Czech University of Life Sciences Prague

Faculty of Economics and Management

Department of Economics

Bachelor Thesis

Traveling around Europe by self-driving

Author: Chi Ya Qian
Supervisor: Ing. Robert Hlavatý, Ph.D.

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BACHELOR THESIS ASSIGNMENT

Yaqian Chi

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Thesis title

Traveling around Europe by self-driving

Objectives of thesis

The purpose of the bachelor thesis is to design an op mal and high-quality travel route for travelling self-driving enthusiasts through quantitative methods for selected locations. The initial place of tourist routes is the Wenceslas Square in Prague and after visit all scenic spot which has to go then will finish in the final location Disneyland of Paris. The final destination is not considered the same as the initial location.

Methodology

The theoretical part of the bachelor thesis will study on self-driving tour, the concept and connotation of self-driving tour, various structural models of European tourist routes, and the principles of tourist route design. We will discuss and analyze the Vogel's approximation algorithm, the savings algorithm and the nearest neighbor algorithm by the qualitative method. The practical part of the bachelor thesis will be the calculation of solutions from these methods. Then compare and analyze these calculations to get the op mal solu ons for those travel self-driving enthusiasts.

The proposed extent of the thesis

30-40

Keywords

travelling salesman, routing problem, driving

Recommended information sources

Lis P. Tussyadiah, Tatsuhito Kono, Hisa Morisugi, 'A Model of Multidestination Travel: Implications for Marketing Strategies'. Journal of travel research, Vol.44, No.4, pp407-416. 2006.
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Y. Zheng, L. Zhang, X. Xie, and W. Ma. 'Mining Interesting Locations and Travel Sequences from GPS Trajectories.

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The Bachelor Thesis Supervisor
Ing. Robert Hlavatý, Ph.D.

Supervising department
Department of Systems Engineering

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doc. Ing. Tomáš Šubrt, Ph.D.

Head of department

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Ing. Mar n Pelikán, Ph.D.

Dean

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Declaration

I declare that I have worked on my bachelor thesis titled "Traveling around Europe by self-driving" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break copyrights of any their person.

In Prague on 03.11.2020 ______________________________

Acknowledgment

Time passed quickly and I was afraid that time would turn around because once it did so, I would say goodbye to the university for three years.

I vividly remember that three years ago, as a foreign student, I came to this strange country and strange school for the first time with my curiosity and expectation. For the language barrier and strange environment, I thought everything would be lonely, but everything seems to be the opposite. This beautiful school not only brings me a good learning environment and students from different countries but also assigns many good teachers. They are friendly, open, and helpful. They respect me and bring me unprecedented warmth; I am very grateful to meet this school.

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Traveling around Europe by self-driving

Abstract

With the rapid development of tourism, travel enthusiasts are no longer satisfied with the general, rigid, and urgent travel routes planned by travel agencies, and self-driving travel gradually becomes people's preferred way of travel. In a foreign country, travel by self-driving is the best way to blend in with the local culture and scenery. If you stop to take a picture when you see good scenery, you can change the travel route at any time with an idea. However, if you are unfamiliar with a foreign country, how to arrange the route is safer and more reasonable? Therefore, the purpose of this bachelor thesis is to assume that I am a travel self-driving enthusiast and choose the 60 most popular scenic spots in four European countries. I will choose location through quantitative methods to design an optimized and high-quality travel route for us, the travel enthusiasts, so as to reduce the number of trips. This thesis is divided into two parts. The theoretical part will refer to the concept of self-driving travel and the research status of world scholars on self-driving travel. More important are the principles of tour route design, TSP problem, and the understanding of the selection of quantitative methods. The practical part will introduce the results of the nearest neighbor algorithm, the Vogel approximation algorithm, and lastly saving algorithm calculated by the program. All the results and the optimal results will be presented in numbers and tables and analyzed one by one.

Keywords: self-driving tour, design of tourism route, the optimal route, quantitative method

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1 Introduction

Due to the increasing pressure of people's work and life, it has become a popular way of leisure to travel during short and long vacations. And tourism is booming, becoming the world's third-largest industry. Judging from the growth trend of international tourism in the past decade, European countries have performed strongly. Tourism accounts for more than 13% of the GDP of European countries and is the largest service industry in Europe. Historical ancient city Rome, fashion capital Milan, European millionaire city Zurich, and other places are all with unique charm. Europe's tourism resources are too rich, and everyone has different preferences, so Europe has become people's first choice of tourist destination.

With the progress of the social economy and the improvement of living standards, the traditional group tour can no longer satisfy people's pursuit of freedom and relaxation in tourism. Therefore, the diversified and differentiated self-driving tour is favored by consumers. In a foreign country, a road trip is the best way to blend in with the local culture and scenery. If you stop to take a picture when you see a good scenery, you can change the route at any time with an idea. However, if you are unfamiliar with a foreign country, how to arrange the route is safer and more reasonable? Therefore, the purpose of this thesis is to design an optimized and high-quality travel route for travel driving enthusiasts through quantitative methods.

Firstly, this paper aims to satisfy the tourist's desire to travel to Europe as much as possible, so that they can get the best sightseeing effect. Secondly, it is convenient for the organization and management of tourism activities. Thirty is convenient for tourists to choose destinations, arrange their own travel activities, avoid aimless travel; Fourth, it is beneficial to give play to the functions of various tourist spots and tourists to make reasonable use of time. The design of tourist routes are extremely important.

2 Objectives and Methodology

2.1 Objectives

The purpose of my bachelor thesis is to design an optimized and high-quality travel route for those travel self-driving enthusiasts through quantitative methods to select locations. The initial place of tourist routes is the Wenceslas Square in Prague and after visit all scenic spot which has to go then will finish in the final location Disneyland of Paris. The final destination is not considered the same as the initial location.

2.2 Methodology

The theoretical part of the bachelor thesis will study on self-driving tour, the concept and connotation of self-driving tour, the research status of world scholars on self-driving travel, and the principles of tourist route design. We will discuss and analyze the Vogel's approximation algorithm, lastly the savings algorithm and the nearest neighbor algorithm by the qualitative method. The practical part of the bachelor thesis will be the calculation of solutions from these methods by TSPKOSA program. Then compare and analyze these calculations to get the optimal solutions for those travel self-driving enthusiasts.

3 Theoretical part of self-driving tour

3.1 The concept of self-driving tour

As the name suggests, “self-driving tour” means driving by yourself. The first China Summit forum in 2006 defined a self-driving tour as a form of tourism that is organized, planned, and self-driving as the main means of transportation. Self-driving tour is a new form of tourism that is different from the traditional group travel. It provides consumers with free space to play. Consumers can arrange their trips according to their time, energy, financial resources, and other characteristics. The self-driving tour first emerged in the middle of the 20^{th} century in the United States, and the automobile industry at that time also developed rapidly. The development of the automobile industry not only promotes the development of tourism but also continuously improves the infrastructure of tourism and the economic level of people. The self-driving tour meets the needs of consumers’ diversified and personalized travel experience, greatly stimulates the overall economic growth of the tourism market.

3.2 Research status of tourist routes

Since the late 1960s, many scholars have explored various structural models of tourist routes from the perspective of space.

3.2.1 Campbell model

Campbell believed that when tourists from a central city had multiple destinations, the tourist routes formed by tourists tended to have a closed circuit. According to the difference of destination type, the model of recreation and holiday travel in the wandering road is described.[9]

3.2.2 Stewart and Vogt's multi-destination travel model

Stewart and Vogt constructed 5 types of travel route models based on the conceptual model multi-destination mode and questionnaire diary data of tourists visiting Branson travel zone in Missouri, USA.[9] Stewart and Vogt confirmed the importance and prevalence of multi-destination travel: 70% of visitors stopped by other attractions during their trip, and 28% made an overnight visit to other destinations.[8]

Because tourists derive utility from the enjoyment of destination characteristics, Stewart and Vogt's multi-destination travel model is putatively appropriate to address the particular structure of the tourism industry. Most research efforts regarding tourism destination, including those applying Lancaster's model, specifically address the choice of a single destination.

3.2.3 Lundgren travel model

The Lundgren model is a hierarchy of four different geographic systems relating to the country of origin and the chosen destination (see Fig.1); in other words, four different types of place of origin and destinations analysed on the basis of their function and geographical position. As these configurations frequently correspond to traveller behaviour, the model is extremely useful because:

- it gives a starting point for considering tourist flows and their distribution in various areas – the number of arrivals and typologies of tourists, the relationship between different places of origin, reasons for travelling to and typology of chosen destination, etc.; and
- it offers a potential framework (although partial) for devising business and tourism development strategies and for designing promotional strategies to appeal to specific targets according to their country of origin.[4]

The original model did not take into account different typologies of tourism, but we can apply the theory behind it to the food and wine tourism sector if we consider the quantitative and qualitative aspects of tourist movements:

- Metropolitan of urban areas
- Suburban areas
- Rural peripheral areas
- Long-distance areas

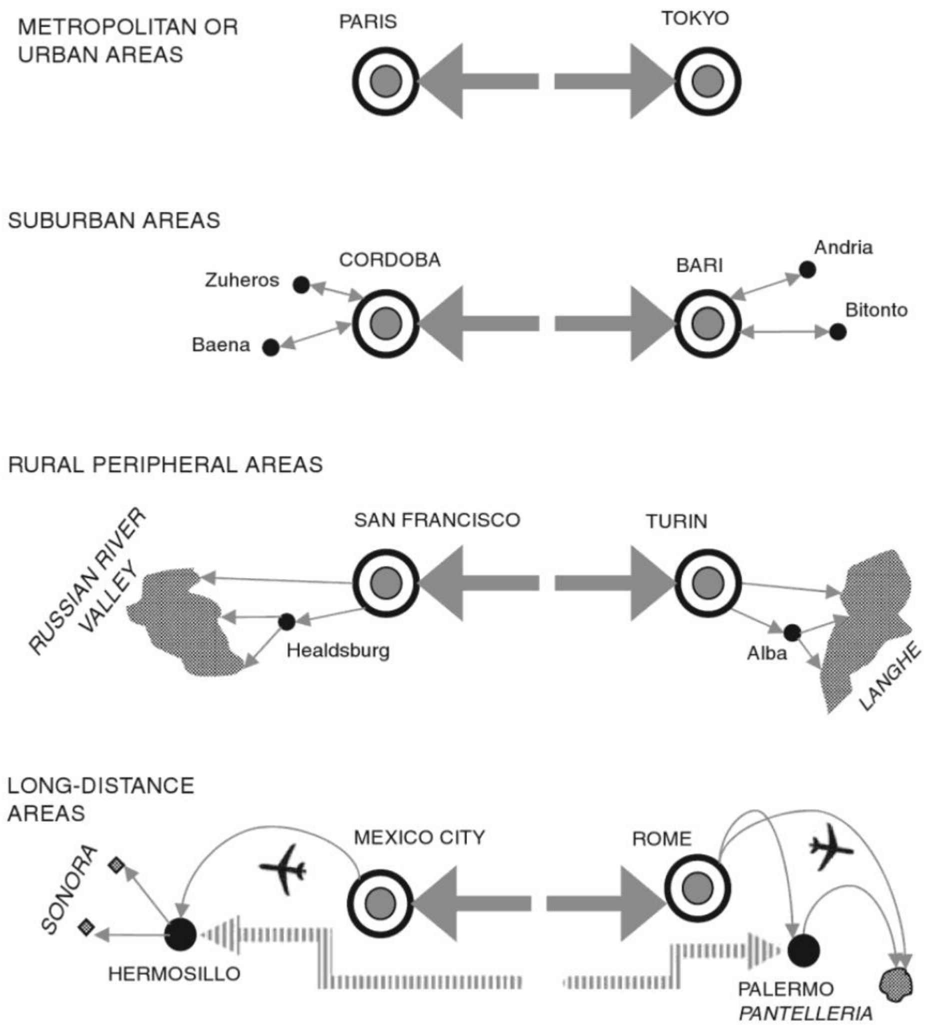

Figure 1: *Hierarchy of spatial systems in origin-destination of tourist flows (source: the authors' own adaptation of Lundgren, 1984)*

