DA350-Final Report

Panoramic Tour of Vietnam

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1 Introduction

Tourism in Vietnam has proved itself to be one of the potential fields of national economic development. In this project, we simulate the decision-making process of a student coming to Vietnam for a 1-month winter break vacation. The student's goal is to visit as many tourist attractions across the country as possible, within their limited time and budget constraints. The student is allowed to choose one means of transportation (walking, bus, taxi, train, airplane, etc.) for each pair of departure and arrival to optimize their traveling plan. In this model, we utilize the "star ratings" of all the attraction spots to incorporate into the objective function.

The model is built on the foundation of the "Traveling Salesman" problem, with new aspects of geographical distances, the means of transportation, and how the variables interact with one another using the data coming from 3 creditable websites: Google Map, Tripadvisor, and Rome2Rio. The reason why we choose Vietnam and build the model for traveling suggestions is because Vietnam is an Asian country with countless pristine scenery. Although tourism in Vietnam has been significantly growing over the last 30 years, there are many places to discover and spaces for development so that we can bring Vietnam closer to the world. The goal of the model is to suggest a list of tourist attractions and the best transportation for traveling in terms of time and budget limitations. Throughout this project, our hope is also to popularize Vietnamese tourism to Denison students while making optimal travel plan for foreigners coming to Vietnam for the first time who don't know where to start.

2 Description

Our preliminary modeling is similar to the Van Gogh lab to some extent. However, with this model, the goal is to maximize the number of "stars" (ratings) collected from the places we travel to. With this objective function, we believe that the model will come with suggestions for the most optimal pathway for traveling throughout Vietnam. The process is also to find the optimal pathway within the student's time and budget constraints. The student may spend at least 5 hours in locations in the same city.

In addition, our model is used to find the optimal transportation selections to which the student can choose among the 5 possible means of transportation: walking, bus, taxi, train, and airplane. Each means of transportation has trade-offs between time and cost, thus this model will help discover the optimal solution that optimizes the student experience with a minimal budget and a limited timeframe.

2.1 Data

We started the project by pulling the data from three different sources: Google Maps (for the locations' co-ordinations), Tripadvisor (for "Stars" ratings of the tourist spots), and Rome2Rio (for the transportation time and cost among the locations). We made some transformations to the data and create a second data set to have information on transportation options and the amount cost for each type of transportation traveling from 1 place to the other. The translated data has the permutation of location pairs with traveling expenses corresponding with the means of transportation the model will select.

City	Tourist Attraction	Region	Star Rating	Latitude	Longitude
Hanoi	Hoan Kiem Lake	North	4.5	21.02784567	105.8522779
Hanoi	Long Bien Bridge	North	4	21.04448346	105.860837
Quang Ninh	Ha Long Bay	North	4.5	20.9712055	107.0490512
Quang Nam	Hoi An Ancient Town	Central	4.5	15.88030077	108.3380075
Ho Chi Minh City	Notre Dame Square	South	4	10.77996466	106.6991047
Ho Chi Minh City	Cu Chi Tunnel	South	4.5	11.02801885	106.5124661
Nha Trang	Thap Tram Huong	Central	3.5	12.24054029	109.196901
Da Nang	Dragon Bridge	Central	4	16.06133551	108.227517
Can Tho	Cai Rang Floating Market	South	4	10.00523704	105.7459387
Ba Ria_Vung Tau	Vung Tau Lighthouse	South	4	10.33430074	107.0776754
Sapa	Fansipan Mountain	North	4.5	22.30653169	103.7747334
Hue	Hue Imperial City	Central	4.5	16.46935024	107.5780543

