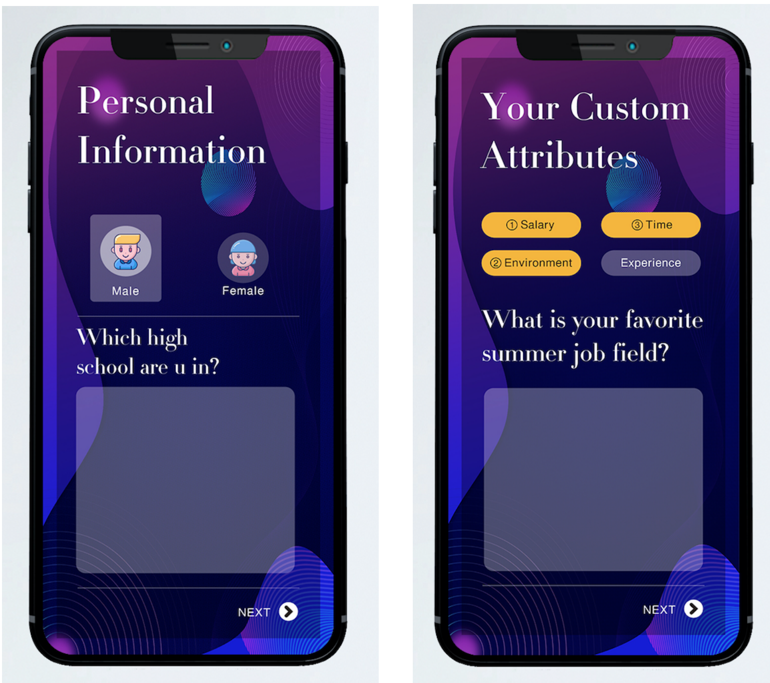
Homepage

The home page is the fundamental part of the app because it will allow customers to gain direct access to five subjects: searching for summer jobs, personal information, the ranking of summer jobs suitable for them, asking questions, and news about summer jobs. The element “Search” allows customers to gain information about all kinds of summer jobs for high school students based on the tags they select. On the left side, the “Personal Information” part will allow people to update their personal information, and the ranking and news will be changed according to the changes of information. The "Ranking" part below will give a list of summer jobs based on the customers’ information, such as what quality of the job they mainly focus on, which is evaluated by our algorithm. Customers can ask questions by clicking the "Questions

Service" part, posting questions on the forum, or contact customer service. For the last part, the "News" will send articles or advertisements related to the customers' interested field.

2 Log-in

The "Log-in" page requires customers to provide their email account and set up their password. Customers can use the email address used frequently and set up the password based on their own will. This will decrease the possibility of losing their own account because they can use their emails to find their password back if they forget their password.



(a) Personal Information (b) Personal Custom Attributes

Figure 11.2: APP page 3 and 4

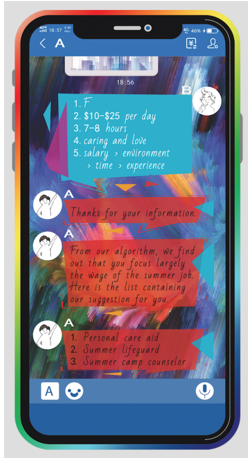
3 Personal Information

After finishing creating their own accounts on the "Log-in" page, customers will need to fill in their personal information. This will not cost them too much time, since all they need to fill in are their gender and the schools they are in. Of course, for the sake of protecting personal privacy, we will only use this information for running the app. And customers have the right to choose not to tell us about their schools and gender, but this will result in a less targeted list of summer jobs.

4 Personal Custom Attributes

Finally, customers would have to select the things that they focus on for their summer jobs. They will select the three factors they pay attention to out of the four. It should be noticed that the "time" tag includes both the intensity of the job, reflected by the frequency or period of the job and also the time people need to spend in the job. After customers finish this page and submit the answer, we are able to use this to offer them a list of summer jobs in the "Ranking" part and send or post news related to their interested field in the "News" section.