3.3 Use quantitative methods to solve problem

Quantitative methods include formalized principles that form the basis for a stringent research process that proceeds from formulation of research questions, research design, and the selection and analysis of data to interpretations and conclusions. The data will be linked to specific variables and standardized methods are applied for data collection. The variables can thus be expressed in numerical form, and the data material can be described in the form of tables, graphs, or statistical measurements. (12)

Quantitative research is defined as a systematic investigation of phenomena by gathering quantifiable data and performing statistical, mathematical, or computational techniques. Quantitative research templates are objective, elaborate, and many times, even investigational. The result achieved from this research method are logical, statistical, and unbiased. Data collection happened using a structured method and conducted on larger samples that represent the entire population. (14)

3.3.1 Operational research

Operations Research (OR) is a term which stands for an approach to problem-solving characterized by a systems orientation, an interdisciplinary philosophy, a focus on the quantification of the relevant aspects of the situation into a model, and the manipulation of this model through the use of mathematical, statistical and computational methodologies in order to develop decisions, plans, and policies. (6)

Operational research is mainly to produce, management and other events in some of the general operational problems to refine, and then use mathematical methods to solve. From the most intuitive and clear point of view, operations research is defined as through the construction, solve the mathematical model programming, optimize the reasonable use of limited resources, to provide a quantitative sentence for scientific decision system knowledge system.

Operational research includes linear programming, nonlinear programming, integer programming, and so on. Among them, linear programming is an important branch of operation research. The solution of linear programming is to find the solution with the least consumption of resources under the condition of limited resources, which fails to achieve the desired optimal goal.
Within the field of tourism, the term OR appears to be first used in the literature by Cesario (16). However, then as today, many tourism researchers and planners use concepts and methodologies which, in the business world, are often associated with the practice of Operations Research. These concepts and methodologies most often deal with problems in the areas of: tourist forecasting; the determination of tourist flows; the measurement and evaluation of the impact of tourism-oriented facilities and activities; and the modelling of decision, planning, and policy problems. (13)

3.3.2 Travelling salesman problem

Traveling salesman problem is a really difficult optimization problem. This problem is mathematical and it generalizes the problem of finding the shortest way around all points in a set of vertexes.
This problem can be formulated as: there are ***n*** points and ways between all of them with known lengths (which means it is simple to find the shortest way between any two points). The target is to find the shortest way, which passes all points right at once, start and end in the same point. It means the target is to find the shortest possible round trip. (1)
In the sense of graph theory, TSP is often referred to as the minimum Hamilton circle problem. On the basic of the weighted graph language is described as ***G= (V, A)*** where V is the set of vertices and A is the set of edges connected with each other. Assuming that $D = (d_y)$ is the distance matrix formed by the distance between the fixed point i and the vertex j, a Hamilton loop with the shortest length is to

be determine, that is, to traverse all the vertices, if and only if the shortest distance is once.

Next, I will describe it in mathematical language.

G=(V, E) is the weighted graph, ***V=(1,2,…,n)*** V is the set of vertices, E is the set of edges connected with each other, the distance between the vertices d_y known $(d_y > 0, d_y = \infty, i,j \in V)$, assuming that $x_y = \begin{cases} 1 & suppose\ (i,j) on\ an\ optimal\ path \\ 0 & other \end{cases}$

then the classical problem can be written as the following mathematical programming model: $min\ \ Z = \sum_{i=1}^{n} \sum_{j=1}^{n} d_y x_y$

s.t.

$$\sum_{j=1}^{n} \lambda_y = 1 \qquad i \in V \qquad \text{(a)}$$

$$\sum_{i=1}^{n} x_y = 1 \qquad j \in V \qquad \text{(b)}$$

$$\sum_{i \in S} \sum_{j \in S} \chi_y \le |S|\text{-}1 \ \ \forall \ \ S \subset \mathrm{V} \qquad \text{(c)}$$

|S| is the number of vertices of G contained in set S. Constraints (a) and (b) mean that for each vertex, there is only one edge in and one edge out. Constraint (c) ensures that there are no subloop solutions. Thus, the deconstruction of the constraint (a)~(c) becomes a Hamilton loop

The above constraints can also be written in other equivalent forms, and this paper does not enumerate them all.

TSP is a classical combinatorial optimization problem and an NP-complete problem. It is a concentrated generalization and simplification of many complex problems in many fields, and has become an indirect comparison standard for various heuristic search optimization algorithms. Therefore, the rapid and effective solution has repeated theoretical value and extremely high practical value.

Vogel's Approximation Method

The Vogel's Approximation Method or VAM is an iterative procedure calculated to find out the initial feasible solution of the transportation problem. Like Least Cost

Method, here also the shipping cost is taken into consideration, but in a relative sense.

The following is showing the steps involved in solving the transportation problem using the Vogel's Approximation Method:

Step-1: find the cells having smallest and next to smallest cost in each row and write the difference (called penalty) along the side of the table in row penalty.

Step-2: Find the cells having smallest and next to smallest cost in each column and write the difference (called penalty) along the side of the table in each column penalty.

Step-3: Select the row or column with the maximum penalty and find cell that has least cost in selected row or column. Allocate as much as possible in this cell. If there is a tie in the values of penalties then select the cell where maximum allocation can be possible.

Step-4: Adjust the supply and demand and cross out (strike out) the satisfied row or column.

Step-5: Repeat the above steps until all supply and demand values are 0.

Nearest Neighbor Algorithm

The nearest neighbor method, first proposed by Cover and Hart in 1968, is a theoretically mature method and one of the simplest machine learning algorithms. The idea of this method is very simple and intuitive: starts with an arbitrarily chosen city x_1 as a partial tour. Then repeats the following step for $k = 1; \dots; n-1$: If the current partial tour is $x_1; \dots; x_k$, then let x_{k+1} be the city closet to x_k subject to the condition that x_{k+1} is not already contained in the partial tour. In the end, the NNR tour returns from city x_n to city x_1. Calculated the total distance of the partial tour. Start other tours from other cities (n tours all together). Compare the distances of the n partial tours. Choose the shortest.

The Savings Algorithm (Parallel)

The saving algorithm is the most famous heuristic algorithm used to solve the vehicle routing problem with an uncertain number of transport vehicles.

The basic idea of the saving algorithm is shown in the figure below. Given that point 0 is the distribution center, it delivers goods to user A and user B respectively.

Let’s say the distance from 0 to user A and user B is a and b respectively. The distance between user A and user B is c, and there are now two delivery schemes, as shown in figure (a) and (b).

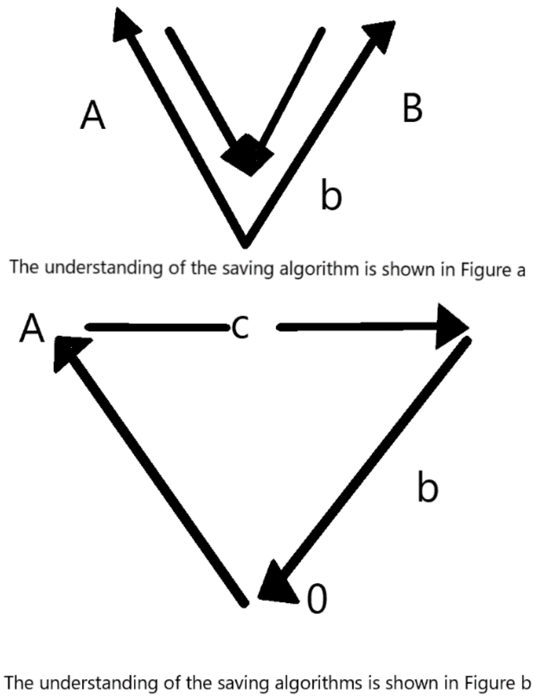

Figure 2 *The basic idea of the saving algorithm*

In figure a, the delivery distance is $2(a+b)$; In figure b, the delivery distance is $a+b+c$. Comparing the two schemes, which one is more suitable? To see which delivery distance is the smallest, the smaller the delivery distance, the more reasonable the scheme. From the delivery distance in figure a minus the delivery distance in figure b, the formula can be obtained

$$2(a+b)-(a+b+c)=(2a+2b)-a-b-c=a+b-c \quad (1)$$

If the picture b is regarded as a triangle, then a, b, and c are the lengths of the three sides of the triangle. It can be seen from the geometric properties of the triangle that the sum of the side lengths of any two sides of the triangle is greater than the side length of the third side. Therefore, it can be concluded that the result in formula (1) is greater than zero.

So $a + b - c > 0 \ \ (2)$

It can be seen from the formula (2) that the scheme in figure b is better than scheme in figure a and saves the mileage of $a + b - c > 0$. The pros and cons of this analysis scheme is the basic idea of the saving algorithms

The core idea of the saving algorithm is to combine the two loops in the transportation problem into one loop in turn, and maximize the reduction of the combined total transportation distance each time until the loading limit of one vehicle is reached, and then optimize the next vehicle. The optimization process can be divided into the parallel mode and serial mode.

3.3.3 TSPKOSA

Program TSPKOSA is aimed at the Traveling Salesman Problem. It was made by Igor Krejčí and Petr Kučera from the department of systems engineering and Hana Vydrová from the department of statistics in the Czech university of life and science in Prague. The program works with four basic methods. TSPKOSA was created in Microsoft Visual Basic 6.5. [6]

- Optimization:
  Branch and Bound
- Approximation:
  Nearest Neighbour Alogrithm (sequential)
  Vogel Approximation Method/ Loss Method
  Saving Method (parallel)

3.4 Principles of tourist route design

In general, for discovering and recommending travel routes, [17] raise three questions that need to be addressed: 1) How to discover popular travel paths and estimate typical stay time within a destination? 2) How to select and organize the destinations in a location to a travel route under certain travel duration constraint? 3)How to meet tourists' diverse preference requirements? To the best of our knowledge, little existing work in literatures has systemically investigated the automatic travel route planning problem. Most existing research efforts on user generated content [15,10,2,18] mainly focus on landmarks recognition, scene visualization and recommendation. At the same time [5,19,7] mined the trajectory of moving object, and demonstrated its usefulness in the analysis of traffic flows, in which the GPS trajectory data was used. [5] proposed to extract interesting locations and classical travel sequences using GPS trajectory data. It is the importance of GPS, so my tutor instructed me to find out the GPS coordinates of 60 of scenic spots in order to figure out the distance between 60 scenic spots.

According to the literature, I came up with 6 principles of tourism route planning.

- Principle of market demand

According to the demand characteristics of tourists, combined with the fashion of different periods, the famous scenic spots with European characteristics are selected and the tourist route products suitable for the market demand are designed. Like the economic developed areas of Europe, people from sightseeing tourism to vacation tourism transition; Young people prefer adventurous and exciting travel activities.

- Principle of non-repetition

A scenic spot is only visited once, if repeated to the same place, will make tourists feel boring, reduce the interest in tourism.