Figure 1: Location Data

Departure	Arrival	Walking	Bus	Taxi	Train	Airplane
Hoan Kiem Lake	Long Bien Bridge	0.5		0.067		
Hoan Kiem Lake	Ha Long Bay		3.15	1.67		2.75
Hoan Kiem Lake	Hoi An Ancient Town		17		17	4.24
Hoan Kiem Lake	Notre Dame Square		35.85	32.55		4.4
Hoan Kiem Lake	Cu Chi Tunnel		35.6		32.55	4.33
Hoan Kiem Lake	Thap Tram Huong		25.9		25.2	5.25
Hoan Kiem Lake	Dragon Bridge		15.8		15.9	3.05
Hoan Kiem Lake	Cai Rang Floating Market		40.4		36.6	4.05
Hoan Kiem Lake	Vung Tau Lighthouse		35.1		34.8	7.6
Hoan Kiem Lake	Fansipan Mountain		4.75		4.8	
Hoan Kiem Lake	Hue Imperial City		13.1		13.3	3.3
Long Bien Bridge	Ha Long Bay		3.2	1.7		2.9
Long Bien Bridge	Hoi An Ancient Town		17.35		18.2	4.4
Long Bien Bridge	Notre Dame Square		36.3		33.85	4.5
Long Bien Bridge	Cu Chi Tunnel		35.9		33.8	4.5
Long Bien Bridge	Thap Tram Huong		26.3		26.5	5.4
Long Bien Bridge	Dragon Bridge		16.3		17.12	3.2
Long Bien Bridge	Cai Rang Floating Market		40.82		37.85	4.2
Long Bien Bridge	Vung Tau Lighthouse		38.15		35.9	7.1
Long Bien Bridge	Fansipan Mountain		5.13		8.9	
Long Bien Bridge	Hue Imperial City		13.38			3.45
Ha Long Bay	Hoi An Ancient Town		20.8		21.35	3.2
Ha Long Bay	Notre Dame Square		40.25		36.95	3.3
Ha Long Bay	Cu Chi Tunnel		37.8		36.95	3.2
Ha Long Bay	Thap Tram Huong		29.15		29.6	4.3

(a) Time Dataset

Departure	Arrival	Walking	Bus	Taxi	Train	Airplane
Hoan Kiem Lake	Long Bien Bridge	0	999	2	999	999
Hoan Kiem Lake	Ha Long Bay	0	20	115	999	263
Hoan Kiem Lake	Hoi An Ancient Town	0	34	999	35.5	65.5
Hoan Kiem Lake	Notre Dame Square	0	55	999	55	102.5
Hoan Kiem Lake	Cu Chi Tunnel	0	94	999	80	127
Hoan Kiem Lake	Thap Tram Huong	0	52	999	41	53.5
Hoan Kiem Lake	Dragon Bridge	0	27	999	28.5	62
Hoan Kiem Lake	Cai Rang Floating Market	0	66.5	999	69	156.5
Hoan Kiem Lake	Vung Tau Lighthouse	0	67.5	999	68	116.5
Hoan Kiem Lake	Fansipan Mountain	0	15	999	14	999
Hoan Kiem Lake	Hue Imperial City	0	20		26.5	83
Long Bien Bridge	Ha Long Bay	0	22	115		263
Long Bien Bridge	Hoi An Ancient Town	0	34		44.5	65.5
Long Bien Bridge	Notre Dame Square	0	55		62	102.5
Long Bien Bridge	Cu Chi Tunnel	0	94		87.5	124
Long Bien Bridge	Thap Tram Huong	0	52		48	53.5
Long Bien Bridge	Dragon Bridge	0	27		37.5	62
Long Bien Bridge	Cai Rang Floating Market	0	66.5		76	156.5
Long Bien Bridge	Vung Tau Lighthouse	0	64		115.5	111.5
Long Bien Bridge	Fansipan Mountain	0	15		21	
Long Bien Bridge	Hue Imperial City	0	20			83
Ha Long Bay	Hoi An Ancient Town	0	59		85	127
Ha Long Bay	Notre Dame Square	0	92		102.5	131
Ha Long Bay	Cu Chi Tunnel	0	111		128	152.5
Ha Long Bay	Thap Tram Huong	0	75.5		88.5	155.5

(b) Cost Dataset

Figure 2: Time and Cost Datasets

Data Preparation : In our dataset, we can see that not all 5 options are always available when we travel from one place to another. Therefore, one of the significant changes that we did (within the process of Data Cleaning with Python) was converting the NULL values in the cost of transportation into 999 (data type: integer). The main reason why we made this change is that our Gurobi model will not select this option when the Gurobi model is executed due to the force of cost constraints. This will mimic the behavior of NULL data while also helping the code work smoothly without running into syntax errors.