(a) Page 01



(b) Page 02

Figure 11.3: Customer Service: Clerk A and Customer B

5 Customer Service

This is the "Question Service" section. Customers will have to reconfirm and further develop their own information that they have already fill in the "Personal Information" section. The clerk will give the customers a summer job survey, and what the customer needs to do is to type these answers in the chat-box. The "Summer Job Survey" is the following image:

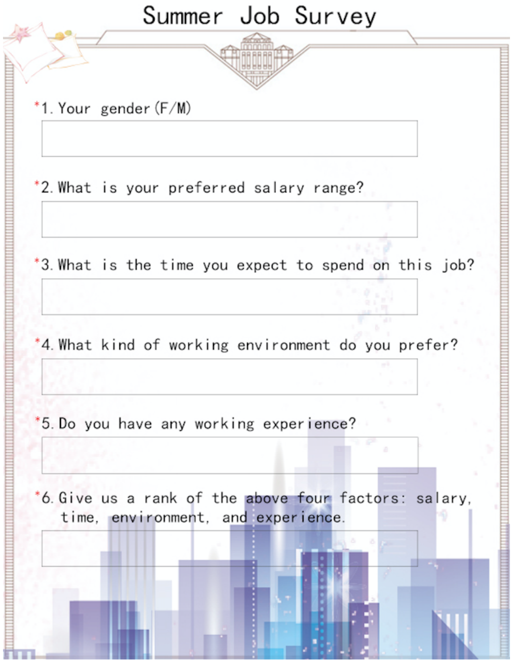


Figure 11.4: Summer Job Survey

12 Strengths and Weaknesses

12.1 Strengths

• The sensitivity of our model is tested to ensure its stability and credibility. Besides, the high sensitivity of our model guarantees that the summer jobs we recommend are based on the employees' own situation and preferences

• We build a model which is objective and comprehensive enough to give practical suggestions on summer jobs for high school students. We consider all important factors influencing the choice of summer jobs of a student.

• We design delicate and readable interfaces for our apps and give them clearly divided functions. The artistic style of our app will give our customers a pleasant view while using our app.

• Our results correspond to our model well. The results we get to match all fictional persons' inclinations. The relevant jobs are also recommended by our designed application perfectly.

12.2 Weaknesses

• Our ranking list might own higher accuracy if more data is collected and used and if our qualitative analysis is done by experts.

• Our app is not capable of exhibiting all the functions that we design due to consideration of usability and a limited amount of time. If we are given more time, the app would definitely be an excellent summer job finder for high school students.

• Having to type the answer to the "Summer Job Survey" in the chat-box may be inconvenient for customers. Given more time, we would further develop this app to solve this problem.

References

[1] Education Issue: THE VALUE OF A SUMMER JOB; SAY Magazine. 2016.

[2] Why You Should Consider a Temporary Summer Job; Kaila Prins. 2019.

[3] Enriching Summer Work: An Evaluation of the Summer Career Exploration Program Enriching Summer Work; Wendy S. McClanahan, Cynthia L. Sipe, Thomas J. Smith. 2004.

[4] What is the Analytic Hierarchy Process?; Saaty T.L. 1988.

[5] How to make a decision: The Analytic Hierarchy Process;European Journal of Operational Research 48 (1990) 9-26 9North-Holland. Thomas L. Saaty. 1990.

[6] The analytic hierarchy process—what it is and how it is used; Mathematical Modelling Volume 9, Issues 3–5, Pages 161-176. A.R. Banai-Kashani. 1987.

[7] The analytic hierarchy process applied to maintenance strategy selection; Reliability Engineering and System Safety, Volume 70, Issue 1, Pages 71-83. Yuan-Shun Way, Der-Yu Hsia. 2000.

[8] Complementary Judgment Matrix Method with Imprecise Information for Multicriteria Decision-Making; Mathematical Problems in Engineeri; Article ID 3695627, 11 pages. Haichao Wang, Risto Lahdelma, Pekka Salminen. 2018.