- Principle of diversity

There are many types of various tourism elements and diversified tourism. For example, visit an art gallery in on place and the next is a place if historic interest, such as the Colosseum in Rome.

- Principle of time rationality

Minimize traffic running time. The process of ensuring the visitor's rest and familiarity with the environment.

- Principle of flexibility

Schedule should not be too tight, a day should not be arranged too much scenic spots, arrangement should be flexible. For example, the strike problem in Europe.

- Travel safety principle

Safety is the most important basic principle that some dangerous areas choose to avoid. As for the current epidemic of COVID-19, avoid high-risk areas.

3.5 Travelling and planning in tourism

Suppose a travel enthusiast wants to travel to the famous tourist attractions of some European countries, but there are many restrictions on package tour, so he chooses to travel to European by driving. Table 1 shows 60 scenic spots of the five landlocked European countries he preselected.

Table 1 *Primary five countries and sixty scenic spots*

Destinations in Prague (Czech Republic)	
Number of destinations	**List of destinations**
1	Wenceslas Square
2	Prague Castle (St. Victor's Cathedral)
3	Charles Bridge
4	The old town square of Prague
5	Petřínská rozhledna
6	Krumlov Castle
Destinations in Munich (German)	
7	Marienplatz
8	Münchner Residenz (Wittelsbach)

9	Munich Olympic Park
10	Munich Frauenkirche
11	BMW Museum
Destinations in Frankfurt (German)	
12	Old Opera House (Alte Oper)
13	Staedel Museum
Destinations in Berlin (German)	
14	Brandenburg Gate
15	Reichstag building
16	Berlin Cathedral
17	Berliner Fernsehturm
18	East side gallery
19	Potsdamer Platz
Destinations in Heidelberg (German)	
20	Heidelberger Schloss
21	Heiderlberg Old Bridge
22	Studentenkarzer
Destinations in Schwangau (German)	
23	New Swan Stone Castle
Destinations in Zurich (Switzerland)	
24	Kunsthaus Zürich
25	The Fraumünster
26	Schweizerishes Nationalmuseum
27	Old Town Zurich
Destinations in Luzern (Switzerland)	
28	Mt.Rigi
29	Swiss Museum of Transport
30	Chapel Bridge (Kapellbrucke)
31	Lion Monument
Destinations in Geneva (Switzerland)	
32	The Jet'd Eau fountain
33	Chillon Castle
Destinations in Milan (Italy)	
34	Milan Cathedral
35	Pinacoteca di Brera
36	Porta Sempione
37	Corso Venezia
Destinations in Bologna (Italy)	
38	Piazza Maggiore
39	Towers of Bologna
40	Basilica of San Petrionio
41	Fountain of Neptune

Destinations in Florence (Italy)	
42	Florence Cathedral
43	Piazzale Michelangelo
44	Piazza dell Signoria
45	Uffizi Gallery
Destinations in Rome (Italy)	
46	Colosseum Rome
47	Arch of Constantine
48	St Peter’s Square
49	St Peter’s Basilica
50	Roman Forum
51	The mouth of truth
52	Piazza di Spagna
53	Trevi Fountain
54	The Pantheon
55	Castel Sant‘ Angelo
Destinations in Paris (France)	
56	Louvre Museum
57	Eiffel Town
58	Notre-Dame de Paris
59	Arc de Triomphe
60	Parc Disneyland

The prosperity of tourism has made travel increasingly popular in people’s everyday lives. Before traveling to an unfamiliar location. Most people have questions about how to plan their trip. Moreover, since the information provided by travelogue is usually unstructured and varies from person to person, from language to language, it is extremely hard for traveller to follow. In this case, an automatic and interactive travel route planning service is highly desired to plan a customized trip according to traveller’s preferences.

In practice, automatic trip planning is a very complex task, which depends on many factors, such as travel duration, travel cost, visiting time, tourist’s age and physical condition, and individual interest, out of which some are difficult to model and predict. [17] Therefore, I will make some factor assumptions for the optimal time-saving route designed in this paper.

Assumption:

(1) Travel only by driving a car.
(2) Travel expenses are out of the question.
(3) Travel duration is not limited.
(4) The place to visit is a famous and representative place in Europe.
(5) Since the human body needs a proper rest every day and cannot drive for too long to prevent fatigue driving, travel and drivable hours are located from 8am to 6pm.
(6) Now the world is facing an unprecedented global health, social and economic emergency with the COVID-19 pandemic. Travel and tourism is among the most affected sectors with airplanes on the ground, hotels closed and travel restrictions put in place in virtually most countries around the world. That's why we have to consider giving up travel to some of the worst-affected areas.

Under the condition that the total time of the whole tourism is not limited and the tourism expenditure is not included, quantitative method will be used to design an optimized time-saving self-driving journey. When it comes to the relationship between the COVID-19, we will choose to exclude some regional scenic spots with severe epidemic to visit, so as to design an optimized time-saving and safest self-driving journey.

4 Practical part of self-driving tour

As one of the most developed regions in the world, Europe has a unique wealth of tourism resources. If similarly developed America is more like a nouveau riche, lacking heritage, Europe is like a traditional aristocrat, elegant, cultivated, with a little romance, with a little luxury. Almost every European country is a dream tourist destination, fantastic natural scenery, strong cultural atmosphere, unique local customs, shopping paradise. People can always find their own happiness in Europe, therefore people always say, once in your life, you have to come to Europe. That’s why thousands of people travel to Europe every year. The best way to travel to such a colorful place is to drive by yourself. Without the shackles of tour groups, you can go wherever you want in Europe, so this article is to design a European tour route for a self-driving travel enthusiast. Assume that five landlocked European countries with a large number of tourists in recent years are found, and 60 most characteristic and representative scenic spots are selected (see Table 1). These attractions are based on the interest statistics of self-driving travel enthusiasts. We will not return to the starting point. The sixty scenic spots are our final destination. There will be no repeated scenic spots in the itinerary, and we only visit one scenic spot and one place once. Although there is no time limit on the journey, the human body needs rest, so when travel enthusiasts travel to different destinations each day, the time between each site ranges from 60 minutes to 90 minutes, but also includes breaks. In conclusion, self-driving travel enthusiasts can travel up to 10 hours a day, including sightseeing, driving, meals and rest time.

4.1 The data collection

Table 2 is the distance (km) between 60 scenic spots in five European landlocked countries collected from the internet, namely the Czech Republic, Germany, Switzerland, Italy and France.