With the process of building up the mathematical backbone for the optimization model, we begin by setting with the time, budget, and transportation data by this following mathematical representation: Let i be the departing location and j be the arrival destination, such that:

- $\boldsymbol{time_{ij}}$: time to take from i-j using that transportation.
- $\boldsymbol{cost_{ij}}$: cost from i-j using that transportation.
- $\boldsymbol{star_i}$: The rating for each location.

2.2 Decision variables

With the decision variables, we have in total of 5 means of transportation, each one comes with a specific amount of traveling time and costs for going from arrival point(i) to departure point(j).

$\boldsymbol{a_{ij}}$, $\boldsymbol{b_{ij}}$, $\boldsymbol{c_{ij}}$, $\boldsymbol{d_{ij}}$, $\boldsymbol{e_{ij}}$ (binary variables): Which transportation to choose from i-j.

- $\boldsymbol{a_{ij}}$: Walking
- $\boldsymbol{b_{ij}}$: Bus
- $\boldsymbol{c_{ij}}$: Taxi
- $\boldsymbol{d_{ij}}$: Train
- $\boldsymbol{e_{ij}}$: Airplane

2.3 Constraints

- **Transportation constraints**: $a_{ij} + b_{ij} + \ldots + e_{ij} \leq 1$

  Their sum has to be 1 as we use 1 transportation for i-j

- **Time constraints**: $\sum time_{ij} \leq 100$ (hours)

  The total hours spent on traveling for 30 days is 100 hours ($\approx$ 3.34 hours/day)

- **Budget constraints**: $\sum cost_{ij} \leq 400$ (\$)

  Total money spent on traveling is \$400

- **Traveling constraints**: $time_{ij}$ have delays of at least 8 hours

  Spend at least 5 hours each time the student arrives at new location

2.4 Objective function

- $\boldsymbol{star_i}$: the rating of the tourist attraction if visited

$$Maximum \sum star_i$$

where we maximize the number of stars of all the locations visited

3 Output Results and Findings

From the output, we found out the most optimal pathway that can maximize the number of stars within the defined constraints of time, budget, and transportation decisions. Here is the optimal pathway and means of transportation suggested to pick:

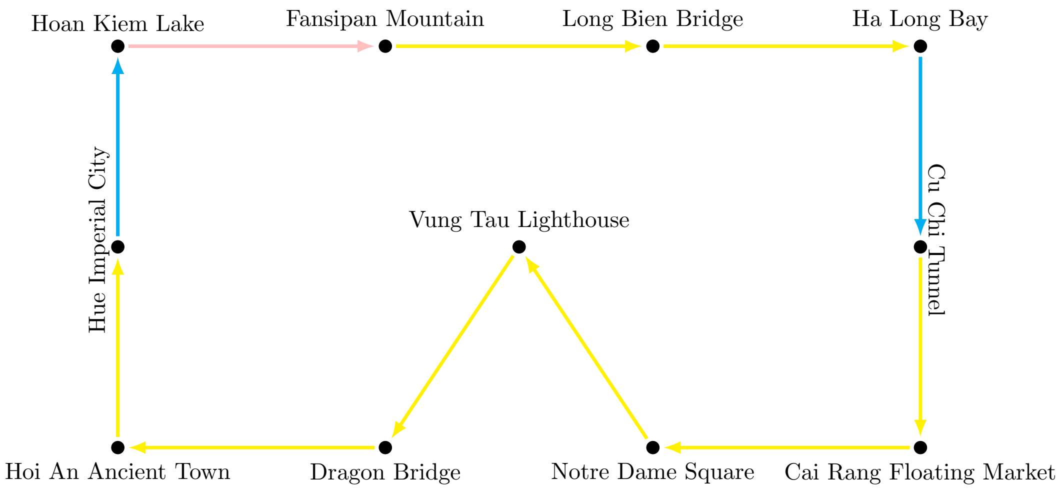

Figure 3: Gurobi Suggestion for the Optimal Pathway of Traveling around Vietnam

Means of Transportation :