[9] An Alternative Measure of Consistency. In: B. L. Golden, A. Wasil and P.T. Harker (eds.); Analytic Hierarchy Process: Applications and Studies, 68-81, New-York: Springer Verlag. Golden, B. L. and Wang, Q. 1990.

[10] Chapter 8: Cluster Analysis: Basic Concepts and Algorithms; Chapter 8: Cluster Analysis: Basic Concepts and Algorithms,Tan, Steinbach, Kumar, S. Parthasarathy. 2014. Introduction to Data Mining by

Appendices

Appendix A Fictional Job Data

ID	Name	Salary	Start	End	rho	T	S	meal	Home
1	Chemistry lab assistant	152	15	23	85%	4	25	1	0
2	Decorate worker	180	8	18	10%	2.75	20	1	0
3	Beverage Stocker at Keurig Dr Pepper Inc.	180	6	15	50%	1	22	1	0
4	Store Associate - Collection Seattle at EXPRESS	143	8	18	5%	0.5	18	0	0
5	Entry Level Behavior Techs & RBTs - Work 1:1 with Children at Gateway Learning Group	125	14	19	0%	0	0	1	0
6	Summer Intern, Technical Program Manager at Pandora	130	8	18	20%	1	16	0	0
7	Research Intern, Novi Economics (PhD) at Facebook	125	9	18	40%	2.5	15	0	0
8	Intern - Financial Analyst at First Republic Bank	200	9	18.5	10%	1.5	25	0	0
9	News - News Anchor/Sports Reporter - WAGM at Gray Television	100	15	23	10%	0.5	15	0	0
10	WAITER/WAITRESS (PART-TIME) at Compass Group	90	10.5	14.5	10%	0.5	25	1	0
11	WAITER/WAITRESS (PART-TIME) at Compass Group	125	15.5	21	10%	0.5	25	1	0
12	Retail Sales Associate Part Time at Tailoredbrands	123	14	20	15%	1.5	22	1	0
13	Sr. Technical Writer (Remote) at CrowdStrike	100	0	24	0%	0	0	0	1
14	News Reporter at Fox Sports	0	9	18.5	20%	1	0	0	0
15	In -Store Promoter (Columbia, SC) at ARS	190	9	18	60%	2.5	22	1	0
16	Warehouse Photo Assistant at Bluecrew	100	9	16	20%	2	20	0	0
17	Supermarket Shopper & Delivery at Shipt	220	8	19	0%	0	22	1	0
18	Dish washer	50	19	21	10%	0.25	30	0	0
19	Sales Associate - Serramonte - 791 at PSEB	100	9	18	20%	0.75	15	0	0
20	Customer Service at Colgate	120	8	18	10%	1.25	20	1	0
21	Player Behavior Sr Analyst at Sony Interactive Entertainment PlayStation	200	10	19	40%	3.25	25	0	1
22	Visual Designer at FitBit	150	9.5	18	40%	2.5	20	0	1
23	Kitchen Design and Sales at John Michael Kitchens	162	9	18	50%	3.25	22	0	0
24	Cybersecurity Teaching Assistant at Fullstack Academy	155	18.5	21.5	0%	0	0	1	0
25	Cybersecurity Teaching Assistant at Fullstack Academy	170	9	13	0%	0	0	1	0
26	Massage Therapist Careers - Albany, NY Area at Massage Envy	140	9	18	5%	0.25	18	0	0
27	Sanitation Worker at Ajinomoto Windsor	50	5	7	10%	1	32	0	0
28	State Tested Nursing Assistant at Atrium Centers Inc.	220	8	20	30%	3.75	26	2	0
29	Preschool Teacher's Assistant at My Little Learning Tree	150	9	18	15%	1.25	20	0	0
30	Assembler at APR Consulting, Inc.	145	6	14.5	0%	0	0	2	0
31	Paralegal/Legal Assistant at Robert A. Flaster, P.C.	215	9	18	40%	2	26	0	0