Table 2 *Distance matrix of the journey*

Distance	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	0	6126	3060	4361	7606	172768	383866	382181	379490	383394	380264	515312	513832	347496	351427	348637	348983	345649	346827	502160	505427	502359	509908	685085	685996	684109	684680	738530	740794	739724	739347
2	5835	0	2803	3545	2543	179989	382427	380741	378051	381955	378824	513873	512393	348767	352698	349908	350254	346919	348098	500721	503987	500920	508468	683646	684556	682670	683241	737090	739355	738285	737908
3	3853	2810	0	755	4683	173879	382791	381106	378415	382320	379189	514237	512757	347608	351539	348749	349095	345761	346939	501085	504352	501284	508833	684010	684921	683034	683605	737455	739720	738649	738272
4	3751	3387	1153	0	5259	175797	385736	384051	381360	385265	382134	517182	515702	347126	351057	348267	348613	345279	346457	504030	507297	504229	511778	686955	687866	685979	686550	740400	742664	741594	741217
5	7703	2538	4672	5413	0	179851	381505	379820	377130	381034	377903	512952	511471	350268	354199	351409	351755	348420	349599	499800	503066	499999	507547	682725	683635	681749	682320	736169	738434	737364	736986
6	175146	182642	176410	178606	182604	0	304426	302741	300051	303955	300824	554257	552776	521669	525600	522810	523156	519822	521000	541467	544734	541666	424828	605663	606574	604688	605258	659108	661373	660302	659925
7	382107	380854	380727	381484	380016	298693	0	2426	8977	2111	10727	399037	397557	583288	583581	585339	586066	592697	583812	333145	336411	333344	120022	310171	311082	309196	309766	363616	365881	364810	364433
8	380779	379527	379399	380157	378688	297365	2396	0	9506	2625	10279	397710	396230	581961	582253	584012	584739	591370	582484	345566	348832	345765	123101	311946	312856	310970	311541	365390	367655	366585	366208
9	378461	377209	377081	377839	376370	295047	9291	9205	0	5761	2548	395392	393911	579643	579935	581693	582421	589052	580166	330660	333927	330859	123401	312247	313157	311271	311842	365691	367956	366886	366509
10	381986	380734	380606	381364	379896	298572	2181	3073	7831	0	9581	398917	397437	583168	583460	585219	585946	592577	583691	332102	335368	332301	121597	310442	311353	309466	310037	363886	366151	365081	364704
11	377856	376604	376476	377234	375765	294442	8925	8600	1010	5419	0	394787	393306	579038	579330	581088	581816	588447	579561	330294	333560	330493	123035	311880	312791	310905	311475	365325	367590	366519	366142
12	512381	511129	511001	511759	510291	546360	396047	394362	391672	395576	392445	0	4518	545435	545728	547486	548213	554844	545959	98933	97761	99194	424105	410275	411186	409300	409870	457113	431000	430087	429238
13	514868	513616	513488	514246	512777	548847	398534	396849	394159	398063	394932	2274	0	548695	548988	550746	551473	558104	549219	90689	89517	90951	431045	402032	402942	401056	401627	448869	422757	421843	420995
14	352431	353423	352536	352509	355972	524264	583700	582015	579325	583229	580098	545149	547167	0	1239	2067	2794	5293	1163	627907	626736	628169	733100	841193	842103	840217	840788	898941	901206	900135	899758
15	349792	350784	349898	349870	353333	521625	584023	582338	579648	583552	580421	545471	547490	1299	0	2895	3622	6932	1972	628230	627059	628492	733423	841516	842426	840540	841111	899264	901529	900458	900081
16	350018	351010	350123	350096	353559	521851	585749	584064	581373	585277	582147	547197	549215	2044	2818	0	884	3383	2603	629956	628784	630217	735149	843241	844152	842265	842836	900989	903254	902184	901806
17	350644	351636	350749	350722	354185	522477	587057	585372	582681	586586	583455	548505	550524	3353	4126	1446	0	3398	4001	631264	630092	631525	736457	844549	845460	843574	844144	902297	904562	903492	903115
18	344055	345047	344160	344133	347596	515888	597061	595376	592686	596590	593459	558509	560528	5479	6253	3572	3629	0	5291	641268	640096	641530	746461	854554	855464	853578	854149	912302	914566	913496	913119
19	348799	349791	348905	348878	352341	520632	586145	584460	581769	585674	582543	547593	549612	1341	2621	3222	3949	5627	0	630352	629180	630613	735545	843637	844548	842662	843232	901385	903650	902580	902203
20	503595	502343	502215	502973	501505	537913	342284	346950	331622	342696	330833	92600	88598	627618	627911	629669	630396	637027	628142	0	434	261	335617	321788	322699	320812	321383	368625	342513	341599	340751
21	507304	506052	505924	506682	505213	541622	345993	350659	335331	346404	334542	92166	88164	627184	627477	629235	629962	636593	627708	1172	0	1433	339326	325497	326407	324521	325092	372334	346222	345308	344460
22	503328	502076	501949	502706	501238	537646	342017	346683	331355	342429	330567	92512	88511	627531	627823	629581	630309	636940	628054	877	2730	0	335351	321521	322432	320545	321116	368359	342246	341332	340484
23	508945	507693	507566	508323	506855	425249	117404	119024	120217	118729	121967	420846	433198	734942	735234	736993	737720	744351	735465	336059	339326	336258	0	237658	238568	236682	237253	291102	293367	292297	291920
24	683658	682406	682279	683036	681568	599962	308875	311644	310775	309287	312525	406752	402750	842482	842774	844533	845260	851891	843005	321965	325232	322164	233958	0	916	1259	737	51434	53699	52628	52251
25	684839	683587	683460	684217	682749	601143	310057	312825	311956	310468	313706	407933	403931	843663	843956	845714	846441	853072	844186	323146	326413	323345	235139	1475	0	2440	1918	51153	53418	52348	51971
26	683568	682316	682188	682946	681478	599872	308785	311554	310685	309197	312435	410811	406809	842392	842684	844442	845170	851801	842915	326024	329291	326223	233868	2610	3521	0	1950	52231	54496	53426	53048
27	683321	682069	681941	682699	681231	599625	308538	311307	310438	308950	312188	406415	402413	842145	842437	844195	844923	851554	842668	321628	324895	321827	233621	731	1641	751	0	50829	53094	52024	51647
28	738599	737347	737219	737977	736509	654903	363816	366585	365716	364228	367466	452508	448507	900657	900949	902708	903435	910066	901180	367722	370988	367921	288899	52111	51010	51424	51064	0	19688	22142	21747
29	740505	739253	739125	739883	738414	656808	365722	368490	367621	366133	369371	426617	422615	902563	902855	904613	905341	911972	903086	341830	345097	342029	290804	54016	52916	53330	52969	19611	0	2863	3017
30	739623	738371	738243	739000	737532	655926	364840	367608	366739	365251	368489	424235	420233	901680	901973	903731	904458	911089	902204	339448	342715	339647	289922	53134	52034	52448	52087	21832	2571	0	1811
31	739092	737840	737713	738470	737002	655396	364310	367078	366209	364721	367959	424225	420224	901150	901443	903201	903928	910559	901674	339439	342705	339638	289392	52604	51503	51918	51557	21753	3190	2120	0
32	961105	959853	959725	960482	959014	873588	582502	585270	584401	582913	586151	578871	574869	1113889	1114182	1115940	1116667	1123298	1114412	494084	497351	494283	507584	278945	286829	277721	278285	294009	267897	266983	266135
33	894988	893736	893609	894366	892898	807472	516386	519154	518285	516797	520035	512755	508753	1047773	1048065	1049824	1050551	1057182	1048296	427968	431234	428167	441468	212829	220713	211605	212169	227893	201781	200867	200019
34	868813	867561	867433	868191	866723	791151	494030	496799	495930	494442	497680	668132	664130	1034892	1035184	1036942	1037670	1044301	1035415	583345	586611	583544	419113	283413	282313	282727	282366	254064	248092	247178	247332
35	866441	865189	865061	865819	864351	788106	491658	494427	493558	492070	495308	665760	661758	1032520	1032812	1034571	1035298	1041929	1033043	580973	584240	581172	416741	281042	279941	280355	279995	251692	245720	244806	244960
36	864178	862926	862798	863556	862087	794874	489395	492163	491295	489807	493045	663496	659495	1030257	1030549	1032307	1033034	1039665	1030780	578710	581976	578909	414478	278778	277677	278092	277731	249428	243457	242543	242697
37	867837	866585	866457	867215	865746	786548	493054	495822	494953	493465	496704	667155	663153	1033915	1034208	1035966	1036693	1043324	1034439	582368	585635	582568	418136	282437	281336	281751	281390	253087	247116	246202	246356
38	941791	940539	940412	941169	939701	798549	559292	559067	566170	563117	566944	882279	878278	1142973	1143266	1145024	1145751	1152382	1143497	797493	800759	797692	506031	497561	496460	496875	496514	468212	462240	461326	461480
39	947305	946053	945926	946683	945215	798186	564806	564581	571684	568631	572458	887794	883792	1148487	1148780	1150538	1151265	1157896	1149011	803007	806273	803206	511546	503075	501975	502389	502028	473726	467754	466840	466994
40	941863	940611	940483	941241	939773	798621	559364	559139	566242	563189	567016	882351	878349	1143045	1143338	1145096	1145823	1152454	1143568	797564	800831	797764	506103	497633	496532	496947	496586	468283	462312	461398	461552
41	941312	940060	939932	940690	939221	798486	558812	558587	565691	562637	566464	881800	877798	1142494	1142786	1144544	1145272	1151903	1143017	797013	800280	797212	505552	497082	495981	496395	496035	467732	461760	460846	461000
42	1029366	1028114	1027986	1028744	1027275	879918	646866	646641	653745	650692	654518	969854	965852	1230548	1230840	1232599	1233326	1239957	1231071	885067	888334	885266	593606	585136	584035	584449	584089	555786	549815	548901	549054
43	1031873	1030621	1030493	1031251	1029782	882425	649373	649148	656252	653199	657025	972361	968359	1233055	1233347	1235105	1235833	1242464	1233578	887574	890841	887773	596113	587643	586542	586956	586596	558293	552322	551408	551561
44	1028718	1027466	1027338	1028096	1026628	879271	646219	645994	653097	650044	653871	969206	965204	1229900	1230193	1231951	1232678	1239309	1230424	884420	887686	884619	592958	584488	583387	583802	583441	555138	549167	548253	548407
45	1029081	1027829	1027701	1028459	1026991	879634	646582	646357	653460	650407	654234	969569	965567	1230263	1230555	1232314	1233041	1239672	1230786	884782	888049	884981	593321	584851	583750	584164	583804	555501	549530	548616	548770
46	1309867	1308615	1308487	1309245	1307776	1160419	927367	927142	934246	931192	935019	1250355	1246353	1511049	1511341	1513099	1513827	1520458	1511572	1165568	1168835	1165767	874107	865637	864536	864950	864590	836287	830315	829402	829555
47	1309775	1308523	1308396	1309153	1307685	1160328	927276	927051	934155	931101	934928	1250264	1246262	1510957	1511250	1513008	1513735	1520366	1511481	1165477	1168743	1165676	874016	865545	864445	864859	864498	836196	830224	829310	829464
48	1302220	1300968	1300840	1301598	1300129	1152772	919720	919495	926599	923546	927372	1242708	1238706	1503402	1503694	1505452	1506180	1512811	1503925	1157921	1161188	1158120	866460	857990	856889	857303	856943	828640	822669	821755	821908
49	1302295	1301043	1300915	1301673	1300204	1152847	919795	919570	926674	923621	927447	1242783	1238781	1503477	1503769	1505527	1506255	1512886	1504000	1157996	1161263	1158195	866535	858065	856964	857378	857018	828715	822744	821830	821983
50	1304085	1302833	1302706	1303463	1301995	1154638	921586	921361	928464	925411	929238	1244573	1240572	1505267	1505560	1507318	1508045	1514676	1505791	1159787	1163053	1159986	868325	859855	858754	859169	858808	830506	824534	823620	823774
51	1303415	1302163	1302035	1302793	1301325	1153968	920916	920691	927794	924741	928568	1243903	1239901	1504597	1504890	1506648	1507375	1514006	1505120	1159116	1162383	1159316	867655	859185	858084	858499	858138	829835	823864	822950	823104
52	1301167	1299915	1299788	1300545	1299077	1151720	918668	918443	925546	922493	926320	1241655	1237654	1502349	1502642	1504400	1505127	1511758	1502873	1156869	1160135	1157068	865408	856937	855837	856251	855890	827588	821616	820702	820856
53	1299924	1298672	1298545	1299302	1297834	1150477	917425	917200	924303	921250	925077	1240412	1236411	1501106	1501399	1503157	1503884	1510515	1501630	1155626	1158892	1155825	864164	855694	854593	855008	854647	826345	820373	819459	819613
54	1299997	1298745	1298617	1299374	1297906	1150549	917497	917272	924376	921322	925149	1240485	1236483	1501179	1501471	1503229	1503956	1510588	1501702	1155698	1158965	1155897	864237	855767	854666	855080	854720	826417	820445	819531	819685
55	1301182	1299930	1299802	1300560	1299092	1151735	918683	918458	925561	922508	926335	1241670	1237668	1502364	1502656	1504415	1505142	1511773	1502887	1156883	1160150	1157082	865422	856952	855851	856265	855905	827602	821631	820717	820871
56	1031801	1030549	1030421	1031179	1029711	1066119	837722	842388	827060	838133	826271	576085	571836	1052801	1053094	1054852	1055579	1062210	1053325	546695	545524	546957	831055	657415	665299	656191	656755	696995	670883	669969	669121
57	1039399	1038147	1038019	1038777	1037309	1073717	845320	849986	834658	845731	833869	583683	579434	1050702	1050994	1052753	1053480	1060111	1051225	554293	553122	554555	838653	657690	665573	656465	657029	697269	671157	670243	669395
58	1030948	1029696	1029568	1030326	1028858	1065266	836869	841535	826207	837281	825418	575232	570983	1051949	1052241	1053999	1054727	1061358	1052472	545843	544671	546104	830202	656563	664446	655338	655902	696142	670030	669116	668268
59	1043010	1041758	1041630	1042388	1040920	1077328	848931	853597	838269	849342	837480	587294	583045	1049565	1049858	1051616	1052343	1058974	1050089	557904	556733	558166	842264	661300	669184	660076	660640	700880	674768	673854	673006
60	998917	997665	997537	998295	996827	1033235	804838	809504	794176	805249	793387	543201	538952	1078220	1078512	1080270	1080998	1087629	1078743	513811	512640	514073	798171	601926	609810	600702	601266	641506	615394	614480	613632

Distance	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1–60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

4.2 Description of the problem

The itinerary requires passing through 60 scenic spots, including starting and ending points. There are no mandatory provisions of what scenic spots as a starting point, what scenic spots for the end. This itinerary absolutely does not go to repeat the location. Since the algorithm used will make the starting point and the end point be the same place, in our optimized scheme, we will accept the consistent results of the starting point and the end point, but in real life, we can end with the previous scenic spot of the end point without returning to the starting point. There are 60 different scenic spots from the beginning to the end in the itinerary.

If follow the numbers assigned to the scenic spots, then Figure 3 is the route from 1-60 shown on the website Mapy.cz.

Route: (1) - (2) - (3) - (4) - (5) - (6) - (7) - (8) - (9) - (10) - (11) - (12) - (13) - (14) - (15) - (16) - (17) - (18) - (19) - (20) - (21) - (22) - (23) - (24) - (25) - (26) - (27) - (28) - (29) - (30) - (31) - (32) - (33) - (34) - (35) - (36) - (37) - (38) - (39) - (40) - (41) - (42) - (43) - (44) - (45) - (46) - (47) - (48) - (49) - (50) - (51) - (52) - (53) - (54) - (55) - (56) - (57) - (58) - (59) - (60)

The total journey took a total of 3877 minutes (excluding rest time and sightseeing time) and the total distance between these 60 scenic spots was 6168.4 kilometers, this route is not the most optimal route.

Figure 3 *the route of 1-60 (Mapy cz)*

4.3 Solve and optimize problem

In order to solve the problem so as to minimize the travel distance and get the optimal solution, the school program recommended by the supervisor was used to solve the problem in this paper. As mentioned in the above part of the theory, we will use the saving algorithm(parallel), Nearest neighbor algorithm(sequential) and Vogel approximation algorithm/loss method in the program to optimize our travel distance. Since these three methods will find the best solution of their own, the shortest travel distance among the various schemes will be regarded as the optimal scheme of the problem in this paper.