- →: Walking
- →: Taxi
- →: Train
- →: Bus
- →: Airplane

In this model output, the total number of hours we spend traveling is **44.7** hours out of the constraint of **100** hours. With the 5-hour stopping periods spent on all 11 visited locations, our total time is **99.7** hours. The total cost we need to spend on transportation is $**387.0** out of $**400.0**. One of the interesting things we found from this output is the line-crossing phenomenon when we try to travel from one place to the other. We believe that this is an acceptable situation since the model has its limitations on transportation options. In many cases when we want to travel from point A to point B, not all 5 means of transportation are offered. The only way to travel within time and budget constraints in order to satisfy the objective functions needs to break the rule of the "Traveling Salesman" problem. Another reason is that the time and cost to travel between places, in real life, is not always as Euclidean distances (A is closer to B than C in terms of Euclidean distance, but travel cost and time from A to B is not always less than A to C). However, our model also carried an optimistic outcome, which makes a good circular route throughout the country. This output follows our expectations and fulfills the constraint requirements. Figure 4 shows the map of locations with the pathways that the model suggested the student to take.

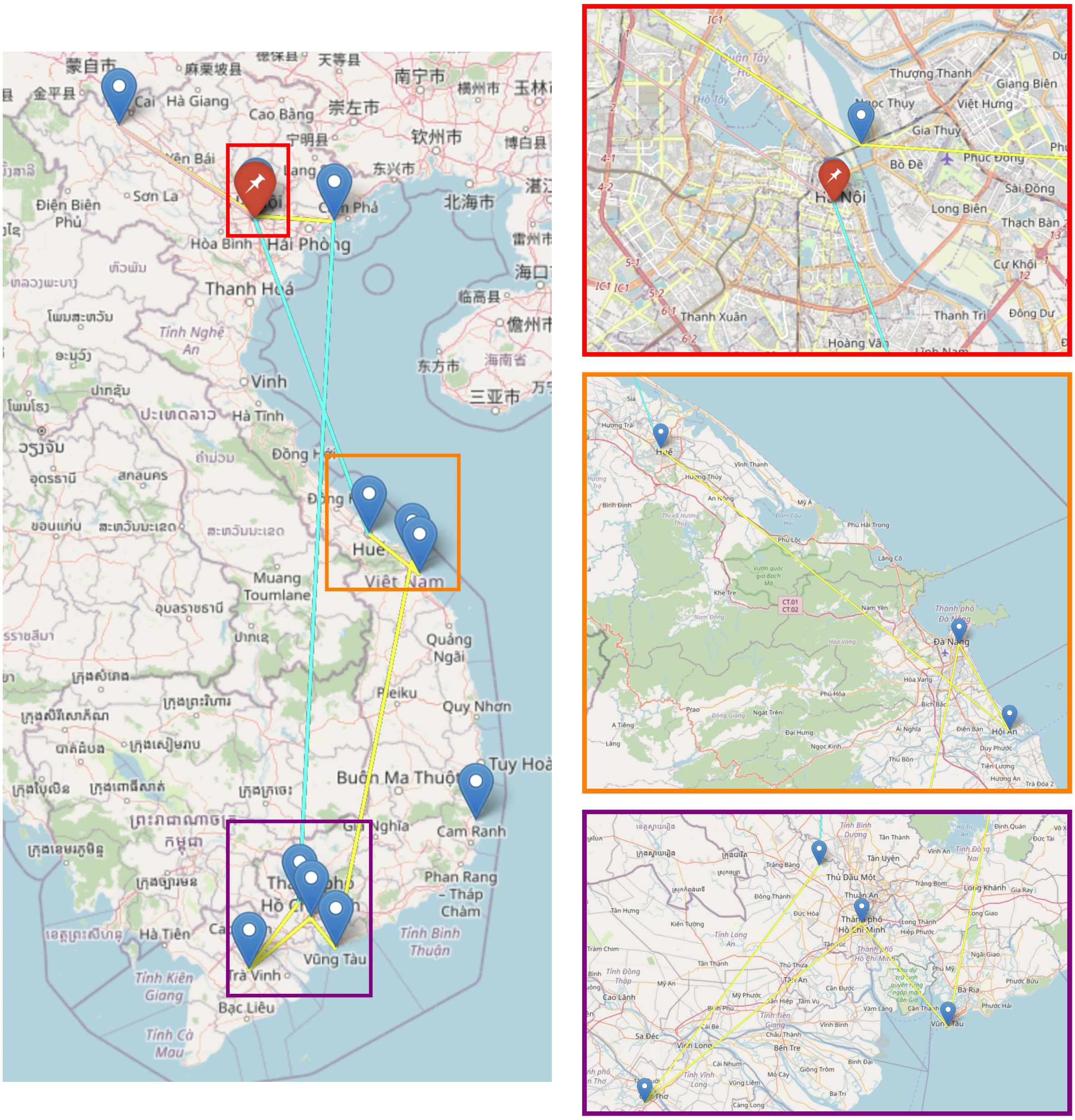

Figure 4: Gurobi Output Result for The Optimal Traveling Pathway

4 Sensitivity Analysis

4.1 Visit all 12 locations

From the stated constraints above, we try to run through the first model after setting it up. The result surprised us since we went to 11 out of 12 locations. Thus, we relieve the time constraint and add a new constraint that the model has to visit all 12 locations. Here is the result of the suggested pathways that Gurobi to visit all locations:

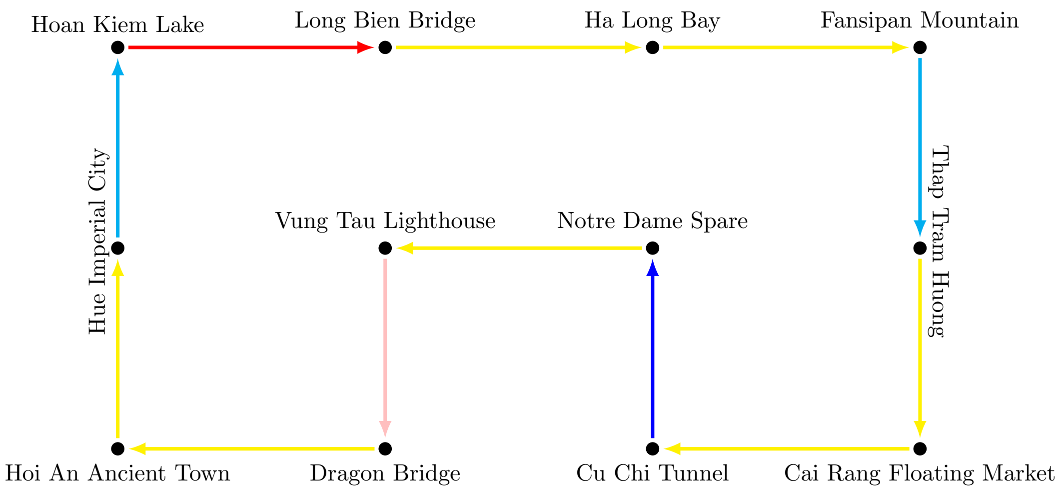

Figure 5: Gurobi Suggestion for the Optimal Pathway of Traveling around Vietnam (all 12 points)

Means of Transportation :

- →: Walking
- →: Taxi
- →: Train
- →: Bus
- →: Airplane

In this model output, the total number of hours we spend traveling is **58.1** hours. With the 5-hour stopping periods spent on all 12 visited locations, our total time is **118.2** hours. The total cost we need to spend on transportation is $**392.5** out of $**400.0**. Figure 6 shows the map of all 12 locations with the pathway suggested by the model.