ID	Name	Intensity	X	Y	Working Condition	Interpersonal Environment	Geographical Location	Academic Knowledge	Experience	SocialSkills
1	Chemistry lab assistant	3	-122.4275473	37.77438749	5	4	3	5	5	2
2	Decorate worker	1	-122.4531583	37.7194976	1	4	3	1	4	2
3	Beverage Stocker at Keurig Dr Pepper Inc.	2	-122.4463303	37.75788165	3	4	2	1	3	3
4	Store Associate - Collection Seattle at EXPRESS	1	-122.4011524	37.73836283	4	3	4	1	2	3
5	Entry Level Behavior Techs & RBTs - Work 1:1 with Children at Gateway Learning Group	2	-122.4595646	37.72469269	4	2	4	5	5	4
6	Summer Intern, Technical Program Manager at Pandora	3	-122.4136846	37.77779846	5	3	5	5	5	4
7	Research Intern, Novi Economics (PhD) at Facebook	3	-122.4332476	37.78561848	5	3	3	5	4	3
8	Intern - Financial Analyst at First Republic Bank	3	-122.384724	37.72675689	4	3	1	5	5	2
9	News - News Anchor/Sports Reporter - WAGM at Gray Television	3	-122.4185061	37.80453468	3	3	2	3	5	5
10	WAITER/WAITRESS (PART-TIME) at Compass Group	2	-122.4084121	37.79626356	2	2	3	1	3	5
11	WAITER/WAITRESS (PART-TIME) at Compass Group	2	-122.4020713	37.76030499	2	2	3	1	3	5
12	Retail Sales Associate Part Time at Tailoredbrands	2	-122.4098928	37.7801135	3	4	5	2	4	1
13	Sr. Technical Writer (Remote) at CrowdStrike	3	-122.4042702	37.78447885	4	5	5	3	1	1
14	News Reporter at Fox Sports	3	-122.4143122	37.77983392	5	3	5	3	3	4
15	In -Store Promoter (Columbia, SC) at ARS	2	-122.4233824	37.7875809	3	3	3	1	4	3
16	Warehouse Photo Assistant at Bluecrew	2	-122.4109284	37.78367787	3	3	5	1	3	3
17	Supermarket Shopper & Delivery at Shipt	1	-122.4242961	37.76557148	2	2	4	1	4	4
18	Dish washer	1	-122.4095299	37.76571844	1	5	4	1	2	1
19	Sales Associate - Serramonte - 791 at PSEB	2	-122.5078846	37.74815613	3	3	1	2	1	4
20	Customer Service at Colgate	2	-122.3923498	37.79264509	4	1	4	2	1	5
21	Player Behavior Sr Analyst at Sony Interactive Entertainment PlayStation	3	-122.4420387	37.80013628	4	5	2	4	3	2
22	Visual Designer at FitBit	3	-122.4181615	37.7777436	4	4	5	5	3	2
23	Kitchen Design and Sales at John Michael Kitchens	2	-122.4615254	37.75150257	3	3	4	3	2	4
24	Cybersecurity Teaching Assistant at Fullstack Academy	2	-122.4783167	37.72997849	4	2	5	4	4	4
25	Cybersecurity Teaching Assistant at Fullstack Academy	2	-122.4245824	37.76854434	4	2	4	4	4	4
26	Massage Therapist Careers - Albany, NY Area at Massage Envy	1	-122.3924532	37.78389388	3	3	4	1	5	3
27	Sanitation Worker at Ajinomoto Windsor	1	-122.4226345	37.74227943	3	4	5	1	3	1
28	State Tested Nursing Assistant at Atrium Centers Inc.	2	-122.3939837	37.79506077	4	3	5	3	4	4
29	Preschool Teacher's Assistant at My Little Learning Tree	2	-122.4209419	37.78759616	5	4	3	3	2	1
30	Assembler at APR Consulting, Inc.	1	-122.4158851	37.78351606	5	4	4	1	4	2
31	Paralegal/Legal Assistant at Robert A. Flaster, P.C.	3	-122.378268	37.73238073	5	2	1	5	5	5