4.3.1 Result of the saving algorithm(parallel)

Put the distance matrix of 60 scenic spots into the TSPKOSA program, use the saving algorithm(parallel), get the result. According to the TSPKOSA program, the minimal cycle Z_min is 4891419 meters.

The result is (28) - (25) - (27) - (24) - (26) - (23) - (7) - (8) - (10) - (9) - (11) - (6) - (5) - (2) - (4) - (3) - (1) - (19) - (16) - (18) - (17) - (14) - (15) - (12) - (13) - (20) - (21) - (22) - (60) - (56) - (57) - (59) - (58) - (32) - (33) - (35) - (34) - (55) - (48) - (49) - (50) - (46) - (47) - (51) - (54) - (52) - (53) - (43) - (42) - (44) - (45) - (40) - (38) - (39) - (41) - (37) - (36) - (31) - (30) - (29) - (28)

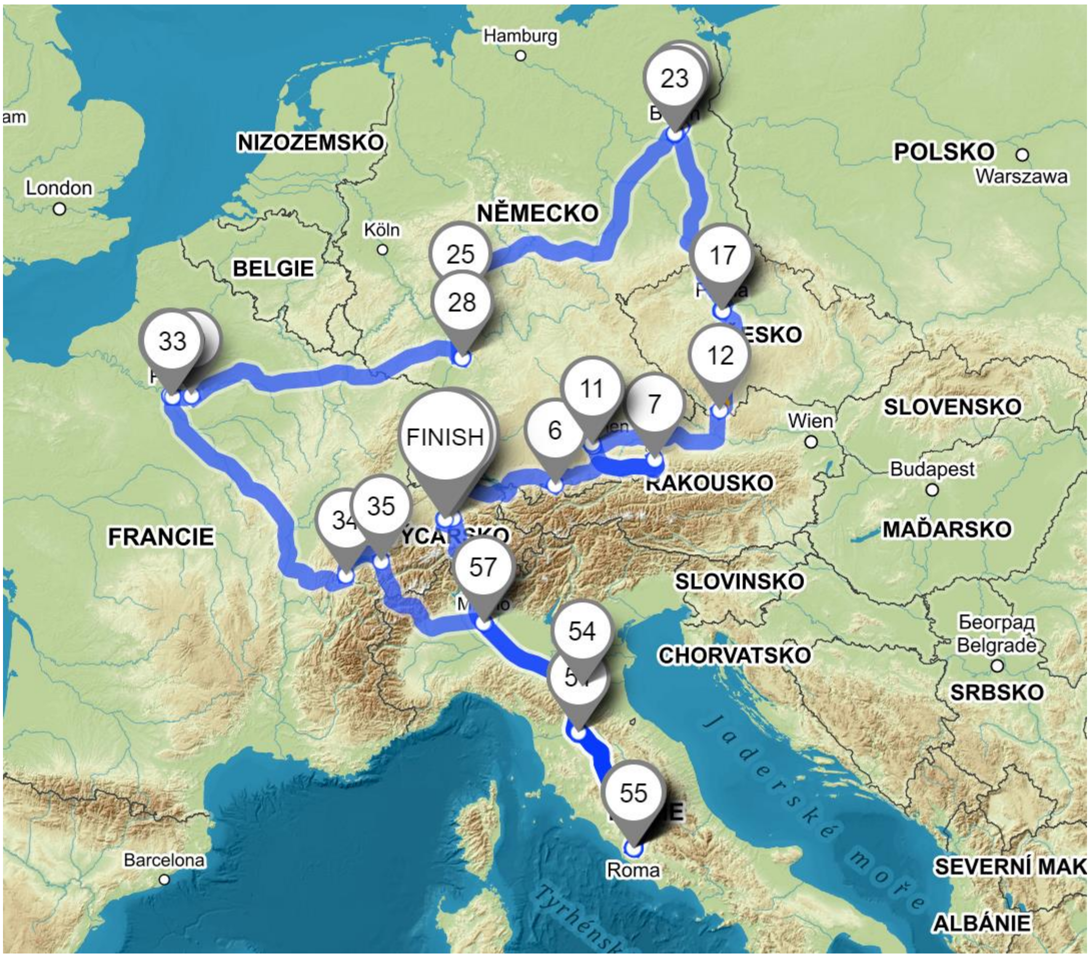

Figure 4 *Result from the saving algorithm(parallel) (Mapy cz)*

4.3.2 Result of nearest neighbor algorithm(sequential)

Put the distance matrix of 60 scenic spots into the TSPKOSA program, use Nearest neighbor algorithm(sequential), get the result. According to the TSPKOSA program, the minimal cycle Z_min is 5035260 meters.

The result is (26) - (27) - (24) - (25) - (28) - (29) - (30) - (31) - (33) - (32) - (36) - (35) - (37) - (34) - (41) - (39) - (40) - (38) - (45) - (44) - (42) - (43) - (55) - (48) - (49) - (54) - (53) - (51) - (50) - (46) - (47) - (52) - (23) - (7) - (10) - (8) - (9) - (11) - (6) - (1) - (3) - (4) - (2) - (5) - (18) - (16) - (17) - (14) - (19) - (15) - (12) - (13) - (21) - (20) - (22) - (60) - (58) - (56) - (57) - (59) - (26)

Figure 5 *Result from Nearest neighbor algorithm(sequential) (Mapy cz)*

Source: Mapy.cz

4.3.3 Result of Vogel approximation algorithm/loss method

Put the distance matrix of 60 scenic spots into the TSPKOSA program, use Vogel approximation algorithm get the result. According to the TSPKOSA program, the minimal cycle Z_min is 5460819 meters.

The result is (34) - (37) - (36) - (35) - (33) - (32) - (57) - (59) - (56) - (58) - (60) - (22) - (20) - (21) - (12) - (13) - (31) - (30) - (29) - (28) - (26) - (24) - (27) - (25) - (23) - (9) - (11) - (10) - (8) - (7) - (6) - (1) - (3) - (4) - (5) - (2) - (16) - (17) - (18) - (19) - (14) - (15) - (40) - (38) - (39) - (41) - (44) - (42) - (45) - (43) - (52) - (55) - (48) - (49) - (54) - (53) - (46) - (47) - (50) - (51) - (34)

Figure 6 *Result from Vogel approximation algorithm/loss method (Mapy cz)*

4.4 The optimal solution

According to the results calculated by the three methods of the TSPKOSA program, it can be known that the result calculated by the saving algorithm(parallel) is the optimal route. The result is as follow: (28) - (25) - (27) - (24) - (26) - (23) - (7) - (8) - (10) - (9) - (11) - (6) - (5) - (2) - (4) - (3) - (1) - (19) - (16) - (18) - (17) - (14) - (15) - (12) - (13) - (20) - (21) - (22) - (60) - (56) - (57) - (59) - (58) - (32) - (33) - (35) - (34) - (55) - (48) - (49) - (50) - (46) - (47) - (51) - (54) - (52) - (53) - (43) - (42) - (44) - (45) - (40) - (38) - (39) - (41) - (37) - (36) - (31) - (30) - (29) - (28)

It's a long trip, there are five countries an 60 scenic spots, and we don't go through them all the time, so we can't calculate the speed from them. Therefore, I will design a travel plan for this period of time. The time plan depends on sightseeing time, driving time and sleeping time. Since there is no way to estimate what will happen during the trip and there is no requirement or restriction on the total travel time, the total travel time will be determined after the travel plan is designed. Sightseeing time depends on the time of most visitors (interest in the destination), driving time is based on the time given by map software, and rest time is based on the normal sleeping time.

There are more than one scenic spot per day, so there may be unlimited scenic spots for sightseeing each day, but the sightseeing must be finished before 6pm. Finally, the tour plan does not include how to start to the first scenic spot as the starting point. Since the saving algorithm(parallel) will calculate the starting point as the end point (route as a circuit), we will use the previous scenic spot of the end point as the last scenic spot, so that the tourist does not have to return to the starting point. Since the optimized route is the result of the saving algorithm, it is possible to visit the same country twice in different time of the total travel time, and two times are different scenic spots. Such tour route planning meets the needs of some tourists who want to travel to a certain country several times, or do not make tourist feel tired and boring after visiting the same country for a long time. This kind of cross-section travel way, is more novel, also more thought-provoking.

4.4.1 Trip plan

The following tour standard will start at 8am and end at 6pm for a day. The rest time has been included in the consideration. The beginning of each day does not incorporate the previous day's end point into the plan.

Day 1: the first leg of the route is Mt.Rigi, although fame is not very big, but Rigi, as the forefront of the Alps, is known as the 'queen', the top is overlooking from Germany to France and Switzerland in the middle of the Alps, so Mt.Rigi need more time to travel, according to the statistics on the net, I will set to travel back and forth Mt.Rigi for five hours. Since it's a long drive from the first attraction, Mt.Rigi, to the second attraction Zurich, there won't be too many attractions to visit on the first day.

Table 3 *The route and time of Day 1*

Destination	Duration of stay(minute)	Driving time from last destination (minute)	Distance from last destination(meters)
28.Mt.Rigi (Rigi kulm)	300	0	0
25.Fraumunster	60	40	51153
27.Old town Zurich	120	3	1641
Total	480	43	52794

The route of day 1 is shown as follow:

Mt.Rigi (Rigi kulm) [Zurich]→ Fraumunster [Zurich] → Old town Zurich [Zurich]

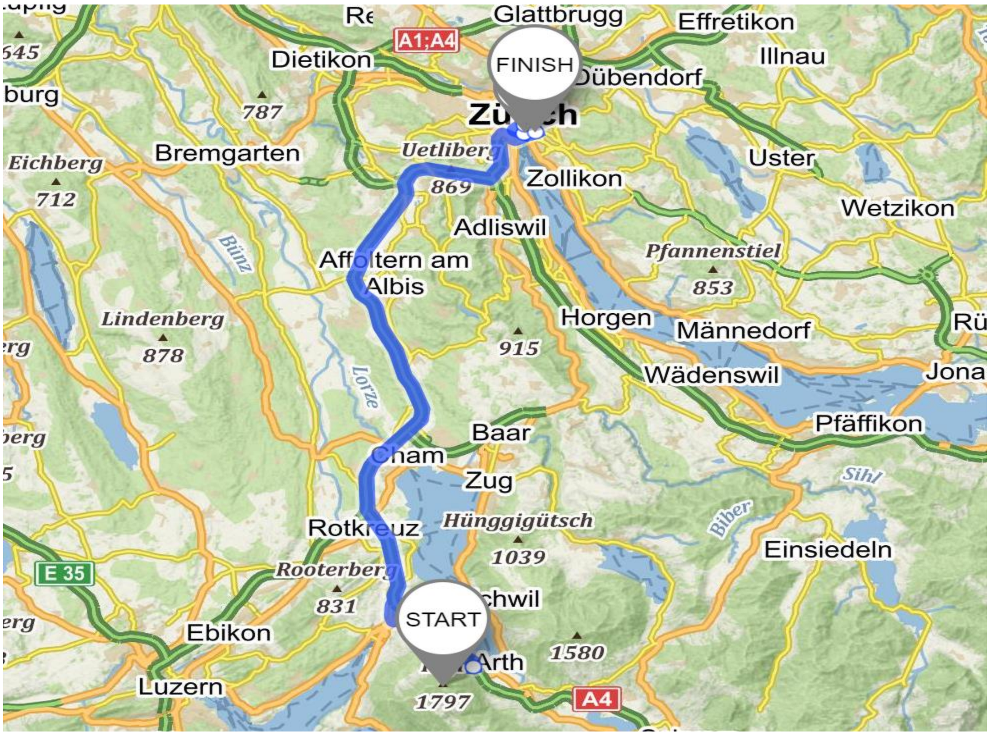

Figure 7 *The route of day one (Mapy cz)*

Day 2: Usually, art galleries are very worthy of people's slow appreciation, so I did not put the visit to Zurich Art Museum (Kunsthaus Zurich) on the first day, because if I put it on the first day, tourists will not have enough rest. I give more time to visit museums and art galleries so that visitors can enjoy themselves slowly. Since, the sixth attraction was a drive from Zurich to New Swan Castle, there were fewer attractions on the second day.