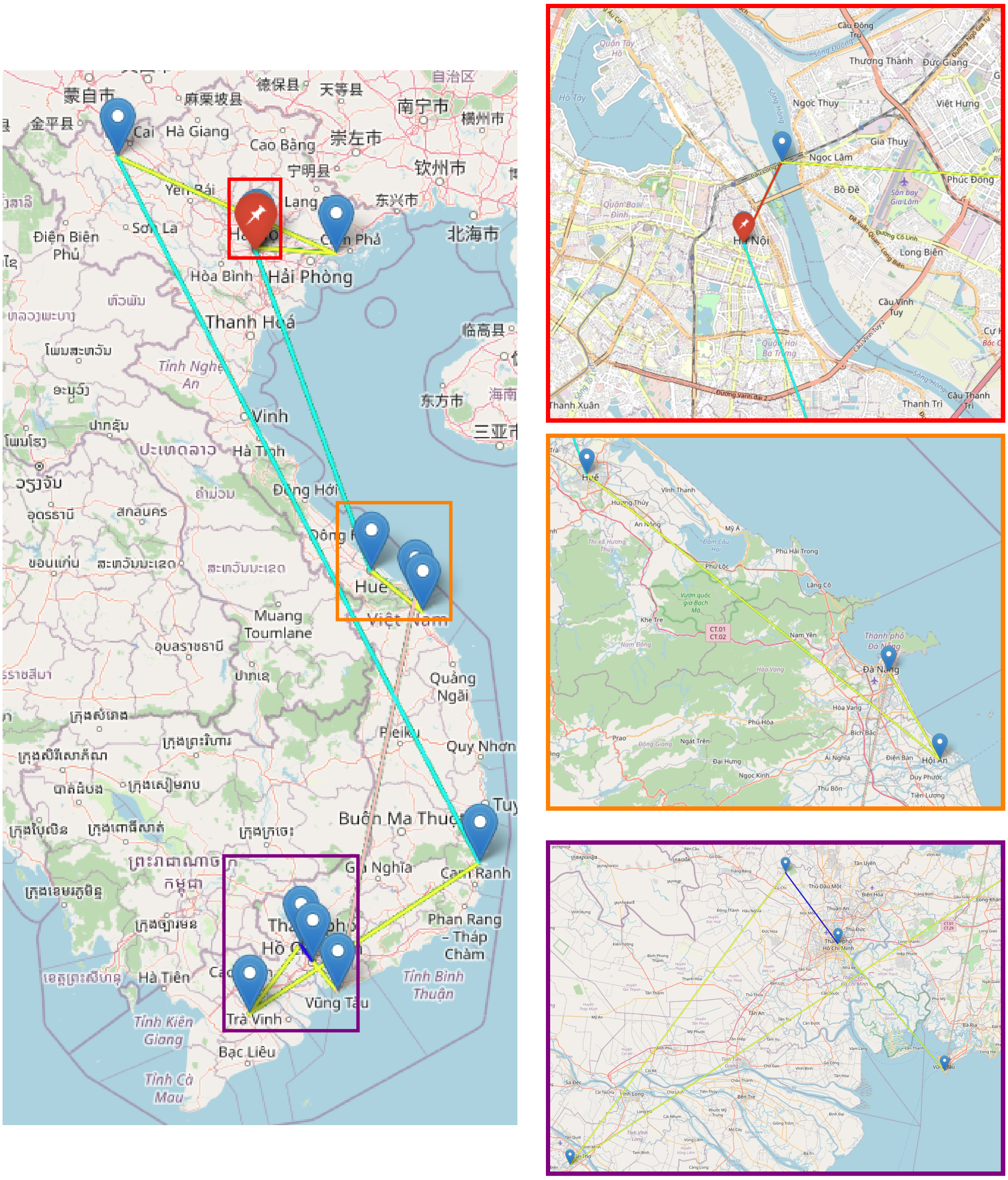

Figure 6: Gurobi Output Result for The Optimal Traveling Pathway to All Locations

4.2 Half budget

This time, we test our model if the student has their budget cut down to half from the original result. Specifically, the student still has 100 total hours, but has only $200 of the budget. Here is the half-budget model's optimal result:

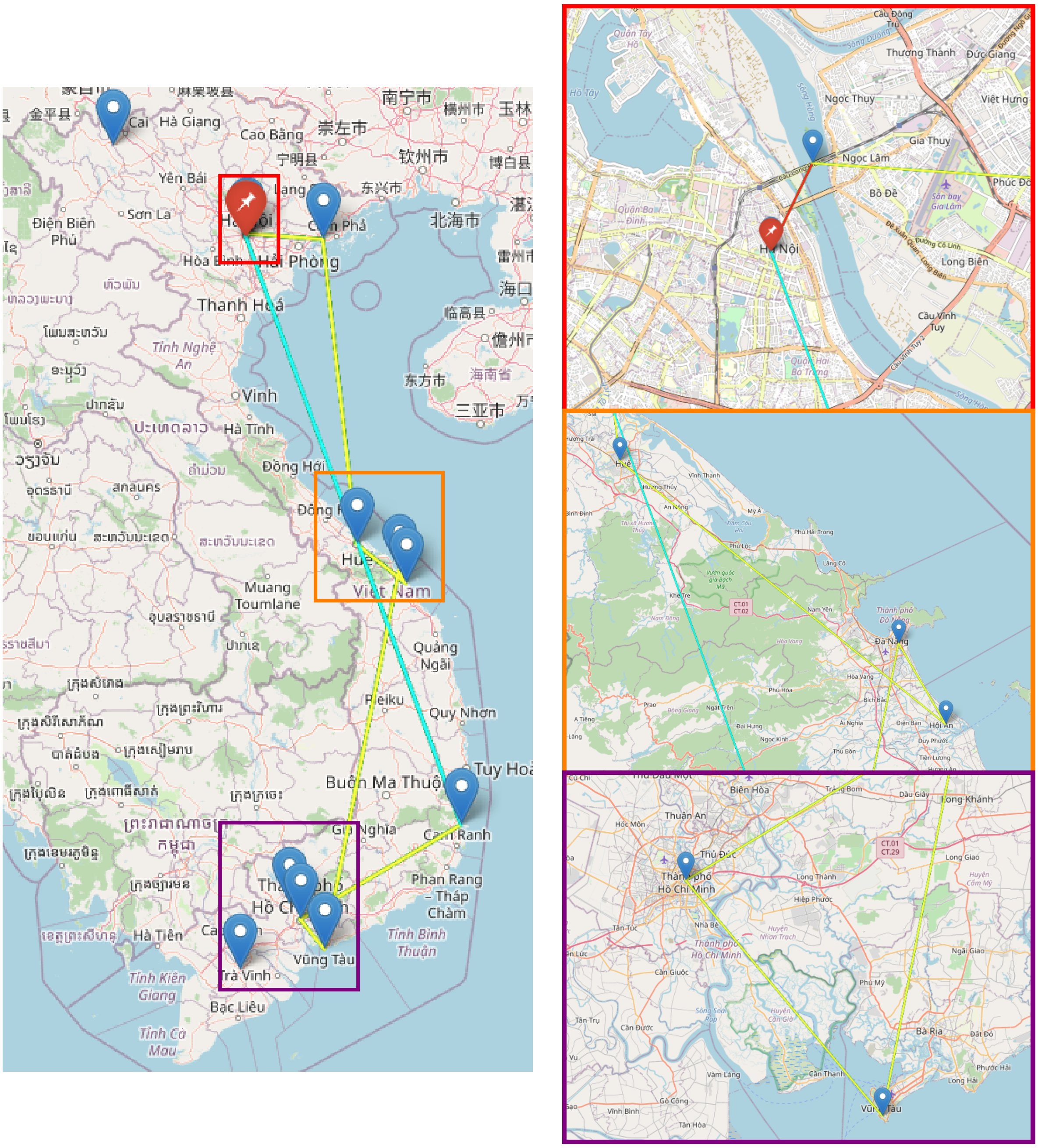

Figure 7: Gurobi Output Result for The Optimal Traveling Pathway with Half Budget