Table 4 *The route and time of Day 2*

Destination	Duration of stay (minute)	Driving time from last destination (minute)	Distance from last destinatio n(meters)
24.Kunsthaus Zurich	120	0	0
26.Schweizerishes National museum	120	3	2610
23.New Swan Stone Castle	300	161	236682

Total	540	164	239292

The route of day 2 is shown as follow:

Kunsthaus Zurich [Zurich]→ Schweizerishes Nationalmuseum[Zurich]→ New Swan Stone Castle [Schwangau]

Figure 8 *The route of day two (Mapy cz)*

Day 3: The third day will start from Schwangau to Munich, because the second day will end at Schwangau in Germany, not in the same city as the first day and the second day, so the tourist will stay in the hotel near the Schwangau, and then the third morning will leave for Munich. There are five scenic spots on the third day, which is more than the previous two days. Because the scenic spots are all in the same city and very similar, the trip is quite full.

Table 5 *The route and time of Day 3*

Destination	Duration of stay (minute)	Driving time from last destination (minute)	Distance from last destinatio n(meters)
23.New Swan Stone Castle	0	0	0
7.Marienplatz	60	103	120022

8.Munchner Residence (Wittelsbach)	120	2	2396
10.Munich Frauenkirche	60	5	3073
9.Munich Olympic Park	60	10	5761
11.BMW Museum	120	4	1010
Total	420	124	132271

The route of day 3 is shown as follow:

New Swan Stone Castle [Schwangau] → Marienplatz [Munich] → Munchner Residence (Wittelsbach) [Munich]→ Munich Frauenkirche [Munich]→ Munich Olympic Park [Munich]→ BMW Museum[Munich]

Figure 9 *The route of day three (Mapy cz)*

Day 4: Since the third day ended in Munich, the fourth day left for Krumlov Castle in the Czech Republic. After travel three hours at the castle, drove to Prague. Bue to the long driving time on the fourth day, there are not many scenic spots arranged.

Table 6 *The route and time of Day 4*

Destination	Duration of stay (minute)	Driving time from last destination (minute)	Distance from last destinatio n(meters)
11. BMW museum	0	0	0
6. Krumlov Castle	180	221	300824
5.Petřínská Rozhledna	60	134	179851
Total	240	355	480675

The route of day 4 is shown as follow:

BMW Museum [Munich]→ Krumlov Castle[České Budějovice]→ Petřínská Rozhledna[Prague]

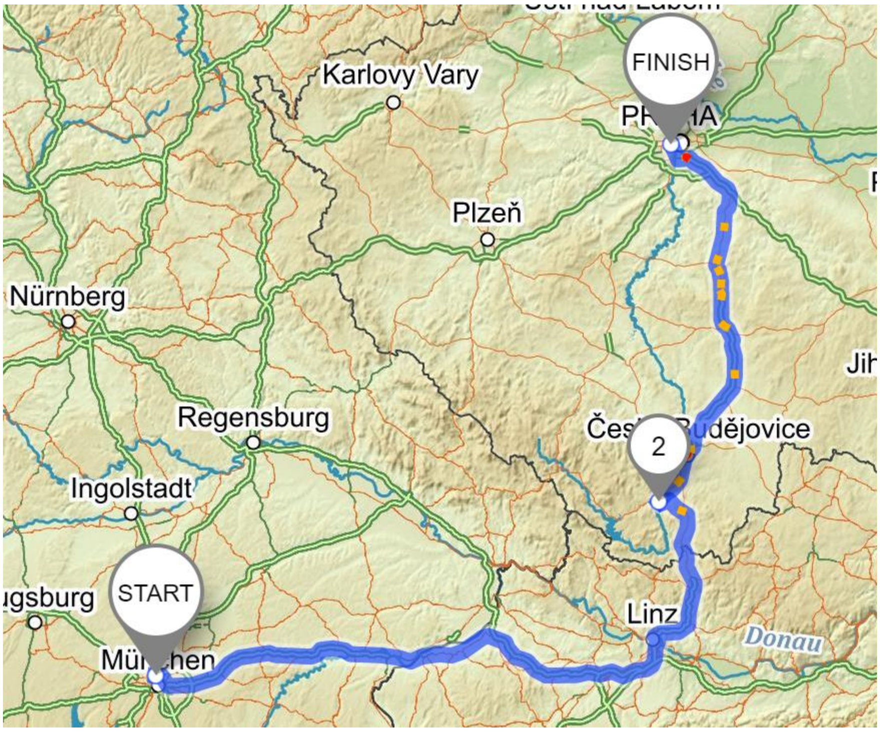

Figure 10 *The route of day four (Mapy cz)*

Day 5: The fifth day's sights were concentrated in Prague, so there was plenty of time for each attraction.

Table 7 *The route and time of Day 5*

Destination	Duration of stay (minute)	Driving time from last destination (minute)	Distance from last destinatio n(meters)
2. Prague Castle	90	0	0
4.The old town square of Prague	90	3	3387
3.Charles Bridge	90	2	755
1.Wenceslas Square	90	10	3060
Total	360	15	7202

The route of day 5 is shown as follow:

Prague Castle [Prague]→ The old town square of Prague [Prague]→ Charles Bridge [Prague] → Wenceslas Square [Prague]

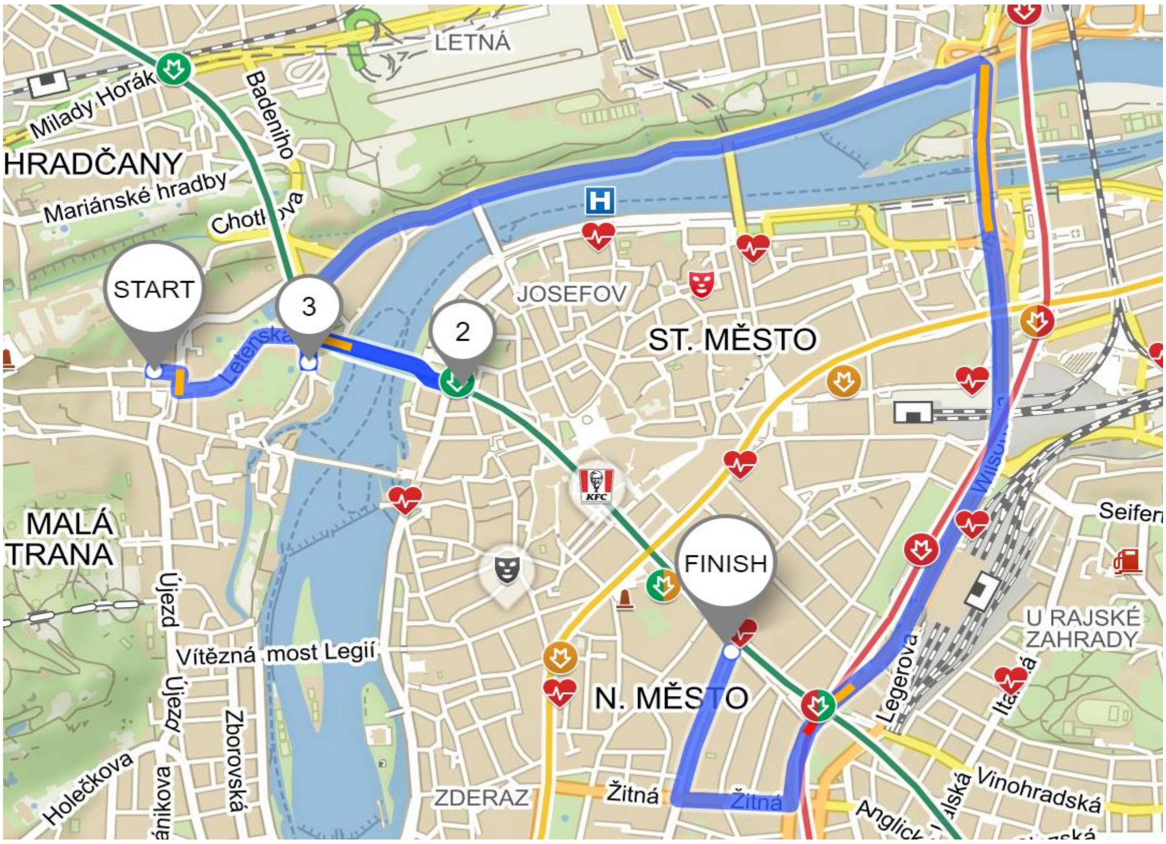

Figure 11 *The route of day five (Mapy cz)*

Day 6: Since the fifth day ends in Prague, the sixth will leave for Berlin. The sixth day's attractions are all concentrated in Berlin, and very close.

Table 8 *The route and time of Day 6*

Destination	Duration of stay (minute)	Driving time from last destination (minute)	Distance from last destinatio n(meters)
1.Wenceslas Square	0	0	0
19.Potsdamer Platz	90	228	348799
16.Berlin Cathedral	60	4	2603
18.East side Gallery	60	6	3572
17.Berliner Fernsehturm	60	7	3398
Total	270	245	358372

The route of day 6 is shown as follow:

Wenceslas Square[Prague]→Potsdamer Platz[Berlin]→Berlin Cathedral [Berlin]→ East side Gallery[Berlin] → Berliner Fernsehturm[Berlin]

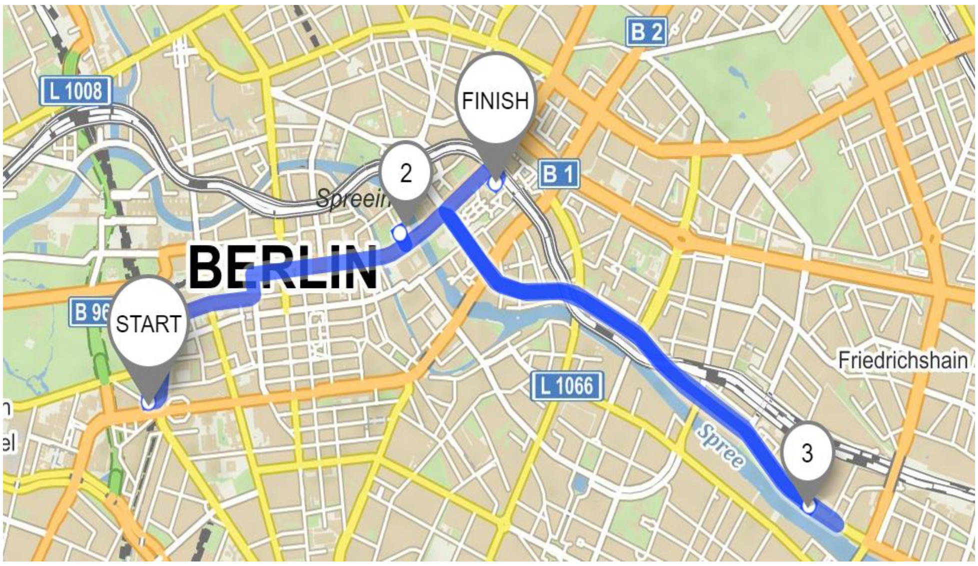

Figure 12 *The route of day six (Mapy cz)*

Day 7: The first second scenic spots are in Berlin, and there are only two landmark buildings, which can only be visited externally, so the sightseeing time dose not need too much. Then from the third scenic spot is in Frankfurt, so half way to drive as long as five hours to reach the Opera House, because the opera house does not need to visit too long, so there is enough time to visit Picasso museum.

Table 9 *The route and time of Day 7*

Destination	Duration of stay (minute)	Driving time from last destination (minute)	Distance from last destinatio n(meters)
14.Brandenburg Gate	30	0	0
15.Reichstag Building	30	0.34	1299
12.Old Opera House (Alte Oper)	60	306	545728
13.Staedel Museum	120	5	2274
Total	240	311.34	549301

The route of day 7 is shown as follow:

Brandenburg Gate[Berlin]→ Reichstag Building [Berlin]→ Old Opera House (Alte Oper) [Frankfurt]→ Staedel Museum [Frankfurt]

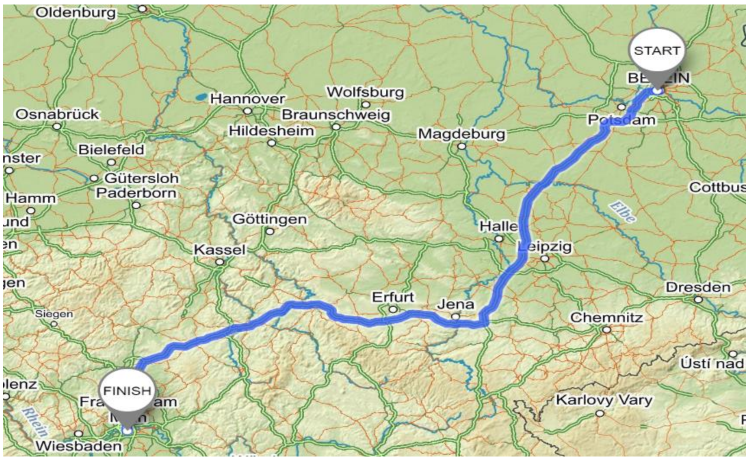

Figure 13 *The route of day seven (Mapy cz)*

Day 8: The eighth day of the trip will take you through three cities. Since the seventh day ends in Frankfurt, the eighth morning will be a drive from Frankfurt to Heidelberg, visiting three iconic Heidelberg attractions, and then a long drive to Paris, France. However, since the first scenic spot in Paris is Disneyland France, there is not enough time to travel on the eighth day, we do not visit Disney immediately, but wait until the ninth day and play in Disney all day.

Table 10 *The route and time of Day 8*

Destination	Duration of stay (minute)	Driving time from last destination (minute)	Distance from last destinatio n(meters)
13.Stadel Museum	0	0	0
20.Heidelberger Schloss	120	60	88598
21.Heidelberg Old Bridge	30	4	1172
22.Studenten-karzer	60	3	2730
60.Parc disneyland	0	283	798171
Total	210	350	890671

The route of day 8 is shown as follow:

Staedel Museum [Frankfurt]→ Heidelberger Schloss [Heidelberg]→ Heidelberg Old Bridge [Heidelberg]→ Studentenkarzer [Heidelberg] → Parc Disneyland [Paris]

Figure 14 *The route of day eight (Mapy cz)*

Day 9: Because Disney is a big amusement park, every day there are a lot of people go to play, so not only need a lot of time, at the same time every entertainment need to line up for a long time, so arrange the ninth day all day at Disney, such as end of the play, we will drive to the center of Paris, the Louvre, near to live in. As the Louvre also needs enough time to visit, I will arrange it to visit on the 10th day.

Table 11 *The route and time of Day 9*

Destination	Duration of stay (minute)	Driving time from last destination (minute)	Distance from last destinatio n(meters)
60.Parc Disneyland	600	0	0
56.Louvre museum	0	36	45141
Total	600	36	45141

The route of day 9 is shown as follow:

Parc Disneyland [Paris]→ Louvre Museum [Paris]

Figure 15 *The route of day night (Mapy cz)*

Day 10: The tenth day is relatively concentrated in Paris, except for the Louvre, which needs more time to visit, the other scenic spots have a relatively even time. Since Paris is a city for fashion, there will be plenty of free time on day 10 for tourists to take a slow tour of the city.

Table 12 *The route and time of Day 10*

Destination	Duration of stay (minute)	Driving time from last destination (minute)	Distance from last destinatio n(meters)
56. Louvre Museum	180	0	0
57. Eiffel Town	90	7	4349
59.Arc de Triomphe	60	4	2086
58.Notre-Dame de Paris	60	10	6252
Total	390	21	12687

The route of day 10 is shown as follow:

Louvre Museum [Paris] → Eiffel Town [Paris] → Arc de Triomphe [Paris]→ Notre-Dame de Paris [Paris]

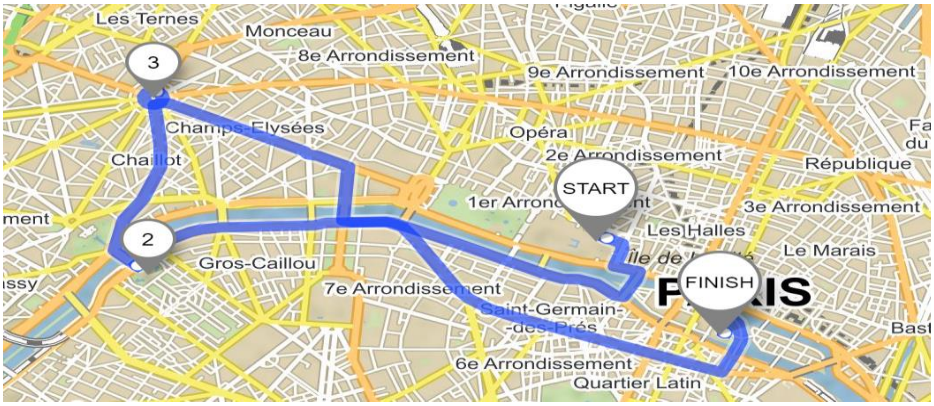

Figure 16 *The route of day tenth (Mapy cz)*

Day 11: The eleventh day was a day of travel, as the tenth day ended in Paris, so the eleventh was a long drive from Paris to Geneva. Due to the distance between the two places to visit in Geneva, tourist had to drive for most of the 11th day. Fortunately, only two attractions were arranged.

Table 13 *The route and time of Day 11*

Destination	Duration of stay (minute)	Driving time from last	Distance from last

		destination (minute)	destination(meters)
58.Notre-Dame de Paris	0	0	0
32.The Jet'd Eau Fountain	60	303	548098
33.Chillon Castle	120	107	97256
Total	180	410	585354

The route of day 11 is shown as follow:

Notre-Dame de Paris [Paris] → The Jet'd Eau Fountain [Geneva] → Chillon Castle [Geneva]

Figure 17 *The route of day eleventh (Mapy cz)*

Day 12: On the 12th day, will drive a long distance from Geneva to Milan, Italy. There are not many scenic spots visited in Milan on that day, so tourist will drive to Rome immediately after the tour in Milan. However, due to more driving time on the 12th day and less visiting time, Castel Sant'Angelo will visit in the 13th day.

Table 14 *The route and time of Day 14*

Destination	Duration of stay (minute)	Driving time from last	Distance from last destinatio n(meters)

		destination (minute)	
33.Chillon Castle	0	0	0
35.Pinacoteca di Brera	60	206	296494
34.Milan Cathdral	60	5	5250
55.Castel Sant’Angelo	0	319	572590
Total	120	530	874334

The route of day 12 is shown as follow:

Chillon Castle[Geneva] → Pinacoteca di Brera [Milan] → Milan Cathdral [Milan]→ Castel Sant’Angelo[Rome]

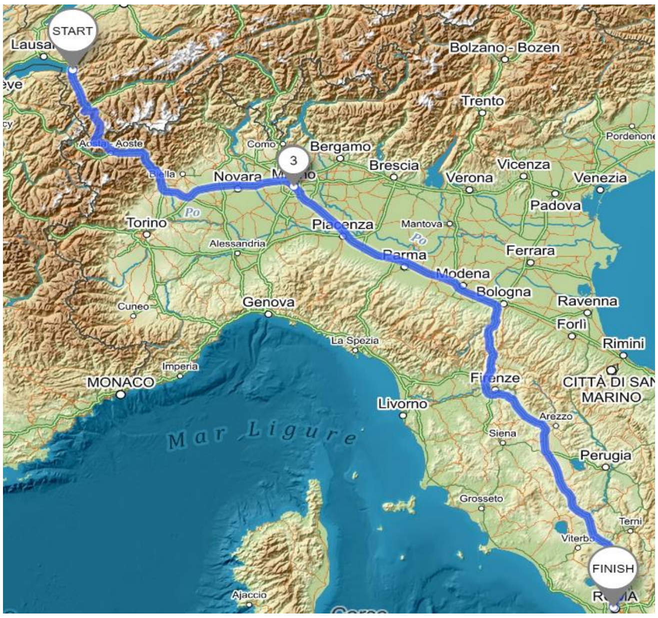

Figure 18 *The route of day twelfth (Mapy cz)*

Day 13: The 13th day was focused on Rome, and there were many tourist attractions on the 13th day because the iconic sites were all similar.

Table 15 *The route and time of Day 13*

Destination	Duration of stay (minute)	Driving time from last	Distance from last destinatio n(meters)

		destination (minute)	
55.Castel Sant’Angelo	90	0	0
48.St Peter’s Square	90	2	218
49.St Peter’s Basilica	60	0.49	1807
50.Roman Forum	90	5	4328
46.Colosseum Rome	90	4	1945
47.Arch of Constantine	30	0.29	2610
51.The mouth of truth	30	3	2810
Total	450	14.78	13718

The route of day 13 is shown as follow:

Castel Sant’Angelo [Rome]→St Peter’s Square [Vatican] → St Peter’s Basilica [Vatican]→ Roman Forum [Rome] → Colosseum Rome [Rome] → Arch of Constantine [Rome] → The mouth of truth [Rome]

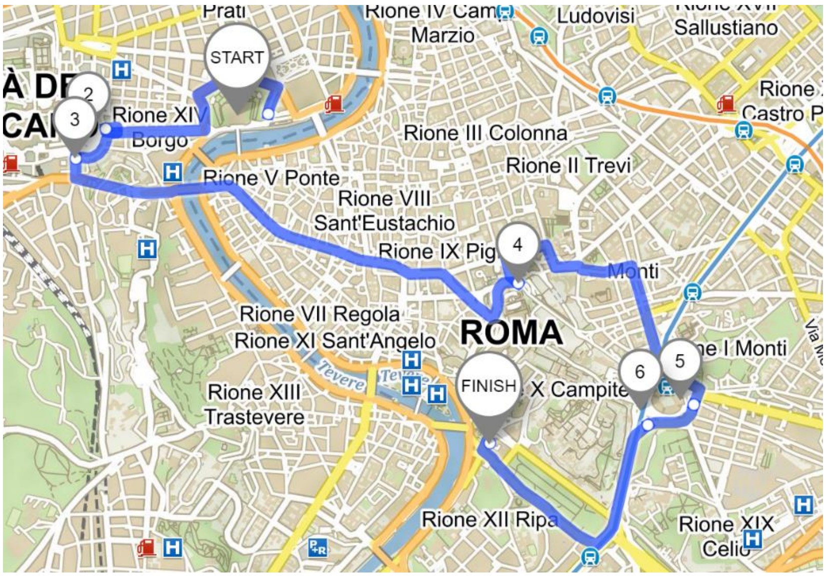

Figure 19 *The route of day thirteenth (Mapy cz)*

Day 14: The 14th day should also start in Rome, and after a simple tour of the city's iconic sights, drive about two hours to Florence, where there's plenty of time to see the sights.