This model suggests a pathway with in total 96.7 hours and $190.5 to visit 9 locations. As we can see, because the budget was cut significantly, the model suggests to take bus most of the time. This is reasonable as bus is a means of transportation that is relatively cheap with affordable traveling time in Vietnam. Figure 7 shows the graphic of those paths suggested by the model:

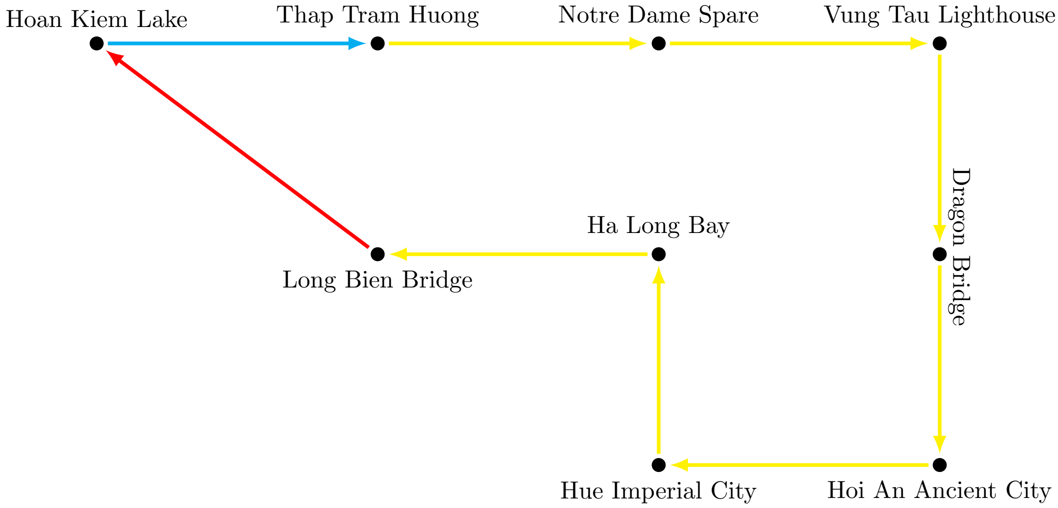

Figure 8: Gurobi Suggestion for the Optimal Pathway of Traveling around Vietnam

Means of Transportation :

- →: Walking
- →: Taxi
- →: Train
- →: Bus
- →: Airplane

With 7 out of 9 paths the model suggested is bus, this partially proves why bus is one of the most picked means of transportation for on-budget traveling in Vietnam.

5 Conclusion

In this study, we utilized Gurobi optimization to tackle the Traveling Salesman Problem and applied it to solve Vietnam Panoramic Tourism Problem. Our objective was to develop an optimal tour route that could travel to most tourist attractions while minimizing travel costs and time. After executing the codes, we discovered an interesting phenomenon of line-crossing when traveling between different places. However, we believe this to be an acceptable situation given the transportation constraints that exist in reality.

We recognize that in most cases, not all modes of transportation are available to travel between two points. As a result, satisfying the objective functions within time and budget constraints necessitates breaking the rules of the Traveling Salesman Problem. Despite this, our model yielded a satisfactory outcome by creating an optimal circular route that traverses the entire country, as anticipated. Furthermore, this solution fulfilled the constraint requirements and satisfied the proposed objectives. We also performed a sensitivity analysis by examining two scenarios. The first scenario entailed forcing the Gurobi model to generate a pathway that traverses all 12 tourist attractions, while the second scenario imposed a budget constraint of $200. We discovered that both scenarios resulted in appropriate solutions and validated our model's effectiveness.

To conclude, this study has demonstrated the efficacy of using Gurobi optimization to solve complex problems such as the Traveling Salesman Problem. Our findings indicate that while transportation limitations may affect the optimal tour route, it is still possible to find a satisfactory solution that meets the proposed constraints and objectives. The sensitivity analysis performed in this study adds further credence to the model's accuracy and utility. We hope that our study contributes to the body of knowledge on optimization techniques while inspiring future studies that utilize Gurobi optimization to solve similar transportation problems and apply the model not only to Vietnam but all other countries around the world to develop their national tourism.