Table 16 *The route and time of Day 14*

Destination	Duration of stay (minute)	Driving time from last destination (minute)	Distance from last destinatio n(meters)
54.The Pantheon	60	0	0
52.Piazza di Spagna	60	10	3773
53.Trevi Fountain	30	2	4669
43.Piazzale Michelangelo	60	204	275481
42.Florence Cathedral	90	2	4195
44. Piazza della Signoria	60	0.26	484
Total	360	218.26	288602

The route of day 14 is shown as follow:

The Pantheon [Rome]→ Piazza di Spagna [Rome] → Trevi Fountain [Rome]→ Piazzale Michelangelo [Florence] → Florence Cathedral [Florence] → Piazza della Signoria [Florence]

Figure 20 *The route of day fourteenth (Mapy cz)*

Day 15: The fifteenth day is a hurried day, visiting three cities. Will begin in Florence with a tour of the Uffizi Gallery and then immediately drive two hours to Bologna. Since bologna's attractions, most of which are architectural, do not take much time to visit, after visiting bologna's attractions, drive to Milan immediately. Although sufficient, such a plan is the majority of the implementation of the travel plan. The reason why we arranged to arrive at Corso Venezia on the fifteenth day is because Corso Venezia is a street where hotels and restaurants are located.

Table 17 *The route and time of Day 15*

Destination	Duration of stay (minute)	Driving time from last destination (minute)	Distance from last destinatio n(meters)
45.Uffizi Gallery	120	0	0
40.Basilica of San Petrionio	30	73	109389
38.Piazza Maggiore	30	2	1376
39.Towers of Bologna	30	0.47	2781
41.Fountain of Neptune	30	2	300
37.Corso Venezia	60	126	213316
Total	280	203.47	327162

The route of day 15 is shown as follow:

Uffizi Gallery [Florence]→ Basilica of San Petrionio [Bologna] → Piazza Maggiore [Bologna]→ Towers of Bologna [Bologna] → Fountain of Neptune [Bologna] → Corso Venezia [Milan]

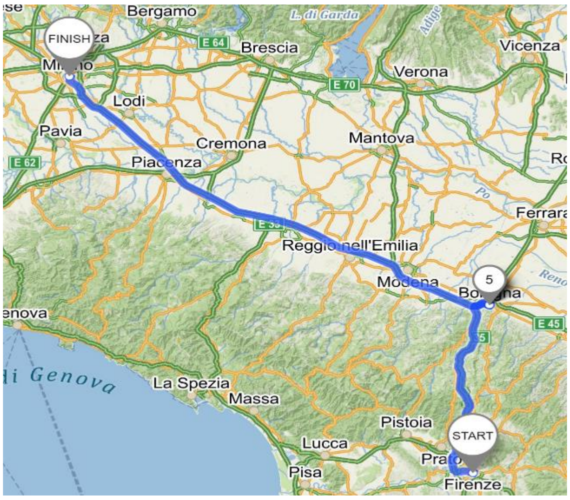

Figure 21 *The route of day fifth (Mapy cz)*

Day 16: The 16th day starts in Milan, and since the journey is almost over, we will start from Milan to return to the city of Lucerne where we started. After one tour in Milan, drive two hours to the last three attractions in Lucerne. Since this tour is designed not to repeat the same scenic spot, we do not have to return to the starting point. The Swiss Museum of Transport will be the end point.

Table 18 *The route and time of Day 16*

Destination	Duration of stay (minute)	Driving time from last destination (minute)	Distance from last destinatio n(meters)
36.Porta Sempione	60	0	0
31.Lion Monument	60	163	243096
30.Chapel Bridge (Kapellbrucke)	60	3	1811
29.Swiss Museum of Transport	60	4	2863
Total	240	170	247770

The route of day 16 is shown as follow:

Porta Sempione [Milan]→ Lion Monument [Luzern]→ Chapel Bridge (Kapellbrucke) [Luzern]→ Swiss Museum of Transport [Luzern]

Figure 22 *The route of day sixteenth (Mapy cz)*

After calculation and arrangement, the optimized route of a road trip to 5 inland countries and 60 scenic spots in Western Europe is obtained. The optimal route of the algorithm is 4891419 meters, but since the end point of the algorithm is the same as the starting point, we will not return to the end point, but finish the journey directly one stop before the end point. It is mean the optimal route is (28) - (25) - (27) - (24) - (26) - (23) - (7) - (8) - (10) - (9) - (11) - (6) - (5) - (2) - (4) - (3) - (1) - (19) - (16) - (18) - (17) - (14) - (15) - (12) - (13) - (20) - (21) - (22) - (60) - (56) - (57) - (59) - (58) - (32) - (33) - (35) - (34) - (55) - (48) - (49) - (50) - (46) - (47) - (51) - (54) - (52) - (53) - (43) - (42) - (44) - (45) - (40) - (38) - (39) - (41) - (37) - (36) - (31) - (30) - (29). The optimal route is a 16-day tour of 4871808 meters.

5 Conclusions

The purpose of this thesis is to design an optimized and high-quality travel route for travel driving enthusiasts through quantitative methods. Based on an online survey of self-driving travel enthusiasts, I have selected 60 iconic sites that are popular in the interior of Western Europe to visit. According to the calculation, the total distance from scenic spot 1 to 60 is 6168400 meters before the optimized tourist routes of 60 scenic spots. In order for self-driving travel enthusiasts to no longer travel aimlessly, I chose TSPKOSA program of Czech university of life and sciences in Prague and used three algorithms in TSPKOSA to find out the optimal driving route of mileage. The optimal mileage for the nearest neighbor algorithm is 5035260 meters, the optimal mileage for the saving algorithm is 4891419 meters, the optimal mileage for the Vogel approximation is 5460819 meters. Because the algorithm will calculate the distance in a circle, which means that it starts from there and ends there. The basis of the optimal route in this article is not repeatedly drive to the same scenic spot of the algorithm result as the end point, so that out end point is inconsistent with the starting point. The reason why didn't go back to the starting point was because didn't want tourists to be troublesome and tired, and it was unnecessary. From this we can conclude that the optimal route will be come from the result of the saving algorithm. The optimized route reduces the distance of the base by 1296592 (6168400-4871808) meters.

5.1 The analysis of the paper itself

First of all, why did I choose to write an optimization article about the trip route through mathematics? In fact, the world is so big. I think everyone is curious about the strange world outside. Traveling has become a favorite thing for many people. Now the European economy is so developed, the way of transportation is much more convenient than before, especially now the plane, no matter how far away the city can quickly reach. But even if a plane is fast and two hours away, why would some tourists drive for hours?

- By self-driving tour, you can take a lot of luggage and food with you on a road trip. You can stop and eat whenever you want. It is very troublesome to limit the weight of luggage by plane. It's not easy to go on a trip, and there are a lot of clothes that need to be changed and washes in a month for a long journey, so it is more convenient to choose a self-driving tour. You can put the clothes in the trunk of the car and use them at any time. If you choose to take a plane but have a lot of luggage, you may be overweight and have to pay extra to check it, and it is very painful to get off the plane and transfer to other means of transportation with a big luggage, it is estimated that many people will collapse.
- Road trips are more flexible and free, while flying to a destination and then calling a taxi is cumbersome. The greatest advantage of self-driving travel is freedom. You can stay as long as you want at your favorite spot, and the tour route can be adjusted at any time. Travel by plane, we arrive at the destination, also have to take a taxi, too restrictive, freedom is not as good as self-driving travel. It may take two hours to arrive by plane, but the plane is usually built far away from the city. It takes us at least three hours to catch the plane and board the plane, and we have to take a taxi to the city center after getting off the plane. When we get to our destination, we waste a lot of time on the road every day, whether it is by cheap bus, subway or taxi. On the other hand, although driving on the road is more difficult, it will save a lot of time on the way to the scenic spots every day after arriving at the destination. We can go whenever we want, instead of crowded buses and subways.
- The table below shows the air ticket prices, train price and oil price in Europe through the re-ticketing website. Depending on the ticket price, a

road trip will cost much less than a plane trip. The price of air tickets and train tickets is about the same, but by plane or train travel, to the destination, the daily travel taxi fares calculated together, the cost is very large. If air tickets and train tickets are calculated according to the table below, plus various transportation costs separately, each of the 16-day trip will cost about 700 Euros. And the price of air tickets fluctuate greatly, there will be a lot of uncertain factors. In addition, the gasoline and highway fees are very cost-effective in Europe. We need to travel 4891419 meters for a 16-day self-driving tour. If we calculate by 4000 kilometers of expressway, the average mileage will be 100 kilometers of 1.25 euros, so we only need to spend more than 50 euros to buy a road ticket. And if we go 20 kilometers for a liter of gas, we only need to spend about 350 euros on gas. That works out to about 400 euros, so it's much cheaper and much more convenient than flying or by train.

	Air Ticket Price (Per)	Railway Ticket Price (Per)
Switzerland → CzechRepublic	123€	65€
CzechRepublic → German	118€	33€
German →French	89€	223€
French → Italy	110€	114€
Italy → Switzerland	94€	79€

Table 19 *The air ticket price and train price of a five-country tour of Europe*

	Oil Price (per liter)
Switzerland	1.23€
CzechRepublic	1.03€
German	1.20€
French	1.33€
Italy	1.39€

Table 20 *Oil price in five European countries*

- The atmosphere of a road trip is better than a plane ride. We seldom go out alone. In order to avoid loneliness, we usually travel together with several good friends or family members. We can take turns driving on the road and chat with each other all the way. On the other hand, even if we are with good friends or family, we seldom talk in order not to affect others. The atmosphere is not as active as that of self-driving travel.
- Moreover, self-driving travel is relatively suitable for more people, which is an optimal choice for adults, the elderly, foreigners and children. In Europe, adult self-driving travel has become a very common phenomenon. As long as the weekend comes, traveling is the first choice for people to relax, especially to travel wherever they want to go. For the elderly with inconvenient movement, self-driving travel is also the first choice, because traveling by plane or by train requires more than two different transportation from the departure to the destination, which is very troublesome for the elderly with inconvenient movement, so self-driving travel is the best choice. For children, although flying is very new, but some children can not adapt to the environment very quickly, so family members take their children to travel by their own car is the most suitable choice for them, in the drive travel, but also can bring children to see different environments, broaden their horizons. For foreigners, when they first arrive at a foreign country, the language barrier and the unadaptability to the strange environment are the biggest obstacles for foreigners to travel to Europe. The 44 countries in Europe speak different languages. Although English is the world language, not every European or foreigner can speak English. When you need to ask for directions, or when you need to check your identity to travel by plane or train, communication becomes difficult. For foreigners, taking a road trip with a mobile phone and downloading a guide to go wherever they want is the option.

So that’s why I wanted to design an optimized itinerary for the travel enthusiast who wants to take a road trip to Europe. And through the method of scientific calculation, make the optimized route calculated more accurately

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